Biological/Natural Systems

4-Day Course #1207

Fleming Training Center

STATE OF TENNESSEE

Fleming Training Center

Biological/Natural Systems

Course # 1207

March 15-18, 2022

Tuesday, March 15:

8:30 Overview of Wastewater Treatment
9:45 Wastewater Microbiology
11:00 Lunch
12:30 Ponds and Lagoons
1:45 Packed Bed Filters

Wednesday, March 16:

8:30 Septic Tanks
9:45 Disinfection
11:00 Lunch
12:30 Effluent Discharge
1:30 Laboratory
2:30 NPDES & 40CFR 136 Excerpt

Thursday, March 17:

8:30 Safety
9:30 Cross Connection Control
11:30 Lunch
12:30 Pumps
1:30 Basic Math Review

Friday, March 18:

8:30 Wastewater Math
11:00 Course Wrap-Up and Final Exam

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Biological/Natural Systems

Section 1

Introduction to Wastewater

Intro to Wastewater Treatment for BNS

Why do we treat waste?

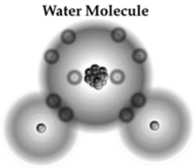
Prevention of Pollution

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

Purpose of Wastewater Treatment

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

What is Pure Water?



H_2O

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

Types of Waste

- Organic waste
    - Contains carbon

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

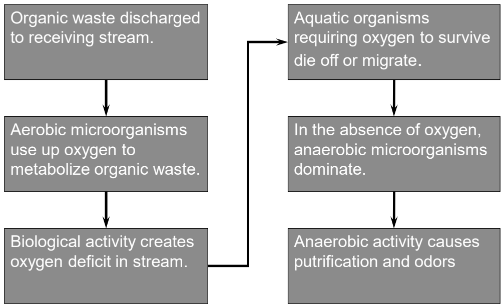
Sludge and Scum

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

Oxygen Depletion

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

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

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

Diseases

- Bacteria
  - Cholera
  - Dysentery
  - Shigella
  - Salmonella
  - Typhoid
- Viruses
  - Polio
  - Hepatitis (Jaundice)
- Protozoa
  - Giardia
  - Cryptosporidiosis

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

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 to surface waters

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.

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

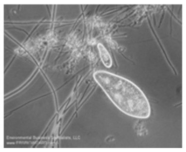
- Dissolved oxygen is oxygen that has been incorporated into water.
- Many aquatic animals require it for their survival.

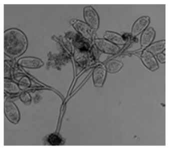
Nutrients

- 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

Microbial Organisms

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



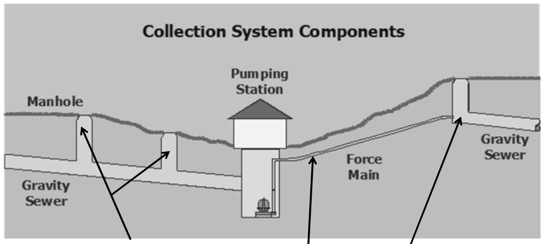


Typical Influent Concentrations

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

Wastewater Collection and Conveyance System



Manholes should be placed every 300-500 feet apart to provide access for inspections and cleaning

Min size is 4”

Constant minimum slope is required to provide a velocity of at least 2 fps to avoid solids depositing

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
- If the ditch is 4 feet or deeper, ladders are required every 25 feet in the ditch

The most practical and best protection

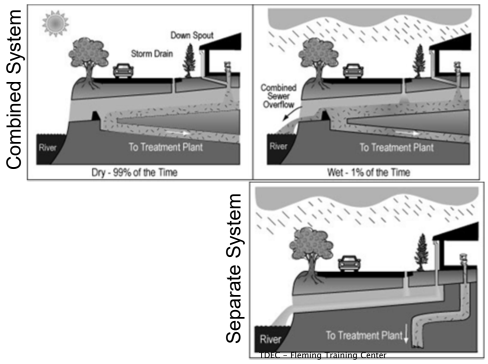
Wastewater Collection Safety

- 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

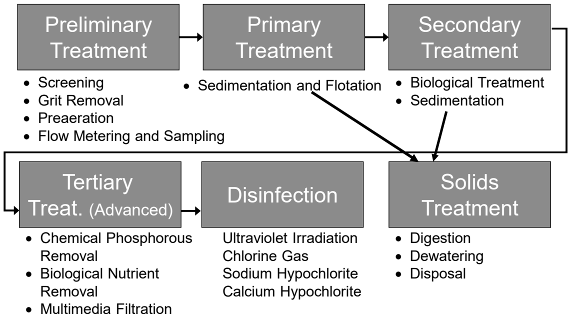
Sanitary, Storm and Combined

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

Primary Treatment
- Sedimentation and Flotation

Secondary Treatment
- Biological Treatment
- Sedimentation

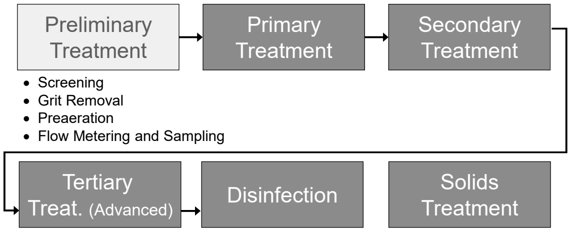
Tertiary Treat. (Advanced)
- Chemical Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

Disinfection

Ultraviolet Irradiation
Chlorine Gas
Sodium Hypochlorite
Calcium Hypochlorite

Solids Treatment
- Digestion
- Dewatering
- Disposal

Wastewater Treatment Processes



Preliminary Treatment
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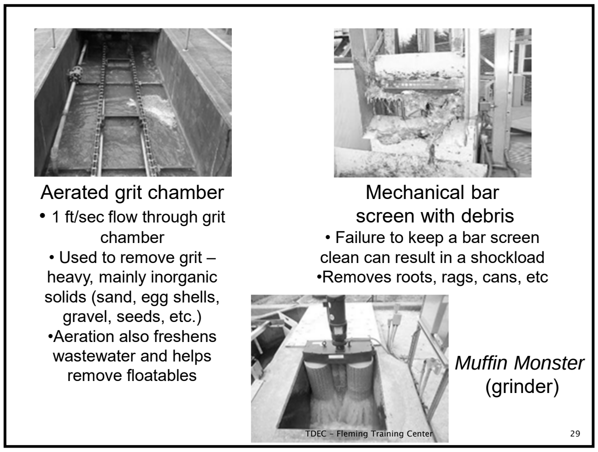
Primary Treatment

Secondary Treatment

Tertiary Treat. (Advanced)

Disinfection

Solids Treatment

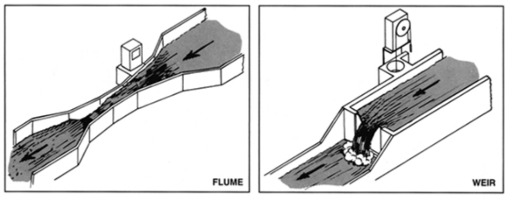


Aerated grit chamber
- 1 ft/sec flow through grit chamber
- Used to remove grit – heavy, mainly inorganic solids (sand, egg shells, gravel, seeds, etc.)
- Aeration also freshens wastewater and helps remove floatables

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

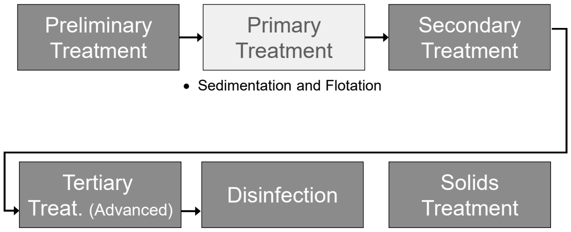
Muffin Monster
(grinder)

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

Wastewater Treatment Processes

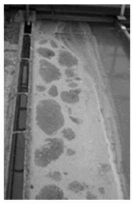


Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection → Solids Treatment

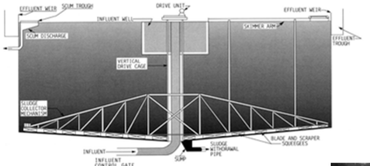
- Sedimentation and Flotation

Primary Clarifier

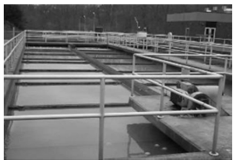
Scum removal



Cross section of circular clarifier

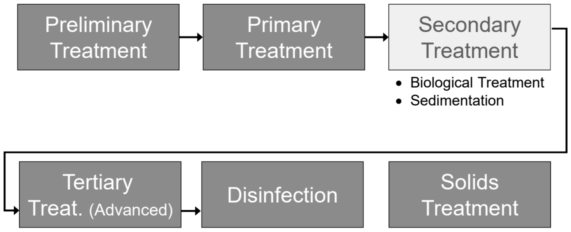


- Velocity drops to < 1 fps
- Separates settleable and floatable solids
- Detention time ~ 1.5-2.0 hrs
- Raw water is gray



Rectangular clarifier

Wastewater Treatment Processes



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

- Biological Treatment
- Sedimentation

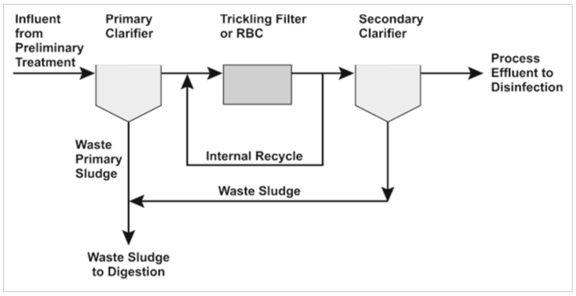
Biological Wastewater (WW) Treatment

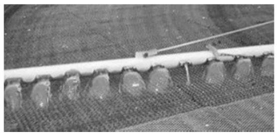
- To remove the suspended solids & the dissolved organic load from the WW by using microbial populations.
- The microorganisms are responsible for:
  - Degradation of the organic matter
  - They can be classified into
    - Aerobic (require oxygen for their metabolism)
    - Anaerobic (grow in absence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

Biological Wastewater (WW) Treatment

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

Attached Growth Biological Treatment Processes

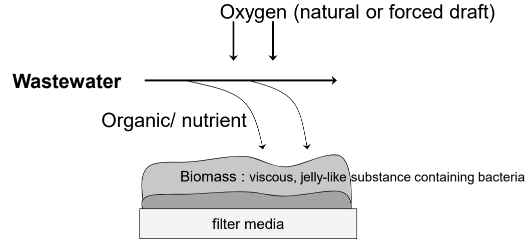




Trickling Filter

Secondary clarifier

Cross-section of Attached Growth Biomass Film

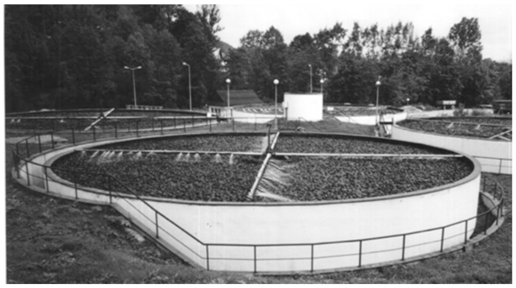


Biomass = “zoogleal mass” or “Biofilm”
Filter media = rock, slag, coal, bricks, redwood blocks or molded plastic

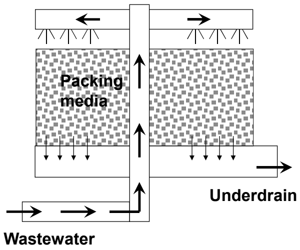
Attached Growth Systems: Advantages

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

Trickling Filter (TF)

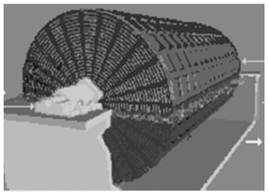


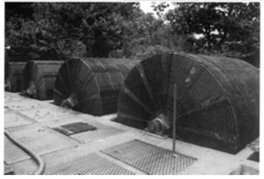
Trickling Filter (TF)- Side View



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

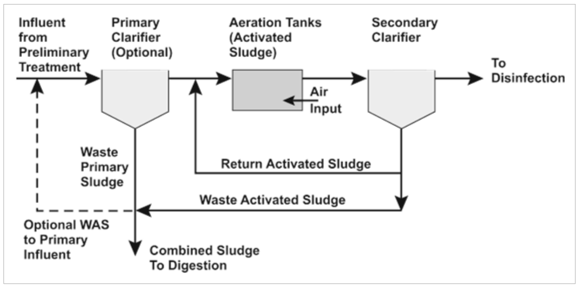
RBC Features





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

Suspended Growth Process Schematic



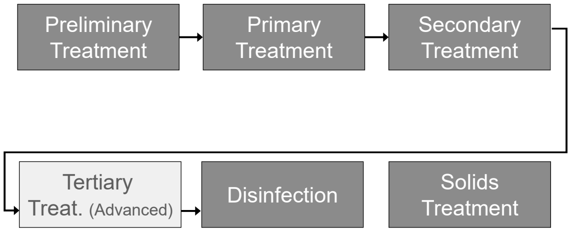
Fine Bubble Diffusers

Mechanical Aeration

Oxidation Ditch

SBR – Sequencing Batch Reactor

Wastewater Treatment Processes



Preliminary Treatment

Primary Treatment

Secondary Treatment

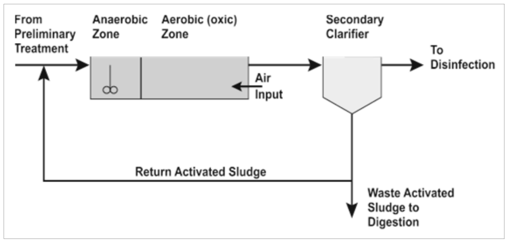
Tertiary Treat. (Advanced)

Disinfection

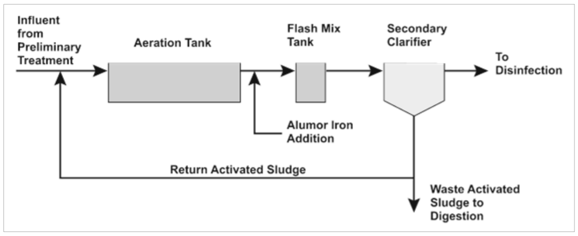
Solids Treatment

- Chemical Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

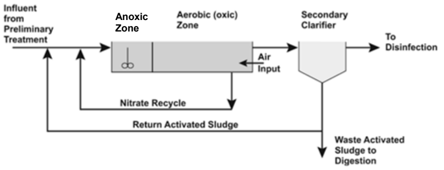
Biological Phosphorus Removal Process Schematic



Chemical Precipitation Process Schematic



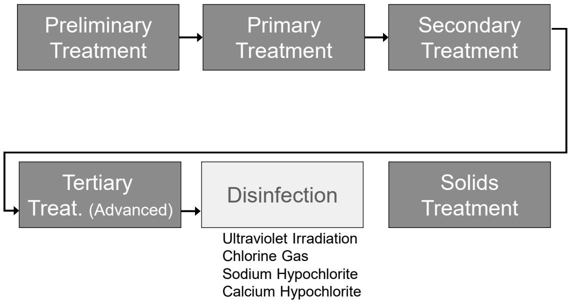
Denitrification Process Schematic



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

Sand Filtration

Wastewater Treatment Processes



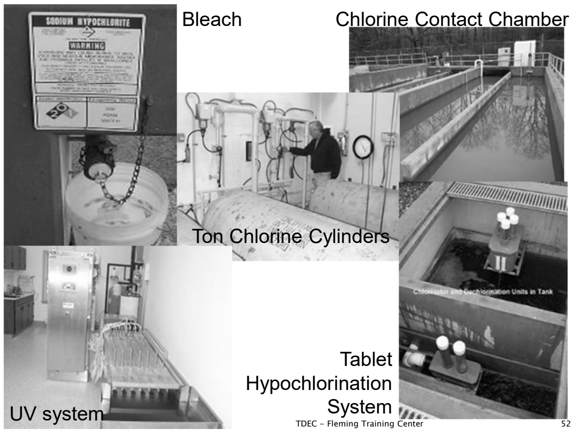
Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

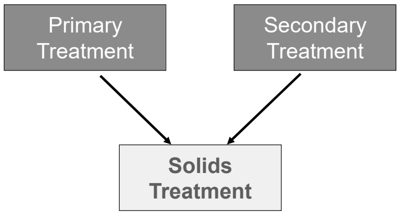
Disinfection:
- Ultraviolet Irradiation
- Chlorine Gas
- Sodium Hypochlorite
- Calcium Hypochlorite

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"



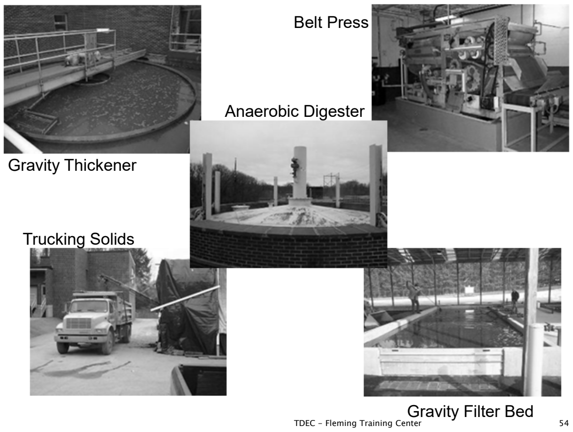
Solids Treatment

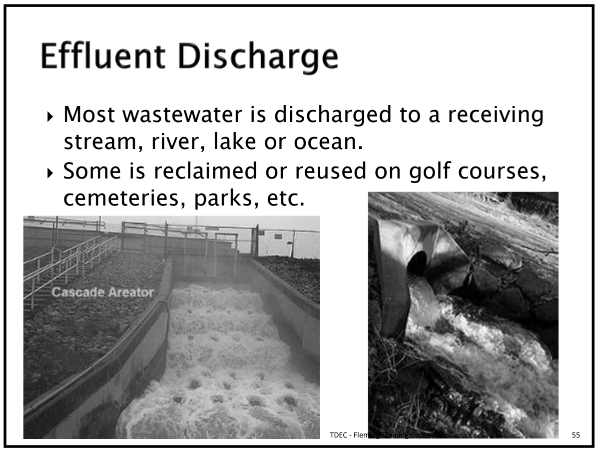


Primary Treatment → Solids Treatment

Secondary Treatment → Solids Treatment

- Digestion
- Dewatering
- Disposal





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.

Any Questions?

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

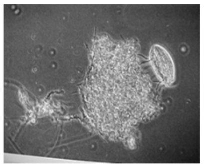
Introduction to Microbiology

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?

E. coli

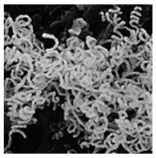
Giardia

- 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

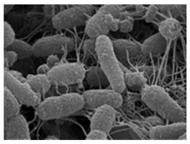
Actinomycetes



Rhizobium bacteria

What key role do they play?

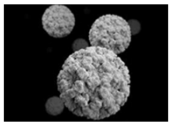
- In lagoons:
  - Bacteria
    - Tiny one-celled organisms
    - Work horse for treatment
  - Algae
    - Use the carbon dioxide the bacteria produce to make oxygen with the help of sunlight
  - Vascular Plants
    - Duckweed



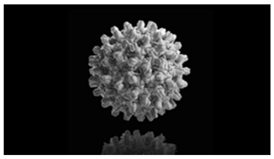
Bacillus sp.

Viruses and Bacteria

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

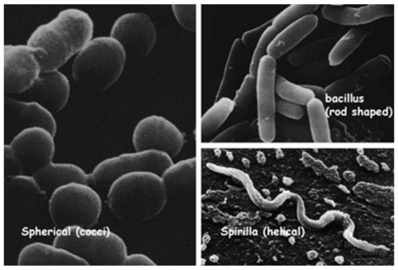


Norovirus

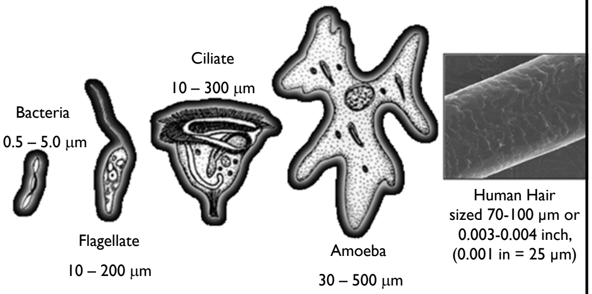


Hepatitis B

Bacteria Found in Wastewater

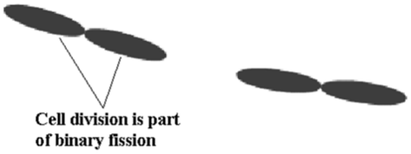


Size Range of Microorganisms



Bacteria

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



Types of Bacteria

Heterotrophic and autotrophic bacteria differ in the source of nutrition they require.

- Heterotrophic:
  - CBOD removers
  - Denitrifiers
  - Organic food
    - Ex: BOD
- Autotrophic
  - Nitrifiers
  - Inorganic food
    - Ammonia
  - Algae
  - Higher plants

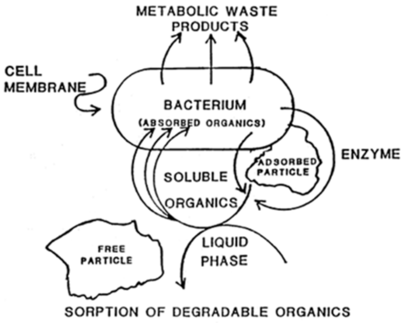
Heterotrophic

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

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

Bacteria "Eating"



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.

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

Autotrophic

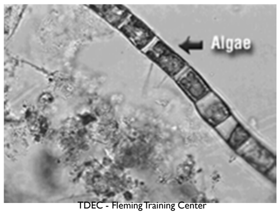
- Use carbon dioxide (inorganic) as a carbon source
  - Autotrophic organisms take inorganic substances into their bodies and transform them into organic nourishment.
  - Autotrophic bacteria make their own food, either by photosynthesis (which uses sunlight, carbon dioxide and water to make food) or 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).

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

Green Algae

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

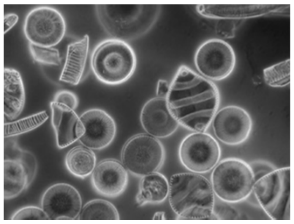


Blue – Green Algae

- 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

Diatoms

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

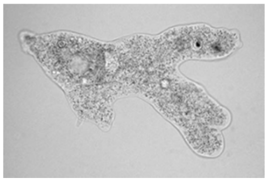


Protozoa

- 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
- Examples: Amoeba, Ciliates, Flagellates

Amoeba

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



Amoeba eating

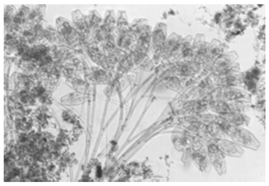
Ciliate

- 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

Ciliate

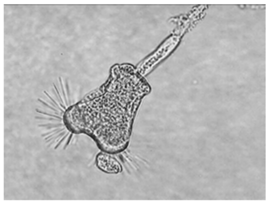
- Stalked ciliates:
  - Cilia rotates to create a vortex to draw food into the mouth opening



Stalked Ciliates

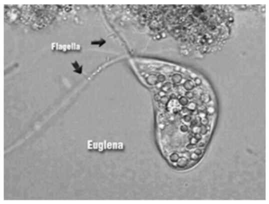
Ciliate

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



Flagellate

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



Metazoa

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

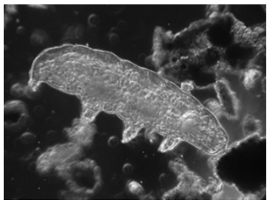
Rotifer

- 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

Water Bear

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

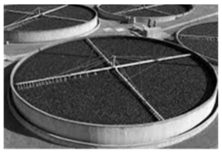


Water Bear

Worms

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

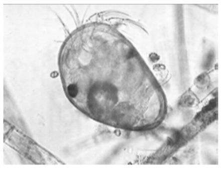
Ascaris and egg



Trickling filter

Other Metazoas

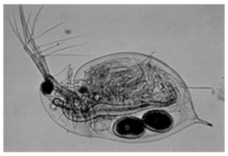
Ostracod
- Seedshrimp
  - Common in lagoons



Copepod
- Crustacean

Other Metazoas

Cadoceran
- Water flea

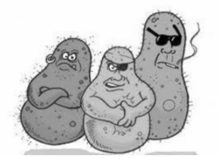


Hydracarina
- Water mite

Fungi

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

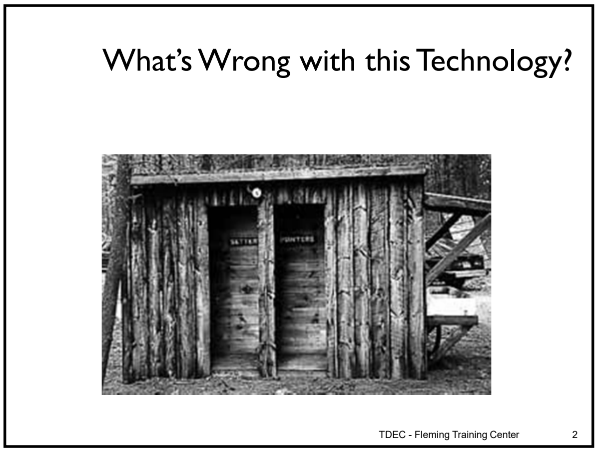
Any Questions?



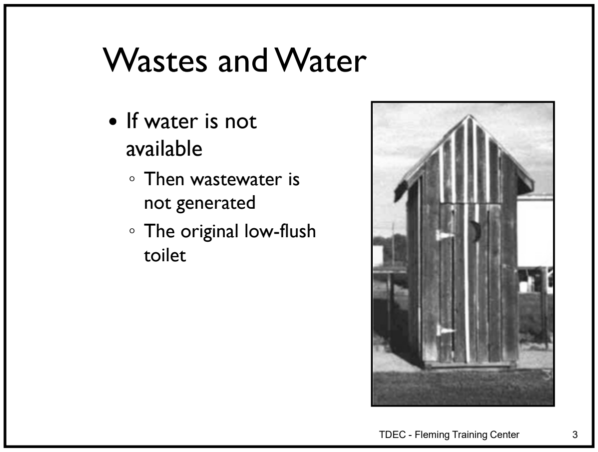
Section 3

Septic Tanks

Septic Tanks



What's Wrong with this Technology?



Wastes and Water

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

Wastewater Defined

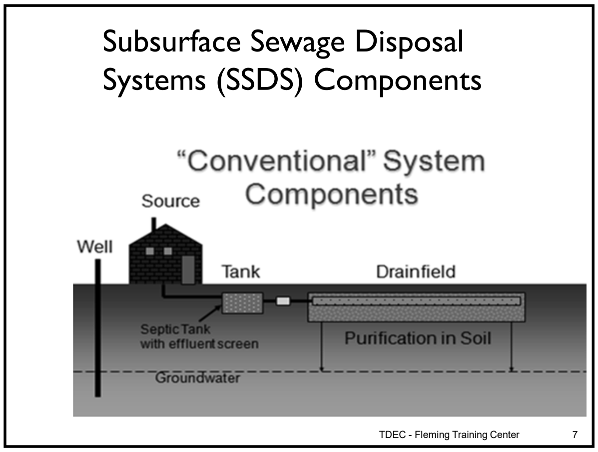
- Used water and water-carried solids that flow to a treatment plant
- Stormwater, surface water, and groundwater infiltration may be included
  - Water that has "stuff" in it
    - Suspended
    - Dissolved
    - Floating
    - Settleable

What Color is it?

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

Onsite Wastewater Treatment

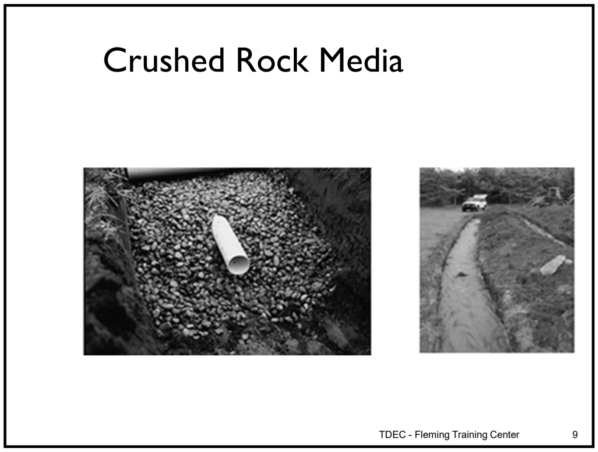
- Usually consists of 2 major parts:
  - A septic tank
    - Provides primary treatment
  - A soil adsorption system
    - Usually a leach field
- Many communities, State parks and schools use individual septic tanks, but the clarified effluent is further treated by a sand filter, wetland or mound system



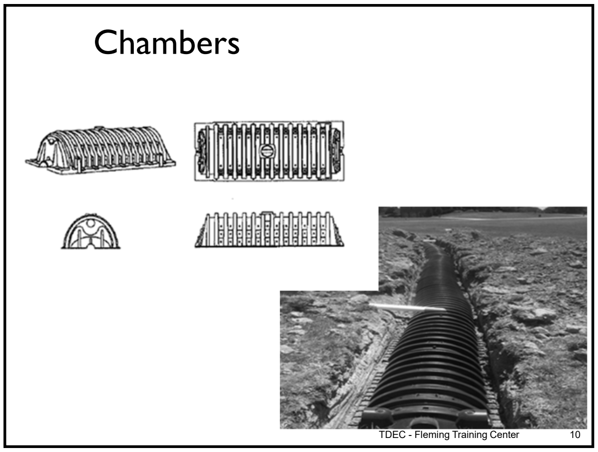
Subsurface Sewage Disposal Systems (SSDS) Components

ABSORPTION FIELD MEDIA AND SUBSTITUTES

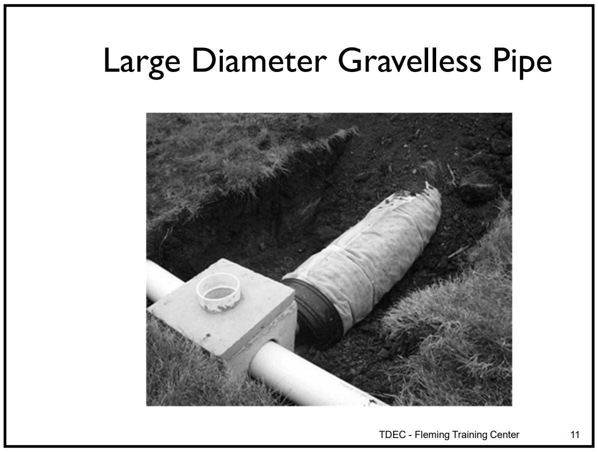
- Crushed Rock Media (Conventional Systems)
- Chambers
- Large Diameter Gravelless Pipe (LDGP)
- Expanded Polystyrene (EPS)



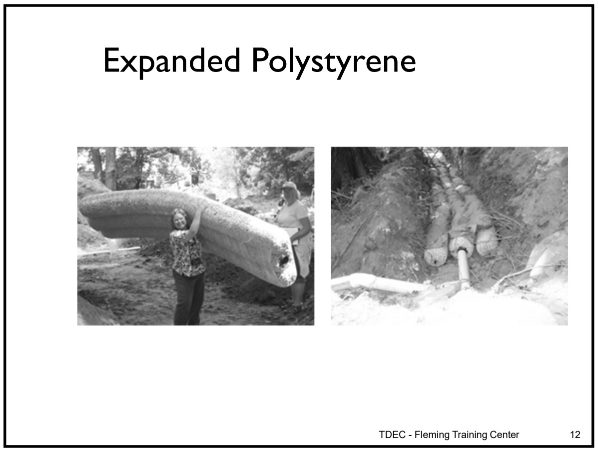
Crushed Rock Media



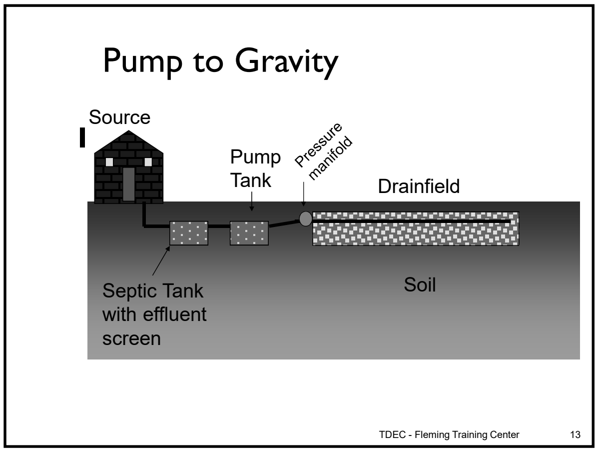
Chambers



Large Diameter Gravelless Pipe



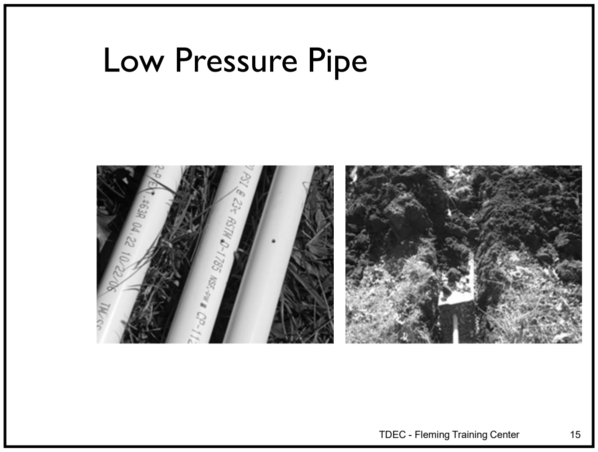
Expanded Polystyrene



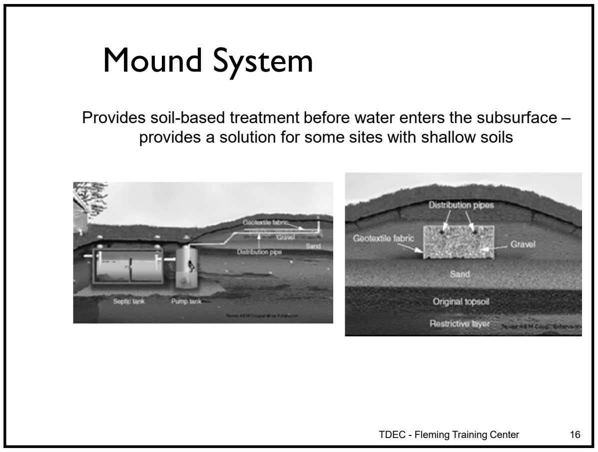
Pump to Gravity

ALTERNATIVE METHODS OF SUBSURFACE SEWAGE DISPOSAL

- Low Pressure Pipe System (LPP)
- Mound System
- Waste Stabilization Lagoon
- Subsurface Drip Disposal System (SDD)
- Advanced Treatment System (ATS)

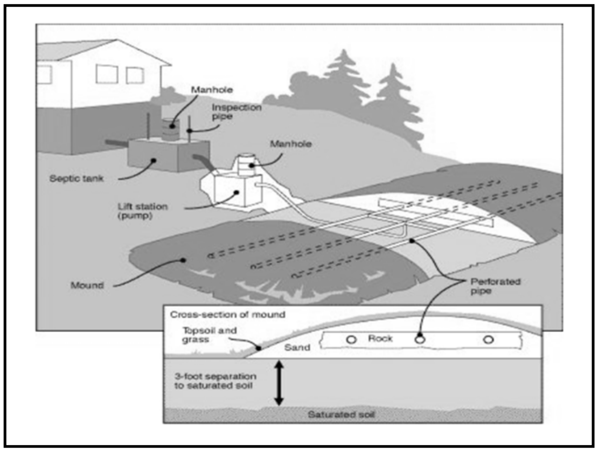


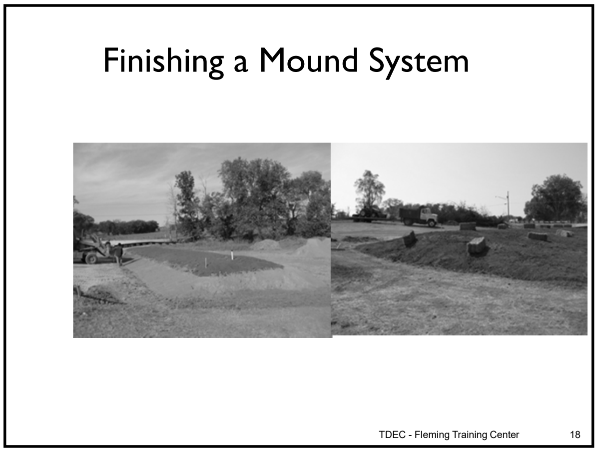
Low Pressure Pipe



Mound System

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





Finishing a Mound System

Lagoon

- Residential lagoons are permitted
  - Five acre homesite
  - Fencing
  - Not a common solution
  - Minimum 5ft. of heavy clay

Subsurface Drip Disposal (SDD) System

- Utilizes pressurized drip irrigation line for the uniform application of treated ww throughout the disposal field

In 2009 effluent treatment devices/systems (ATU/ATS) and subsurface drip disposal (SDD) systems were added to the list of approved alternative systems

Advanced Treatment System (ATS)

- Secondary treatment device that is used to improve the quality of septic tank effluent for residential wastewater flows

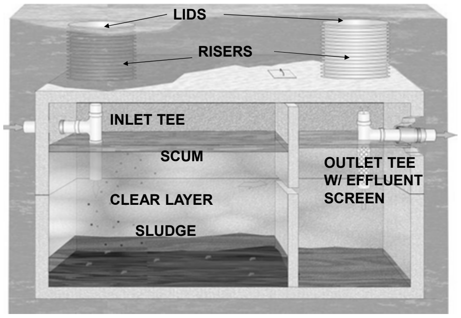
Septic Tanks

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

Septic Tanks

- A typical septic tank may be a single-compartment tank or divided into two compartments
  - The first compartment commonly is as large as the second compartment and acts as the primary clarifier where the majority of grease, oils and retained and digested solids are removed
  - This first compartment also performs the function of the anaerobic digester where bacteria in the tank break down or reduce some of the heavy solids (sludge) that have accumulated on the bottom
- TN Regs 0400-48-01-.09(1)
  - Tanks installed after 1991 shall be of two compartment design

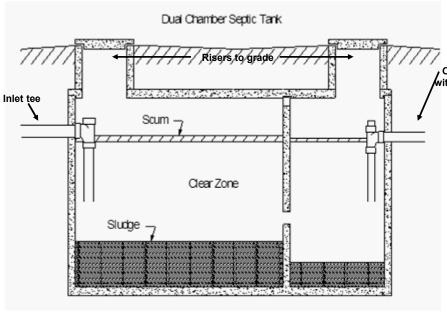
Small System Primary Treatment



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

Typical Cross Section



Liquid-Solid Separation

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

Materials Of Construction

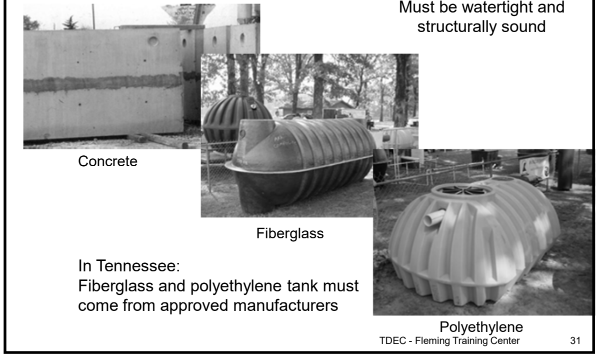
- Reinforced concrete
  - Most common
- Fiber glass
- Polyethylene
- Steel (not used in TN)
  - Require a coating of other corrosion resistance treatment and cathodic protection in corrosive soils to prevent rusting and possible leakage.

- Must be structurally sound and watertight
  - Hydrostatic
  - Vacuum

Watertightness – Why is it important?

- Leakage into septic tank may hydraulically overload it and reduce detention time
  - ◦ Areas with high groundwater table
- Settleable and floatable solids, grease, oils may be flushed out of tank and into disposal system
  - ◦ Plug the soil or shorten the useful life of treatment and disposal system
- Prevent leaking out of septic tank into groundwater
  - ◦ Leaking could drop water level so that scum is released

Tank Materials



Must be watertight and structurally sound

Concrete

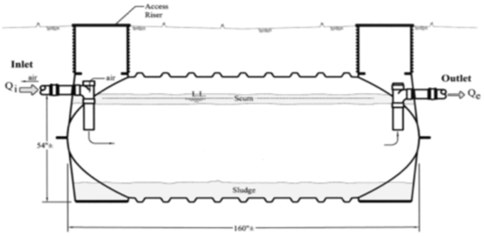
Fiberglass

Polyethylene

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

Concrete Tank Delivery

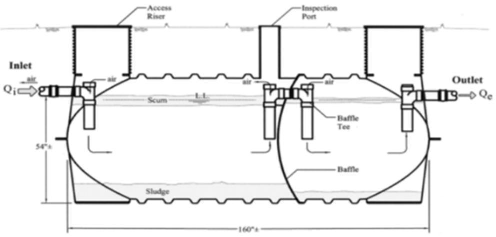
Typical Ribbed Fiberglass Septic Tanks



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.

Sizing

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

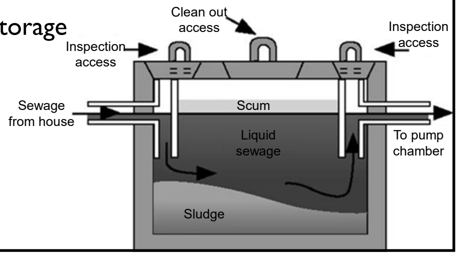
Wastewater Sources

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

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

Processes Within Septic Tank

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



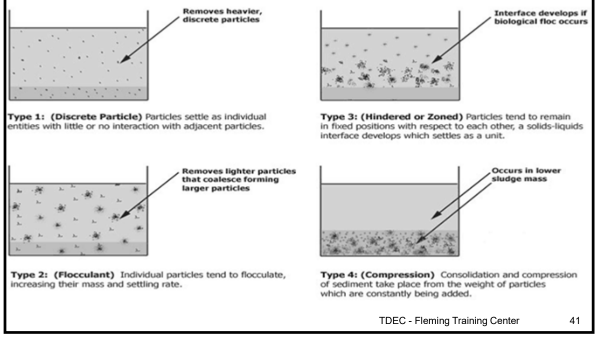
Basic Assumptions

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

Sedimentation Theory

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

Types Of Settling Phenomena



Type 1: (Discrete Particle) Particles settle as individual entities with little or no interaction with adjacent particles.

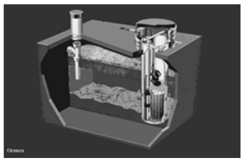
Type 3: (Hindered or Zoned) Particles tend to remain in fixed positions with respect to each other, a solids-liquids interface develops which settles as a unit.

Type 2: (Flocculant) Individual particles tend to flocculate, increasing their mass and settling rate.

Type 4: (Compression) Consolidation and compression of sediment take place from the weight of particles which are constantly being added.

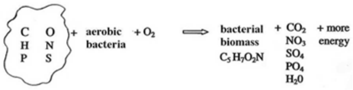
Compartmentation

- 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



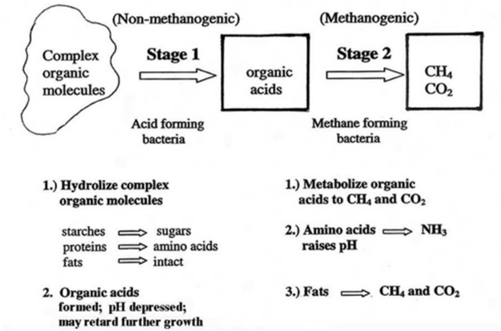
Biological Decomposition

- 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

Two Stages In Anaerobic Decomposition



1.) Hydrolize complex organic molecules

starches ⟹ sugars
proteins ⟹ amino acids
fats ⟹ intact

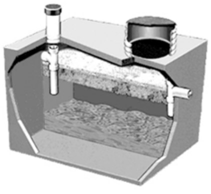
2. Organic acids formed; pH depressed; may retard further growth

1.) Metabolize organic acids to CH_4 and CO_2

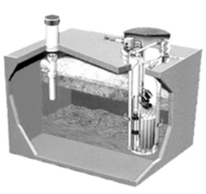
2.) Amino acids ⟹ NH_3 raises pH

3.) Fats ⟹ CH_4 and CO_2

Single Compartments

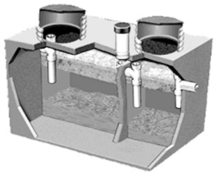


Typical Gravity Septic Tank

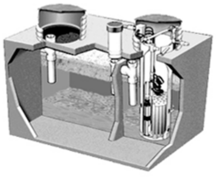


Typical Dosing Septic Tank

Two Compartments



Typical Gravity Septic Tank



Typical Dosing Septic Tank

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
  - Scum layer = 12-14 inches thick
  - Sludge blanket = 24 inches deep
- Determines pump out intervals
- Empirical relationships show (sludge + scum) accumulation in gal/capita/year

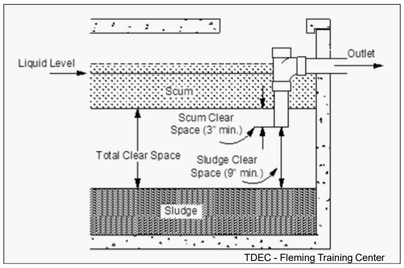
Checking Solids

Sludge Judge

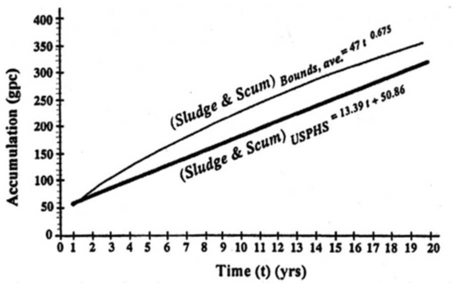
- Used mainly at municipal wastewater treatment plants
- The dip-stick does not have a ball but a ball valve that takes a truer core of the septic tank and it is less prone to clogging.
  - It is important to get the measurement on the first try because the action of putting the instrument down disturbs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

Need for Pumping

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



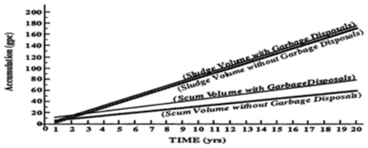
Rate of Septage Accumulation



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%



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

Circular Tanks

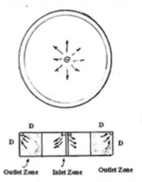


Figure a.
Circular Tank
Center Feed
Elevation View

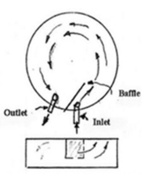
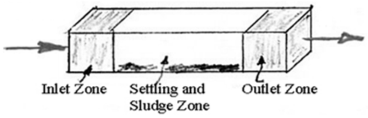
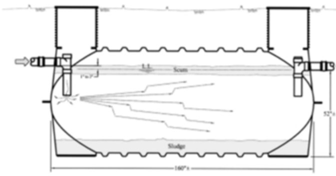


Figure b.
Circular Tank
Peripheral Feed
Elevation view

Four Zones Of Settling



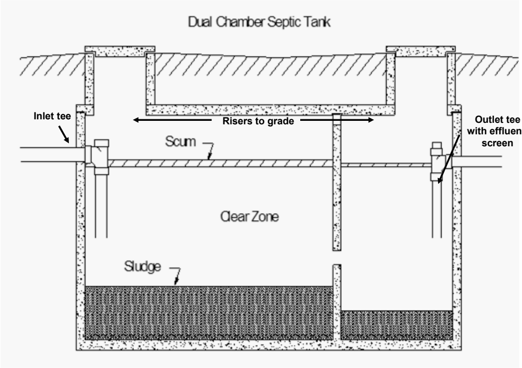
Four zones of settling in large tanks



Zones of settling in a septic tank

Inlets And Outlets

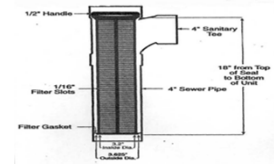
- Inlet – sanitary tee or baffle minimizes short circuiting and dissipates kinetic energy.
- Outlet – sanitary tee or baffle minimizes carryover of solids.
- Effluent filters and screens are final chance to trap solids.
- Gas deflection baffles deflect gases away from outlet

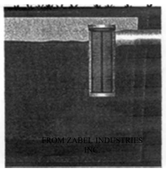


Goal is Near Zero Velocity in Tank for Optimum Solids Removal

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

Outlet Filter Devices

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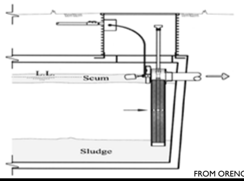
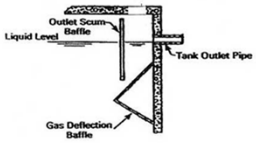
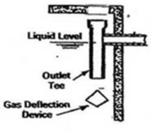


FROM ORENCO

Outlet Filter Devices (Continued)



Gas deflection baffles



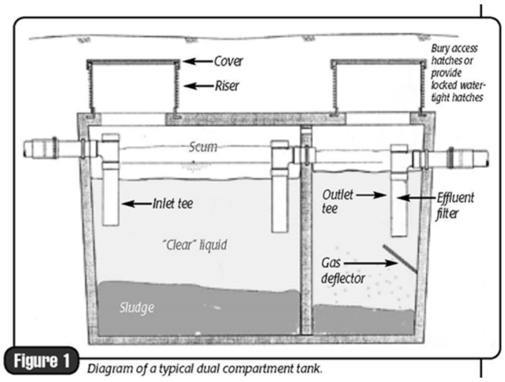
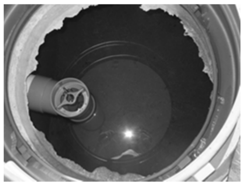


Figure 1 Diagram of a typical dual compartment tank.

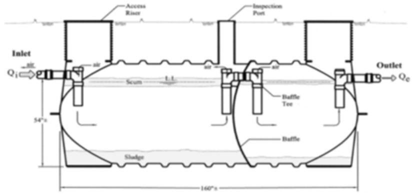
Effluent Screens

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

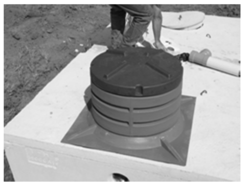


Access

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

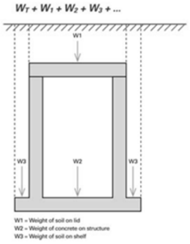


Adding an After-Market Riser to a Septic tank

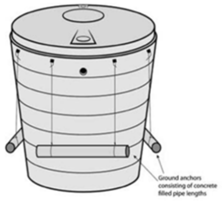


Anti-Floatation Collars

- Prevents tank from floating in high groundwater



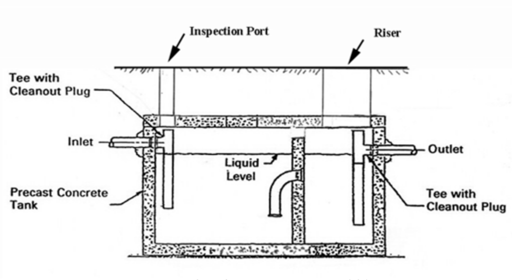
- Without pre-cast anti-flotation collars, ground anchors are required



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
- Grease will plug leach fields

Double-Compartment Grease Trap



From US EPA Design Manual 1980

Trace Organics

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

Septage

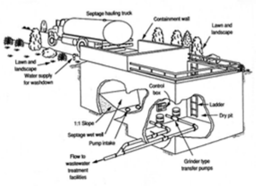
- Highly variable odoriferous material in septic tank
- Solids content 3-10%

Septage Management

- Land application
  - Spread by hauler truck or farm equipment
  - Injected below the surface
  - Subsurface incorporation
  - pH raised to at least 12

Septage Management

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

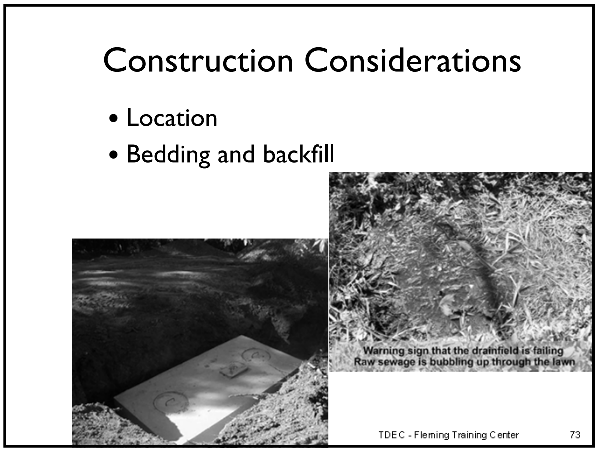


Speaking of Additives

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

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



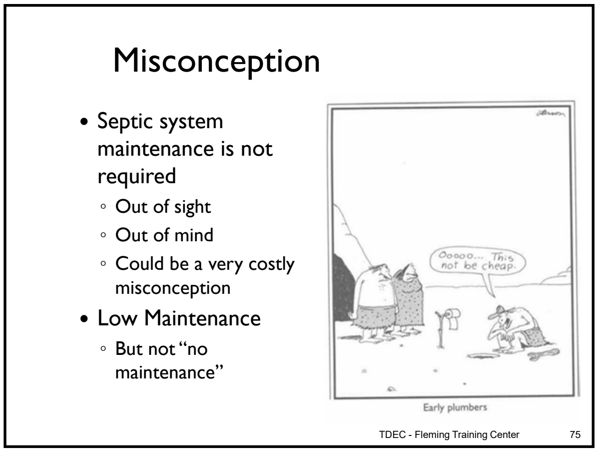
Construction Considerations

- Location
- Bedding and backfill

Warning sign that the drainfield is failing
Raw sewage is bubbling up through the lawn

System Maintenance

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



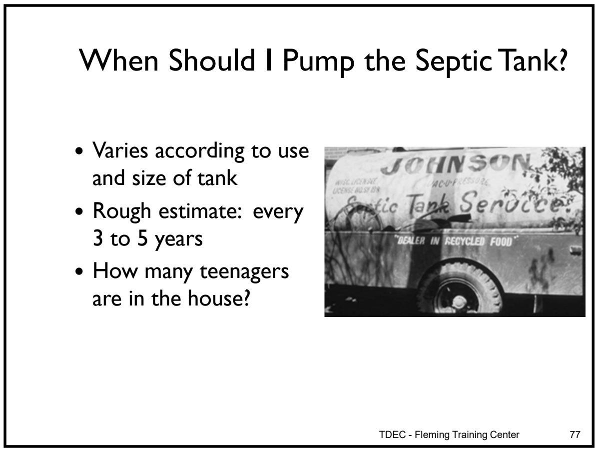
Misconception

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

Early plumbers

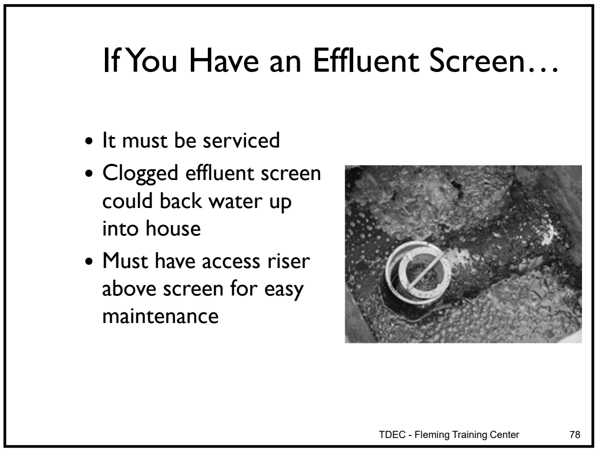
Operation and Maintenance

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



When Should I Pump the Septic Tank?

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



If You Have an Effluent Screen…

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

Effluent Screen Cleaning

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

After Pumping…

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

After Pumping….

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

Regulations

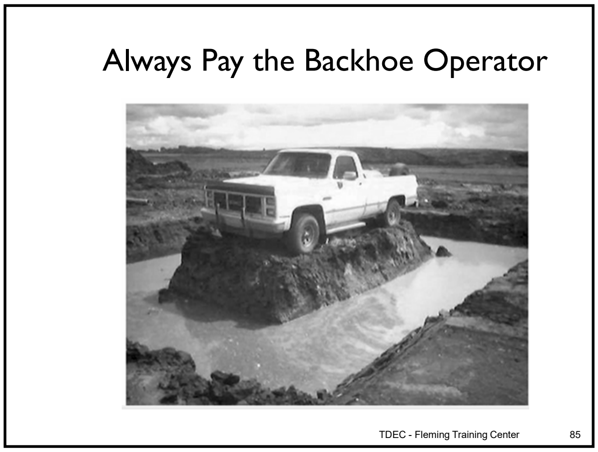
- State and local health departments promulgate and enforce laws
  - Early codes relied on soil percolation test
  - Regulations became standardized in spite of differing climate and soil conditions
  - Led to prescriptive designs
  - By late 1970s there was a gradual increase in sizes of septic tank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

Regulations

- Regulations
  - Tennessee has a state-wide program
  - **0400-48-01 Regulations to Govern Subsurface Sewage Disposal Systems**
    - TDEC staff located in most counties
    - They approve the site before system is covered
  - Several cities/counties have a local program
    - Local program must be equally or more stringent than State program

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

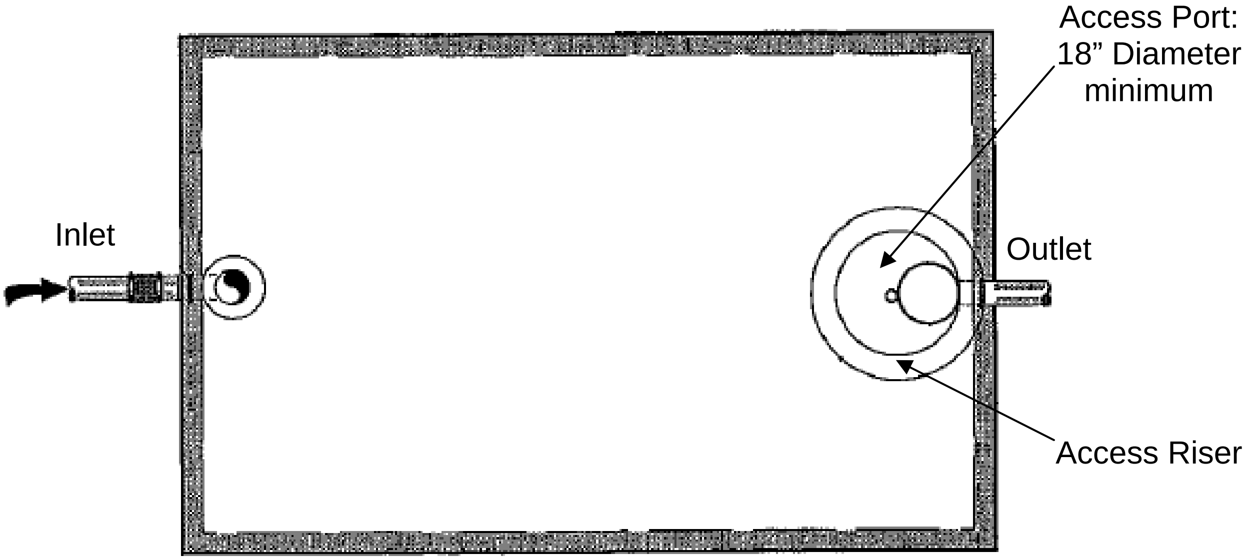


Always Pay the Backhoe Operator

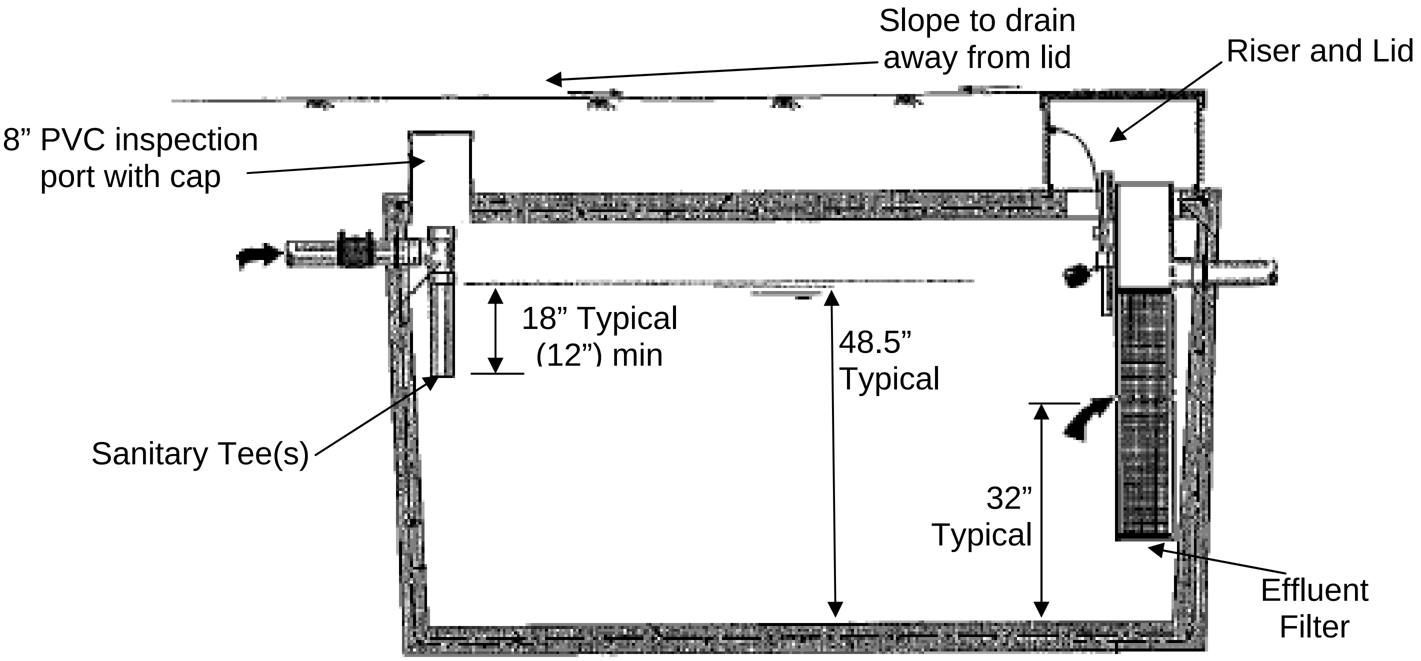
TDEC - Fleming Training Center 85

Single Compartment Septic Tank

Top View

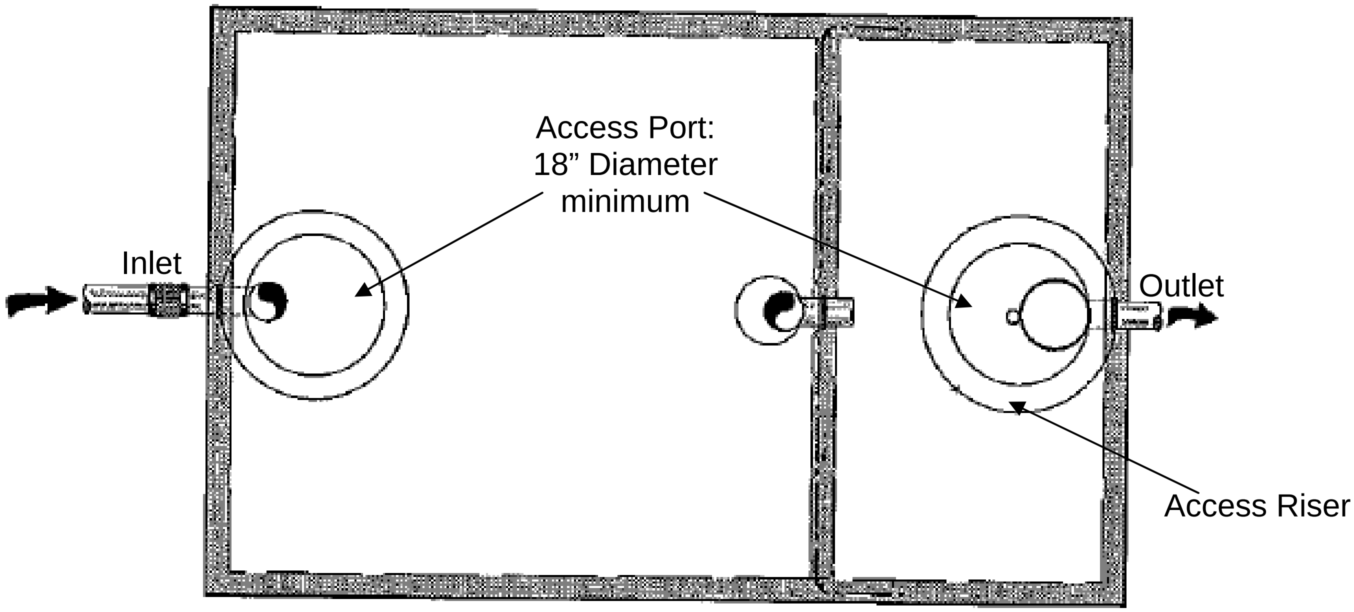


Side View

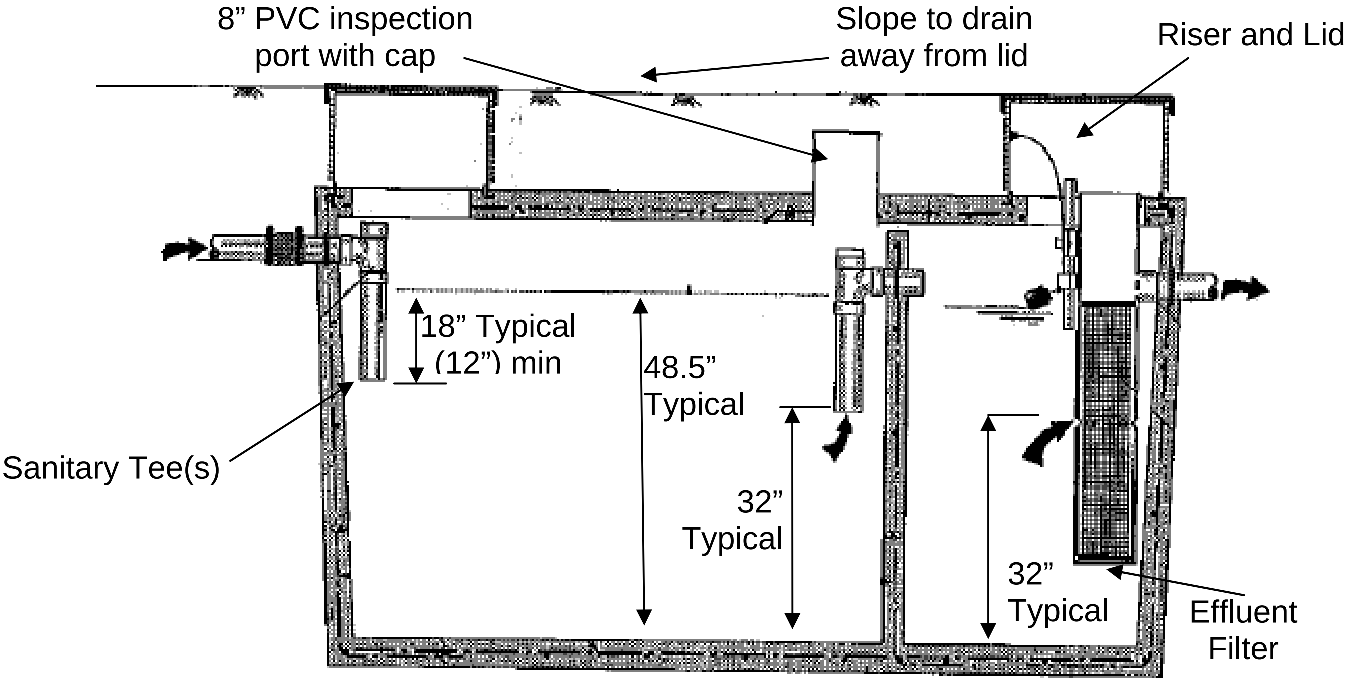


Two Compartment Septic Tank

Top View



Side View



United States
Environmental Protection
Agency

Office of Water
(4606)

EPA 816-F-01-021
July 2001

Source Water Protection Practices Bulletin

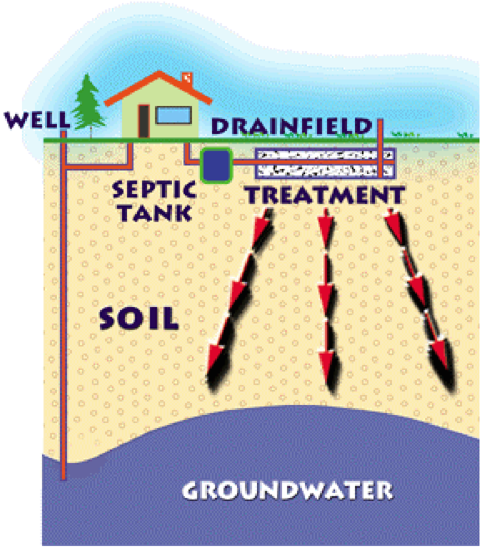
Managing Septic Systems to Prevent Contamination of Drinking Water

Septic systems (also known as onsite wastewater disposal systems) are used to treat and dispose of sanitary waste. When properly sited, designed, constructed, and operated, they pose a relatively minor threat to drinking water sources. On the other hand, improperly used or operated septic systems can be a significant source of ground water contamination that can lead to waterborne disease outbreaks and other adverse health effects.

