FLORIDA RURAL WATER ASSOCIATION

Wastewater

Certification Review

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Wastewater Operator Exam Review

Florida Rural Water Association

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Overview

- Collection Systems
- Rain Water Inflow & Infiltration
- Wastewater Flow Measurement
- Preliminary Treatment
- Grit Removal

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Overview

- Bar Screens
- Activated Sludge Processes
- Clarification
- Microbiology Protozoans and Metazoans
- Filtration

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Overview

- Digestion Aerobic and Anaerobic
- FDEP Rules
- Safety
- Laboratory
- Math

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Collection Systems

- *Purpose*: Collect and convey wastewater from homes and industries
- *Sanitary Sewer*: Household (domestic) wastewater
- *Storm Sewer*: Conveys stormwater to DRA's
- *Combined Sewer*: Collects both sanitary and storm water

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Collection System Components

- Sanitary Sewer Main—Velocity of flow must be at least 2' per second
- Manholes—Distance between manholes 300-500'
- Laterals—Connects house to sewer main
- Force Main—Pumps sewage from lift station to plant

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Collection System Problems

- Rainwater Inflow and Infiltration
- Flat Grades
- Bellies
- Tree Roots
- Manhole Deterioration
- Grease Accumulation
- Flushable wipes

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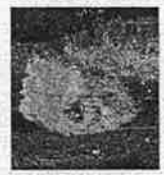
Collection System Problems



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Rain Water Inflow and Infiltration (I&I)

- Enters collection system through cracks and holes in pipes, open cleanouts, cross connections, manholes
- Can cause hydraulic overload at WWTF, decreased capacity due to sand and grit accumulation, lift station pump failures and overflows, increased operating costs

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Inflow

- Direct flow of water to sewer system

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Example of Inflow

Improperly located manholes and poorly sealed manhole covers can add to high flows.

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Infiltration

- Groundwater entering sewer pipes through cracks and openings

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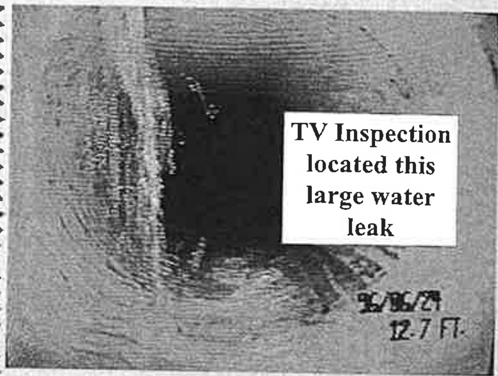

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Is it Inflow or Infiltration?

- Record lift station run times and rainfall daily
- Compare rain event readings with dry weather readings to locate problem areas

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Rain Water I&I *(continued)*

- I&I studies include collection system inspection, smoke testing and televising sewer lines
- 10 three-inch open cleanouts adds up to a 30-inch hole in the collection system!
- A one-inch rainfall in one acre equals approximately 27,000 gallons of water!

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Smoke Blower

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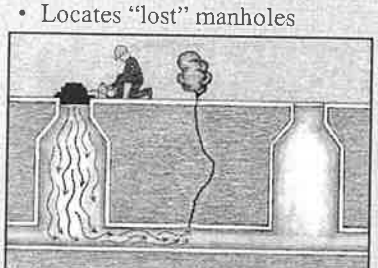
Smoke Testing

- Locates broken sewers
- Locates "lost" manholes



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Smoke testing is one way of locating broken sewer pipes, like this one in a ditch.

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Excessive Hydraulic Loading

Cause: Inflow
- Downspouts
- Yard drains
- Clean-outs

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Excessive Hydraulic Loading

Cause: Inflow
- Storm drains

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TV Inspection Equipment

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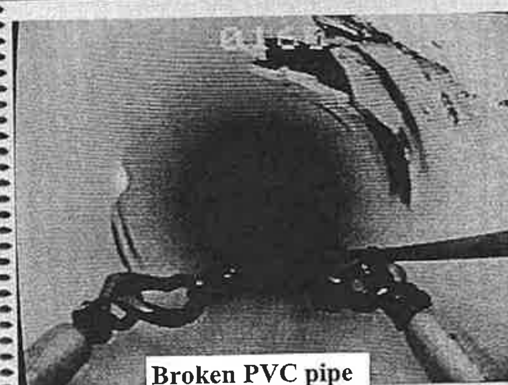

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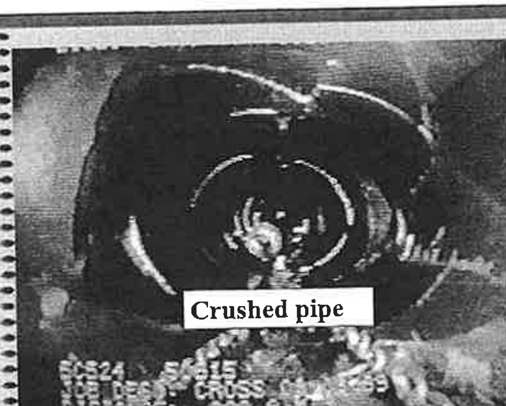

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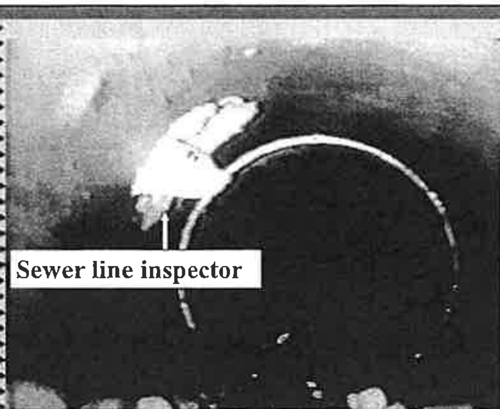

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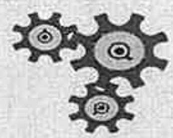
What effect does grit have?

- Excessive wear on plant equipment
- Grit takes up valuable volume in tanks
- Excessive solids handling for grit removal



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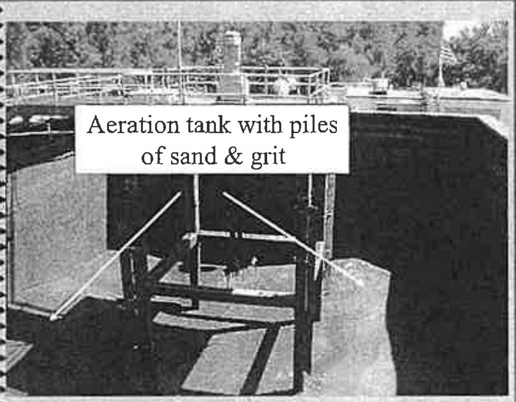

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Bellies and Flat Grade Sewers

- Allows septic conditions to develop
- Allows formation of Hydrogen Sulfide (H_2S)
- Can cause low influent pH
- Causes odors
- Can increase oxygen demand at plant
- Can contribute to sludge bulking
- H_2S causes deterioration of manholes, pipes and lift stations

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Wastewater Flow

- Flow is measured as a quantity (gallons) moving past a point (primary device) during a specific time interval
- Recording flow is required by DEP
- Recording flow @ plants 1 MGD are taken continuously.

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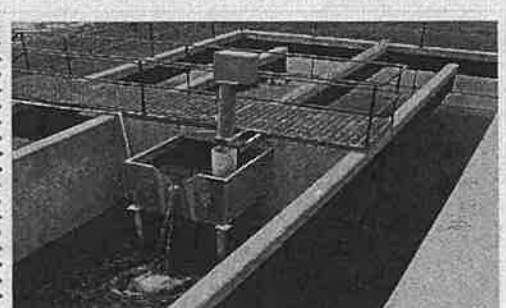
Flow Measurement



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Wastewater Flow

- Primary Devices: Weirs and Flumes
- *Secondary Devices*: Float Type, Ultrasonic, Bubbler, Magnetic, E.T. meters on pumps
- Secondary devices calibrated at least annually, a permit requirement of DEP

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Wastewater Types

- *Organic*- mainly plant and animal waste
- *Inorganic*- sand, grit, iron, calcium
- *Thermal*- heated wastewater from industrial sources
- *Radioactive*- hospitals, research labs, toxic disposal industries, nuke plants

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Wastewater Contents

- Domestic waste is 99.9% water
- Contains pathogenic (disease causing) bacteria, viruses, cysts that can cause Typhoid, Cholera, Dysentery, Polio and Hepatitis
- Floatable, settleable, suspended, dissolved, colloidal solids

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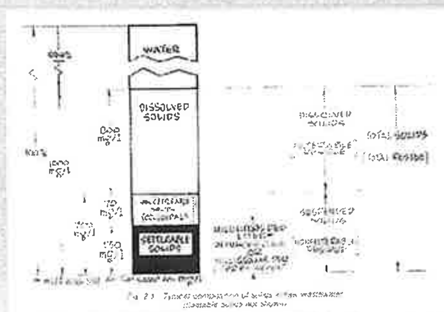
Raw Wastewater Solids Composition



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Preliminary Treatment

- Flow Equalization / Surge Basins
- Bar Screens and Racks
- Moving or Rotating Screens
- Grit Chambers / Channels

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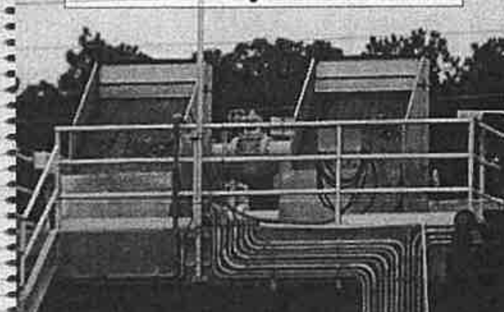
Preliminary Treatment



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Preliminary Treatment

Unit processes include:

- Odor control
- Screening
- Grit removal

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Odor Control

- Odor producing substances are small, mostly volatile molecules
- Most result from anaerobic decomposition of organic matter containing sulfur and nitrogen

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Odor Control, continued

Gases produced from wastewater decomposition:

- Hydrogen sulfide (H_2S)
- Ammonia (NH_3)
- Carbon dioxide (CO2)
- Methane (CH_4)

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Barscreens and Racks

- Influent is screened to remove debris that can clog and damage downstream equipment

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Barscreens and Racks

- Solids removed are referred to as screenings
- Consist of rags, roots, sticks, plastics and other large debris
- Must be placed in covered container and sent to approved landfill

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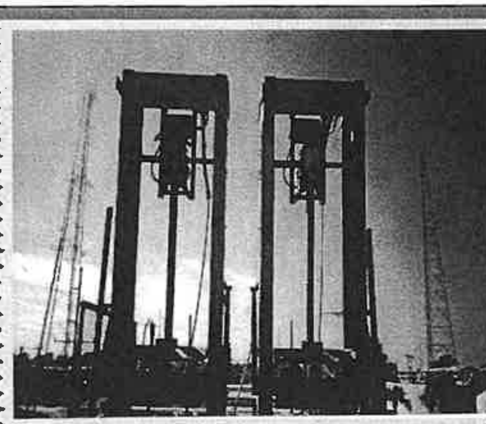

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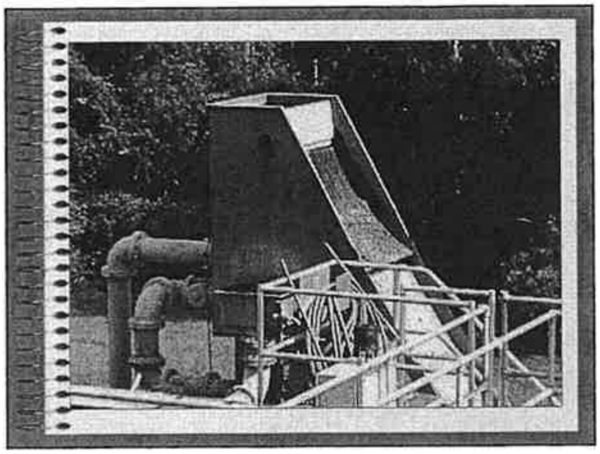

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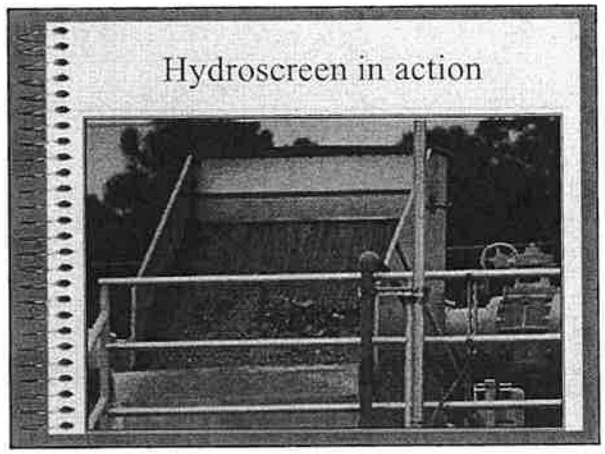

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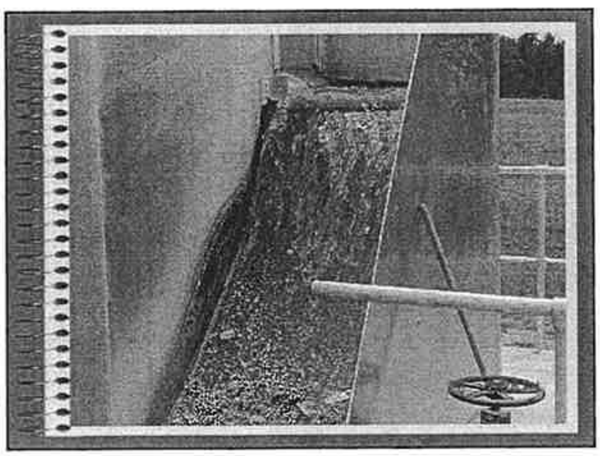

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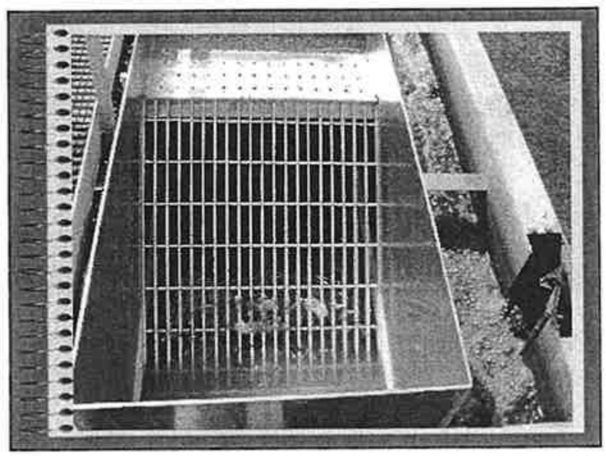

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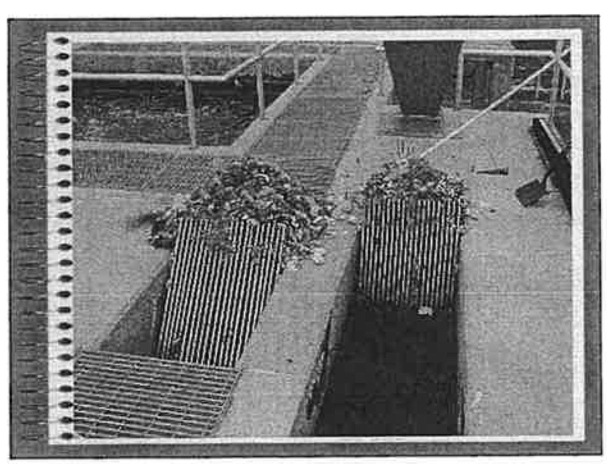

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Influent grinding

- Comminutors and Barminutors grind or chop large solids
- Returns chopped solids to influent flow
- Shredded rags adversely affect downstream processes
- Not very common, slowly being replaced

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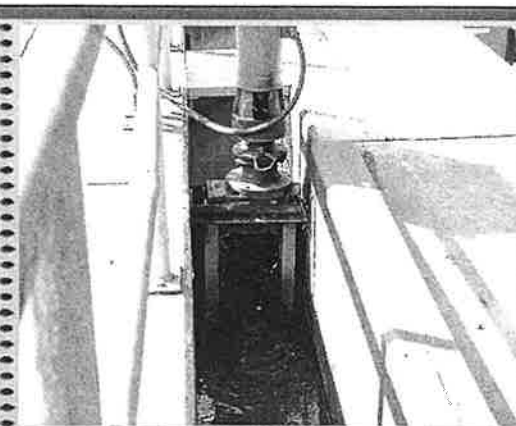

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Grit Removal

- Grit is removed to protect downstream equipment from its abrasive nature
- Grit consists of sand, gravel, pipe debris and eggshells
- Grit can plug pipelines, fill usable tank space, damage pumps and valves

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Volume of grit entering WWTP depends on following variables:

- Type of collection system (sanitary, combined)
- Material used in collection system construction
- Amount of street sand flushed into sewer
- Integrity of collection system
- Industrial waste containing grit from washing processes

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Grit removal

- A variety of equipment is used for grit removal
- Most grit removal techniques slow flow velocity to 1.0 fps to allow grit to settle

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Aerated Grit Removal

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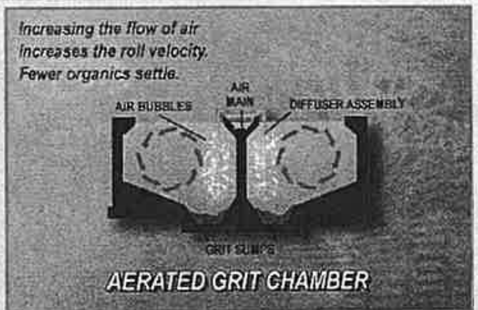
Aerated Grit Removal



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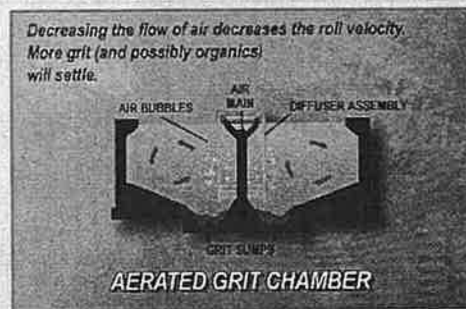
Aerated Grit Removal



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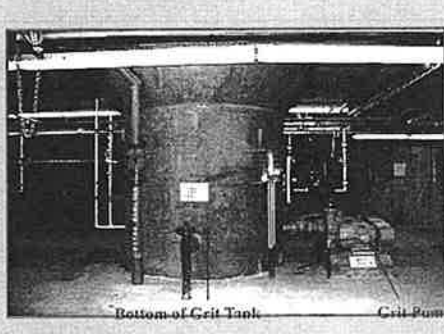
Aerated Grit Removal



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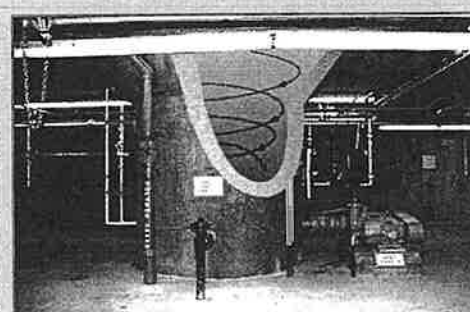
Aerated Grit Removal



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Grit Pumping

- Grit pumps are typically recessed impeller centrifugal pumps
- Pumps are usually timer controlled
- Grit is pumped to a cyclone degritter or dewatering screen

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Cyclone Degritter

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Mechanically Cleaned Chambers

- Most are rectangular shaped
- Most use a chain and flight system to move grit to a sump
- A bucket elevator or inclined screw lifts grit to a classifier or washer

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Mechanically Cleaned Chambers

- Collectors operate at low speed, only fast enough to collect grit as it settles
- Run times of collectors depends on rate of grit accumulation
- Additional grit chambers should be placed on-line if grit loading exceeds that of on-line units

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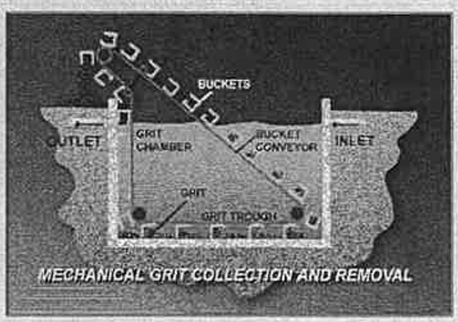
Mechanically Cleaned Chambers



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Grit channels

- Basically long channels that reduce flow velocity to 1.0 feet per second
- Use two or more channels
- One channel stays on-line, other channel off for draining and cleaning

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Grit Channels

- Grit is manually removed (armstrong method)
- May be found as a back-up to a mechanical grit removal system

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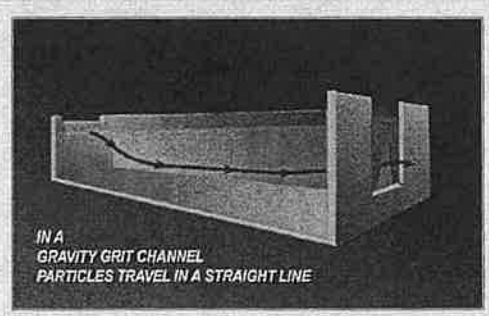
Grit Channels



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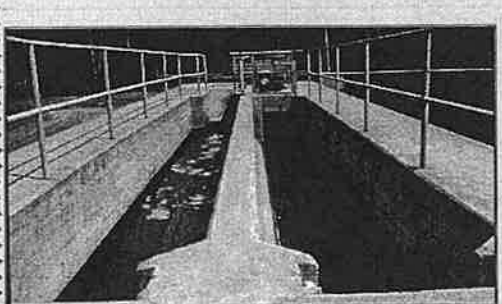
Grit Channels



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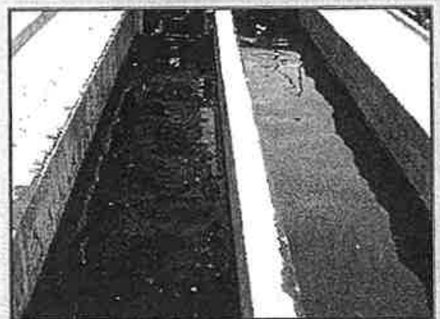
Grit Channels



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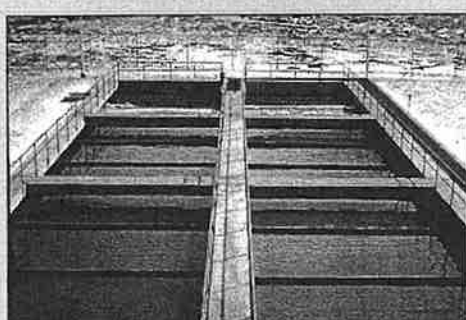
Primary Treatment



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Why Primary Treatment?

- Primary treatment lessens the solids burden on secondary treatment processes
- Trickling filters / RBC's
- Activated sludge processes

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Why Primary Treatment?