This fact sheet discusses ways to prevent septic systems from contaminating sources of drinking water. Septic systems that receive non-sanitary wastes (e.g., industrial process wastewater) are considered industrial injection wells, and are not the primary focus of this fact sheet. Other fact sheets in this series address prevention measures for contamination sources such as fertilizers, pesticides, animal feeding operations, and vehicle washing.

SOURCES OF SEPTIC SYSTEM EFFLUENT

About 25 percent of U.S. households rely on septic systems to treat and dispose of sanitary waste that includes wastewater from kitchens, clothes washing machines, and bathrooms. Septic systems are primarily located in rural areas not served by sanitary sewers.



A typical household septic system consists of a septic tank, a distribution box, and a drain field. The septic tank is a rectangular or cylindrical container made of concrete, fiberglass, or polyethylene. Wastewater flows into the tank, where it is held for a period of time to allow suspended solids to separate out. The heavier solids collect in the bottom of the tank and are partially decomposed by microbial activity. Grease, oil, and fat, along with some digested solids, float to the surface to form a scum layer. (Note: Some septic tanks have a second compartment for additional effluent clarification.)

The partially clarified wastewater that remains between the layers of scum and sludge flows to the distribution box, which distributes it evenly through the drain field. The drain field is a network of perforated pipes laid in gravel-filled trenches or beds. Wastewater flows out of the pipes, through the gravel, and into the surrounding soil. As the wastewater effluent percolates down through the soil, chemical and biological processes remove some of the contaminants before they reach ground water.

Large capacity septic systems are essentially larger versions (with larger capacities and flow rates) of single family residential septic systems, but they may have more than one septic tank or drain field for additional treatment capacity. In some cases, an effluent filter may be added at the outlet of the large capacity septic tank to achieve further removal of solids. Many large systems rely on pumps rather than gravity to provide an even flow distribution into the drain field.

WHY IS IT IMPORTANT TO MANAGE SEPTIC SYSTEMS NEAR THE SOURCES OF YOUR DRINKING WATER?

Septic systems are a significant source of ground water contamination leading to waterborne disease outbreaks and other adverse health effects. The bacteria, protozoa, and viruses found in sanitary wastewater can cause numerous diseases, including gastrointestinal illness, cholera, hepatitis A, and typhoid.

Nitrogen, primarily from urine, feces, food waste, and cleaning compounds, is present in sanitary wastewater. Consumption of nitrates can cause methemoglobinemia (blue baby syndrome) in infants, which reduces the ability of the blood to carry oxygen. If left untreated, methemoglobinemia can be fatal for affected infants. Due to this health risk, a drinking water maximum contaminant level (MCL) of 10 milligrams per liter (mg/l) or parts per million (ppm) has been set for nitrate measured as nitrogen. Even properly functioning conventional septic systems, however, may not remove enough nitrogen to attain this standard in their effluent.

AVAILABLE PREVENTION MEASURES TO ADDRESS SEPTIC SYSTEMS

Septic systems can contribute to source water contamination for various reasons, including improper siting, poor design, faulty construction, and incorrect operation and maintenance. Most States and localities regulate siting, design, and construction of septic systems and only regulate operation and maintenance for large capacity septic systems. Some of the more widely used prevention measures are described below. Your local health department should be able to advise you on specific requirements for your community.

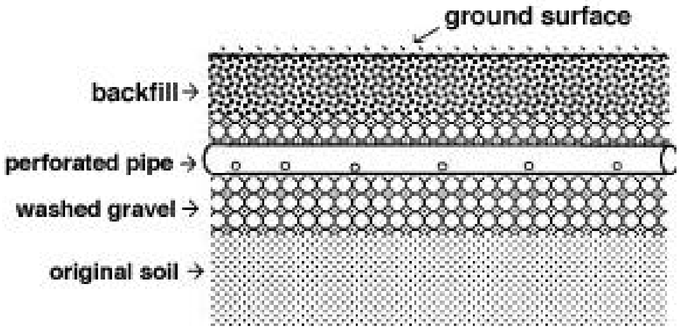
Please keep in mind that individual prevention measures may or may not be adequate to prevent contamination of source waters. Most likely, individual measures should be combined in an overall prevention approach that considers the nature of the potential source of contamination, the purpose, cost, operational, and maintenance requirements of the measures, the vulnerability of the source water, the public’s acceptance of the measures, and the community’s desired degree of risk reduction

Siting

Most jurisdictions have adopted, for septic systems, ***minimum horizontal setback distances*** from features such as buildings and drinking water wells and ***minimum vertical setback distances*** from impermeable soil layers and the water table. Septic systems should be located a safe distance from drinking water sources to avoid potential contamination. Areas with high water tables and shallow impermeable layers should be avoided because there is insufficient unsaturated soil thickness to ensure sufficient treatment. ***Soil permeability must be adequate*** to ensure proper treatment of septic system effluent. If permeability is too low, the drain field may not be able to handle wastewater flows, and surface ponding (thus contributing to the contamination of surface water through runoff) or plumbing back-ups may result. If permeability is too high, the effluent may reach ground water before it is adequately treated. As a result, alternative systems may be necessary in karst areas. Well-drained loamy soils are generally the most desirable for proper septic system operation. In making siting decisions, local health officials should also evaluate whether soils and receiving waters can absorb the combined effluent loadings from all of the septic systems in the area.

Design and Construction

Septic tanks and ***drain fields should be of adequate size*** to handle anticipated wastewater flows. In addition, soil characteristics and topography should be taken into account in designing the drain field. Generally speaking, the lower the soil permeability, the larger the drain field required for adequate treatment. Drain fields should be located in relatively flat areas to ensure uniform effluent flow.



Septic drain field

Effluent containing excessive amounts of grease, fats, and oils may clog the septic tank or drain field and lead to premature failure. The installation of ***grease interceptors*** is recommended for restaurants and other facilities with similar wastewater characteristics.

Construction should be performed by a ***licensed septic system installer*** to ensure compliance with applicable regulations. The infiltration capacity of the soil may be reduced if the soil is overly compacted. Care should be taken not to drive heavy vehicles over the drain field area during construction or afterward. Construction equipment should operate from upslope of the drain field area. Construction should not be performed when the soil is wet, or excessive soil smearing and soil compaction may result.

Operation and Maintenance

Proper operation and maintenance of septic systems is perhaps the most crucial prevention measure to preventing contamination. Inadequate septic system operation and maintenance can lead to failure even when systems are designed and constructed according to regulation. Homeowners associations and tenant associations can play an important role in educating their members about their septic systems. In commercial establishments such as strip malls, management companies can serve a similar role. Septic system owners should continuously monitor the drain field area for signs of failure, including odors, surfacing sewage, and lush vegetation. The septic tank should be ***inspected annually*** to ensure that the internal structures are in good working order and to monitor the scum level.

Many septic systems fail due to hydraulic overloading that leads to surface ponding. Reducing wastewater volumes through ***water conservation*** is important to extend the life of the drain field. Conservation measures include using water-saving devices, repairing leaky plumbing fixtures, taking shorter showers, and washing only full loads of dishes and laundry. Wastewater from basement sump pumps and water softeners should not be discharged into the septic system to minimize hydraulic load. In addition, surface runoff from driveways, roofs, and patios should be directed away from the drain field.

If an excessive amount of sludge is allowed to collect in the bottom of the septic tank, wastewater will not spend a sufficient time in the tank before flowing into the drain field. The increased concentration of solids entering the drain field can reduce soil permeability and cause the drain field to fail. Septic tanks should be pumped out every two to five years, depending on the tank size, wastewater volume, and types of solids entering the system. Garbage disposals increase the volume of solids entering the septic tank, requiring them to be pumped more often.

Household chemicals such as solvents, drain cleaners, oils, paint, pharmaceuticals, and pesticides can interfere with the proper operation of the septic system and cause ground water contamination. Homeowners should take advantage of ***local hazardous waste collection programs*** to dispose of these wastes whenever possible. Grease, cooking fats, coffee grounds, sanitary napkins, and cigarettes do not easily decompose, and contribute to the build-up of solids in the tank. The use of additives containing yeast, bacteria, enzymes, and solvents has not been proven to improve the performance of septic systems, and may interfere with their normal operation. Bacterial "starters" are not necessary because a wide range of bacteria are normally present in sewage entering the tank. Additives containing solvents or petrochemicals can cause ground water contamination.

Vehicles and heavy equipment should be kept off the drain field area to prevent soil compaction and damage to pipes. Trees should not be planted over the drain field because the roots can enter the perforated piping and lead to back-ups. Last, any type of construction over the drain field should be avoided. Impervious cover can reduce soil evaporation from the drain field, reducing its capacity to handle wastewater.

FOR ADDITIONAL INFORMATION

For information on septic system regulations in your community, contact your state or local health department. The information sources below contain information on measures to prevent septic system failures. All of the documents listed are available free of charge on the Internet.

Numerous documents on septic systems are available for download from U.S. Department of Agriculture Cooperative State Research, Education, and Extension Service State Partners. Links to the various State Partners can be found at http://www.reeusda.gov/1700/statepartners/usa.htm. Several examples of these documents are presented below:

Bicki, T.J. and D.G. Peterson. "Septic Systems: Operation and Maintenance of On-site Sewage Disposal Systems." *Land and Water: Conserving Natural Resources in Illinois*, Number 15, Cooperative Extension Service, University of Illinois at Urbana-Champaign. Retrieved February 26, 2001 from the World Wide Web: http://web.aces.uiuc.edu/vista/pdf_pubs/SEPTIC.PDF.

Hiller, Joe and Andrea Lewis. (October 1994). *Septic System Failure: What To Do.* University of Wyoming Cooperative Extension Service. B-1007. Retrieved February 27, 2001 from the World Wide Web: http://www.uwyo.edu/ag/ces/PUBS/Wy1007.pdf.

Hiller, Joe and Andrea Lewis. (October 1994). *Septic System Maintenance.* University of Wyoming Cooperative Extension Service. B-1008. Retrieved February 26, 2001 from the World Wide Web: http://www.uwyo.edu/ag/ces/PUBS/Wy1008.pdf.

Porter, E., R. Rynk, K. Babin, and B.N. Burnell. *Care and Maintenance of Your Home Septic System.* University of Idaho College of Agriculture, Cooperative Extension System. CIS 1027. Retrieved February 27, 2001 from the World Wide Web: http://info.ag.uidaho.edu/Resources/PDFs/CIS1027.pdf.

Powell, G. Morgan. (March 1996). *Get to Know Your Septic System.* Kansas Cooperative Extension Service, Kansas State University. MF-2179. Retrieved February 26, 2001 from the World Wide Web: http://www.oznet.ksu.edu/library/H20QL2/MF883.PDF.

Powell, G. Morgan. (July 1992). *Septic Tank – Soil Adsorption System.* Kansas Cooperative Extension Service, Kansas State University. MF-944. Retrieved February 27, 2001 from the World Wide Web: http://www.oznet.ksu.edu/library/H20QL2/MF944.PDF.

Powell, G. Morgan, Barbara L. Dallemand, Judith M. Willingham. (August 1998). *Septic Tank Maintenance: A Key to Longer Septic System Life.* Kansas Cooperative Extension Service, Kansas State University. MF-947. Retrieved February 28, 2001 from the World Wide Web: http://www.oznet.ksu.edu/library/H20QL2/MF947.PDF.

Powell, G. Morgan, Barbara L. Dallemand, Judith M. Willingham. (December 1998). *Why Do Septic Systems Fail?* Kansas Cooperative Extension Service, Kansas State University. MF-946. Retrieved February 27, 2001 from the World Wide Web: http://www.oznet.ksu.edu/library/H20QL2/MF946.PDF.

Runyan, R. Craig, *Septic Tank Maintenance.* Cooperative Extension Service, College of Agriculture and Home Economics, New Mexico State University, Guide M-113.

Washington State University Cooperative Extension and U.S. Department of Agriculture. (Reprinted January 1998). *Properly Managing Your Septic Tank System.* EB1671. Retrieved February 26, 2001 from the World Wide Web: http://cru.cahe.wsu.edu/CEPublications/eb1671/eb1671.html.

The National Small Flows Clearinghouse has developed a series of brochures on septic systems. They can be found at http://www.estd.wvu.edu/nsfc/NSFC_septic_news.html.

North Carolina State University Water Quality Group. *Septic Systems*. Retrieved February 27, 2001 from the World Wide Web: http://h2osparc.wq.ncsu.edu/estuary/rec/septic.html.

Septic Information Website: Inspecting, Designing, & Maintaining Residential Septic Systems. Retrieved February 28, 2001 from the World Wide Web: http://www.inspect-ny.com/septbook.htm.

Stormwater Manager's Resource Center. *Non-Stormwater Fact Sheet: Septic Systems*. Retrieved February 26, 2001 from the World Wide Web: http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool7-Non_Stormwater/SepticSystems.htm.

U.S. Environmental Protection Agency. (September 1999). *The Class V Underground Injection Control Study, Volume 5: Large Capacity Septic Systems*. Retrieved February 27, 2001 from the World Wide Web: http://www.epa.gov/safewater/uic/classv/volume5.pdf.

U.S. Environmental Protection Agency. *Decentralized Onsite Management for Treatment of Domestic Wastes.* Retrieved May 1, 2001 from the World Wide Web: http://www.epa.gov/seahome/decent.html.

U.S. Environmental Protection Agency. *Principles and Design of Onsite Waste Disposal with Septic Systems.* Retrieved May 1, 2001 from the World Wide Web: http://www.epa.gov/seahome/onsite.html.

Section 4

Ponds and Lagoons

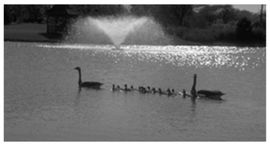
Wastewater Ponds & Lagoons

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 (algae – green water)
- 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 →

BOD or "food"

Oxygen

Nitrogen, Phosphorus & Iron

CO_2 + H_2o + new bugs + stable matter

Carbon Dioxide

Water

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

Lagoon Treatment Process

- Physical
- Chemical
- Biological
- Indirect

Lagoon Treatment Process

Physical

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

Chemical

- Precipitation in sludge layer

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

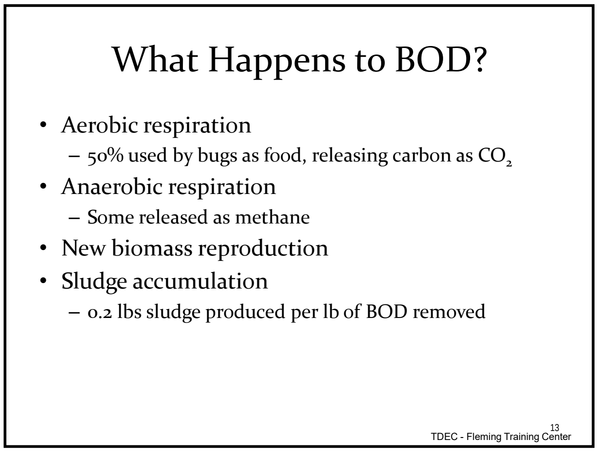
Indirect

- 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

Photosynthesis vs. Respiration

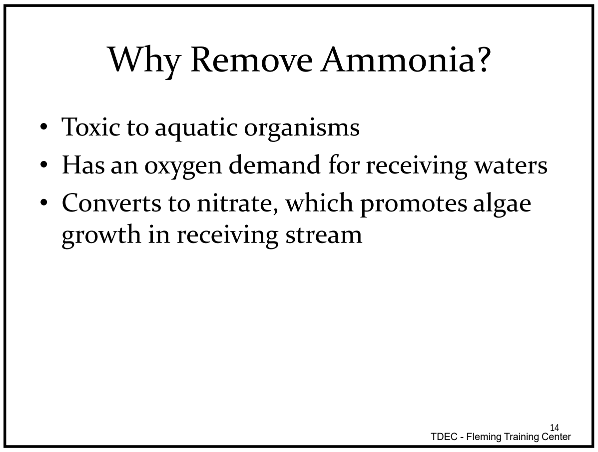
$$\underset{\xleftarrow{\text{Respiration}}}{CO_2 + H_2o} \leftrightarrow \overset{\xrightarrow{\text{Photosynthesis}}}{O_2 + \underset{\text{carbohydrate}}{CH_2O}}$$

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



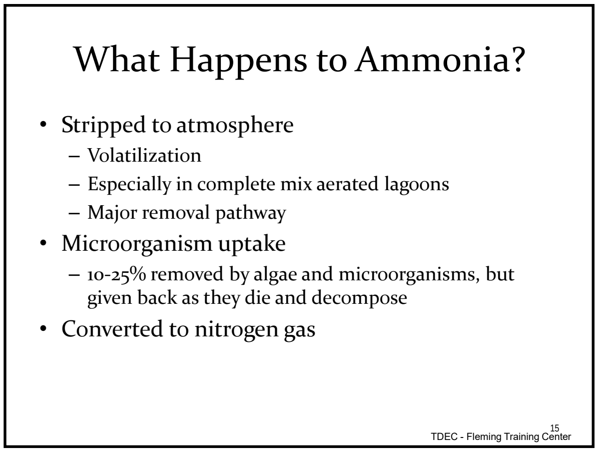
What Happens to BOD?

- 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



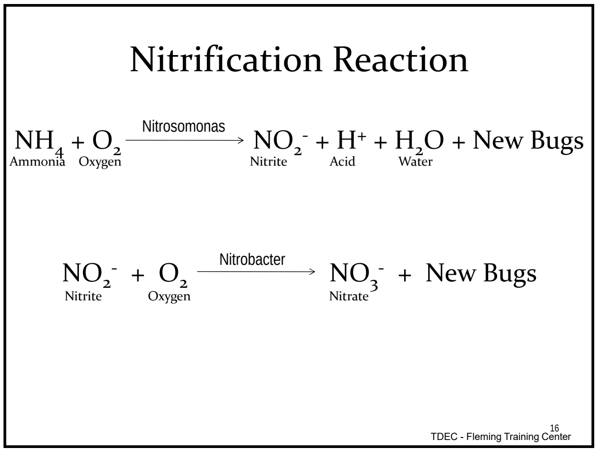
Why Remove Ammonia?

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



What Happens to Ammonia?

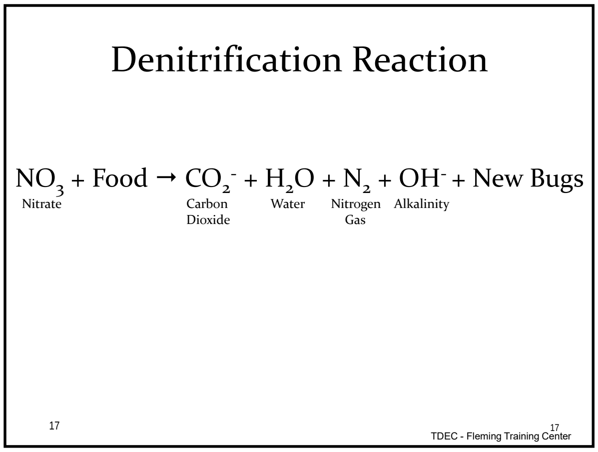
- Stripped to atmosphere
  - Volatilization
  - Especially in complete mix aerated lagoons
  - Major removal pathway
- Microorganism uptake
  - 10-25% removed by algae and microorganisms, but given back as they die and decompose
- Converted to nitrogen gas



Nitrification Reaction

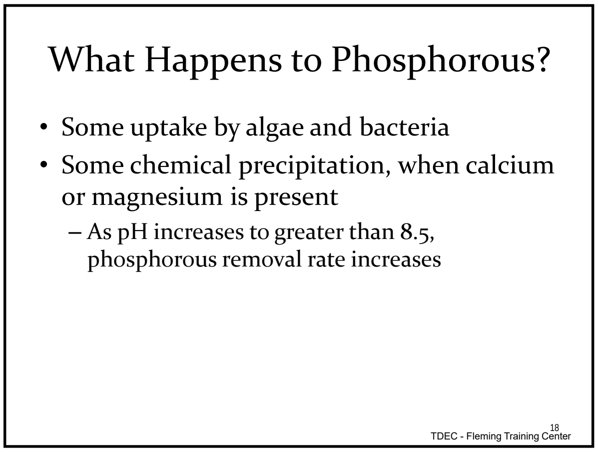
$$\underset{\text{Ammonia}}{NH_4} + \underset{\text{Oxygen}}{O_2} \xrightarrow{\text{Nitrosomonas}} \underset{\text{Nitrite}}{NO_2^-} + \underset{\text{Acid}}{H^+} + \underset{\text{Water}}{H_2O} + \text{New Bugs}$$

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



Denitrification Reaction

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



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

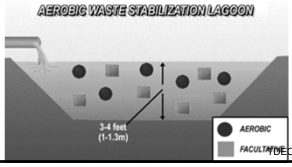
Types of Lagoons

- Aerobic
- Anaerobic
- Facultative
- Aerated

Types of Bacteria in Stabilization Lagoons

Aerobic Pond

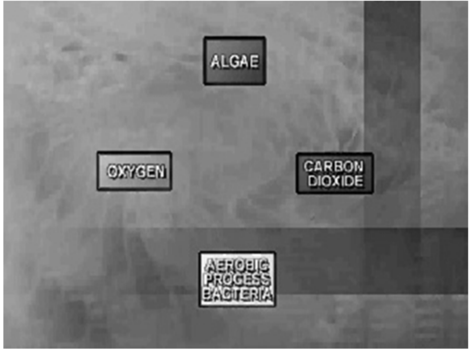
- Shallow: 3-4 ft deep
- D.O. throughout water column
- Flat terrain with much sunshine
- D.O. due to photosynthesis



Aerobic Pond

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

Decomposition in Aerobic Layers of a Pond



Wind Action

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

Temperature

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

Sunlight

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

Nutrients

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

pH

- The pH of a lagoon indicates whether its contents are acidic or alkaline
- An alkaline environment produces the best results.
- The pH normally varies throughout the day depending on algal activity
- The pH is usually higher during the day because algae are consuming more carbon dioxide (photosynthesis) than they are producing (respiration)
- The pH is typically lower at night because CO2 is being produced (respiration) but not consumed by algae

Dissolved Oxygen

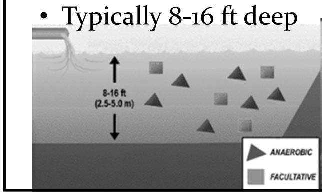
- DO is vital for aerobic bacteria and preferred by facultative bacteria
- Some DO is produced by natural reaeration and much is produced by algal activity
- In warm months, DO levels during the day will often exceed saturation
- It is good practice to monitor DO levels in lagoons to determine normal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

Flow

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

Anaerobic Pond

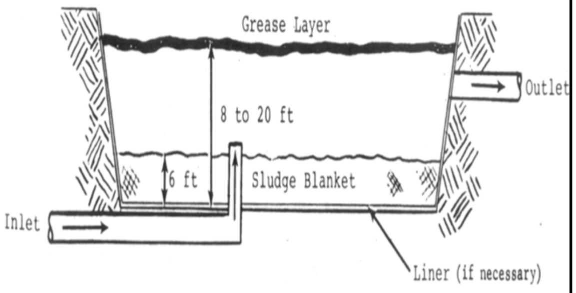
- No dissolved oxygen
- Treatment due to fermentation of sludge on bottom
- Highly efficient removal organic wastes
- Typically 8-16 ft deep



Anaerobic Lagoons

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

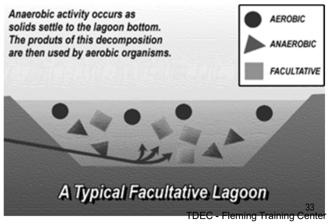
Anaerobic Lagoons



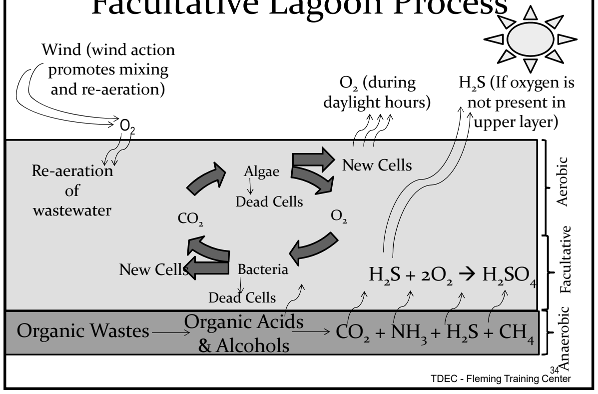
Ref: EPA, 1980, Innovative and Alternative Technology Assessment Manual

Facultative Lagoon

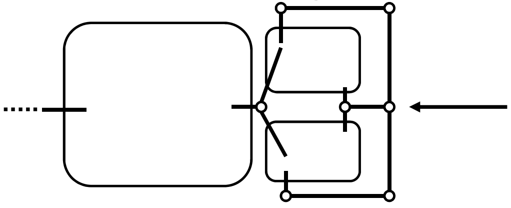
- Most common
- Upper portion aerobic due to algae
- Sludge layer anaerobic
- Depth: 4-8 ft
- DT: 5-30 day+



Facultative Lagoon Process



Facultative Lagoons



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

Facultative Lagoons

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

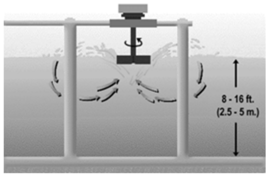
Aerated Lagoons

Aerated compared to Facultative	**Detention Times**
Shorter detention times	Aerated Lagoons: 3-10 d
Heavier loadings	Facultative Lagoons: • 5-30 days (typical) • 180 days (in cold climates)

Mechanically Aerated Ponds

Stationary or floating aerators

Allows for higher organic loading or shorter detention time in lagoon



Dissolved Oxygen

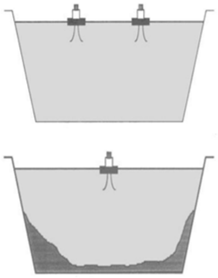
- DO is necessary for bacterial stabilization of organic matter
- The purpose of the aeration equipment is to supply the needed oxygen
- In most cases, operators should have the capability to control aerator “run-time” so that they can provide the amount of oxygen needed
- Many aerators are automatically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

Methods of Controlling DO

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

Aerated Lagoons: Partial vs. Complete Mix

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



Partial Mixed Aerated Lagoons (PMALs)

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

Partial Mixed Aerated Lagoons

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

Complete Mixed Aerated Lagoons (CMALs)

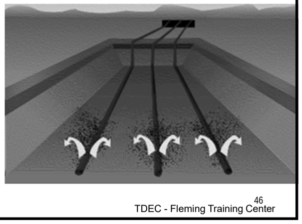
- Hydraulic residence time of 1-6 days
- Depth of 8-16 feet
- Will be completely aerobic (oxygen throughout)
- Aerators provide both oxygen and mixing. Aerators do not completely mix the contents of the basin but keep most solids in suspension.
- The mixing within the lagoon prevents algae from being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

Complete Mixed Aerated Lagoons

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

Diffused Aeration Lagoons

Less mixing; more efficient oxygen transfer



Temperature

- Temperature is important to an aerated lagoon's performance for 2 reasons:
  - Water will hold more oxygen at a cold temperature than at a warmer temperature
  - Biological activity decreases with a reduction in temperature
- A 10-degree drop in temperature can reduce bacterial activity by 50%

Nutrients

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

Flow

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

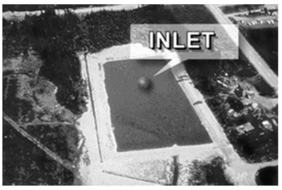
Typical Lagoon Design

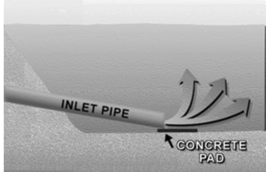
Parameter	Aerobic	Facultative	Anaerobic	Aerated
Size, ac	<10, multiples	2-10 multiples	0.5-2.0	2-10, multiples
Operation	Series or Parallel	Series or Parallel	Series	Series or Parallel
Detention Time, days	10-40	5-30*	20-50	3-10
Depth, ft	3-4	4-8	8-16	6-20
pH	6.5-10.5	6.5-8.5	6.5-7.2	6.5-8.0
Temperature 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

Pond Structures: Inlet

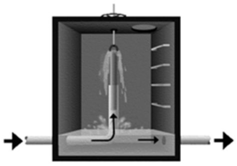
- Force main vs. gravity
- Single vs. multiple inlets
- Below surface best: prevents freezing

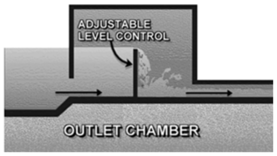




Pond Structures: Outlet

- 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

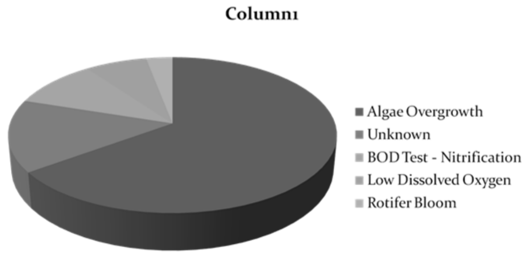
Factors Effecting Pond Operation

- 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



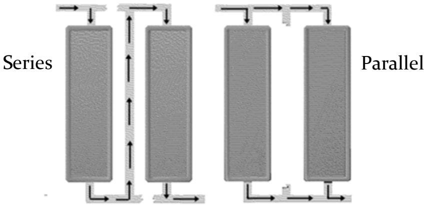
Lagoons in Series

Advantages

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

Disadvantages

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



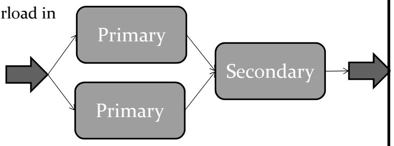
Lagoons in Parallel

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



Primary

Primary

Secondary

Factors Operators Influent

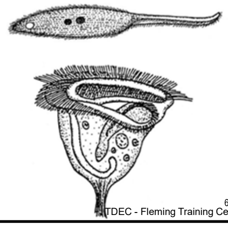
- Number of cells in series
- Continuous versus intermittent discharge
- Parallel versus series
- Recirculation
- Short-circuiting prevention
- Aerator operation
- Monitor organic loading
- Monitor sludge accumulation

Microorganisms in Wastewater Treatment Lagoons

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

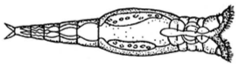
Protozoa

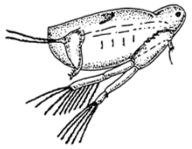
- Flagellates
  - Consume organic matter
  - Compete with bacteria
- Ciliates
  - Consume bacteria and algae in wastewater



Metazoa

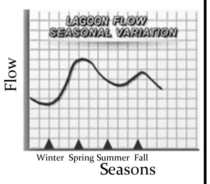
- Rotifers
  - Filter organic waste & bacteria
  - Indicate effective biological treatment
- Crustaceans feed on algae.

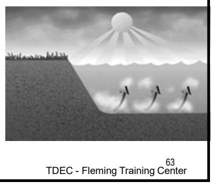




Monitoring Performance

- 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"





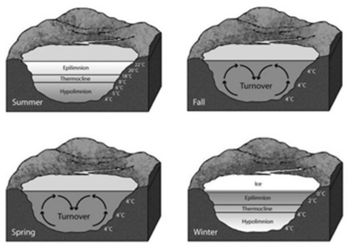
Overturn/Turnover

- Mixing of all layers in a reservoir when the water temperatures become similar from top to bottom
- May occur in Spring and/or Fall
- Spring: surface water warms to similar temp as bottom
- Fall: surface water cools to similar temp as bottom
- Wind plays a role

Overturn/Turnover

Epilimnion, Thermocline, Hypolimnion

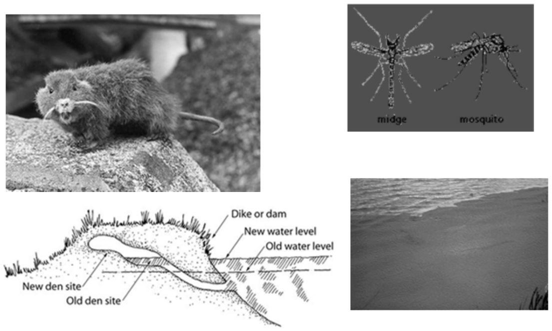
- Thermocline = The middle, transitional layer of a reservoir that shows rapid temperature change
- Separates the warm surface waters from the cold, denser waters at the bottom



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

Daily O & M

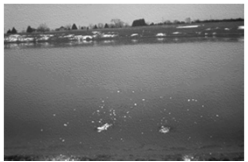


Causes of Poor Quality Effluent

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

Low D.O. in Lagoon

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



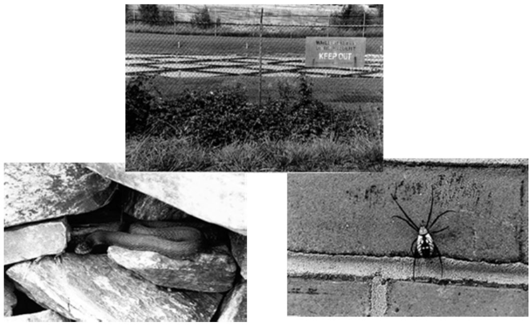
Odors in Lagoons

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

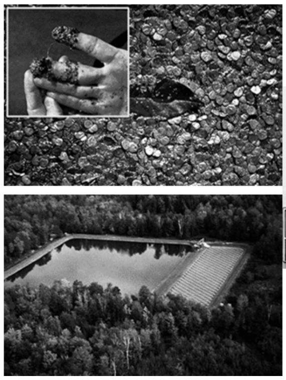
Lagoon Safety

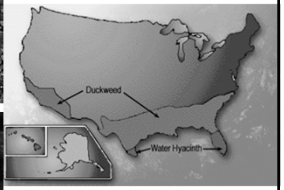
- Never work around a lagoon alone
- Never perform maintenance from a boat
- Never take a boat onto the lagoon alone

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

Any Questions?

?

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

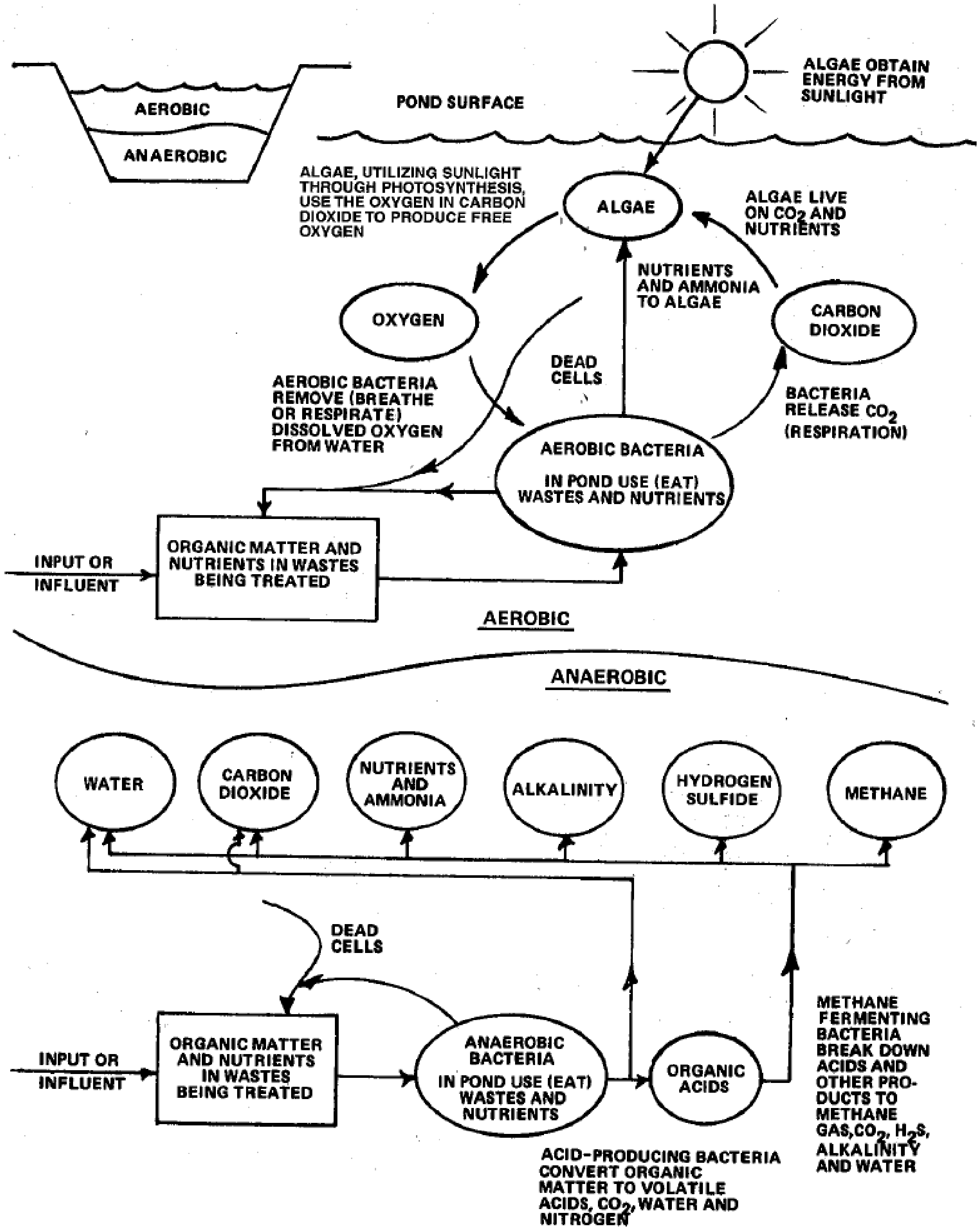


Fig. 9.3 Process of decomposition in aerobic and anaerobic layers of a pond

Section 5

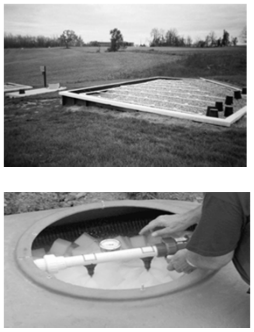
Packed Bed Filters

Packed Bed Filters

TN Department of Environment & Conservation

Packed Bed Filters Introduction

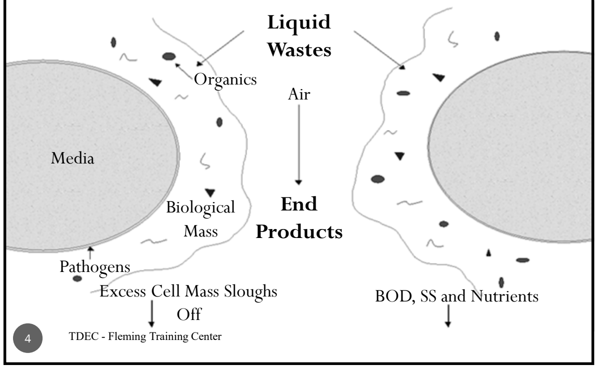
- Secondary treatment units
- Follow primary treatment in a septic tank
- Fixed film treatment systems
  - Biomass grows on media
- A passive aerobic system
- Examples: open sand filter, RSF, open cell foam, textile, peat moss.



PBF Treatment Process

- Wastewater applied in small doses
- Percolates over media in thin film
- Organisms on media contact wastewater
  - Can't let them dry out
- ***<u>Air maintained in media pores</u>***
- Oxygen transferred into the thin film and to organisms
- Aeration may be active or passive

Fixed Film Treatment



Liquid Wastes

Organics

Air

Media

Biological Mass

End Products

Pathogens

Excess Cell Mass Sloughs Off

BOD, SS and Nutrients

Theory of Operation

- Organisms are "fixed" on media surface
- WW is "micro-dosed" to the filter
- WW is treated as it moves over media surfaces in contact with organisms

Modes of Treatment

- Filtration and trapping of organic matter and pathogens
- Adsorption of pathogens, ammonium and some phosphorus
- Biological decomposition of organic matter
- Biochemical transformations

Typical Concentrations of Effluent from Septic Tanks and PBFs

	BOD, mg/L	TSS, mg/L	Nitrate – N, mg/L	Ammonia – N, mg/L	DO, mg/L	Fecal Coliform, cfu/100 mL
Septic Tank	130 – 250	30 – 130	0 – 2	25 – 60	Less than 2	10^5 – 10^7
PBF	5 – 25	5 – 30	15 – 30	0 – 4	3 – 5	10^2 – 10^4

Packed Bed Filter Effluent vs. Septic Tank Effluent

- Low oxygen demand (BOD) → 90% removed
- Low in total and volatile solids → 90% removed
- Will not form a significant biomat in soils
- Low in pathogens → 99% removed
- Significant reduction total nitrogen – 40-80% removed

Two Major Categories of PBF

- Single Pass: through once
  - Intermittent filters
- Recirculating: part passes through more than once
  - Recirculating filters

Media Types

- Natural and mineral media
  - Sand and gravel
  - Expanded shale
  - Cinders
  - Limestone
  - Activated carbon
  - Peat or peat fiber

Manufactured Media Types

- Textile fabric
- Open cell foam cubes
- Hard plastic
- Crushed recycled glass
- Chipped recycled tires
- Processed slag

Sand and Gravel Filters

- Designed and constructed to operate in either single pass or recirculating mode
- Media must meet specific specifications
- Must (generally) be processed to provide the right gradation
  - Sometimes crushed
  - Screened for proper gradation
  - Washed
- Must be handled carefully after processing to maintain the specification and remain free of fines

Biological Processes

- Biofilm forms on sand grains
- Oxygen around the film promotes aerobic activity
- Many microorganism species present at all times
- Most in the upper 12 inches
- Insufficient food limits organisms in lower layers
- Most BOD removal occurs in the top few inches
  - SS and CBOD removed in top ~6 inches
  - Nitrifying organisms thrive deeper in the surface layer
- Organic matter consumed by microbes in the biofilm

Important Biological Design Parameters

- Choice of media
  - Surface area
  - Void space
- Provision for aeration
  - Active
  - Passive
- Small doses of wastewater applied uniformly
  - Keeps flow in the biofilm – i.e. unsaturated flow
  - Provides residence time in thin films on surfaces
  - Prevents displacing air from voids

More on Biological Processes

- Nitrogen removal is a biological process
- Nitrifying bacteria convert ammonium-N (NH_4)and organic-N to nitrate-N (NO_3)
- Most conversion to NO_3 occurs in the top 12 inches
- In small pores and lower in the filter, oxygen concentrations are reduced and biological Denitrification is thought to occur in smaller saturated pores
- Nitrogen gas (N_2) is released to the air

Oxygen Requirements of a PBF

- Based on the BOD_5 and Nitrogen load applied
- BOD_5 load applied is determined by flow and concentration of applied effluent
  - lbs BOD_5/day = (BOD_5, mg/L)(Q, MGD)(8.34)
  - lbs TKN/day = (TKN, mg/L)(Q, MGD)(8.34)
  - lbs O_2/day = (1.2)(BOD_5, lbs/day) + (4.6)(TKN, lbs/day)

Single Pass Systems

- Any of the media options may be used in either single pass or recirculating mode
- Natural/Mineral media are more likely to be used in single pass mode
- Manufactured media are usually used in recirculating mode

Single Pass Sand Filters

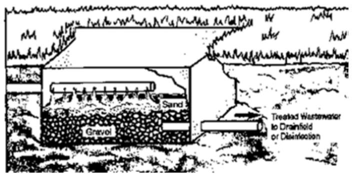
- Several designs are in use
  - Free access (open)
  - Buried single pass
  - Pressure dosed single pass

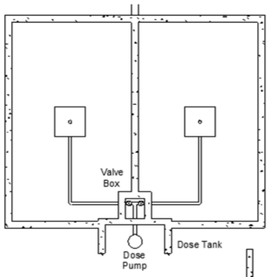
Free Access Sand Filters

- Oldest form for individual sites
- Used for community wastewater treatment since late 1800's in Massachusetts
- May be large – several acres in size
- Depth ranged from 3 to 8 feet

Free Access (Open) Sand Filters

- Wastewater is pump or siphon dosed to the filter, discharged at a single point
- Gravity flow over the surface of the filter
- Require frequent maintenance of the surface to break up or remove accumulated solids

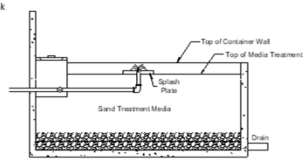




Two Cell Open or Free Access Sand Filter

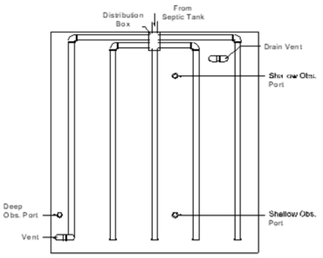
←Plan View

Cross Section →



Buried, Gravity Fed Single Pass Sand Filters

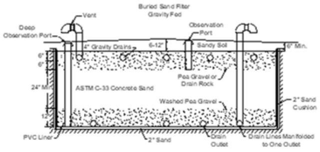
- Distribution is through 4-inch diameter pipe with large (1/2" +) perforations
- Septic tank effluent flows by gravity to the filter at whatever rate it flows from the tank
- Poor distribution limits the life
- Effluent quality is better than might be expected, similar to pressure dosed single pass systems



Buried Gravity Flow Single Pass Sand Filter

← Plan View

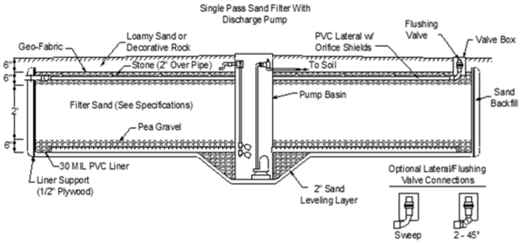
Cross Section →



Pressure Dosed Single Pass Sand Filters (SPSF)

- The preferred system – uniform application
- Pump control can include a timer so that effluent can be "micro-dosed" to the sand filter uniformly over time as well as space
- Provides the ultimate in slow, unsaturated flow
  - Assures film flow
  - Long residence time for biological reactions
  - Air remains in pores for oxygen diffusion into the moisture films on surfaces – to microbes

Single Pass Pressure Dosed Sand Filter With Pump Basin – Cross Section



SPSF Sand System Design

- **Surface area loading = 1–1.25 gpd/ft^2 (design Q)**
- **Media depth 24 inches**
- Maximum soil cover 8–12 inches
- Texture of soil cover: sand or loamy sand
- Bottom layer: 6–8 inches of pea gravel around drain
- Maximum flow distance to 4" slotted drain: 15 ft

SPSF Cut-Away Illustration

SPSF Showing Valve Boxes Over Cleanouts

Hydraulic and Organic Loading – SPSF

- Typical design hydraulic loading is 1–1.2 gpd/ft^2
- For cold climates, keep hydraulic load < 1.0 gpd
- Dose volume < 0.5 gal/orifice/dose
- Typical doses per day: 18–24

Maintenance For SPSF

- Good maintenance is key
- Maintenance minimum annually
- First visit MUST be within the first few weeks of use
  - To catch construction damage or errors
  - To be sure controls are set correctly for the use pattern
  - To check for leaks, including leaky tanks
  - To advise owner/resident on SPSF use
  - To be sure landscaping does not add depth, compact or cause other damage

Maintenance Routine for the SPSF

- The septic tank(s) should be inspected periodically (not every visit) and pumped as needed
- Flush pressure pipe network
- Check pressure at end of laterals: compare with previous
- Check sand filter for ponding (in monitoring tubes)
- Check pump controls for proper operation
- Read pump run-time meter and event counter
- Check pump voltage (off and while pumping) and amp draw while pumping
- Pull and observe the final effluent in a clear sample bottle checking for clarity and odor.

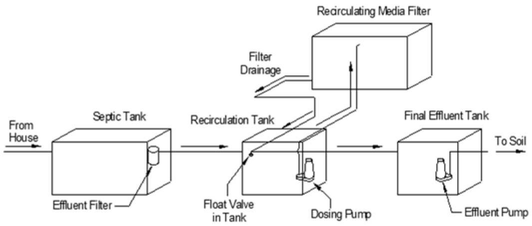
Drainfield Check as Part of Maintenance Visit

- Check for wetness around the drainfield
- Note vegetation patterns
- Note ponding level in observation tubes
- Observe surface flow patterns
  - Be sure surface runoff is directed away from drainfield and SPSF
  - Roof water/downspout drainage away from system

Recirculating Systems

- Recirculation is used in many wastewater treatment processes, usually to retain organism populations
- Recirculating sand filter concept was introduced by Hines and Favreau in the 1970's.
- Involve mixing a portion of the filtered effluent with incoming septic tank effluent
- This blended effluent can be applied to filter media at higher loading rates

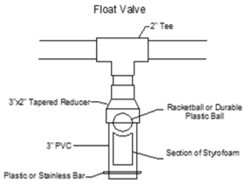
Recirculating Packed Bed Filter Schematic



Achieving Recirculation

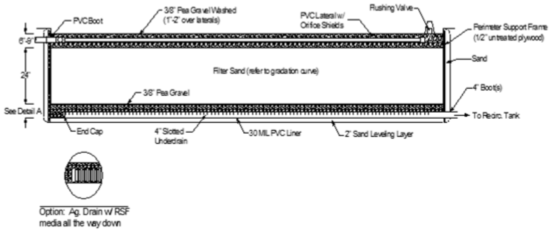
- Drainage from the filter is directed through a flow divider
  - One part is sent to final dispersal
  - 3 – 5 parts, more or less, are returned to the recirc. tank for another pass through the filter
- The pump control timer is set to deliver the desired total quantity of flow to the filter daily
  - Qf = Qi (Rr +1)

Simple Float Valve Illustration



- Valve is mounted in the recirc. tank on the filter drain return line
- When the valve is closed, all the flow is sent to final dispersal
- When the valve is open, all the flow drops into the tank
- By setting the timer for the correct total daily flow to the filter, the system provides the proper recirculation ratio.

Typical RSF Cross Section



Adapted from Orenco Systems, Inc.
Note, this may not be the best drawing

Benefits of Recirculation

- Diluted effluent is applied to the filter
  - Can apply effluent a greater forward flow loading rate
  - Less odor
- Smaller filter for a given flow
- Can withstand somewhat higher strength incoming wastewater
- Can cope with flow variations, including peak flows
- Provides a means for making adjustments for variations in flow and strength through varying recirculation ratios

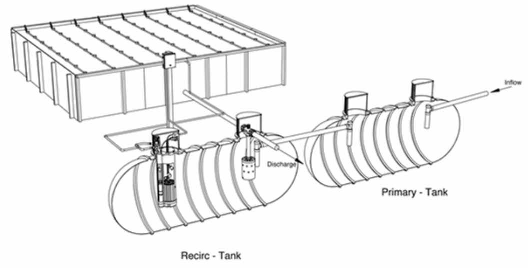
Typical RSF Media

- Fine gravel media with effective size of 2.5 – 3 mm
- Note lack of fines on the media
- This is a good material for an RSF for domestic effluent

Recirculation Tank Design

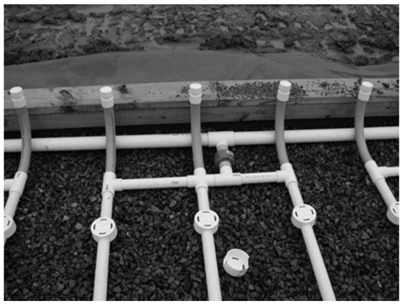
- Size: volume equal to daily design flow
- Configuration:
  - Septic tank effluent and return flow from filter enter at same end of the tank to mix
  - Pump(s) to filter are at opposite end of tank
  - Provide long flow path to pump end
  - Pumps mounted up off tank floor
    - Preferably in a vault with effluent screen ahead of pump intake
    - Intake to pump system at mid-depth of tank

RSF -- Recirculation Tank Illustration



Multiple Cell Community RSF Makes Maintenance Easier

Laterals End with Constant Flow Out



Sand Filter Frame Ready for Media

Sand Filter Drain Network

RSF Effluent Quality

RSF Maintenance Tasks

- Check observation sumps in S.F. for ponding
- Flush distribution system lines
- Check pressure to determine orifice clogging
- Clean orifices as needed
- Make sure drain(s) are not submerged and can "breath" air into filter

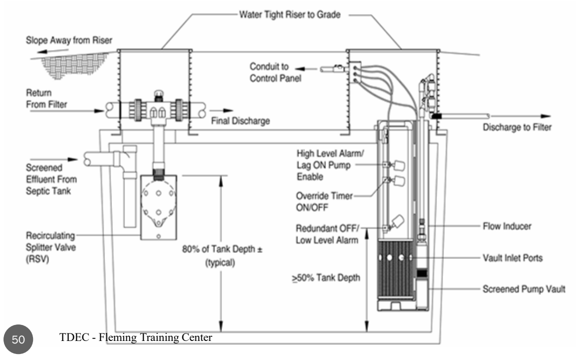
RSF Maintenance Tasks

- Check pump controls for proper operation and adjustment
- Check pump voltage – off and while pumping
- Check pump amp draw while pumping
- Check Soil Absorption System observations sumps
- Check sludge and scum in septic tank(s) & pump tank

PBF Controls

- Control systems for pumps and dosing are critical to proper operation
- Uniform distribution and small, frequent doses are required for best treatment
- Timer control for pumps is preferred
- For single pass systems, timers can be turned on and off by floats

Pump in a recirc. tank with floats to control the timer, alarms, and a second pump



Float Type Controls

- Floats may contain mechanical or mercury switches
- Should be mounted on a separate bracket or float "tree"
  - Separate from pump discharge pipe
  - Removable as a unit for float position adjustment
  - Allow pump removal without disturbing floats
- Floats must be positioned so as not to become inhibited by chords, other floats, or piping

Pump Selection

- Pumps used are usually submersible
  - High head turbine pumps – a converted well pump
  - Effluent pumps – higher flow, low head
- Turbine pumps are desirable for feeding distribution systems with small holes (typical 1/8")
  - Steep curve assists in providing self cleaning
  - Head increases rapidly as flow is reduced
- If effluent pumps are used, in-line screens can be added to help protect against orifice clogging
- Both types of pumps, if selected for effluent applications, will provide long service life
- Liquid levels should be designed to keep pumps submerged.

Peat Filters

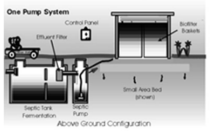
- Peat is excellent media for PBFs
- Forms: fiber, moss, pellets or prefabricated peat bales
- Modular, ready to set in place and connect up
- Peat is carefully chosen and often processed

Peat Filters (cont.)

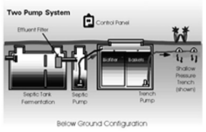
- Typically used in single pass mode
- Peat houses a wide variety of microflora from bacteria to nematodes
- Peat deteriorates over time and must be replaced
- Good, long term performance
- Effluent quality similar to sand filters, but much less space required: about 1/6 as much

Open Cell Foam Filters

- Developed for use in Ontario as the "Waterloo Biofilter"
- Polyurethane foam (2" cubes)
- Wastewater sprayed over the top of media
- Long retention time in the filter provides good treatment
- Sometimes requires forced air



Above Ground Configuration



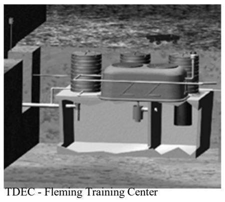
Below Ground Configuration

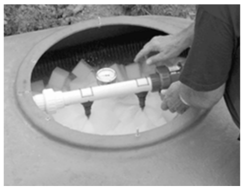
Waterloo® Open Cell Foam Filters

- Foam cubes have large surface area and large void volume percentage.
- Foam is not decomposed by organisms in wastewater.
- Media 36 to 102" deep.
- Doses/day: 80 to 140.

SCAT® Open Cell Foam Filter

- Hydraulic load: 11 to 16 gpd/ft^2
- Helical spray nozzle @ 5 to 8 psi
- Void space: 30%
- Dose Volume: 1.2 to 1.5 gal/ft^2





AdvanTex® Textile Filter

- Most has geosynthetic or geotextile fabric
- Vertical sections of fabric are 2 ft long hung side by side
- Wastewater applied in small, uniform doses several times per hour
- Hydraulic load:
  - 25 to 35 gpd/ft^2 (very high due to increased surface area)

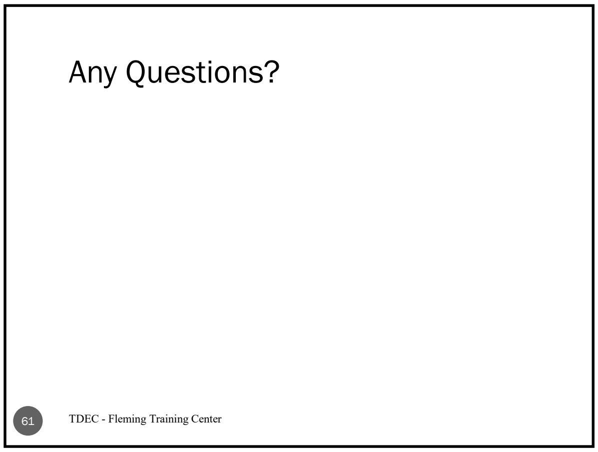
South Blount Utility has these and the effluent then goes to a drip field

AdvanTex® Textile Filter

- Operated in recirculating mode
- Aerobic conditions maintained due to large volume of pore space (90%)
- BOD and TSS removed efficiently
- Ammonia is nitrified
- Denitrification for nitrogen removal possible

Conclusion

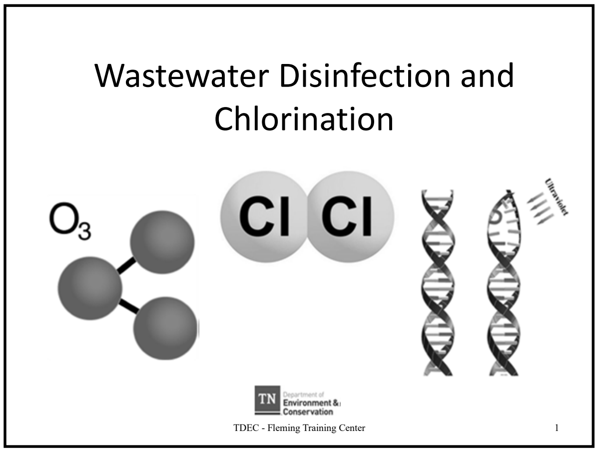
- Media Filters are capable of providing reliable, long term service and excellent effluent quality if they are:
  - Properly sited
  - Properly designed
  - Properly used by the owner/occupant
  - Properly maintained on a regular basis
- The greatest challenge to be addressed before widespread adoption of technologies like PBF's can be commonplace is the development and public acceptance of management organizations and fee structures to assure that the systems are properly maintained on a regular basis.



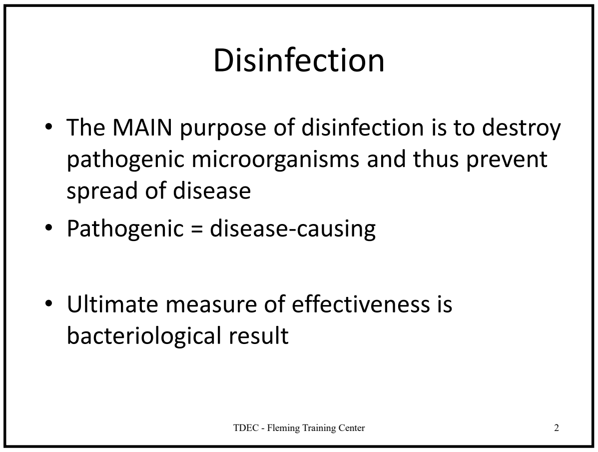
Any Questions?

Section 6

Disinfection

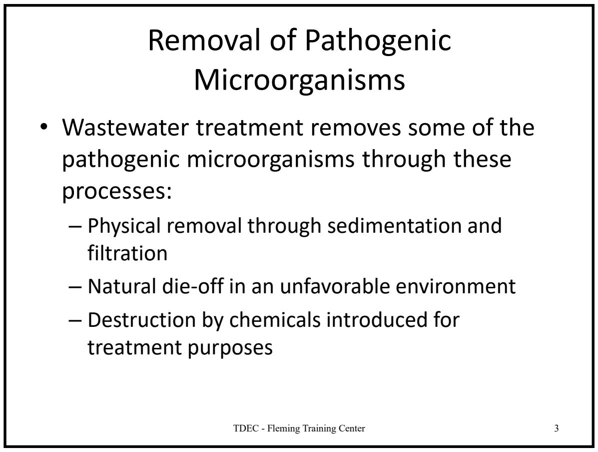


Wastewater Disinfection and Chlorination



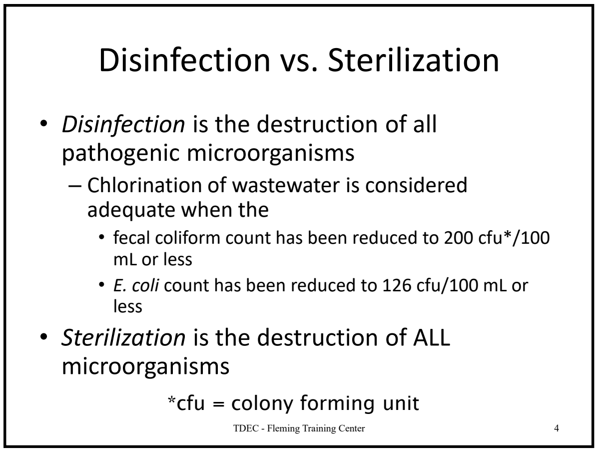
Disinfection

- The MAIN purpose of disinfection is to destroy pathogenic microorganisms and thus prevent spread of disease
- Pathogenic = disease-causing
- Ultimate measure of effectiveness is bacteriological result



Removal of Pathogenic Microorganisms

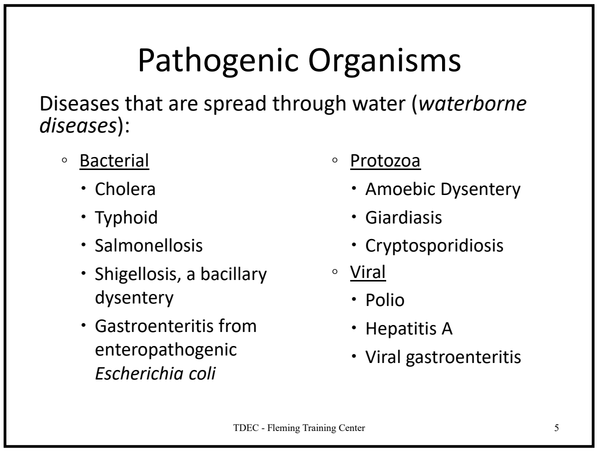
- Wastewater treatment removes some of the pathogenic microorganisms through these processes:
  - Physical removal through sedimentation and filtration
  - Natural die-off in an unfavorable environment
  - Destruction by chemicals introduced for treatment purposes



Disinfection vs. Sterilization

- *Disinfection* is the destruction of all pathogenic microorganisms
  - Chlorination of wastewater is considered adequate when the
    - fecal coliform count has been reduced to 200 cfu*/100 mL or less
    - *E. coli* count has been reduced to 126 cfu/100 mL or less
- *Sterilization* is the destruction of ALL microorganisms

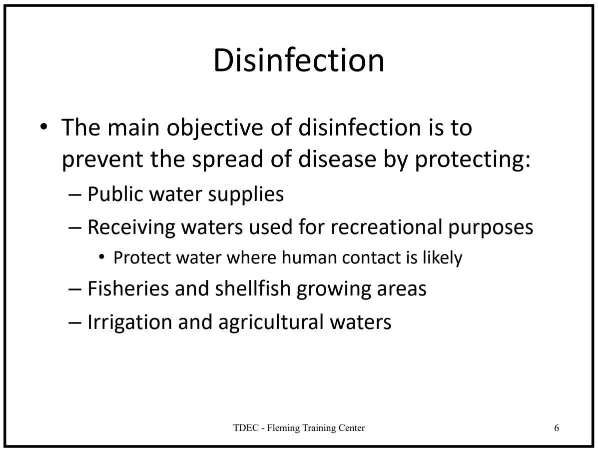
*cfu = colony forming unit



Pathogenic Organisms

Diseases that are spread through water (*waterborne diseases*):

- Bacterial
  - Cholera
  - Typhoid
  - Salmonellosis
  - Shigellosis, a bacillary dysentery
  - Gastroenteritis from enteropathogenic *Escherichia coli*
- Protozoa
  - Amoebic Dysentery
  - Giardiasis
  - Cryptosporidiosis
- Viral
  - Polio
  - Hepatitis A
  - Viral gastroenteritis



Disinfection

- The main objective of disinfection is to prevent the spread of disease by protecting:
  - Public water supplies
  - Receiving waters used for recreational purposes
    - Protect water where human contact is likely
  - Fisheries and shellfish growing areas
  - Irrigation and agricultural waters

Chlorine Chemicals

- Elemental chlorine
  - Yellow-green gas or amber liquid
  - 100% chlorine
- Sodium hypochlorite – Bleach
  - Clear, pale yellow liquid
  - 5-15% chlorine
- Calcium hypochlorite – HTH
  - White, pale yellow granules or tablets
  - 65% chlorine
- Chlorine dioxide
  - Green-yellow gas generated on-site

Chemical formulas

- Elemental chlorine (Free chlorine)
  - Cl_2
- Hypochlorite (OCl-)
  - Sodium hypochlorite - Bleach
    - NaOCl
  - Calcium hypochlorite – HTH
    - $Ca(OCl)_2$
- Chlorine dioxide
  - ClO_2

Chlorine

- Reacts with:
  - Hydrogen sulfide (H_2S)
  - Iron
  - Manganese
  - Nitrite
  - Phenols
  - Ammonia
  - And lastly used for disinfection

Chlorine Demand

Chemistry of Chlorination

- Each form of chlorine (Cl_2, OCl^-, ClO_2) has a similar reaction with water and forms:

  <u>Hypochlorous Acid</u> or <u>Hypochlorite</u>

- Adding any form of chlorine to wastewater results in hydrolysis
  - *Hydrolysis* = a chemical reaction in which a compound is converted into another compound by taking up water

Chemistry of Chlorination

- *Oxidizing agent* = any substance (ex: oxygen [O_2] or chlorine [Cl_2]) that will readily add (take on) electrons
  - When O_2 or Cl_2 is added to water, organic substances are oxidized
- *Reducing agent* = any substance (ex: base metal such as iron or the sulfide ion [S^{2-}]) that will readily donate (give up) electrons

Chemistry of Chlorination

$$Cl_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{hydrochloric acid}}{HCl}$$

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7

    Dissociates at higher pH:

    $$HOCl \rightarrow H+ + \underset{\text{hypochlorite ion}}{OCl–}$$
  - Hypochlorite ion is only 1% as effective as hypochlorous acid.

Chemistry of Hypochlorination

$NaOCl + H_2O \rightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

$Ca(OCl)_2 + 2H_2O \rightarrow Ca(OH)_2 + 2HOCl$

- Calcium hypochlorite does the same

Chlorine Dioxide (ClO_2): Chemistry

- Made onsite and very unstable

$2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$

Sodium Chlorite   Chlorine   Sodium Chloride   Chlorine Dioxide

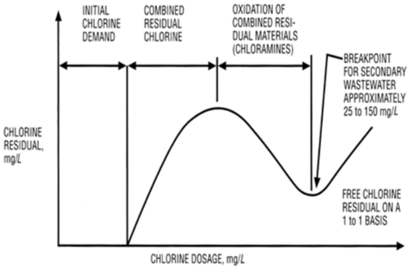
- $2ClO_2 + H2O \rightarrow ClO_3^- + ClO_2^- + 2H^+$

Chlorine dioxide   Water   Chlorate Ion   Chlorite Ion   Hydrogen Ion

Chlorine Dose

- ➢ Chlorine Dose = Chlorine Demand + Chlorine Residual
- ➢ Chlorine Residual = Combined Chlorine forms + Free Chlorine
- *Free chlorine residual* = the residual formed after the chlorine demand has been met
- *Combined chlorine residual* = residual chlorine produced by the reaction of chlorine with substances in the water (it can be combined with ammonia, organic nitrogen, or both)
  - Chloramines and Chlororganics
  - It is still available to oxidize organic matter and kill bacteria, but not as effective as free residual

Breakpoint Chlorination Curve



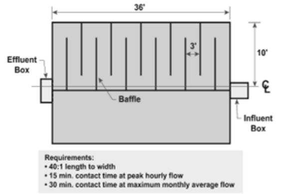
Factors Influencing Disinfection

- Injection point and method of mixing
- Design or shape of contact chamber
- Contact time
  - Most contact chambers are designed to give 30 min contact time
- Effectiveness of upstream processes
  - The lower the SS, the better the disinfection
- Temperature
- Dose and type of chemical
- pH
- Numbers and types of microorganisms

Chlorine Demand

- Chlorine demand can be caused by environmental factors such as:
  - Temperature
  - pH
  - Alkalinity
  - Suspended solids
  - Biochemical and chemical oxygen demand
  - Ammonia nitrogen compounds

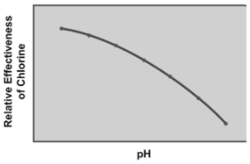
Typical Layout - Contact Basin



- Design Criteria (10.2.2.4-5):
  - 30:1 length to width
    - The total length of the channel created by the baffles should be 30 times the distance between the baffles
  - 15 min. contact time at peak hourly flow
  - 30 min. contact time at max monthly avg. flow

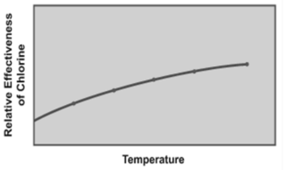
Relative Effectiveness

vs. pH



The lower the ph (<7), the disinfection action increases because hypochlorous acid is formed from chlorine and has 40 to 80 times greater disinfection potential.