- Separates the settleable and floatable solids from waste stream

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Primary Sludge

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Primary Scum

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Primary Removal Stats

- Primary treatment can achieve 40-60% removal of influent TSS
- 25 –30% of influent BOD

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Primary Clarifier Design

- Primary clarifiers can be rectangular or circular
- Designed to decrease influent flow velocity to allow for solids settling

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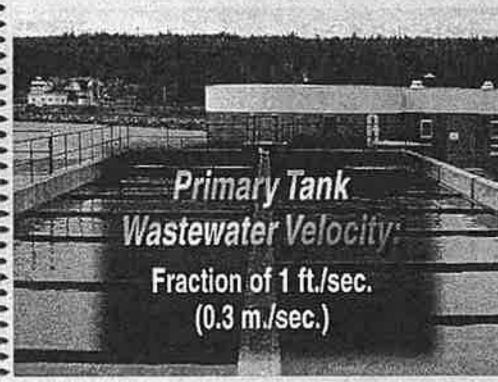

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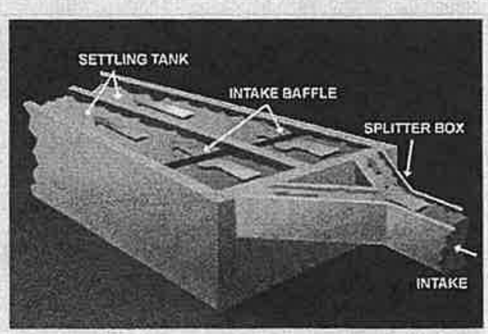
Slow the Flow



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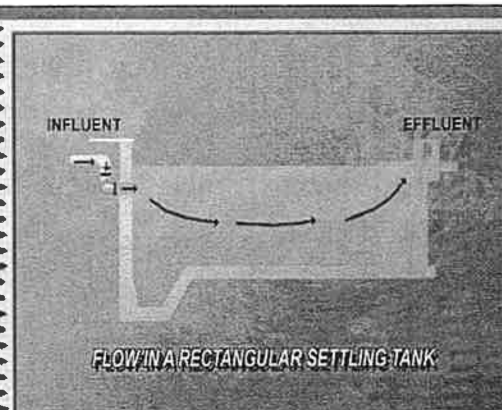

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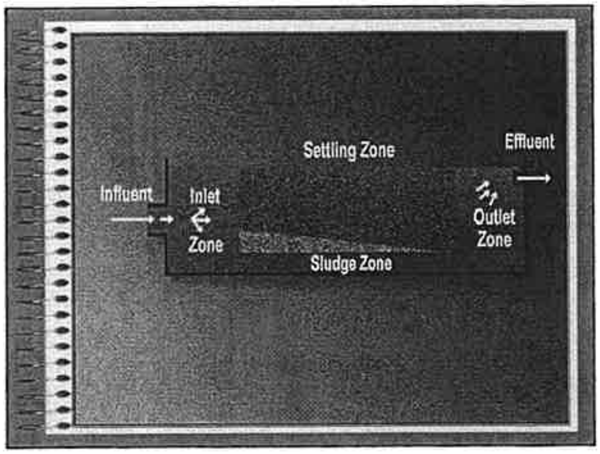

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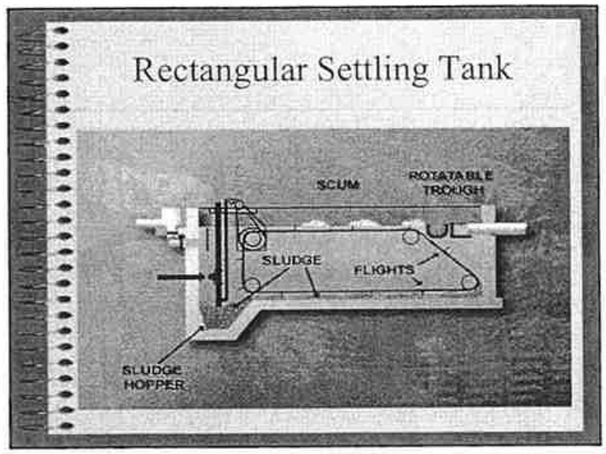

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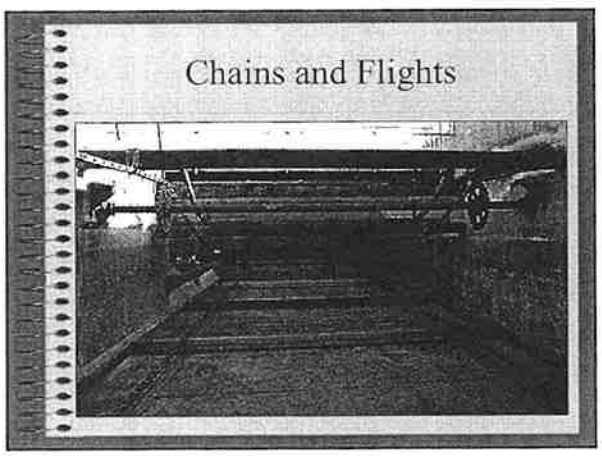

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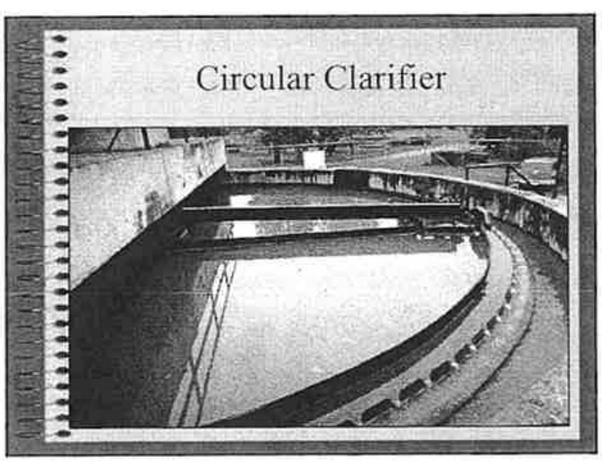

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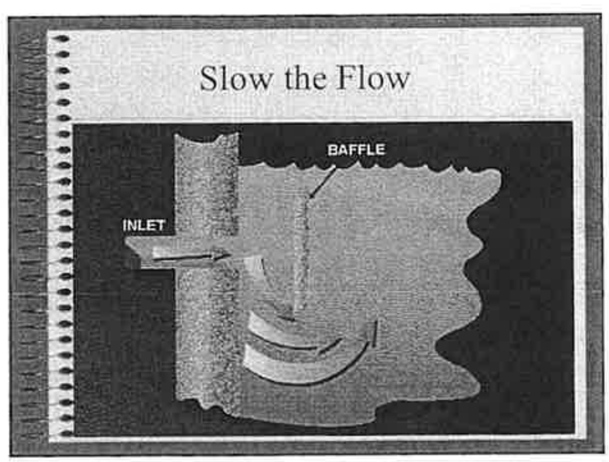

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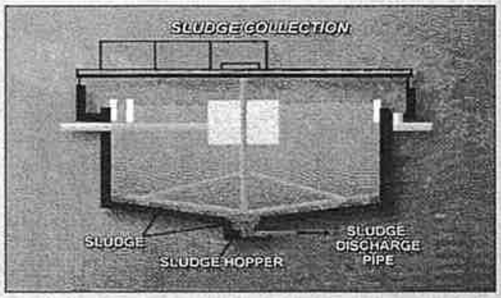
Circular Clarifier



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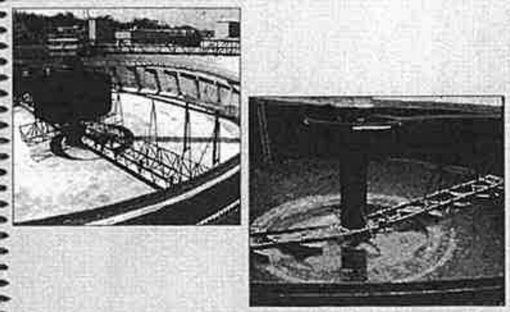
Circular Clarifiers



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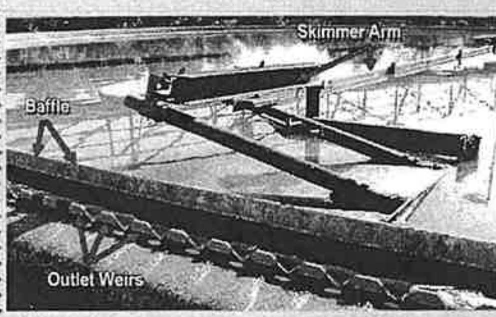
Scum Collection



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Factors Affecting Solids Removal

- Surface oveflow rates
- Detention time
- Tank configuration
- Wastewater characteristics
- Industrial contribution
- Temperature
- Particle characteristics

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Hydraulic Loading Parameters

Surface Overflow Rate

Tank surface area governs overflow rate

Overflow rate varies with flow, since tank sizes are fixed

Range = 800-1000 gal/ft^2/day

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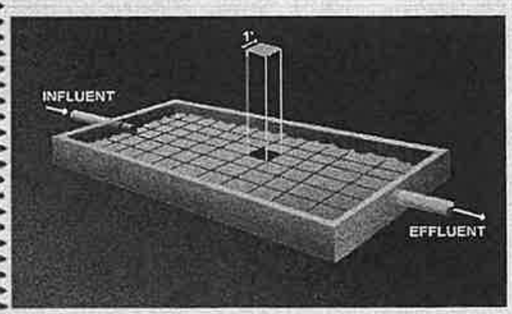
Surface Area, ft^2



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Surface Area

$$\text{Surface area, gpd/sq ft} = \frac{\text{flow, gpd}}{\text{tank surface area, sq. ft.}}$$

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Detention Time

- Time required for a unit of volume to pass entirely through the tank at a given flow rate.
- Should be sufficient to allow nearly complete removal of settleable solids
- Usually 1 to 2 hours

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Detention Time

$$\text{Detention time, hrs} = \frac{\text{tank volume, gal} \times 24 \text{ hours}}{\text{flow, gpd}}$$

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Particle Characteristics

- Dense particles settle faster than light ones
- Particles with large surface area:weight ratio settle slowly
- Irregularly shaped particles settle slowly

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Temperature

- Warm weather increases rate of biological degredation, increasing gasification
- Low viscosity of warm water tends to speed settling
- Cold temps slow settling

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Industrial Wastewater

Industries may contribute:

- Large, short term hydraulic surges
- Short term, high organic loading

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Effluent Weirs

Overflow weirs MUST be perfectly level to ensure good flow distribution and prevent short circuiting.

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Effluent Weirs

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Primary Sludge Pumping

- Primary sludge should be withdrawn frequently, in small amounts
- Poor sludge pumping practice is most common operational error
- Can lead to septic conditions, high solids loading on secondary treatment units

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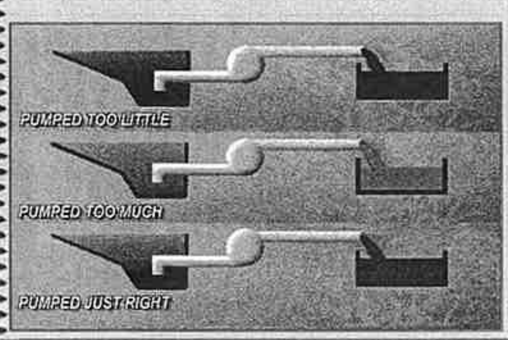
Primary Sludge Pumping



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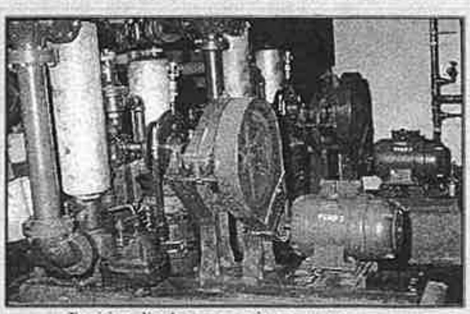
Primary Sludge Pumping



Positive displacement piston pumps

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See Any Problems?

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Secondary Treatment

BIOLOGICAL PROCESSES
Rotating Biological Contactors (RBCs)
Trickling Filters
Activated Sludge Processes

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RBCs and Trickling Filters

- Rotating Biological Contactors (RBCs) and Trickling Filters use bacteria that grow on media to treat wastewater
- These processes are located after primary clarifiers

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Rotating Biological Contactor

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Rotating Biological Contactors

- RBC’s can be ran in series or parallel

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RBC

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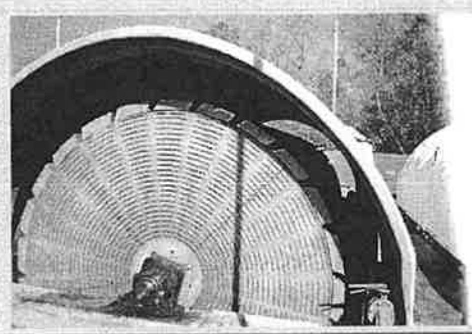
RBC



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Rotating Biological Contactors

- RBC's are designed to rotate approximately 1 rpm
- D.O. is maintained between 1-3 mg/l

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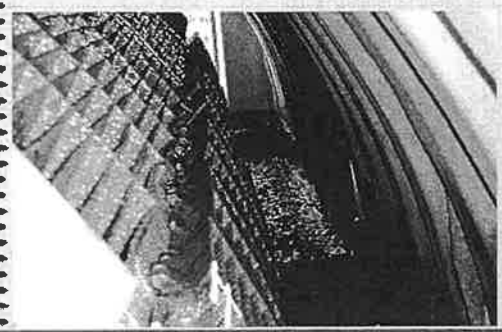
RBC



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RBC Media

- Color of biomass growing on RBC media can indicate operating conditions.
  - White media indicates hydrogen sulfide condition.
  - Black media can indicate septic conditions in tank, or high organic loading.

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Trickling Filters

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Trickling Filters

- Trickling filters use attached growth to treat wastes.
- Zoogleal (bacteria) growth continuously grows and sloughs off media.
- Sloughings flow to secondary clarifier.

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Trickling Filters

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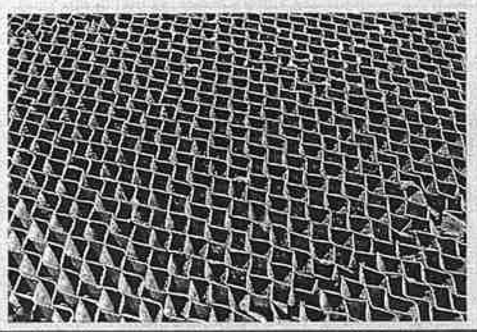
Trickling Filters



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Trickling Filters

- Wastewater is collected in underdrains
- Use rotary distributors or fixed nozzle distributors
- Can use rock or plastic media
- Have vents to allow air circulation

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Trickling Filters

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Trickling Filter Problems

- Ponding
- Filter Flies

Flood the Filter !

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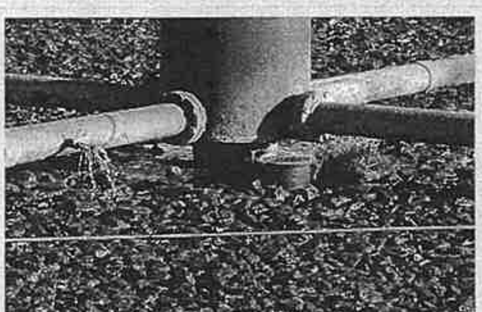
Trickling Filters



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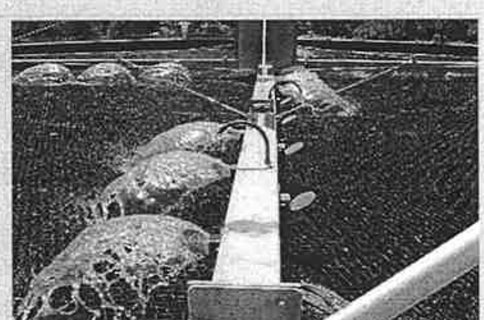
Trickling Filters



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Activated Sludge

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Activated Sludge

Most Common

- Conventional
- Complete Mix
- Step Feed
- Contact Stabilization
- Extended Aeration
- Oxidation Ditch

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Activated Sludge
Conventional Mode

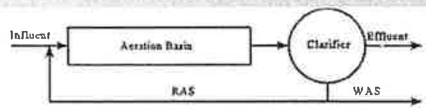


Figure 3-1: Conventional Activated Sludge

Plug flow design; 4-8 hour detention time;
F/M = 0.2-0.5 lb BOD/lb MLVSS;
1000-3000 mg/L MLSS;
5-15 day MCRT

123

Activated Sludge
Complete Mix Mode

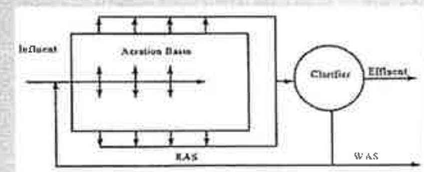


Figure 3-2: Complete Mix Activated Sludge

Not plug flow; 3-5 hour detention time;
F/M = 0.2-0.6 lbs BOD/lb MLVSS;3000-6000mg/L MLSS;
5-15 day MCRT

124

Activated Sludge
Step Feed Mode

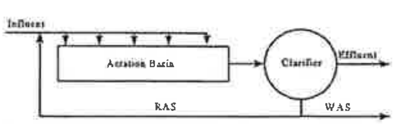


Figure 3-3: Step-feed Activated Sludge

Plug flow; 3-8 hour detention time;
F/M = 0.2-0.5 lbs BOD/lb MLVSS;

2000-3500 mg/L MLSS; 5-15 day MCRT

125

Activated Sludge
Contact Stabilization Mode

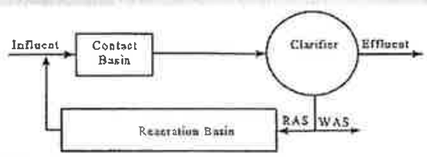


Figure 3-4: Contact Stabilization Activated Sludge

Plug flow pattern; 0.5-1.5 hr Detention time (contact);
F/M = 0.2-0.6 lbs BOD/lb MLVSS; 1000-3000 mg/L MLSS (contact); 5-15 day MCRT

126

Activated Sludge
Extended Aeration Mode

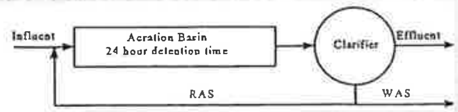
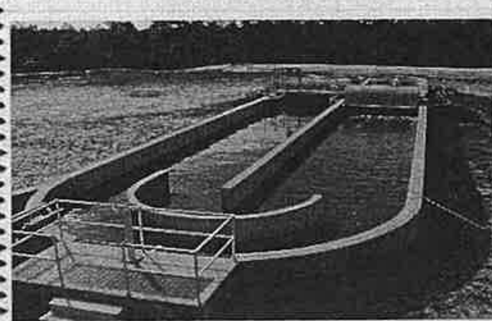


Figure 3-5: Extended Aeration Activated Sludge

Complete mix; 18-30 hour detention time; F/M = 0.05-0.15 lbs BOD/lb MLVSS; 2000-6000 mg/L MLSS; 20-30 day MCRT

127

Oxidation Ditch



128

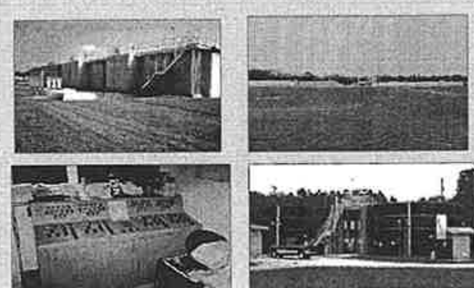
Activated Sludge

Other Modifications:

- Kraus Process
- High Rate
- Pure Oxygen
- Ludzack / Ettinger Process
- Wuhrman Process
- Sequencing Batch Reactor (SBR)
- Bardenpho process

129

SBR's of Today



130

Principles of SBR Operation

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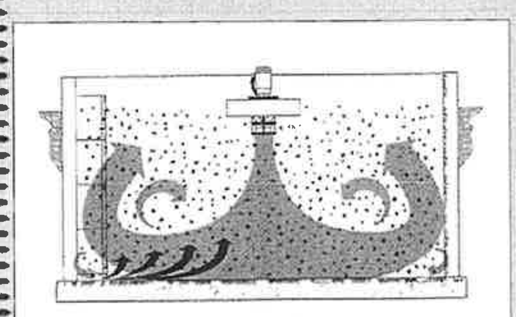
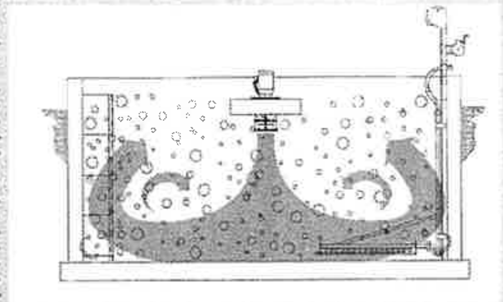
Fill Stage



132

React Stage



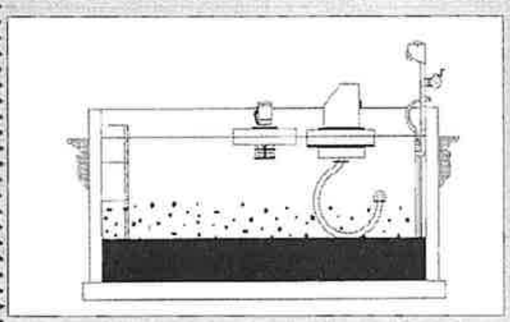
133

React Stage

- Influent flow is terminated
- Mixing and aeration continue
- Intermittent operation of aeration system may continue to complete the nitrification/de-nitrification process or to conserve energy

134

Settle Stage



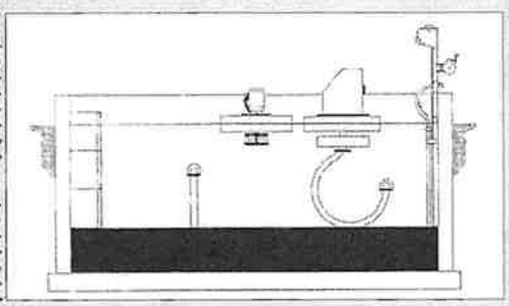
135

Settle Stage

- Mixing and aeration cease
- Solids/liquid separation takes place under quiescent conditions

136

Decant and Sludge Waste



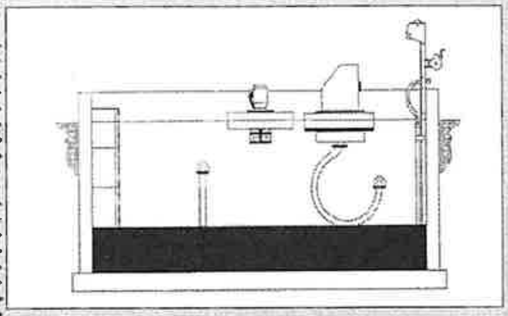
137

Decant and Sludge Waste

- The mixer and aeration remain off
- The decantable volume is removed by means of subsurface withdrawal
- A small amount of sludge is wasted each cycle
- The reactor is immediately available to receive the next batch of raw influent

138

Idle Stage



139

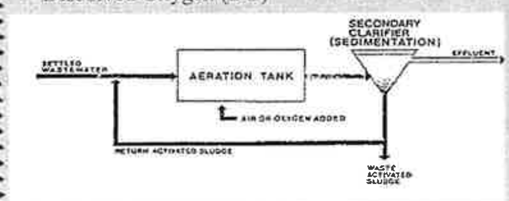
Idle Stage

- Occurs in multi-basin systems anytime that flow conditions are less than peak design flow
- Idle times will vary depending on actual flow conditions

140

Activated Sludge Control Methods

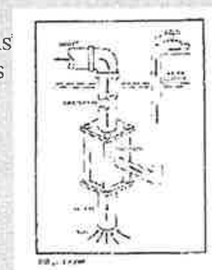
- Return Activated Sludge (RAS)
- Waste Activated Sludge (WAS)
- Dissolved Oxygen (DO)



141

Return Activated Sludge (RAS)

- Return microorganisms back to aeration basins from clarifiers
- Constant Rate
- Flow Percentage Rate



142

Return Sludge Eductor Pipe

- RAS flow can be reduced by rags, thick sludge, sticks, cans, blankets, bicycle rims, tools, bumpers, cinder blocks, buckets, pipes, etc …

If it can fall into the clarifier, it will clog the RAS piping!