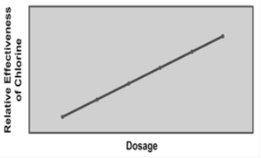
vs. Temperature



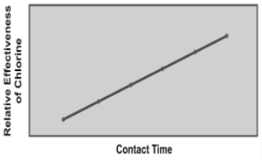
When the temperature increases the disinfection action of chlorine increases.

Relative Effectiveness

vs. Dosage

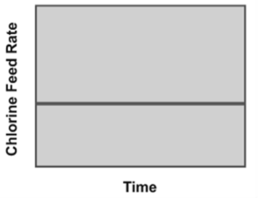


vs. Contact Time

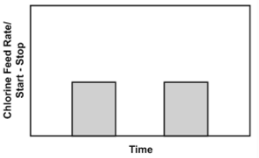


Types of Feed Control

Manual Control

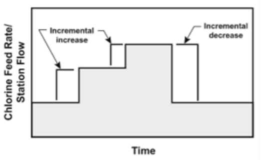


Start Stop Control

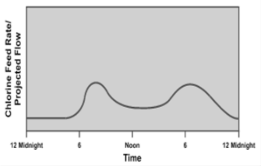


Types of Feed Control

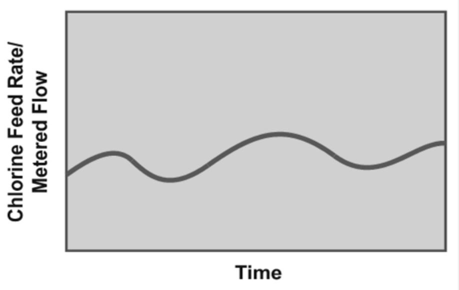
Step Rate Control



Timed Program Control



Flow Proportional Control



Chlorine Hazards

- Chlorine gas is:
  - 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
- Exhaust fans should be located at floor level in the chlorine room.
- Self-contained air (SCBA) required
  - Should be on-site, located outside of Cl_2 room

Chlorine Leaks

- To locate chlorine leaks you should use a commercial ammonia water (containing 28-30% ammonia as NH_3 which is the same as 58% ammonium hydroxide, NH_4OH, or commercial 26º Baumé)
  - The ammonia water can be put in a polyethylene squeeze bottle about half full and squeeze the ammonia vapors around potential Cl_2 leak.
  - When ammonia vapor comes in contact with chlorine, a white cloud of ammonia chloride is formed.
  - A ammonia soaked rag wrapped around a stick will also do.
  - Household ammonia is not strong enough.
- Never put water on a chlorine leak because the mixture of water and chlorine will increase the rate of corrosion at the leak.

Chlorine Leaks

- To shut down a gas chlorination system for maintenance:
  - Turn off the chlorine gas supply
  - Wait for the rotameter ball to drop to 0 lbs
  - Turn off the injector water supply to insure that all gas has been expelled

Physiological Response to Chlorine Gas

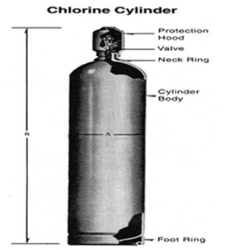
Effect	Parts of Chlorine Gas per Million Parts of Air by Volume (ppm)
Slight symptoms after several hours' exposure	1*
Detectable odor	0.08 – 0.4
60-min inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Dangerous from ½ - 1 hour	40
Death after a few deep breaths	1,000

*OSHA regs specify that exposure to chlorine shall at NO time exceed 1 ppm.

Chlorine

- Chlorine is available in:
  - 150 lb cylinders
  - 1 ton containers
  - Up to 90 ton railroad cars
- These containers under normal conditions of temperature and pressure contain chlorine as a liquid and a gas form.
  - If you take chlorine from the bottom of the container, it will be liquid
  - If you take chlorine from the top of the container, it will be gas
  - Liquid chlorine expands in volume by 460 times as a gas at atmospheric pressure

Chlorine Cylinder (100 or 150 lb.)

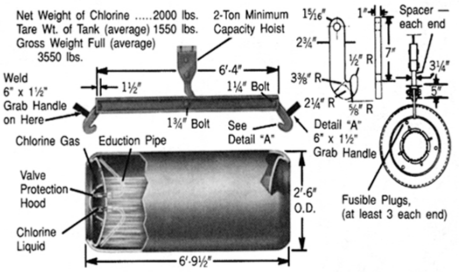


Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, Inches	
		A	B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¼	54½

* Stamped tare weight on cylinder shoulder does not include valve protection hood.

- The fusible plug melts at 158-165°F to prevent build-up of excessive pressure and possible rupture
- Move cylinders with properly balanced hand truck with clamp supports that fasten at least 2/3 of the way up the cylinder
- Cylinders must be kept away from direct heat
- It is not advisable to draw more than 40 lbs of chlorine in a 24-hr period because of the danger of freezing and slowing down the chlorine flow

Ton Container



Ton Container

- Ton tanks weigh ~ 3,700 pounds
- Most ton tanks have 6-8 fusible plugs that are designed to melt at the same temperature range as the safety plug in the cylinder valve
- Ton tanks should be stored and used on their sides, above the floor or ground on steel or concrete supports
- Ton tanks should be placed on trunnions
- The upper valve will discharge chlorine gas and he lower valve will discharge liquid chlorine
- The max withdrawal rate for a ton container is 400 lbs/day.

Chlorine Repair Kits

Kit B

Kit A

Chlorination Equipment

Chlorinator

- Vacuum fed (safer)
- Used to establish a feed rate in pounds per day
- Components include:
  - Differential regulating valve
  - V-Notch orifice with plug positioner
  - Rotameter

Evaporator

- Installed where large amounts of chlorine are fed
- An evaporator is a hot water heater surrounding a steel tank and the liquid chlorine is evaporated to gas at 110-120°F

Dechlorination

- Dechlorination is the physical or chemical removal of all traces of residual chlorine remaining after the disinfection process and prior to the discharge of the effluent to the receiving waters
- Removal methods:
  - Aeration
  - Sunlight
  - Long detention time
  - Chemicals

Chemicals Used for Dechlorination

- Sulfur dioxide
  - SO_2
  - One-to-one basis
  - Most popular
- Sodium sulfite
  - Na_2SO_3
- Sodium bisulfate
  - $NaHSO_3$
- Sodium metabisulfite
  - $Na_2S_2O_5$
- Sodium Thiosulfate
  - $Na_2S_2O_3$

Sulfur Dioxide (SO_2)

- Colorless gas with a characteristic pungent odor
- Not flammable or explosive
- Not corrosive unless in a moist environment (can form sulfuric acid)
- Detecting for sulfur dioxide leaks is done the same way for chlorine by using ammonia vapor dispenser or ammonia soaked rags.

SO_2 Application Point

- The typical application point is just before discharge into receiving stream
- This allows for maximum time for disinfection to take place

SO_2 Chemical Reaction

- Reacts almost instantaneously
- Conversion of all active positive chlorine ions to the nonactive negative chloride ions
- Organic materials present may require extra SO_2
- Excess SO_2 dosage should be avoided because it will lead to:
  1. reduction in DO
  2. drop in pH
  3. increase in BOD/COD

Physiological Response to Sulfur Dioxide

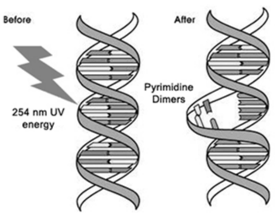
Effect	Concentration
Lowest concentration detectable by odor	3-5 ppm
Lowest concentration immediately irritating to throat	8-12 ppm
Lowest concentration immediately irritating to eyes	20 ppm
Lowest concentration causing coughing	20 ppm
Maximum allowable concentration for 8-hr exposure	10 ppm
Maximum allowable concentration for 1-hr exposure	50-100 ppm
Tolerable (briefly)	150 ppm
Immediately dangerous concentration	400-500 ppm
OSHA 8-hour TWA (Time Weighted Average) is 2 ppm and the 15-minute STEL (Short Term Exposure Limit) is 5 ppm	

Ultraviolet Radiation

- Ultraviolet radiation is commonly referred to as ultraviolet light or UV
- With growing concern with safety of chlorine handling and the possible health effects of chlorination by-products, UV is gaining popularity
- UV disinfection may become a practical alternative to chlorine disinfection at STP

Ultraviolet Radiation

- A UV system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material.
  - When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce
  - UV radiation, generated by an electrical discharge through mercury vapor, penetrates the genetic material of microorganisms and retards their ability to reproduce.



Ultraviolet Radiation

- The effectiveness of a UV system depends on:
  - Characteristics of the WW
  - Intensity of the UV radiation
  - Amount of time the microorganisms are exposed to the radiation
  - Reactor configuration

  - For any one treatment plant, the disinfection success is directly related to the concentration of colloidal and particulate constituents in the WW

UV – System Components

- Mercury arc lamps
- Reactor
- Ballast

- Source of UV can either be low-pressure or medium pressure mercury arc lamp with low or high intensities.

UV – System Components

- The optimum wavelength to effectively inactivate microorganisms is in the range of 250-270 nm.
- The intensity of the radiation emitted from the lamp dissipates as the distance from the lamp increases.
- Low-pressure lamps emit essentially monochromatic light at a wavelength of 253.7 nm.
- Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5-2.0 cm.
- The ideal lamp wall temperature is between 95-122º

Low Pressure UV Lamps

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

UV – System Components

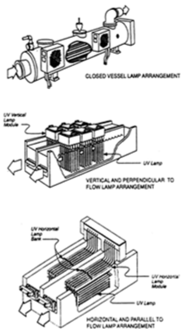
- Medium-pressure lamps are generally used for large facilities
- They have approximately 15-20 times the germicidal UV intensity of low-pressure lamps
- The medium-pressure lamp disinfect faster and has greater penetration capability because of its higher intensity.
- However, these lamps operate at higher temperatures with higher energy consumption

UV Operation

- Lamp output declines as they age
  - Operators must monitor output and replace bulbs that no longer meet design standards
- Turbidity and flow must be monitored
  - Suspended particles can shield microorganisms from the UV light
  - Flows should be somewhat turbulent to ensure complete exposure of all organisms to the bulbs
- UV light does NOT leave a residual like chlorine
  - Bacteriological tests must be run frequently to ensure adequate disinfection is taking place
  - Microorganisms that were not killed may be able to heal themselves

Typical UV Lamp Configurations

- Closed vessel lamp arrangements are more typically found in drinking water plants
- Wastewater plants normally have UV bulbs placed in an open channel either horizontal or perpendicular to flow



Safety with UV Systems

- The light from a UV lamp can cause serious burns to your eyes and skin
- Always take precautions to protect your eyes and skin
- NEVER look into the uncovered sections of the UV chamber without protective glasses
- UV lamps contain mercury vapor, which is a hazardous substance that can be released if the lamp is broken

Maintenance

- Quartz sleeves
  - Cleaning frequency depends on water quality and treatment chemicals
  - Dip modules in nitric acid or phosphoric acid for 5 minutes to remove scale
  - Cleaned by removing modules from channel or by in-channel cleaning
  - In-channel cleaning requires back-up channel and greater volume of cleaning solution
    - Precautions should be taken to protect concrete walls of channel from being damaged by acid

Maintenance

- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

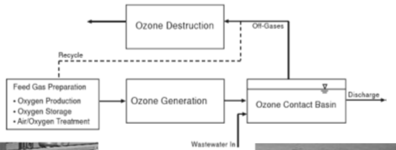
UV - Advantages

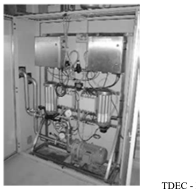
- Effective at inactivating most viruses, spores and cysts
- Physical process rather than a chemical disinfectant
  - Eliminates the need to generate, handle, transport or store toxic/hazardous or corrosive chemicals
- No residual effect that can be harmful to humans or aquatic life
- User-friendly for operators
- Shorter contact time when compared with other disinfectants
  - Approximately 20-30 seconds with low-pressure lamps
- Requires less space than other methods

UV - Disadvantages

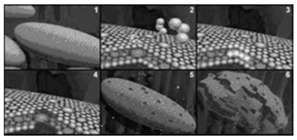
- Low dose may not effectively inactivate some viruses, spores or cysts
- Organisms can sometimes repair and reverse the destructive effects of UV through a “repair mechanism” known as photo reactivation, or in the absence of light known as “dark repair”
- Preventive maintenance program is necessary to control fouling of tubes
- Turbidity and TSS in the WW can render UV disinfection ineffective
  - UV disinfection with low-pressure lamps is not as effective for secondary effluent with TSS levels above 30 mg/L
- Not as cost-effective as chlorination, bust costs are competitive when chlorination and dechlorination is used and fire codes are met

Process of Ozone Disinfection





Effects of Ozone on Bacteria



Ozone disinfection steps:
- 1 – Computer animation of a bacterial cell
- 2 – Close-up of an ozone molecule on the bacterial cell wall
- 3 – Ozone penetrates the cell wall and causes corrosion
- 4 – Close-up of the effect of ozone on the cell wall
- 5 – Bacterial cell after it has come in contact with a number of ozone molecules
- 6 – Cell destruction (lysis)

Ozone

$$O_2 + \textbf{Energy} \rightarrow O + O$$
$$O + O_2 \rightarrow O_3$$

- Produced when oxygen (O_2) molecules are exposed to an energy source and converted to the unstable gas, ozone (O_3)
- Most WW plants generate ozone by imposing a high voltage alternating current (6-20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas.
- Ozone is generated on-site because it is unstable and decomposes to elemental oxygen in a short amount of time after generation.

Ozone

- Extremely dry air or pure oxygen is exposed to a controlled, uniform high-voltage discharge at a high or low frequency.
- The dew point of the feed gas must be -60ºC (-76ºF) or lower
- The gas stream generated from air will contain about 0.5-3.0% ozone by weight
  - Pure oxygen will form approximately 2-4 times that concentration

Ozone

- After generation, ozone is fed into a down-flow contact chamber containing the wastewater
- The main purpose of the contactor is to transfer ozone from the gas bubble into the bulk liquid while providing sufficient contact time for disinfection
- Because it is consumed quickly, it must be contacted uniformly in a near plug flow contactor
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test

Ozone

- Effectiveness depends on:
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of ozone
- The key process control guidelines are dose, mixing, and contact time

Equipment

- Ozone Generator
- Consists of a pair of electrodes separated by a gas space and a layer of glass insulation
- Air passes through the empty space
- Electrical discharge occurs across the gas space and ozone is formed

Oxygen from air + Electrical voltage → Ionized oxygen + Heat
$O_2 + \text{electricity} \rightarrow 2(O)$

Ionized oxygen + Non-ionized oxygen → Ozone
$2(O) + 2(O_2) \rightarrow 2\ (O_3)$

Maintenance

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

Safety

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

Ozone - Advantages

- More effective than chlorine in destroying viruses and bacteria
- Short contact time (10-30 min)
- No harmful residues left in water
- No re-growth of microorganisms
  - Except for those protected by particulates in water
- Generated on-site
  - Fewer safety problems associated with shipping and handling
- Elevates DO levels in effluent
  - Can eliminate needs for post aeration
  - Can raise DO levels in receiving stream

Ozone - Disadvantages

- Low dose may not effectively inactivate some viruses, spores and cysts
- More complex technology
  - Requiring more complex equipment and efficient contacting systems
- Very reactive and corrosive
  - Requiring corrosive-resistant materials such as stainless steel
- Not economical for WW with high levels of solids, BOD, COD or total organic carbon (TOC)
- Extremely irritating and possibly toxic to humans at concentrations of 1 ppm or greater in air
- Cost can be high in capital and power intensiveness

Any Questions?

Chlorination – Review Questions

1. Water is the universal ____________________.

2. The destruction of all pathogenic microorganisms is called _________________________, which is not to be confused with _______________________________, in which all microorganisms (pathogenic **and** nonpathogenic) are destroyed.

3. What is meant by "breakpoint chlorination?"

4. How do you determine the Chlorine Dose?

5. Explain why each of these factors that influence disinfection are important:
    a. pH
    b. Temperature
    c. Microorganisms
    d. Turbidity
    e. Reducing agents

6. When chlorine is added to water, it breaks down into what two products? Which of these products is a more effective disinfectant?

7. Why are contact time and residual chlorine levels considered critical factors in the disinfection process?

8. Which of the following is not an approved method for chlorine analysis?
    a. Amperometric titration
    b. DPD Colorimetric
    c. DPD Color Comparator
    d. DPD Titrimetric
    e. Ion Specific Electrode

9. When analyzing Total Chlorine using the Hach procedure (method 8167), you can read the sample immediately (within 1 minute) of adding the DPD pillow. True or False

10. A water sample is tested and found to have a chlorine demand of 1.7 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose (in mg/L)?

11. The chlorine dosage for water is 2.7 mg/L. If the chlorine residual after a 30 minute contact time is found to be 0.7 mg/L, what is the chlorine demand (in mg/L)?

12. What should the chlorinator setting be (in pounds per day) to treat a flow of 2.35 MGD if the chlorine demand is 3.2 mg/L and a chlorine residual of 0.9 mg/L is desired?

Section 7

Effluent Discharge

EFFLUENT DISPOSAL

Biological Natural Systems

EFFLUENT DISPOSAL

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

DISPOSAL BY DILUTION

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

DISPOSAL BY DILUTION

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

LAND TREATMENT OF WASTEWATER EFFLUENT

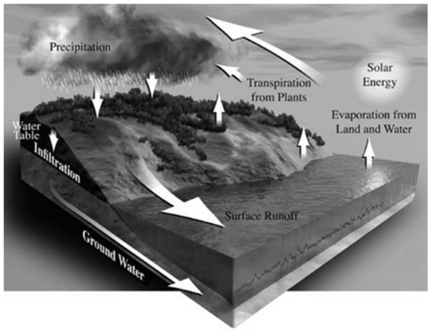
LAND TREATMENT SYSTEMS

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

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

Hydrologic Cycle



Land Application System

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

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

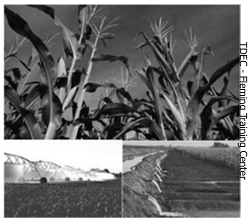
Wastewater Reclamation: Land Application

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

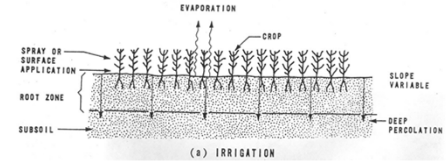
Wastewater Treatment Plant & Poplar Tree Reuse System; Woodburn, Oregon

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



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

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

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.

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.

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.

IRRIGATION - SPRAY SYSTEMS

- Fixed
  - Buried or on surface
  - Cultivated crops or
- 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 %

IRRIGATION - SPRAY SYSTEMS

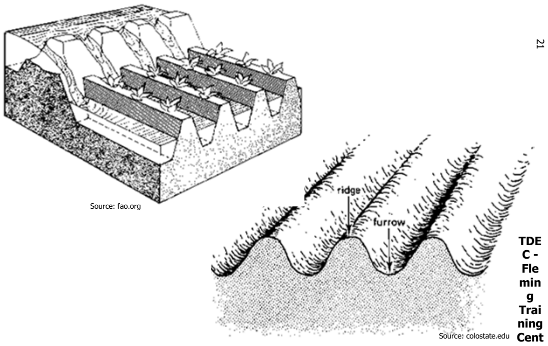
Center Pivot – Moving Spray Irrigation

Fixed Spray Irrigation on Risers

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

IRRIGATION – RIDGE AND FURROW

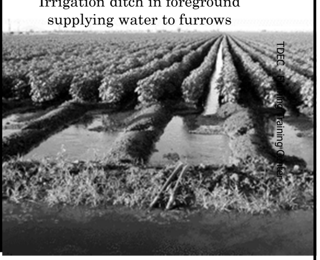


Source: fao.org

Source: colostate.edu

IRRIGATION – RIDGE & FURROW

Gated pipe applying flow to furrows



Irrigation ditch in foreground supplying water to furrows

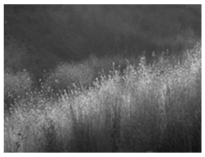
IRRIGATION – REMOVAL EFFICIENCIES

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

IRRIGATION – REMOVAL EFFICIENCIES

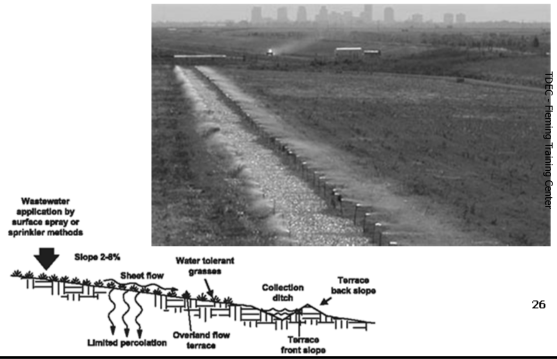
- Under normal circumstances:
  - Water and nitrogen are absorbed by crops
  - Phosphorus and metals are adsorbed by soil particles
  - Bacteria is removed by filtration
  - Viruses are removed by adsorption
- Nitrogen cycle
  - Secondary effluent contains ammonia, nitrate and organic nitrogen
  - Ammonia 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

OVERLAND FLOW



- Spray or surface application
- 2-8% slope
- Slow surface flow treats wastewater
- Water removed by evaporation & percolation
- Runoff collection
- 6-12 hours/day, 5-7 days/week

OVERLAND FLOW



OVERLAND FLOW

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

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

DISTRIBUTION METHODS

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

SUITABLE GRASSES

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

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

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

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

SUBSURFACE DRIP DISPOSAL (SDD)

- 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.

SUBSURFACE DRIP DISPOSAL (SDD)

- 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

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.

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

FURROW VS. SUBSURFACE

Less weed growth with subsurface drip irrigation

LEACH FIELDS

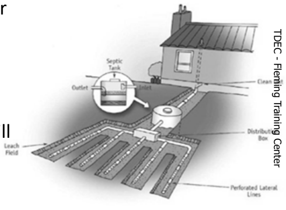
- Effluent from the septic tank flows by gravity or is pumped to a leach field for disposal.
- The wastewater effluent is absorbed by soil particles and moves both horizontally and vertically through the soil pores.
- The dissolved organic material in the effluent is removed by bacteria which live in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

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.

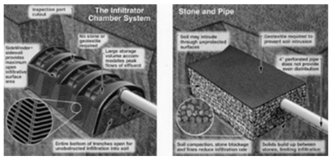
LEACH FIELD DESIGN

- 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.

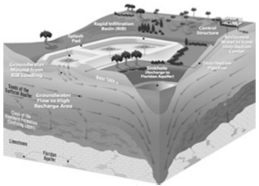


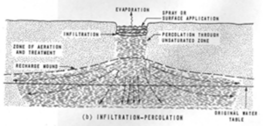
LEACH FIELD DESIGN

- 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.



RAPID INFILTRATION





(b) INFILTRATION-PERCOLATION

- 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

RAPID INFILTRATION

- Top– Picture of a seepage basin in Nevada
- Bottom - Large volumes of reclaimed water, which have undergone advanced secondary treatment, are reused through land-based applications in a 40-square-mile area near Orlando, Florida.

RAPID INFILTRATION

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

LAND TREATMENT LIMITATIONS

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

LAND TREATMENT LIMITATIONS

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

MONITORING REQUIREMENTS

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

WATER QUALITY INDICATORS

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

ANY QUESTIONS?

Onsite Wastewater Treatment Systems Technology Fact Sheet 12

Land Treatment Systems

Description

Land (surface) treatment systems (figures 1 and 2) are permitted in some states, but are not widely used because of their large land area requirements exacerbated by code-required setbacks. For example, a spray irrigation system requires about four times the area of an individual home lagoon. When these systems are used, large buffer areas and fencing may be required to ensure minimal human exposure. Also, given the nature of these systems, all requirements include disinfection and significant pretreatment before application. In wet and cold areas, an additional basin for storage or a larger dosing

Figure 1. Conceptual schematic of spray irrigation system

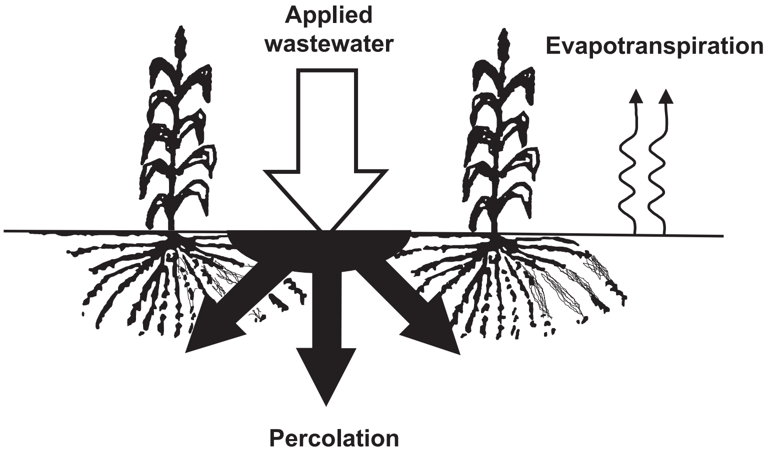


Figure 2. Conceptual schematic of rapid infiltration system

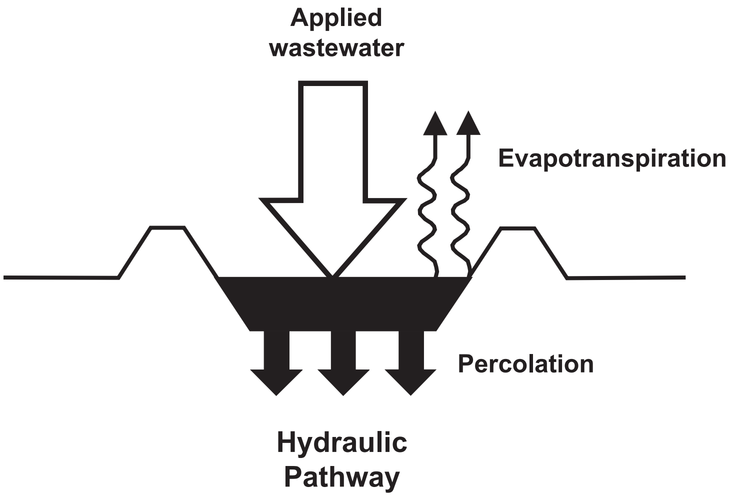
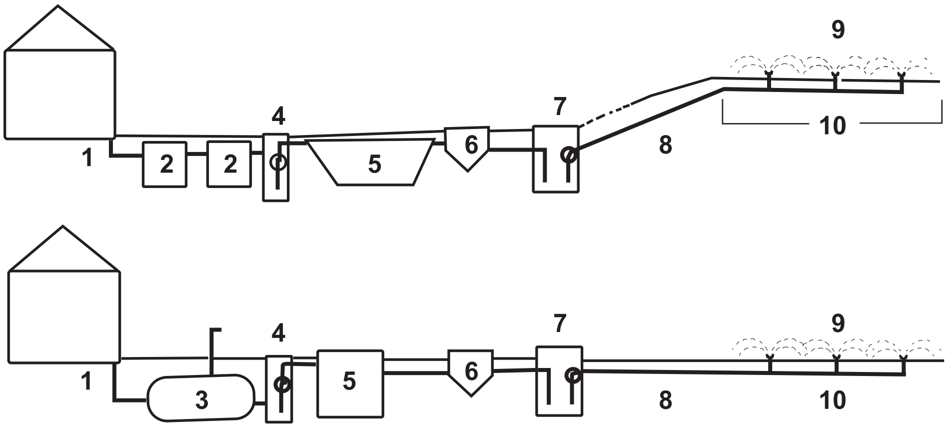


Figure 3. Typical residential spray irrigation systems



1. House sewer; 2. Septic tank (two required); 3. Aerobic unit; 4. Dosing tank; 5. Sand filter; 6. Cl_2 disinfection (or UV); 7. Tank and pump (plus storage); 8. Piping system; 9. Sprinklers; 10. Application site

Source: Adapted from McIntyre et al., 1994.

tank is necessary to eliminate possible runoff from the application area. The most used variation of these systems is the spray irrigation system (figure 3).

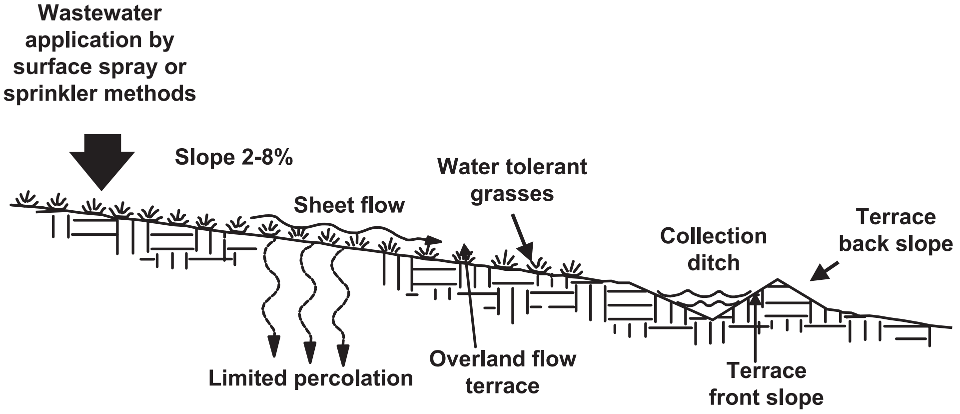
Spray irrigation systems distribute wastewater evenly on a vegetated plot for final treatment and discharge. Spray irrigation can be useful in areas where conventional onsite wastewater systems are unsuitable due to low soil permeability, shallow water depth table or impermeable layer, or complex site topography. Spray irrigation is not often used for residential onsite systems because of its large areal demands, the need to discontinue spraying during extended periods of cold weather, and the high potential for human contact with the wastewater during spraying. Spray irrigation systems are among the most land-intensive disposal systems. Drifting aerosols from spray heads can be a nuisance and must be monitored for impact on nearby land use and potential human contact. Buffer zones for residential systems must often be as large as, or even larger than, the spray field itself to minimize problems.

In a spray irrigation system, pretreatment of the wastewater is normally provided by a septic tank (primary clarifier) and aerobic unit, as well as a sand (media) filter and disinfection unit. Some states do not require the aerobic unit if the filter is used. The pretreated wastewater in spray irrigation systems is applied at low rates to grassy or wooded areas. Vegetation and soil microorganisms metabolize most nutrients and organic compounds in the wastewater during percolation through the first several inches of soil. The cleaned water is then absorbed by deep-rooted vegetation, or it passes through the soil to the ground water.

Rapid infiltration (RI) is a soil-based treatment method in which pretreated (clarified) wastewater is applied intermittently to a shallow earthen basin with exposed soil surfaces. It is only used where permeable soils, which generally can accept a conventional OWTS, are available. Because loading rates are high, most wastewater infiltrates the subsoil with minimal losses to evaporation. Treatment occurs within the soil before the wastewater reaches the ground water. The RI alternative is rarely used for onsite wastewater management. It is more widely used as a small-community wastewater treatment system in the United States and around the world.

The third and last type of land surface treatment is the overland flow (OF) process. In this system, pretreated wastewater is spread along a contour at the top of a gently sloping site that has minimum permeability. The wastewater then flows down the slope and is treated by microorganisms attached to vegetation as it travels by sheet flow over very impermeable soils until it is collected at the bottom of the slope for discharge. This system (figure 4) requires land areas similar to the spray

Figure 4. Overland flow system schematic



irrigation system. However, surface water discharge requirements (e.g., disinfection) from the OF system must still be met. Overland flow, like rapid infiltration, is rarely used for onsite wastewater management.

Typical applications

Spray irrigation (SI) is normally considered at site locations that do not permit a conventional SWIS because of relative impermeability and shallow depths caused by restrictive conditions (e.g., ground water or impermeable bedrock or fragipan). SI is normally the final step in the treatment sequence as the effluent is reintroduced to the environment. Most states require advanced treatment and disinfection prior to SI treatment.

Design assumptions

After pretreatment, which at a minimum should be a typical ISF effluent followed by disinfection, the treated wastewater is conveyed to a holding tank with a pump and controls that deliver it to the sprinkler system. The sprinklers spread the wastewater over a predetermined area at specific times. In wet climates or frozen soil conditions, an additional holding (storage) basin or larger dosing tank is required to prevent irrigation during periods when the wastewater would not be accepted by the soil for treatment and intended environmental incorporation. Regulations for buffer requirements from Texas, Virginia, and Pennsylvania are incorporated into table 1. Typically, the features listed below and their peripheral buffer zones are fenced to prevent exposure.

Application rates vary. Texas determines design rates based on evaporation, Virginia bases rates on soil texture, and Pennsylvania uses a combination of soil depth and slope. From a performance code approach, the application rate should be based on protecting the receiving surface/ground waters. It should be based on wastewater characteristics, critical constituent required concentrations (at a monitoring location where a specific quality standard must be met), and the characteristics of the site (i.e., features that will mitigate wastewater contaminants in order to meet the constituent concentration at the point of use).

In practical terms, all three states require the same pretreatment sequence, which yields SI influent of approximately 5, 5, 25, and 4 mg/L of CBOD, TSS, TN, and TP, respectively, in addition to a fecal coliform (FC) level of about 10 cfu/100 mL (if the disinfection step is working properly). Passage through 1 foot of unsaturated soil should for a few years remove most CBOD, TSS, TP, and FC; therefore, nitrogen will be the

Table 1. Buffer requirements to various features

Feature	Buffer distance (ft)
Property lines	10 - 100
Roads, driveways	25
Dwellings	0 - 100
Streams and lakes	25 - 100
Wells and water supplies	100
Recreation areas	100

Source: North Carolina DEHNR, 1996.

constituent of most concern. During the growing season, removal should be feasible by crop uptake and, to a lesser degree, ammonia volatilization.

Therefore, the hydraulic and nitrogen loading rates for a specific site are the primary design parameter. Also, these systems are rarely considered for permeable soils. The design approach described below is for this set of circumstances.

Spray irrigation systems are designed to treat wastewater and evenly distribute the effluent on a vegetated lot for final treatment. The application rate is determined by two major factors: hydraulic loading and nutrient loading (usually nitrogen is the limiting factor). The application rate is designed to meet the capacity of the soil to accept the effluent hydraulically and subsequently allow it to drain through the soil. The application rate can be varied according to the permeability of the soil. In Pennsylvania and Virginia, this method results in application rates of 0.6 to 2.5 cm/week. Lower rates can greatly improve nitrogen removal. The treated wastewater is spread over the required application area through a sprinkler or drip irrigation system.

Sprinklers are generally low-angle (7 to 13 degrees), large-drop-size nozzles designed to minimize aerosols. Application areas must be vegetated (with crops not intended for human consumption) and have slopes that preclude runoff to streams. The type of vegetation determines the nitrogen loading capacity of the site, but the hydraulic capacity depends on climate and soil characteristics. Additional nitrogen losses may occur through denitrification (only about 25 percent due to the low BOD:N ratio) and ammonia volatilization (about 10 percent if soil pH is high; less to none if it is acidic).

Spray irrigation of wastewater effluent must be timed to coincide with plant uptake and nutrient use. Temperature factors in some areas of the country may preclude the use of spray irrigation during certain times of the year. The wastewater may need to be stored in holding tanks during the coldest period of the year, because plant growth is limited and the nitrogen in effluent discharged during this time will be mineralized and unavailable for plant uptake.

Some SI systems irrigate only one or two days per week so that the soil can drain and aerate between applications. Others spray twice during the night or in the early morning to minimize inconvenience to the homeowner and to minimize the potential for human contact.

The width of the required buffer zone depends on the slope of the site, the average wind direction and velocity, the type of vegetation, and the types of nearby land uses. For wastewater produced by a single-family home, the minimum recommended SI plot area, including buffer zones, is commonly about 2 acres (0.81 hectares) in Pennsylvania and Virginia.

Performance

Studies that sample both the soil below the spray field and its runoff show that spray irrigation systems work as well as other methods of managing wastewater. Spray irrigation systems are designed for no degradation; therefore, hydraulic and nutrient loading rates are based on the type of vegetation used and the hydraulic properties of the soils. If the vegetation cannot assimilate the amount of nitrogen applied, for example, then nitrogen removal to reduce the nitrogen content of the effluent prior to spray irrigation may be required. The overall efficiency of a spray irrigation system in removing pollutants will be a function of the pollutant removal efficiencies of the entire treatment process and plant uptake.

There have been few documented cases of health problems due to the spray irrigation, but use of proper buffer zones is crucial. One benefit of spray irrigation is savings on potable water because the wastewater is used for irrigation.

Management needs

Construction factors include site preparation and installation of runoff controls, irrigation piping, return systems, and storage facilities. Since sustained wastewater infiltration is an important component of successful system operation, it is critical that construction activity be limited on the application site. Where stormwater runoff can be significant, measures must be taken to prevent excessive erosion, including terracing of steep slopes, contour plowing, no-till farming, establishment of grass border strips, and installation of sediment control basins. Earthworking operations should be conducted in such a way as to minimize soil compaction. Soil moisture should generally be low during these operations. High-flotation tires are recommended for all construction vehicles.

The soil profile must also be managed to maintain infiltration rates by avoiding soil compaction and maintaining soil chemical balance. Compaction and surface sealing (caused by harvesting equipment and development of fine layers from multiple wastewater applications) can reduce soil infiltration and increase runoff.

Local regulatory agencies may require ground water monitoring to evaluate system performance. Soil fertility and chemical balance should be evaluated periodically to determine if soil amendments are necessary. Trace elements may also be analyzed to monitor possibly toxic accumulations.

Residuals produced by slow-rate land application systems are limited to harvested crops and crop residues that are not for human consumption. Agricultural crop applications require the most intensive management, while forest application requires the least management. Management tasks may include soil tillage, planting and harvesting of crops, nutrient control, pH adjustment, and sodium and salinity control. No special equipment, other than the appropriate agricultural equipment, is required. Typical pump, controls, and basin requirements prevail for the dosing system.

Virginia's O/M requirements for onsite spray irrigation systems (not including pretreatment unit processes) include the following:

- *Monthly.* Walk over spray area and examine for
  - Ponding of effluent
  - Bad odors
  - Damage to spray heads
  - Surfacing liquids
  - Vegetation problems
  - Surface soil collapse
- *Quarterly*. Conducted by a qualified, semi-skilled operator
  - Proper spray sequence
  - Proper pump function
  - Proper liquid levels
- *Biannually*
  - Erosion
  - Storage unit capacity
- *Annually*. Effluent sampling by a certified laboratory
  - Test water supplied to spray irrigation area for pH, total Kjeldahl nitrogen, fecal coliform bacteria, chlorine, TSS, and BOD
  - Reports of analyses are to be submitted by the laboratory to the local/district health department within 10 days of the completion of the analyses.

A management contract with an approved operator or operations firm is also required.

Risk management issues

No crops grown on the SI application area should be consumed by humans. Buffer zones should minimize aerosol exposure. Spray irrigation systems with sufficient storage capacity are essentially unaffected by major flow variations. A water balance should be conducted to determine the need under the climate conditions, soils, and application rates and patterns of each rate. Similarly, toxic shock loadings should be largely dissipated in the preceding pretreatment steps, but phytotoxic compounds may still be a concern at the application site. Spray irrigation cannot function during saturated or frozen conditions, and the pretreated influent must be stored until proper vegetative uptake (usually nitrogen) conditions return. Power outages will affect the upstream pretreatment processes rather than the SI system, even though the system must have power to function.

However, by the time the wastewater effluent is discharged by the sprinklers, the water should be sufficiently treated so as not to pose health risks. There have been no documented cases of health problems due to the spray irrigation of properly treated wastewater. However, drifting aerosols from the spray heads should be monitored for impact on nearby land uses. A benefit of spray irrigation is the use of effluent, instead of potable tap water, to water the landscape.

Costs

Construction costs of SI systems are very high if the generally required pretreatment is included, especially if both an aerobic unit and a sand filter treating septic tank effluent are included. Such a system could easily cost $20,000 or more.

O/M costs for the SI system alone primarily include labor (15 to 20 hours per year), power (for pumps and other pretreatment needs) and materials (e.g., chlorine, if chosen). O/M costs are estimated at more than $500 per year, given the entire treatment train suggested by figure 3. If the aerobic treatment unit is not required ahead of the sand filter, and a UV disinfection unit is used, this cost may reduce to $300 to $400 annually.

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Section 8

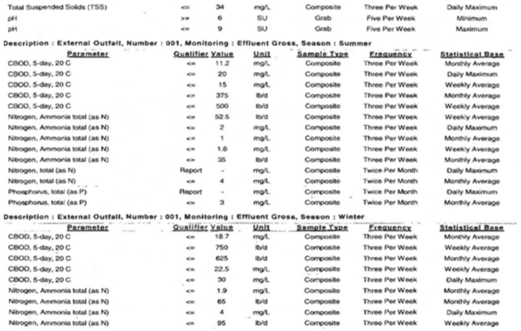
Introduction to Wastewater Laboratory, Standard Methods, SOPs, & QA/QC

INTRODUCTION TO A WASTEWATER LABORATORY

Biological Natural Systems

NPDES Permit

1.1 NUMERICAND NARRATIVE EFFLUENT LIMITATIONS



Total Suspended Solids (TSS)	<=	34	mg/L	Composite	Three Per Week	Daily Maximum
pH	>=	6	SU	Grab	Five Per Week	Minimum
pH	<=	9	SU	Grab	Five Per Week	Maximum

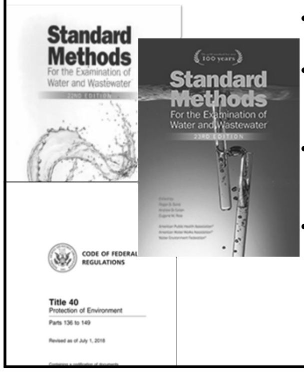
Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Summer

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
CBOD, 5-day, 20 C	<=	11.2	mg/L	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	20	mg/L	Composite	Three Per Week	Daily Maximum
CBOD, 5-day, 20 C	<=	15	mg/L	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	375	lb/d	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	500	lb/d	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	52.5	lb/d	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	2	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	1.6	mg/L	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	35	lb/d	Composite	Three Per Week	Monthly Average
Nitrogen, total (as N)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Nitrogen, total (as N)	<=	4	mg/L	Composite	Twice Per Month	Monthly Average
Phosphorus, total (as P)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Phosphorus, total (as P)	<=	3	mg/L	Composite	Twice Per Month	Monthly Average

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

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
CBOD, 5-day, 20 C	<=	18.7	mg/L	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	750	lb/d	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	625	lb/d	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	22.5	mg/L	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	30	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1.9	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	65	lb/d	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	4	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	95	lb/d	Composite	Three Per Week	Weekly Average

Tools for Success



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

Tools for Success

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

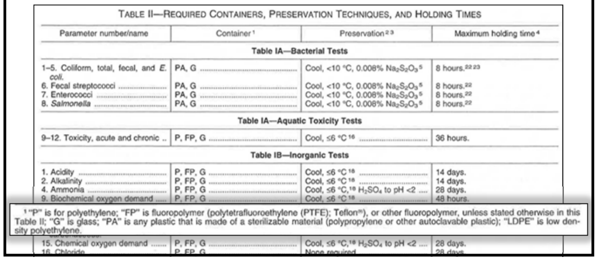


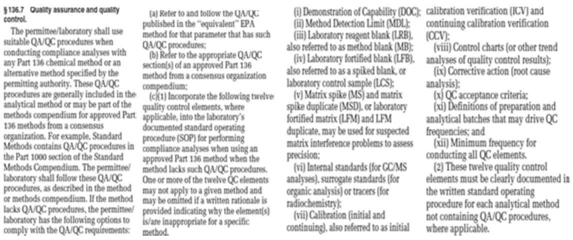
TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

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

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

Tools for Success

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



§ 136.7 Quality assurance and quality control.

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

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

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

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

(i) Demonstration of Capability (DOC);

(ii) Method Detection Limit (MDL);

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

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

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

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

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

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

(ix) Corrective action (root cause analysis);

(x) QC acceptance criteria;

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

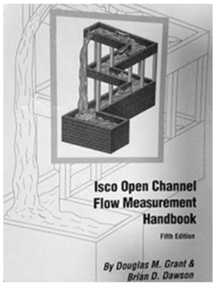
(xii) Minimum frequency for conducting all QC elements.

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

Tools for Success

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

Tools for Success



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

Why Sample?

1. Meet compliance requirements
2. Process control
3. Ensure public safety and protect the environment

Sampling Plan

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

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

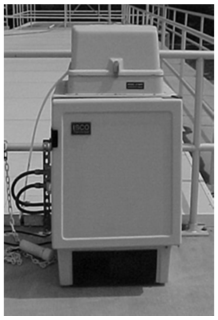
Reliable sampling data are obtained by collecting samples:

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

Automated Samplers

Manual Sampling Device

Automatic Sampling Device



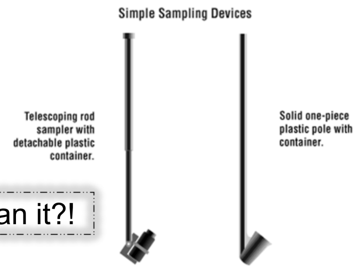
- Timesaver
- Composite: set to collect specific volumes over a period of time
- Refrigerated and thoroughly mixed
- Clean intake line regularly to prevent growth of bacteria or algae

Preventative Sampler Maintenance

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

Samplers

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



Can you clean it?!

Samplers – Approved or Not?

Considerations

- Collection
- Volume
- Storage and preservation
- Sample points
- Sampling frequency

- Include Sampling Plan in SOP

40 CFR 136 Table II

NPDES permit

Sample Types

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

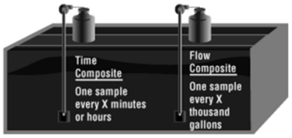
Grab Samples

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

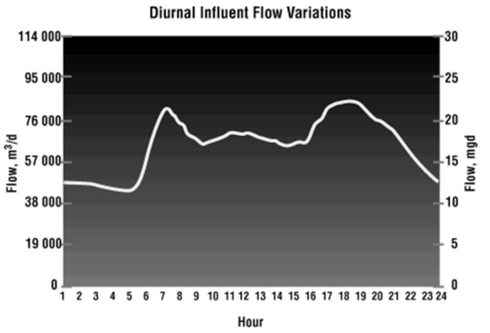
Composite Sample

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

1. Fixed volume or time composite
2. Flow proportioned



Flow Variations



Example of Flow-Proportioned Sample Collection

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

Composite Sample

- Composite sampling is used when:
  - This is required by the permit
  - Plant removal efficiencies are calculated
  - Average data are needed to make process adjustments
- Refrigerated and thoroughly mixed
- BOD, total N, settleable solids
- NEVER use composite sample for bacterial analysis

Sampling Guidelines

- Representative
- Proper container
- Do not contaminate the lid
- Preservative/ dechlorinating agent
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out

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

Sampling Guidelines

- Hold by base
- Turn into current
- Avoid air bubbles

- Label containers with:

1. Sample Location
2. Date and Time of collection
3. Name of collector
4. Any other pertinent information

Sample Labeling

Location: 196 E. Main Street, Springfield, TN

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

Sampled by: BS (Bob Smith)

Comments: grab sample

pH < 2 with H_2SO_4 and stored at 4°C

Chain of Custody

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

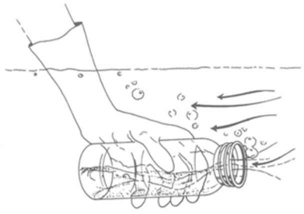
Sample Volume

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

Sampling Point Selection

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

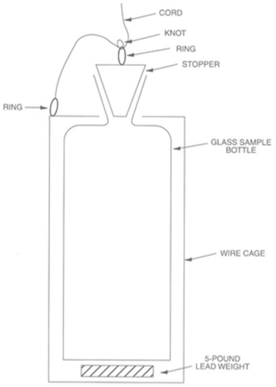
Subsurface Sampling



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

Homemade Depth Sampler

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



Process Monitoring and Control Tests

- DO
- BOD_5 or $cBOD_5$
- COD
- Solids
- Microscopic Examination
- Temp
- Depth of sludge
- pH
- Nitrogen
  - Ammonia
  - Nitrate
  - Nitrite
  - Total Kjeldalh (TKN)
- Phosphorus
- Chlorine
- Alkalinity
- Coliforms
  - E.coli

Dissolved Oxygen (DO)

- Measurement of the amount of oxygen dissolved in a unit volume of water
- Two options for testing DO
  - DO probe and meter
  - Winkler method
- Hold Time = 15 minutes!

- BOD and nitrification are both aerobic processes

Dissolved Oxygen

The amount of oxygen that given volume of water can hold is a function of:

1. Barometric pressure (the pressure the atmospheric oxygen is exerting at the air-water interface)
2. Water temperature
3. Amount of other substances dissolved in the water
   - Salinity

Dissolved Oxygen

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

Dissolved Oxygen

- Organic material (in the presence of oxygen and bacteria)
  - Organic material will require oxygen to decompose.
  - More organic material requires more DO, and will tend to deplete water of DO.

- Oxygen Demand
  - The amount of oxygen required to oxidize a material.

Biochemical Oxygen Demand

- Biochemical oxygen demand, or BOD is the amount of oxygen used during the breakdown of organic material.
- BOD is considered an indirect measure of the organic content of a sample.
- Dissolved oxygen measured by Winkler method (titration) or using a meter and electrode.
- BOD_5 (or $CBOD_5$)
  - The Biological Oxygen Demand lasts 5 days

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.

Incubated at 20 ± 1° C for 5 days in the dark

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

Biochemical Oxygen Demand

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

Biochemical Oxygen Demand

- Requirements for valid BOD results:
  1. Blank depletion must be ≤ 0.2 mg/L DO
     - Preferably <0.1 mg/L DO
  2. Initial DO must be ≤ 9.0 mg/L
  3. Samples must deplete at least 2.0 mg/L DO
  4. Samples must have at least 1.0 mg/L DO remaining at the end of the incubation period

Biochemical Oxygen Demand

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

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

BOD Calculation

- Initial DO = 8.2 mg/L
- Final DO = 4.5 mg/L
- Sample Volume = 6 mL
- BOD_5, mg/L = $\frac{D_1 - D_2}{P}$
- Where P = % sample
  - 6/300 = 0.02

- BOD_5, mg/L = $\frac{8.2 - 4.5}{0.02}$

  = 185 mg/L

BOD Calculation

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

BOD Calculation

- P = 12/300 = 0.04
- BOD_5, mg/L = $\frac{8.1 - 4.0}{0.04}$

  = 102.5 mg/L

Chemical Oxygen Demand (COD)

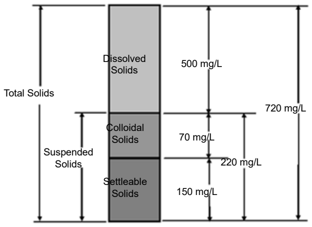
- COD is the equivalent amount of oxygen needed to break down organic matter using strong oxidizing agents.
- Sometimes measured to use as quick (2-4 hrs) process control test.
  - Faster than BOD
- Usually higher than BOD, but ratio varies
  - Because it measures the oxidation of both organic and inorganic substances
- Can be used to approximate BOD

Solids

- Cause many problems:
  - Fill storage areas, clog ditches and channels.
    - Settled solids often create anaerobic zones on the bottom of natural streams due to depletion of all the oxygen
  - Interfere with mechanical systems.
  - Associated with taste/color/clarity problems in drinking water.

Solids

- Total solids
  - the matter left behind after drying a sample of water at 103-105ºC.
- Dissolved solids
- Suspended solids
  - Settleable
  - Nonsettleable
    - Colloidal
- Organic and inorganic solids
- Floatable solids



Solids (TSS and TDS)

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

Suspended Solids (TSS)

- Amount of material suspended in sample
  - Suspended solids are a combination of settleable solids and those that will remain in suspension
- The SS test measures the amount of solids in suspension that can be removed by filtration
- The sample is filtered through a pre-weighed filter paper and dried in an oven at 103-105ºC

Suspended Solids (TSS)

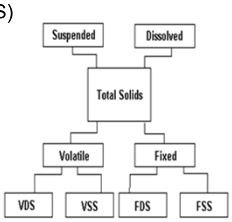
103 – 105 degrees C

Solids

- Total volatile solids is the portion of the sample lost after the sample has been heated to 550ºC. 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.

Solids

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



Solids

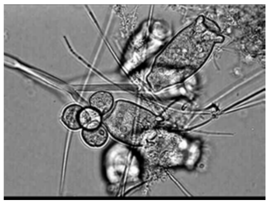
- The mass of solids per known volume of water is:

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

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

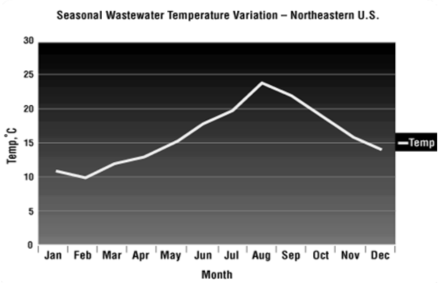
Microscopic Examination

- Microscopic examinations should be performed immediately after sample collection
- Can provide valuable information if performed routinely
  - Biological characteristics and health of system
  - Warning signs (Ex: toxicity)



Temperature

- Microorganisms will respond to temperature changes
  - Metabolic rate will be slower in colder temperatures



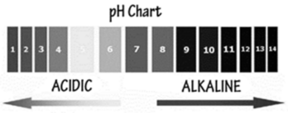
Thermometers

- Periodically check thermometer's bias against a reference thermometer certified by NIST
  - At least annually
  - Record of certification
- NIST = National Institute of Standards and Technology
  - Formerly NSB (National Bureau of Standards)
- Can use a metal case to protect from breaking in the field
- Temps in lab should be taken daily

Thermometers

- After calibration, mark the necessary calibration correction factor on each device so that only calibrated/corrected temperature values are recorded.

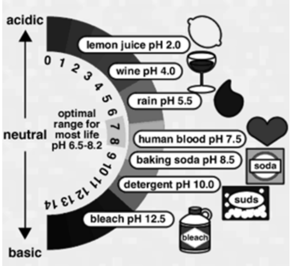
pH

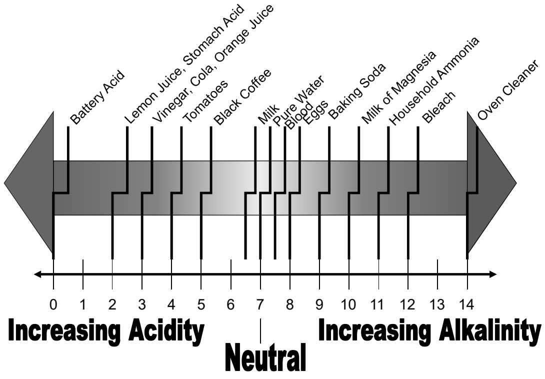


- Power of hydrogen
  - Measurement of the hydrogen ion concentration
  - **pH = -log [H^+]**
  - Each decrease in pH unit equals a 10x increase in acid
- Scale runs from 0 to 14, with 7 being neutral
- Probe measures millivolts, then converts into pH units
  - Temperature affects millivolts generated, therefore you need a Automatic Temperature Compensator (ATC)
- If the pH of the mixed liquor varies too far from neutral (pH = 7.0), microorganisms may become inhibited or may start to die.
  - Discharge limit 6 – 9

pH

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





Nutrients

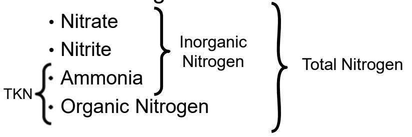
- A balanced nutrient ration is essential for microorganism health
  - Function at maximum efficiency
- Most important nutrients are
  1. Carbon
  2. Nitrogen
  3. Phosphorus

Carbon

- Principal component of the organic substances found in wastewater
- Biodegraded by microorganisms in activated sludge
  - Anaerobic conditions
  - Anoxic conditions (denitrification)
  - Aeration basin (nitrification)
- Use carbon to build cell structures and generate energy

Nitrogen Group - N

- In water and wastewater the forms of nitrogen that are of greatest interest are:



- Nitrate
- Nitrite
- Ammonia
- Organic Nitrogen

Nitrogen

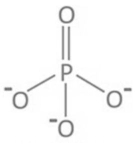
- The influent wastewater contains:
  - Organic N
  - Ammonium N (NH_4^-)
- Organic N converted to NH_4^- by bacteria in activated sludge
  - NH_4^- → Nitrite → Nitrate
- The Nitrogen compounds not degraded are converted in anoxic zone
  - Nitrate → Nitrogen gas

Phosphorus Group - P

- 3 Main types of phosphorus in water

1. Orthophosphate
   - "reactive phosphorus"
2. Condensed phosphate
   - (Ex: Polyphosphates)
3. Organic phosphate
   - Organically bound

➢ All of these together form Total P



phosphate ion

Phosphorus Group - P

- Elemental phosphorus never occurs by itself in water, always as some kind of compound
  - Dissolved or particulate
- Phosphorus occurs in natural water and wastewater almost solely as phosphates
  - Inorganic form (ortho and poly)
  - Organic (organically bound)
- During biological WW treatment, polyphosphates and organically bound phosphorus are converted to orthophosphate

Phosphorus

- Types of Phosphorus Analyses include:
  - Orthophosphate
  - Acid Hydrolyzable Phosphate/Condensed Phosphate
  - Total Phosphorous/Organic Phosphate
- Only Orthophosphate can be measured directly
  - Other forms must be converted to this

Chlorine Residual

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

Chlorine Residual

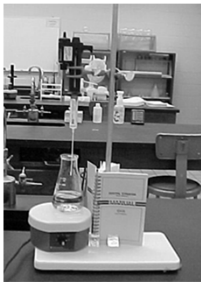
- Approved Methods:
  - Amperometric titration
  - Iodmetric titration – starch endpoint
  - Back titration
  - DPD - FAS
  - Spectrophotometric, DPD
  - Electrode
- NOTE: DPD color comparator is NOT an approved method

Chlorine Residual

- DPD colorimetric method most commonly used
  - Match color of sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Wait ***three minutes*** (Hach method)
  - Place it into colorimeter and take reading

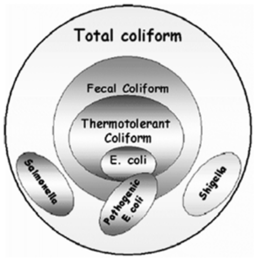
Alkalinity

- 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.



Coliform Bacteria

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

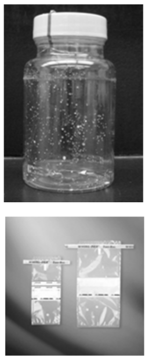


Testing for Microbial Organisms

- 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®.

Sampling



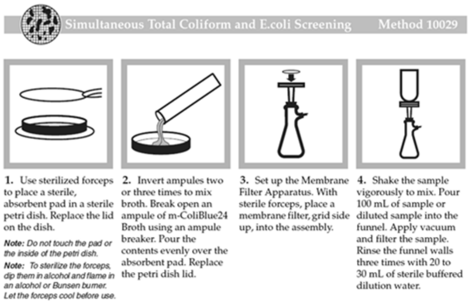
- Clean, sterilized borosilicate glass or plastic bottles or sterile plastic bags.
- Leave ample air space for mixing.
- Collect samples representative of wastewater tested.
- Use aseptic techniques; avoid sample contamination.
- Test samples as soon as possible.

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.

Membrane Filtration



Simultaneous Total Coliform and E.coli Screening Method 10029

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

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

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

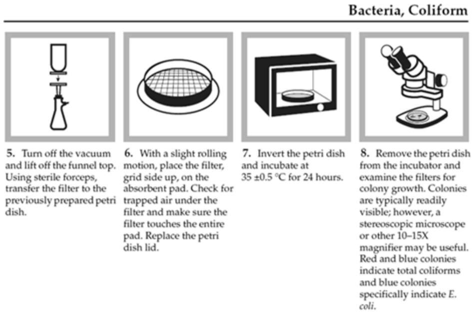
2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish lid.

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

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

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

Membrane Filtration



Bacteria, Coliform

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

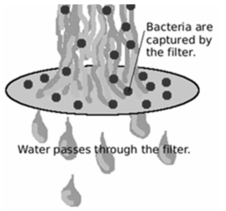
6. With a slight rolling motion, place the filter, grid side up, on the absorbent pad. Check for trapped air under the filter and make sure the filter touches the entire pad. Replace the petri dish lid.

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

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

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

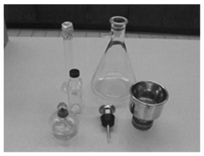
Membrane Filtration Equipment



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

Membrane Filtration Supplies and Glassware

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



FECAL COLIFORM

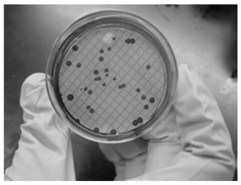
Membrane filtration (SM9222 D-1997)

Fecal Coliform

- A 100 mL volume of sample is filtered through a 47-mm membrane filter using standard techniques.
- Filter is transferred to a 50-mm petri plate containing an absorbent pad saturated with mFC Broth.
- Invert filter and incubate at 44.5±0.2°C for 24 ± 2 hrs.
- Fecal coliform density reported as number of colonies per 100 mL of sample.
  - Fecal coliforms appear blue.
  - Colonies = colony forming unit = cfu
- NPDES permit limit: monthly average of 200 cfu/100 mL; daily maximum of 1000 cfu/100 mL.
- Interferences
  - None, but excess particulates may cause colonies to grow together on a crowded filter or slow the sample filtration process.

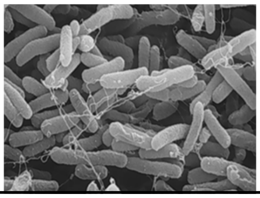
Fecal Coliform

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

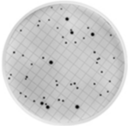


ESCHERICHIA COLI (E.COLI)

m-ColiBlue24® with Membrane Filtration

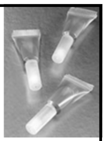


E. coli m-ColiBlue24®



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

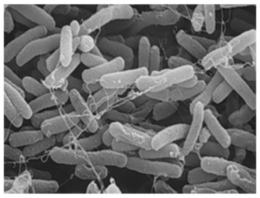
E. coli m-ColiBlue24®



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

ESCHERICHIA COLI (E.COLI)

Colilert



Colilert® & Colilert-18®

MPN (Most Probable Number) Method

- Add substrate to a 100 mL sample
- If making dilutions, use sterile DI water, not sterile buffered water.

Colilert® & Colilert-18®

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

Colilert® & Colilert-18®

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

Colilert® & Colilert-18®

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

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

Colilert® & Colilert-18®

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

All Bacteriological Checks

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

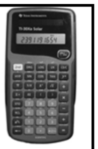
Geometric Mean

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

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

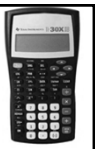
$$\text{Geometric Mean} = \sqrt[n]{(X_1)(X_2)(X_3)\ldots(X_n)}$$

Geometric Mean



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

Geometric Mean



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

Geometric Mean

- Now, try one on your own:
- 20, 20, 210, 350
- Geometric Mean = 73.6

Geometric Mean

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

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.

- Collect samples in wide-mouth, glass jars
- Cool to <6°C, preserve with HCL or H_2SO_4 to pH <2
- Max hold time = 28 days

TDEC - Fleming Training Center

Water Quality Indicators

- Receiving water measurements = tests used to determine the effect of discharge on the receiving waters and on the beneficial uses (water supply, recreation, fishery) of the receiving waters after effluent has mixed with receiving waters
- To measure impact:
  - Take a measurement upstream (not affected) and downstream (affected) and compare the two results
- "Oxygen profile" (Dissolved oxygen) to get a good measure of the effect of the effluent
  - Measure the DO at several different cross sections downstream from discharge to find out where the lowest DO level occurs

Water Quality Indicators

- To determine impact, the following questions must be answered:

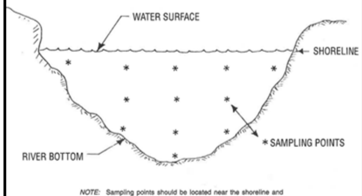
1. What are the characteristics upstream?
   - Temperature
   - Dissolved oxygen (DO)
2. What are the characteristics downstream?
3. If upstream and downstream are different, does the discharge cause the difference?
4. Are the downstream characteristics in violation of established standards or objectives
5. If downstream is in violation, did the discharge cause it?

Water Quality Indicators

- If results do not look correct, do not reject outright. Investigate and attempt to identify the reasons for the result.
  - Sampling errors, testing errors, recording errors
- Sudden drop in DO downstream (without a similar drop upstream) indicates that the plant's BOD removal efficiency has decreased
- Sudden drop in DO could be caused by increase in temperature due to an industrial or stormwater discharge
- Sudden changes in effluent may be due to:

1. Process failure
2. Sudden increase in flow quantity
3. Change in influent characteristics such as industrial waste discharges into the system

Water Quality Indicators – DO profile



NOTE: Sampling points should be located near the shoreline and approximately one foot (0.3 m) below the water surface and one foot (0.3 m) above the bottom. The number of sampling points between the water surface and the bottom will depend on the depth of the water, and the number of vertical sampling sections will depend on the width of the stream. Total number of sampling points also will depend on budget, time, water quality indicators being sampled, and desired accuracy.

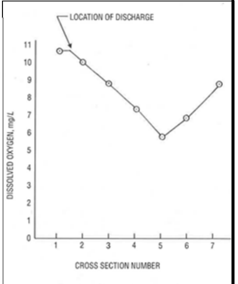


Fig. 13.4 Dissolved oxygen profile

Source: Operation of Wastewater Treatment Plants, Vol II, seventh ed., p.250-251

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
  - WET testing (Whole Effluent Toxicity)

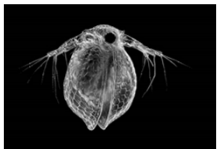
Whole Effluent Toxicity (WET) Testing

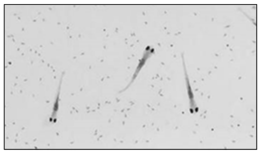
- Whole Effluent Toxicity (WET) test refers to the combined toxic effect to aquatic organisms from all pollutants contained in a wastewater effluent
  - Also known as Biomonitoring
  - Looks at the effluent as a single component
- WET tests measure wastewater's effects on specific test organisms' ability to survive, grow and reproduce

- Acute toxicity
  - Short term, lethal effects
  - "End of pipe" conditions
- Chronic toxicity
  - Long term, sub-lethal effects
  - Mixed water conditions
  - More sensitive test

Whole Effluent Toxicity (WET) Testing

- NPDES permit limits found in Sections 3.4, 3.5
- Methods for compliance with NPDES permits in 40 CFR 136.3
- Test organisms:
  - Water flea *(Ceriodaphnia dubia)*
    - Invertebrate crustacean
  - Fathead Minnow *(Pimephales promelas)*





Any Questions?

🤔

Standard Methods, SOP's & Introduction to QA/QC

BNS Class

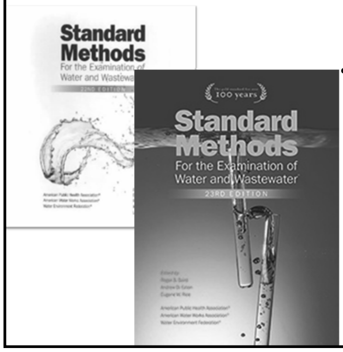
Standard Methods

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

Standard Methods

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

Standard Methods



- Standard Methods for the Examination of Water and Wastewater

Code of Federal Regulations (CFR)

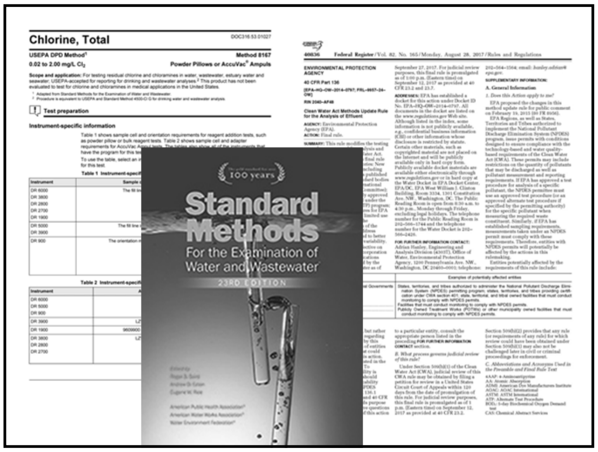
- The purpose of the CFR is to present the official and complete text of agency regulations in one organized publication and to provide a comprehensive and convenient reference for all those who may need to know the text of general and permanent Federal regulations

Code of Federal Regulations (CFR)

- The CFR is divided into 50 titles representing broad areas subject to Federal regulation
  - Each title divided into chapters
  - Each chapter divided into parts
  - Each part divided into sections
- Wastewater: 40 CFR 136
- Drinking Water: 40 CFR 141
- Sometimes CFR supersedes Standard Methods

Code of Federal Regulations (CFR)

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



Chlorine, Total DOC316.53.01027

USEPA DPD Method[1] Method 8167

0.02 to 2.00 mg/L Cl_2 Powder Pillows or AccuVac® Ampuls

Scope and application: For testing residual chlorine and chloramines in water, wastewater, estuary water and seawater; USEPA-accepted for reporting for drinking and wastewater analyses.[2] This product has not been evaluated to test for chlorine and chloramines in medical applications in the United States.

[1] Adapted from Standard Methods for the Examination of Water and Wastewater.

[2] Procedure is equivalent to USEPA and Standard Method 4500-Cl G for drinking water and wastewater analysis.

Test preparation

Instrument-specific information

Standard Methods For the Examination of Water and Wastewater

23RD EDITION

100 years

40836 Federal Register / Vol. 82, No. 165 / Monday, August 28, 2017 / Rules and Regulations

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 136

[EPA–HQ–OW–2014–0797; FRL–9957–24–OW]

RIN 2040–AF48

Clean Water Act Methods Update Rule for the Analysis of Effluent

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

Standard Operating Procedure (SOP)

- All procedures must be documented in some type of SOP
- It can be very simple but must provide the information necessary for someone who is not familiar with the test to perform it
  - Step by step instructions on how and where to collect the samples and then how to run the test

Standard Operating Procedure (SOP)

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

Standard Operating Procedure (SOP)

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

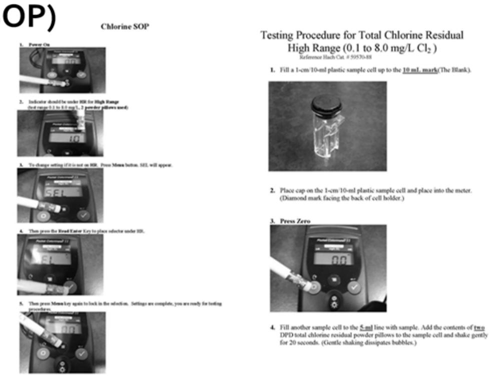
Standard Operating Procedure (SOP)

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

Standard Operating Procedure (SOP)

- Common documents in an SOP:
  - Copy of method from manufacturer on how to calibrate instrument, run samples, etc.
  - QA/QC information from TDEC
  - Step-by-step instruction for you plant on the 12 Steps that apply to that test
  - Where you grab your samples

Standard Operating Procedure (SOP)



Chlorine SOP

1. **Power On**
2. Indicator should be under HR for **High Range** (test range 0.1 to 8.0 mg/L, 2 powder pillows used)
3. To change setting if it is not on HR. Press **Menu** button. SEL will appear.
4. Then press the **Read/Enter** Key to place selector under HR.
5. Then press **Menu** key again to lock in the selection. Settings are complete, you are ready for testing procedures.

Testing Procedure for Total Chlorine Residual
High Range (0.1 to 8.0 mg/L Cl_2)
Reference Hach Cat. # 59570-88

1. Fill a 1-cm/10-ml plastic sample cell up to the **10 mL mark**(The Blank).
2. Place cap on the 1-cm/10-ml plastic sample cell and place into the meter. (Diamond mark facing the back of cell holder.)
3. **Press Zero**
4. Fill another sample cell to the **5-ml** line with sample. Add the contents of **two** DPD total chlorine residual powder pillows to the sample cell and shake gently for 20 seconds. (Gentle shaking dissipates bubbles.)

Standard Operating Procedure

5. Place sample cell in meter and cover instrument with cap. Let sample stand 3 to 6 minutes, then **press Read/Enter**.

QA/QC for Chlorine

DOC- Demonstration of Capability – Each operator analyzes 4 standards and signs form documenting reading and understanding SOP for specific instrument used.

MDL – Method Detection Limit
Run 7 samples annually at low levels.

Method Blank
Analyze Deionized or distilled water as a sample 2/month.

LFB – Lab Fortified Blank
Analyze a known standard of 0.5 mg/L concentration 2/month.

DUP – Duplicates
Analyze a sample twice (use fresh sample for duplicate) run 2/month.

ICAL/CCV - Initial Calibration and Continuing Calibration Verification
Prepare potassium permanganate or chlorine standards 1 month. Verify meter daily with secondary standards. (Gel Standards)

- What are some key points that are missing from this SOP?

Documentation/Record Keeping

- Review of log books
  - Instrument calibration (daily)
  - Temperature
  - Maintenance
  - Sampler
  - Standard preparation
  - Calibration
- Lab instruments - yearly maintenance check (or more frequently)
  - including thermometers and weights
- Flow measurement devices – yearly maintenance check
- QA/QC that has been done

Record Keeping

- Maintain a complete and accurate list of exact locations of all sampling sites
- Maintain a complete and accurate list of all test procedures used
  - Record method numbers on bench sheets
- Write in pen
- Initial your entries
- Use a notebook that has numbered pages

Bench Sheets

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

Three QA Options

- A. …follow equivalent EPA procedures
- B. Refer to QA/QC in consensus organization compendium. (Follow Standard Methods)
- C. Follow the 12 Steps where applicable.
- The 13th step requires an SOP (standard operating procedures)

12 Quality Control Elements

1. DOC – demonstration of capability
2. MDL – method detection level
3. LRB/MB – method blank
4. LFB – laboratory fortified blank (standard)
5. LFM/LFMD – laboratory fortified matrix/duplicate (spike)
6. Internal standards, surrogate standards or tracer – ***only applies to organic analysis and radiochemistry***
7. Calibration- initial and continuing
8. Control charts or other trend analysis
9. Corrective action – root cause analysis
10. QC acceptance criteria
11. Definition of a batch (preparation and analytical)
12. Minimum frequency for conducting all QC elements
13. Unwritten 13th Step – SOP – Standard Operating Procedures need to be written and followed for all lab sampling and analyses

Not all of these items apply to all tests, there are many exceptions!

Applicable tests for Drinking Water

- Total Residual Chlorine
- pH
- TSS
- Settleable Solids
- Aluminum

- Does your plant have a NPDES permit?

Can you defend what you do?

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

What You Are Already Doing

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

[Photo credit: Patient Care Technician]

Demonstration of Capability (DOC)

- DOC once for each analyst
- Standard Methods 1020.B.1
  - As a minimum, include a reagent blank and at least 4 LFBs at a concentration between 10 times the MDL and the midpoint of a calibration curve.
  - Something to keep along with these records is a signed form (documentation) that analyst has read and understands all appropriate SOPs and Methods.
- How often?
  - Once for each analyst
  - Recommended yearly for backup analyst who does not perform tests frequently
  - Each analyst should have a file kept on their training within and for the lab.
  - DW: chlorine, pH, TSS
  - WW: Ammonia, BOD/CBOD, Chlorine, pH, DO, Total phosphorus, TSS

Method Detection Limit (MDL)

- Estimation of the detection limit for variety of physical and chemical methods
- EPA defines as: "the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results"
- What tests does this apply to?
- DW: Chlorine
- WW: Ammonia, Chlorine, and Total Phosphorus

- How often?
  - Annually – but at least every 13 months
  - Ongoing data collection and MDL validation is now required quarterly

What IS an MDL study?

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

Method Detection Limit (MDL)

- Initial MDL
  - Process at least 7 spiked samples and 7 method blank samples
    - As a starting point for selecting the concentration to use when determining the MDL, use an estimate of five times the estimated true detection level
    - Ideally, use pooled data from several analysts
  - Must be prepared in at least 3 batches on 3 separate dates and analyzed on 3 separate dates
    - Preparation and analysis can be on the same day

Method Detection Limit (MDL)

- Initial MDL continued…
  - If multiple instruments will be assigned the same MDL, sample analyses must be distributed across all the instruments
    - Minimum of 2 spiked and 2 blank samples per instrument, analyzed on different dates
  - Compute MDL_s – value based on spiked samples
  - Compute MDL_b – value based on blank samples
    - Use the MDL calculator on the FTC website
  - Whichever is greater is your MDL

Method Detection Limit (MDL)

- Ongoing Data Collection:
  - MDL_s: Value calculated from the spiked samples
    - Minimum of 2 spiked samples on each instrument
    - Minimum of 8 per year (2 per quarter)
  - MDL_b: value calculated from the method blanks
    - No additional samples required – just use the routine method blanks

Method Detection Limit (MDL)

- Samples used to calculate MDL should be performed throughout the year, not on a single date
  - Samples analyzed every quarter, but calculation performed only once a year
- Lab has the option to pool data from multiple instruments to calculate one MDL that represents multiple instruments

Method Detection Limit (MDL)

- Annual Verification:
  - At least once every 13 months you need to re-calculate your MDL_s and MDL_b
    - Ideally, use all method blank results from the last 24 months for the MDL_b calculation
    - There is an option to use less data included in the rule
  - The verified MDL is the higher of the two numbers (either the MDL_s or the MDL_b)
  - Your existing MDL may be left unchanged if specific criteria are met
    - See 40 CFR 136 Appendix B

Method Detection Limit (MDL)

- Where do I find the MDL Calculator?

1. Go to Fleming Training Center's website
   - https://www.tn.gov/environment/program-areas/wr-water-resources/fleming-training-center.html
2. On left side, click on "Course Books and Reference Material"
3. In the drop-down menu, click on "Waste Water Information"
4. Click on "Method Update Rule – Method Detection Limit Math 2018"

Method Detection Limit (MDL)

- Some things to remember…
  - Record values in multiple places so you don't lose them
  - You need to "save as" for each parameter
  - Save a copy of the calculator before you change the I3 cell date (every 13 months)
  - You need an electronic or a hardcopy on file
    - Play it safe – have both

Laboratory Reagent Blank (LRB)

- Also known as Method Blank
- Standard Methods 1020.B.5
  - A reagent blank (method blank) consists of reagent water and all reagents that normally are in contact with a sample during the entire analytical procedure (distillation, incubation, etc.)

- DW: Chlorine, TSS
- WW: Ammonia, BOD/cBOD, Chlorine, Total Phosphorus and TSS

- How often?
  - Depends on method QA/QC

Laboratory Fortified Blank (LFB)

- Standard Methods 1020.B.6
  - A laboratory-fortified blank is a reagent water sample to which a known concentration of the analyte of interest has been added
  - Sample batch = 5% basis = 1 every 20 samples
  - At least once a month
  - Use an added concentration of at least 10 times the MDL, or less than or equal to the midpoint of the calibration curve

Laboratory Fortified Blank (LFB) cont.

- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement

- DW: Chlorine, TSS
- WW: Ammonia, BOD/cBOD, Chlorine, Total Phosphorus, TSS

Laboratory Fortified Matrix and Duplicate (LFM/LFMD)

- Also known as a Spike and Spike dup
- Standard Methods 1020.B.7
  - A laboratory matrix (LFM) is an additional portion of a sample to which a known amount of the analyte of interest is added before sample preparation
  - The LFM is used to evaluate analyte recovery in a sample
  - Sample batch = 5% basis = 1 every 20 samples
  - At least once a month
  - Add a concentration less than or equal to the midpoint of the calibration curve
  - Preferably the same concentration as the LFB (laboratory fortified blank)

Laboratory Fortified Matrix and Duplicate (LFM/LFMD)

- Also called a Matrix Spike/Matrix Spike Duplicate (MS/MSD)
- Shows if there are interferences in the effluent matrix

- WW: Ammonia and Total Phosphorus

- How often?

For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:

  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

Duplicate (Dup)

- Not a part of the 12 Steps of QA, an addition from the State of TN
- Why is this important?
  - *Precision* refers to the closeness of two or more measurements to each other
- Standard Methods 1020.B.8
  - As a minimum, include one duplicate sample with each sample set or on a 5% basis
- Standard Methods 1020.B.12
  - Calculate the RPD (relative percent difference)
  - Equal to or less than 20% RPD

Duplicate (Dup)

- DW: Chlorine, pH, TSS, and Settleable Solids
- WW: BOD/CBOD, chlorine, pH, DO, TSS and Settleable Solids

- How often?

For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria: (10% would be once every 10 samples for TSS)

  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

Initial Calibration Verification (ICV)

- **ICV**
  - Standard Methods 1020.B.11.b
  - Perform Initial Calibration using at least 3 concentrations of standards for linear curve
  - Calibrate meter (DO, pH) or verify scale, colorimeter/spectrophotometer, and thermometer

Continuing Calibration Verification (CCV)

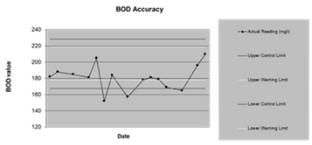
- **CCV**
  - Standard Methods 1020.B.11.c
  - Analysts periodically use a calibration standard to confirm that the instrument performance has not changed significantly since initial calibration.
  - Verify calibration by analyzing one standard at a concentration near or at the mid-point of the calibration range.
  - Verify the calibration (especially if preset by manufacturer) at beginning of day, after every 10 readings and at the end of the batch
  - **Daily**

Control Charts

- Accuracy Control Charts
- Standard Methods 1020 B.13.a
  - The accuracy chart for QC samples (e.g., reagent blanks, LFBs, calibration check standards and LFMs) is constructed from the average and standard deviation of measurements.
  - The accuracy chart includes upper and lower warning levels (WL) and upper and lower control levels (CL).
  - Common practice is to use ±2*s* and ±3*s* limits for the WL and CL, respectively, where *s* represents standard deviation.
- Precision Control Charts
- Standard Methods 1020 B.13.b
  - The precision chart also is constructed on the average and standard deviation of a specified number of measurements (e.g., %RSD [relative standard deviation] or RPD) for a replicate or duplicate analyses of the analyte of interest.

Control Charts

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



Corrective Action

- Standard Methods 1020 B.15
  - QC data that are outside the acceptance limits or exhibit a trend are evidence of unacceptable error in the analytical process.
  - Take corrective action promptly to determine and eliminate the source of error.
  - Do not report data until the cause of the problem is identified and either corrected or qualified (see Table 1020:II)
- The corrective action plan needs to be in your SOP for each method on what to do if your QC tests fail or are out of range
- If you have a "boo boo", write down how you fixed it
- Any issues should be recorded and a sentence on how it can be prevented, if possible, in the future
- Common problems and their corrections should be covered in your Standard Operating Procedures (SOP)
  - If you see things frequently, you can give them qualifiers that are noted in your SOP
  - Ex: B = blanks failed, R = rain event

QC Acceptance

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

Batch Size & QC Frequency

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

Any questions?

Section 9

NPDES Excerpt

STATE OF TENNESSEE

NPDES PERMIT

No. «PERMIT_NUMBER»

Authorization to discharge under the
National Pollutant Discharge Elimination System (NPDES)

Issued By

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

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

Discharger:	**«Permittee_Name»** **«Project_Name»**
is authorized to discharge:	**«EFFLUENT_DESCRIPTION»**
from a facility located:	**in «Site_City», «County» County, Tennessee**
to receiving waters named:	**«RECEIVING_STREAM»**

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

This permit shall become effective on:

This permit shall expire on:

Issuance date:

____
for Jennifer Dodd
Director

CN-0759 RDA 2366

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«Staff_Initials»
«PERMIT_NUMBER».DOC

1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

The City of «Site_City» is authorized to discharge «EFFLUENT_DESCRIPTION» to the «RECEIVING_STREAM». Discharge 001 consists of municipal wastewater from a treatment facility with a design capacity of «Flow_Rate» MGD. Discharge 001 shall be limited and monitored by the permittee as specified below:

Notes: The permittee shall achieve % removal of $CBOD_5$ and TSS on a monthly average basis. The permittee shall report all instances of releases, overflows and/or bypasses. See Part 2.3.3.a for the definition of overflow and Part 1.3.5.1 for reporting requirements.

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

See Part 1.2.3 for test procedures.

See Part 3.4 for biomonitoring test and reporting requirements. See next page for percent removal calculations.

Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR, Part 136 as amended. The method detection level (MDL) for TRC shall not exceed 0.05 mg/l unless the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the higher MDL and have it available for review upon request. In cases where the permit limit is less that the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

Monitoring and reporting requirements for both total nitrogen (TN) and total phosphorus (TP) begin the effective date of the permit. The annual rolling load (lb/year) is calculated and reported monthly using the data from the current month and previous 11 months. Each annual load is the grand total of the average pounds per day for 12 months multiplied by 365 days.

Each daily load is calculated by multiplying the day's sample concentration (mg/l) by the effluent flow rate (MGD) for the day of the sample was collected by 8.34.

$$Load = \binom{Effluent}{Concentration} \; x \; \binom{Effluent\ flow\ for\ the\ day\ the}{day\ the\ sample\ was\ collected} \; x \; (8.34)$$

The average pound per day is the mathematical average where the sum of all the calculated loads during the current month and previous 11 months is divided by the number of calculated loads. Each load is calculated using the day's sample concentration (mg/l) and the effluent flow rate for the day the sample was collected.

$$Average\ Pounds\ per\ Day = \left(\frac{\begin{array}{c} Sum\ of\ All\ Loads\ in\ \frac{lbs}{day}\ During\ the \\ Current\ Month\ and\ the\ Previous\ 11\ Months \end{array}}{\begin{array}{c} Total\ Number\ of\ Loads\ \ Calculated\ During \\ the\ Current\ Month\ and\ Previous\ 11\ Months \end{array}} \right)$$

The annual rolling load for the current month is calculated by multiplying the average of all sample loads for the current month and the previous 11 months by 365.

$$Annual\ Rolling\ Load = \left(\frac{Sum\ of\ All\ Loads\ in\ \frac{lbs}{day}\ During\ the\ Current\ Month\ and\ Previous\ 11\ Months}{Total\ Number\ of\ Loads\ \ Calculated\ During\ the\ Current\ Month\ and\ Previous\ 11\ Months} \right) x\ (365)$$

(Copy and paste Narrative Conditions for this Permit from the ICIS Limit Sets in WL here. Include all narrative conditions with a due date that require tracking by DWR during the permit term. This includes dates that are a function of the final permit effective date.)

The wastewater discharge must be disinfected to the extent that viable coliform organisms are effectively eliminated. The concentration of the *E. coli* group after disinfection shall not exceed 126 cfu per 100 ml as the geometric mean calculated on the actual number of samples collected and tested for *E. coli* within the required reporting period. The permittee may collect more samples than specified as the monitoring frequency. Samples may not be collected at intervals of less than 12 hours. For the purpose of determining the geometric mean, individual samples having an *E. coli* group concentration of less than one (1) per 100 ml shall be considered as having a concentration of one (1) per 100 ml. In addition, the concentration of the *E. coli* group in any individual sample shall not exceed a specified maximum amount. A maximum daily limit of 487 colonies per 100 ml applies to lakes and exceptional Tennessee waters. A maximum daily limit of 941 colonies per 100 ml applies to all other recreational waters.

There shall be no distinctly visible floating scum, oil or other matter contained in the wastewater discharge. The wastewater discharge must not cause an objectionable color contrast in the receiving stream.

The wastewater discharge shall not contain pollutants in quantities that will be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream.

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

Nothing in this permit authorizes take for the purposes of a facility's compliance with the Endangered Species Act. (40 C.F.R. 125.98(b)(1)).

For the purpose of evaluating compliance with the permit limits established herein, where certain limits are below the State of Tennessee published required detection levels (RDLs) for any given effluent characteristics, the results of analyses below the RDL shall be reported as Below Detection Level (BDL), unless in specific cases other detection limits are demonstrated to be the best achievable because of the particular nature of the wastewater being analyzed.

For CBOD$_5$ and TSS, the treatment facility shall demonstrate a minimum of % removal efficiency on a monthly average basis. This is calculated by determining an average of all daily influent concentrations and comparing this to an average of all daily effluent concentrations. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{average of daily effluent concentration}}{\text{average of daily influent concentration}} \right] \times 100\% \quad = \%\ \text{removal}$$

The treatment facility will also demonstrate % minimum removal of the CBOD$_5$ and TSS based upon each daily composite sample. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{daily effluent concentration}}{\text{daily influent concentration}} \right] \times 100\% \quad = \%\ \text{removal}$$

1.2. MONITORING PROCEDURES

1.2.1. Representative Sampling

Samples and measurements taken in compliance with the monitoring requirements specified herein shall be representative of the volume and nature of the monitored discharge, and shall be taken after treatment and prior to mixing with uncontaminated storm water runoff or the receiving stream. Appropriate flow measurement devices and methods consistent with accepted scientific practices shall be selected and used to insure the accuracy and reliability of measurements of the volume of monitored discharges. The devices shall be installed, calibrated and maintained to insure that the accuracy of the measurements is consistent with accepted capability of that type of device. Devices selected shall be capable of measuring flows with a maximum deviation of less than plus or minus 10% from the true discharge rates throughout the range of expected discharge volumes.

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

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

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

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

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

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

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

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

1.2.2. Sampling Frequency

Where the permit requires sampling and monitoring of a particular effluent characteristic(s) at a frequency of less than once per day or daily, the permittee is precluded from marking the “No Discharge” block on the Discharge Monitoring Report if there has been any discharge from that particular outfall during the period which coincides with the required monitoring frequency; i.e. if the required monitoring frequency is once per month or 1/month, the monitoring period is one month, and if the discharge occurs during only one day in that period then the permittee must sample on that day and report the results of analyses accordingly.

1.2.3. Test Procedures

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

b. Unless otherwise noted in the permit, all pollutant parameters shall be determined according to methods prescribed in Title 40, CFR, Part 136, as amended, promulgated pursuant to Section 304 (h) of the Act.

c. Composite samples must be proportioned by flow at time of sampling. Aliquots may be collected manually or automatically. The sample aliquots must be maintained at ≤ 6 degrees Celsius during the compositing period.

d. In instances where permit limits established through implementation of applicable water criteria are below analytical capabilities, compliance with those limits will be determined using the detection limits described in the TN Rules, Chapter 0400-40-03-.05(8).

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

1.2.4. Recording of Results

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

a. The exact place, date and time of sampling or measurements;

b. The exact person(s) collecting samples or measurements;

c. The dates and times the analyses were performed;

d. The person(s) or laboratory who performed the analyses;

e. The analytical techniques or methods used, and;

f. The results of all required analyses.

1.2.5. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation shall be retained for a minimum of three (3) years, or longer, if requested by the Division of Water Resources.

1.3. REPORTING

1.3.1. Monitoring Results

Monitoring results shall be recorded monthly and submitted monthly using NetDMR. Submittals shall be no later than 15 days after the completion of the reporting period. If NetDMR is not functioning, a completed DMR with an original signature shall be submitted to the following address:

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

Nashville, Tennessee 37243-1102

If NetDMR is not functioning, a copy of the completed and signed DMR shall be mailed to the «EFO_Name» Environmental Field Office (EFO) at the following address:

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER RESOURCES
«Efo_Full_Name»
«Efo_Address»
«Efo_City», Tennessee «Efo_Zip»

In addition, any communication regarding compliance with the conditions of this permit must be sent to the two offices listed above.

The first DMR is due on the 15th of the month following permit effectiveness.

DMRs and any other information or report must be signed and certified by a responsible corporate officer as defined in 40 CFR 122.22, a general partner or proprietor, or a principal municipal executive officer or ranking elected official, or his duly authorized representative. Such authorization must be submitted in writing and must explain the duties and responsibilities of the authorized representative.

For purposes of determining compliance with this permit, data provided to the division electronically is legally equivalent to data submitted on signed and certified DMR forms.

1.3.2. Additional Monitoring by Permittee

If the permittee monitors any pollutant more frequently than required at the location(s) designated, using approved analytical methods as specified herein, the results of such monitoring shall be included in the calculation and reporting of the values required in the DMR form. Such increased frequency shall also be indicated on the form.

1.3.3. Falsifying Results and/or Reports

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

1.3.4. Monthly Report of Operation

Monthly operational reports shall be submitted on standard forms to the appropriate Division of Water Resources Environmental Field Office in Jackson, Nashville, Chattanooga, Columbia, Cookeville, Memphis, Johnson City, or Knoxville. Reports shall be submitted by the 15th day of the month following data collection.

1.3.5. Bypass, Release and Overflow Reporting

1.3.5.1. Report Requirements

A summary report of known instances of sanitary sewer overflows, releases, and bypasses shall accompany the Discharge Monitoring Report (DMR). The report must contain the date(s), estimated duration in hours, estimated quantity of wastewater in gallons, and if applicable, the receiving stream for each instance of sanitary sewer overflow, release, or bypass. For each sanitary sewer overflow and release, the report shall identify (using the permittee's naming conventions) the next downstream pump station. For each sanitary sewer overflow, the report shall also identify whether it was a dry weather overflow.

The report must also detail activities undertaken during the reporting period to correct the reported sanitary sewer overflows and releases.

On the DMR, the permittee must separately report: the total number of sanitary sewer overflows for the reporting month and the cumulative total for the previous 12 months; the total number of dry-weather overflows for the reporting month and the cumulative total for the previous 12 months; the total number of releases for the reporting month; and the total number of bypasses for the reporting month. On the DMR, sanitary sewer overflows are coded "SSO, Dry Weather and SSO, Wet Weather" and releases are coded "Release [Sewer], Dry Weather and Release [Sewer], Wet Weather." Estimated total monthly volume for each type of event will be reported as gallons per month. Each release due to improper operation or maintenance shall be reported as such. Each discrete location of a sanitary sewer overflow or a release shall be reported as a separate value.

1.3.5.2. Anticipated Bypass Notification

If, because of unavoidable maintenance or construction, the permittee has need to create an in-plant bypass which would cause an effluent violation, the permittee must notify the division as soon as possible, but in any case, no later than 10 days prior to the date of the bypass.

1.3.6. Reporting Less Than Detection; Reporting Significant Figures

A permit limit may be less than the accepted detection level. If the samples are below the detection level, then report "BDL" or "NODI =B" on the DMRs. The permittee must use the correct detection levels in all analytical testing required in the permit. The required detection levels are listed in the Rules of the Department of

Environment and Conservation, Division of Water Resources, Chapter 0400-40-03-.05(8).

For example, if the limit is 0.02 mg/l with a detection level of 0.05 mg/l and detection is shown; 0.05 mg/l must be reported. In contrast, if nothing is detected reporting “BDL” or “NODI =B” is acceptable.

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

1.4. COMPLIANCE WITH SECTION 208

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

1.5. REOPENER CLAUSE

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

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

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

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

1.6. SCHEDULE OF COMPLIANCE

Full compliance and operational levels shall be attained from the effective date of this permit.

2.0. GENERAL PERMIT REQUIREMENTS

2.1. GENERAL PROVISIONS

2.1.1. Duty to Reapply

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

2.1.2. Right of Entry

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

a. To enter upon the permittee's premises where an effluent source is located or where records are required to be kept under the terms and conditions of this permit, and at reasonable times to copy these records;

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

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

2.1.3. Availability of Reports

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

2.1.4. Proper Operation and Maintenance

a. The permittee shall at all times properly operate and maintain all facilities and systems (and related appurtenances) for collection and treatment which are installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance also includes adequate laboratory and process controls and appropriate quality assurance procedures. This provision requires the operation of backup or auxiliary facilities or similar systems, which are installed by a permittee only when the operation is necessary to achieve compliance with the conditions of the permit. Backup continuous pH and flow monitoring equipment are not required.

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

2.1.5. Treatment Facility Failure (Industrial Sources)

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

2.1.6. Property Rights

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

2.1.7. Severability

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

2.1.8. Other Information

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

2.2. CHANGES AFFECTING THE PERMIT

2.2.1. Planned Changes

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

a. The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source in 40 CFR 122.29(b); or

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

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

2.2.2. Permit Modification, Revocation, or Termination

a. This permit may be modified, revoked and reissued, or terminated for cause as described in 40 CFR 122.62 and 122.64, Federal Register, Volume 49, No. 188 (Wednesday, September 26, 1984), as amended.

b. The permittee shall furnish to the director, within a reasonable time, any information which the director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the director, upon request, copies of records required to be kept by this permit.

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

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

2.2.3. Change of Ownership

This permit may be transferred to another party (provided there are neither modifications to the facility or its operations, nor any other changes which might affect the permit limits and conditions contained in the permit) by the permittee if:

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

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

c. The director, within 30 days, does not notify the current permittee and the new permittee of his intent to modify, revoke or reissue, or terminate the permit and to require that a new application be filed rather than agreeing to the transfer of the permit.

Pursuant to the requirements of 40 CFR 122.61, concerning transfer of ownership, the permittee must provide the following information to the division in their formal notice of intent to transfer ownership: 1) the NPDES permit number of the subject permit; 2) the effective date of the proposed transfer; 3) the name and address of the transferor; 4) the name and address of the transferee; 5) the names of the responsible parties for both the transferor and transferee; 6) a statement that the transferee assumes responsibility for the subject NPDES permit; 7) a statement that the transferor relinquishes responsibility for the subject NPDES permit; 8) the signatures of the responsible parties for both the transferor and transferee pursuant to the requirements of 40 CFR 122.22(a), “Signatories to permit applications”; and, 9) a statement regarding any proposed modifications to the facility, its operations, or any other changes which might affect the permit limits and conditions contained in the permit.

2.2.4. Change of Mailing Address

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

2.3. NONCOMPLIANCE

2.3.1. Effect of Noncompliance

The permittee shall comply with all conditions of this permit. Any permit noncompliance constitutes a violation of applicable state and federal laws and is grounds for enforcement action, permit termination, permit modification, or denial of permit reissuance.

2.3.2. Reporting of Noncompliance

a. 24-Hour Reporting

In the case of any noncompliance which could cause a threat to public drinking supplies, or any other discharge which could constitute a threat to human health or the environment, the required notice of non-compliance shall be provided to the Division of Water Resources in the appropriate Environmental Field Office within 24-hours from the time the permittee becomes aware of the circumstances. (The Environmental Field Office should be contacted for names and phone numbers of environmental response team).

A written submission must be provided within five days of the time the permittee becomes aware of the circumstances unless the director on a case-by-case basis waives this requirement. The permittee shall provide the director with the following information:

i. A description of the discharge and cause of noncompliance;

ii. The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue; and

iii. The steps being taken to reduce, eliminate, and prevent recurrence of the noncomplying discharge.

b. Scheduled Reporting

For instances of noncompliance which do not cause a threat to public drinking supplies, or any other discharge which could constitute a threat to human health or the environment,, the permittee shall report the noncompliance on the Discharge Monitoring Report. The report shall contain all information concerning the steps taken, or planned, to reduce, eliminate, and prevent recurrence of the violation and the anticipated time the violation is expected to continue.

2.3.3. Overflow

a. Sanitary sewer overflows, including dry-weather overflows, are prohibited.

b. The permittee shall operate the collection system so as to avoid sanitary sewer overflows and releases due to improper operation or maintenance. A “release” may be due to improper operation or maintenance of the collection system or may be due to other cause(s). Releases caused by improper operation or maintenance of the permittee’s collection and transmission system are prohibited.

c. The permittee shall take all reasonable steps to minimize any adverse impact associated with overflows and releases.

d. No new or additional flows shall be added upstream of any point in the collection or transmission system that experiences greater than 5 sanitary sewer overflows and/or releases per year[1] or would otherwise overload any portion of the system. Unless there is specific enforcement action to the contrary, the permittee is relieved of this requirement after: 1) an authorized representative of the Commissioner of the Department of Environment and Conservation has approved an engineering report and construction plans and specifications prepared in accordance with accepted engineering practices for correction of the problem; 2) the correction work is underway; and 3) the cumulative, peak-design, flows potentially added from new connections and line extensions upstream of any chronic overflow or release point are less than or proportional to the amount

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[1] This includes dry weather overflows, wet weather overflows, dry weather releases and wet weather releases.

of inflow and infiltration removal documented upstream of that point. The inflow and infiltration reduction must be measured by the permittee using practices that are customary in the environmental engineering field and reported in an attachment to a Monthly Operating Report submitted to the local TDEC Environmental Field Office. The data measurement period shall be sufficient to account for seasonal rainfall patterns and seasonal groundwater table elevations.

e. In the event that chronic sanitary sewer overflows or releases have occurred from a single point in the collection system for reasons that may not warrant the self-imposed moratorium of the actions identified in this paragraph, the permittee may request a meeting with the Division of Water Resources EFO staff to petition for a waiver based on mitigating evidence.

2.3.4. Upset

a. "***Upset***" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

b. An upset shall constitute an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitations if the permittee demonstrates, through properly signed, contemporaneous operating logs, or other relevant evidence that:

   i. An upset occurred and that the permittee can identify the cause(s) of the upset;

   ii. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures;

   iii. The permittee submitted information required under "Reporting of Noncompliance" within 24-hours of becoming aware of the upset (if this information is provided orally, a written submission must be provided within five days); and

   iv. The permittee complied with any remedial measures required under "Adverse Impact."

2.3.5. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the waters of Tennessee resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge. It shall not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

2.3.6. Bypass

a. "***Bypass***" is the intentional diversion of waste streams from any portion of a treatment facility. "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which would cause them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

b. Bypasses are prohibited unless all of the following 3 conditions are met:

   i. The bypass is unavoidable to prevent loss of life, personal injury, or severe property damage;

   ii. There are no feasible alternatives to bypass, such as the construction and use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass, which occurred during normal periods of equipment downtime or preventative maintenance;

   iii. The permittee submits notice of an unanticipated bypass to the Division of Water Resources in the appropriate Environmental Field Office within 24 hours of becoming aware of the bypass (if this information is provided orally, a written submission must be provided within five days). When the need for the bypass is foreseeable, prior notification shall be submitted to the director, if possible, at least 10 days before the date of the bypass.

c. Bypasses not exceeding permit limitations are allowed **only** if the bypass is necessary for essential maintenance to assure efficient operation. All other bypasses are prohibited. Allowable bypasses not exceeding limitations are not subject to the reporting requirements of 2.3.6.b.iii, above.

2.3.7. Washout

a. For domestic wastewater plants only, a "washout" shall be defined as loss of Mixed Liquor Suspended Solids (MLSS) of 30.00% or more. This refers to the MLSS in the aeration basin(s) only. This does not include MLSS decrease due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to infiltration and inflow.

b. A washout is prohibited. If a washout occurs the permittee must report the incident to the Division of Water Resources in the appropriate Environmental Field Office within 24 hours by telephone. A written submission must be provided within five days. The washout must be noted on the discharge monitoring report. Each day of a washout is a separate violation.

2.4. LIABILITIES

2.4.1. Civil and Criminal Liability

Except as provided in permit conditions for "***Bypassing*,**" "***Overflow,***" and "***Upset*,**" nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance. Notwithstanding this permit, the permittee shall remain liable for any damages sustained by the State of Tennessee, including but not limited to fish kills and losses of aquatic life and/or wildlife, as a result of the discharge of wastewater to any surface or subsurface waters. Additionally, notwithstanding this Permit, it shall be the responsibility of the permittee to conduct its wastewater treatment and/or discharge activities in a manner such that public or private nuisances or health hazards will not be created.

2.4.2. Liability Under State Law

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or the Federal Water Pollution Control Act, as amended.

Division of Solid Waste Management			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	1301 Riverfront Parkway, Suite 206	37402	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 520-6688
Columbia	1421 Hampshire Pike	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37216	(615) 687-7000

Keep this paragraph if sludge disposal is to a municipal solid waste landfill: The current method of sludge disposal is to a municipal solid waste landfill (or co - composting facility). This method of disposal is controlled by the rules of the Tennessee Division of Solid Waste Management (DSWM) and Federal Regulations at 40 CFR 258. If the permittee anticipates changing its disposal practices to either land application or surface disposal, the Division of Water Resources shall be notified prior to the change. A copy of the results of pollutant analyses required by the Tennessee Division of Solid Waste Management (DSWM) and / or 40 CFR 258 shall be submitted to the Division of Water Resources.

3.4. BIOMONITORING REQUIREMENTS, CHRONIC

The permittee shall conduct a 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test and a 7-Day Fathead Minnow *(Pimephales promelas)* Larval Survival and Growth Test on samples of final effluent from Outfall 001.

The measured endpoint for toxicity will be the inhibition concentration causing 25% reduction in survival, reproduction and growth (IC_{25}) of the test organisms. The IC_{25} shall be determined based on a 25% reduction as compared to the controls, and as derived from linear interpolation. The average reproduction and growth responses will be determined based on the number of *Ceriodaphnia dubia* or *Pimephales promelas* larvae used to initiate the test.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

<u>If the permit limit is above 25%, but below 90%, use this table:</u>
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

<u>If the permit limit is at or below 25%, use this table:</u>
<u>(enter the permit limit in the appropriate field, highlight the entire row, press F9)</u>

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in <u>Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms</u>, EPA-821-R-02-013 (or the most current edition). A chronic standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the IC_{25} is less than or equal to the permit limit indicated for each outfall in the above table(s).

All tests will be conducted using a minimum of three 24-hour flow-proportionate composite samples of final effluent collected on days 1, 3 and 5. If, in any control more than 20% of the test organisms die in 7 days, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013 (or the most current edition), or if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

CHOOSE 1 OF THE 2 PARAGRAPHS BELOW. USE PARAGRAPH (1) WHEN DILUTION RATIO IS GREATER THAN 500 TO 1:

(1)

The toxicity tests specified herein shall be conducted yearly (1/yr) for Outfall 001 and begin no later than 90 days from the effective date of this permit. Monitoring frequency will be 1/quarter when a non-categorical Significant Industrial User (SIU) or a Categorical Industrial User (CIU) discharges to the treatment works.

(2)

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. **The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.**

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. **During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months.** Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. **During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.**

Test procedures, quality assurance practices, determinations of effluent survival/reproduction and survival/growth values, and report formats will be made in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analyses shall be compiled in a report. The report will be written in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Resources office address (see table below):

Division of Water Resources			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	1301 Riverfront Pkwy., Suite 206	37402	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 520-6688
Columbia	1421 Hampshire Pike	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37216	(615) 687-7000

3.5. BIOMONITORING REQUIREMENTS, ACUTE

The permittee shall conduct a 48-hour static acute toxicity test on two test species on samples of final effluent from Outfall 001. The test species to be used are Water Fleas (Ceriodaphnia dubia) and Fathead Minnows (Pimephales promelas).

The measured endpoint for toxicity will be the concentration causing 50% lethality (LC_{50}) of the test organisms. The LC_{50} shall be determined based on a 50% lethality as compared to the controls, and as derived from linear interpolation.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

If the permit limit is above 25%, but below 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

If the permit limit is at or below 25%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition). An acute standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the LC_{50} is less than or equal to the permit limit indicated for each outfall in the above table(s).

All tests will be conducted using four separate grab samples of final effluent, to be used in four separate tests, and shall be collected at evenly spaced (6-hour) intervals over a 24-hour period. If in any control, more than 10% of the test organisms die in 48 hours, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition), if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months. Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.

Test procedures, quality assurance practices and determination of effluent lethality values will be made in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analysis shall be compiled in a report. The report shall be written in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Resources office address (see table below):

Division of Water Resources			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	1301 Riverfront Pkwy., Suite 206	37402	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 520-6688
Columbia	1421 Hampshire Pike	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37216	(615) 687-7000

4.0. DEFINITIONS AND ACRONYMS

4.1. DEFINITIONS

“***Biosolids***” are treated sewage sludge that have contaminant concentrations less than or equal to the contaminant concentrations listed in Table 1 of subparagraph (3)(b) of Rule 0400-40-15-.02, meet any one of the ten vector attraction reduction options listed in part (4)(b)1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 of Rule 0400-40-15-.04, and meet either one of the six pathogen reduction alternatives for Class A listed in part (3)(a)3, 4, 5, 6, 7, or 8, or one of the three pathogen reduction alternatives for Class B listed in part (3)(b)2, 3, or 4 of Rule 0400- 40-15-.04.

A "***bypass***" is defined as the intentional diversion of waste streams from any portion of a treatment facility.

A “***calendar day***” is defined as the 24-hour period from midnight to midnight or any other 24-hour period that reasonably approximates the midnight to midnight time period.

A "***composite sample***" is a combination of not less than 8 influent or effluent portions, of at least 100 ml, collected over a 24-hour period. Under certain circumstances a lesser time period may be allowed, but in no case, less than 8 hours.

The "***daily maximum concentration***" is a limitation on the average concentration in units of mass per volume (e.g. milligrams per liter), of the discharge during any calendar day. When a proportional-to-flow composite sampling device is used, the daily concentration is the concentration of that 24-hour composite; when other sampling means are used, the daily concentration is the arithmetic mean of the concentrations of equal volume samples collected during any calendar day or sampling period.

“***Discharge***” or “discharge of a pollutant” refers to the addition of pollutants to waters from a source.

A “***dry weather overflow***” is a type of sanitary sewer overflow and is defined as one day or any portion of a day in which unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall occurs and is not directly related to a rainfall event. Discharges from more than one point within a 24-hour period shall be counted as separate overflows.

“Degradation” means the alteration of the properties of waters by the addition of pollutants, withdrawal of water, or removal of habitat, except those alterations of a short duration, withdrawal of water, or removal of habitat, except those alterations of a short duration.

“***De Minimis***” - Degradation of a small magnitude, as provided in this paragraph.

(a) Discharges and withdrawals

1. Subject to the limitation in part 3 of this subparagraph, a single discharge other than those from new domestic wastewater sources will be considered de minimis if it uses less than five percent of the available assimilative capacity for the substance being discharged.
2. Subject to the limitation in part 3 of this subparagraph, a single water withdrawal will be considered de minimis if it removes less than five percent of the 7Q10 flow of the stream.
3. If more than one activity described in part 1 or 2 of this subparagraph has been authorized in a segment and the total of the authorized and proposed impacts uses no more than 10% of the assimilative capacity, or 7Q10 low flow, they are presumed to be de minimis. Where the total of the authorized and proposed impacts uses 10% of the assimilative capacity, or 7Q10 low flow, additional degradation may only be treated as de minimis if the Division finds on a scientific basis that the additional degradation has an insignificant effect on the resource.

(b) Habitat alterations authorized by an Aquatic Resource Alteration Permit (ARAP) are de minimis if the Division finds that the impacts, individually and cumulatively are offset by impact minimization and/or in-system mitigation, provided however, in ONRWs the mitigation must occur within the ONRW.

An “***ecoregion***” is a relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

The "***geometric mean***" of any set of values is the n^{th} root of the product of the individual values where “n” is equal to the number of individual values. The geometric mean is equivalent to the antilog of the arithmetic mean of the logarithms of the individual values. For the purposes of calculating the geometric mean, values of zero (0) shall be considered to be one (1).

A "***grab sample***" is a single influent or effluent sample collected at a particular time.

The "***instantaneous maximum concentration***" is a limitation on the concentration, in milligrams per liter, of any pollutant contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The "***instantaneous minimum concentration***" is the minimum allowable concentration, in milligrams per liter, of a pollutant parameter contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The "***monthly average amount***", is the arithmetic mean of all the measured daily discharges by weight during the calendar month when the measurements were made.

The "***monthly average concentration***", other than for *E. coli* bacteria, is the arithmetic mean of all the composite or grab samples collected in a one-calendar month period.

A "***one week period***" (or "***calendar-week***") is defined as the period from Sunday through Saturday. For reporting purposes, a calendar week that contains a change of month shall be considered part of the latter month.

"***Pollutant***" means sewage, industrial wastes, or other wastes.

A "***quarter***" is defined as any one of the following three-month periods: January 1 through March 31, April 1 through June 30, July 1 through September 30, and/or October 1 through December 31.

A "***rainfall event***" is defined as any occurrence of rain, preceded by 10 hours without precipitation that results in an accumulation of 0.01 inches or more. Instances of rainfall occurring within 10 hours of each other will be considered a single rainfall event.

A "***rationale***" (or "fact sheet") is a document that is prepared when drafting an NPDES permit or permit action. It provides the technical, regulatory and administrative basis for an agency's permit decision.

A "***reference site***" means least impacted waters within an ecoregion that have been monitored to establish a baseline to which alterations of other waters can be compared.

A "***reference condition***" is a parameter-specific set of data from regional reference sites that establish the statistical range of values for that particular substance at least-impacted streams.

A "***release***" is the flow of sewage from any portion of the collection or transmission system owned or operated by the permittee other than through permitted outfalls that does not add pollutants to waters. In addition, a "release" includes a backup into a building or private property that is caused by blockages, flow conditions, or other malfunctions originating in the collection and transmission system owned or operated by the permittee. A "release" does not include backups into a building or private property caused by blockages or other malfunctions originating in a private lateral.

A **"*sanitary sewer overflow (SSO*)"** is defined as an unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall.

"***Sewage***" means water-carried waste or discharges from human beings or animals, from residences, public or private buildings, or industrial establishments, or boats, together with such other wastes and ground, surface, storm, or other water as may be present.

“***Severe property damage***” when used to consider the allowance of a bypass or SSO means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass or SSO. Severe property damage does not mean economic loss caused by delays in production.

“***Sewerage system***” means the conduits, sewers, and all devices and appurtenances by means of which sewage and other waste is collected, pumped, treated, or disposed.

“***Sludge***” or “***sewage sludge***” is solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

A “***subecoregion***” is a smaller, more homogenous area that has been delineated within an ecoregion.

“***Upset***” means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

The term, “***washout***” is applicable to activated sludge plants and is defined as loss of mixed liquor suspended solids (MLSS) of 30.00% or more from the aeration basin(s).

“***Waters***” means any and all water, public or private, on or beneath the surface of the ground, which are contained within, flow through, or border upon Tennessee or any portion thereof except those bodies of water confined to and retained within the limits of private property in single ownership which do not combine or effect a junction with natural surface or underground waters.

The "***weekly average amount***", shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar week when the measurements were made.

The "***weekly average concentration***", is the arithmetic mean of all the composite samples collected in a one-week period. The permittee must report the highest weekly average in the one-month period.

4.2. ACRONYMNS AND ABBREVIATIONS

1Q10 – 1-day minimum, 10-year recurrence interval

30Q5 – 30-day minimum, 5-year recurrence interval

7Q10 – 7-day minimum, 10-year recurrence interval

BAT – best available technology economically achievable

BCT – best conventional pollutant control technology

BDL – below detection level

BOD_5 – five day biochemical oxygen demand

BPT – best practicable control technology currently available

$CBOD_5$ – five day carbonaceous biochemical oxygen demand

CEI – compliance evaluation inspection

CFR – code of federal regulations

CFS – cubic feet per second

CFU – colony forming units

CIU – categorical industrial user

CSO – combined sewer overflow

DMR – discharge monitoring report

D.O. – dissolved oxygen

E. coli – Escherichia coli

EFO – environmental field office

LB(lb) - pound

IC_{25} – inhibition concentration causing 25% reduction in survival, reproduction and growth of the test organisms

IU – industrial user

IWS – industrial waste survey

LC_{50} – acute test causing 50% lethality

MDL – method detection level

MGD – million gallons per day

MG/L(mg/l) – milligrams per liter

ML – minimum level of quantification

ml – milliliter

MLSS – mixed liquor suspended solids

MOR – monthly operating report

NODI – no discharge

NPDES – national pollutant discharge elimination system

PL – permit limit

POTW – publicly owned treatment works

RDL – required detection limit

SAR – semi-annual [pretreatment program] report

SIU – significant industrial user

SSO – sanitary sewer overflow

STP – sewage treatment plant

TCA – Tennessee code annotated

TDEC – Tennessee Department of Environment and Conservation

TIE/TRE – toxicity identification evaluation/toxicity reduction evaluation

TMDL – total maximum daily load

TRC – total residual chlorine

TSS – total suspended solids

WQBEL – water quality based effluent limit

Section 10

40 CFR 136 Excerpt

Note: This is not the complete 40 CFR 136. This packet only contains certain segment and is intended for educational purposes only.

Title 40 - Protection of Environment
Chapter I - Environmental Protection Agency
Subchapter D - Water Programs
Part 136 - Guidelines Establishing Test Procedures for the Analysis of Pollutants

§ 136.3 Identification of test procedures.

(a) Parameters or pollutants, for which methods are approved, are listed together with test procedure descriptions and references in Tables IA, IB, IC, ID, IE, IF, IG, and IH of this section. The methods listed in Tables IA, IB, IC, ID, IE, IF, IG, and IH are incorporated by reference, see paragraph (b) of this section, with the exception of EPA Methods 200.7, 601-613, 624.1, 625.1, 1613, 1624, and 1625. The full texts of Methods 601-613, 624.1, 625.1, 1613, 1624, and 1625 are printed in appendix A of this part, and the full text of Method 200.7 is printed in appendix C of this part. The full text for determining the method detection limit when using the test procedures is given in appendix B of this part. In the event of a conflict between the reporting requirements of 40 CFR parts 122 and 125 and any reporting requirements associated with the methods listed in these tables, the provisions of 40 CFR parts 122 and 125 are controlling and will determine a permittee's reporting requirements. The full texts of the referenced test procedures are incorporated by reference into Tables IA, IB, IC, ID, IE, IF, IG, and IH. The date after the method number indicates the latest editorial change of the method. The discharge parameter values for which reports are required must be determined by one of the standard analytical test procedures incorporated by reference and described in Tables IA, IB, IC, ID, IE, IF, IG, and IH or by any alternate test procedure which has been approved by the Administrator under the provisions of paragraph (d) of this section and §§ 136.4 and 136.5. Under certain circumstances (paragraph (c) of this section, § 136.5(a) through (d) or 40 CFR 401.13,) other additional or alternate test procedures may be used.

Table IA - List of Approved Biological Methods for Wastewater and Sewage Sludge

Parameter and units	Method[1]	EPA	Standard methods	AOAC, ASTM, USGS	Other
			Bacteria		
1. Coliform (fecal), number per 100 mL or number per gram dry weight	Most Probable Number (MPN), 5 tube, 3 dilution, or	p. 132,[3] 1680,[11][15] 1681[11][20]	9221 E-2014		
	Membrane filter (MF)[2][5], single step	p. 124[3]	9222 D-2015[29]	B-0050-85[4]	
2. Coliform (fecal), number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 132[3]	9221 E-2014; 9221 F-2014[33]		
	Multiple tube/multiple well, or				Colilert-18®.[13][18][28]
	MF[2][5], single step[5]	p. 124[3]	9222 D-2015[29]		
3. Coliform (total), number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221 B-2014		
	MF[2][5], single step or two step	p. 108[3]	9222 B-2015[30]	B-0025-85[4]	

Parameter and units	Method[1]	EPA	Standard methods	AOAC, ASTM, USGS	Other
	MF[2,5], with enrichment	p. 111[3]	9222 B-2015[30]		
4. *E. coli,* number per 100 mL	MPN[6,8,16] multiple tube, or		9221 B2014/9221 F-2014[12,14,33]		
	multiple tube/multiple well, or		9223 B-2016[13]	991.15[10]	Colilert®[13,18] Colilert-18®[13,17,18]
	MF[2,5,6,7,8], two step, or		9222 B-2015/9222 I-2015[31]		
	Single step	1603[21]			m-ColiBlue24®.[19]
5. Fecal streptococci, number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 139[3]	9230 B-2013		
	MF[2], or	p. 136[3]	9230 C-2013[32]	B-0055-85[4]	
	Plate count	p. 143[3]			
6. Enterococci, number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 139[3]	9230 B-2013		
	MPN[6,8], multiple tube/multiple well, or		9230 D-2013	D6503-99[9]	Enterolert®.[13,23]
	MF[2,5,6,7,8] single step or	1600[24]	9230 C-2013[32]		
	Plate count	p. 143[3]			
7. *Salmonella,* number per gram dry weight[11]	MPN multiple tube	1682[22]			
Aquatic Toxicity					
8. Toxicity, acute, fresh water organisms, LC_{50}, percent effluent	Water flea, Cladoceran, *Ceriodaphnia dubia* acute	2002.0[25]			
	Water fleas, Cladocerans, *Daphnia pulex* and *Daphnia magna* acute	2021.0[25]			

Parameter and units	Method[1]	EPA	Standard methods	AOAC, ASTM, USGS	Other
	Fish, Fathead minnow, *Pimephales promelas,* and Bannerfin shiner, *Cyprinella leedsi,* acute	2000.0 [25]			
	Fish, Rainbow trout, *Oncorhynchus mykiss,* and brook trout, *Salvelinus fontinalis,* acute	2019.0 [25]			
9. Toxicity, acute, estuarine and marine organisms of the Atlantic Ocean and Gulf of Mexico, LC_{50}, percent effluent	Mysid, *Mysidopsis bahia,* acute	2007.0 [25].			
	Fish, Sheepshead minnow, *Cyprinodon variegatus,* acute	2004.0 [25]			
	Fish, Silverside, *Menidia beryllina, Menidia menidia,* and *Menidia peninsulae,* acute.	2006.0 [25].			
10. Toxicity, chronic, fresh water organisms, NOEC or IC_{25}, percent effluent	Fish, Fathead minnow, *Pimephales promelas,* larval survival and growth	1000.0 [26]			
	Fish, Fathead minnow, *Pimephales promelas,* embryo-larval survival and teratogenicity	1001.0 [26]			
	Water flea, Cladoceran, *Ceriodaphnia dubia,* survival and reproduction	1002.0 [26]			
	Green alga, *Selenastrum capricornutum,* growth	1003.0 [26]			

Parameter and units	Method[1]	EPA	Standard methods	AOAC, ASTM, USGS	Other
11. Toxicity, chronic, estuarine and marine organisms of the Atlantic Ocean and Gulf of Mexico, NOEC or IC_{25}, percent effluent	Fish, Sheepshead minnow, *Cyprinodon variegatus,* larval survival and growth	1004.0 [27].			
	Fish, Sheepshead minnow, *Cyprinodon variegatus,* embryo-larval survival and teratogenicity	1005.0 [27]			
	Fish, Inland silverside, *Menidia beryllina,* larval survival and growth	1006.0 [27]			
	Mysid, *Mysidopsis bahia,* survival, growth, and fecundity	1007.0 [27]			
	Sea urchin, *Arbacia punctulata,* fertilization	1008.0 [27]			

Table IA notes:

[1] The method must be specified when results are reported.

[2] A 0.45-µm membrane filter (MF) or other pore size certified by the manufacturer to fully retain organisms to be cultivated and to be free of extractables which could interfere with their growth.

[3] Microbiological Methods for Monitoring the Environment, Water and Wastes, EPA/600/8-78/017. 1978. U.S. EPA.

[4] U.S. Geological Survey Techniques of Water-Resource Investigations, Book 5, Laboratory Analysis, Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. 1989. USGS.

[5] Because the MF technique usually yields low and variable recovery from chlorinated wastewaters, the Most Probable Number method will be required to resolve any controversies.

[6] Tests must be conducted to provide organism enumeration (density). Select the appropriate configuration of tubes/filtrations and dilutions/volumes to account for the quality, character, consistency, and anticipated organism density of the water sample.

[7] When the MF method has been used previously to test waters with high turbidity, large numbers of noncoliform bacteria, or samples that may contain organisms stressed by chlorine, a parallel test should be conducted with a multiple-tube technique to demonstrate applicability and comparability of results.

[8] To assess the comparability of results obtained with individual methods, it is suggested that side-by-side tests be conducted across seasons of the year with the water samples routinely tested in accordance with the most current *Standard Methods for the Examination of Water and Wastewater* or EPA alternate test procedure (ATP) guidelines.

[9] Annual Book of ASTM Standards-Water and Environmental Technology, Section 11.02. 2000, 1999, 1996. ASTM International.

[10] Official Methods of Analysis of AOAC International. 16th Edition, 4th Revision, 1998. AOAC International.

[11] Recommended for enumeration of target organism in sewage sludge.

[12] The multiple-tube fermentation test is used in 9221B.2-2014. Lactose broth may be used in lieu of lauryl tryptose broth (LTB), if at least 25 parallel tests are conducted between this broth and LTB using the water samples normally tested, and this comparison demonstrates that the false-positive rate and false-negative rate for total coliform using lactose broth is less than 10 percent. No requirement exists to run the completed phase on 10 percent of all total coliform-positive tubes on a seasonal basis.

[13] These tests are collectively known as defined enzyme substrate tests.

[14] After prior enrichment in a presumptive medium for total coliform using 9221B.2-2014, all presumptive tubes or bottles showing any amount of gas, growth or acidity within 48 h ± 3 h of incubation shall be submitted to 9221F-2014. Commercially available EC-MUG media or EC media supplemented in the laboratory with 50 µg/mL of MUG may be used.

[15] Method 1680: Fecal Coliforms in Sewage Sludge (Biosolids) by Multiple-Tube Fermentation Using Lauryl-Tryptose Broth (LTB) and EC Medium, EPA-821-R-14-009. September 2014. U.S. EPA.

[16] Samples shall be enumerated by the multiple-tube or multiple-well procedure. Using multiple-tube procedures, employ an appropriate tube and dilution configuration of the sample as needed and report the Most Probable Number (MPN). Samples tested with Colilert® may be enumerated with the multiple-well procedures, Quanti-Tray® or Quanti-Tray®/2000 and the MPN calculated from the table provided by the manufacturer.

[17] Colilert-18® is an optimized formulation of the Colilert® for the determination of total coliforms and *E. coli* that provides results within 18 h of incubation at 35 °C rather than the 24 h required for the Colilert® test and is recommended for marine water samples.

[18] Descriptions of the Colilert®, Colilert-18®, Quanti-Tray®, and Quanti-Tray®/2000 may be obtained from IDEXX Laboratories, Inc.

[19] A description of the mColiBlue24® test is available from Hach Company.

[20] Method 1681: Fecal Coliforms in Sewage Sludge (Biosolids) by Multiple-Tube Fermentation Using A-1 Medium, EPA-821-R-06-013. July 2006. U.S. EPA.

[21] Method 1603: *Escherichia coli* (*E. coli*) in Water by Membrane Filtration Using Modified Membrane-Thermotolerant *Escherichia coli* Agar (modified mTEC), EPA-821-R-14-010. September 2014. U.S. EPA.

[22] Method 1682: *Salmonella* in Sewage Sludge (Biosolids) by Modified Semisolid Rappaport-Vassiliadis (MSRV) Medium, EPA-821-R-14-012. September 2014. U.S. EPA.

[23] A description of the Enterolert® test may be obtained from IDEXX Laboratories Inc.

[24] Method 1600: Enterococci in Water by Membrane Filtration Using Membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI), EPA-821-R-14-011. September 2014. U.S. EPA.

[25] Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, EPA-821-R-02-012. Fifth Edition, October 2002. U.S. EPA; and U.S. EPA Whole Effluent Toxicity Methods Errata Sheet, EPA 821-R-02-012-ES. December 2016.

[26] Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, EPA-821-R-02-013. Fourth Edition, October 2002. U.S. EPA; and U.S. EPA Whole Effluent Toxicity Methods Errata Sheet, EPA 821-R-02-012-ES. December 2016.

[27] Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms, EPA-821-R-02-014. Third Edition, October 2002. U.S. EPA; and U.S. EPA Whole Effluent Toxicity Methods Errata Sheet, EPA 821-R-02-012-ES. December 2016.

[28] To use Colilert-18® to assay for fecal coliforms, the incubation temperature is 44.5 ± 0.2 °C, and a water bath incubator is used.

[29] On a monthly basis, at least ten blue colonies from positive samples must be verified using Lauryl Tryptose Broth and EC broth, followed by count adjustment based on these results; and representative non-blue colonies should be verified using Lauryl Tryptose Broth. Where possible, verifications should be done from randomized sample sources.

[30] On a monthly basis, at least ten sheen colonies from positive samples must be verified using lauryl tryptose broth and brilliant green lactose bile broth, followed by count adjustment based on these results; and representative non-sheen colonies should be verified using lauryl tryptose broth. Where possible, verifications should be done from randomized sample sources.

[31] Subject coliform positive samples determined by 9222 B-2015 or other membrane filter procedure to 9222 I-2015 using NA-MUG media.

[32] Verification of colonies by incubation of BHI agar at 10 ± 0.5 °C for 48 ± 3 h is optional. As per the Errata to the 23rd Edition of *Standard Methods for the Examination of Water and Wastewater* "Growth on a BHI agar plate incubated at 10 ± 0.5 °C for 48 ± 3 h is further verification that the colony belongs to the genus *Enterococcus."*

[33] 9221 F.2-2014 allows for simultaneous detection of *E. coli* and thermotolerant fecal coliforms by adding inverted vials to EC-MUG; the inverted vials collect gas produced by thermotolerant fecal coliforms.

Table IB - List of Approved Inorganic Test Procedures

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
1. Acidity, as $CaCO_3$, mg/L	Electrometric endpoint or phenolphthalein endpoint		2310 B-2011	D1067-16	I-1020-85.[2]
2. Alkalinity, as $CaCO_3$, mg/L	Electrometric or Colorimetric titration to pH 4.5, Manual		2320 B-2011	D1067-16	973.43,[3] I-1030-85.[2]
	Automatic	310.2 (Rev. 1974)[1]			I-2030-85.[2]
3. Aluminum - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 D-2011 or 3111 E-2011		I-3051-85.[2]
	AA furnace		3113 B-2010.		
	STGFAA	200.9, Rev. 2.2 (1994)/			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Direct Current Plasma (DCP)[36]			D4190-15	See footnote.[34]
	Colorimetric (Eriochrome cyanine R)		3500-Al B-2011.		
4. Ammonia (as N), mg/L	Manual distillation[6] or gas diffusion (pH > 11), followed by any of the following:	350.1, Rev. 2.0 (1993)	4500-NH_3 B-2011		973.49.[3]
	Nesslerization			D1426-15 (A)	973.49,[3] I-3520-85.[2]
	Titration		4500-NH_3 C-2011.		
	Electrode		4500-NH_3 D-2011 or E-2011	D1426-15 (B).	
	Manual phenate, salicylate, or other substituted phenols in Berthelot reaction-based methods		4500-NH_3 F-2011		See footnote.[60]
	Automated phenate, salicylate, or other substituted phenols in Berthelot reaction-based methods	350.1,[30] Rev. 2.0 (1993)	4500-NH_3 G-2011 4500-NH_3 H-2011		I-4523-85,[2] I-2522-90.[80]
	Automated electrode				See footnote.[7]
	Ion Chromatography			D6919-17.	
	Automated gas diffusion, followed by conductivity cell analysis				Timberline Ammonia-001.[74]
	Automated gas diffusion followed by fluorescence detector analysis				FIAlab100.[82]
5. Antimony - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011.		
	AA furnace		3113 B-2010.		

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12.	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
6. Arsenic-Total,[4] mg/L	Digestion,[4] followed by any of the following:	206.5 (Issued 1978)[1].			
	AA gaseous hydride		3114 B-2011 or 3114 C-2011	D2972-15 (B)	I-3062-85.[2]
	AA furnace		3113 B-2010	D2972-15 (C)	I-4063-98.[49]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12.	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05.[70]
	Colorimetric (SDDC)		3500-As B-2011	D2972-15 (A)	I-3060-85.[2]
7. Barium-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 D-2011		I-3084-85.[2]
	AA furnace		3113 B-2010	D4382-18.	