143

Waste Activated Sludge (WAS)

The most important control of the activated sludge process

It affects the following:

- Effluent Quality
- Microorganism growth rate
- Oxygen uptake rate
- Settleability rates
- Nitrification rates
- Foaming / frothing

144

Waste Activated Sludge *(Continued)*

- Control Techniques: Constant MLSS/MLVSS F/M ratio, Sludge age (MCRT,SRT)
- Wasting can be intentional or unintentional.
- Wasting can be done from the aeration tank or a portion of the return sludge.
- Make waste changes gradually (10-15% per day) to avoid shock to system.

145

Dissolved Oxygen Requirements

- Aeration serves two purposes:
  1. Provides DO (1-3 mg/l)
  2. Mixes MLSS
- High DO (>5.0) can shear floc, waste energy.
- Low DO (<0.5) can lead to bulking, poor effluent quality.

146

Dissolved Oxygen Requirements

- 1.5 pounds of oxygen are required to convert 1 pound of BOD.
- 4.6 pounds of oxygen are required to convert 1 pound of ammonia.
- 2 approved methods of measuring DO are Winkler method & DO probe.

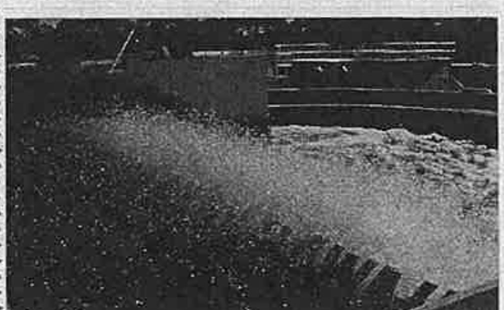
147

Aeration Methods

- Compressed air / Diffused aeration
  - Centrifugal blowers
  - Positive displacement blowers
- Mechanical aeration
  - Floating aerator
  - Fixed aerator

148

Brush rotors



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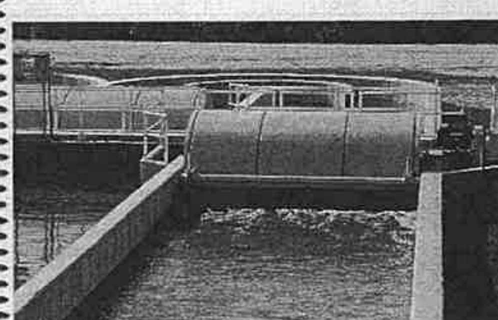
Brush Rotors



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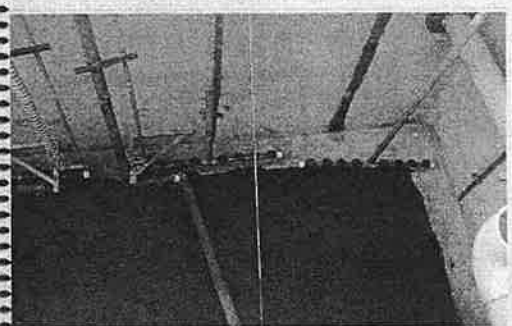
Brush rotors

151

Diffusers



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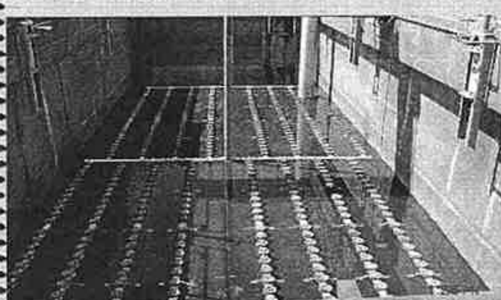
Diffusers



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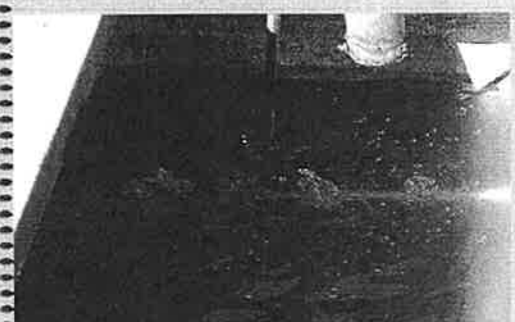
Diffusers



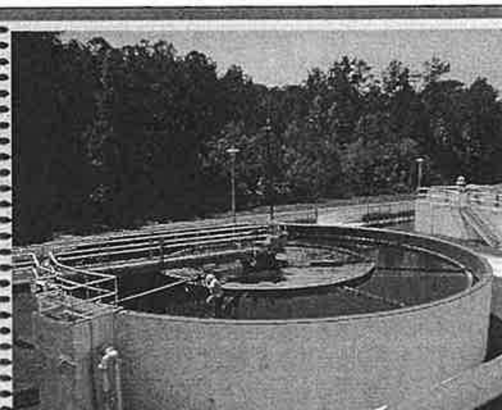
154

Activated Sludge Secondary Clarifiers

- Typical Loading Rates:
  - Detention Time - 2 to 3 hours
  - Hydraulic loading - 300 to 1200 gpd/sq.ft.
  - Solids loading - 20 to 30 lbs/day/sq.ft.
  - Weir overflow - 5,000 to 15,000 gpd/ft.

These are relative numbers, clarifiers vary between manufacturer and installation. Also, sludge quality changes these parameters.

155



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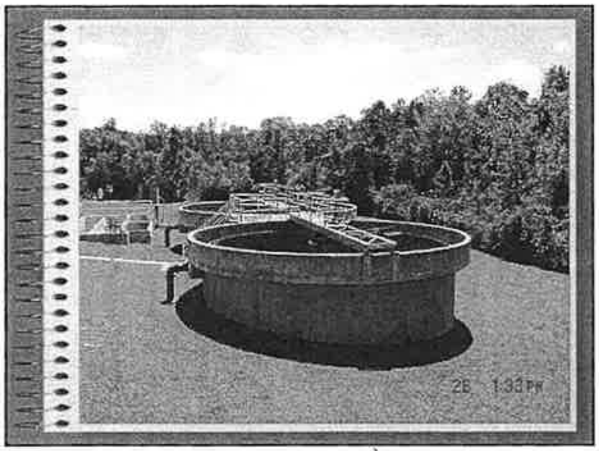

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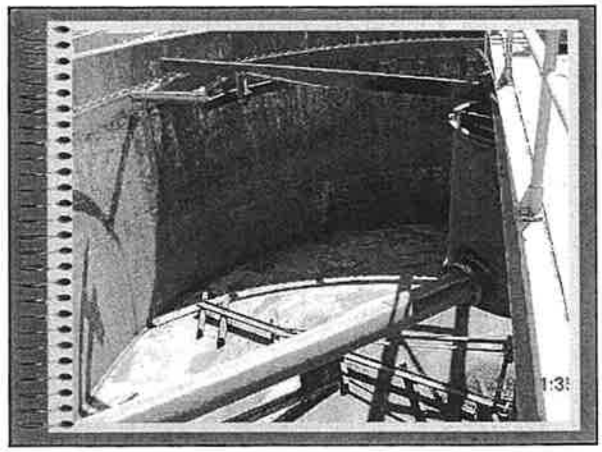

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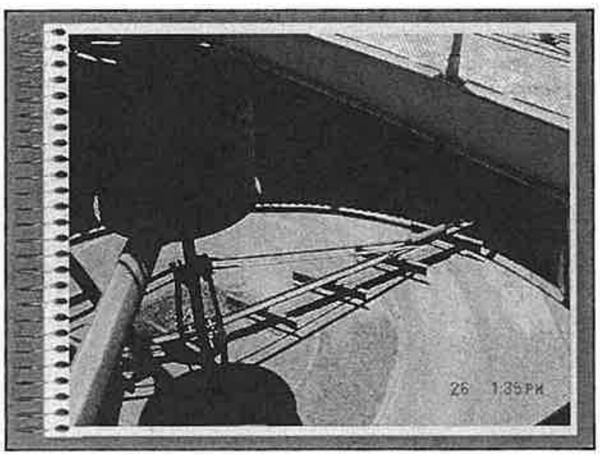

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Secondary Clarifiers *(continued)*

Monitor these parameters:

- Sludge levels (25% of total depth)
- MLSS concentrations
- Return sludge flows
- Turbidity of clarifier effluent
- DO in effluent
- Effluent pH

160

Understanding Activated Sludge Parameter Relationships

A look at how process parameters work together

161

Exam Preparation

- Important to know and understand how these parameters relate
- Applies to everyday operation of WWTP
- Simplifies troubleshooting

162

Floc Particles

- *Straggler floc*: As seen in settleometer or clarifier, about the size of half your pinky fingernail.
- Suspended, slow settling
- Large, irregularly-shaped, fluffy
- Young Sludge

163

Floc Particles

- *Pin-Floc:* As seen in settleometer or clarifier, small particles, about the size of a pin head.
- Leaves a turbid, cloudy appearance
- Sludge settles rapidly, rounded shape, grainy appearance
- Old Sludge

164

Foam Characteristics

- Young: White foam produced from low MLSS
- White, billowy, sudsy, crisp
- Large amounts of surfactants, plant start-up

165

Foam Characteristics

- Old: Dark foam produced from high MLSS
- Shiny, dark tan
- Dark and leathery as sludge gets older.
- Influent oil and grease contribute.