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011		I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
	DCP[36]				See footnote.[34]
8. Beryllium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 D-2011 or 3111 E-2011	D3645-15 (A)	I-3095-85.[2]
	AA furnace		3113 B-2010	D3645-15 (B).	
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
	DCP			D4190-15	See footnote.[34]
	Colorimetric (aluminon)		See footnote.[61].		
9. Biochemical oxygen demand (BOD_5), mg/L	Dissolved Oxygen Depletion		5210 B-2016[85]		973.44,[3] p. 17,[9] I-1578-78,[8] See footnote.[10, 63]
10. Boron - Total,[37] mg/L	Colorimetric (curcumin)		4500-B B-2011		I-3112-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/AES	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP			D4190-15	S7ee footnote.[34]
11. Bromide, mg/L	Electrode			D1246-16	I-1125-85.[2]
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1, Rev 1.0 (1997)	4110 B-2011, C-2011, D-2011	D4327-17	993.30,[3] I-2057-85.[79]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
12. Cadmium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D3557-17 (A or B)	974.27,[3] p. 37,[9] I-3135-85[2] or I-3136-85.[2]
	AA furnace		3113 B-2010	D3557-17 (D)	I-4138-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-1472-85[2] or I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
	DCP[36]			D4190-15	See footnote.[34]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Voltammetry[11]			D3557-17 (C).	
	Colorimetric (Dithizone)		3500-Cd-D-1990.		
13. Calcium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011	D511-14 (B)	I-3152-85.[2]
	ICP/AES	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011		I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP				See footnote.[34]
	Titrimetric (EDTA)		3500-Ca B-2011	D511-14 (A).	
	Ion Chromatography			D6919-17.	
14. Carbonaceous biochemical oxygen demand ($CBOD_5$), mg/L[12]	Dissolved Oxygen Depletion with nitrification inhibitor		5210 B-2016[85]		See footnote.[35] [63]
15. Chemical oxygen demand (COD), mg/L	Titrimetric	410.3 (Rev. 1978)[1]	5220 B-2011 or C-2011	D1252-06(12) (A)	973.46,[3] p. 17,[9] I-3560-85.[2]
	Spectrophotometric, manual or automatic	410.4, Rev. 2.0 (1993)	5220 D-2011	D1252-06(12) (B)	See footnotes.[13] [14] [83], I-3561-85.[2]
16. Chloride, mg/L	Titrimetric: (silver nitrate)		4500-Cl^- B-2011	D512-12 (B)	I-1183-85.[2]
	(Mercuric nitrate)		4500-Cl^- C-2011	D512-12 (A)	973.51,[3] I-1184-85.[2]
	Colorimetric: manual				I-1187-85.[2]
	Automated (ferricyanide)		4500-Cl^- E-2011		I-2187-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Potentiometric Titration		4500-Cl⁻ D-2011.		
	Ion Selective Electrode			D512-12 (C).	
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1, Rev 1.0 (1997)	4110 B-2011 or 4110 C-2011	D4327-17	993.30,[3] I-2057-90.[51]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
17. Chlorine-Total residual, mg/L	Amperometric direct		4500-Cl D-2011	D1253-14.	
	Amperometric direct (low level)		4500-Cl E-2011.		
	Iodometric direct		4500-Cl B-2011.		
	Back titration ether end-point[15]		4500-Cl C-2011.		
	DPD-FAS		4500-Cl F-2011.		
	Spectrophotometric, DPD		4500-Cl G-2011.		
	Electrode				See footnote.[16]
17A. Chlorine-Free Available, mg/L	Amperometric direct		4500-Cl D-2011	D1253-14.	
	Amperometric direct (low level)		4500-Cl E-2011.		
	DPD-FAS		4500-Cl F-2011.		
	Spectrophotometric, DPD		4500-Cl G-2011.		
18. Chromium VI dissolved, mg/L	0.45-micron filtration followed by any of the following:				
	AA chelation-extraction		3111 C-2011		I-1232-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Ion Chromatography	218.6, Rev. 3.3 (1994)	3500-Cr C-2011	D5257-17	993.23.[3]
	Colorimetric (diphenyl-carbazide)		3500-Cr B-2011	D1687-17 (A)	I-1230-85.[2]
19. Chromium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011	D1687-17 (B)	974.27,[3] I-3236-85.[2]
	AA chelation-extraction		3111 C-2011.		
	AA furnace		3113 B-2010	D1687-17 (C)	I-3233-93.[46]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003),[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12.	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05[70] I-4472-97.[81]
	DCP[36]			D4190-15	See footnote.[34]
	Colorimetric (diphenyl-carbazide)		3500-Cr B-2011.		
20. Cobalt - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011 or 3111 C-2011	D3558-15 (A or B)	p. 37,[9] I-3239-85.[2]
	AA furnace		3113 B-2010	D3558-15 (C)	I-4243-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES	200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05[70] I-4472-97.[81]
	DCP			D4190-15	See footnote.[34]
21. Color, platinum cobalt units or dominant wavelength, hue, luminance purity	Colorimetric (ADMI)		2120 F-2011[78].		
	Platinum cobalt visual comparison		2120 B-2011		I-1250-85.[2]
	Spectrophotometric				See footnote[18]
22. Copper - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D1688-17 (A or B)	974.27,[3] p. 37,[9] I-3270-85[2] or I-3271-85.[2]
	AA furnace		3113 B-2010	D1688-17 (C)	I-4274-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05,[70], I-4472-97.[81]
	DCP[36]			D4190-15	See footnote.[34]
	Colorimetric (Neocuproine)		3500-Cu B-2011.		
	Colorimetric (Bathocuproine)		3500-Cu C-2011		See footnote.[19]
23. Cyanide - Total, mg/L	Automated UV digestion/distillation and Colorimetry				Kelada-01.[55]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Segmented Flow Injection, In-Line Ultraviolet Digestion, followed by gas diffusion amperometry			D7511-12(17).	
	Manual distillation with $MgCl_2$, followed by any of the following:	335.4, Rev. 1.0 (1993)[57]	4500-CN^- B-2016 and C-2016	D2036-09(15)(A), D7284-13(17)	10-204-00-1-X.[56]
	Flow Injection, gas diffusion amperometry			D2036-09(15)(A) D7284-13(17).	
	Titrimetric		4500-CN^- D-2016	D2036-09(15)(A)	p. 22.[9]
	Spectrophotometric, manual		4500-CN^- E-2016	D2036-09(15)(A)	I-3300-85.[2]
	Semi-Automated[20]	335.4, Rev. 1.0 (1993)[57]	4500-CN^- N-2016		10-204-00-1-X,[56] I-4302-85.[2]
	Ion Chromatography			D2036-09(15)(A).	
	Ion Selective Electrode		4500-CN^- F-2016	D2036-09(15)(A).	
24. Cyanide-Available, mg/L	Cyanide Amenable to Chlorination (CATC); Manual distillation with $MgCl_2$, followed by Titrimetric or Spectrophotometric		4500-CN^- G-2016	D2036-09(15)(B).	
	Flow injection and ligand exchange, followed by gas diffusion amperometry[59]			D6888-16	OIA-1677-09.[44]
	Automated Distillation and Colorimetry (no UV digestion)				Kelada-01.[55]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
24.A Cyanide-Free, mg/L	Flow Injection, followed by gas diffusion amperometry			D7237-15 (A)	OIA-1677-09.[44]
	Manual micro-diffusion and colorimetry			D4282-15.	
25. Fluoride - Total, mg/L	Manual distillation,[6] followed by any of the following:		4500-F$^-$ B-2011	D1179-16 (A).	
	Electrode, manual		4500-F$^-$ C-2011	D1179-16 (B).	
	Electrode, automated				I-4327-85.[2]
	Colorimetric, (SPADNS)		4500-F$^-$ D-2011.		
	Automated complexone		4500-F$^-$ E-2011.		
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1, Rev 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30.[3]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
26. Gold - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011.		
	AA furnace	231.2 (Issued 1978)[1]	3113 B-2010.		
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP				See footnote.[34]
27. Hardness - Total, as $CaCO_3$, mg/L	Automated colorimetric	130.1 (Issued 1971)[1].			
	Titrimetric (EDTA)		2340 C-2011	D1126-17	973.52B[3], I-1338-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Ca plus Mg as their carbonates, by any approved method for Ca and Mg (See Parameters 13 and 33), provided that the sum of the lowest point of quantitation for Ca and Mg is below the NPDES permit requirement for Hardness		2340 B-2011.		
28. Hydrogen ion (pH), pH units	Electrometric measurement		4500-H^+ B-2011	D1293-99 (A or B)	973.41,[3] I-1586-85.[2]
	Automated electrode	150.2 (Dec. 1982)[1]			See footnote,[21] I-2587-85.[2]
29. Iridium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011.		
	AA furnace	235.2 (Issued 1978)[1].			
	ICP/MS		3125 B-2011.		
30. Iron - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D1068-15 (A)	974.27,[3] I-3381-85.[2]
	AA furnace		3113 B-2010	D1068-15 (B).	
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP[36]			D4190-15	See footnote.[34]
	Colorimetric (Phenanthroline)		3500-Fe B-2011	D1068-15 (C)	See footnote.[22]
31. Kjeldahl Nitrogen[5] - Total, (as N), mg/L	Manual digestion[20] and distillation or gas diffusion, followed by any of the following:		4500-N_{org} B-2011 or C-2011 and 4500-NH_3 B-2011	D3590-17 (A)	I-4515-91.[45]
	Titration		4500-NH_3 C-2011		973.48.[3]
	Nesslerization			D1426-15 (A).	
	Electrode		4500-NH_3 D-2011 or E-2011	D1426-15 (B).	
	Semi-automated phenate	350.1, Rev. 2.0 (1993)	4500-NH_3 G-2011 4500-NH_3 H-2011		
	Manual phenate, salicylate, or other substituted phenols in Berthelot reaction based methods		4500-NH_3 F-2011		See footnote.[60]
	Automated gas diffusion, followed by conductivity cell analysis				Timberline Ammonia-001.[74]
	Automated gas diffusion followed by fluorescence detector analysis				FIAlab 100.[82]
	Automated Methods for TKN that do not require manual distillation				
	Automated phenate, salicylate, or other substituted phenols in Berthelot reaction based methods colorimetric (auto digestion and distillation)	351.1 (Rev. 1978)[1]			I-4551-78.[8]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Semi-automated block digestor colorimetric (distillation not required)	351.2, Rev. 2.0 (1993)	4500-N_{org} D-2011	D3590-17 (B)	I-4515-91[45]
	Block digester, followed by Auto distillation and Titration				See footnote.[39]
	Block digester, followed by Auto distillation and Nesslerization				See footnote.[40]
	Block Digester, followed by Flow injection gas diffusion (distillation not required)				See footnote.[41]
	Digestion with peroxdisulfate, followed by Spectrophotometric (2,6-dimethyl phenol)				Hach 10242.[76]
	Digestion with persulfate, followed by Colorimetric				NCASI TNTP W10900.[77]
32. Lead - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D3559-15 (A or B)	974.27,[3] I-3399-85.[2]
	AA furnace		3113 B-2010	D3559-15 (D)	I-4403-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	DCP[36]			D4190-15	See footnote.[34]
	Voltammetry[11]			D3559-15 (C).	
	Colorimetric (Dithizone)		3500-Pb B-2011.		
33. Magnesium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011	D511-14 (B)	974.27,[3] I-3447-85.[2]
	ICP/AES	200.5, Rev. 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP				See footnote.[34]
	Ion Chromatography			D6919-17.	
34. Manganese - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011	D858-17 (A or B)	974.27,[3] I-3454-85.[2]
	AA furnace		3113 B-2010	D858-17 (C).	
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	DCP[36]			D4190-15	See footnote.[34]
	Colorimetric (Persulfate)		3500-Mn B-2011		920.203.[3]
	Colorimetric (Periodate)				See footnote.[23]
35. Mercury - Total, mg/L	Cold vapor, Manual	245.1, Rev. 3.0 (1994)	3112 B-2011	D3223-17	977.22,[3] I-3462-85.[2]
	Cold vapor, Automated	245.2 (Issued 1974)[1].			
	Cold vapor atomic fluorescence spectrometry (CVAFS)	245.7 Rev. 2.0 (2005)[17]			I-4464-01.[71]
	Purge and Trap CVAFS	1631E[43].			
36. Molybdenum - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 D-2011		I-3490-85.[2]
	AA furnace		3113 -2010		I-3492-96.[47]
	ICP/AES	200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
	DCP				See footnote.[34]
37. Nickel - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D1886-14 (A or B)	I-3499-85[2]
	AA furnace		3113 B-2010	D1886-14 (C)	I-4503-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994)			

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/AES[36]	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05[70] I-4472-97.[81]
	DCP[36]			D4190-15	See footnote.[34]
38. Nitrate (as N), mg/L	Ion Chromatography	300.0, Rev. 2.1 (1993) and 300.1, Rev. 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30.[3]
	CIE/UV	4140 B-2011	D6508-15	D6508, Rev. 2.[54]	
	Ion Selective Electrode		4500-NO_3^- D-2016.		
	Colorimetric (Brucine sulfate)	352.1 (Issued 1971)[1]			973.50,[3] 419D[17], p. 28.[9]
	Spectrophotometric (2,6-dimethylphenol)				Hach 10206[75]
	Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40)				
39. Nitrate-nitrite (as N), mg/L	Cadmium reduction, Manual		4500-NO_3^- E-2016	D3867-16 (B).	
	Cadmium reduction, Automated	353.2, Rev. 2.0 (1993)	4500-NO_3^- F-2016 4500-NO_3^- I-2016	D3867-16 (A)	I-2545-90.[51]
	Automated hydrazine		4500-NO_3^- H-2016.		
	Reduction/Colorimetric				See footnote.[62]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	Ion Chromatography	300.0, Rev. 2.1 (1993) and 300.1, Rev. 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30.[3]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
	Enzymatic reduction, followed by automated colorimetric determination			D7781-14	I-2547-11.[72] I-2548-11.[72] N07-0003.[73]
	Enzymatic reduction, followed by manual colorimetric determination		4500-NO_3^- J-2018.		
	Spectrophotometric (2,6-dimethylphenol)				Hach 10206.[75]
40. Nitrite (as N), mg/L	Spectrophotometric: Manual		4500-NO_2- B-2011		See footnote.[25]
	Automated (Diazotization)				I-4540-85,[2] See footnote.[62] I-2540-90.[80]
	Automated (*bypass cadmium reduction)	353.2, Rev. 2.0 (1993)	4500-NO_3^- F-2016 4500-NO_3^- I-2016	D3867-16 (A)	I-4545-85.[2]
	Manual (*bypass cadmium or enzymatic reduction)		4500-NO_3^- E-2016, 4500-NO_3^- J-2018	D3867-16 (B).	
	Ion Chromatography	300.0, Rev. 2.1 (1993) and 300.1, Rev. 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30.[3]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
	Automated (*bypass Enzymatic reduction)			D7781-14	I-2547-11[72] I-2548-11[72] N07-0003.[73]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
41. Oil and grease - Total recoverable, mg/L	Hexane extractable material (HEM): *n*-Hexane extraction and gravimetry	1664 Rev. A; 1664 Rev. B[42]	5520 B-2011[38].		
	Silica gel treated HEM (SGT-HEM): Silica gel treatment and gravimetry	1664 Rev. A; 1664 Rev. B[42]	5520 B-2011[38] and 5520 F-2011[38].		
42. Organic carbon - Total (TOC), mg/L	Combustion		5310 B-2014	D7573-09(17)	973.47,[3] p. 14.[24]
	Heated persulfate or UV persulfate oxidation		5310 C-2014 5310 D-2011	D4839-03(17)	973.47,[3], p. 14.[24]
43. Organic nitrogen (as N), mg/L	Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4)				
44. Ortho-phosphate (as P), mg/L	Ascorbic acid method:				
	Automated	365.1, Rev. 2.0 (1993)	4500-P F-2011 or G-2011		973.56,[3] I-4601-85,[2] I-2601-90.[80]
	Manual, single-reagent		4500-P E-2011	D515-88 (A)	973.55.[3]
	Manual, two-reagent	365.3 (Issued 1978)[1].			
	Ion Chromatography	300.0, Rev. 2.1 (1993) and 300.1, Rev. 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30.[3]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
45. Osmium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 D-2011.		

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	AA furnace	252.2 (Issued 1978)[1].			
46. Oxygen, dissolved, mg/L	Winkler (Azide modification)		4500-O (B-F)-2016	D888-12 (A)	973.45B,[3] I-1575-78.[8]
	Electrode		4500-O G-2016	D888-12 (B)	I-1576-78.[8]
	Luminescence-Based Sensor		4500-O H-2016	D888-12 (C)	See footnote.[63] See footnote.[64]
47. Palladium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011.		
	AA furnace	253.2 (Issued 1978)[1].			
	ICP/MS		3125 B-2011.		
	DCP				See footnote.[34]
48. Phenols, mg/L	Manual distillation,[26] followed by any of the following:	420.1 (Rev. 1978)[1]	5530 B-2010	D1783-01(12).	
	Colorimetric (4AAP) manual	420.1 (Rev. 1978)[1]	5530 D-2010[27]	D1783-01(12) (A or B).	
	Automated colorimetric (4AAP)	420.4 Rev. 1.0 (1993)			
49. Phosphorus (elemental), mg/L	Gas-liquid chromatography				See footnote.[28]
50. Phosphorus - Total, mg/L	Digestion,[20] followed by any of the following:		4500-P B (5)-2011		973.55.[3]
	Manual	365.3 (Issued 1978)[1]	4500-P E-2011	D515-88 (A).	
	Automated ascorbic acid reduction	365.1 Rev. 2.0 (1993)	4500-P (F-H)-2011		973.56,[3] I-4600-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/AES [4 36]	200.7, Rev. 4.4 (1994)	3120 B-2011		I-4471-97.[50]
	Semi-automated block digestor (TKP digestion)	365.4 (Issued 1974)[1]		D515-88 (B)	I-4610-91.[48]
	Digestion with persulfate, followed by Colorimetric				NCASI TNTP W10900.[77]
51. Platinum - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011.		
	AA furnace	255.2 (Issued 1978)[1].			
	ICP/MS		3125 B-2011.		
	DCP				See footnote.[34]
52. Potassium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011		973.53,[3] I-3630-85.[2]
	ICP/AES	200.7, Rev. 4.4 (1994)	3120 B-2011.		
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	Flame photometric		3500-K B-2011.		
	Electrode		3500-K C-2011.		
	Ion Chromatography			D6919-17.	
53. Residue - Total, mg/L	Gravimetric, 103-105°		2540 B-2015		I-3750-85.[2]
54. Residue - filterable, mg/L	Gravimetric, 180°		2540 C-2015	D5907-13	I-1750-85.[2]
55. Residue - non-filterable (TSS), mg/L	Gravimetric, 103-105° post-washing of residue		2540 D-2015	D5907-13	I-3765-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
56. Residue - settleable, ml/L	Volumetric (Imhoff cone), or gravimetric		2540 F-2015.		
57. Residue - Volatile, mg/L	Gravimetric, 550°	160.4 (Issued 1971)[1]	2540 E-2015		I-3753-85.[2]
58. Rhodium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration, or		3111 B-2011.		
	AA furnace	265.2 (Issued 1978)[1].			
	ICP/MS		3125 B-2011.		
59. Ruthenium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration, or		3111 B-2011.		
	AA furnace	267.2[1].			
	ICP/MS		3125 B-2011.		
60. Selenium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA furnace		3113 B-2010	D3859-15 (B)	I-4668-98.[49]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES[36]	200.5, Rev 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12.	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05[70] I-4472-97.[81]
	AA gaseous hydride		3114 B-2011, or 3114 C-2011	D3859-15 (A)	I-3667-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
61. Silica - Dissolved,[37] mg/L	0.45-micron filtration followed by any of the following:				
	Colorimetric, Manual		4500-SiO_2 C-2011	D859-16	I-1700-85.[2]
	Automated (Molybdosilicate)		4500-SiO_2 E-2011 or F-2011		I-2700-85.[2]
	ICP/AES	200.5, Rev. 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-2011		I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
62. Silver - Total,[4 31] mg/L	Digestion,[4 29] followed by any of the following:				
	AA direct aspiration		3111 B-2011 or 3111 C-2011		974.27,[3] p. 37,[9] I-3720-85.[2]
	AA furnace		3113 B-2010		I-4724-89.[51]
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4472-97.[81]
	DCP				See footnote.[34]
63. Sodium - Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011		973.54,[3] I-3735-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	ICP/AES	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011		I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP				See footnote.[34]
	Flame photometric		3500-Na B-2011.		
	Ion Chromatography			D6919-17.	
64. Specific conductance, micromhos/cm at 25 °C	Wheatstone bridge	120.1 (Rev. 1982)[1]	2510 B-2011	D1125-95(99) (A)	973.40,[3] I-2781-85.[2]
65. Sulfate (as SO_4), mg/L	Automated colorimetric	375.2, Rev. 2.0 (1993)	4500-SO_4^{2-} F-2011 or G-2011		
	Gravimetric		4500-SO_4^{2-} C-2011 or D-2011		925.54.[3]
	Turbidimetric		4500-SO_4^{2-} E-2011	D516-16.	
	Ion Chromatography	300.0, Rev. 2.1 (1993) and 300.1, Rev. 1.0 (1997)	4110 B-2011 or C-2011	D4327-17	993.30$_3$, I-4020-05[70]
	CIE/UV		4140 B-2011	D6508-15	D6508, Rev. 2.[54]
66. Sulfide (as S), mg/L	Sample Pretreatment		4500-S^{2-} B, C-2011.		
	Titrimetric (iodine)		4500-S^{2-} F-2011		I-3840-85.[2]
	Colorimetric (methylene blue)		4500-S^{2-} D-2011.		
	Ion Selective Electrode		4500-S^{2-} G-2011	D4658-15.	

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
67. Sulfite (as SO_3), mg/L	Titrimetric (iodine-iodate)		4500-SO_3^{2-} B-2011.		
68. Surfactants, mg/L	Colorimetric (methylene blue)		5540 C-2011	D2330-02.	
69. Temperature, °C	Thermometric		2550 B-2010		See footnote.[32]
70. Thallium-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011.		
	AA furnace	279.2 (Issued 1978)[1]	3113 B-2010.		
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES	200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12.	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4471-97[50] I-4472-97.[81]
71. Tin-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 B-2011		I-3850-78.[8]
	AA furnace		3113 B-2010.		
	STGFAA	200.9, Rev. 2.2 (1994).			
	ICP/AES	200.5, Rev. 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994).			
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
72. Titanium-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 D-2011.		
	AA furnace	283.2 (Issued 1978)[1].			
	ICP/AES	200.7, Rev. 4.4 (1994).			
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14.[3]
	DCP				See footnote.[34]
73. Turbidity, NTU[53]	Nephelometric	180.1, Rev. 2.0 (1993)	2130 B-2011	D1889-00	I-3860-85[2] See footnote.[65] See footnote.[66] See footnote.[67]
74. Vanadium-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration		3111 D-2011.		
	AA furnace		3113 B-2010	D3373-17.	
	ICP/AES	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05.[70]
	DCP			D4190-15	See footnote.[34]
	Colorimetric (Gallic Acid)		3500-V B-2011.		
75. Zinc-Total,[4] mg/L	Digestion,[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-2011 or 3111 C-2011	D1691-17 (A or B)	974.27,[3] p. 37,[9] I-3900-85.[2]

Parameter	Methodology[58]	EPA[52]	Standard methods[84]	ASTM	USGS/AOAC/Other
	AA furnace	289.2 (Issued 1978)[1].			
	ICP/AES[36]	200.5, Rev. 4.2 (2003);[68] 200.7, Rev. 4.4 (1994)	3120 B-2011	D1976-12	I-4471-97.[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2011	D5673-16	993.14,[3] I-4020-05[70] I-4472-97.[81]
	DCP[36]			D4190-15	See footnote.[34]
	Colorimetric (Zincon)		3500 Zn B-2011		See footnote.[33]
76. Acid Mine Drainage		1627[69].			

Table IB Notes:

[1] Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020. Revised March 1983 and 1979, where applicable. U.S. EPA.

[2] Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Book 5, Chapter A1., unless otherwise stated. 1989. USGS.

[3] Official Methods of Analysis of the Association of Official Analytical Chemists, Methods Manual, Sixteenth Edition, 4th Revision, 1998. AOAC International.

[4] For the determination of total metals (which are equivalent to total recoverable metals) the sample is not filtered before processing. A digestion procedure is required to solubilize analytes in suspended material and to break down organic-metal complexes (to convert the analyte to a detectable form for colorimetric analysis). For non-platform graphite furnace atomic absorption determinations, a digestion using nitric acid (as specified in Section 4.1.3 of Methods for Chemical Analysis of Water and Wastes) is required prior to analysis. The procedure used should subject the sample to gentle acid refluxing, and at no time should the sample be taken to dryness. For direct aspiration flame atomic absorption (FLAA) determinations, a combination acid (nitric and hydrochloric acids) digestion is preferred, prior to analysis. The approved total recoverable digestion is described as Method 200.2 in Supplement I of “Methods for the Determination of Metals in Environmental Samples” EPA/600R-94/111, May, 1994, and is reproduced in EPA Methods 200.7, 200.8, and 200.9 from the same Supplement. However, when using the gaseous hydride technique or for the determination of certain elements such as antimony, arsenic, selenium, silver, and tin by non-EPA graphite furnace atomic absorption methods, mercury by cold vapor atomic absorption, the noble metals and titanium by FLAA, a specific or modified sample digestion procedure may be required, and, in all cases the referenced method write-up should be consulted for specific instruction and/or cautions. For analyses using inductively coupled plasma-atomic emission spectrometry (ICP-AES), the direct current plasma (DCP) technique or EPA spectrochemical techniques (platform furnace AA, ICP-AES, and ICP-MS), use EPA Method 200.2 or an approved alternate procedure (e.g., CEM microwave digestion, which may be used with certain analytes as indicated in Table IB); the total recoverable digestion procedures in EPA Methods 200.7, 200.8, and 200.9 may be used for those respective methods. Regardless of the digestion procedure, the results of the analysis after digestion procedure are reported as “total” metals.

[5] Copper sulfate or other catalysts that have been found suitable may be used in place of mercuric sulfate.

[6] Manual distillation is not required if comparability data on representative effluent samples are on file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies. In general, the analytical method should be consulted regarding the need for distillation. If the method is not clear, the laboratory may compare a minimum of 9 different sample matrices to evaluate the need for distillation. For each matrix, a matrix spike and matrix spike duplicate are analyzed both with and without the distillation step (for a total of 36 samples, assuming 9 matrices). If results are comparable, the laboratory may dispense with the distillation step for future analysis. Comparable is defined as < 20% RPD for all tested matrices). Alternatively, the two populations of spike recovery percentages may be compared using a recognized statistical test.

[7] Industrial Method Number 379-75 WE Ammonia, Automated Electrode Method, Technicon Auto Analyzer II. February 19, 1976. Bran & Luebbe Analyzing Technologies Inc.

[8] The approved method is that cited in Methods for Determination of Inorganic Substances in Water and Fluvial Sediments, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 5, Chapter A1. 1979. USGS.

[9] American National Standard on Photographic Processing Effluents. April 2, 1975. American National Standards Institute.

[10] In-Situ Method 1003-8-2009, Biochemical Oxygen Demand (BOD) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[11] The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

[12] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test method which measures “total 5-day BOD.” The addition of the nitrification inhibitor is not a procedural option but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required can the permittee report data using a nitrification inhibitor.

[13] OIC Chemical Oxygen Demand Method. 1978. Oceanography International Corporation.

[14] Method 8000, Chemical Oxygen Demand, Hach Handbook of Water Analysis, 1979. Hach Company.

[15] The back-titration method will be used to resolve controversy.

[16] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97-70. 1977. Orion Research Incorporated. The calibration graph for the Orion residual chlorine method must be derived using a reagent blank and three standard solutions, containing 0.2, 1.0, and 5.0 mL 0.00281 N potassium iodate/100 mL solution, respectively.

[17] Method 245.7, Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry, EPA-821-R-05-001. Revision 2.0, February 2005. US EPA.

[18] National Council of the Paper Industry for Air and Stream Improvement (NCASI) Technical Bulletin 253 (1971) and Technical Bulletin 803, May 2000.

[19] Method 8506, Bicinchoninate Method for Copper, Hach Handbook of Water Analysis. 1979. Hach Company.

[20] When using a method with block digestion, this treatment is not required.

[21] Industrial Method Number 378-75WA, Hydrogen ion (pH) Automated Electrode Method, Bran & Luebbe (Technicon) Autoanalyzer II. October 1976. Bran & Luebbe Analyzing Technologies.

[22] Method 8008, 1,10-Phenanthroline Method using FerroVer Iron Reagent for Water. 1980. Hach Company.

[23] Method 8034, Periodate Oxidation Method for Manganese, Hach Handbook of Wastewater Analysis. 1979. Hach Company.

[24] Methods for Analysis of Organic Substances in Water and Fluvial Sediments, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 5, Chapter A3, (1972 Revised 1987). 1987. USGS.

[25] Method 8507, Nitrogen, Nitrite-Low Range, Diazotization Method for Water and Wastewater. 1979. Hach Company.

[26] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[27] The colorimetric reaction must be conducted at a pH of 10.0 ± 0.2.

[28] Addison, R.F., and R.G. Ackman. 1970. Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography, *Journal of Chromatograph*y, 47(3):421-426.

[29] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to pH of 12. Therefore, for levels of silver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[30] The use of EDTA decreases method sensitivity. Analysts may omit EDTA or replace with another suitable complexing reagent provided that all method-specified quality control acceptance criteria are met.

[31] For samples known or suspected to contain high levels of silver (e.g., in excess of 4 mg/L), cyanogen iodide should be used to keep the silver in solution for analysis. Prepare a cyanogen iodide solution by adding 4.0 mL of concentrated NH_4OH, 6.5 g of KCN, and 5.0 mL of a 1.0 N solution of I_2 to 50 mL of reagent water in a volumetric flask and dilute to 100.0 mL. After digestion of the sample, adjust the pH of the digestate to >7 to prevent the formation of HCN under acidic conditions. Add 1 mL of the cyanogen iodide solution to the sample digestate and adjust the volume to 100 mL with reagent water (NOT acid). If cyanogen iodide is added to sample digestates, then silver standards must be prepared that contain cyanogen iodide as well. Prepare working standards by diluting a small volume of a silver stock solution with water and adjusting the pH>7 with NH_4OH. Add 1 mL of the cyanogen iodide solution and let stand 1 hour. Transfer to a 100-mL volumetric flask and dilute to volume with water.

[32] "Water Temperature-Influential Factors, Field Measurement and Data Presentation," Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1. 1975. USGS.

[33] Method 8009, Zincon Method for Zinc, Hach Handbook of Water Analysis, 1979. Hach Company.

[34] Method AES0029, Direct Current Plasma (DCP) Optical Emission Spectrometric Method for Trace Elemental Analysis of Water and Wastes. 1986-Revised 1991. Thermo Jarrell Ash Corporation.

[35] In-Situ Method 1004-8-2009, Carbonaceous Biochemical Oxygen Demand (CBOD) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[36] Microwave-assisted digestion may be employed for this metal, when analyzed by this methodology. Closed Vessel Microwave Digestion of Wastewater Samples for Determination of Metals. April 16, 1992. CEM Corporation

[37] When determining boron and silica, only plastic, PTFE, or quartz laboratory ware may be used from start until completion of analysis.

[38] Only use *n*-hexane (*n*-Hexane - 85% minimum purity, 99.0% min. saturated C6 isomers, residue less than 1 mg/L) extraction solvent when determining Oil and Grease parameters - Hexane Extractable Material (HEM), or Silica Gel Treated HEM (analogous to EPA Methods 1664 Rev. A and 1664 Rev. B). Use of other extraction solvents is prohibited.

[39] Method PAI-DK01, Nitrogen, Total Kjeldahl, Block Digestion, Steam Distillation, Titrimetric Detection. Revised December 22, 1994. OI Analytical.

[40] Method PAI-DK02, Nitrogen, Total Kjeldahl, Block Digestion, Steam Distillation, Colorimetric Detection. Revised December 22, 1994. OI Analytical.

[41] Method PAI-DK03, Nitrogen, Total Kjeldahl, Block Digestion, Automated FIA Gas Diffusion. Revised December 22, 1994. OI Analytical.

[42] Method 1664 Rev. B is the revised version of EPA Method 1664 Rev. A. U.S. EPA. February 1999, Revision A. Method 1664, *n*-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated *n*-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. EPA-821-R-98-002. U.S. EPA. February 2010, Revision B. Method 1664, *n*-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated *n*-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. EPA-821-R-10-001.

[43] Method 1631, Revision E, Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, EPA-821-R-02-019. Revision E. August 2002, U.S. EPA. The application of clean techniques described in EPA's Method 1669: *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels,* EPA-821-R-96-011, are recommended to preclude contamination at low-level, trace metal determinations.

[44] Method OIA-1677-09, Available Cyanide by Ligand Exchange and Flow Injection Analysis (FIA). 2010. OI Analytical.

[45] Open File Report 00-170, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Ammonium Plus Organic Nitrogen by a Kjeldahl Digestion Method and an Automated Photometric Finish that Includes Digest Cleanup by Gas Diffusion. 2000. USGS.

[46] Open File Report 93-449, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Chromium in Water by Graphite Furnace Atomic Absorption Spectrophotometry. 1993. USGS.

[47] Open File Report 97-198, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Molybdenum by Graphite Furnace Atomic Absorption Spectrophotometry. 1997. USGS.

[48] Open File Report 92-146, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Total Phosphorus by Kjeldahl Digestion Method and an Automated Colorimetric Finish That Includes Dialysis. 1992. USGS.

[49] Open File Report 98-639, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Arsenic and Selenium in Water and Sediment by Graphite Furnace-Atomic Absorption Spectrometry. 1999. USGS.

[50] Open File Report 98-165, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Elements in Whole-water Digests Using Inductively Coupled Plasma-Optical Emission Spectrometry and Inductively Coupled Plasma-Mass Spectrometry. 1998. USGS.

[51] Open File Report 93-125, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Inorganic and Organic Constituents in Water and Fluvial Sediments. 1993. USGS.

[52] Unless otherwise indicated, all EPA methods, excluding EPA Method 300.1, are published in U.S. EPA. May 1994. Methods for the Determination of Metals in Environmental Samples, Supplement I, EPA/600/R-94/111; or U.S. EPA. August 1993. Methods for the Determination of Inorganic Substances in Environmental Samples, EPA/600/R-93/100. EPA Method 300.1 is U.S. EPA. Revision 1.0, 1997, including errata cover sheet April 27, 1999. Determination of Inorganic Ions in Drinking Water by Ion Chromatography.

[53] Styrene divinyl benzene beads (e.g., AMCO-AEPA-1 or equivalent) and stabilized formazin (e.g., Hach StablCal^{TM} or equivalent) are acceptable substitutes for formazin.

[54] Method D6508-15, Test Method for Determination of Dissolved Inorganic Anions in Aqueous Matrices Using Capillary Ion Electrophoresis and Chromate Electrolyte. 2015. ASTM

[55] Kelada-01, Kelada Automated Test Methods for Total Cyanide, Acid Dissociable Cyanide, and Thiocyanate, EPA 821-B-01-009, Revision 1.2, August 2001. U.S. EPA. Note: A 450-W UV lamp may be used in this method instead of the 550-W lamp specified if it provides performance within the quality control (QC) acceptance criteria of the method in a given instrument. Similarly, modified flow cell configurations and flow conditions may be used in the method, provided that the QC acceptance criteria are met.

[56] QuikChem Method 10-204-00-1-X, Digestion and Distillation of Total Cyanide in Drinking and Wastewaters using MICRO DIST and Determination of Cyanide by Flow Injection Analysis. Revision 2.2, March 2005. Lachat Instruments.

[57] When using sulfide removal test procedures described in EPA Method 335.4-1, reconstitute particulate that is filtered with the sample prior to distillation.

[58] Unless otherwise stated, if the language of this table specifies a sample digestion and/or distillation “followed by” analysis with a method, approved digestion and/or distillation are required prior to analysis.

[59] Samples analyzed for available cyanide using OI Analytical method OIA-1677-09 or ASTM method D6888-16 that contain particulate matter may be filtered only after the ligand exchange reagents have been added to the samples, because the ligand exchange process converts complexes containing available cyanide to free cyanide, which is not removed by filtration. Analysts are further cautioned to limit the time between the addition of the ligand exchange reagents and sample filtration to no more than 30 minutes to preclude settling of materials in samples.

[60] Analysts should be aware that pH optima and chromophore absorption maxima might differ when phenol is replaced by a substituted phenol as the color reagent in Berthelot Reaction (“phenol-hypochlorite reaction”) colorimetric ammonium determination methods. For example, when phenol is used as the color reagent, pH

optimum and wavelength of maximum absorbance are about 11.5 and 635 nm, respectively - see, Patton, C.J. and S.R. Crouch. March 1977. *Anal. Chem.* 49:464-469. These reaction parameters increase to pH > 12.6 and 665 nm when salicylate is used as the color reagent - see, Krom, M.D. April 1980. *The Analyst* 105:305-316.

[61] If atomic absorption or ICP instrumentation is not available, the aluminon colorimetric method detailed in the 19th Edition of *Standard Methods for the Examination of Water and Wastewater* may be used. This method has poorer precision and bias than the methods of choice.

[62] Easy (1-Reagent) Nitrate Method, Revision November 12, 2011. Craig Chinchilla.

[63] Hach Method 10360, Luminescence Measurement of Dissolved Oxygen in Water and Wastewater and for Use in the Determination of BOD_5 and $CBOD_5$. Revision 1.2, October 2011. Hach Company. This method may be used to measure dissolved oxygen when performing the methods approved in Table IB for measurement of biochemical oxygen demand (BOD) and carbonaceous biochemical oxygen demand (CBOD).

[64] In-Situ Method 1002-8-2009, Dissolved Oxygen (DO) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[65] Mitchell Method M5331, Determination of Turbidity by Nephelometry. Revision 1.0, July 31, 2008. Leck Mitchell.

[66] Mitchell Method M5271, Determination of Turbidity by Nephelometry. Revision 1.0, July 31, 2008. Leck Mitchell.

[67] Orion Method AQ4500, Determination of Turbidity by Nephelometry. Revision 5, March 12, 2009. Thermo Scientific.

[68] EPA Method 200.5, Determination of Trace Elements in Drinking Water by Axially Viewed Inductively Coupled Plasma-Atomic Emission Spectrometry, EPA/600/R-06/115. Revision 4.2, October 2003. U.S. EPA.

[69] Method 1627, Kinetic Test Method for the Prediction of Mine Drainage Quality, EPA-821-R-09-002. December 2011. U.S. EPA.

[70] Techniques and Methods Book 5-B1, Determination of Elements in Natural-Water, Biota, Sediment and Soil Samples Using Collision/Reaction Cell Inductively Coupled Plasma-Mass Spectrometry, Chapter 1, Section B, Methods of the National Water Quality Laboratory, Book 5, Laboratory Analysis, 2006. USGS.

[71] Water-Resources Investigations Report 01-4132, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Organic Plus Inorganic Mercury in Filtered and Unfiltered Natural Water with Cold Vapor-Atomic Fluorescence Spectrometry, 2001. USGS.

[72] USGS Techniques and Methods 5-B8, Chapter 8, Section B, Methods of the National Water Quality Laboratory Book 5, Laboratory Analysis, 2011 USGS.

[73] NECi Method N07-0003, “Nitrate Reductase Nitrate-Nitrogen Analysis,” Revision 9.0, March 2014, The Nitrate Elimination Co., Inc.

[74] Timberline Instruments, LLC Method Ammonia-001, “Determination of Inorganic Ammonia by Continuous Flow Gas Diffusion and Conductivity Cell Analysis,” June 2011, Timberline Instruments, LLC.

[75] Hach Company Method 10206, “Spectrophotometric Measurement of Nitrate in Water and Wastewater,” Revision 2.1, January 2013, Hach Company.

[76] Hach Company Method 10242, “Simplified Spectrophotometric Measurement of Total Kjeldahl Nitrogen in Water and Wastewater,” Revision 1.1, January 2013, Hach Company.

[77] National Council for Air and Stream Improvement (NCASI) Method TNTP-W10900, “Total (Kjeldahl) Nitrogen and Total Phosphorus in Pulp and Paper Biologically Treated Effluent by Alkaline Persulfate Digestion,” June 2011, National Council for Air and Stream Improvement, Inc.

[78] The pH adjusted sample is to be adjusted to 7.6 for NPDES reporting purposes.

[79] I-2057-85 U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chap. A11989, Methods for Determination of Inorganic Substances in Water and Fluvial Sediments, 1989.

[80] Methods I-2522-90, I-2540-90, and I-2601-90 U.S. Geological Survey Open-File Report 93-125, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory-Determination of Inorganic and Organic Constituents in Water and Fluvial Sediments, 1993.

[81] Method I-1472-97, U.S. Geological Survey Open-File Report 98-165, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory-Determination of Inorganic and Organic Constituents in Water and Fluvial Sediments, 1998.

[82] FIAlab Instruments, Inc. Method FIAlab 100, “Determination of Inorganic Ammonia by Continuous Flow Gas Diffusion and Fluorescence Detector Analysis”, April 4, 2018, FIAlab Instruments, Inc.

[83] MACHEREY-NAGEL GmbH and Co. Method 036/038 NANOCOLOR® COD LR/HR, “Spectrophotometric Measurement of Chemical Oxygen Demand in Water and Wastewater”, Revision 1.5, May 2018, MACHEREY-NAGEL GmbH and Co. KG.

[84] Please refer to the following applicable Quality Control Sections: Part 2000 Methods, Physical and Aggregate Properties 2020 (2017); Part 3000 Methods, Metals, 3020 (2017); Part 4000 Methods, Inorganic Nonmetallic Constituents, 4020 (2014); Part 5000 Methods, and Aggregate Organic Constituents, 5020 (2017). These Quality Control Standards are available for download at *www.standardmethods.org* at no charge.

[85] Each laboratory may establish its own control limits by performing at least 25 glucose-glutamic acid (GGA) checks over several weeks or months and calculating the mean and standard deviation. The laboratory may then use the mean ± 3 standard deviations as the control limit for future GGA checks. However, GGA acceptance criteria can be no wider than 198 ± 30.5 mg/L for BOD_5. GGA acceptance criteria for CBOD must be either 198 ± 30.5 mg/L, or the lab may develop control charts under the following conditions:

- Dissolved oxygen uptake from the seed contribution is between 0.6-1.0 mg/L.

- Control charts are performed on at least 25 GGA checks with three standard deviations from the derived mean.

- The RSD must not exceed 7.5%.

- Any single GGA value cannot be less than 150 mg/L or higher than 250 mg/L.

Table IC - List of Approved Test Procedures for Non-Pesticide Organic Compounds

Parameter[1]	Method	EPA[27]	Standard methods	ASTM	Other
1. Acenaphthene	GC	610			
	GC/MS	625.1, 1625B	6410 B-2000		See footnote[9], p. 27.
	HPLC	610	6440 B-2005	D4657-92 (98)	
2. Acenaphthylene	GC	610			
	GC/MS	625.1, 1625B	6410 B-2000		See footnote[9], p. 27.
	HPLC	610	6440 B-2005	D4657-92 (98)	
3. Acrolein	GC	603			
	GC/MS	624.1,[4] 1624B			
4. Acrylonitrile	GC	603			

(xx) Water-Resources Investigation Report 01-4098, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Moderate-Use Pesticides and Selected Degradates in Water by C-18 Solid-Phase Extraction and Gas Chromatography/Mass Spectrometry. 2001. Table ID, Note 13.

(xxi) Water-Resources Investigations Report 01-4132, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Organic Plus Inorganic Mercury in Filtered and Unfiltered Natural Water With Cold Vapor-Atomic Fluorescence Spectrometry. 2001. Table IB, Note 71.

(xxii) Water-Resources Investigation Report 01-4134, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory - Determination of Pesticides in Water by Graphitized Carbon-Based Solid-Phase Extraction and High-Performance Liquid Chromatography/Mass Spectrometry. 2001. Table ID, Note 12.

(xxiii) Water Temperature - Influential Factors, Field Measurement and Data Presentation, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1. 1975. Table IB, Note 32.

(39) Waters Corporation, 34 Maple Street, Milford MA 01757, Telephone: 508-482-2131, Fax: 508-482-3625.

(i) Method D6508, Test Method for Determination of Dissolved Inorganic Anions in Aqueous Matrices Using Capillary Ion Electrophoresis and Chromate Electrolyte. Revision 2, December 2000. Table IB, Note 54.

(ii) [Reserved]

(c) Under certain circumstances, the Director may establish limitations on the discharge of a parameter for which there is no test procedure in this part or in 40 CFR parts 405 through 499. In these instances the test procedure shall be specified by the Director.

(d) Under certain circumstances, the Administrator may approve additional alternate test procedures for nationwide use, upon recommendation by the Alternate Test Procedure Program Coordinator, Washington, DC.

(e) Sample preservation procedures, container materials, and maximum allowable holding times for parameters are cited in Tables IA, IB, IC, ID, IE, IF, IG, and IH are prescribed in Table II. Information in the table takes precedence over information in specific methods or elsewhere. Any person may apply for a change from the prescribed preservation techniques, container materials, and maximum holding times applicable to samples taken from a specific discharge. Applications for such limited use changes may be made by letters to the Regional Alternative Test Procedure (ATP) Program Coordinator or the permitting authority in the Region in which the discharge will occur. Sufficient data should be provided to assure such changes in sample preservation, containers or holding times do not adversely affect the integrity of the sample. The Regional ATP Coordinator or permitting authority will review the application and then notify the applicant and the appropriate State agency of approval or rejection of the use of the alternate test procedure. A decision to approve or deny any request on deviations from the prescribed Table II requirements will be made within 90 days of receipt of the application by the Regional Administrator. An analyst may not modify any sample preservation and/or holding time requirements of an approved method unless the requirements of this section are met.

Table II - Required Containers, Preservation Techniques, and Holding Times

Parameter number/name	**Container [1]**	**Preservation [2] [3]**	**Maximum holding time [4]**
Table IA - Bacterial Tests			
1-4. Coliform, total, fecal, and *E. coli*	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ [5]	8 hours.[22] [23]
5. Fecal streptococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ [5]	8 hours.[22]
6. Enterococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ [5]	8 hours.[22]
7. *Salmonella*	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ [5]	8 hours.[22]
Table IA - Aquatic Toxicity Tests			
8-11. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C [16]	36 hours.
Table IB - Inorganic Tests			
1. Acidity	P, FP, G	Cool, ≤6 °C [18]	14 days.
2. Alkalinity	P, FP, G	Cool, ≤6 °C [18]	14 days.

Parameter number/name	Container [1]	Preservation [2 3]	Maximum holding time [4]
4. Ammonia	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C [18]	48 hours.
10. Boron	P, FP, or Quartz	HNO_3 to pH <2	6 months.
11. Bromide	P, FP, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C [18]	48 hours.
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
16. Chloride	P, FP, G	None required	28 days.
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
21. Color	P, FP, G	Cool, ≤6 °C [18]	48 hours.
23-24. Cyanide, total or available (or CATC) and free	P, FP, G	Cool, ≤6 °C [18], NaOH to pH >10 [5 6], reducing agent if oxidizer present	14 days.
25. Fluoride	P	None required	28 days.
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH <2	6 months.
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
Table IB - Metals [7]			
18. Chromium VI	P, FP, G	Cool, ≤6 °C [18], pH = 9.3-9.7 [20]	28 days.
35. Mercury (CVAA)	P, FP, G	HNO_3 to pH <2	28 days.
35. Mercury (CVAFS)	FP, G; and FP-lined cap [17]	5 mL/L 12N HCl or 5 mL/L BrCl [17]	90 days.[17]
3, 5-8, 12, 13, 19, 20, 22, 26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62, 63, 70-72, 74, 75. Metals, except boron, chromium VI, and mercury	P, FP, G	HNO_3 to pH <2, or at least 24 hours prior to analysis [19]	6 months.
38. Nitrate	P, FP, G	Cool, ≤6 °C [18]	48 hours.
39. Nitrate-nitrite	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
40. Nitrite	P, FP, G	Cool, ≤6 °C [18]	48 hours.

Parameter number/name	Container [1]	Preservation [2] [3]	Maximum holding time [4]
41. Oil and grease	G	Cool to ≤6 °C [18], HCl or H_2SO_4 to pH <2	28 days.
42. Organic Carbon	P, FP, G	Cool to ≤6 °C [18], HCl, H_2SO_4, or H_3PO_4 to pH <2	28 days.
44. Orthophosphate	P, FP, G	Cool, to ≤6 °C [18] [24]	Filter within 15 minutes; Analyze within 48 hours.
46. Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes.
47. Winkler	G, Bottle and top	Fix on site and store in dark	8 hours.
48. Phenols	G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
49. Phosphorus (elemental)	G	Cool, ≤6 °C [18]	48 hours.
50. Phosphorus, total	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2	28 days.
53. Residue, total	P, FP, G	Cool, ≤6 °C [18]	7 days.
54. Residue, Filterable (TDS)	P, FP, G	Cool, ≤6 °C [18]	7 days.
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C [18]	7 days.
56. Residue, Settleable	P, FP, G	Cool, ≤6 °C [18]	48 hours.
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C [18]	7 days.
61. Silica	P or Quartz	Cool, ≤6 °C [18]	28 days.
64. Specific conductance	P, FP, G	Cool, ≤6 °C [18]	28 days.
65. Sulfate	P, FP, G	Cool, ≤6 °C [18]	28 days.
66. Sulfide	P, FP, G	Cool, ≤6 °C [18], add zinc acetate plus sodium hydroxide to pH >9	7 days.
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes.
68. Surfactants	P, FP, G	Cool, ≤6 °C [18]	48 hours.
69. Temperature	P, FP, G	None required	Analyze within 15 minutes.
73. Turbidity	P, FP, G	Cool, ≤6 °C [18]	48 hours.

Table IC - Organic Tests [8]

Parameter number/name	Container [1]	Preservation [2 3]	Maximum holding time [4]
13, 18-20, 22, 24, 25, 27, 28, 34-37, 39-43, 45-47, 56, 76, 104, 105, 108-111, 113. Purgeable Halocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], HCl to pH 2 [9]	14 days.[9]
26. 2-Chloroethylvinyl ether	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], HCl to pH 2 [9]	14 days.[9]
3, 4. Acrolein and acrylonitrile	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$, pH to 4-5 [10]	14 days.[10]
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols [11]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$	7 days until extraction, 40 days after extraction.
7, 38. Benzidines [11 12]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	7 days until extraction.[13]
14, 17, 48, 50-52. Phthalate esters [11]	G, FP-lined cap	Cool, ≤6 °C [18]	7 days until extraction, 40 days after extraction.
82-84. Nitrosamines [11 14]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction.
88-94. PCBs [11]	G, FP-lined cap	Cool, ≤6 °C [18]	1 year until extraction, 1 year after extraction.
54, 55, 75, 79. Nitroaromatics and isophorone [11]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction.
1, 2, 5, 8-12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons [11]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction.
15, 16, 21, 31, 87. Haloethers [11]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction.

Parameter number/name	**Container[1]**	**Preservation[2][3]**	**Maximum holding time[4]**
29, 35-37, 63-65, 73, 107. Chlorinated hydrocarbons[11]	G, FP-lined cap	Cool, ≤6 °C[18]	7 days until extraction, 40 days after extraction.
60-62, 66-72, 85, 86, 95-97, 102, 103. CDDs/CDFs[11]	G	See footnote 11	See footnote 11.
Aqueous Samples: Field and Lab Preservation	G	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5], pH <9	1 year.
Solids and Mixed-Phase Samples: Field Preservation	G	Cool, ≤6 °C[18]	7 days.
Tissue Samples: Field Preservation	G	Cool, ≤6 °C[18]	24 hours.
Solids, Mixed-Phase, and Tissue Samples: Lab Preservation	G	Freeze, ≤−10 °C	1 year.
114-118. Alkylated phenols	G	Cool, <6 °C, H_2SO_4 to pH <2	28 days until extraction, 40 days after extraction.
119. Adsorbable Organic Halides (AOX)	G	Cool, <6 °C, 0.008% $Na_2S_2O_3$, HNO_3 to pH <2	Hold *at least* 3 days, but not more than 6 months.
120. Chlorinated Phenolics	G, FP-lined cap	Cool, <6 °C, 0.008% $Na_2S_2O_3$, H_2SO_4 to pH <2	30 days until acetylation, 30 days after acetylation.
Table ID - Pesticides Tests			
1-70. Pesticides[11]	G, FP-lined cap	Cool, ≤6 °C[18], pH 5-9[15]	7 days until extraction, 40 days after extraction.
Table IE - Radiological Tests			
1-5. Alpha, beta, and radium	P, FP, G	HNO_3 to pH <2	6 months.
Table IH - Bacterial Tests			
1, 2. Coliform, total, fecal	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$[5]	8 hours.[22]
3.*E. coli*	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$[5]	8 hours.[22]
4. Fecal streptococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$[5]	8 hours.[22]
5. Enterococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$[5]	8 hours.[22]

Parameter number/name	Container [1]	Preservation [2] [3]	Maximum holding time [4]
Table IH - Protozoan Tests			
6. *Cryptosporidium*	LDPE; field filtration	1-10 °C	96 hours.[21]
7. *Giardia*	LDPE; field filtration	1-10 °C	96 hours.[21]

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

[2] Except where noted in this Table II and the method for the parameter, preserve each grab sample within 15 minutes of collection. For a composite sample collected with an automated sample (e.g., using a 24-hour composite sample; see 40 CFR 122.21(g)(7)(i) or 40 CFR part 403, appendix E), refrigerate the sample at ≤6 °C during collection unless specified otherwise in this Table II or in the method(s). For a composite sample to be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤6 °C, unless specified otherwise in this Table II or in the method(s), until collection, splitting, and preservation is completed. Add the preservative to the sample container prior to sample collection when the preservative will not compromise the integrity of a grab sample, a composite sample, or aliquot split from a composite sample within 15 minutes of collection. If a composite measurement is required but a composite sample would compromise sample integrity, individual grab samples must be collected at prescribed time intervals (e.g., 4 samples over the course of a day, at 6-hour intervals). Grab samples must be analyzed separately and the concentrations averaged. Alternatively, grab samples may be collected in the field and composited in the laboratory if the compositing procedure produces results equivalent to results produced by arithmetic averaging of results of analysis of individual grab samples. For examples of laboratory compositing procedures, see EPA Method 1664 Rev. A (oil and grease) and the procedures at 40 CFR 141.24(f)(14)(iv) and (v) (volatile organics).

[3] When any sample is to be shipped by common carrier or sent via the U.S. Postal Service, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirement of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater; Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before the start of analysis and still be considered valid. Samples may be held for longer periods only if the permittee or monitoring laboratory have data on file to show that, for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional ATP Coordinator under § 136.3(e). For a grab sample, the holding time begins at the time of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR part 403, appendix E), the holding time begins at the time of the end of collection of the composite sample. For a set of grab samples composited in the field or laboratory, the holding time begins at the time of collection of the last grab sample in the set. Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if it knows that a shorter time is necessary to maintain sample stability. See § 136.3(e) for details. The date and time of collection of an individual grab sample is the date and time at which the sample is collected. For a set of grab samples to be composited, and that are all collected on the same calendar date, the date of collection is the date on which the samples are collected. For a set of grab samples to be composited, and that are collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14-15. For a composite sample collected automatically on a given date, the date of collection is the date on which the sample is collected. For a composite sample collected automatically, and that is collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14-15. For static-renewal toxicity tests, each grab or composite sample may also be used to prepare test solutions for renewal at 24 h, 48 h, and/or 72 h after first use, if stored at 0-6 °C, with minimum head space.

[5] ASTM D7365-09a specifies treatment options for samples containing oxidants (e.g., chlorine) for cyanide analyses. Also, Section 9060A of Standard Methods for the Examination of Water and Wastewater (23rd edition) addresses dechlorination procedures for microbiological analyses.

[6] Sampling, preservation and mitigating interferences in water samples for analysis of cyanide are described in ASTM D7365-09a (15). There may be interferences that are not mitigated by the analytical test methods or D7365-09a (15). Any technique for removal or suppression of interference may be employed, provided the laboratory demonstrates that it more accurately measures cyanide through quality control measures described in the analytical test method. Any removal or suppression technique not described in D7365-09a (15) or the analytical test method must be documented along with supporting data.

[7] For dissolved metals, filter grab samples within 15 minutes of collection and before adding preservatives. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR part 403, appendix E), filter the sample within 15 minutes after completion of collection and before adding preservatives. If it is known or suspected that dissolved sample integrity will be compromised during collection of a composite sample collected automatically over time (e.g., by interchange of a metal between dissolved and suspended forms), collect and filter grab samples to be composited (footnote 2) in place of a composite sample collected automatically.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] If the sample is not adjusted to pH 2, then the sample must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity (*i.e.,* use all necessary preservatives and hold for the shortest time listed). When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to ≤6 °C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (regarding the requirement for thiosulfate reduction), and footnotes 12, 13 (regarding the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 30 days at <0 °C.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Place sufficient ice with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, immediately measure the temperature of the samples and confirm that the preservation temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature. Aqueous samples must not be frozen. Hand-delivered samples used on the day of collection do not need to be cooled to 0 to 6 °C prior to test initiation.

[17] Samples collected for the determination of trace level mercury (<100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. A sample collected for dissolved trace level mercury should be filtered in the laboratory within 24 hours of the time of collection. However, if circumstances preclude overnight shipment, the sample should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. If sample integrity will not be maintained by shipment to and filtration in the laboratory, the sample must be filtered in a designated clean area in the field within the time period necessary to maintain sample integrity. A sample that has been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

[18] Aqueous samples must be preserved at ≤6 °C, and should not be frozen unless data demonstrating that sample freezing does not adversely impact sample integrity is maintained on file and accepted as valid by the regulatory authority. Also, for purposes of NPDES monitoring, the specification of "≤ °C" is used in place of the "4 °C" and "<4 °C" sample temperature requirements listed in some methods. It is not necessary to measure the sample temperature to three significant figures (1/100th of 1 degree); rather, three significant figures are specified so that rounding down to 6 °C may not be used to meet the ≤6 °C requirement. The preservation temperature does not apply to samples that are analyzed immediately (less than 15 minutes).

[19] An aqueous sample may be collected and shipped without acid preservation. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. If the sample must be analyzed within 24 hours of collection, add the acid immediately (see footnote 2). Soil and sediment samples do not need to be preserved with acid. The allowances in this footnote supersede the preservation and holding time requirements in the approved metals methods.

[20] To achieve the 28-day holding time, use the ammonium sulfate buffer solution specified in EPA Method 218.6. The allowance in this footnote supersedes preservation and holding time requirements in the approved hexavalent chromium methods, unless this supersession would compromise the measurement, in which case requirements in the method must be followed.

[21] Holding time is calculated from time of sample collection to elution for samples shipped to the laboratory in bulk and calculated from the time of sample filtration to elution for samples filtered in the field.

[22] Sample analysis should begin as soon as possible after receipt; sample incubation must be started no later than 8 hours from time of collection.

[23] For fecal coliform samples for sewage sludge (biosolids) only, the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB-EC) or 1681 (A-1): Class A composted, Class B aerobically digested, and Class B anaerobically digested.

[24] The immediate filtration requirement in orthophosphate measurement is to assess the dissolved or bio-available form of orthophosphorus (*i.e.,* that which passes through a 0.45-micron filter), hence the requirement to filter the sample immediately upon collection (*i.e.,* within 15 minutes of collection).

[38 FR 28758, Oct. 16, 1973]

EDITORIAL NOTE

Editorial Note: For Federal Register citations affecting § 136.3, see the List of CFR Sections Affected, which appears in the Finding Aids section of the printed volume and at *www.govinfo.gov*.

Section 11

Safety

Safety

Biological Natural Systems

Safety

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

General Duty Clause

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

Before Leaving the Yard

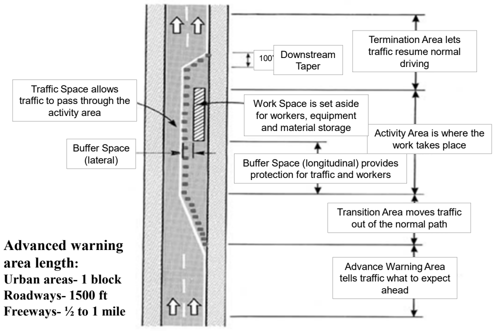
- Work assignments
- Equipment needs
- Equipment inspection
- Vehicle inspection
    - When backing up a truck, one person should always be at the rear of the truck in view of the driver
    - Mirrors and windows
    - Lights and horn
    - Brakes
    - Tires
    - Trailer hitch/safety chain

Traffic Safety

Traffic Control Zones

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

Traffic Control Zones



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

Manhole Hazards

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

Onsite/Decentralized Systems

EPA Guidelines for Management of Onsite/Decentralized WW Systems

- Onsite systems are often significant contributors of pathogens and nutrients
- U.S. Bureau of Census indicated at least 10% have stopped working
    - 70% failure rate in some communities
- Failing systems are the 3rd most common source of groundwater contamination

OSHA Guidelines for safely entering and cleaning sewage tanks

- Atmospheric hazards
    - Oxygen deficiency, flammable or toxic gases
    - Gases detectable only by properly calibrated instruments
- Biological hazards
    - Pathogens – bacteria, viruses, protozoa, parasitic worms, fungi
    - Hepatitis, typhoid fever, dystentery, cholera
    - Inhaling or ingesting contaminated mists may result in serious illness

OSHA Guidelines for safely entering and cleaning sewage tanks

- Physical hazards
    - Slips, trips, falls due to slippery and sloping surfaces
    - Limited access and egress
    - Corroded ladder rungs
    - Risk of punctures and cuts from sharp edges
- Mechanical hazards
    - Energized equipment, rotating machinery, waste stream leaks
- Chemical hazards
    - Ammonium compounds, formaldehyde, chlorine products, odor control and sewage-biodegrading enzymes, pharmaceutical drugs, hormones, and heavy metals

Confined Space

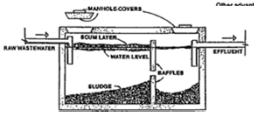
Confined Space Conditions

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

Confined Space Examples

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

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



Equipment Needed for Confined Spaces

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

Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus

Permit Required Confined Space

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

Atmospheric Hazards

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

Hydrogen Sulfide – H_2S

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

Hydrogen Sulfide – H_2S

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

Hydrogen Sulfide – H_2S

Methane Gas – CH_4

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

Methane Gas – CH_4

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

Carbon Monoxide - CO

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

Carbon Monoxide - CO

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

Carbon Monoxide - CO

Carbon Monoxide poisoning

Canaries used to CO detection

Oxygen – O_2

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

Oxygen – O_2

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

Oxygen – O_2

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

Oxygen – O_2

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

Atmospheric Alarm Units

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

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

Atmospheric Alarm Units

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

Atmospheric Alarm Units

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

Safety Procedures if Explosive Atmosphere Discovered

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

Ventilation

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

Infectious Disease Hazards

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

Best method of protection is person cleanliness!

Lockout / Tagout

LOTO General Requirements

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

Requirements for Lockout of Equipment

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

Recommend Steps for Lockout/Tagout

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

Lockout/Tagout

Steps for Restoring Equipment

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

Training Requirements

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

Inspections

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

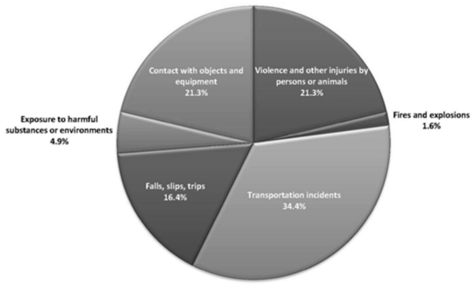
Required Record Keeping

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

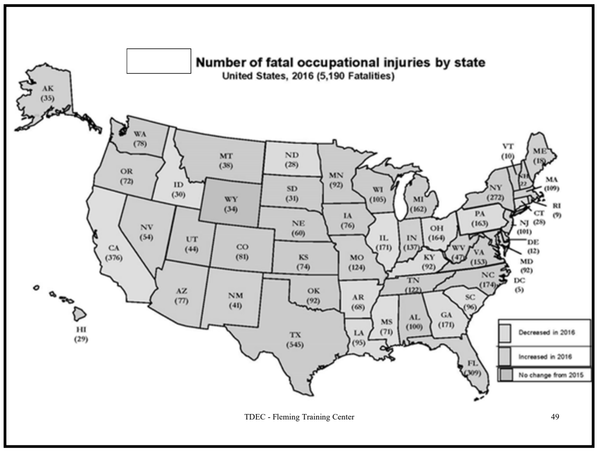
Most Cited Industry Standards By TOSHA

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

Percent distribution of workplace fatal injuries by event or exposure
Tennessee, 2016 (122 fatalities)

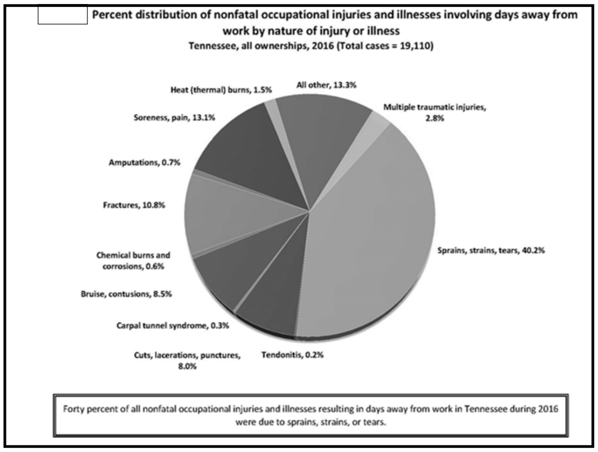


During 2016 in Tennessee there were 42 (34 percent) work-related fatalities due to transportation incidents. These events resulted in 34 percent of all fatal work-related injuries during the calendar year.



Number of fatal occupational injuries by state

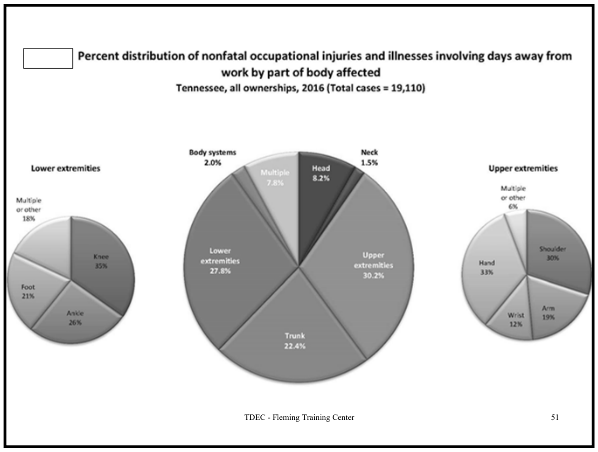
United States, 2016 (5,190 Fatalities)



Percent distribution of nonfatal occupational injuries and illnesses involving days away from work by nature of injury or illness

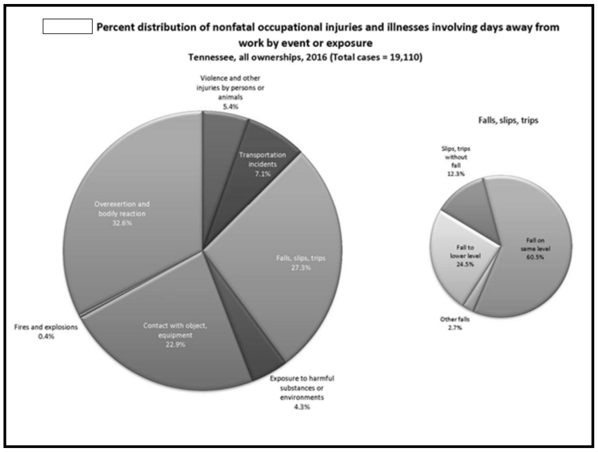
Tennessee, all ownerships, 2016 (Total cases = 19,110)

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



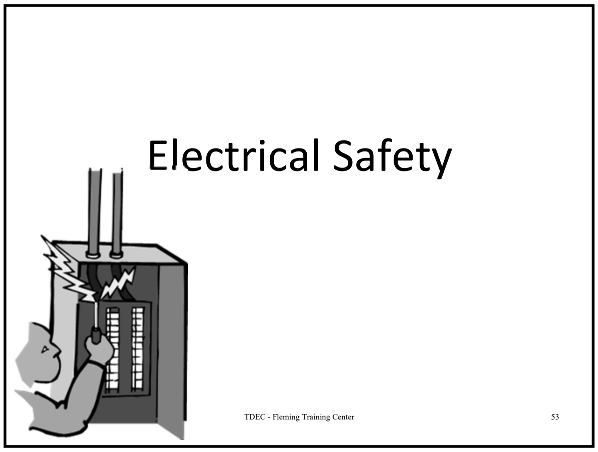
Percent distribution of nonfatal occupational injuries and illnesses involving days away from work by part of body affected

Tennessee, all ownerships, 2016 (Total cases = 19,110)



Percent distribution of nonfatal occupational injuries and illnesses involving days away from work by event or exposure

Tennessee, all ownerships, 2016 (Total cases = 19,110)



Electrical Safety

OSHA Says

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

Fire Protection

Fire Protection Equipment

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

Types of Fire Extinguishers

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

Types of Fire Extinguishers

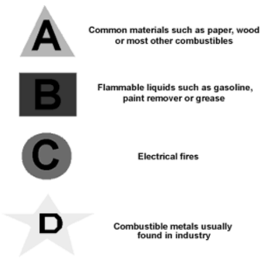
- Class C
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

Types of Fire Extinguishers

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

Types of Fire Extinguishers

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

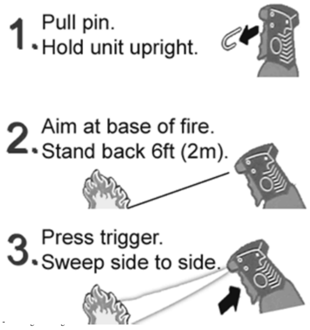


Fire Extinguishers

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

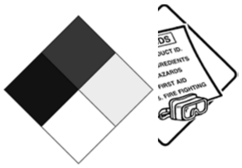
Fire Extinguishers

Combo Extinguisher



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

Chemical Safety

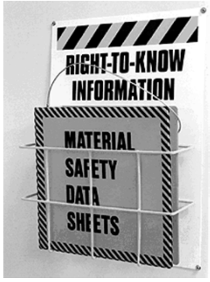


Personal Protective Equipment

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

Safety Data Sheets

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



MSDS to SDS

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

Minimum Info for SDS

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

* Non mandatory

MSDS to SDS

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

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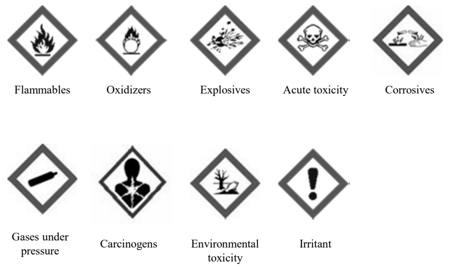
OSHA Pictograms



NFPA

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

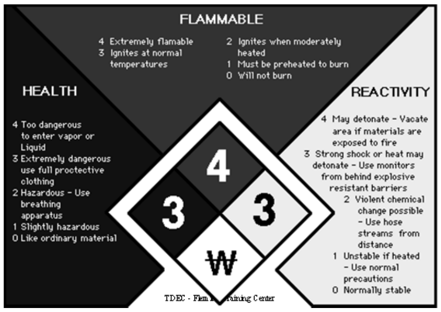
RTK Labels

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

Degrees of Hazard

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

Chemical Label



Terms

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

Trenching

Trenching Basics

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

Trenching Basics

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

Any Questions?

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. C
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 12

Cross Connection Control

Cross-Connection Control

TN Department of Environment & Conservation

Outline

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

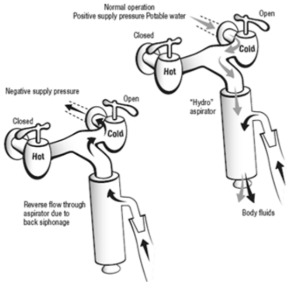
Backflow Case Study

Human Blood in the Water System

Blood observed in drinking fountains at a funeral home

Hydraulic aspirator used to drain body fluids during embalming

Contamination caused by low water pressure while aspirator was in use



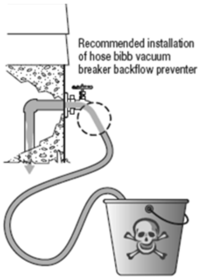
Backflow Case Study

Kool-Aid Laced with Chlordane

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

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

A dozen children and three adults became sick



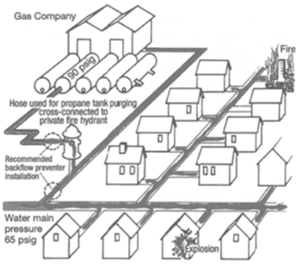
Backflow Case Study

Propane Gas in the Water Mains

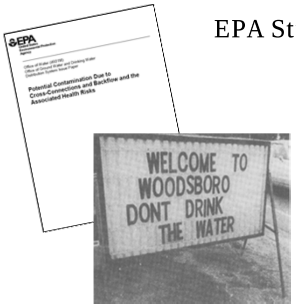
Gas company initiated repairs on 30,000 gallon liquid propane tank by flushing with fire hydrant

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

Hundreds evacuated, two homes caught fire, water supply contaminated



Backflow Case Study

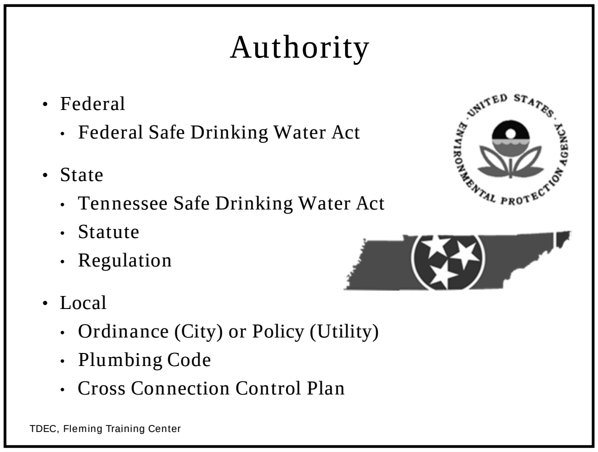


EPA Study

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

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

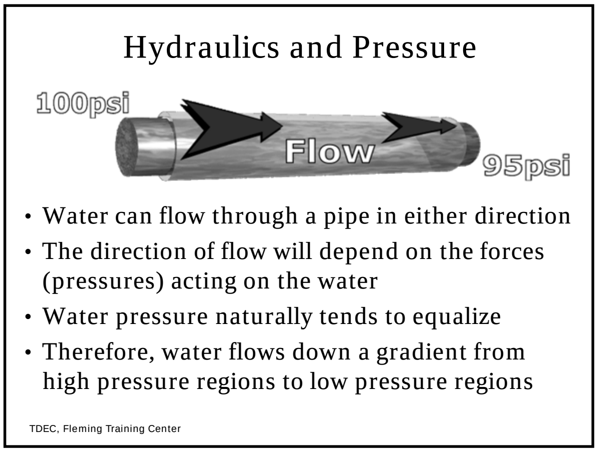
Backflow incidents can result in property damage, personal injury, and even death



Authority

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

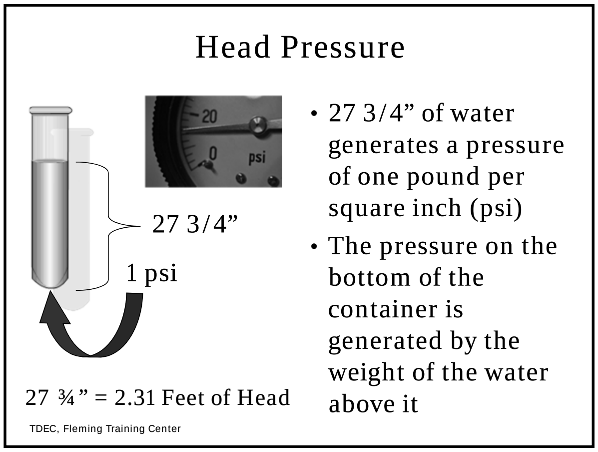
TDEC, Fleming Training Center



Hydraulics and Pressure

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

TDEC, Fleming Training Center

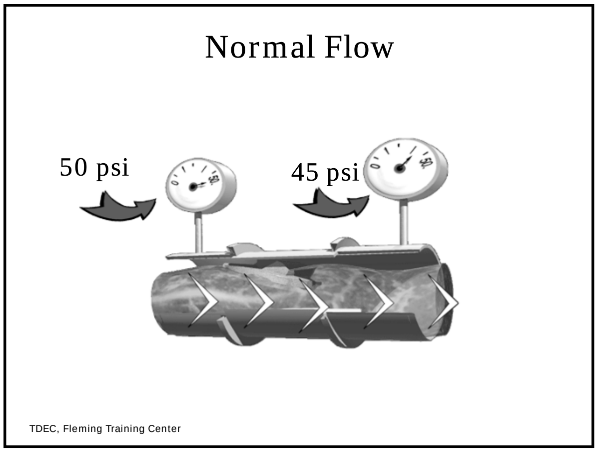


Head Pressure

27 ¾" = 2.31 Feet of Head

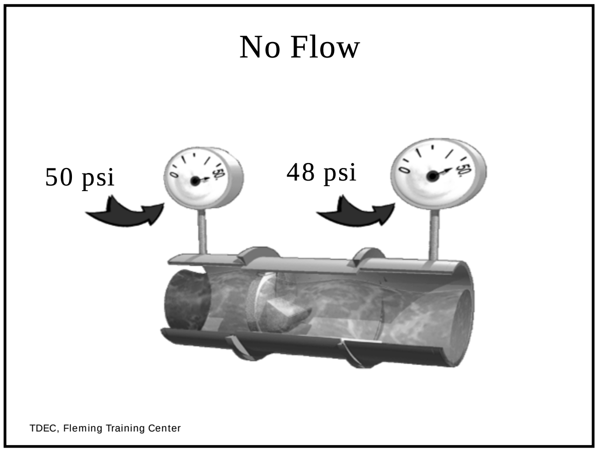
- 27 3/4" of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

TDEC, Fleming Training Center



Normal Flow

TDEC, Fleming Training Center



No Flow

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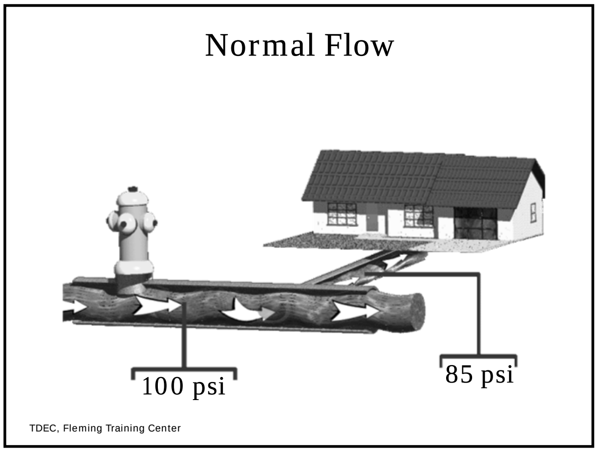
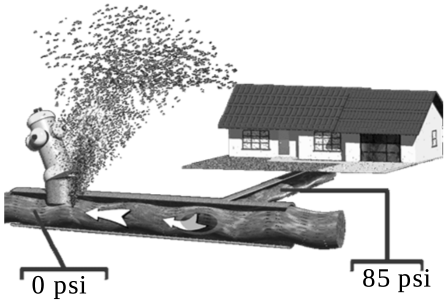


Normal Flow

TDEC, Fleming Training Center

Reverse Flow - Backflow



Backflow

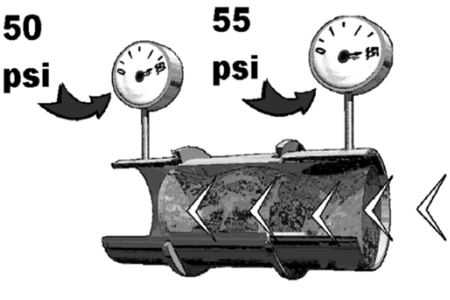
- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

Backpressure

- Pressure in downstream piping greater than supply pressure

Normal Direction of Flow

Backpressure



Backsiphonage

- Sub-atmospheric pressure in the water system

Normal Direction of Flow

Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

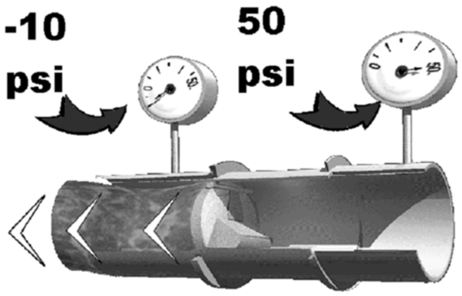
- As backsiphonage occurs air will be drawn up into the water pipes

Backsiphonage

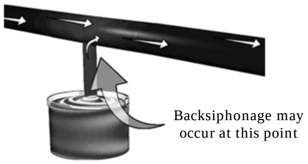
What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel...

Backsiphonage



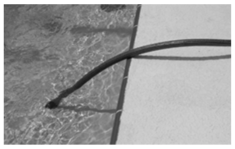
Aspirator Effect



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

Cross-Connection

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



Direct Cross-Connection

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

Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

Indirect Cross Connection

Submerged Inlet

Low Inlet

Low Inlet

Direct Cross Connection?

Degree of Hazard

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

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.

Five Means of Preventing Backflow

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

Air Gap

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

Air Gap

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

Air Gap Separation Limitations

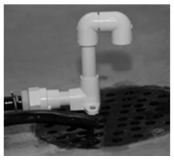
- The air gap is the best method of backflow prevention, but it is easily defeated through modifications or being bypassed
- The air gap separation causes a loss of pressure in the system
- Sanitary control is lost - cannot be installed in an environment containing airborne contamination

Approved Air Gap Separation

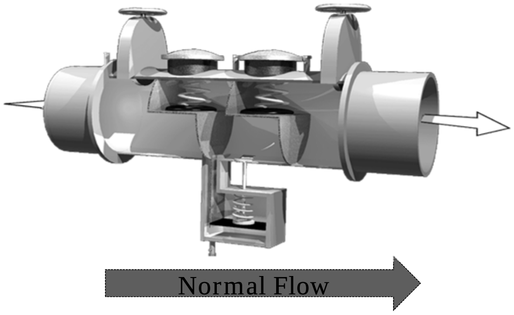
Backflow Protection Against:

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

BEST METHOD OF PROTECTION



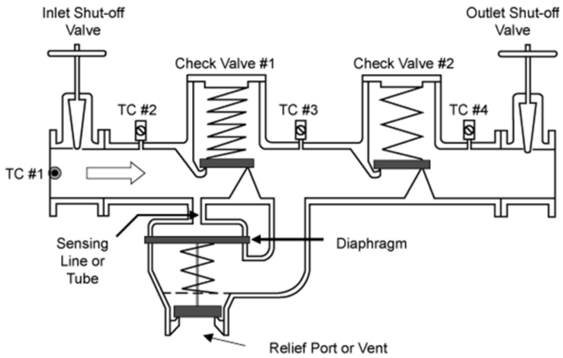
Reduced Pressure Principle Assembly



Reduced Pressure Principle Assembly

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

RP



RP

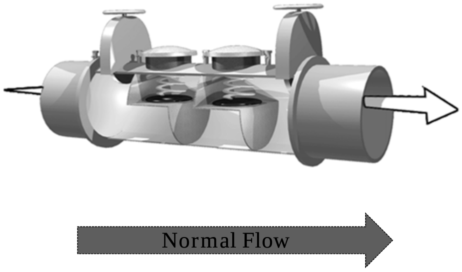
- The two check valves loaded in the closed position mechanically keep the water flowing in one direction through the assembly
- The relief valve assembly is designed to maintain a lower pressure in the zone between the two checks than in the supply side of the unit which hydraulically keeps the water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

RP

BEST DEVICE FOR PROTECTION

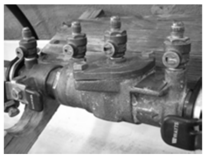
<u>Backflow Protection Against</u>:
- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

Double Check Valve Assembly (DC)



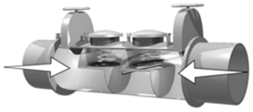
Double Check Valve Assembly (DC)

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



Double Check Valve Assembly (DC)

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



Second check fouled during backpressure

Double Check Valve Assembly (DC)

<u>Backflow Protection Against</u>:
- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

Proper Installation for DC and RP

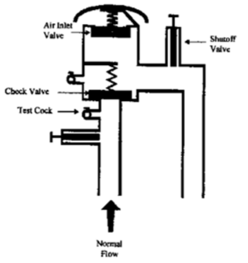
- Lowest part of the relief valve should be a minimum of 12 inches above either: the ground, the top of the opening of the enclosure wall, or the maximum flood level
  - Whichever is highest, in order to prevent any part of the assembly from becoming submerged
- Maximum 60" above grade to the center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

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

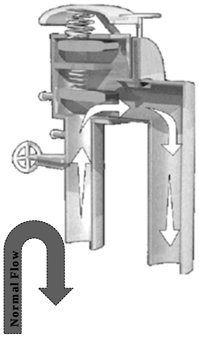
Proper Installation for DC and RP

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

Pressure Vacuum Breaker (PVB)

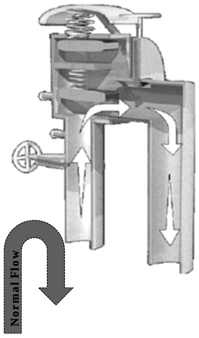


Pressure Vacuum Breaker (PVB)



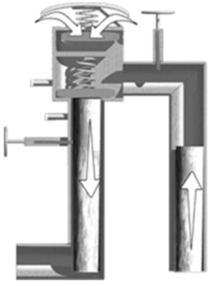
- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve loaded in the closed position and an independently operating air inlet valve loaded in the open position and located on the discharge side of the check valve, with tightly closing shutoff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

Pressure Vacuum Breaker (PVB)



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

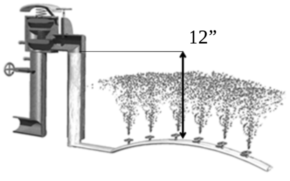
PVB Backsiphonage Condition



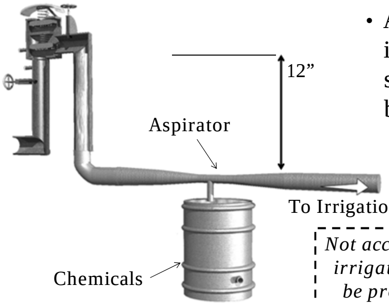
- In a backsiphonage condition there is a loss of supply pressure and the check valve is forced closed
- If the body loses pressure the air inlet valve is forced open allowing air into the body of the pressure vacuum breaker and breaking any siphon
- Only to be used to protect against backsiphonage

Installation of PVB

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



Pressure Vacuum Breaker

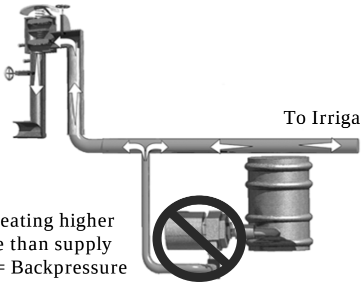


- Acceptable installation not subject to backpressure

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

Pressure Vacuum Breaker

- Improper installation subject to backpressure



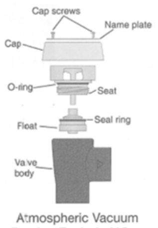
Pump creating higher pressure than supply pressure = Backpressure

Pressure Vacuum Breaker

<u>Backflow Protection Against</u>:

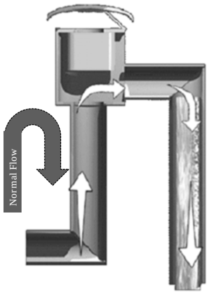
- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12” above downstream piping

Atmospheric Vacuum Breaker (AVB)



Atmospheric Vacuum Breaker Exploded View

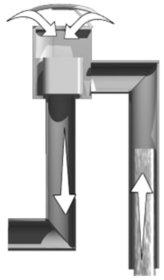
Atmospheric Vacuum Breaker (AVB)



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

Atmospheric Vacuum Breaker (AVB)

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

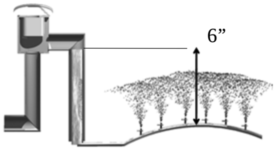


Loss of supply pressure

TDEC, Fleming Training Center

Installation of AVB

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



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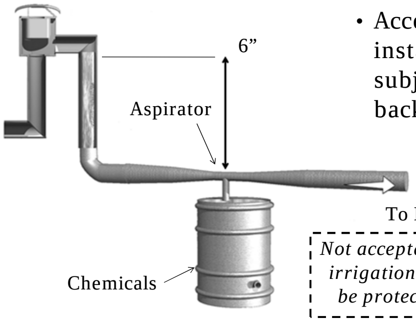
Atmospheric Vacuum Breaker



- Acceptable installation not subject to backpressure

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

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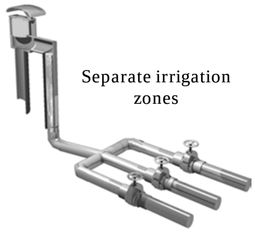
Atmospheric Vacuum Breaker

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



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Atmospheric Vacuum Breaker

<u>Backflow Protection Against</u>:

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

TDEC, Fleming Training Center

	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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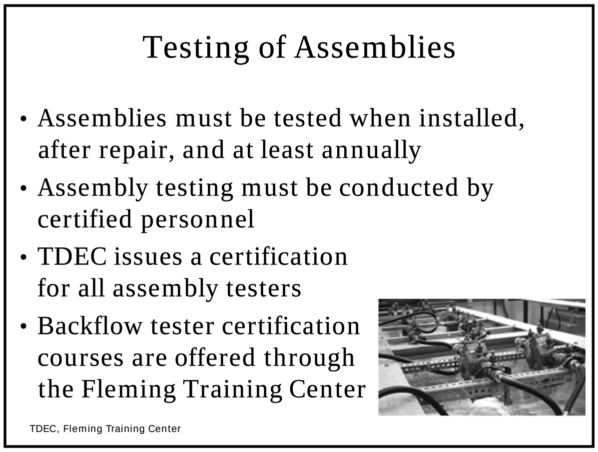

Testing of Assemblies

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

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Cross Connection Control

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

Cross Connection Vocabulary Words

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Check Valve – A mechanical device designed to allow flow in one direction only.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The RP is the best device for preventing backflow.

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

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

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

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

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

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

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

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

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

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

Cross-Connections Examples and Potential Hazards

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

Cross Connection Vocabulary

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

Word Bank

Differential pressure
Pollutant
Air Gap
Feed Water
Water Purveyor
Overflow Rim
Atmospheric Vacuum Breaker
Cross Connection

Reduced Pressure Principle Assembly
Pressure Vacuum Breaker
Auxiliary Supply
Check Valve
Backflow
Backsiphonage
Backpressure

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?

    -
    -
    -
    -
    -
    -
    -

Section 13

Pumps and Equipment

Maintenance

PUMPS

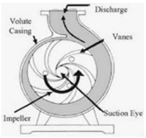
California State University: Sacramento

Necessity Of Pumps

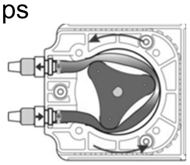
- Pumps are required when gravity cannot supply water with sufficient pressure to all parts of the distribution system
- Pumps account for the largest energy cost for a water supply operation

Types of Pumps

- Velocity Pumps



- Positive-Displacement Pumps

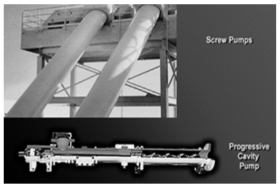


Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps
    - sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal

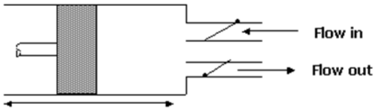
Positive-Displacement Pumps

- Chemical feed pumps
- Delivers a constant volume with each stroke
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**
- Types: piston, diaphragm, gear, or screw pump



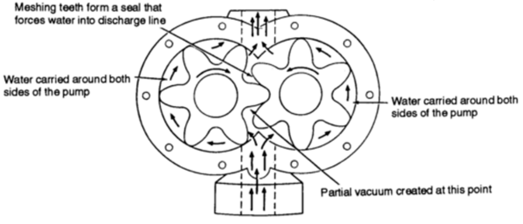
Positive-Displacement Pumps

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



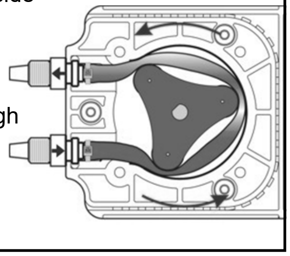
Positive-Displacement Pumps

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



Positive Displacement Pumps

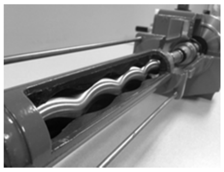
- Peristaltic Pump
  - Fluid to be pumped flows through flexible tube inside a pump casing
  - Rotor inside turns and compresses the tube
  - Rotor forces fluid through tube



Screw Pumps

Incline screw pumps handle large solids without plugging

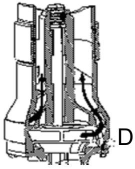
- Aka progressive cavity pumps
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point



Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water

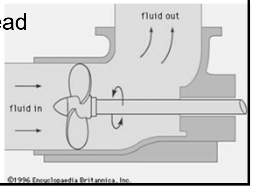
Volute



Diffuser

Velocity Pump Design Characteristics

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



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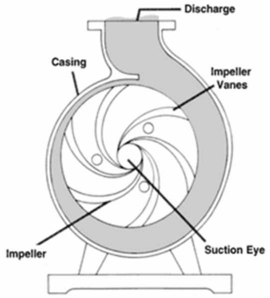
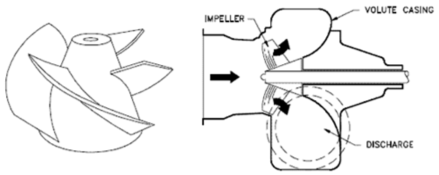
Velocity Pump Design Characteristics

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



Velocity Pump Design Characteristics

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



Centrifugal Pump

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

Centrifugal Pumps

- Volute-casing type most commonly used in water utilities
- Impeller rotates in casing - radial flow
- Single or multi-stage
- By varying size, shape, and width of impeller, a wide range of flows and pressures can be achieved

Advantages of Centrifugal Pumps

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

Single Volute

Disadvantages of Centrifugal Pumps

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

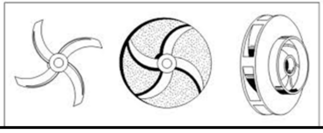
Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye

#1: If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



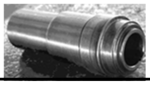
Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end

#2: Never pump a liquid for which the pump was not designed

Shaft and Sleeves

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.



Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.

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

Bearings

- Anti-friction devices for supporting and guiding pump and motor shafts
- Get noisy as they wear out
- If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

Let's Build a Centrifugal Pump

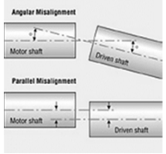
- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor

#4: See that pump and motor flanges are parallel and vertical and that they stay that way.

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

Misalignment of Pump & Motor



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

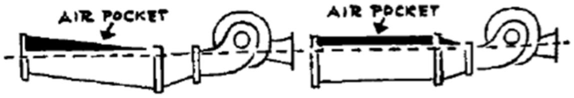
Common Pump & Motor Connections

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

Let's Build a Centrifugal Pump

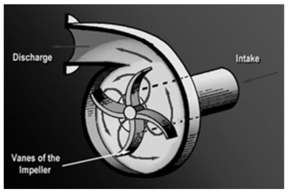
- Now we need a "straw" through which liquid can be sucked
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction

#5: Any down-sloping toward the pump in suction piping should be corrected



Let's Build a Centrifugal Pump

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



#6: See that piping puts absolutely no strain on the pump casing.

Mechanical Details of Centrifugal Pumps

- Casing
  - Housing surrounding the impeller; also called the volute
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape

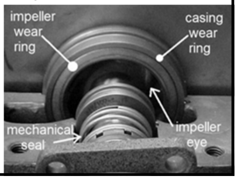
Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

Let's Build a Centrifugal Pump

- So we add wear rings to plug internal liquid leakage
  - Wear rings fill the gaps without having to move the parts of the pump closer together

#7: Never allow a pump to run dry. Water is a lubricant between the rings and impeller.



Wear Rings

- Restrict flow between impeller discharge and suction
- Leakage reduces pump efficiency
- Installed to protect the impeller and pump casing from excessive wear
- Provides a replaceable wearing surface
- Inspect regularly

#8: Examine wearing rings at regular intervals. When seriously worn, their replacement with greatly improve pump efficiency.

Let's Build a Centrifugal Pump

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

Stuffing Box

#9 – Packing should be replace periodically. Forcing in a ring or two of new packing instead of replacing worn packing is bad practice. It is apt to dislodge the seal cage.

#10 - Never tighten a gland more than necessary as excessive pressure will wear shaft sleeves unduly.

#11 – If shaft sleeves are badly scored, replace them immediately.

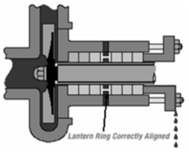
Let's Build a Centrifugal Pump

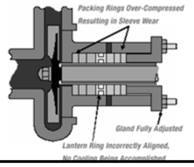
- To make packing more airtight, we add water seal piping
  - In the center of each stuffing box is a "seal cage"
  - This liquid acts both to block out air intake and to lubricate the packing
  - To control liquid flow, draw up the packing gland just tight enough to allow approximately one drop/second flow from the box

#12 – If the liquid being pumped contains grit, a separate source of sealing liquid should be obtained.

Lantern Rings

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





Packing Rings

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

Packing Rings

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

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

Mechanical Seals

- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- The operating temperature on a mechanical seal should never exceed 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

Mechanical Seals

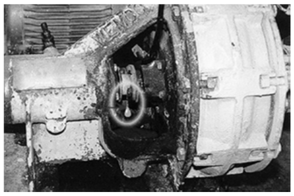
- Required instead of packing rings for suction head greater than 60 psi
- Prevents water from leaking along shaft, keeps air out of pump
  - Should not leak any water

Packing vs. Mechanical Seals

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

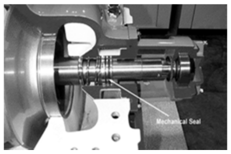
Packing Rings vs. Mechanical Seal

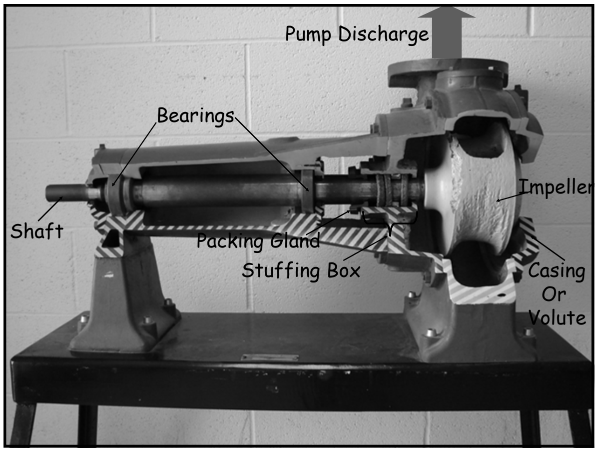
- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

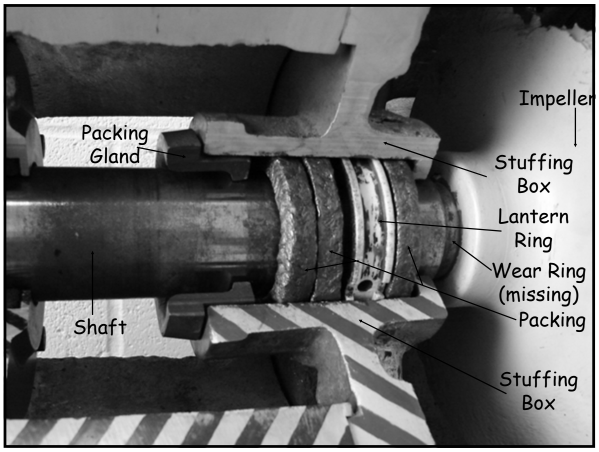


Mechanical Seal vs. Packing Rings

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







Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

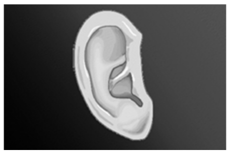
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

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

Monitoring Operational Variables

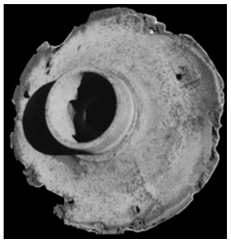
- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

Monitoring Operational Variables



- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound
- Best method to prevent it from occurring is to reduce the suction lift

Inspection and Maintenance

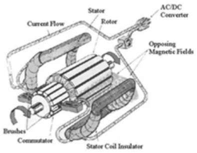
- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler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

Inspection: Impellers

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

This impeller was damaged by cavitation

Pump Won't Start?



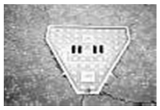
- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

Pump Safety

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

Pump Safety: Wet Wells

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



Any Questions?

Pumps, Motors, and Equipment Maintenance Vocabulary

1. A ________________________ is a safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
2. ______________________ describes the tiny indentations (dents) that occur high on the shoulder of the bearing race or bearing. A type of bearing failure.
3. A ____________________ is a protective device having a strip or wire of fusible metal that, when placed in a circuit, will melt and break the electric circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.
4. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve is known as ______________________. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. This is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.
5. _____________________ is the electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
6. The frequent starting and stopping of an electric motor is called ______________________.
7. The term_________________ describes the movement or flow of electricity.
8. A ________________________ is an instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring.
9. ________________________ is the strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
10. ______________________ is that property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.
11. A _______________________ is the complete path of an electric current, including the generating apparatus or other source; or a specific segment or section of the complete path.
12. A ________________________ is an anti-friction device that is used to support and guide a pump and motor shaft.
13. The___________________________ is a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe, but closes to prevent water from passing out of it at the bottom end. It keeps the prime.
14. The rotating set of vanes that force water through the pump are known as the _____________________.
15. The ____________________________ is a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
16. A ______________________ seal is placed on the pump shaft to prevent water from leaking from thepump along the shaft; the seal also prevents air from entering the pump.
17. Rings of graphite-impregnated cotton, flax, or synthetic materials that are used to control leakage along a valve stem or a pump shaft are called __________________________.
18. A _______________________________ pump delivers a precise volume of liquid with each stroke of the piston or rotation of the shaft.

19. A __________________________ pump consists of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at a high velocity, and the casing shape concerts this velocity into pressure.
20. The expanding section of a pump casing which converts velocity head to pressure head is the ________________.
21. The term ______________________________ describes the potentially damaging slam that occurs ina pipe when a sudden change in water velocity (usually the result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
22. _______________ rings are made of brass or bronze and placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Word Bank

Amperage

Brinelling

Bearing

Cavitation

Centrifugal

Circuit

Circuit Breaker

Current

Foot Valve

Fuse

Impeller

Jogging

Lantern Ring

Mechanical

Megger

Packing

Positive Displacement

Resistance

Voltage

Volute

Water Hammer

Wear

Pumps and Motors Review Questions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

<u>Equipment Maintenance Review Questions</u>

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 <u>two</u> types of protective/safety devices found in main electrical panels or control units?

5. What is the <u>most common pump driver</u> used in lift stations?

6. Why should inexperienced, unqualified, or unauthorized persons and even qualified and authorized persons be extremely careful around electrical panels, circuits, wiring, and equipment?

7. Under what conditions would you recommend the installation of a screw pump?

8. What is the <u>purpose</u> of packing?

9. What is the purpose of the lantern ring?

10. How often should impellers be inspected for wear?

11. What is the purpose of wear rings?

12. What causes cavitation?

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

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

15. What is the purpose of lubrication?

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

17. If an ammeter reads higher than expected, the high current could produce
    a. “Freezing” of motor windings
    b. Irregular meter readings
    c. Lower than expected output horsepower
    d. Overheating and damage equipment

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

19. Flexible shafting is used where the pump and driver are
    a. Coupled with belts
    b. Difficult to keep properly aligned
    c. Located relatively far apart
    d. Required to be coupled with universal joints

20. Never operate a compressor without the suction filter because dirt and foreign materials will cause
    a. Deterioration of lubricants
    b. Effluent contamination
    c. Excessive water
    d. Plugging of the rotors, pistons or blades

Section 14

Math

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

  - X must be by itself on one side of equal sign
    - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

    - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$3x = 14$$

- Since X is multiplied by 3, you can get rid of the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{\cancel{3}x}{\cancel{3}} = \frac{14}{3}$$

$$x = \frac{14}{3}$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{\cancel{3847}} \times \frac{\cancel{3847}}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

$$0.5 = \frac{(165)(3)(8.34)}{x}$$

Simplify

$$0.5 = \frac{4128.3}{x}$$

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{\cancel{x}} \times \frac{\cancel{x}}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(\cancel{0.5})}{\cancel{0.5}} = \frac{4128.3}{0.5}$$

$$x = \frac{4128.3}{0.5}$$

$$x = 8256.6$$

Solving for X when squared

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{(\cancel{0.785})(x^2)}{\cancel{0.785}} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

$$0.46. \rightarrow 46.0\%$$

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

$$.79.5\% \rightarrow 0.795$$

- Remember:

  You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"

- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 = x\% \times 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾
2. ⅝
3. ¼
4. ½

Convert the following percents to decimals:

5. 35%
6. 99%
7. 0.5%
8. 30.6%

Convert the following decimals to percents:

9. 0.65
10. 0.125
11. 1.0
12. 0.05

Calculate the following:

13. 15% of 125
14. 22% of 450
15. 473 is what % of 2365?
16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1. 1.8
2. 5.7
3. 5.3
4. 5,976,990
5. 8256.6
6. 8.1
7. 0.005
8. 360
9. 1649
10. 244.7
11. 11
12. 5
13. 7994
14. 590.4
15. 2817
16. 4903
17. 547,616
18. 117
19. 508,000
20. 0.35

Finding x^2

21. 80
22. 12
23. 40
24. 0.83
25. 10.9

Percent Practice Problems

1. 0.75
2. 0.625
3. 0.25
4. 0.5
5. 0.35
6. 0.99
7. 0.005
8. 0.306
9. 65%
10. 12.5%
11. 100%
12. 5%
13. 18.75
14. 99
15. 20%
16. 20%

DIMENSIONAL ANALYSIS

MATHEMATICS MANUAL FOR WATER AND
WASTEWATER TREATMENT PLANT OPERATORS
BY FRANK R. SPELLMAN

DIMENSIONAL ANALYSIS

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

DIMENSIONAL ANALYSIS

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} =$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

EXAMPLE 1

- Convert 1800 ft^3 into gallons.
- We need the conversion factor that connects the two units
- This is a ratio, so it can be written two different ways
- We want to use the version that allows us to cancel out units

---

EXAMPLE 1

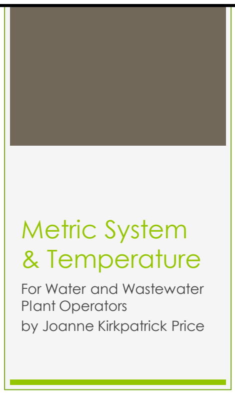
$$\left(\frac{1800\ ft^3}{1}\right)$$

- Will anything cancel out?

NO

- Let's try the other version
- Will anything cancel out?

YES



Metric System
& Temperature
For Water and Wastewater
Plant Operators
by Joanne Kirkpatrick Price

Metric Units

Primary Unit

mega	....	kilo	hecto	deka	no	deci	centi	milli	....	micro
(M)		(k)	(h)	(da)	prefix	(d)	(c)	(m)		(μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

↓

meter – linear measurement

liter – volume measurement

gram – weight measurement

King Henry Died By Drinking Chocolate Milk

Metric Units

Kilo	**Hecto**	**Deca**	**Basic Unit**	**Deci**	**Centi**	**Milli**
King	Henry	Died	By	Drinking	Chocolate	Milk
1000X larger	100X larger	10X larger	Meter Liter Gram ***1 unit***	10X smaller	100X smaller	1000X smaller

→ **MULTIPLY** numbers by 10 if you are getting smaller

← **DIVIDE** number by 10 if you are getting bigger

Problem 1

- Convert 2500 milliliters to liters

Primary Unit

mega	....	kilo	hecto	deka	no	deci	centi	milli	....	micro
(M)		(k)	(h)	(da)	prefix	(d)	(c)	(m)		(μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

↓

- Converting milliliters to liters requires a move of three place values to the left
- Therefore, move the decimal point 3 places to the left

meter – linear measurement

liter – volume measurement

gram – weight measurement

2 5 0 0. =

3 2 1

Problem 2

- Convert 0.75 km into cm

Primary Unit

mega	....	kilo	hecto	deka	no	deci	centi	milli	....	micro
(M)		(k)	(h)	(da)	prefix	(d)	(c)	(m)		(μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

↓

- From kilometers to centimeters there is a move of 5 value places to the right

meter – linear measurement

liter – volume measurement

gram – weight me

0. 7 5 =

1 2 3 4 5

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 2100 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a meter?

8. How many meters in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

11. Express a flow of 5 cfs in terms of gpm.

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

20. Convert a flow of 4,270,000 gpd to cfm.

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

Volume and Flow Conversions

1. 2,431 gal
2. 5,533 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.05 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gal/min
14. 2,620,800 gal/day
15. 6.02 ft^3/sec
16. 5,968.4 gpm
17. 16,911.67 lb/min
18. 4,146,912 gal/day
19. 19,959,955.2 lb/day
20. 2.43 MGD
21. 5,428,684.8 gal/day
22. 585.82 ft^3/min

Basic Conversions Extra Problems

1. 60 sec
2. 60 min
3. 24 hr
4. 1440 min
5. 12 in
6. 5280 ft
7. 3.28 ft
8. 1610 m
9. 8.34 lbs
10. 62.4 lbs
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.03 gpm
18. 83.56 ft^3/min
19. 6684.49 ft^3/hr
20. 396.43 ft^3/min
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

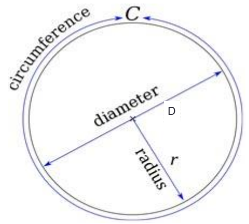
CIRCUMFERENCE AND AREA

Suggested Strategy to Solving Word Problems

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Parts of a Circle

- Diameter is distance across the center of circle
- Radius is distance from circle's center to the edge
- Circumference is the distance around a circle or a circular object



Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (3.14)(Diameter)$$

Example 1

- Find the circumference in inches of a 6 inch diameter pipe.

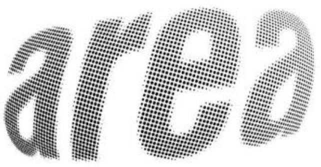
$$Circumference = (3.14)(diameter)$$

$$C = (3.14)(6\ inches)$$

$$C = 18.85\ inches$$

Area

- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, acres, etc.

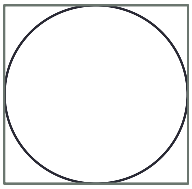


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

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



A circle takes up 78.5% of a circle.

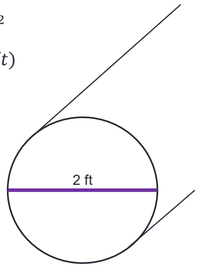
Example 2

- Find the area of the cross section of a pipe in ft² that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

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

$$A = 3.14\, ft^2$$

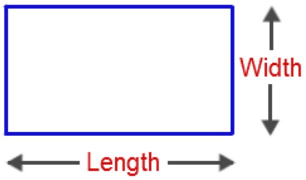


Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



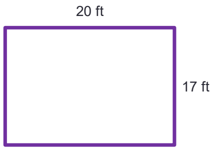
Example 2

- Find the area in ft² of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

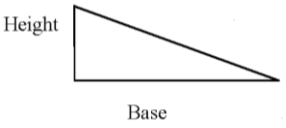


Area

- Area of Right Triangle

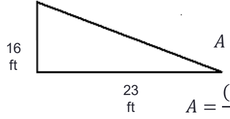
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft² of a right triangle where the base is 23 feet long with a height of 16 feet.



$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$

$$A = \frac{368ft^2}{2}$$

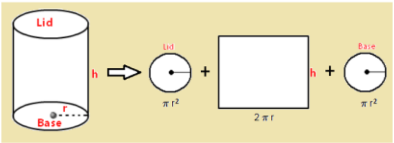
$$A = 184ft^2$$

Area

- Area of Cylinder (total exterior surface area)

$$Area = [surface\ area\ of\ end\ \#1] + [surface\ area\ of\ end\ \#2] + [(3.14)(Diameter)(height)]$$

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$



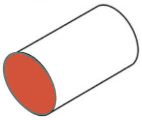
Example 4

- Find the total surface area in ft² of a pipeline that is 2 ft in diameter and 20 feet long.

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$

$$A_1 = (0.785)(D)^2$$

$$A_1 = A_2$$



$$A_1 = (0.785)(2ft)(2ft)$$

$$A_1 = 3.14ft^2$$

$$A = 3.14ft^2 + 3.14ft^2 + [(3.14)(2ft)(20ft)]$$

$$A = 3.14ft^2 + 3.14ft^2 + 125.6ft^2$$

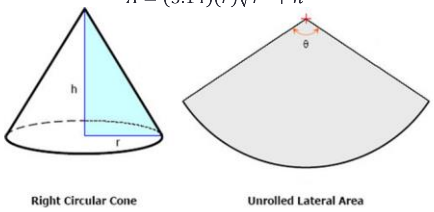
$$A = 131.88\ ft^2$$

Area

- Area of Cone (lateral area)

$$Area = (3.14)(radius)\sqrt{radius^2 + height^2}$$

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$

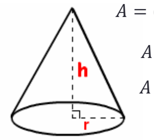


Example 5

- Find the lateral area (in ft²) of a cone that is 3 feet tall and has a radius of 1.5 feet.

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$

$$A = (3.14)(1.5ft)\sqrt{(1.5ft)(1.5ft) + (3ft)(3ft)}$$



$$A = (3.14)(1.5ft)\sqrt{2.25ft^2 + 9ft^2}$$

$$A = (3.14)(1.5ft)\sqrt{11.25ft^2}$$

$$A = (3.14)(1.5ft)(3.3541ft)$$

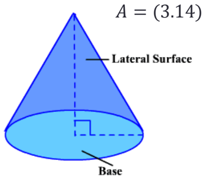
$$A = 15.79ft^2$$

Area

- Area of Cone (total surface area)

$$Area = (3.14)(radius)(radius + \sqrt{radius^2 + height^2}\ )$$

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$



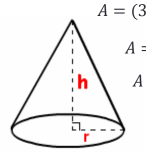
Example 6

- Find the total surface area in ft² of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{(3ft)(3ft) + (4.5ft)(4.5ft)}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2}\ )$$



$$A = (3.14)(3ft)(3ft + \sqrt{29.25ft^2}\ )$$

$$radius = \frac{1}{2}D$$

$$A = (3.14)(3ft)(3ft + 5.4083ft)$$

$$r = \left(\frac{1}{2}\right)6ft$$

$$A = (3.14)(3ft)(8.4083ft)$$

$$A = 79.21ft^2$$

Volume

Volume

- Volume is the capacity of a unit or how much it will hold

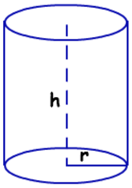
- Measured in
  - cubic units (ft^3, m^3, yd^3) or
  - liquid volume units (gallons, liters, million gallons)

- The answer will come out in cubic units
  - You must then convert it to liquid volume units

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$



Example 1

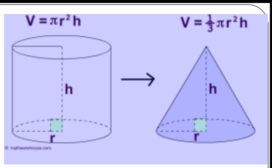
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone



$$Volume = (^1/_3)(0.785)(Diameter^2)(height)$$

$$Vol = (^1/_3)(0.785)(D^2)(h)$$

Example 2

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (^1/_3)(0.785)(D^2)(h)$$

$$Vol = (^1/_3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

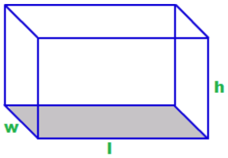
$$Vol, gal = (251.1749\ \cancel{ft}^3)(7.48\ \frac{gal}{\cancel{ft}^3})$$

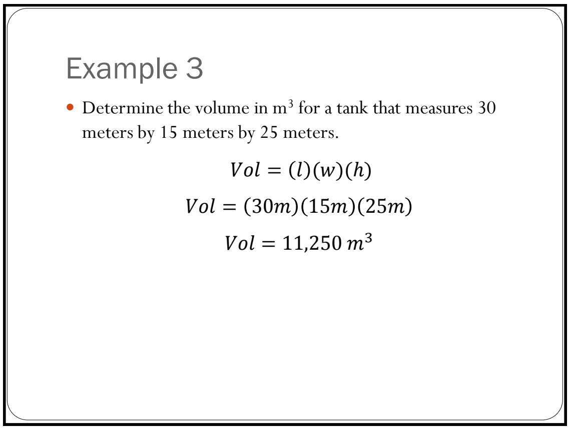
$$Vol, gal = 1878.78\ gallons$$

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$





Example 3

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

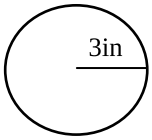
$$Vol = (l)(w)(h)$$

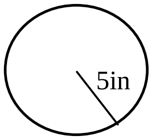
$$Vol = (30m)(15m)(25m)$$

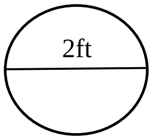
$$Vol = 11{,}250\ m^3$$

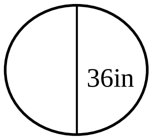
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

Circumference

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) around the top of a circular clarifier that has a diameter of 32 feet?

Area

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

2. If the diameter of a circle is 10 inches, what is the cross-sectional area in square feet?

3. Calculate the surface area (in ft^2) of the top of basin which is 90 feet long, 25 feet wide, and 10 feet deep.

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

5. What is the area of the rectangle that is 3 feet by 9 feet?

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

Volume

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

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

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

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

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

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

DON'T THINK TOO HARD ON THIS ONE...

7. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference	Area	Volume
1. 18.85 in	1. 540 ft^2	1. 1000 ft^3
2. 31.42 in	2. 0.55 ft^2	2. 9050.8 gal
3. 6.28 ft	3. 2250 ft^2	3. 359.04 gal
4. 113.10 in	4. 3.14 ft^2	4. 678.58 ft^3
5. 75.40 ft	5. 27 ft^2	5. 48442.35 gal
6. 150.80 in	6. 1.77 ft^2	6. 150,000 gal
7. 100.53 ft		7. 446671.14 gal
		8. No, it quadruples it (4X)

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\ ft}{3\ min}$$

$$Vel = 41.67\ ^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - $^{ft^3}/_{sec}$ $^{ft^3}/_{min}$ $^{gal}/_{day}$ $^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ ^{ft}/_{sec}\right)$$

$$Q = 9\ ^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft³/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$D = (6\ in)(\frac{1\ ft}{12\ in})$

$D = 0.5\ ft$

$$Q = AV$$

$$Q = (0.785)(D^2)\ (vel)$$

$$Q = (0.785)(0.5\ ft)(0.5\ ft)\left(4.5\ ^{ft}/_{sec}\right)$$

$$Q = 0.88\ ^{ft^3}/_{sec}$$

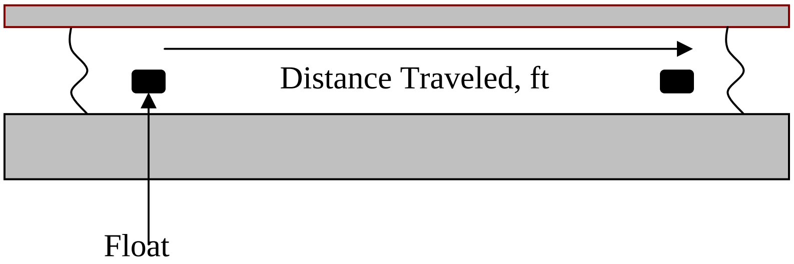
Basic Math for Water and Wastewater
Flow and Velocity

Velocity

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

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

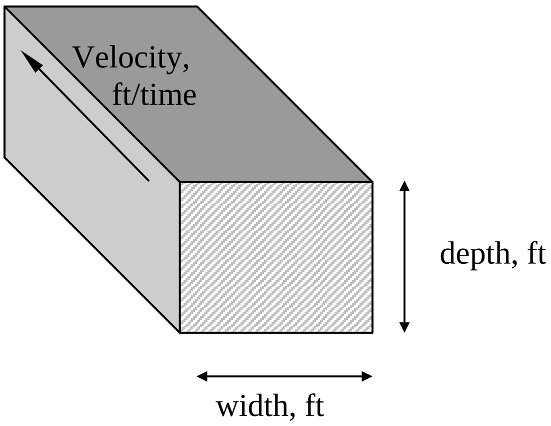
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



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

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

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



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

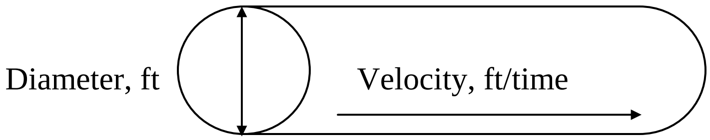
Flow in a channel

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

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

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

4.) 16.8 ft^3/sec 5.) 900ft^3/min; 9.7 MGD 6.) 1.8 ft



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

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

Flow through a full pipe

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

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

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

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

7.) 10.05 ft3/sec   8.) 0.59 ft3/sec   9.) 6 in   10.) 532.4 gpm

Basic Math for Water and Wastewater
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

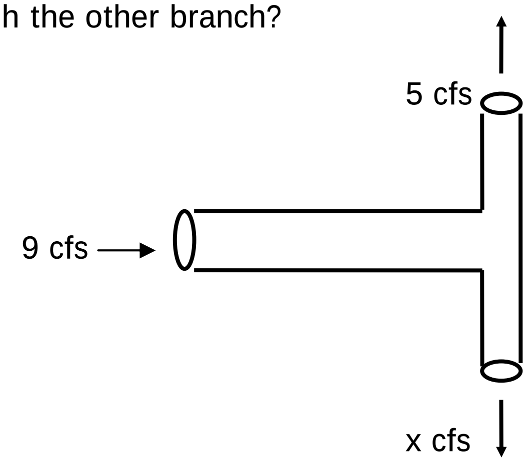
9. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

10. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

11. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

12. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24” main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month?

13. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 120 ft/min
10. 1.5 ft/sec
11. 1,533.33 ft^3/min
12. 136.83 MG
13. 4 ft^3/sec

Lagoon Math

BOD Loading

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

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

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

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

Organic Loading Rate

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

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

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

BOD Removal Efficiency

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

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

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

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

Hydraulic Loading Rate

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

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

Population Loading

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

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

Detention Time

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

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

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

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

ANSWERS:

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

Applied Math for BNS
Chemical Dosage

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

Chemical Feed Rate (Full Strength), lbs/day

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

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

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

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

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

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

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

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

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

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

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

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

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

Chlorine Dose, Demand and Residual, mg/L

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

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

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

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

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

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

Chemical Dosage, mg/L

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

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

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

Hypochlorination

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

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

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

Use the following information for problems 25 – 28:

At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

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

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

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

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

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

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

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

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

Answers:

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

Applied Math for Wastewater Treatment
Laboratory

Bacteriological, fecal coliform and *E. coli*

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

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

Solutions

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

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

Biochemical Oxygen Demand, BOD

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

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

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

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

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

7. Given the following primary effluent BOD test results, calculate the 7-day average:

   April 10 – 190 mg/L
   April 11 – 198 mg/L
   April 12 – 205 mg/L
   April 13 – 202 mg/L
   April 14 – 210 mg/L
   April 15 – 201 mg/L
   April 16 – 197 mg/L

Alkalinity

8. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 24 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.2 to 4.5.

9. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 10.1 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.5 to 4.5.

Temperature

10. The influent to a treatment plant has a temperature of 72°F. What is the temperature expressed in degrees Celsius?

11. Convert 56° F to degrees Celsius.

12. The effluent of a treatment plant is 22°C. What is this temperature expressed in degrees F?

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 150 mg/L
6. 123 mg/L
7. 200 mg/L
8. 240 mg/L
9. 101 mg/L
10. 22.2°C
11. 13.3°C
12. 71.6°F

Applied Math for Wastewater
Pump Horsepower & Efficiency

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost of power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

Section 15

TN Regs - Excerpts from the Design Criteria for Sewage Works

CHAPTER 2

Sewers and Wastewater Pumping Stations

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems must ensure that the downstream conveyance system and the receiving wastewater treatment plant are either:

a. Capable of adequately conveying or processing the added hydraulic and organic load, or

b. Capable of providing adequate conveyance or treatment facilities on a time schedule acceptable to the Division

2.1.2 Ownership

Sewer systems including pumping stations integral to gravity sewer and low-pressure sewer designs require ownership by a responsible party, such as a public entity, for operation and maintenance.

2.1.3 Design

The design and construction of new sewer systems must achieve total containment of sanitary wastes and exclusion of infiltration and inflow (I/I). This includes installing pipe with watertight joints, watertight connections to manholes, and watertight connections to service laterals or service lateral stubs and trench design that minimizes the potential for migration of water along the trench. However, the new sewer system and appurtenances must be able to convey the wastewater load, including existing I/I, from upstream areas as appropriate.

2.1.4 Overflows

The Division of Water Resources (Division) will not permit overflows in separate sanitary sewers or new overflows in existing combined sewers. The Division will not permit overflows in new interceptor sewers intercepting existing combined sewers. An alarm system to signal existing overflow conditions and procedures for reporting overflows may be required.

2.1.5 Calculations

The Division requires the submittal of all computations and other data used for design of the sewer system.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection sewers (Laterals and Submains)

The Division requires collection sewers for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk, and Interceptor Sewers

The Division requires certain design factors for trunk sewers:

a. Possible solids deposition, odor, and pipe corrosion that might occur at initial flows
b. Population and economic growth projections and the accuracy of the projections
c. Comparative costs of staged construction alternatives
d. Effect of sewer sizing on land use and development

2.2.2 Basis of Design

The Division's design requirements for new sewer systems are on the basis of per capita flows or alternative methods.

2.2.2.1 Per Capita Flow

The Division requires the use of Appendix 2-A. Substitutions or additions to the information presented in this table are acceptable if better or more accurate data is available.

The Division requires the following:

a. Lateral and Submains: Minimum peak design flow should be not less than 400 percent of the average design flow.

"Lateral" - a sewer that has no other common sewers discharging into it.

"Submain" is defined as a sewer that receives flow from one or more lateral sewers.

b. Main, Trunk, and Interceptor sewers: Minimum peak design flow should be not less 250 percent of the average design flow.

"Main" or "trunk" is defined as a sewer that receives flow from one or more submains.

"Interceptor" - a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

The Division allows alternative methods other than on the basis of per capita flow rates. Alternative methods may include the use of peaking factors of the contributing area, allowances for future commercial and industrial areas, separation of infiltration and inflow from the normal sanitary flow (for new sewers serving existing upstream sewers), and modification of per capita flow rates (based on specific data). There should be no allowance for infiltration or inflow into newly constructed or proposed sewers.

2.2.3 Design Factors

The Division requires consideration of the following factors:

a. Peak wastewater flows from residential, commercial, institutional, and industrial sources
b. Potential for groundwater infiltration from existing upstream sewers
c. Topography and depth of excavation
d. Treatment plant location
e. Soils conditions
f. Pumping requirements
g. Maintenance, including manpower and budget
h. Existing sewers
i. Existing and future surface improvements
j. Controlling service connection elevations
k. Proximity to surface streams, including minimizing the potential for draining or diversion of stream water into the pipe trench
l. Watertight and exclude groundwater and surface water.

2.3 Design and Construction Details

2.3.1 Gravity Sewers

The Division requires gravity sewers to be approximately one-half full when conveying the anticipated peak daily dry weather flow and does not surcharge when conveying the anticipated peak wet weather flow.

2.3.1.1 Minimum Size

The minimum size of new public sewers should be 8 inches (nominal) in diameter.

2.3.1.2 Depth

Generally, sewers should not be less than 2 ½ feet deep but should be sufficiently deep to prevent freezing and physical damage.

2.3.1.3 Roughness Coefficient

The Division requires that a roughness coefficient "n" value of 0.013 be used in Manning's formula for the design of all sewer facilities unless a roughness coefficient specific to the given pipe material is available. The roughness coefficient selected must consider the long-term condition of the sewer. However, the Division requires an "n" value equal to or greater than 0.011.

2.3.1.4 Slope

Sewers must be self-cleansing and capable of transporting most solids to the desired point, usually a treatment facility. Two methods are approved for design in the State of Tennessee: 1) Tractive Force and 2) Traditional (Ten-State Standards). For reasons of economical design and long-term maintenance, the Division prefers the Tractive Force Method.

Tractive Force Method:

ASCE and WEF (WEF Manual of Practice No. FD-5 *Gravity Sanitary Sewer Design and Construction*, 2007, Section 5.6) now advocates a transition to the tractive force approach for self-cleansing design. "Tractive Force (TF) design is a major improvement over traditional methods to achieve self-cleansing in gravity sewers. This approach results in a self-cleansing pipe slope value (S_{min}) for the design minimum flow rate (Q_{min}) in each sewer reach. Q_{min} is the predicted largest 1-hour flow rate in the reach during the lowest flow week over the sewer design life. Past design practices seldom included accurate estimation of Q_{min} values, but good estimates of Q_{min} are crucial for TF design. The engineer should show in the engineering report the calculations for Q_{min} for new sewer pipe projects. As compared to traditional minimum slopes, S_{min} slopes via the TF method are flatter for sewers carrying typical to larger Q_{min} values and steeper for sewers carrying smaller Q_{min} values." (Merritt, LaVere B., *Tractive Force Design for Sanitary Sewer Self-Cleansing*, ASCE, May 2009)

Once a good estimate has been developed for Q_{min}, then Table 2-1 (WEF, 2007, Table 5.5, page 148) for calculating minimum slopes for a typical condition in sewers is provided to assist designers with applying TF principles.

Table 2-1 Tractive Force Equations for Minimum Slope

Sewer Size (inches)	When n is Variable* value of S_{min} = (Q in cfs)
8	$0.000848\ Q_{min}^{-0.5707}$
10	$0.000887\ Q_{min}^{-0.5721}$
12	$0.000921\ Q_{min}^{-0.5731}$
15	$0.000966\ Q_{min}^{-0.5744}$
18	$0.001004\ Q_{min}^{-0.5754}$
21	$0.001038\ Q_{min}^{-0.5761}$
24	$0.001069\ Q_{min}^{-0.5768}$
27	$0.001097\ Q_{min}^{-0.5774}$
30	$0.001123\ Q_{min}^{-0.5778}$
36	$0.001169\ Q_{min}^{-0.5787}$
42	$0.001212\ Q_{min}^{-0.5812}$

3Based on Darcy-Weisbach

Traditional Method:

The Traditional Method for conventional gravity sewers requires mean velocities, when flowing full, of not less than 2.0 feet per second. Table 2-2 provides minimum slopes when using the traditional method; however, slopes greater than these are desirable.

Table 2-2 Minimum Slope from Traditional Method

Sewer Size (inches)	Minimum Slope***** (feet per 100 feet)
8	0.40
10	0.28
12	0.22
15	0.15
18	0.12
21	0.10
24	0.08
27	0.067
30	0.058
36	0.05 ******
42	0.042*******

*	Great Lakes Upper Mississippi River Board, 1997.
**	Recommended steeper – to give velocity of 2.1 ft/sec (WEF, 2007)
***	Recommended steeper – to give velocity of 2.3 ft/sec (WEF, 2007)

Under special condition, the using the Traditional Method, the Division may allow slopes slightly less than those required for the 2.0 feet-per-second velocity when flowing full may be permitted. Such decreased slopes will only be considered where the depth of flow will be 0.3 of the diameter or greater for design average flow. Whenever such decreased slopes are proposed, the design engineer should furnish with his report his computations of the depths of flow in such pipes at minimum, average, and daily or hourly rates of flow. The maintaining wastewater agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Uniform slope between manholes is required.

A minimum of 5 feet of horizontal separation between gas mains is required.

Anchors are required for sewers on 20 percent slope or greater. Secure anchors will have a minimum two-foot thick tightly compacted clay collar or equal. Suggested minimum anchorage spacing is as follows:

a. Not over 36 feet center to center on grades 20 percent and up to 35 percent.

b. Not over 24 feet center to center on grades 35 percent and up to 50 percent.

c. Not over 16 feet center to center on grades 50 percent and over.

2.3.1.5 Alignment

Straight alignment between manholes is required for gravity sewers. However, curved sewers may be approved where circumstances warrant but only in large (i.e., 24" and larger) diameter segments.

2.3.1.6 Increasing Size

When a smaller sewer joins a larger one, the Division requires the alignment to maintain the same energy gradient. An approximate method for securing these results is to match the crowns of the sewers entering/ exiting the manhole or junction structure.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, the Division requires protective measures against internal erosion or displacement by shock.

2.3.2 Materials

The Division will consider any generally accepted material for sewers. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. The Division requires careful consider of pipes and compression joint materials subjected to corrosive or solvent wastes. Chemical/stress failure and stability in the presence of common household chemicals such as cooking oils, detergents and drain cleaners are factors.

The specifications should stipulate need to keep clean the pipe interior, sealing surfaces, fittings and other accessories. Pipe bundles should be stored on flat surfaces with uniform support. The protection of stored pipe is required. Pipe with prolonged exposure (six months or more) to sunlight requires a suitable covering (canvas or other opaque material). The Division requires care be given to gaskets. Ensure that gasket not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight. Consult with the manufacturers for specific storage and handling recommendations.

2.3.2.1 Rigid Pipe

Rigid pipe includes, but is not be limited to, concrete pipe. Any rigid pipe should have a minimum crushing strength of 2000 pounds per lineal foot. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Semi-rigid pipe includes, but is not be limited to, ductile iron. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Flexible pipe includes, but is not be limited to, ABS solid wall pipe, polyvinyl chloride pipe (PVC), polyethylene pipe (PE), fiberglass composite pipe, reinforced plastic mortar pipe (RPM) and reinforced thermosetting resin pipe (RTR). PVC pipe should have a minimum Standard Dimension Ratio (SDR) of 35. The Division requires that all other flexible pipe have the same calculated minimum deflection under identical conditions as the SDR 35 PVC pipe.

To calculate the flexible pipe deflection under earth loading use the formula presented in the ASCE/WPCF publication, Design and Construction of Sanitary and Storm Sewers.

All pipes should meet appropriate ASTM and/or ANSI specifications. ASTM D-3033 and D-3034 PVC pipes differ in wall thickness and have non-interchangeable fittings.

2.3.3 Pipe Bedding and Backfilling

The Division requires that all sewers designs provide protection from damage from superimposed loads. The width and depth of the trench require allowances be made for loads on the sewer. Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

The Division requires ductile iron pipe in roadways where cover is less than 4 feet. In such cases, a minimum cover of six inches is required.

The Division requires ductile iron pipe or relocation when the top of the sewer is less than 18 inches below the bottom of a culvert or conduit.

2.3.3.1 Rigid Pipe

Bedding Classes A, B, or C as described in ASTM C-12 or WPCF MOP No. 9 (ASCE MOP No. 37) should be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. The Division requires the use of ASTM-C-12 (placement of bedding and backfill).

2.3.3.2 Semi-Rigid Pipe

The Division requires the use of Bedding Classes I, II, III, or IV (ML and CL only) as described in ASTM D-2321 for all semi-rigid pipe provided with the specified bedding to support the anticipated load.

The Division requires ASTM-A-746 be used to install ductile iron pipe.

2.3.3.3 Flexible Pipe

The Division requires the use of Bedding Classes I, II, or III as described in ASTM D-2321 for all flexible pipe. The Division requires the proper strength pipe with the specified bedding to support the anticipated load.

The Division requires ASTM-D-2321 for bedding, haunching, initial backfill, and backfill.

The Division requires Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4. (polyethylene pipe).

2.3.3.4 Alternate Bedding Option

The Division will allow all sewers bedded and backfilled with a minimum of 12 inches of Class I material over the top and below the invert of the pipe--an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3.

2.3.3.5 Deflection Testing

The Division requires deflection testing of all flexible pipes. The Division requires backfill testing after it has been in place at least 24 hours.

No pipe should exceed a deflection of 5%.

The test should be run with a rigid ball or an engineer approved 9-arm mandrel having a diameter equal to 95% of the inside diameter of the pipe. The test requires manually pulling the test device through the line.

2.3.4 Joints

The Division requires the specification to include the method of making joints and the materials used. The Division requires that sewer joints eliminate infiltration and prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints, and ABS solvent-cement welded joints are required. The Division requires the use of ASTM-F2620 for butt fusion joining technique with polyethylene pipe. The Division requires the removal of internal beads for butt fusion joints on pipelines with slopes less than one percent. Cement mortar joints are not acceptable. Field solvent welds for PVC and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

The Division requires the use of ASTM-C-828 for low-pressure air testing for all pipes. The time required for the pressure to drop from the stabilized 3.5 psig to 2.5 psig should be greater than or equal to the minimum calculated test time (the Division requires that air loss rate be part of the test criteria).
The testing method should take into consideration the range in groundwater elevations projected and the situation during the test. The height of the groundwater should be measured from the top of the invert (one foot of $H_20 = 0.433$ psi).

Table 2-3 provides the minimum test times and allowable air loss values for various pipe size per 100 ft.

Table 2-3 Leakage Test Parameters

Pipe Size (inches)	**Time**, T (sec/100 ft)	**Allowable Air Loss**, Q (ft^3/min)
6	42	2.0
8	72	2.0
10	90	2.5
12	108	3.0
15	126	4.0
18	144	5.0
21	180	5.5
24	216	6.0
27	252	6.5
30	288	7.0

2.3.6 Visual Inspection

The Division requires that new sewers be video inspected to confirm proper installation and to provide a visual record of the condition of the newly constructed sewer for future reference.

2.3.7 Low Pressure Systems

2.3.7.1 Application

The Division requires the consideration of low-pressure systems for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.7.2 Grinder Pumps

The Division requires all the collection and transport of raw wastewater from individual buildings/dwellings to the pressure system by appropriately sized grinder pumps.

Grinder pumps do not require a septic tank.

All pumps should have operating curves that do not allow backflow under maximum head conditions.

Pumps should be watertight and located above the seasonal groundwater table were possible where possible.

2.3.7.3 Septic Tank Effluent Pump (STEP) system

All STEP installations require careful attention to the following design details and construction techniques:

a. All STEPs preceded by a watertight septic tank. Retrofitting a STEP to an existing septic tank will require a visual inspection of the tank.

   Replacement of all defective septic tanks.

b. STEPs retrofitted to an existing septic tank and drain field must provide a positive means of preventing groundwater from backing up through the drain field to the STEP.

c. The STEP should be located as close as possible to the septic tank.

d. Electrical power supplied through the main circuit box. Electricity furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.7.4 Hydraulic

Hydraulic calculations are of extreme importance. Head losses within the low-pressure system will change with each pump activation.

2.3.7.5 Minimum Velocity

The recommended minimum operating velocity in a pressure system should be 2 feet per second (fps).

2.3.7.6 Flushing

There should be a means of cleaning the system, particularly to clear any settleable solids or grease accumulation.

2.3.7.7 Pressure Testing

There should be means for isolating and pressurizing sections of the system to detect and locate leaks.

2.3.7.8 Alarms

There should be an external visual warning system to indicate the malfunction of the pump. The high-level (in storage tank) warning system should be a dual audio / visual system.

2.3.7.9 Cleanouts

The Division requires cleanouts at a maximum of 400-foot intervals.

2.3.7.10 Ventilation

Ventilation of the pumping station should be provided via house vents where allowable or through a separate system.

2.3.8 Manholes

2.3.8.1 Location

The Division requires manholes at the end of each 8-inch diameter sewer or greater. The Division will waive this requirement if a stub-out is installed (assumes line will be extended in near future).

The Division requires manholes at all changes in grade, size, or alignment; at all intersections; and at distances not greater than 400 feet for sewers 15 inches or less. The Division requires manholes at 500 feet for sewer 18 inches to 30 inches. The Division may allow greater spacing in larger sewers and in those carrying a settled effluent.

2.3.8.2 Drop Connection

The Division requires a drop connection for a sewer entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, a filleted invert will prevent solids deposition.

2.3.8.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame shall meet current OSHA standards.

2.3.8.4 Flow Channels

Flow channels in manholes should be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. Channeling height should be to the crowns of the sewers. Benches should be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.8.5 Water tightness

The Division requires watertight manhole covers wherever the manhole tops may be flooded. Manholes of brick or segmented block are not appropriate materials for manhole construction where groundwater conditions are unfavorable. In pre-cast concrete manholes, the Division requires plastic gaskets, pre-molded rubber gaskets or flexible, plastic gaskets.

2.3.8.6 Connections

The Division requires special attention be paid to the connection between the manhole wall and the sewer pipe in order to minimize long-term infiltration into the system. The Division requires flexible joints for line connections directly to the manholes, or to short stubs integral with the manholes. Flexible joints are joints that permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.8.7 Ventilation

The Division requires consideration of ventilation of gravity sewer systems where continuous watertight sections are greater than 1,000 feet in length. Vent height and construction must consider flood conditions.

2.3.8.8 Frames, Covers, and Steps

Frames, covers, and steps, if utilized, should be of suitable material and designed to accommodate prevailing site conditions and to provide for a safe installation.
Materials used for manhole steps should be highly corrosion-resistant. The Division requires aluminum or plastic with reinforcing bar.

2.3.8.9 Vacuum Testing

New manholes should be vacuum tested after construction to verify they will not be new sources of infiltration or inflow. The Division requires the test to include the manhole frame. The Division considers the test acceptable if the vacuum remains at 10 inches of mercury or drops to no less than 9 inches of mercury within one minute. The Division may allow alternative testing methods--if demonstrated to be equal of better than vacuum testing.