166

Indicator Organisms (bugs)

- Young: Amoebae and Flagellates
- Old: Rotifers and Worms
- Predominance of these bugs depends on sludge age

167

MLSS

- Young Sludge: Low mixed liquor
- Reasons
  - Plant start-up
  - Excessive solids washout
  - Excessive wasting
- Solutions
  - Stop or decrease waste rate
  - Control hydraulics through plant

168

MLSS

- Old Sludge: High mixed liquor
- Reasons
  - Poor sludge wasting practices
  - High organic and solids loading
- Solutions
  - Increase wasting
  - Haul sludge more frequently

169

Sludge Age / MCRT

- When MLSS is low, sludge age is young
- Reasons
  - Plant start-up
  - Solids washout
  - Excessive wasting
- Solutions
  - Slow or stop wasting

170

Sludge Age / MCRT

- When MLSS is high, sludge age is old
- Reasons
  - Poor wasting practices
  - Limited digester capacity
  - High organic/solids loading
- Solutions
  - Increase wasting

171

F/M Ratio

Amount of food, in pounds, available to a pound of MLVSS (bugs)

- High: Young Sludge
- Lots of food (CBOD) per pound of MLVSS (bugs)

172

F/M Ratio

Amount of food, in pounds, available to a pound of MLVSS (bugs)

- Low: Old sludge
- Limited amount of food (CBOD) per pound of MLVSS (bugs)

173

Sludge Volume Index (SVI)

- Young: High SVI (>300)
- Reasons
  - Plant start-up
  - Low MLSS
  - Excessive wasting
  - Solids washout

174

Sludge Volume Index (SVI)

- Old: Low SVI (<80)
- Reasons
  - Rapid-settling sludge
  - Small grainy particles

175

Sludge Settleability

- Young sludge: Slow settling
- Reasons
  - Supernate may be cloudy
  - Leaving stragglers
- Solutions
  - Reduce waste rate

176

Sludge Settleability

- Old sludge: Fast settling
- Supernate may be cloudy with pin point floc suspended
- Rapid settling leaves small stuff behind
- Increase sludge waste rate

177

Waste Activated Sludge (WAS)

- The key to controlling the activated sludge process
- Most facilities don't waste sludge properly

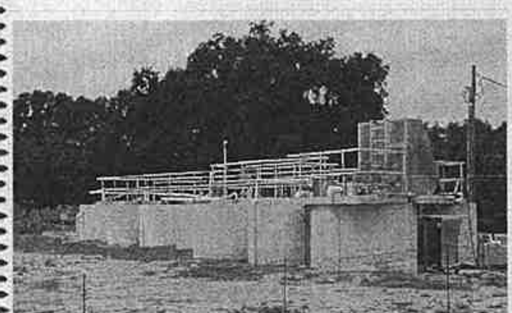
178

One more

- One of the most common causes of repeated sludge bulking is a high F/M ratio, low sludge age
- What waste rate change would you make?

179

Activated Sludge Troubleshooting



180

Typical Activated Sludge Problems

- Foams
- Excessive effluent suspended solids
- Excessive effluent BOD/NH_3
- Low effluent pH

181

Foam

182

Foaming Organisms

- Nocardia is hydrophobic and difficult to get rid of!
- Nocardia is the most common *SHORT* filament

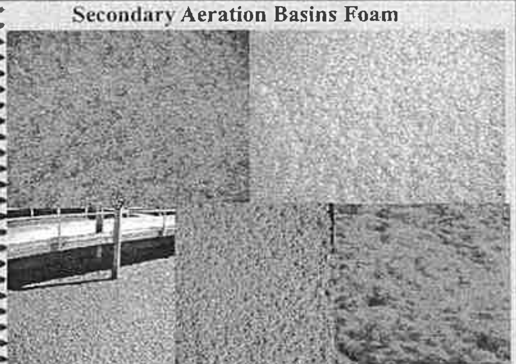
183

Foam Types

- Pumice-like foam
  - Solids return from sludge processing
- Gray, thick, slimy foam
  - Nutrient deficiency
- Dark brown, thick, scummy foam
  - Old sludge, Nocardia

184

Secondary Aeration Basins Foam



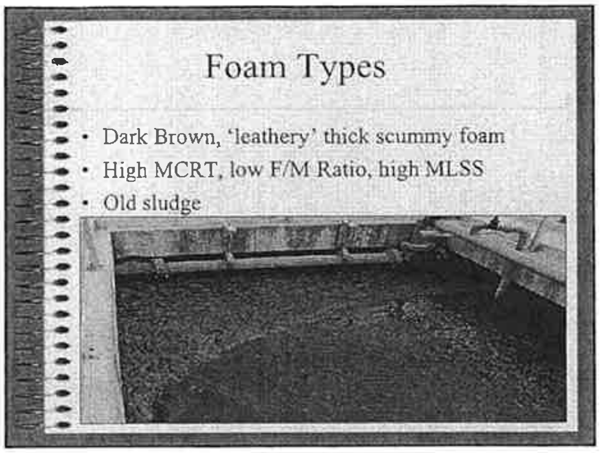
How much foam? What color is your foam?

185

Foam Types

- Billowy white foam – Young Sludge
  - Plant start up
  - High surfactant load

186



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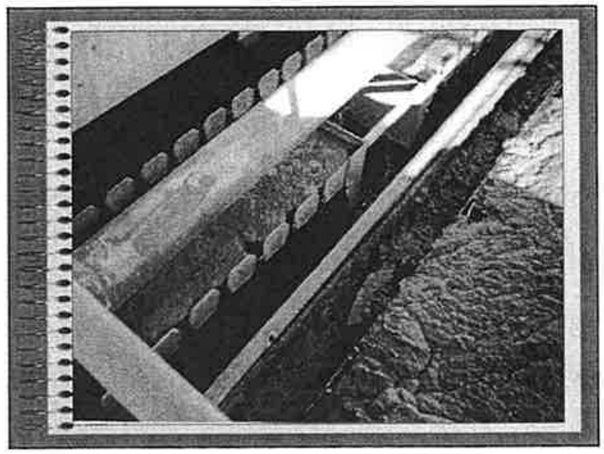

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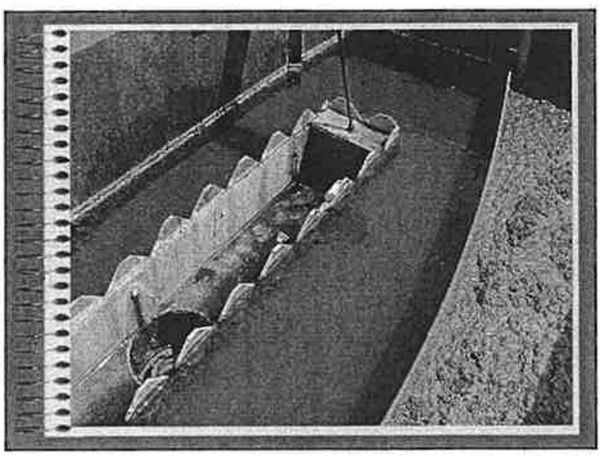

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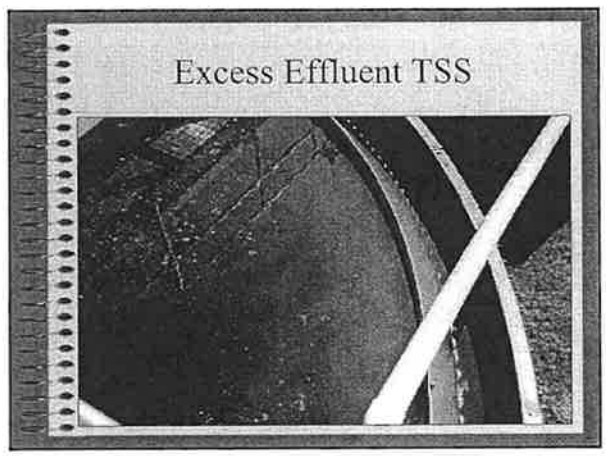

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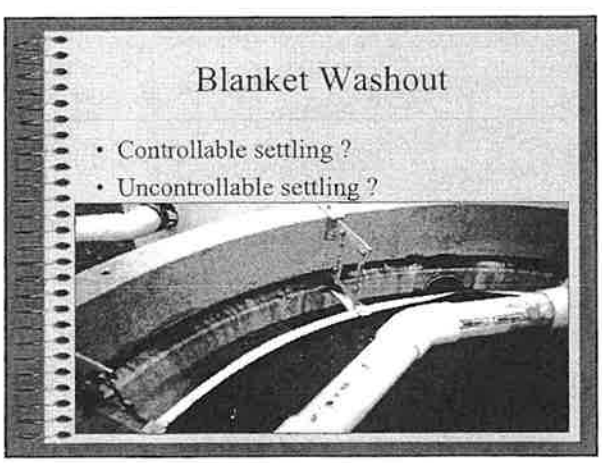

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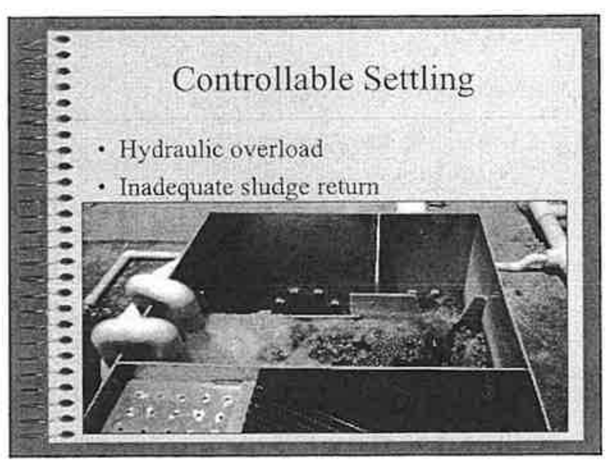

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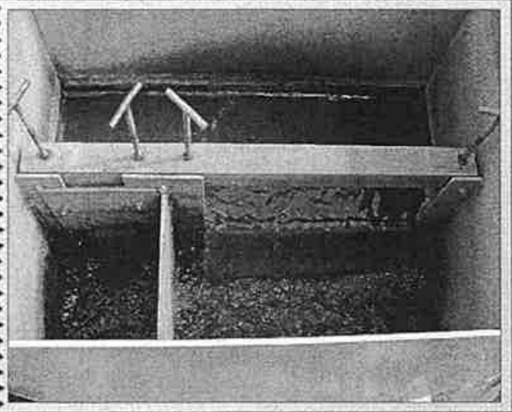

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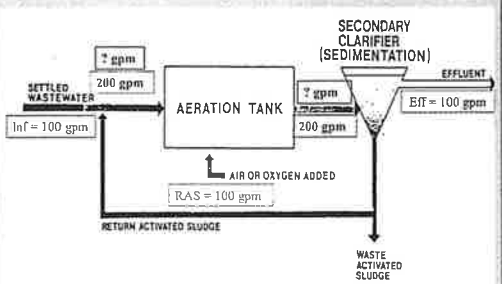
Controllable Settling

100 % MLSS

Good settling in an undiluted sample, but washout in clarifier, indicates hydraulic overload.