2.4 Special Details

2.4.1 Protection of Water Supplies

2.4.1.1 Water Supply Interconnections

There shall be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto.

2.4.1.2 Relation to Water Mains

Horizontal Separation: Whenever possible, the Division requires at least 10 feet horizontal separation of the sewer from any existing or proposed water main. Should local conditions prevent a lateral separation of 10 feet, the Division may allow the sewer closer than 10 feet to a water main if in a separate trench and if the elevation of the top (crown) of the sewer is at least 18 inches below the bottom (invert) of the water main.

Vertical Separation: Whenever sewers must cross under water mains, the Division requires the sewer at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. The Division will consider other alternatives if the sewer evaluation cannot be varied.

When it is impossible to obtain proper horizontal and vertical separation as stipulated above, the sewer should be designed and constructed equal to the water main pipe and should be pressure-tested to assure water-tightness (see drinking water criteria) or the joints of the sewer pipe should be encased in concrete to inhibit infiltration/exfiltration. Details of the encasement should be clear and extend the necessary distance to achieve design goals. The designer should consider the temperature differential between the

pipe and the surrounding materials in their determination if reinforcement is necessary. Such arrangements are discouraged.
The Division requires the designer's evaluation, calculations, and conclusions in the project record and provided to all interested parties upon request.

2.4.2 Backflow Preventers

State approved reduced pressure backflow prevention devices are required on all potable water mains serving the wastewater treatment plant or pumping station. The Division can provide a list of approved backflow preventers.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Site Characterizations for Sewers in Proximity to Streams

For new sewers or existing sewers replaced in the same trench that cross or have an alignment within 50 feet of the bank of a surface stream, upon notification of the potential route of the proposed sewer, the Division will perform a site characterization to determine the potential for stream capture. (See Section 1.2.4.1 of Chapter 1) If the Division determines there is potential for stream capture, a site-specific Aquatic Resource Alteration Permit (ARAP) is required, and obtaining this permit will require the design engineer to provide a plan to prevent stream capture. This may require additional study of the characteristics of the stream, including soil classification data, rock depth (if present), recommendations for controlling seepage, cut and fill recommendations, a trench dewatering plan, and other site specific data.

2.4.3.2 Location of Sewers in Streams

Open trench sewers located along streams should be located outside of the streambed and sufficiently removed there from to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gate boxes or other structures should be located so they do not interfere with the free discharge of flood flows of the stream.

The Division requires open trench sewer crossings of streams to cross the stream as nearly perpendicular to the stream flow as possible and be free from change in grade.

2.4.3.3 Construction

Sewers entering or crossing streams should be ductile iron pipe from manhole to manhole, wrapped in plastic and encased in high strength flowable fill. (Note: This provision is subject to a case-by-case review. In this case, the Division requires an impermeable barrier that might be flowable fill, concrete, liners, casing pipe or a combination. The best practice may be different depending upon stream flow, local soils, topography and geology).

The sewer should be free of alignment or grade changes. The Division requires sewer systems designs to minimize the number of stream crossings. The Division requires the stream returned as nearly as possible to its original condition upon completion of construction. The Division requires the stream banks to be seeded or other erosion prevention methods employed to prevent erosion. Stream banks should be sodded, if necessary, to prevent erosion. The consulting engineer should specify the method or methods in the construction of the sewers in or near the stream to control siltation.

With regard to prohibitions on the contractor, the Division requires that the specifications contain the following clauses:

- unnecessarily disturbing or uprooting trees and vegetation along the stream bank and in the vicinity of the stream,
- dumping of soil and debris into streams and/or on banks of streams,
- changing course of the stream without encroachment permit,
- leaving cofferdams in streams,
- leaving temporary stream crossings for equipment,
- operating equipment in the stream, or
- pumping silt-laden water into the stream.

The Division requires provisions in the specifications to:

- retard the rate of runoff from the construction site,
- control disposal of runoff,
- liberal use of silt fencing to trap sediment resulting from construction in temporary or permanent silt-holding basins,
- pump discharges resulting from dewatering operations;
- deposit out of the flood plain area all material and debris removed from the streambed.

Specifications should require that cleanup, grading, seeding, planting or restoration of the work area should be carried out as early as practical as the construction proceeds. The Division requires the specifications mandate a trench-dewatering plan for new sewer alignments that cross a stream or are within 50 feet of the bank of the stream defined in Section 1.2.4.1.

2.4.3.4 Special Construction Requirements

The Division requires the employment of special design requirements to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. The Division requires an in trench impounding structure of compacted clay or concrete check dams. The Division will consider other proposals.

2.4.3.5 Aerial Crossings

The Division may allow sewers that lay on piers across ravines or streams if no other practical alternative exists or, in the design engineer's judgment, other methods will not be as reliable.

The Division requires support for all joints. All supports designs must prevent frost heave, overturning or settlement. The Division requires precautions against freezing, such as insulation or increased slope and expansion joints between aboveground and belowground sewers. The Division requires deigns to consider the impact of floodwaters and debris. The design should consider maintenance of an adequate waterway for the 100-year flood flows. The design engineer should analyze the impact of the proposed aerial crossing(s) on flooding, including hydraulic modeling, such as Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling, as necessary.

2.4.3.6 Permits

It is the owner's responsibility to obtain all necessary permits along streams or rivers; i.e., Corps of Engineers, TVA, or the Natural Resources Section of the Division of Water Resources.

2.4.4 Inverted Siphons

Under normal conditions, the Division will not allow inverted siphons. However, if they are, the Division requires that the following:

- Minimum of two barrels,
- Minimum pipe size of six inches--provided with necessary appurtenances for convenient flushing and maintenance,
- Manholes with adequate clearances for rodding,
- Sufficient head and pipe sizes to secure velocities of at least 3.0 feet per second for average flows,
- Inlet and outlet details arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning,
- Design engineer furnishes hydraulic calculations with the plans,
- Proper access maintained.

2.5 General Requirements for Wastewater Pumping Stations

2.5.1 Location and Flood Protection

The Division requires wastewater pumping stations located as far as practicable from present or proposed built-up residential areas, with an all-weather road and noise control, odor control, and station architectural design taken into consideration. Sites for stations should be of sufficient size for future expansion or addition, if applicable. The Division requires security for the pumping station and controls.

The Division requires protection from the 100-year flood for the station's operational components.

Where the wet well is at a depth greater than the water table elevation, special provisions should be made to ensure watertight construction of the wet well. The Division requires connections to the pumping station at an elevation higher than the maximum water table elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units should be provided, each capable of handling the expected maximum flow. The Division requires the submittal of pump head and system head curves.

For three or more units the Division requires a design to fit actual flow conditions and must be of such capacity that, with any one unit out of services, the remaining units will have capacity to handle the maximum wastewater flow.

A station expected to operate at a flow rate less than one-half the average design flow for an extended period may create septic conditions due to long holding times in the wet well. The design should consider the need for additional measures to prevent the formation of odors.

The design should the use of variable-speed or multiple staged pumps, particularly when the pumping station delivers flow directly to a treatment plant. The design allows delivery of the wastewater at approximately the same rate as received at the pumping station.

2.5.3 Grit and Clogging Protection

Where it may be necessary to pump wastewater prior to grit removal, the design of the wet well should receive special attention, and the design of the discharge piping should be to prevent grit settling in pump discharge lines of pumps not operating.

Design of the pumping station should consider the protection of the pump from damage caused by grit and debris, where warranted. To accomplish this--maintain minimum pump operational speeds, through the installation of bar screens with a grinder or comminutor, or similar devices. For the larger or deeper stations, duplicate protection units, each sized at full capacity, are preferred.

2.5.4 Pumping Units

2.5.4.1 Pump Openings

The Division requires pumps be capable of passing a 3-inch compressible solid. The Division requires pump suction and discharge openings to be at least 4 inches in diameter unless it is a pump with chopping or grinding capabilities.

2.5.4.2 Priming

The Division requires the placement of pumps so that under normal operating conditions they will operate under a positive suction head (except for suction lift pumps).

2.5.4.3 Intake

Each pump should have an individual intake. Wet well design should be such as to avoid turbulence near the intake.

2.5.4.4 Controls

The location of controls should ensure that the flows entering the wet well to not affect them, by the suction of the pumps, or by proximity to wet well walls. Controls must be able to activate additional pumps if the water in the wet well continues to rise. Controls can be float switches, air-operated pneumatic, radar, ultrasonic or capacitance probe types. Provisions should be made to automatically alternate the pumps in use. Pumping stations with motors and/or controls below grade should be equipped with a secure external disconnect switch. The Division requires consideration of an “intrinsically safe” power source if float switches are used.

The Division requires consideration of redundant controls and/or remote monitoring to assist in preventing overflows.

2.5.5 Flow Measurement

At pumping stations with flow capacity greater than 0.5 million gallons per day (mgd), the Division recommends providing suitable devices for measuring flow.

2.5.6 Alarm System

The Division recommends an alarm system for all pumping stations such as, telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel (when reliability classification or property damage warrants it). The Division requires an audiovisual device at the station for external observation when telemetry is not used.

The Division requires alarms for high wet well and power failure, as a minimum, for all pumping stations. For larger stations, the Division requires alarms signalizing pump and other component failures or malfunctions.

The Division requires a backup power supply, such as a battery pack with an automatic switchover feature, for the alarm system, such that a failure of the primary power source will not disable the alarm system. The alarm system must be tested and verified that it is in good working order.

2.5.7 Overflows and/or Bypasses

Pumping stations should be designed and built without any type of overflow or bypass structure.

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

Materials must not contain hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in wastewater. The Division recommends the use of concrete additives or protective coatings to prevent deterioration caused by corrosive gases.

2.6.1.2 Electrical Equipment

Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, and control circuits) in enclosed or partially enclosed spaces where flammable mixtures occasionally may be present (including raw wastewater wet wells) should comply with the National Electrical Code requirements for Class I Division 1 locations.

2.6.1.3 Water Supply

There should be no physical connection between any potable water supply and a wastewater pumping station that under any conditions might cause contamination of the potable water supply. A potable water supply must comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting is required for the entire pumping station.

2.6.1.5 Pump and Motor Removal

The Division requires the removal of pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Safety

The Division requires suitable and safe means of access to equipment requiring inspection or maintenance and that stairways and ladders satisfy all OSHA requirements.

2.6.1.7 Valves and Piping

The Division requires suitable shutoff valves on suction and discharge lines of each pump for normal pump isolation and a check valve on each discharge line between the shutoff valve and the pump. Pump suction and discharge piping should not be less than 4 inches in diameter except where design of special equipment allows. The velocity in the suction line should not exceed 6 feet per second and, in the discharge piping, 8 feet per second. A separate shutoff valve is desirable on the common line leaving the pumping station.

2.6.1.8 Ventilation

The Division requires ventilation for all pumping stations during all periods when the station is manned. Portable ventilation equipment is acceptable for small pumping stations. Mechanical ventilation is required if screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well. In pits over 15 feet deep, multiple inlets and outlets are desirable. The Division requires that dampers not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

The Division requires complete separation of wet and dry wells, including their superstructures.

The Division recommends dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning where continuity of pumping station operation is necessary.

2.6.2.2 Wet Well Size and Design

Provide an evaluation of the effective capacity of the wet well based on pumping requirements and reliability classifications.

Wet well design should consider approaches for minimizing solids deposition.

2.6.2.3 Dry Well Dewatering

The Division requires a separate sump pump in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. The Division will not approve water ejectors connected to a potable water supply. All floor and walkway surfaces should have an adequate slope to a point of drainage.

2.6.3 Suction Lift Stations

2.6.3.1 Priming

Conventional suction-lift pumps should be of the self-priming type, as demonstrated by a reliable record of satisfactory operation. The maximum recommended lift for a suction lift pumping station is 15 feet, using pumps of 200 gallons per minute (gpm) capacity or less.

2.6.3.2 Capacity

The capacity of suction lift pumping stations should be limited by the net positive suction head and specific speed requirements, as stated on the manufacturer's pump curve, for the most severe operating conditions.

2.6.3.3 Air Relief

a. Air Relief Lines
An air relief line on the pump discharge piping is required for all suction lift pumps. This line should be located at the maximum elevation between the pump discharge flange and the discharge check valve to ensure the maximum bleed-off of entrapped air. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves
The Division requires air relief valves in air relief lines on pumps not discharging to gravity sewer collection systems. The air relief valve should be located as close as practical to the discharge side of the pump.

2.6.3.4 Pump Location

For standard designs, suction lift pumps are mounted on the wet well but not within the wet well.

2.6.3.5 Access to Wet Well

Access to the wet well should not be through the dry well, and the dry well should have a gastight seal when mounted directly above the wet well.

2.6.4 Submersible Pumps

2.6.4.1 Pump Removal

Submersible pumps should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well.

The Division recommends a hoist or crane system for removing the pumps from the wet well either through a permanent installation at the site or a mobile system that could be utilized at multiple sites.

2.6.4.2 Controls

The control panel should be located outside the wet well and suitably protected from weather, humidity, vandalism, and gases migrating from the wet well.

2.6.4.3 Valves

The Division recommends all control valves on the discharge line for each pump in a convenient location outside the wet well in separate pits and protected from weather and vandalism.

2.6.4.4 Submergence

Positive provision, such as backup controls, is required to assure submergence of the pumping units.

2.6.5 Grinder and Effluent Pumps

The requirements for grinder pumps are included in Section 2.3.6.

2.7 Operability and Reliability

2.7.1 Objective

The objective of reliability is to prevent the discharge of raw or partially treated wastewater to any waters and to protect public health by preventing backup of wastewater and subsequent discharge to basements, streets, and other public and private property.

2.7.2 Backup Units

A minimum of two pumps or pneumatic ejectors are required in each station in accordance with section 2.5.2.

2.7.3 Power Outages

An emergency power source or auxiliary power is required for all pumping stations larger than 1 MGD to ensure continuous operability unless experience has shown the frequency and duration of outages to be low and the pumping station and/or sewers provide storage sufficient for expected interruptions in power service.

2.7.4 Emergency Power Supply (for Treatment Plants as well as Pumping stations)

2.7.4.1 General

The Division requires provision of an emergency power supply for pumping stations (and treatment plants) to at least two independent public utility sources, or by provision of portable or in-place internal combustion engine equipment that will generate electrical or mechanical energy, or by the provision of portable pumping equipment. Emergency power must be provided for all stations which are 1 MGD or larger, or as determined by the reliability classification.

Emergency power should be provided that, alone or combined with storage, will prevent overflows from occurring during any power outage that is equal to the maximum outage in the immediate area during the last 10 years. If available data were less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.4.2 In -Place Equipment

The utilization of in-place internal combustion equipment requires the following guidelines:

a. Placement: bolted in place. Facilities for unit removal for purposes of major repair or routine maintenance.
b. Controls: automatic and manual startup and cut-in.
c. Size: adequate to provide power for lighting and ventilation systems and such further systems that affect capability and safety as well as the pumps.
d. Engine Location: located above grade, with suitable and adequate ventilation of exhaust gases.
e. Underground Fuel Storage Tank: design and construction must conform to the applicable requirements of Federal Regulations 40 CFR 280 and 281. Contact the Tennessee Division of Superfund, Underground Storage Tank Program, for guidance.

2.7.4.3 Portable Equipment

The utilization of portable equipment requires the following guidelines:

Pumping units have connections to operate between the wet well and the discharge side of station and the station provided with permanent fixtures that will facilitate rapid and easy connection of lines.

2.7.5 Storage

The Division requires wet well and tributary main capacity above the high-level alarm sufficient to hold the peak flow expected during the maximum power outage duration during the last 10 years.

2.8 Force Mains

2.8.1 Size

Minimum size force mains required to be not less than 4 inches in diameter, except for grinder pumps or septic tank effluent applications

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 3 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 fps.

2.8.3 Air/Vacuum Relief Valve

An air relief valve is required at the necessary high points in the force main to relieve air locking. Vacuum relief values may be necessary to relieve negative pressures on force mains to protect against pipe collapse.

2.8.4 Termination

The force main should enter the receiving manhole with its centerline horizontal and with an invert elevation that will ensure a smooth flow transition to the gravity flow section; but in no case should the force main enter the gravity sewer system at a point more than 1 foot above the flow line of the receiving manhole. The design should minimize turbulence at the point of discharge.

The Division requires the use of inert materials or protective coatings for the receiving manhole to prevent deterioration because of hydrogen sulfide or other chemicals where such chemicals are present or suspected to be present because of industrial discharges or long force mains.

2.8.5 Materials of Construction

The pipe material should be adapted to local conditions, such as character of industrial wastes, soil characteristics, exceptionally heavy external loadings, internal erosion, corrosion, and similar problems.

Installation specification should contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements should be set forth in the specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations, not create excessive side fill pressures or ovality of the pipe, nor seriously impair flow capacity.

The Division requires that the design of all pipes prevent damage from superimposed loads. Proper design allowance for loads on the pipe because of the width and depth of trench is required.

2.8.6 Pressure Tests

The Division requires testing, before backfilling, of all force mains at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage should not exceed the amount given by the following formula:

$$\mathbf{L = ND\ (P)}^{.5}\ /7{,}400$$

Where **L** is allowable leakage in gallons per hour
N is the number of pipe joints
D is the pipe diameter in inches
P is the test pressure in psi

2.8.7 Anchorage

The Division requires sufficient anchorage of force mains within the pumping station and throughout the line length to include, thrust blocks, restrained joints, and/or tie rods.

2.8.8 Friction Losses

The Division requires the use of a C factor that will take into consideration the conditions of the force main at its design usage. For example, a grease-coated pipe after several years will not have the same C factor as a new pipe.

2.8.9 Water Hammer

The force main design should investigate the potential for the existence of water hammer.

2.8.10 Isolation and Valving

The Division recommends the installation of isolation valves at strategic locations along the force main to facilitate maintenance of the system.

APPENDIX 2-A

Design Basis for Wastewater Flow and Loadings

Table 2-A.1. Typical Wastewater Flow Rates from Commercial Sources (Source: Crites and Tchobanoglous, 1998)

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table 2-A.2. Typical Wastewater Flow Rates from Institutional Sources (Source: Crites and Tchobanoglous, 1998)

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table 2-A.3. Typical Wastewater Flow Rates from Commercial Sources

(Source: Crites and Tchobanoglous, 1998)

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5

CHAPTER 4

Preliminary and Pretreatment Facilities

PRELIMINARY AND PRETREATMENT FACILITIES

4.1 Screening and Grinding

4.1.1 General

Some type of screening and/or grinding device shall be provided at all mechanical wastewater plants. The effective removal of grit, rocks, debris, excessive oil or grease and the screening of solids shall be accomplished prior to any activated sludge process. Any grinding which does not dispose of the shredded material outside of the wastewater stream must be evaluated with regard to the influent characteristics (rags, combined sewers) of the waste prior to any activated sludge process.

4.1.2 Location

4.1.2.1 Indoors

Screening devices installed in a building where other equipment or offices are located shall be accessible only through an outside entrance. Adequate lighting, ventilation and access for maintenance or removal of equipment and screenings shall be provided.

4.1.2.2 Outdoors

The removal point for screenings should be as practical as possible for the plant personnel, preferably at ground level. Ladder access is not acceptable unless hoisting facilities for screenings are provided. Separate hoisting is not required for bar screens in manual bypass channels.

4.1.2.3 Deep Pit Installations

Stairway access, adequate lighting and ventilation with a convenient and adequate means for screenings removal shall be provided.

4.1.3 Bar Screens

4.1.3.1 Manually Cleaned

Clear openings between bars shall be from 1 to 2 inches. Slope of the bars shall be 30 to 60 degrees from the vertical. Bar size shall be from 1/4 to 5/8 inches with 1 to 3 inches of depth, depending on the length and material to maintain integrity. A perforated drain plate shall be installed at the top of the bar screen for temporary storage and drainage.

4.1.3.2 Mechanically Cleaned

Mechanically cleaned bar screens are recommended for all plants greater than 1 MGD. Both front cleaned or back cleaned models may be acceptable. Clear openings no less than 5/8 inch are acceptable. Protection from freezing conditions should be considered.

Other than the rakes, no moving parts shall be below the water line.

4.1.3.3 Velocities

Approach velocities no less than 1.25 fps nor a velocity greater than 3.0 fps through the bar screen is desired.

4.1.4 Fine Screens

4.1.4.1 General

Fine screens shall be preceeded by a trash rack or coarse bar screen. Comminution shall not be used ahead of fine screens. A minimum of two fine screens shall be provided, each capable of independent operation at peak design flow. The design engineer must fully evaluate a proposal where fine screens are to be used in lieu of primary sedimentation. Fine screens shall not be considered equivalent to primary sedimentation or grit removal, but will be reviewed on a case-by-case basis. Oil and grease removal must be considered.

4.1.4.2 Design

The operation should be designed to not splash operating personnel with wastewater or screenings. Fine screens will generally increase the dissolved oxygen content of the influent which may be beneficial in certain circumstances. The screens must be enclosed or otherwise protected from cold weather freezing conditions. Disposal of screenings must be addressed. To be landfilled, screenings must be dried to approximately 20% solids. Odors may be a problem in sensitive locations.

4.1.5 Comminution

4.1.5.1 General

In-line comminution may not be acceptable prior to an activated sludge process for facilities with a history of problems with rags. Out-of-stream comminution or disintegration is acceptable for activated sludge processes; however, screenings should not return to the wastewater stream.

4.1.5.2 Design

A coarse bar screen with an automatic bypass shall precede comminution for all mechanical plants. Gravel traps shall precede comminution which is not preceded by grit removal. Clear openings of 1/4 inch are prefered in the comminution device. An automatic unit bypass or other means of protection shall be provided to protect the comminutor motor from flooding. The design shall incorporate a method for removing the equipment from service and for repairs or sharpening of the teeth.

4.1.6 Operability

All screening devices shall have the capability of isolation from the wastewater stream. Sufficient wash water shall be available for cleanup of the area. All mechanical screening devices shall be provided with a manually cleaned bar screen bypass. Multiple bar screens should be considered for plants with rag problems instead of comminutors.

Adequate space must be provided for access to each screening or comminution device. This is critical in elevated, indoor or deep pit installations.

4.1.7 Disposal

All screenings shall be disposed of in an approved manner. Suitable containers shall be provided for holding the screenings. Run-off control must be provided around the containers, where applicable. If fine screens are proposed, consideration must be given to the wastewater overflow if the screens clog or blind. Overflows must be contained and bypassed around the screens by dikes or other means.

4.2 Grit Removal

4.2.1 General

Grit removal is recommended for all mechanical wastewater plants and is required in duplicate for plants receiving wastewater from combined sewers. Systems with a history of substantial grit accumulations may be required to provide for grit removal. Where a system is designed without grit removal facilities, the design shall allow for future installation by providing adequate head and area. Grit washing may be required.

4.2.2 Location

Wherever circumstances permit, grit removal shall be located prior to pumps and comminution when so equiped. Bar screens shall be prior to grit removal. Adequate lighting, ventilation and access for maintenance and removal of grit shall be provided. Stairway access is required if the chamber is above or below ground level. Adequate and convenient means of grit removal shall be provided.

4.2.3 Design

4.2.3.1 Channel Type

A controlled velocity of one foot per second is recommended. Control by either sutro or proportional weir should be used. If a Parshall flume is used for control, the grit chamber must be designed to approach a parabolic cross-section. The length of the channel depends on the size of grit to be removed. The design engineer shall provide this information. Inlet and outlet turbulence must be minimized.

4.2.3.2 Square Type

Square-type basins or similar arrangements should be sized for an overflow rate of 46,300 (WPCF) gallons per day per square foot at the peak flow based on 65-mesh grit at a specific gravity of 2.65. Other overflow rates may be used when the design incorporates particle travel distance and detention. Inlet and outlet turbulence must be minimized.

4.2.3.3 Aerated Type

Aerated grit chambers shall be designed on the basis of detention and/or particle travel distance. Detention time of 2-5 minutes at peak flow is acceptable. Control of the air shall be provided for flexibility. Skimming equipment must be provided in the aerated grit chamber if the outlet is below the water surface.

4.2.3.4 Other Types

Cyclone or swirl-type grit removal processes may be acceptable. The design engineer will be expected to provide a complete treatment analysis for approval.

4.2.4 Disposal

Temporary storage containers shall be provided to hold the grit. Run-off control shall be provided. Attention should be given to operations which may splash waste or grit on operating personnel. Grit washing is required before removal to drying beds. If not washed, the grit shall be disposed of in an approved landfill.

4.2.5 Operability

Adjustable control valves shall be included in each diffuser air line to control mixing and particle segregation. Variable speed arrangements should be provided in cyclone or mechanical type systems. Provisions shall be made for isolation and dewatering each unit or units.

4.3 Pre-Aeration

Pre-aeration is desirable in certain instances, such as to reduce septicity. Pre-aeration may be required where pressure or small diameter collection systems are used. Long detention times in pump stations or collection lines should also be considered. Units shall be designed so that removal from service will not interfere with normal plant operations.

4.4 Flow Equalization

4.4.1 General

Equalization may be used to minimize random or cyclic peaking of organic or hydraulic loadings when the total flow is ultimately processed through the plant. Either in-line or side-line equalization is acceptable. Equalization may be required where peak flows are greater than 2 times the average design flow.

4.4.2 Location

Tanks are generally located after screening and grit removal. Care should be taken in design to minimize solids deposition if located upstream of primary clarifiers. Equalization downstream of primary clarifiers should be investigated, as primary clarifier performance is less sensitive to flow peaking when compared to other processes. Other locations will be evaluated on a case-by-case basis.

4.4.3 Design and Operability

Generally, aeration will be required. Minimum requirements are to maintain 1.0 mg/l of dissolved oxygen. Odor consideration must be addressed when a plant is located in a sensitive area or large equalization basins are used. Large tanks must be divided into compartments to allow for operational flexibility, repair and cleaning. Each compartment shall be capable of dewatering and access. In plant upgrades, existing units which are otherwise to be abandoned may be used for equalization, where possible. Sizing the tankage and compartments will depend on the intended use; i.e., when equalization is for periodic high organic loadings, peak flow events, toxics, etc. A complete analysis shall accompany all engineering report (or plan) submission.

The tank must be capable of being drained and isolated. Controlling the flow rate from the equalization tank to the plant is desirable.

4.5 Swirls and Helical Bends

These units are not to be used in lieu of primary clarification unless special design considerations are used. They are primarily designed for 'coarse' floating and settleable solids removal and will be considered only on a case-by-case basis for in-plant processes. They will, however, be approved for replacing regulators in combined sewer systems, as an interim measure until separation of the sanitary and storm flows is completed. Treatability studies will be required as part of the design. A separate NPDES permit will be required for each of these units that will discharge to a surface water.

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.

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

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:

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

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

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

Sludge processing and disposal should be considered.

9.3 Special Details

9.3.1 General

9.3.1.1 Location

a. Distance from Habitation

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

b. Prevailing Winds

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

c. Surface Runoff

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

d. Water Table

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

e. Ground Water Protection

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

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

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

f. Floodwaters

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

9.3.1.2 Pond Shape

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

9.3.1.3 Recirculation

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

9.3.1.4 Flow Measurement

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

9.3.1.5 Level Gauges

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

9.3.1.6 Pond Dewatering

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

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

9.3.1.7 Control Building

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

9.3.1.8 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock and discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All access gates shall be provided with locks. Cyclone-type fences, 5 to 6 feet high with 3 strands of barbed wire, are desirable, with appropriate warning signs required.

9.3.1.9 Provision for Sludge Accumulation

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

9.3.2 Stabilization Ponds

9.3.2.1 Depth

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

9.3.2.2 Influent Structures and Pipelines

a. Manholes

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

b. Influent Pipelines

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

c. Inlets

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

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

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

d. Discharge Apron

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

9.3.2.3 Interconnecting Piping and Outlet Structures

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

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

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

The lowest drawoff lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond.

A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed 6 inches above the maximum water level shall be provided.

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

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

9.3.2.4 Minimum and Maximum Pond Size

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

9.3.2.5 Number of Ponds

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

9.3.2.6 Parallel/Series Operation

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

9.3.3 Aerated Lagoons

9.3.3.1 Depth

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

9.3.3.2 Influent Structures and Pipelines

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

9.3.3.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping

The same requirements apply as described for facultative systems.

b. Outlet Structure

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

9.3.3.4 Number of Ponds

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

9.3.3.5 Aeration Equipment

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

9.4 Pond Construction Details

9.4.1 Liners

9.4.1.1 Requirement for Lining

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

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

9.4.1.2 General

Pond liner systems that should be evaluated and considered include (1) earth liners, including native soil or local soils mixed with commercially prepared bentonite or comparable chemical sealing compound, and (2) synthetic membrane liners.

The liner should not be subject to deterioration in the presence of the wastewater. The geotechnical recommendations should be carefully considered during pond liner design.

Consideration should also be given to construct test wells when required by the Department in any future regulations, or when industrial waste is involved.

9.4.1.3 Soil Liners

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

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

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

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

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

Bentonite and other similar liners should be considered as a form of earth liner. Their seepage characteristics should be analyzed as previously mentioned, and laboratory testing should be performed using the mixture of the native or local soil and bentonite or similar compound.

In general, the requirements for bentonite or similar compounds should include the following: (1) The bentonite or similar compound should be high swelling and free flowing and have a particle size distribution favorable for uniform application and minimizing of wind drift; (2) the application rate should be least 125 percent of the minimum rate found to be adequate in laboratory tests; (3) application rates recommended by a supplier should be confirmed by an independent laboratory; and (4) the mixtures of soil and bentonite or similar compound should be compacted at a water content greater than the optimum moisture content.

9.4.1.4 Synthetic Membrane Liners

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

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

9.4.1.5 Other Liners

Other liners that have been successfully used are soil cement, gunite, and asphalt concrete.

The performance of these liners is highly dependent on the experience and skill of the designer. Close review of the design of these types of liners is recommended.

9.4.2 Pond Construction

9.4.2.1 General

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

9.4.2.2 Top Width

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

9.4.2.3 Side Slopes

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

9.4.2.4 Freeboard

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

9.4.2.5 Erosion Control

Erosion control should be considered for the inside slopes of the dike to prevent the formation of wavecut beaches in the dike slope. In the event that earth liners or membrane liners with earth cover are used, consideration should be given to erosion protection directly beneath aeration units. If the currents are strong enough, considering the type of material used for the earth cover, erosion pads may be necessary beneath the aeration units. Erosion control should also be considered wherever influent pipes empty into the pond.

If a grass cover for the outer slopes is desired, they should be fertilized and seeded to establish a good growth of vegetative cover. This vegetative cover will help control erosion from runoff. Consideration should also be given to protection of the outer slopes in the event that flooding occurs. The erosion protection should be able to withstand the currents from a flood.

9.4.3 Prefilling

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

9.4.4 Utilities and Structures Within Dike Sections

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

9.5 Hydrograph Controlled Release (HCR) Lagoons

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

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

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

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

9.6 Polishing Lagoons

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

9.7 Operability

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

9.8 Upgrading Existing Systems

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

CHAPTER 10

Disinfection

DISINFECTION

10.1 General

10.1.1 Requirement for Disinfection

Proper disinfection of treated wastewater before disposal is required for all plants (with the exception of some land application systems) to protect the public health.

Disinfection as a minimum shall:

a. Protect public water supplies

b. Protect fisheries and shellfish waters

c. Protect irrigation and agricultural waters

d. Protect water where human contact is likely

10.1.2 Methods of Disinfection

10.1.2.1 Chlorination

Chlorination using dry chlorine (see definition in following section) is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method.

10.1.2.2 Ozonation

Ozonation may be considered as an alternative to chlorination for the reasons described above. Ozonation is considered as Developmental Technology, and should only be considered for very large installations.

10.1.2.3 Other

Other potential methods of disinfection, such as by ultraviolet light, are available and their application will be considered on a case-by-case basis.

10.1.3 Dechlorination

Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need.

10.2 Chlorination

10.2.1 General

10.2.1.1 Forms of Chlorine

a. Dry Chlorine

Dry chlorine is defined as elemental chlorine existing in the liquid or gaseous phase, containing less than 150 mg/l water. Unless otherwise stated, the word "chlorine" wherever used in this section refers to dry chlorine.

b. Sodium Hypochlorite

Sodium hypochlorite may be used as an alternative to chlorine whenever dry chlorine availability, cost, or public safety justifies its use. The requirements for sodium hypochlorite generation and feeding will be determined on a case-by-case basis.

c. Other

Other chlorine compounds such as chlorine dioxide or bromine chloride may be used as alternatives to chlorine whenever cost or environmental concerns justify their use. The acceptability of other chlorine compounds will be determined on a case-by-case basis.

10.2.1.2 Chlorine Feed Equipment

Solution-feed vacuum-type chlorinators are generally preferred for large installations. The use of hypochlorite feeders of the positive displacement type may be considered. Dry chlorine tablet type feeders may also be considered for small flows, into large streams.

Liquid chlorine evaporators should be considered where more than four 1-ton containers will be connected to a supply manifold.

10.2.1.3 Chlorine Supply

a. Cylinders

Cylinders should be considered where the average daily chlorine use is 150 pounds or less. Cylinders are available in 100-pound or 150-pound sizes.

b. Containers

The use of 1-ton containers should be considered where the average daily chlorine consumption is over 150 pounds.

c. Large-Volume Shipments

At large installations, consideration should be given to the use of truck or railroad tank cars, or possibly barge tank loads, generally accompanied by gas evaporators.

10.2.1.4 Chlorine Gas Withdrawal Rates

The maximum withdrawal rate for 100- and 150- pound cylinders should be limited to 40 pounds per day per cylinder.

When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container.

10.2.2 Design Considerations

10.2.2.1 General

Chlorination system designs should consider the following design factors:

Flow

Contact time

Concentration and type of chlorine residual

Mixing

pH

Suspended solids

Industrial wastes

Temperature

Concentration of organisms

Ammonia concentration

10.2.2.2 Capacity

Required chlorinator capacities will vary, depending on the use and point of application of the chlorine. Chlorine dosage should be established for each individual situation, with those variables affecting the chlorine reaction taken into consideration. For normal wastewater, the following dosing capacity may be used as a guideline.

Type of Treatment	**Dosage Capacity* (mg/l)**
Prechlorination for Odor Control	20-25
Activated Sludge Return	5-10
Trickling Filter Plant Effluent (non-nitrified)	3-15
Activated Sludge Plant Effluent (non-nitrified)	2-8
Tertiary Filtration Effluent	1-6
Nitrified Effluent	2-6
Stabilization Pond Effluent	Up to 35

*** Based on Average Design Flow.**

The design should provide adequate flexibility in the chlorination equipment and control system to allow controlled chlorination at minimum and peak flows over the entire life of the treatment plant. Special consideration should be given to the chlorination requirements during the first years of operation to ensure the chlorination system is readily operable at less than design flows without overchlorination. Chlorination equipment should operate between 25% and 75% of total operating range, to allow for adjusting flexibility at design average flow.

10.2.2.3 Mixing

The mixing of chlorine and wastewater can be accomplished by hydraulic or mechanical mixing.

Hydraulic mixing is preferred in smaller plants over mechanical mixing and should be done according to the following criteria.

a. Pipe Flow:

A Reynolds Number of greater than or equal to 1.9 X 10^4 is required.

Pipes up to 30 inches in diameter: chlorine injected into center of pipe.

Pipes greater than 30 inches in diameter: chlorine injected with a grid-type diffuser.

Chlorine applied at least 10 pipe diameters upstream from inlet to contact tank.

b. Open channel flow:

A hydraulic jump with a minimum Froude Number of 4.5 is necessary to provide adequate hydraulic mixing. Point of chlorine injection must be variable because jump location will change with changes in flow.

When mechanical mixing must be used, the following criteria apply:

Use where Reynolds Number for pipe flow is less than 1.9 X 10^4 or for open channel flow without a hydraulic jump.

A mixer-reactor unit is necessary that provides 6 to 18 seconds contact.

Inject chlorine just upstream from mixer.

Mixer speed a minimum of 50 revolutions per minute (rpm).

Jet Chlorinators may be used in a separate chamber from the contact chamber.

The contact chamber shall conform to Section 10.2.2.4 with an average design flow minimum detention time reduced to 15 minutes and a peak detention time of 7.5 minutes.

10.2.2.4 Contact Period

Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

10.2.2.5 Contact Chambers

The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached. It is recommended that baffles be constructed parallel to the longitudinal axis of the chamber with a minimum length-to-width ratio of 30:1 (the total length of the channel created by the baffles should be 30 times the distance between the baffles). Shallow unidirectional contact chambers should also have cross-baffles to reduce short-circuiting caused by wind currents.

Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent. To accomplish continuous disinfection, the chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. A sump or drain within each compartment, with the drainage flowing to a raw sewage inlet, shall be provided for dewatering, sludge accumulation, and maintenance. Unit drains shall not discharge into the outfall pipeline. Baffles shall be provided to prevent the discharge of floating material.

A readily accessible sampling point shall be provided at the outlet end of the contact chamber.

In some instances, the effluent line may be used as chlorine contact chambers provided that the conditions set forth above are met.

10.2.2.6 Dechlorination

a. Sulfur Dioxide

Sulfur dioxide can be purchased, handled, and applied to wastewater in the same way as chlorine. Sulfur dioxide gas forms sulfurous acid, a strong reducing agent, when combined with water. When mixed with free and combined chlorine residuals, sulfurous acid will neutralize these active chlorine compounds to the nontoxic chloride ion.
Sulfur dioxide dosage required for dechlorination is 1 mg/l of SO_2 for 1 mg/l of chlorine residual expressed as Cl_2. Reaction time is essentially

instantaneous. Detention time requirements are based on the time necessary to assure complete mixing of the sulfur dioxide.

b. Other Methods

For very small treatment systems, detention ponds should be considered for dechlorination.

Design rationale and calculations shall be submitted upon request to justify the basis of design for all major components of other dechlorination processes.

10.2.2.7 Sampling, Instrumentation, and Control

For treatment facility designs of 0.5 mgd and greater, continuously modulated dosage control systems should be used. The control system should adjust the chlorine dosage rate to accommodate fluctuations in effluent chlorine demand and residual caused by changes in waste flow and waste characteristics with a maximum lag time of five minutes. These facilities should also utilize continuous chlorine residual monitoring.

Flow proportional control is preferred over manual control for smaller facilities and may be required on a case-by-case basis. The design shall shut off the chlorination for small systems where the flow is zero, such as late at night.

In all cases where dechlorination is required, a compound loop control system or equivalent should be provided.

All sample lines should be designed so that they can be easily purged of slimes and other debris and drain or be protected from freezing.

Alarms and monitoring equipment that adequately alert the operators in the event of deficiencies, malfunctions, or hazardous situations related to chlorine supply metering equipment, leaks, and residuals may be required on a case-by-case basis.

Design of instrumentation and control equipment should allow operation at initial and design flows.

10.2.2.8 Residual Chlorine Testing

Equipment should be provided for measuring chlorine residual.
There are five EPA accepted methods for analysis of total residual chlorine and they are:

1) Ion Selective Electrode,
2) Amperometric End Point Titration Method,
3) Iodometric Titration Methods I & II,
4) DPD Colormetric Method and,
5) DPD Ferrous Titrimetric Method.

Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

10.2.3 Design Details

10.2.3.1 Housing

a. General

An enclosed structure shall be provided for the chlorination equipment.

Chlorine cylinder or container storage area shall be shaded from direct sunlight.

Chlorination systems should be protected from fire hazards, and water should be available for cooling cylinders or containers in case of fire.

Any building which will house chlorine equipment or containers should be designed and constructed to protect all elements of the chlorine system from fire hazards. If flammable materials are stored or processed in the same building with chlorination equipment (other than that utilizing hypochlorite solutions), a firewall should be erected to separate the two areas.

If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building. Doors to this room shall open only to the outside of the building and shall be equipped with panic hardware. Such rooms should be at or above ground level and should permit easy access to all equipment.

A reinforced glass, gastight window shall be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be viewed without entering the room.

Adequate room must be provided for easy access to all equipment for maintenance and repair. The minimum acceptable clearance around and in back of equipment is 2 feet, except for units designed for wall or cylinder mounting.

b. Heat

Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55° F. A temperature of 65° F is recommended.

The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55° F unless evaporators are used and liquid chlorine is withdrawn.

All rooms containing chlorine should also be protected from excess heat.

The room containing ozone generation units shall be maintained above 35^{o}F at all times.

c. Ventilation

All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute, except "package" buildings with less than 16 square feet of floor space, where an entire side opens as a door and sufficient cross-ventilation is provided by a window. For ozonation systems, continuous ventilation to provide at least 6 complete air changes per hour should be installed. The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas. The air inlet should be located to provide cross-ventilation by air at a temperature that will not adversely affect the chlorination equipment.

Chlorinators and some accessories require individual vents to a safe outside area. The vent should terminate not more than 25 feet above the chlorinator or accessory and have a slight downward slope from the highest point. The outside end of the vent should bend down to preclude water entering the vent and be covered with a screen to exclude insects.

d. Electrical

Electrical controls for lights and the ventilation system should operate automatically when the entrance doors are opened. Manually controlled override switches should be located adjacent to and outside of all entrance doors, with an indicator light at each entrance. Electrical controls should be excluded, insofar as possible, from rooms containing chlorine cylinders, chlorine piping, or chlorination equipment.

e. Dechlorination equipment (SO2) shall not be placed in the same room as the Cl2 equipment. SO2 equipment is to be located such that the safety requirements of handling Cl2 are not violated in any form or manner.

10.2.3.2 Piping and Connections

a. Dry Chlorine

Piping systems should be as simple as possible, with a minimum number of joints; piping should be well supported, adequately sloped to allow drainage, protected from mechanical damage, and protected against temperature extremes.

The piping system to handle gas under pressure should be constructed of Schedule 80 black seamless steel pipe with 2,000-pound forged steel fittings. Unions should be ammonia type with lead gaskets. All valves should be Chlorine Institute-approved. Gauges should be equipped with a silver protector diaphragm.

Piping can be assembled by either welded or threaded connections. All threaded pipe must be cleaned with solvent, preferably trichlorethylene, and dried with nitrogen gas or dry air. Teflon tape should be used for thread lubricant in lieu of pipe dope.

b. Injector Vacuum Line

The injector vacuum line between the chlorinator and the injector should be Schedule 80 PVC or fiber cast pipe approved for moist chlorine use.

c. Chlorine Solution

The chlorine solution lines can be Schedule 40 or 80 PVC, rubber-lined steel, saran-lined steel, or fiber cast pipe approved for moist chlorine use. Valves should be PVC, PVC-lined, or rubber- lined.

10.2.3.3 Water Supply

An ample supply of water shall be available for operating the chlorinator. Where a booster pump is required, duplicate equipment shall be provided, and, when necessary, standby power as well. When connection is made from domestic water supplies, equipment for backflow prevention shall be provided. Where treated effluent is used, a wye strainer shall be required. Pressure gauges should be provided on chlorinator water supply lines.

10.2.3.4 Standby Equipment and Spare Parts

Standby chlorination capabilities should be provided which will ensure adequate disinfection with any unit out of operation for maintenance or repairs. An adequate inventory of parts subject to wear and breakage should be maintained at all times.

10.2.3.5 Scales

Scales shall be provided at all plants using chlorine gas. At large plants, scales of the indicating and recording type are recommended. Scales shall be provided for each cylinder or container in service; one scale is adequate for a group of cylinders or containers connected to a common manifold. Scales should be constructed of or coated with corrosion-resistant material. Scales shall be recommended for day tanks when using HTH.

10.2.3.6 Handling Equipment

Handling equipment should be provided as follows for 100- and 150-pound cylinders:

A hand truck specifically designed for cylinders

A method of securing cylinders to prevent them from falling over

Handling equipment should be provided as follows for 2,000-pound containers:

Two-ton-capacity hoist

Cylinder lifting bar

Monorail or hoist with sufficient lifting height to pass one cylinder over another cylinder trunnions to allow rotating the cylinders for proper connection.

10.2.3.7 Container Space

Sufficient space should be provided in the supply area for at least one spare cylinder or container for each one in service.

10.2.3.8 Automatic Switchover of Cylinders and Containers

Automatic switchover of chlorine cylinders and containers at facilities having less than continuous operator attendance is desirable and will be required on a case-by-case basis.

10.2.4 Safety

10.2.4.1 Leak Detection and Controls

A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks.

All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors. Continuous chlorine leak detectors would be desirable at all installations. Whenever chlorine leak detectors are installed, they should be connected to a centrally located alarm system and shall automatically start exhaust fans.

10.2.4.2 Breathing Apparatus

At least one gas mask in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored. Instructions for using, testing, and replacing mask parts, including canisters, shall be posted. At large installations, where 1-ton containers are used, self- contained air breathing apparatus of the positive pressure type shall be provided.

10.2.4.3 Container Repair Kits

All installations utilizing 1-ton containers should have Chlorine Institute Emergency Container Kits. Other installations using cylinders should have access to kits stored at a central location.

10.2.4.4 Piping Color Codes

It is desirable to color code all piping related to chlorine systems.

10.3 Alternate Methods

10.3.1 Ozonation

10.3.1.1 Application

Ozonation may be substituted for chlorination whenever chlorine availability, cost, or environmental benefits justify its application.

Ozone is generated on-site from either air or high-purity oxygen. Ozonation should be considered if high-purity oxygen is available at the plant for other processes.

10.3.1.2 Design Basis

The design requirements for ozonation systems should be based on pilot testing or similar full-scale installations.

As a minimum, the following design factors should be considered:

a. Ozone dosage

b. Dispersion and mixing of ozone in wastewater

c. Contactor design

All design criteria shall be submitted upon request to justify the basis of design of the ozonation system. The detailed design requirements will be determined on a case-by-case basis.

10.3.2 Ultraviolet Disinfection

10.3.2.1 Application

UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost, or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required or chlorine toxicity is suspected, UV disinfection is a viable alternative.

10.3.2.2 Design Basis

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics

b. Factors affecting transmission of UV light to the microorganisms

c. Properties of the wastewater being disinfected.

UV disinfection is considered as Developmental Technology and all design criteria shall be submitted upon request to justify the basis of the UV disinfection system. The detailed design requirements will be determined on a case-by-case basis.

CHAPTER 13

Plant Flow Measurement and Sampling

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.

13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.

13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.

13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement.
Two primary devices and flow charts may be required in some cases.

13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases, measurement of the total flow (influent plus recycle) may be desirable.

13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.

13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulance is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.

13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.

13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.

13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths.

The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow -lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.

13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.

13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.

13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.

13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.

13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.

13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.

13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of 15-20 times the maximum head on the crest in order to minimize the approach velocity.

The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissable.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

13.2.6 Hydrograph Controlled Release (HCR) Systems

For plants utilizing HCR systems, accurate stream flow measurements are required. Detailed plans must be submitted outlining the construction of the primary stream flow measuring device and the associated instrumentation. The following factors should be emphasized in the design.

13.2.6.1 Accuracy over the flow range required for effluent discharge limiting purposes.

13.2.6.2 Operational factors such as cleaning and maintenance requirements.

13.2.6.3 Cost

The use of sharp crested weirs as described in Section 13.2.3 will not be allowed due to the installation requirements such as approach channel details and upstream pool depth and since entrapment and accumulation of silt and debris may cause the device to measure inaccurately. Parshall Flumes may be used due to their self-cleaning ability but field calibration will be required. Self-cleaning V-notch weirs are recommended due to their accuracy in low flow ranges. The weir can be made self-cleaning by sloping both sides of the weir away from the crest. The top portion of the crest shall be covered with angle-iron to prevent its breakdown. The angle of the V-notch should be determined by the stream characteristics; however, a smaller angle will increase accuracy in the low flow range. The primary device shall be built with sufficient depth into the stream bed to prevent undercutting and sufficient height to cover the required flow range.

It is recommended that the wastewater system director, engineer, or other city official contact the U.S. Geological Survey (USGS), Water Resources Division, in Nashville, Tennessee, for assistance with the design and installation of the flow measuring device. They offer a program which shares much of the costs for designing and maintaining the device. After visiting the site, they can assist with the design of a self-cleaning weir for the stream. They provide the consultant with a field design that shows the proper location and installation of the weir. From this field design, the consultant must provide detailed plans to the State.

The wastewater system is responsible for constructing the weir at their own cost. The flow measuring station is installed, maintained, and calibrated by USGS personnel so that accurate results are insured.

The primary device will record continuous flow of the stream and can be designed to send a feedback signal to the WWTP for other purposes such as controlling plant discharge rates.

This program benefits both the local wastewater system, the State of Tennessee, and the USGS, as it adds to stream flow data bases archived for public use. Cost sharing allows the flow measuring station to be built and operated at a lower cost for all parties concerned.

13.3 Sampling

13.3.1 Automatic Sampling Equipment

The following general guidelines should be adhered to in the use of automatic samplers:

13.3.1.1 Automatic samplers shall be used where composite sampling is necessary.

13.3.1.2 The sampling device shall be located near the source being sampled, to prevent sample degradation in the line.

13.3.1.3 Long sampling transmission lines should be avoided.

13.3.1.4 If sampling transmission lines are used, they shall be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines cleanable. Minimum velocities in sample lines shall be 3 feet per second under all operating conditions.

13.3.1.5 Samples shall be refrigerated unless the samples will not be effected by biological degradation.

13.3.1.6 Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.

13.3.1.7 Influent automatic samplers should draw a sample downstream of bar screens or comminutors. They should be located before any return sludge lines or scum lines.

13.3.1.8 Effluent sampling should draw a sample immediately upstream of the chlorination point. This will eliminate the need to dechlorinate and then re-seed the sample.

13.3.2 Manual Sampling

Because grab samples are manually obtained, safe access to sampling sites should be considered in the design of treatment facilities.

13.3.3 Long Outfall Lines

Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits.

Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line and the receiving stream on all outfall lines greater than one mile in length.

Dissolved oxygen, fecal coliform, and chlorine residual may have to be measured at the remote sampling station for permit compliance purposes.

13.3.4 Sampling Schedules

Samples must be taken and analyzed for two purposes: permit compliance and process control. Any time a new permit is issued, a sampling schedule for permit compliance will be determined by the Division of Water Pollution Control. An additional sampling program needs to be set up for process control purposes. This would include all testing required for completing the monthly operational report, as well as any other tests that might aid the operation of the plant. This schedule can be determined by the Division of Water Pollution Control, Wastewater Treatment Section or the appropriate field office once final plans are approved. The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines. This makes it possible to determine the efficiency of each treatment process. Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136. Information about sampling locations and techniques can be obtained from the EPA Aerobic Biological Wastewater Treatment Facilities Process Control Manual and EPA's NPDES Compliance Inspection Manual.

CHAPTER 16

Design Guidelines for Wastewater Treatment Systems Using Spray Irrigation

SPRAY IRRIGATION
LAND TREATMENT SYSTEMS

16.1 General

16.1.1 General

This chapter provides guidelines and criteria for the design of surface spray irrigation land treatment systems.

The wastewater loading rate is limited by the maximum amount of a particular wastewater constituent that can be applied to a specific site. For wastewater from municipalities, the limiting design factor is usually either the hydraulic capacity of the soil or the nitrogen content of the wastewater. For industrial wastewater, the limiting design factor may be the hydraulic capacity of the soil, nitrogen or any other wastewater constituent such as metals, organics, etc.

16.1.2 Applicability

Spray irrigation wastewater treatment systems must be designed and operated so that there is no direct discharge to surface waters. Treatment consists of evaporation directly to the atmosphere, by transpiration to the atmosphere via vegetation uptake and by percolation to groundwater. A State of Tennessee Operation Permit (SOP) is required for operation of spray irrigation land treatment systems.

16.1.3 Location

The spray irrigation treatment site should be relatively isolated, easily accessible and not susceptible to flooding. The site can be developed on agricultural land and/or forests or can include parks, golf courses, etc. Site location shall take into account dwellings, roads, streams, etc. A site evaluation by the Division of Water Pollution will be required before review of the Engineering Report and/or application for an SOP.

16.1.4 Topography

Maximum grades for wastewater spray fields should be limited to 8% for row crops, 15% for forage crops and 30% for forests. The greater the slope the greater potential for lateral subsurface drainage, ponding and extended saturation of the soil. Depressions, sink holes, etc., are to be avoided.

16.1.5 Soils

The infiltrative capacity of soil is a critical factor to be considered when designing any type of spray irrigation system. If the profile of a particular soil considered for spray irrigation extended to a significant depth without a restrictive horizon (most limiting layer), the ability to load that soil per unit area would be relatively high.

On the other extreme, if a soil being considered for spray irrigation has a shallow restrictive horizon, the ability to load that soil would be lower relative to the deeper soil. Depth to restrictive horizon, soil permeability and slope of the restrictive horizon are factors that control the amount and rate at which ground water can exit an area. If the amount of treated effluent applied to an area, in combination with rainfall over the area and groundwater moving into the area, exceed the soil profile's ability to transmit the water away from the application area, surface runoff of wastewater effluent will likely occur.

Evaluation of a soil area's suitability for spray irrigation should take into consideration limiting aspects of the soil profile. Sites with shallow restrictive horizons overlain by low permeability soils represent one of the more limited scenarios for spray irrigation and the application rate and/or application area should be suitably modified.

Also critical when designing systems in soils with shallow restrictive horizons are the presence and location of hydrologic boundaries such as drainage ways and waterways. These hydrologic boundaries provide an outlet for ground water discharge. Not only is it critical to identify these features in consideration of appropriate setbacks/buffers, it is also critical to factor in their role in the overall hydrologic cycle of the landscape.

Horizons along which lateral flow would be expected include, but are not necessarily limited to: bedrock, fragipans, and zones with high clay percentage overlain by more permeable soil.

Spray irrigation design submittals should take into consideration all factors influencing the infiltrative capacity of the soil and the ability of the soil and site to transport ground water away from the application area. Spray pattern designs must properly utilize the site soil and topography. It should be noted that the use of historical information from existing systems installed and operated in similar soils, with documented loading rates, landscape positions and design conditions similar to the proposed system may be applicable. Therefore, soils that have been highly compacted and/or disturbed, such as old road beds, foundations, etc., must be excluded when evaluating suitable areas for surface spray irrigation systems.

16.2 Soil Investigations

16.2.1 General

Preliminary soil investigations should be done to identify areas best suited for surface spray irrigation. The proposed surface spray area must be mapped at sufficient accuracy to identify each soils series (or lowest possible level of soil classification) present and the boundary location between series. Once those areas are identified, the more detailed procedures outlined below will be employed.

It is required that all soil investigations be performed by a soil scientist currently on the Ground Water Protection list of approved soil scientists/soil consultants.

For spray irrigation wastewater treatment systems, moderately permeable and well-drained soils are desirable. However, the use of any soil is acceptable if it meets the following four (4) criteria:

1. The applied effluent loading rate does not exceed the applicable hydraulic loading rate in **Table 16-1**. The applicable hydraulic loading rate is determined by a detailed site evaluation in which the site is mapped utilizing soil borings and pits to determine the physical properties of soil horizons and soil map units.
2. The applied effluent maximum loading rate does not exceed 10% of the minimum NRCS saturated vertical hydraulic conductivity (K_{SAT}) for the soil series or 0.25 GPD/SF whichever is least. Note: this may have to be lowered based upon the results of the nutrient loading rate calculation per Equation 16-1.
3. The soil does not have a restrictive horizon within its top twenty (20) inches.
4. The soil is well drained, or capable of being drained.

   It is desirable to have a minimum depth of twenty (20) inches of undisturbed soil above a restrictive horizon (eg., rock, fragipan, high water table, etc.)

TABLE 16-1

Hydraulic Loading Rates (GPD/SF) – For Spray Irrigation Systems

(Reference: EPA/R-00/08, February 2002, “*Onsite Wastewater Treatment Systems Manual*”)

TEXTURE	**STRUCTURE**		**HYDRAULIC LOADING RATE***	
	SHAPE	**GRADE**	**GPD / SF BOD ≤ 150 mg/L**	**GPD / SF BOD ≤ 30 mg/L**
Coarse Sand, Loamy Coarse Sand	**NA**	**NA**	**0.80**	**NA**
Sand	**NA**	**NA**		**NA**
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	**Single Grain**	**Structureless**	**0.40**	**1.00**
Coarse Sandy Loam, Sandy Loam	**Massive**	**Structureless**	**0.20**	**0.60**
	Platy	**Weak**	**0.20**	**0.50**
		Moderate, Strong	▨	▨
	Blocky, Granular	**Weak**	**0.20**	**0.70**
		Moderate, Strong	**0.40**	**1.00**
Loam	**Massive**	**Structureless**	**0.20**	**0.50**
	Platy	**Weak, Moderate, Strong**	▨	▨
	Angular, Blocky	**Weak**	**0.40**	**0.60**
	Granular, Subangular	**Moderate, Strong**	**0.60**	**0.80**
Silt Loam	**Massive**	**Structureless**	▨	**0.20**
	Platy	**Weak, Moderate, Strong**	▨	▨
	Angular, Blocky, Granular, Subangular	**Weak**	**0.40**	**0.60**
		Moderate, Strong	**0.60**	**0.80**
Sandy Clay Loam,	**Massive**	**Structureless**	▨	▨

Clay Loam, Silty Clay Loam	**Platy**	**Weak, Moderate, Strong**	▨	▨
	Angular, Blocky Granular, Subangular	**Weak**	▨	**0.30**
		Moderate, Strong	▨	**0.60**
Sandy Clay Clay, Silty Clay	**Massive**	**Structureless**	▨	▨
	Platy	**Weak, Moderate, Strong**	▨	▨
	Angular, Blocky Granular, Subangular	**Weak**	▨	▨
		Moderate, Strong	**0.20**	**0.30**

*** Maximum allowable is 0.25 GPD/SF; however all hydraulic loading rates may be adjusted based upon special site specific evaluations approved by TDEC.**

▨ **These soils are considered unacceptable for spray irrigation.**

16.2.2 Soil Mapping

The mapping procedure will usually begin with the property/land being generally evaluated to delineate or separate areas with suitable characteristics. This procedure will save time and money since some areas will be too shallow, too wet, too steep, etc. Adequate ground control is mandatory for all sites. The ground control is necessary to reproduce the map if needed. All located coordinates (soil map boundaries and pit locations) must be shown on the final Water Pollution Control (WPC) Soil Map.

Soil data collection shall be based upon one, or combination of the following:

1. Grid staking at intervals sufficient to allow the soils scientist to attest to the accuracy of the map for the intended purpose;
2. Mapping of pits and critical auger locations using dual frequency survey grade Global Positioning System (GPS) units.
3. Other controls adequate to map the location of pits, physical features, and separations.
4. Grid stakes and GPS data points must be locatable to within two (2) feet of distance shown.
5. The ground control has to correlate to the exterior boundaries of the property so as to show the location of the soils areas within the bounds of the project and must be certified by a Registered Land Surveyor per TCA 62-18-102(3).

The soil scientists are responsible for conducting a sufficient number of borings that, in their professional opinion, will allow them to certify the soils series (or lowest possible level of soil classification) present, identify boundaries between series, and describe each soil horizon as to color, depth to restrictive horizon, and depth to rock. Any redoximorphic features observed are to be described. This delineation should be based upon the texture and structure of the soils to a depth of forty-eight (48) inches or restrictive horizon whichever is shallower.

After the mapped soils area is established and marked, soil borings to a minimum depth of forty-eight (48) inches or restrictive horizon, whichever is shallowest, shall be taken at sufficient intervals to identify and map the boundaries of the soils series (or lowest possible level of soil classification) present on the site. The exact number and location of borings will be determined by the soils scientist in consultation with the design engineer. Sufficient borings should be made to identify any dissimilar soils accounting for more than 10 percent of the total proposed surface spray irrigation area.

The soil scientist shall excavate an adequate number of pits to determine the typical profiles and soils characteristics that are expected for all soils mapped. It is recommended that a minimum of two (2) pits per acre in polygons of qualifying soils be excavated; however, the actual number and location of pits will be left to the best professional judgment of the soil scientist. If less than two (2) pits per acre are utilized, the soil scientist must include the rationale in notes on the WPC Soil Map.

The pit description must be entered onto a pedon sheet and submitted with the soils map and engineering report. The "Soil Description" should include all of the information contained on form NRCS-Soils-232G (5-86), U.S. Department of Agriculture, Natural Resources Conservation Service (as shown in Chapter 17, Appendix D).

In their description of the pit profiles, the soil scientists must describe the soil's structure, texture, color, and any redoximorphic features present. They should also describe root depth and presence of macropores, etc. The series name or lowest possible level of soil classification will be recorded. The depth to hard rock using an auger or a tile probe must be specified if the depth is less than forty-eight (48) inches and estimated if greater than forty-eight (48) inches. The auger borings and soil backhoe pits should be located, numbered and shown on the WPC Soil Map. The soil scientist will be required to prepare and sign a detailed certification statement for each site evaluated as follows:

Water Pollution Control Soil Map Completed by:

Signature Date

John/Jane Doe, Soils Consultant

The following statement should appear on the map:

"I, (Soils Consultant's Name) affirm that this Water Pollution Control Soil Map has been prepared in accordance with accepted standards of soil science practice and the standards and methodologies established in the NRCS Soil Survey Manual and USDA Soil Taxonomy. No other warranties are made or implied."

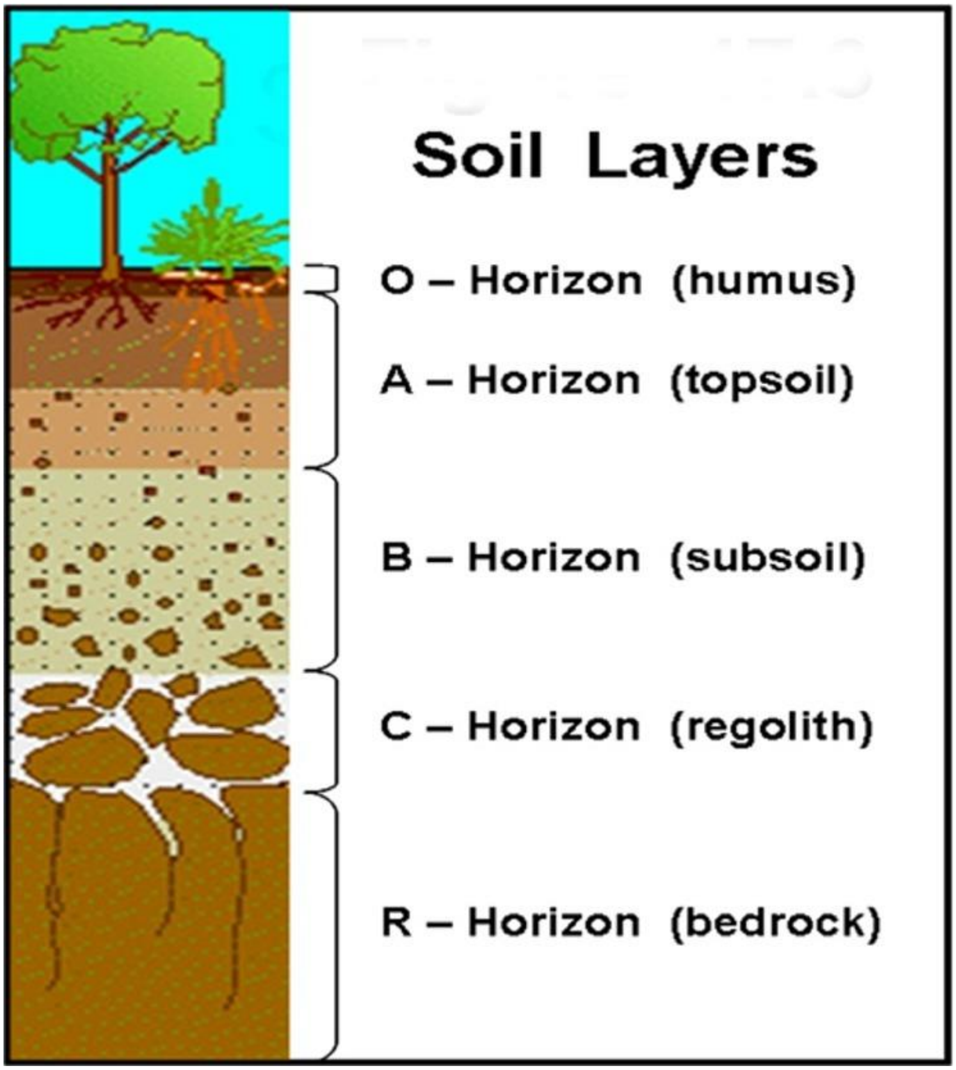
Soil profile information and pit excavation, as described in these design criteria, are additional requirements deemed necessary to properly assess an area's suitability for surface spray irrigation.

16.2.3 Soil Definitions

Soil Horizons (layers): Soil is made up of distinct horizontal layers; these layers are called horizons and display vertical zones. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock).

Soil horizons develop due to the nature of soil formation. Soil is the product of the weathering of parent material (i.e. bedrock), accompanied by the addition of organic matter. The method for naming the soil horizons is quite simple as the **Figure 16.1** shows. In the simplest naming system, soils horizons are designated **O** (organic), **A** (topsoil), **B** (mineral soil), **C** (weathered parent material), and **R** is the unweathered rock (bedrock) layer that is beneath all the other layers. The horizons of most importance to plant growth and forest health are the **O** and **A horizons**. The **litter layer** found covering the soil is also of interest because it provides most of the organic matter found in the O and A horizons.

FIGURE 16.1



The **Litter Layer** is the topmost layer on the forest floor. It consists of leaves, needles and other non-decomposed material on the forest floor. While this is not considered part of the soil, it is interesting to measure the depth of the litter layer when sampling the soil. The depth of the litter layer can vary greatly even within a particular site. Because of this, several measurements are required to attempt to characterize litter layer depth. The litter layer can be considered part of the overall soils depth.

The **O-Horizon** primarily consists of decomposed organic matter and has a dark rich color, increased porosity, and increased aggregate structure (larger soil "clumps"). The depth of the O horizon is measured from the surface of the soil (after the litter layer has been cleared away) to the point where the darker organic color changes to a slightly lighter colored soil that contains increased mineral particles in addition to organic matter.

The transition from the O to the A horizon can also be recognized by a significant increase in the mineral soil particles. In many urban soils, the O horizon may very thin if it exists at all. The O horizon can also be considered part of the overall soils depth.

The **A-Horizon** is the **mineral** “topsoil” and consists of highly weathered **parent material** (rocks), which is somewhat lighter in color than the O horizon due to a decrease in **organic matter**. The particles in the A horizon are more granular and “crumb-like”. Seeds germinate and plant roots grow in this layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. The depth of the A horizon is measured from the region of color changes from the dark O horizon to the transition to the B horizon. The transition to the B horizon can be identified by increased clay content (see below) and the absence of organic material: no root hairs, small pieces of needle, etc.

The most thorough soil study involves analysis on separate O and A horizon samples. This requires separating and storing O and A horizon samples. It also involves completing the entire soil analysis on both the O and A samples. If this is not possible, the O and A samples can be combined (or composited) and the analysis can be completed on the O and A sample together.

The **B-Horizon** is also called the **subsoil -** this layer is beneath the A horizon and above the C horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives when soil solution containing dissolved minerals drips from the soil above.

The B horizon is identified by increased clay content which makes the soil hold together when moist. A simple test for clay content is to moisten a small handful of soil and attempt to smear a small portion up the forefinger. Soils high in clay will hold together and form a “ribbon”, soils with more sand and silt will be granular and fall apart. It is lighter in color and often may be reddish due to the iron content.

The **C Horizon** (layer beneath the B Horizon) consists of porous rock (broken-up bedrock, bedrock with holes). It is also called regolith or **saprolyte** which means "rotten rock." Plant roots do not penetrate into this layer; very little organic material is found in this layer.

The **R-Horizon** is the unweathered rock (bedrock) layer that is beneath all the other layers. For the purposes of drip dispersal designs, the R horizon is considered an impermeable layer.

Water Pollution Control (WPC) Soils Map. A first order survey as defined in the Soil Survey Manual, United States Department of Agriculture, October 1993.

These surveys are made for various land use that requires detailed soils information.

Map scale should be one (1) inch equals one hundred (100) feet or a scale that will allow the map to fill a 24” x 36” plan sheet. These maps should have adequate cartographic detail to satisfy the requirements of project. The WPC Soils Map is essentially a special map that shows a very high degree of soil and landscape detail. Baseline mapping standards for these WPC Soil Maps prepared in support of surface spray irrigation should be a first order survey in accordance with the current edition of the Soil Survey Manual, United States Department of Agricultural, October 1993. Soil profile information and pit excavation, as described in these design criteria are additional requirements deemed necessary to properly assess an area’s suitability for surface spray irrigation. These maps should be clearly marked or labeled as “Water Pollution Control Soil Map”.

Soil map unit. A unique collection of areas that have common soil characteristics and/or miscellaneous physical and chemical features.

Soil scientist. A person having the experience and education necessary to measure soil properties and classify soils per *Soil Taxonomy*, synonymous with the term “soil consultant”.

Soil series. A group of soils having similar properties; the lowest level of soil classification.

Most limiting horizon. A horizon in the soil (bedrock or fragipan) that either provides the greatest impediment to or completely stops, the downward movement of liquids through the soil.

16.3 Preapplication Treatment Requirements

16.3.1 General

Wastewater spray irrigation systems have a demonstrated ability to treat high strength organic wastes to low levels. However, such systems require a high degree of management with particular attention paid to organic loading rates and aeration of the soil profile between wastewater applications.

The Division of Water Pollution requires that all domestic and municipal wastewaters receive biological treatment prior to irrigation.

This is necessary to:

a. Protect the health of persons contacting the irrigated wastewater.

b. Reduce the potential for odors in storage and irrigation.

Some industrial wastewaters may be suitable for direct land treatment by irrigation under intensive management schemes. The Division of Water Pollution Control will evaluate such systems on a case-by-case basis.

16.3.2 BOD and TSS Reduction, and Disinfection

Preapplication treatment standards for domestic and municipal wastewaters prior to storage and/or irrigation are as follows:

a. Sites Closed to Public Access

All wastewater must be treated to a level afforded by lagoons which are designed in accordance with Chapter 9.

Disinfection is generally not required for restricted and fenced access land treatment sites. The Division of Water Pollution Control may, however, require disinfection when deemed necessary.

b. Sites Open to Public Access

Sites open to public access include golf courses, cemeteries, green areas, parks, and other public or private land where public use occurs or is expected to occur. Wastewater that is spray irrigated on public access sites must not exceed a 5-day Biochemical Oxygen Demand and Total Suspended Solids of 30 mg/L, as a monthly average. Disinfection to reduce E. coli bacteria to 23 colonies/100 mL is required.

The preapplication treatment standards for wastewater that is to be applied to public access areas will be reviewed by the Division of Water Pollution Control on a case-by-case basis. More stringent preapplication treatment standards may be required as the Division of Water Pollution Control deems necessary. The Division of Water Pollution Control recommends that the engineer give preference to pretreatment systems that will provide the greatest degree of reliability.

16.3.3 Treatment and Storage Ponds

The storage pond and irrigation pump station must be hydraulically separate from the treatment cells (i.e., pumping must not affect hydraulic detention time in these cells). The Division of Water Pollution Control recommends the use of Chapter 9 of the Design Criteria for Sewage Works, as well as the United States Environmental Protection Agency's October 1983 Design Manual: Municipal Wastewater Stabilization Ponds as a reference for design of preapplication treatment ponds.

16.4 Inorganic Constituents of Treated Wastewater

Inorganic constituents of effluent from preapplication treatment should be compared with Table 16-2 to insure compatibility with land treatment site soils and cover crops.

Table 16-2

Recommended Values for Inorganic Constituents in Wastewater Surfaced Applied to Land

Potential Problem and Constituent	No Problem	Increasing Problem	Severe Problem
pH (Standard Units)	6.5 – 8.4		<5.0 or >9.0
Permeability			
Electrical Conductivity (mho/cm)	>0.50	<0.50	<2.0
Sodium Adsorption Ratio (a)	<5.0	5.0 – 9.0	>9.0
Salinity			
Electrical Conductivity (mho/cm)	<0.75	0.75 – 3.0	>3.0
Anions:			
Bicarbonate (meq/L)	<1.5	1.5 – 8.5	>8.5
(mg/L as $CaCO_3$)	<150	150 – 850	>850
Chloride (meq/L)	<3.0	3.0 – 10	>10
(mg/L)	<100	100 – 300	>300
Fluoride (mg/L)	<1.8		
Cations:			
Ammonia (mg/L as N)	<5.0	5.0 – 30	>30
Sodium (meq/L)	<3.0	3.0 – 9.0	>9.0
(mg/L)	<70	70 or greater	
Trace Metals (mg/L)			
Aluminum	<10		
Arsenic	<0.2		
Beryllium	<0.2		
Boron	<0.5	0.5 – 2.0	>2.0
Cadmium	<0.02		
Chromium	<0.2		
Cobalt	<0.1		
Copper	<0.4		
Iron	<10		
Lead	<10		
Lithium	<2.5		
Manganese	<0.4		
Molybdenum	<0.02		
Nickel	<0.4		
Selenium	<0.04		
Zinc	<4.0		

(a) Sodium Adsorption Ratio (SAR) = $\dfrac{Na^{+1}}{\text{SQR (} Ca^{+2} + Mg^{+2}\text{) / 2}}$

Where, Na+1, Ca+2, and Mg+2 in wastewater are expressed in milliequivalents per liter(meq/L).

SQR represents “Square Root of”

16.5 Protection of Irrigation Equipment

Prior to pumping to the spray field distribution system, the wastewater must be screened to remove fibers, coarse solids, oil and grease which might clog distribution pipes or spray nozzles. As a minimum, screens with a nominal diameter smaller than the smallest flow opening in the distribution system should be provided. Screening to remove solids greater than one-half (½) the diameter of the smallest sprinkler nozzle is recommended by some sprinkler manufacturers. The planned method for disposal of the screenings must be provided.

Pressurized, clean water for backwashing screens should be provided. This backwash may be manual or automated. Backwashed screenings should be captured and removed for disposal. These screenings should not be returned to the storage pond(s) or preapplication treatment system.

16.6 Determination of Design Application Rates

16.6.1 General

One of the key steps in the design of a spray irrigation system is to develop a "design application rate" in gallons per day per square foot (GPD/SF). This value is derived from either the hydraulic (water) loading rate (Lwh) based upon the most restrictive of (1) the NRCS hydraulic conductivity data and the texture and structure (per Table 16-1), or (2) the nutrient (nitrogen) loading rate (Lwn) calculations to determine design wastewater loading(s) and, thus, spray irrigation field area requirements.

16.6.2 Design Values

The most limiting horizon, of each soil series shall be identified. Any surface condition which limits the vertical or lateral drainage of the soil profile shall also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Design considerations relative to the soils per Section 16.1.5 must be used.

Sites with seasonal high groundwater less than twenty-four (24) inches deep may require drainage improvements before they can be utilized for spray irrigation land treatment. The design hydraulic conductivity at such sites is a function of the design of the drainage system.

16.7 Determination of Design Wastewater Loading

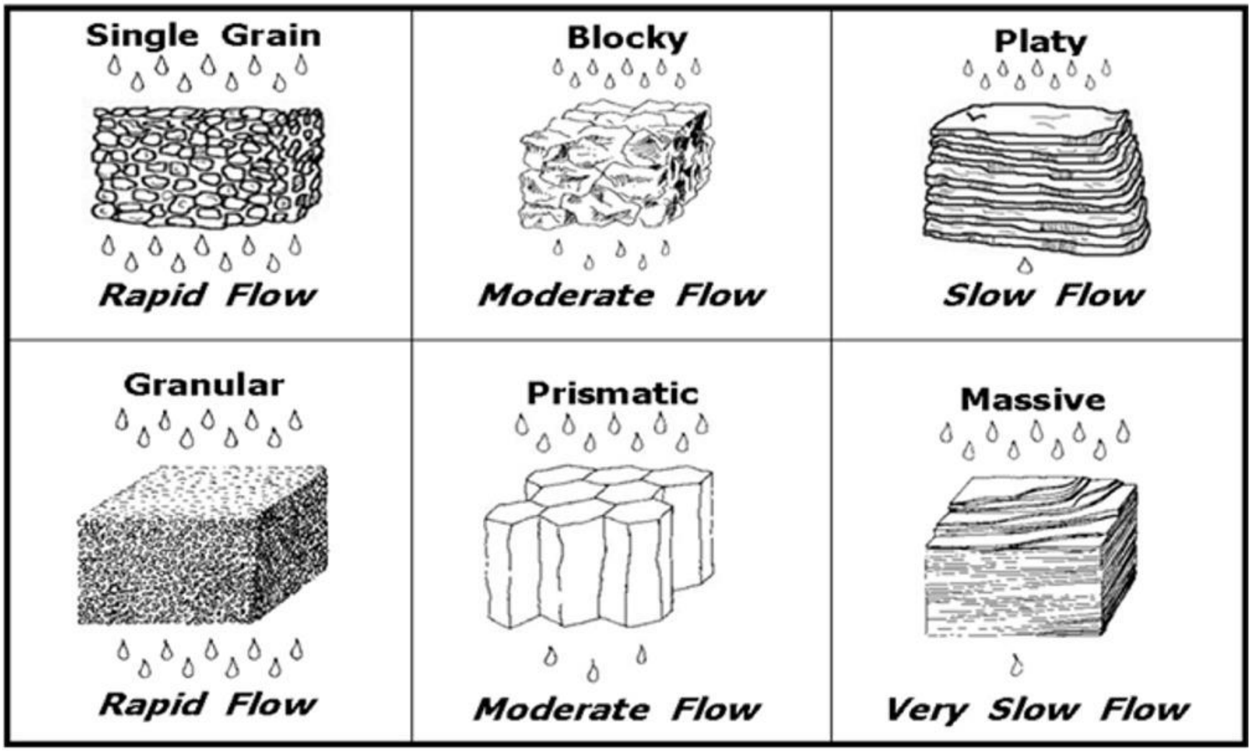
16.7.1 General

The design wastewater loading is a function of:

a. Precipitation.
b. Evapotranspiration.
c. Design hydraulic conductivity rate.
d. Nitrogen loading limitations.
e. Other constituent (i.e., organic/BOD) loading limitations.
f. Groundwater and drainage conditions.
g. Average and peak design wastewater flows.
h. Soil denitrification rates
i. Rate of nitrogen uptake in site vegetation

Therefore, developing the design wastewater loading is an interative process. The Lwh value is determined by a detailed site evaluation and will be dependent upon the soil characteristics as shown in Table 16-1 and pictorially represented in **Figure 16.2**. This loading is then compared to the Lwn loading limitations (reference Section 16.8). If the initial Lwh value exceeds the Lwn value, the design wastewater loading resulting from the nitrogen reduction evaluation described in Section 16.8 becomes the design loading rate.

FIGURE 16.2



16.8 Nitrogen Loading and Crop Selection and Management

16.8.1 General

Nitrate concentration in percolate from wastewater spray irrigation systems will be limited via a State Operation Permit (SOP) to not exceed 10 mg/L nitrate-nitrogen at the site property line. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from using the criteria stipulated in 16.1.5 for hydraulic loading rates must be checked against nitrogen loading limitations.

16.8.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

16.8.3 Organic / BOD Loading

When wastewater is high strength (above 150 mg/L BOD), the organic loading rate should be limited as follows based upon the soil:

10,000 pounds of BOD per acre per year for Clays.

15, 000 pounds of BOD per acre per year for Loams.

20,000 pounds of BOD per acre per year for Sandy.

(Reference: Dr. Robert Rubin, NC State University, who cited work by Phillips and Carlile)

Equation 16-1 is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

(**Equation 16-1)**

$$\mathbf{Lwn} = \frac{Cp\ (Pr - PET) + U(4.413)}{(1 - f)(Cn) - Cp}$$

Where:

Lwn = allowable monthly hydraulic loading rate based on nitrogen limits, inches/month

Cp = nitrogen concentration in the percolating wastewater, mg/L.

This will usually be 10mg/L Nitrate-Nitrogen

Pr = Five-year return monthly precipitation, inches/month

PET = potential evapotranspiration, inches/month

U = nitrogen uptake by cover, lbs/acre/year pounds/acre/year

(value should not exceed 100 lbs/acre/year)

Cn = Nitrate-Nitrogen concentration in applied wastewater, mg/L

(after losses in preapplication treatment)

F = fraction of applied nitrogen removed by denitrification and volatilization.

The values of ***Lwh*** and ***Lwn*** are compared for each month.

The lesser of the two values will be used to determine the amount of acreage needed.

NOTES:

- A "**Cn**" value of less than 23 mg/L will become a permit condition.
- The allowable vegetative uptake "**U**" of nitrogen on the drip area will be limited to an uptake rate of 100 pounds per acre per year unless trees are the vegetation.
- The "**f**" values for denitrification have been estimated based upon data supplied by the University of Tennessee and Oak Ridge National Laboratory. Denitrification rates (f) ranging from 25% in January and February to 35% in July and August are very conservative, but are defendable based upon the literature. Denitrification rates are assumed to vary linearly with the temperature and the actual rates are likely to be higher than the default values shown in Table 16-1.
- Conversion Factor - **4.413** mg-acre-inch/liter-lb. The equation and factor are from the TDHE Design Criteria for Sewage Works (April 1989).

The factor comes from assuming that one pound of contaminant of concern is diluted within a volume of water equal to one acre-inch. For Example calculation see Chapter 17, Appendix 17-A. For the derivation of this factor see Chapter 17, Appendix 17-C.

Table 16-2 shows the default values for Lwn calculations. Other values may be used provided adequate rationale and documentation is presented to, and approved by the Division of Water Pollution Control.

TABLE 16-2

MONTH	$Pr^{(1)}$ Inches / Month	$PET^{(2)}$ Inches / Month	N $Uptake^{(3)}$ Percent / Month	f $Denitrification^{(4)}$ Percent / Month
JAN	7.62	0.10	1%	25%
FEB	6.72	0.27	2%	25%
MAR	8.85	0.97	4%	27%
APR	6.59	2.30	8%	29%
MAY	6.13	3.59	12%	31%
JUN	5.52	4.90	15%	33%
JUL	6.85	5.44	17%	35%
AUG	4.73	5.00	15%	35%
SEP	5.54	3.79	12%	34%
OCT	4.47	1.98	8%	32%
NOV	6.11	0.82	4%	29%
DEC	7.55	0.27	2%	26%

(1) Based upon Table A-3 – 5-year return monthly precipitation

(2) Based upon Table A-2 – Potential Evapotranspiration

(3) Based upon Table A-5 – Monthly Nitrogen Uptake by Vegetation

(4) Applied Nitrogen Fraction Removed by Denitrification / Volatilization

Note: Appendix 16-B shows Equation 16-1, using the default values.

16.8.4 Cover Crop Selection and Management

Row crops may be irrigated with wastewater via spray irrigation only when not intended for direct human consumption. Livestock must not be allowed on wet fields so that severe soil compaction and reduced soil infiltration rates can be avoided. Further, wet grazing conditions can also lead to animal hoof diseases. Pasture rotation should be practiced so that wastewater spray application can be commenced immediately after livestock have been removed. In general, a pasture area should not be grazed longer than 7 days. Typical regrowth periods between grazings range from 14 to 35 days. Depending on the period of regrowth provided, one to three spray applications can be made during the regrowth period. At least 3 to 4 days drying time following an application should be allowed before livestock are returned to the pasture. Unmanaged, volunteer vegetation (i.e., weeds) is not an acceptable spray irrigation field cover. Disturbed areas in forest systems must be initially grassed and replanted for succession to forest.

Spray irrigation field cover crops require management and periodic harvesting to maintain optimum growth conditions assumed in design. Forage crops should be harvested and removed several times annually. Pine forest systems should be harvested at 20 to 25 year intervals. Hardwood forest systems should be harvested at 40 to 60 years. It is recommended that whole tree harvesting be considered to maximize nutrient removal. However, wastewater spray irrigation loadings following the harvesting of forest systems must be reduced until the hydraulic capacity of the site is restored. Spray field area to allow for harvesting and the regeneration cycle should be considered by the design engineer.

While high in nitrogen and phosphorus, domestic and municipal wastewaters are usually deficient in potassium and trace elements needed for vigorous agronomic cover crop growth. High growth rate forage crops such as Alfalfa and Coastal Bermuda will require supplemental nutrient addition to maintain nitrogen uptake rates assumed in design. Industrial wastewaters considered for irrigation should be carefully evaluated for their plant nutrient value.

16.9 Land Area Requirements

16.9.1 General

The land area to which wastewater is spray irrigated is termed a "field". The total land requirement includes not only the field area, but also land for any preapplication treatment facilities, storage reservoir(s), buffer zone, administration/maintenance structures and access roads. Field and buffer zone requirements are addressed in this Section. Land area for storage reservoirs is discussed in Section 16.10. All other land requirements will be dictated by standard engineering practices and will not be addressed in this document.

16.9.2 Field Area Requirements

The area required for the field is determined by using the following equation:

$$A = \frac{(Q_y + V)C}{Lwd} \qquad \textbf{(Eq. 16-2)}$$

Where:

A = Field area, acres

Q_y = Flow, MG per year

V = Net loss or gain in stored wastewater due to precipitation, evaporation and/or seepage at the storage reservoir, gallons per day

Lwd = Design hydraulic loading rate, in/year

$$C = \frac{1{,}000{,}000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{12 \text{ in}}{\text{ft}} \times \frac{\text{acre}}{43{,}560 \text{ ft}^2} = 36.83$$

The first calculation of the field area must be made without considering the net gain or loss from the storage reservoir. After the storage reservoir area has been calculated, the value of V can be completed. The final field area is then recalculated to account for V. The Appendix includes the use of Equation 16-2.

16.9.3 Buffer Zone Requirements

The objectives of buffer zones around land treatment sites are to control public access, improve project aesthetics and, in case of spray irrigation, to minimize the transport of aerosols. Since development of off-site property adjacent to the treatment site may be uncontrolable, the buffer zone must be the primary means of separating the field area from off-site property. Table 16-3 gives minimum widths of buffer zones for varying site conditions:

Table 16-3

On-Site Buffer Zone Requirements

	SURFACE SPREAD	**SPRINKLER SYSTEMS (Edge of Impact Zone)**	
		Open Fields	Forested
Site Boundaries	100 Feet	300 Feet	150 Feet
On-Site streams, ponds and roads	50 Feet	150 Feet	75 Feet

16.10 Storage Requirements

16.10.1 General

The design of a wastewater spray irrigation land application system must take into account that wastewater application will be neither continuous nor constant. Provisions must be made for containing wastewater when conditions exist such that either wastewater cannot be applied or when the volume of wastewater to be applied exceeds the maximum application rate. The minimum storage requirement should be sixty (60) days at design flow unless engineering rationale can be presented and approved by the Division of Water Pollution Control that justifies less storage capacity.

The storage requirement may be determined and/or evlauted by either of two methods. The first method involves the use of water balance calculations and is illustrated in Appendix A. The second method involves the use of a computer program that was developed based upon an extensive NOAA study of climatic variations throughout the United States. The program entitled EPA-2 would probably be the most appropriate of the three programs available. For information on the use of the computer program, contact the National Climatic Center of NOAA at (704) 259-0448.

16.10.2 Estimation of Storage Requirements Using Water Balance Calculations

The actual wastewater that is available is compared to the actual amount that can be applied. Any excess wastewater must be stored. The actual wastewater volume must be converted to units of depth for that comparison. Equation 16-3 will be used:

$$Wp = \frac{Qm \times C}{Ap} \qquad (\textbf{Eq. 16-3})$$

Where:

Wp = depth of wastewater, in inches

Qm = volume of wastewater for each month of the year, in million gallons

$$C = \frac{1{,}000{,}000 \text{ gd}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{\text{acre}}{43{,}560 \text{ ft}^2} \times \frac{12 \text{ in}}{\text{ft}} = 36.83$$

Ap = field area, in acres

The months in which storage is required are cumulated to determine the maximum amount of total storage needed. The use of the method is illustrated in Appendix A.

The maximum storage amount in inches, over the field area, is converted to a volume, in cubic feet. A suitable depth is chosen and a storage basin surface area is calculated.

This storage basin will be affected by three factors: precipitation, evaporation and seepage. These three factors are determined and the result is V, which is then introduced back into equation 16-2. A new, final field area is calculated and a corresponding new storage volume is determined.

In Tennessee, the maximum seepage is 1/4 inch per day. This amount can be used unless the storage basin will be constructed so that a lesser seepage rate will result. In some cases, where an impervious liner will be constructed, the seepage rate will be zero.

16.11 Distribution System

16.11.1 General

The design of the distribution system is a critical aspect of the land application. The field area and the storage volume were derived with the assumption that wastewater would be evenly distributed. For high strength wastes or wastes with high suspended/settleable solids, sprinkler applications are preformed. Sprinklers will distribute these wastes more evenly over the treatment area whereas surface application may result in accumulation of solids and odors near the application point.

16.11.2 Surface Spreading

With surface spreading, wastewater is applied to the ground surface, usually by perforated pipe or by an irrigation-type ditch, and flows uniformly over the field by gravity. The uniform flow is critically dependent upon a constant slope of the field, both horizontal and perpendicular to the direction of flow. Several other factors are of importance:

a. Uniform distribution cannot be achieved on highly permeable soils. The wastewater will tend to percolate into the soil that is nearest to the point of application.

b. A relatively large amount of wastewater must be applied each time so that wastewater will reach all portions of the field.
The dosing must account for the fact that the field area nearest the point of application will be wetted for a longer period of time and, thus, will percolate more wastewater.

c. Erosion and/or runoff may be a problem. Since a surface discharge will not be allowed to occur, a return system may be necessary.

16.11.3 Sprinkler Spreading

Sprinkler systems can be classified into one of three general categories:
(1) solid set, (2) portable and (3) continuously moving.

The following factors should be considered during design:

a. The hydraulic conditions within the distribution system must be given a thorough review. Head losses through pipes, bends, nozzles, etc., must be balanced so that the wastewater is uniformly applied to the field.

b. Design must consider the effects of cold weather. Nozzles, risers, supply pipes, etc., must be designed to prevent wastewater from freezing in the various parts.

c. Wind can distort the spray pattern. Also, aerosols may be carried off the field area. A properly designed buffer zone should alleviate most of the aerosol problems. Also, the O&M manual can include a provision which would prevent spraying when the wind velocity is high enough to carry wastewater off the field area.

d. Crop selection is important. The higher humidity level may lead to an increase in crop disease.

e. Higher slopes can be used than in surface spreading. Also, slopes do not need to be constant. Further, the type of crop is nearly unlimited. Forests can be irrigated with solid set sprinklers. Forage crops can be irrigated with any of the three basic types of systems.

f. The system layout must take into consideration the method that will be used for harvesting the crop.

16.12 Spray Irrigation of Wastewater from Gray Water Facilities

16.12.1 General

This Section provides criteria for facilities that produce a "gray water" wastewater. These facilities include coin-operated laundries, car washes and swimming pool backwash filters.

Wastewater disposal requirements are not as complex as are those for domestic wastewater. An engineering report which provides information on the design of the facilities must be submitted to the Division of Water Pollution Control.

16.12.2 Site Location

16.12.2.1 The Division of Water Pollution Control must inspect and approve the proposed site prior to <u>any</u> construction being undertaken.

16.12.2.2 The site must be chosen such that the operation of the system will not affect surrounding property owners. No surface runoff or stream discharge will be allowed.

16.12.3 Design Flow

Since these are service enterprises, the amount of wastewater that is generated is directly related to the desire of people to use the facilities. Thus, an estimate of the number of potential users (and frequency) is extremely important.

Various factors must be taken into consideration:

a. A rural setting would tend to have a shorter daily usage period than would an urban location.

b. An area that is predominately single-family houses would tend to have a lesser usage rate for laundries and car washes than would an area with apartment complexes.

c. The amount of water that washing machines use will vary among manufacturers and models. The Division recommends the use of water-saving machines.

The design engineer should use 250 gpd/washer for laundries and 700 gpd/bay for car washes unless more reliable data is available.

16.12.4 Pretreatment

16.12.4.1 General

Facilities that produce gray water have different pretreatment requirements, designed not only to the type of facility but also to the specific establishment.

16.12.4.2 Laundries

a. All laundry wastewater (does not include sanitary wastes) shall pass through a series of lint screens.
A series will consist of five screens, starting with a screen with 1-inch mesh and ending with a screen that is basically equivalent to a window screen.

b. Since some detergents produce a wastewater with a pH in the range of 11.0 to 11.5, some type of pH adjustment may be necessary. This may occur as a retrofit if the vegetation in the spray plots is being stressed by the high pH.

c. Disinfection will generally not be required unless the operation of the facilities will result in a potential hazard to the public. The need for disinfection will be determined by the Division of Water Pollution Control on a case-by-case basis.

16.12.4.3 Car Washes

a. All car wash wastewater shall pass through a grit removal unit. The flow-through velocity shall be less than 0.5 feet per second. The grit removal unit shall be constructed to facilitate the removal of grit.

b. The use of detergents with a neutral (or nearly neutral) pH is recommended. The use of high-pH detergents may require neutralization if the vegetation is being stressed by the high pH.

16.12.4.4 Swimming Pools

a. A holding tank/pond shall be provided to receive the backwash water from the swimming pool filters. The solids shall be allowed to settle to the bottom before the supernatant is removed for disposition on the spray plots.

b. Dechlorination may be required if the vegetation on the plots is being stressed by the chlorine in the water.

c. If the entire pool volume is to be emptied, by using the spray plots, the rate shall be controlled so as to not exceed the application rate that is specified in Section 16.7.

16.12.5 Field Requirements

16.12.5.1 The maximum wastewater that can be sprayed on a site is based either on the nitrogen content of the wastewater or an amount equal to 10% of the infiltration rate of the most restrictive layer of soil which shall be determined by the design engineer with input from a qualified soil scientist.

16.12.5.2 The application of wastewater shall alternate between at least two separate plots. Each plot shall not receive wastewater for more than three consecutive days and must have at least three days rest between applications. Reserve land area of equivalent capacity must be available for all gray water systems.

16.12.5.3 Ground slopes shall not exceed 30%. Extra precautions must be taken on steep slopes (15-30%) to prevent runoff and erosion.

16.12.5.4 The field shall be covered with a good lawn or pasture grass unless an existing forested area is chosen. The ground cover should be a sturdy perennial that will resist erosion and washout. Forested areas should be chosen so that installation of sprinkler equipment will not damage the root systems of the trees and will not produce runoff due to the usual lack of grass in forested areas.

16.12.6 Application Equipment

16.12.6.1 Sprinklers shall be of a type and number such that the wastewater will be evenly distributed over the entirety of a plot. Information on sprinklers shall be included in the engineering report. In forest plots, sprinklers shall be on risers which shall be tall enough to allow the wastewater to be sprayed above the undergrowth. Sprinklers shall be of the type that are not susceptible to clogging.

16.12.6.2 All piping (excluding risers) shall be buried to a depth that will prevent freezing in the lines. An exception to this burial requirement can be made in the case where piping will be laid in forested areas. Burial in this case may be difficult, expensive and may kill some trees. All risers shall be designed such that wastewater will drain from them when wastewater is not being pumped. This can be accomplished by either draining all lines back into the pump sump or by placing a gravel drain pit at the base of each riser. Each riser would necessarily be equipped with a weep hole. Particular attention must be given during the design so that the entire subsurface piping does not drain into these pits.

16.12.6.3 The engineering report must contain hydraulic calculations that show that each nozzle distributes an equivalent amount of wastewater. Differences in elevation and decreasing pipe sizes will be factors which need to be addressed.

16.12.6.4 The piping must be of a type that will withstand a pressure equal to or greater than 1-1/2 times the highest pressure point in the system. The risers should be of a type of material such that they can remain erect without support. The pipe joints should comply with the appropriate ASTM requirements. Adequate thrust blocks shall be installed as necessary.

16.12.6.5 A sump shall be provided into which the wastewater will flow for pumping to the spray plots. The pump can be either a submersible type, located in the sump, or a dry-well type, located immediately adjacent to the sump in a dry-well. The pump shall be capable of pumping the maximum flow that can be expected to enter the sump in any 10-minute period. The pump shall be operated by some type of float mechanism. The float mechanism shall activate the pump when the water level reaches 2/3 of the depth of the sump and should de-activate the pump before the water level drops to the point to where air can enter the intake.

If the distribution system is designed to drain back into the sump, the sump shall be enlarged to account for that volume.

If desired, the sump for laundries can also contain the lint screens. The screens shall, in any case, be constructed so that they cannot be bypassed. They shall be built so that they can be easily cleaned. A container shall be provided for disposal of the lint which is removed from the screens.

16.12.6.6 The pipe from the facility to the sump shall be large enough to handle the peak instantaneous flow that could be realistically generated by the facility. Flow quantities, head loss calculations, etc., shall be included in the engineering report.

16.12.7 Operation of System

16.12.7.1 The operator shall insure that wastewater is applied to alternate plots on a regular basis.

16.12.7.2 Monthly operating reports shall be submitted to the appropriate field office of the Division of Water Pollution Control. The parameters to be reported shall be delineated by field office personnel but should include, as a minimum, dates of spray plot alternation.

16.12.7.3 The owner of the system shall apply for and receive an operating permit from the Division of Water Pollution Control prior to initiation of operation of the system.

16.12.7.4 The system operator shall inspect and maintain the pump and sprinklers in accordance with manufacturer's recommendations. An operations manual shall be located at the facility for ready reference.

16.12.7.5 The operator shall inspect the wastewater facilities on a regular basis. The inspection shall include the spray plots to determine whether or not runoff and/or erosion are or have occurred, the spray patterns of the sprinklers, the physical condition of the system (looking for damage due to adverse pH conditions, etc.)

16.12.7.6 The spray plots shall be mowed on a regular basis to enhance evapotranspiration. Grass height shall not exceed 6-inches.

16.12.7.7 The lint screen at laundries shall be cleaned on a schedule that is frequent enough to prevent upstream problems due to head loss through the screens. Disposition of the lint shall be in accordance with applicable requirements.

16.12.7.8 The grit traps at car washes shall be cleaned at a frequency that is sufficient to keep the trap in its designed operating condition.

16.12.7.9 If the car wash is equipped with an automatic wax cycle, the operator shall be especially attentive to the possibility of wax build-up on the sump, pump and all downstream piping.

16.12.7.10 The operator shall insure that the car wash facility is not used as a sanitary dumping station for motor homes or for washing trucks/trailers that are used for hauling livestock. If necessary, the facility shall be posted with signs which clearly indicate this prohibition.

16.12.7.11 The sludge holding tank/pond at a swimming pool facility shall be cleaned at a frequency that is sufficient to prevent solids from being carried over into the pump sump. Cleaning shall be performed in a manner that will minimize re-suspending the solids and allowing them to enter the pump sump.

16.13 Plan of Operation and Management

A Plan of Operation and Management (POM) is required before an Operation Permit (SOP) can be issued. The Plan is written by the owner or the owner's engineer during construction of the slow rate land treatment system. Once accepted by the Division, the Plan becomes the operating and monitoring manual for the facility and is incorporated by reference into the Permit.

This manual must be kept at the facility site and must be available for inspection by personnel from the Tennessee Department of Health and Environment.

This POM should include, but not be limited to, the following information:

16.13.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, preapplication treatment system and spray fields.

2. A map of the land treatment facility showing the preapplication treatment system, storage pond(s), spray fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.

3. A map of force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.

4. A schematic and plan of the preapplication treatment sytem and storage pond(s) identifying all pumps, valves and process control points.
5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, sprinklers, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life. Include procedures or precautions which will compensate for these limitations.

c. A copy of facility's State Operation Permit.

16.13.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.

2. Define the work hours, duties and responsibilities of each staff member.

16.13.3 Facility Operation and Management

a. Preapplication Treatment System:

1. Describe how the sytem is to be operated.
2. Discuss process control.
3. Discuss maintenance schedules and procedures

b. Irrigation System Management:

1. Wastewater Application.

   Discuss how the following will be monitored and controlled.
   Include rate and loading limits:

   - (a) Wastewater loading rate (inches/week)
   - (b) Wastewater application rate (inches/hour)
   - (c) Spray field application cycles
   - (d) Organic, nitrogen and phosphorus loadings (lbs/acre per month, etc)

2. Discuss how the system is to be operated and maintained.
   - (a) Storage pond(s)
   - (b) Irrigation pump station(s)
   - (c) Spray field force main(s) and laterals
3. Discuss start-up and shut-down procedures.
4. Discuss system maintenance.
   - (a) Equipment inspection schedules
   - (b) Equipment maintenance schedules
5. Discuss operating procedures for adverse conditions.
   - (a) Wet weather

        (b) Freezing weather

        (c) Saturated Soil

        (d) Excessive winds

        (e) Electrical and mechanical malfunctions

6. Provide troubleshooting procedures for common or expected problems.

7. Discuss the operation and maintenance of back-up, stand-by and support equipment.

c. Vegetation Management:

1. Discuss how the selected cover crop is to be established, monitored and maintained.

2. Discuss cover crop cultivation procedures, harvesting schedules and uses.

3. Discuss buffer zone vegetative cover and its maintenance.

d. Drainage System (if applicable):

1. Discuss operation and maintenance of surface drainage and runoff control structures.

2. Discuss operation and maintenance of subsurface drainage systems.

16.13.4 Monitoring Program

a. Discuss sampling procedures, frequency, location and parameters for:

1. Preapplication treatment system.

2. Irrigation System:

    (a) Storage pond(s)

    (b) Groundwater monitoring wells

    (c) Drainage system discharges (if applicable)

    (d) Surface water (if applicable)

b. Discuss soil sampling and testing:

c. Discuss ambient conditions monitoring:

1. Rainfall
2. Wind speed
3. Soil moisture

d. Discuss the interpretation of monitoring results and facility operation:

1. Preapplication treatment system.
2. Spray fields.
3. Soils.

16.13.5 Records and Reports

a. Discuss maintenance records:

1. Preventive.
2. Corrective.

b. Monitoring reports and/or records should include:

1. Preapplication treatment system and storage pond(s).
    (a) Influent flow
    (b) Influent and effluent wastewater characteristics
2. Irrigation System.
    (a) Wastewater volume applied to spray fields.
    (b) Spray field scheduling.
    (c) Loading rates.
3. Groundwater Depth.
4. Drainage system discharge parameters (if applicable).

5. Surface water parameters (if applicable).
6. Soils data.
7. Rainfall and climatic data.

CHAPTER 17

Design Guidelines for Wastewater Dispersal Using Drip Irrigation

DRIP DISPERSAL TREATMENT

17.1 General

17.1.1 General

This chapter provides guidelines and criteria for the design of drip dispersal systems for domestic wastewater effluent treated to a level of secondary treatment. It is not applicable to spray irrigation, overland flow or rapid infiltration. The design engineer should use best professional judgment (BPJ) to produce a system that will be robust and sustainable for many years.

17.1.2 Applicability

Drip dispersal systems are designed and operated to allow the soil to provide final treatment of the wastewater prior to its introduction to groundwater. Dispersal and treatment occurs via physical, chemical and biological processes within the soil and through evapotranspiration and nutrient uptake by plant matter.

The ultimate goal is to create a treatment and dispersal system that will return the treated water to the environment while protecting ground water and surface waters from excessive pollution. Water does not disappear in the soil column, it evaporates into the atmosphere, is used by plants and/or organisms, or moves through the soils to ground water or into water courses. There are many factors to be considered when designing drip dispersal systems, such as the quality of treated effluent being applied, depth of soils, and retention time in the soils before water returns to either ground water or surface water. The development of these guidelines utilized general assumptions, best professional judgment (BPJ) and empirical data.

The infiltrative capacity of soil is a critical factor to be considered when designing any type of subsurface sewage disposal system. However, equal consideration should be given to other factors that control the overall lateral movement of groundwater within the soil profile.

If the profile of a particular soil considered for drip dispersal extended to a significant depth without a restrictive horizon (most limiting layer), the ability to load that soil per unit area would be relatively high. On the other extreme, if a soil being considered for drip dispersal had a shallow restrictive horizon, the ability to load that soil would be lower relative to the deeper soil. Depth to restrictive horizon, soil permeability and slope of the restrictive horizon are factors that control the amount and rate at which ground water can exit an area. If the amount of treated effluent applied to an area, in combination with rainfall over the area and groundwater moving into the area, exceed the soil profile's ability to transmit the water away from the application area, mounding and runoff will occur.

Evaluation of a soil area's suitability for drip dispersal should take into consideration limiting aspects of the soil profile. Level sites with shallow restrictive horizons overlain by low permeability soils represent one of the more limited scenarios for drip dispersal and the application rate and/or application area should be suitably modified.

Also critical when designing systems in soils with shallow restrictive horizons are the presence and location of hydrologic boundaries such as drainage ways and waterways.

These hydrologic boundaries provide an outlet for ground water discharge. Not only is it critical to identify these features in consideration of appropriate setbacks/buffers, it is also critical to factor in their role in the overall hydrologic cycle of the landscape.

Horizons along which lateral flow would be expected include, but are not necessarily limited to: bedrock, fragipans, and zones with high clay percentage overlain by more permeable soil.

Drip dispersal design submittals should take into consideration all factors influencing the infiltrative capacity of the soil and the ability of the soil and site to transport ground water away from the application area. It should be noted that the use of historical information from existing systems installed and operated in similar soils, with documented loading rates, landscape positions and design conditions similar to the proposed system may be applicable. Therefore, soils that have been highly compacted and/or disturbed, such as old road beds, foundations, etc., must be excluded when evaluating suitable areas for drip dispersal systems.

17.1.3 Slopes and Buffers

Slopes - Slopes up to and including 50% slope with suitable soils may be considered for drip dispersal. Depending upon the overall shape of the slope (concave, convex or linear on the planar and profile view) the design engineer may have to make adjustments in the aspect ratio of the drip lines on the slope, the loading rate, or both to ensure that all applied effluent will move down gradient and/or into the underlying formations without surfacing. It is important to note that when the proposed drip field area slopes are greater than 30%, the design engineer may need to a obtain a geologic investigation conducted by a geologist or geotechnical engineer evaluating the slip potential of the slope under operating conditions. When slopes increase above 10 percent, wastewater flow down the slope (parallel to the slope) may control the hydraulic design of the system.

For land application areas with slopes between 10 percent and 50 percent and with a restrictive horizon less than 48 inches, the design engineer should calculate the percentage saturation of the soil column at the narrowest portion of the cross-sectional area of the dispersal area perpendicular to the direction of flow. This landscape loading rate analysis will determine the saturation depth at design load and flow of the most restrictive cross-section in the down gradient flow path within and beyond the drip field. The aspect of ratio of the drip field should be adjusted or the loading rate reduced as necessary to ensure that surfacing does not occur.

Buffers - Treatment and dispersal system components should be located so as to protect potable water supplies and distribution systems and surface waters. The design engineer is responsible to identify setbacks on construction drawings. Setbacks from water bodies, water courses, and sink holes will be a function of local subsurface geology and quality of the applied effluent. It is important to note that varying site conditions may require different distances of separation. The distances may increase or decrease as soil conditions so warrant as determined by a qualified professional (engineer, soil scientist, geologist, etc.).

If site buffers are different from Table 17-1, then the design engineer must provide rationale used for the recommended site buffers which must be approved by the Tennessee Department of Environment and Conservation.

TABLE 17-1

	Buffer Distance	
Site Feature	**Septic Tank and /or Dosing Chamber (Feet)**	**Dispersal Field (Feet)**
Wells and Springs	**50**	**50**
Dwellings and Buildings	**5**	**10**
Property Lines	**10**	**10**
Underground Utilities	**10**	**10**
Septic Tank	**NA**	**5**
Gullies, Ravines, Blue Line Streams, Drains Drainways, Cutbanks, and Sinkholes	**25**	**25**
Closed Depressions	*****	*****
Soil Improvement Practice	**25**	**25**

*****To be determined by the design engineer and approved by the Division of Water Pollution Control.

17.1.4 Soils

In general, moderately permeable and well-drained soils are desirable. However, the use of any soil is acceptable if it meets the following four (4) criteria:

1. The applied effluent loading rate does not exceed the applicable hydraulic loading rate in **Table 17-2**. The applicable hydraulic loading rate is determined by a detailed site evaluation in which the site is mapped utilizing soil borings and pits to determine the physical properties of soil horizons and soil map units.
2. The applied effluent maximum loading rate does not exceed 10% of the minimum NRCS saturated vertical hydraulic conductivity (K_{SAT}) for the soil series or 0.25 GPD/SF whichever is least. Note: this may have to be lowered based upon the results of the nutrient loading rate calculation per Section 17.5.2.
3. The soil does not have a restrictive horizon within its top twenty (20) inches.
4. The soil is well drained, or capable of being drained.

TABLE 17-2

Hydraulic Loading Rates (GPD/SF) – For Drip Dispersal Systems

TEXTURE	STRUCTURE		HYDRAULIC LOADING RATE* GPD / SF BOD ≤ 30 mg/L
	SHAPE	GRADE	
Coarse Sand, Loamy Coarse Sand	NA	NA	NA
Sand	NA	NA	NA
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	Single Grain	Structure less	1.00
Coarse Sandy Loam, Sandy Loam	Massive	Structure less	0.60
	Platy	Weak	0.50
		Moderate, Strong	▨
	Blocky, Granular	Weak	0.70
		Moderate, Strong	1.00
Loam	Massive	Structure less	0.50
	Platy	Weak, Moderate, Strong	▨
	Angular, Blocky	Weak	0.60
	Granular, Sub angular	Moderate, Strong	0.80
Silt Loam	Massive	Structure less	0.20
	Platy	Weak, Moderate, Strong	▨
	Angular, Blocky, Granular, Sub angular	Weak	0.60
		Moderate, Strong	0.80
Sandy Clay Loam, Clay Loam, Silty Clay Loam	Massive	Structure less	▨
	Platy	Weak, Moderate, Strong	▨
	Angular, Blocky	Weak	0.30
	Granular, Sub angular	Moderate, Strong	0.60
Sandy Clay, Clay, Silty Clay	Massive	Structure less	▨
	Platy	Weak, Moderate, Strong	▨
	Angular, Blocky	Weak	▨
	Granular, Sub angular	Moderate, Strong	0.30

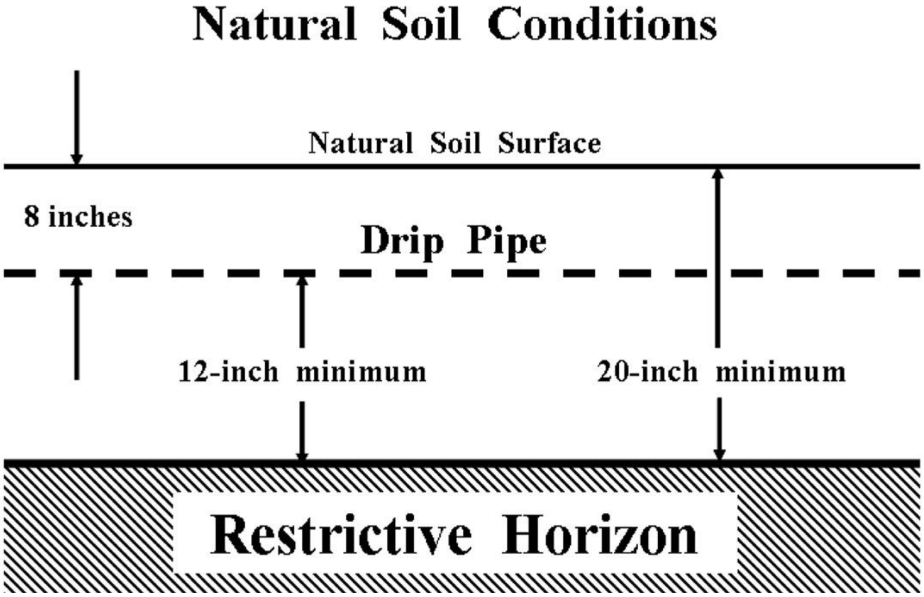
***Maximum allowable hydraulic loading rate is 0.25 GPD/SF; however, all hydraulic loading rates may be adjusted based upon special site specific evaluations approved by TDEC.**

▨ **These soils are considered unacceptable for drip dispersal.**

Reference: EPA/R-00/08, February 2002, "*Onsite Wastewater Treatment Systems Manual*"

It is desirable to have a minimum depth of twenty (20) inches of undisturbed soil above a restrictive horizon which may need to be increased as slope increases. This is necessary to provide adequate installation depth and buffer below the drip line. (For example, see **Figure 17.1**).

FIGURE 17.1



Even if a soil meets the depth requirements it may not be suitable due to the texture and/or structure. If a soil shows signs of wetness within a depth of 20 inches of the soil surface, it will most likely require a soil improvement practice such as an interceptor or drawdown drain. The location and size of the drains and buffers must be factored into the total area required for the drip dispersal system.

17.1.5 Line Spacing

In an attempt to achieve even distribution of the wastewater and maximum utilization of the soil, it is recommended that the emitter line spacing and emitter spacing be at 2-foot spacing. Depending upon site conditions (soil type, slope and reserve area) the Department of Environment and Conservation may allow spacing to increase to ensure that each emitter supplies a minimum wetted area of not more than ten (10) square feet (i.e., 5-foot line spacing with 2-foot emitter spacing or 10-foot line spacing with 1-foot emitter spacing).

17.1.6 Line Depth

Drip dispersal lines should be placed at depths of six (6) to ten (10) inches below the surface. The drip lines should be laid level and should run with the contour.

17.2 Soil Investigations

17.2.1 General

Preliminary soil investigations should be done to identify areas best suited for subsurface wastewater drip dispersal. The proposed drip dispersal area must be mapped at sufficient accuracy to identify each soils series (or lowest possible level of soil classification) present and the boundary location between series. Once those areas are identified, the more detailed procedures outlined below will be employed. It is required that all soil investigations be performed by a soil scientist currently on the Ground Water Protection list of approved soil scientists/soil consultants.

17.2.2 Soil Mapping

The mapping procedure will usually begin with the property/land being generally evaluated to delineate or separate areas with suitable characteristics. This procedure will save time and money since some areas will be too shallow, too wet, too steep, etc.

Adequate ground control is mandatory for all sites. The ground control is necessary to reproduce the map if needed. All located coordinates (soil map boundaries and pit locations) must be shown on the final Water Pollution Control (WPC) Soils Map.

Soil data collection shall be based upon one, or combination of the following:

1. Grid staking at intervals sufficient to allow the soils scientist to attest to the accuracy of the map for the intended purpose;
2. Mapping of pits and critical auger locations using dual frequency survey grade Global Positioning System (GPS) units.
3. Other controls adequate to map the location of pits, physical features, and separations.
4. Grid stakes and GPS data points must be locatable to within two (2) feet of distance shown.
5. The ground control has to correlate to the exterior boundaries of the property so as to show the location of the soils areas within the bounds of the project and must be certified by a Registered Land Surveyor per TCA 62-18-102(3).

The soil scientists are responsible for conducting a sufficient number of borings that, in their professional opinion, will allow them to certify the soils series (or lowest possible level of soil classification) present, identify boundaries between series, and describe each soil horizon as to color, depth to restrictive horizon, and depth to rock. Any redoximorphic features observed are to be described. This delineation should be based upon the texture and structure of the soils to a depth of forty-eight (48) inches or restrictive horizon whichever is shallower.

After the mapped soils area is established and marked, soil borings to a minimum depth of forty-eight (48) inches or restrictive horizon, whichever is shallowest, shall be taken at sufficient intervals to identify and map the boundaries of the soils series (or lowest possible level of soil classification) present on the site. The exact number and location of borings will be determined by the soils scientist in consultation with the design engineer. Sufficient borings should be made to identify any dissimilar soils accounting for more than 10 percent of the total proposed drip dispersal area.

The soil scientist shall excavate an adequate number of pits to determine the typical profiles and soils characteristics that are expected for all soils mapped. It is recommended that a minimum of two (2) pits per acre in polygons of qualifying soils be excavated; however, the actual number and location of pits will be left to the best professional judgment of the soil scientist. If less than two (2) pits per acre are utilized, the soil scientist must include the rationale in notes on the WPC Soil Map. The pit description must be entered onto a pedon sheet and submitted with the soils map and engineering report. The "Soil Description" should include all of the information contained on form NRCS-Soils-232G (5-86), U.S. Department of Agriculture, Natural Resources Conservation Service (as shown in Appendix D).

In their description of the pit profiles, the soil scientists must describe the soil's structure, texture, color, and any redoximorphic features present. They should also describe root depth and presence of macropores, etc. The series name or lowest possible level of soil classification will be recorded. The depth to hard rock using an auger or a tile probe must be specified if the depth is less than forty-eight (48) inches and estimated if greater than forty-eight (48) inches. The auger borings and soil backhoe pits should be located, numbered and shown on the WPC Soils Map. The soil scientist will be required to prepare and sign a detailed certification statement for each site evaluated as follows:

Water Pollution Control Soils Map Completed by:

Signature Date

John/Jane Doe, Soils Consultant

The following statement should appear on the map:

"I, (Soils Consultant's Name) affirm that this Water Pollution Control Soils Map has been prepared in accordance with accepted standards of soil science practice and the standards and methodologies established in the NRCS Soil Survey Manual and USDA Soil Taxonomy. No other warranties are made or implied."

Soil profile information and pit excavation, as described in these design criteria, are additional requirements deemed necessary to properly assess an area's suitability for drip dispersal.

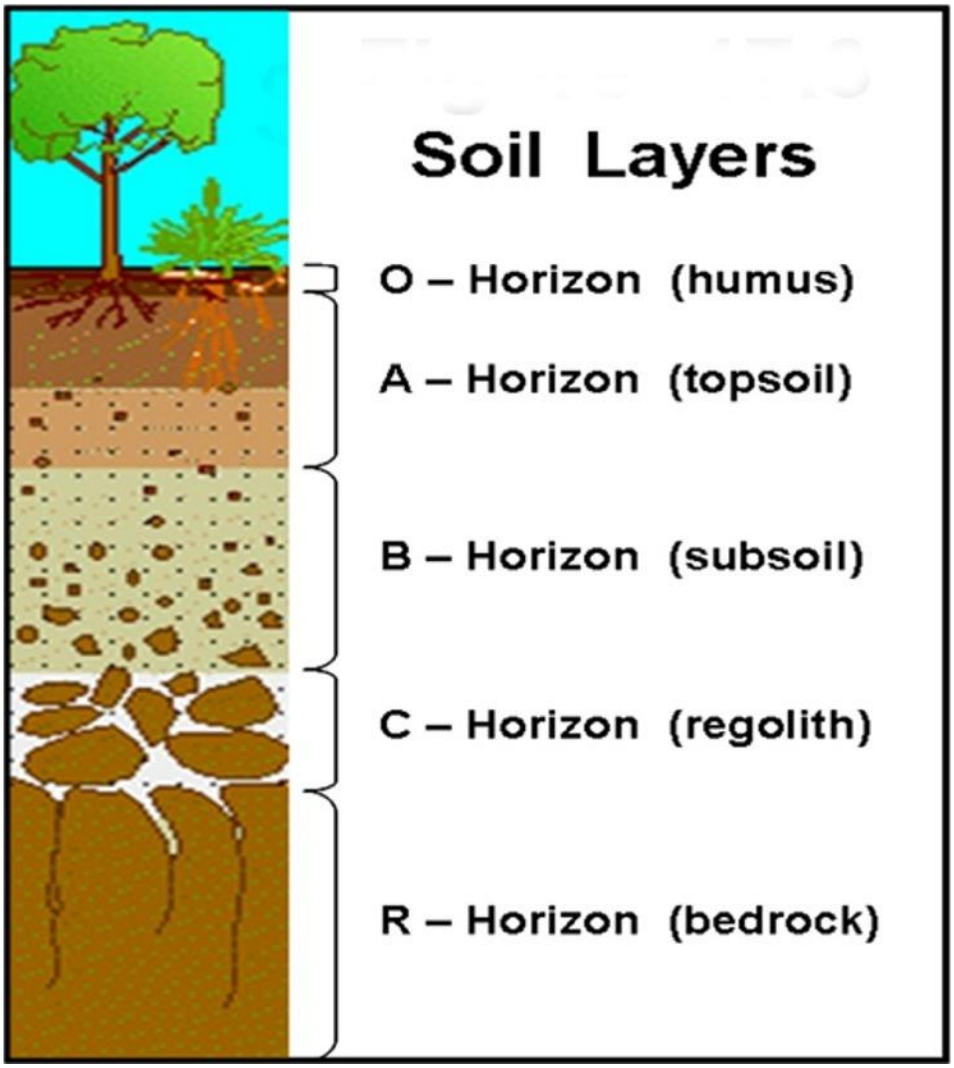
17.2.3 Definitions:

Soil Horizons (layers): Soil is made up of distinct horizontal layers; these layers are called horizons and display vertical zones. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock).

Soil horizons develop due to the nature of soil formation. Soil is the product of the weathering of parent material (i.e. bedrock), accompanied by the addition of organic matter. The method for naming the soil horizons is quite simple as the **Figure 17.2** shows.

In the simplest naming system, soils horizons are designated **O** (organic), **A** (topsoil), **B** (mineral soil), **C** (weathered parent material), and **R** is the un-weathered rock (bedrock) layer that is beneath all the other layers. The horizons of most importance to plant growth and forest health are the **O** and **A horizons**. The **litter layer** found covering the soil is also of interest because it provides most of the organic matter found in the O and A horizons.

FIGURE 17.2



The **Litter Layer** is the topmost layer on the forest floor. It consists of leaves, needles and other non-decomposed material on the forest floor. While this is not considered part of the soil, it is interesting to measure the depth of the litter layer when sampling the soil. The depth of the litter layer can vary greatly even within a particular site. Because of this, several measurements are required to attempt to characterize litter layer depth. The litter layer can be considered part of the overall soils depth.

The **O-Horizon** primarily consists of decomposed organic matter and has a dark rich color, increased porosity, and increased aggregate structure (larger soil "clumps"). The depth of the O horizon is measured from the surface of the soil (after the litter layer has been cleared away) to the point where the darker organic color changes to a slightly lighter colored soil that contains increased mineral particles in addition to organic matter. The transition from the O to the A horizon can also be recognized by a significant increase in the mineral soil particles. In many urban soils, the O horizon may very thin if it exists at all. The O horizon can also be considered part of the overall soils depth.

The **A-Horizon** is the **mineral** "topsoil" and consists of highly weathered **parent material** (rocks), which is somewhat lighter in color than the O horizon due to a decrease in **organic matter**. The particles in the A horizon are more granular and "crumb-like". Seeds germinate and plant roots grow in this layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. The depth of the A horizon is measured from the region of color changes from the dark O horizon to the transition to the B horizon. The transition to the B horizon can be identified by increased clay content (see below) and the absence of organic material: no root hairs, small pieces of needle, etc.

The most thorough soil study involves analysis on separate O and A horizon samples. This requires separating and storing O and A horizon samples. It also involves completing the entire soil analysis on both the O and A samples. If this is not possible, the O and A samples can be combined (or composited) and the analysis can be completed on the O and A sample together.

The **B-Horizon** is also called the **subsoil** - this layer is beneath the A horizon and above the C horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives when soil solution containing dissolved minerals drips from the soil above.

The B horizon is identified by increased clay content that makes the soil hold together when moist. A simple test for clay content is to moisten a small handful of soil and attempt to smear a small portion up the forefinger. Soils high in clay will hold together and form a "ribbon", soils with more sand and silt will be granular and fall apart. It is lighter in color and often may be reddish due to the iron content.

The **C Horizon** (layer beneath the B Horizon) consists of porous rock (broken-up bedrock, bedrock with holes). It is also called regolith or **saprolyte** which means "rotten rock." Plant roots do not penetrate into this layer; very little organic material is found in this layer.

The **R-Horizon** is the un-weathered rock (bedrock) layer that is beneath all the other layers. For the purposes of drip dispersal designs, the R horizon is considered an impermeable layer.

Water Pollution Control (WPC) Soils Map. A first order survey as defined in the Soil Survey Manual, United States Department of Agriculture, October 1993. These surveys are made for various land use that requires detailed soils information. Map scale should be one (1) inch equals one hundred (100) feet or a scale that will allow the map to fill a 24" x 36" plan sheet. These maps should have adequate cartographic detail to satisfy the requirements of project. The WPC Soils Map is essentially a special map that shows a very high degree of soil and landscape detail. Baseline mapping standards for these WPC Soils Maps prepared in support of drip dispersal should be a first order survey in accordance with the current edition of the Soil Survey Manual, United States Department of Agricultural; October 1993. Soil profile information and pit excavation, as described in these design criteria are additional requirements deemed necessary to properly assess an area's suitability for drip dispersal. These maps should be clearly marked or labeled as "Water Pollution Control Soils Map".

Soil map unit. A unique collection of areas that have common soil characteristics and/or miscellaneous physical and chemical features.

Soil scientist. A person having the experience and education necessary to measure soil properties and classify soils per *Soil Taxonomy*, synonymous with the term "soil consultant".

Soil series. A group of soils that have similar properties; the lowest level of soil classification.

Most limiting horizon. A horizon in the soil (bedrock or fragipan) that either provides the greatest impediment to or completely stops the downward movement of liquids through the soil.

17.2.4 Special Soil/Geologic Considerations

For sites with slopes between 30% and 50%, TDEC may request, a special investigation (performed by a qualified professional, such as a geologist, geo-tech engineer, engineering geologist, etc.) to be conducted to evaluate those sites. To adequately complete these determinations the following information should be provided.

- Strike and dip angle of underlying bedrock
- Depth to either hard rock and partly weathered rock
- Type of rock (limestone, shale, etc.)
- Soil particle-size class designation to a depth of six (6) feet or to hard rock whichever is less
- Slippage potential of slope
- Certification statement signed by a qualified professional that addresses all of the above characteristics.

For sites with slopes between 30% and 50%, in addition to meeting all other soil suitability requirements, the site should also meet the following requirements:

- Have a vertical depth of at least twenty (20) inches of soil above the rock layer.
- Not have a predominant particle size class of fragmental or sandy-skeletal.

17.3 Determination of Design Application Rates

17.3.1 General

One of the key steps in the design of a drip dispersal system is to develop a "design application rate" in gallons per day per square foot (GPD/SF). This value is derived from either the hydraulic (water) loading rate (Lwh) based upon the most restrictive of (1) the NRCS hydraulic conductivity data and the texture and structure (per Table 17-2), or (2) the nutrient (nitrogen) loading rate (Lwn) calculations to determine design wastewater loading(s) and, thus, drip field area requirements.

17.3.2 Design Values

The most limiting horizon, of each soil series (or lowest possible level of soil classification) shall be identified. Any surface condition that limits the vertical or lateral drainage of the soil profile shall also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Design considerations relative to the soils per Section 17.1.4 must be used.

Sites with seasonal high groundwater less than twenty-four (24) inches deep may require drainage improvements before they can be utilized for slow rate land treatment. The design hydraulic conductivity at such sites is a function of the design of the drainage system.

17.4 Determination of Design Wastewater Loading

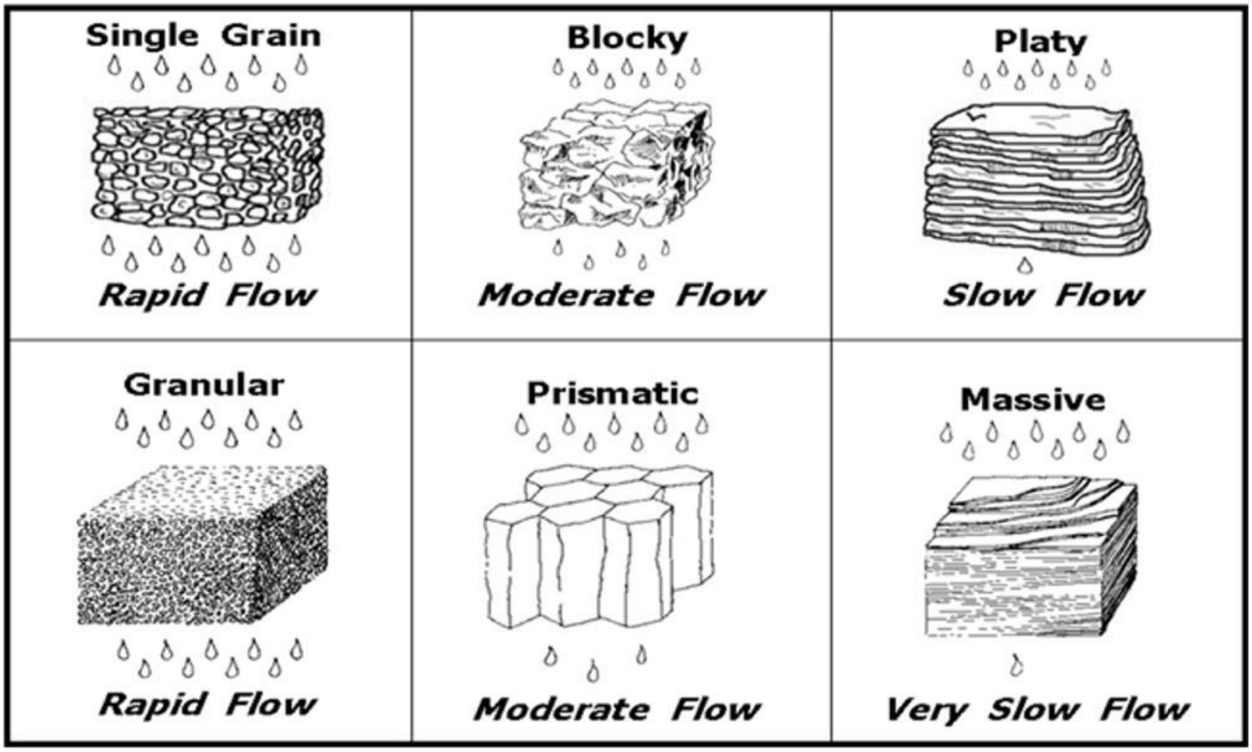
17.4.1 General

The design wastewater loading is a function of:

a. Precipitation.
b. Evapotranspiration.
c. Design hydraulic conductivity rate.
d. Nitrogen loading limitations.
e. Other constituent loading limitations.
f. Groundwater and drainage conditions.
g. Average and peak design wastewater flows.
h. Soil denitrification rates
i. Rate of nitrogen uptake in site vegetation

Therefore, developing the design wastewater loading is an iterative process. The Lwh value is determined by a detailed site evaluation and will be dependent upon the soil characteristics as shown in Table 17-2 and pictorially represented in **Figure 17.3**. This loading is then compared to the Lwn loading limitations (reference Section 17.5). If the initial Lwh value exceeds the Lwn value, the design wastewater loading resulting from the nitrogen reduction evaluation described in Section 17.5 becomes the design loading rate.

FIGURE 17.3



17.5 Nitrogen Loading and Crop Selection and Management

17.5.1 General

Nitrate concentration in percolate from wastewater irrigation systems will be limited via a State Operation Permit (SOP) to not exceed 10 mg/L nitrate-nitrogen at the site property line. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from using the criteria stipulated in 17.1.4 for hydraulic conductivity must be checked against nitrogen loading limitations.

17.5.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

Equation **17-2** is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

$$\mathbf{Lwn} = \frac{Cp\,(Pr - PET) + N(4.413)}{(1 - f)(Cn) - Cp} \qquad \textbf{(Equation 17-2)}$$

Where:

Lwn = allowable monthly hydraulic loading rate based on nitrogen limits, inches/month
Cp = nitrogen concentration in the percolating wastewater, mg/L.
This will usually be 10mg/L Nitrate-Nitrogen
Pr = Five-year return monthly precipitation, inches/month
PET = potential evapotranspiration, inches/month
U = nitrogen uptake by cover, lbs./acre/year
N = nitrogen uptake by cover, lbs./acre/month
Cn = Nitrate-Nitrogen concentration in applied wastewater, mg/L
(after losses in pre-application treatment)
f = fraction of applied nitrogen removed by denitrification and volatilization.

The values of Lwh and Lwn are compared for each month.

The lesser of the two values will be used to determine the amount of acreage needed.

NOTES:

- A "**Cn**" value of less than 23 mg/L will become a permit condition.
- The allowable (default value) vegetative uptake "**U**" of nitrogen on the drip area will be an uptake rate of 100 pounds per acre per year unless trees or other vegetation are acceptable to, and permitted by WPC.
- The "**f**" values for denitrification have been estimated based upon data supplied by the University of Tennessee and Oak Ridge National Laboratory. Denitrification rates (f) ranging from 25% in January and February to 35% in July and August are very conservative, but are defendable based upon the literature. Denitrification rates are assumed to vary linearly with the temperature and the actual rates are likely to be higher than the default values shown in Table 17-2.
- Conversion Factor - **4.413**mg-acre-inch/liter-lb. The equation and factor are from the TDHE Design Criteria for Sewage Works (April 1989). The factor comes from assuming that one pound of contaminant of concern is diluted within a volume of water equal to one acre-inch. For the derivation of this factor see Appendix 17-C.

Table **17-3** shows the default values for Lwn calculations. Other values may be used provided adequate rationale and documentation is presented to, and approved by the Department of Environment and Conservation.

TABLE 17-3

MONTH	Pr(1) Inches / Month	PET(2) Inches / Month	N Uptake(3) Percent / Month	f Denitrification(4) Percent / Month
JAN	7.62	0.10	1%	25%
FEB	6.72	0.27	2%	25%
MAR	8.85	0.97	4%	27%
APR	6.59	2.30	8%	29%
MAY	6.13	3.59	12%	31%
JUN	5.52	4.90	15%	33%
JUL	6.85	5.44	17%	35%
AUG	4.73	5.00	15%	35%
SEP	5.54	3.79	12%	34%
OCT	4.47	1.98	8%	32%
NOV	6.11	0.82	4%	29%
DEC	7.55	0.27	2%	26%

(1) Based upon Table A-3 of Chapter 16 – 5-year return monthly precipitation

(2) Based upon Table A-2 of Chapter 16 – Potential Evapotranspiration

(3) Based upon Table A-5 of Chapter 16 – Monthly Nitrogen Uptake by Vegetation

(4) Applied Nitrogen Fraction Removed by Denitrification / Volatilization

Note: Appendix 17-B shows Equation 17-2, using the default values.

17.6 Plan of Operation and Management

Each decentralized wastewater treatment system utilizing drip effluent dispersal should be covered by a Plan of Operation and Management (POM). For public utility systems, a General POM applicable to all of the utility's facilities and covering the items discussed below will suffice. The POM is written by the owner or the owner's engineer and once accepted by the Division of Water Pollution Control, the POM becomes the operating and monitoring manual for the facility. This manual should be kept on file by the facility owner and should be available for inspection by personnel from the Tennessee Department of Environment and Conservation.

This Plan should include, but not be limited to, the following information unless previously submitted via the permit application process:

17.6.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, pre-application treatment system and drip fields.

2. A map of the land treatment facility showing the pre-application treatment system, drip fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.

3. A map of the collection system including gravity lines, force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.

4. A schematic and plan of the pre-application treatment system identifying all pumps, valves and process control points.

5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life.

Include procedures or precautions that will compensate for these limitations.

17.6.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.

2. Define the work hours, duties and responsibilities of each staff member.

3. Describe the location of operational and maintenance personnel relative to the location of the treatment system.

17.6.3 Facility Operation and Management

a. Pre-application Treatment System:

1. Describe how the system is to be operated.

2. Discuss process control.

3. Discuss maintenance schedules and procedures.

4. Discuss the use of telemetry

b. Drip Dispersal System Management:

1. Wastewater Application. Discuss how the following will be monitored and controlled. Include rate and loading limits.

(a) Wastewater loading rate

(gallons per day per square foot or inches/week)

(b) Drip dispersal field application cycles

2. Discuss how the system is to be operated and maintained.

(a) Storage pond(s), where utilized.

(b) Irrigation pump station(s)

(c) Drip dispersal field force main(s) and laterals

3. Discuss start-up and shut-down procedures.

4. Discuss system maintenance.

(a) Equipment inspection schedules

(b) Equipment maintenance schedules

5. Discuss operating procedures for adverse conditions.

(a) Electrical and mechanical malfunctions

6. Provide troubleshooting procedures for common or expected problems.

7. Discuss the operation and maintenance of back-up, stand-by and support equipment.

c. Drainage System (if applicable):

1. Discuss operation and maintenance of surface drainage and run off control structures.

2. Discuss operation and maintenance of subsurface drainage systems.

17.6.4 Monitoring Program

a. Discuss sampling procedures, frequency, location and parameters for:

1. Pre-application treatment system.

2. Drip Dispersal System:

(a) Storage pond(s), where utilized

(b) Groundwater monitoring wells

(c) Drainage system discharges (if applicable)

(d) Surface water (if applicable)

b. Discuss soil sampling and testing:

c. Discuss ambient conditions monitoring:

1. Rainfall
2. Soil moisture

d. Discuss the interpretation of monitoring results and facility operation:

1. Pre-application treatment system.
2. Drip dispersal fields.
3. Soils.

17.6.5 Records and Reports

a. Discuss maintenance records:

1. Preventive.
2. Corrective.

b. Monitoring reports and/or records should include:

1. Pre-application treatment system and storage pond(s).
    (a) Influent flow
    (b) Influent and effluent wastewater characteristics
2. Drip Dispersal System.
    (a) Wastewater volume applied to drip dispersal fields.
    (b) Loading rates.
3. Groundwater Depth.
4. Drainage system discharge parameters (if applicable).
5. Soils data.
6. Rainfall and climatic data.