194

Controllable Settling



195

Diluted Settleability

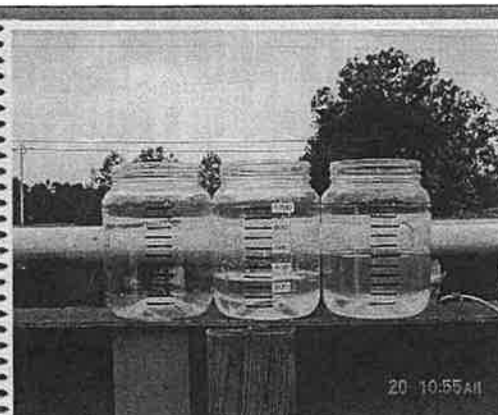
- A modification of the settleability test
- Uses different dilutions to simulate how sludge would settle if some of the solids were wasted

196

Diluted Settleability

- Use clarifier effluent water for dilutions
- Don't use the garden hose laying at the plant for dilution water
- Keep conditions consistent with actual operation

197



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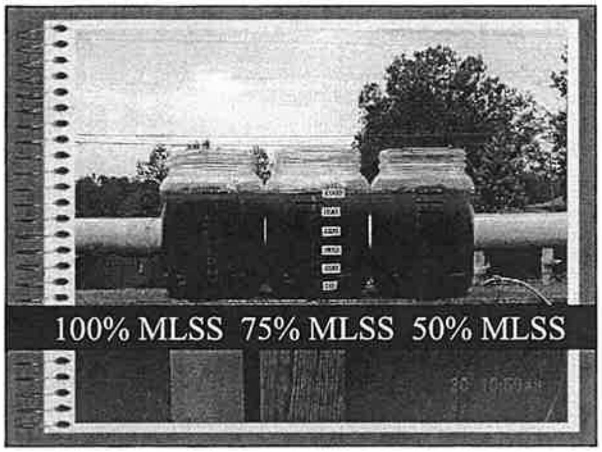

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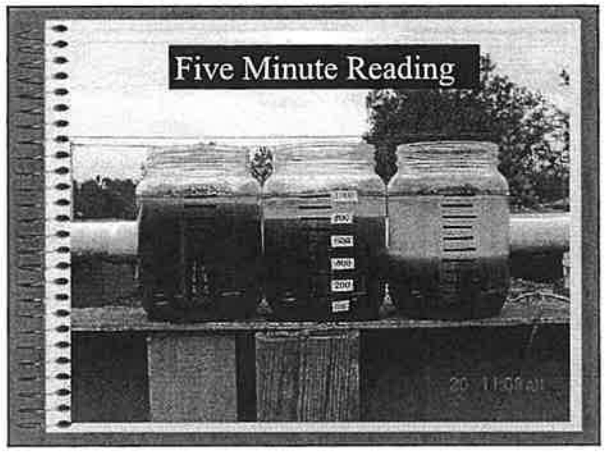

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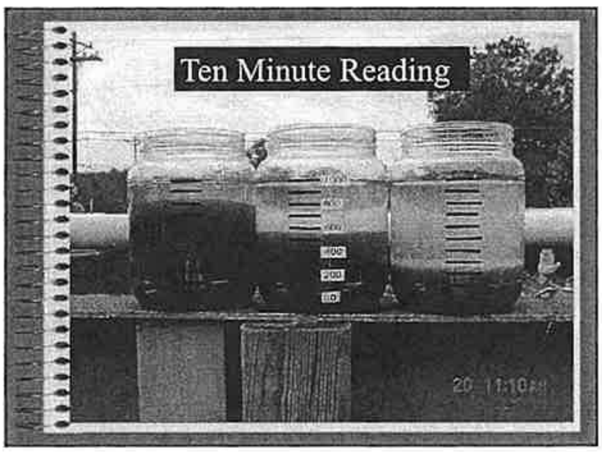

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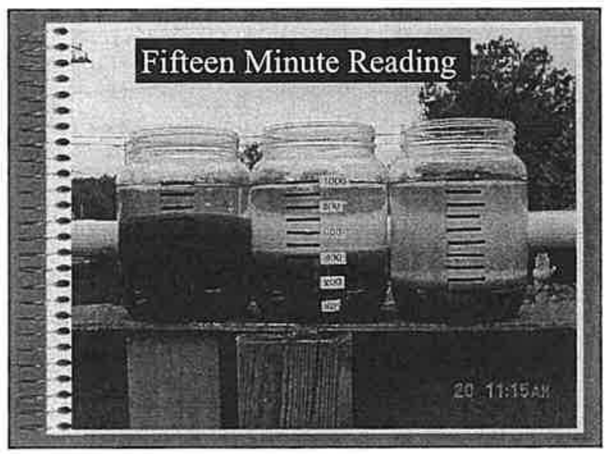

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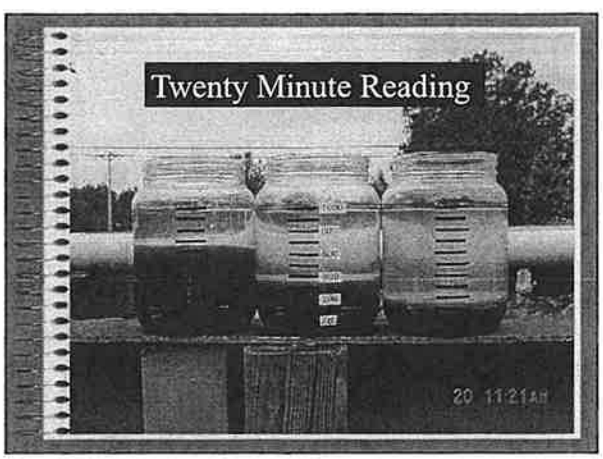

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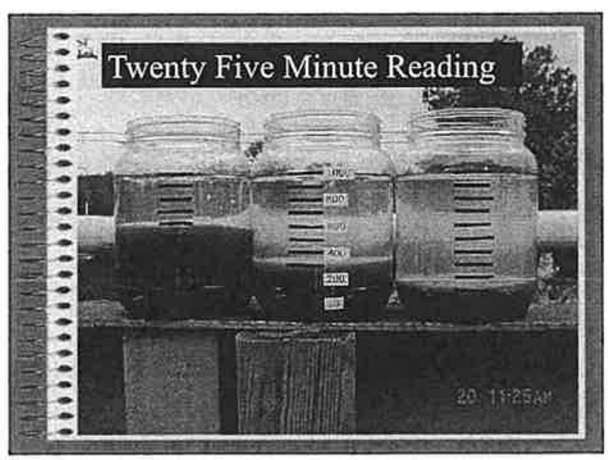

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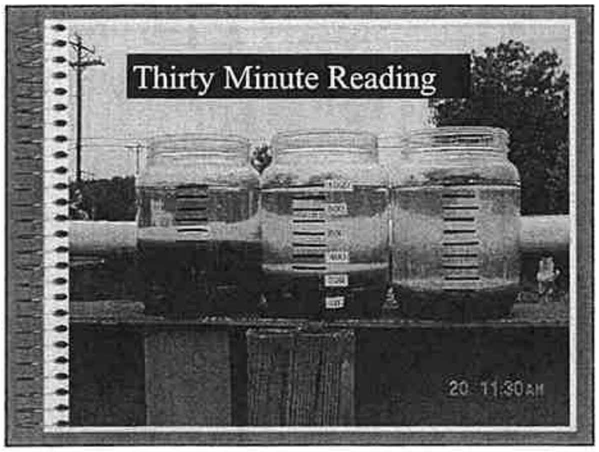
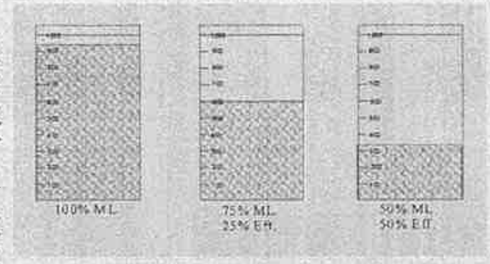


205

Good Settling with Diluted Settleometer



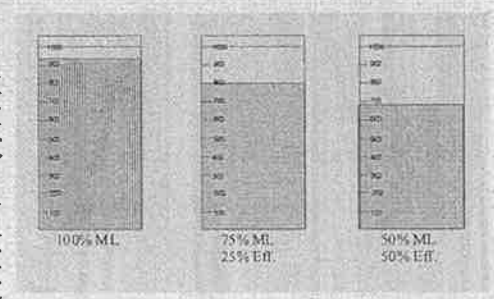
206

Good Settling with Diluted Settleometer

- Excess old sludge
- Glutted system
- Increase waste rates

207

Poor Settling with Diluted Settleometer



208

Poor Settling with Diluted Settleometer

- Slime Bulking
- Filamentous sludge (True Bulking)

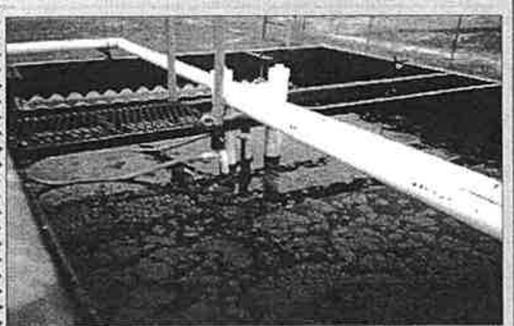
209

Excess Effluent TSS

- Pop ups can wash out over weirs
- Reasons
  - Denitrification in clarifier
  - Septic sludge in clarifier

210

Excess Effluent TSS



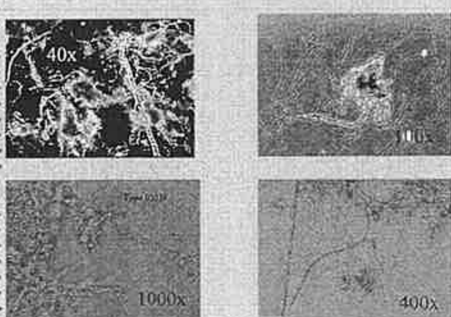
211

Filamentous

- Low DO
- Low F/M
- Nutrient deficiency
- Sulfides
- Readily metabolized substrate
- Slowly metabolized substrate
- Surface seeding

212

Magnification



213

Filamentous

Low DO promotes low DO filaments:

1) Type 1701
2) *S. Natans*
3) *H. Hydrossis*
4) *M. Parvicella*

214

Individual Particle Washout

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Individual Particle Washout

- Pin-floc
- Straggler floc
- Individual bacterial cells

216

Pin-floc

- High MCRT / Low F/M Ratio
  - Highly underloaded plant
  - Clarifier denitrification
- Solids recycle from solids processing
- Very small particles, about the size of a pin head

217

Pin-floc

- Pin floc can lead to 'ashing' on the surface of clarifiers
- MLSS getting high, sludge getting old
- Increase wasting

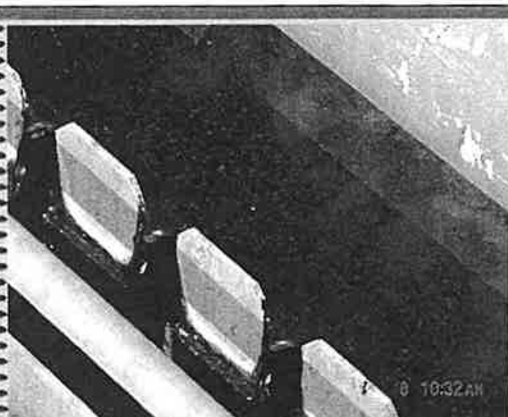
218

219

Straggler Floc

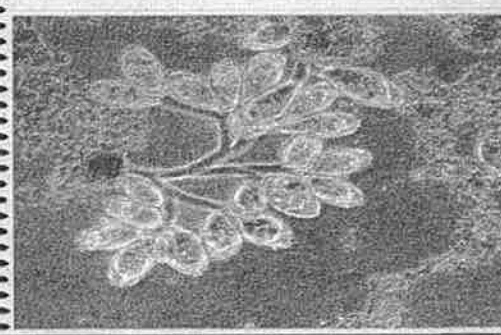
- Associated with Low MCRT or High F/M Ratio
- Filamentous
- Non-filamentous
- Larger particles, about the size of a half fingernail

220



221

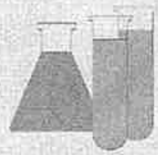
How Does Your WWTP Work?



222

Chemical Requirement for Treatment

- DO, NO_3
- pH
- Alkalinity
- Nutrients



223

Nutrients

- Carbon
- Nitrogen
- Phosphorus
- Trace minerals

224

Ratio

BOD: Nitrogen: Phosphorus: Iron

100: 5: 1: 0.5

225

Types of Bugs, Critters & Microorganisms in *your* WWTP

- Bacteria
- Protozoa
- Metazoa
- Algae
- Fleas?
- Bears?!?

226

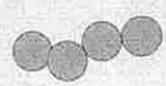
Bacteria:
The Workhorses of Treatment

- Floc-forming (stick together)
- Filamentous (backbone of floc)
- Heterotrophic (utilize *organic* carbon)
- Autotrophic (utilize *inorganic* carbon)
- Aerobic (free dissolved oxygen)
- Anaerobic (fermentation)
- Facultative (free DO or bound Oxygen - NO_3, SO_4)

227

Floc-Forming

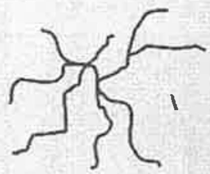
- Non-filamentous bacteria that stick together



228

Filamentous Bacteria

- Form backbone of good floc
- Excessive filaments can cause a bulking sludge and settling problems



229

Heterotrophic Bacteria

- Carbon source is organic – BOD
- Fast growing under proper conditions
- Facultative - function with free DO or bound oxygen (NO_3, SO_4)

230

Autotrophic Bacteria

- Carbon source is inorganic - carbonate and carbon dioxide
- Slow growing
- Require O_2 as an electron acceptor

231

Environments

- Aerobic - Free dissolved oxygen present
- Anoxic - No free dissolved oxygen present, but nitrate present
- Anaerobic - No free dissolved oxygen or nitrate present

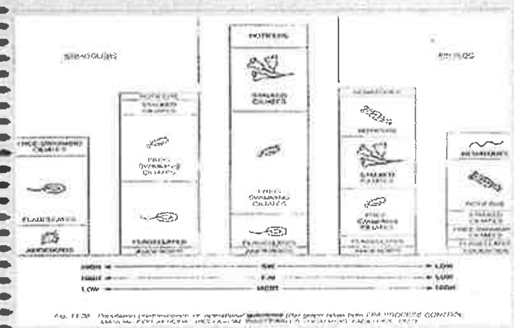
232

Facultative Bacteria

- Can reproduce under aerobic or anoxic conditions
- Can utilize free dissolved oxygen or bound oxygen (nitrate)
- Will utilize free dissolved oxygen first

233

The Indicator Organisms



234

Indicator Organisms

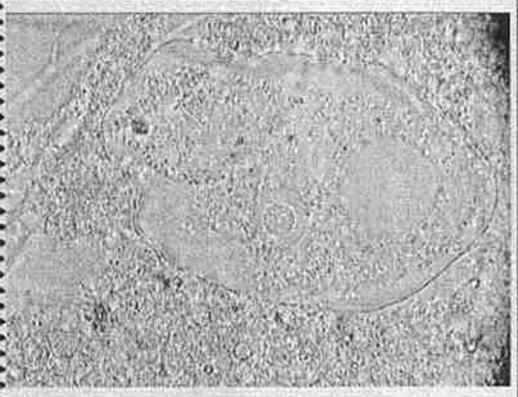
- While bacteria are performing the actual work of BOD and TSS reduction, we use certain protozoans as *indicators* to determine the degree of treatment.
  - Amoebae
  - Flagellates
  - Free Swimming Ciliates
  - Stalked Ciliates
  - Suctoria

235

Amoebae

- No distinct shape, since flow of cytoplasm continually changes shape
- Feed on bacteria and protozoa
- Found during plant start-up or toxic overload
- Poor biomass health when amoeba predominate
- Indicate young sludge

236



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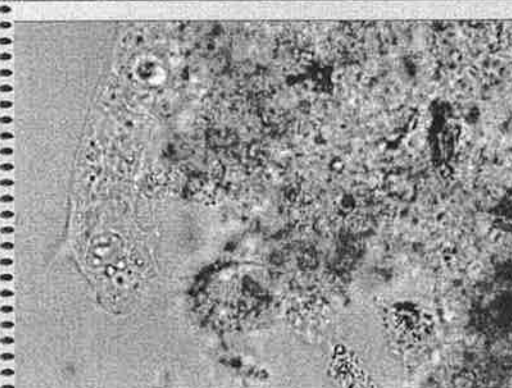

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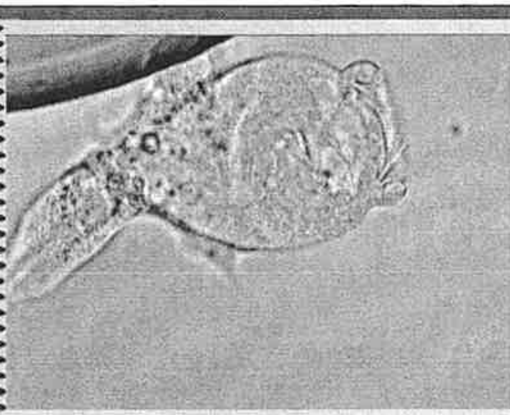
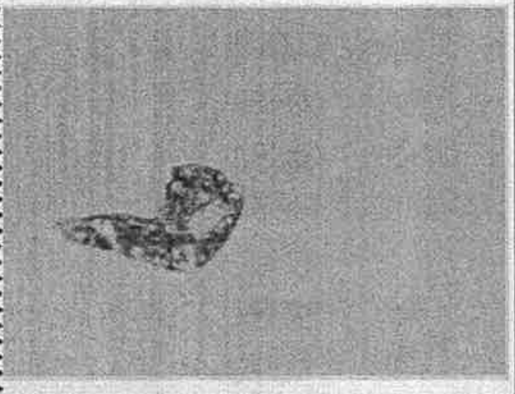


239

Flagellated Protozoa

- Use a flagellum (whip-like tail) for locomotion
- Present during start-up or plant upset
- Feed on specific strains of bacteria
- Indicate young sludge
- High energy requirement
- Elevated CBOD in effluent

240

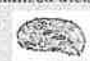


241

Free Swimming Ciliates

- Present during start-up or plant upset
- Bulk Liquid - *Have large 'mouths' to collect food in liquid, high energy requirements, higher BOD*
- Crawler - *Smaller 'mouths', crawls over floc to scrape bacteria off, less energy required, decreasing BOD*
- Carnivorous - *BOD limited, specialized diets, least amount of energy used*





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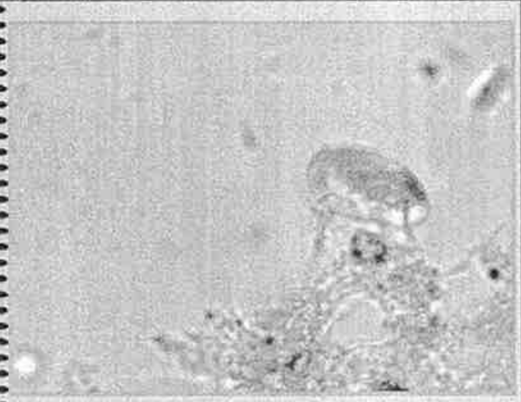

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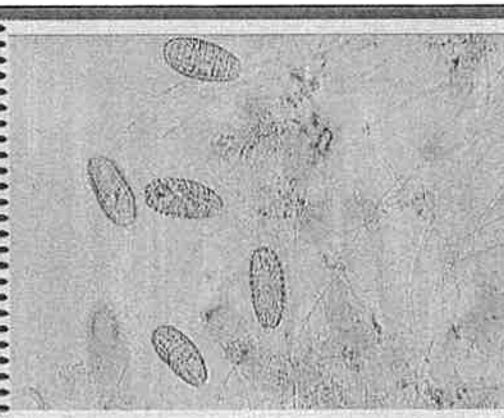


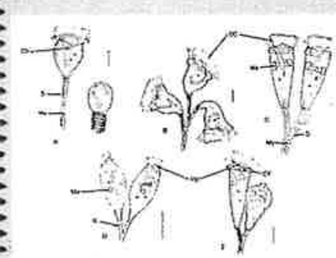
244

Stalked Ciliates

- Inverted bell shaped bodies mounted on a stalk which is attached to a substratum
- Conspicuous oral cililiation located in the oral region of the body
- Low energy requirements, BOD reduced, improves effluent quality

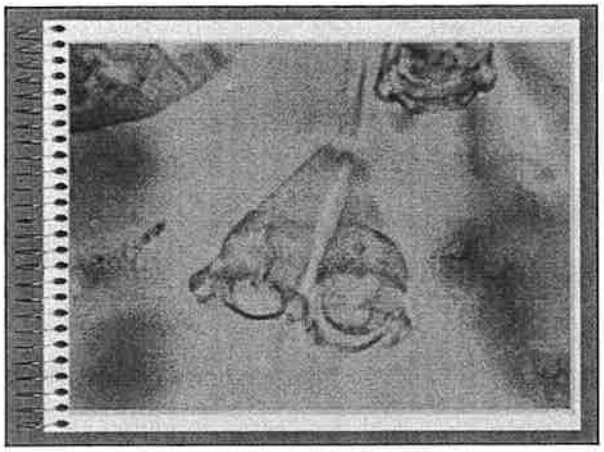
245

Stalked Ciliates



A Vorticella
B Carchesium
C Zoothanmium
D Opercularia
E Epistylis

246



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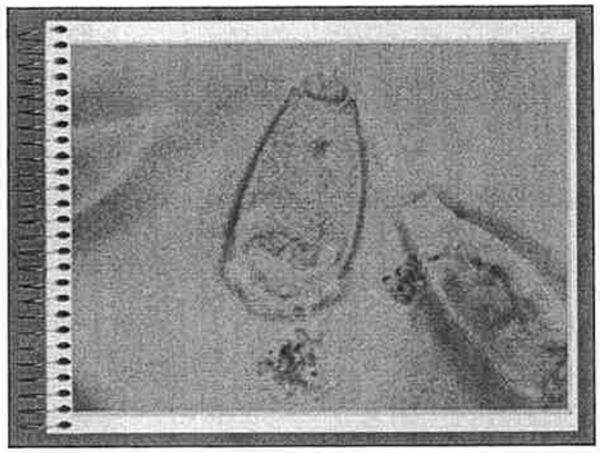

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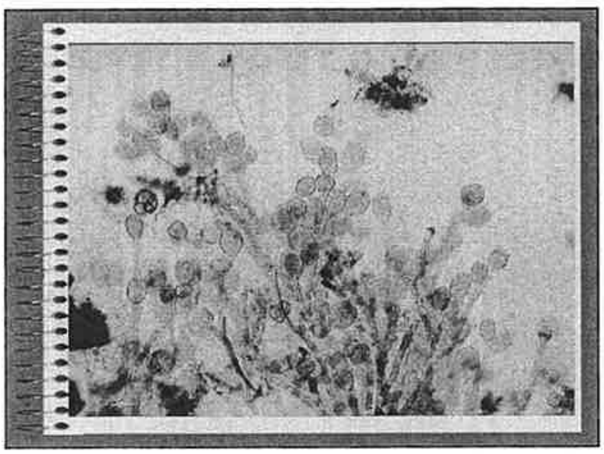

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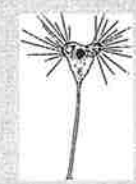
Suctoria

- Carnivorous protozoa
- Has hollow tentacles
- Feeds on small protozoa and bacteria
- Remains motionless
- Little energy exerted



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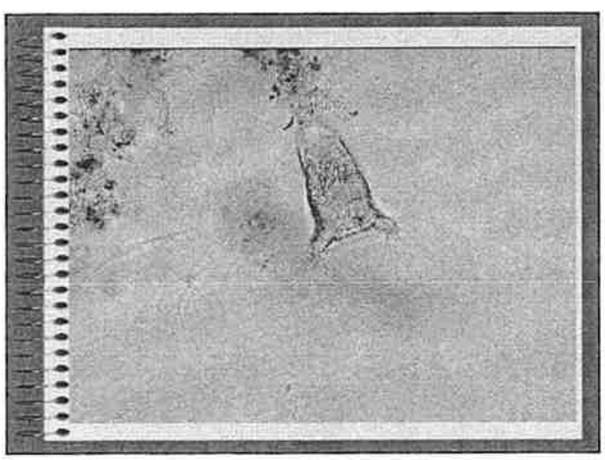

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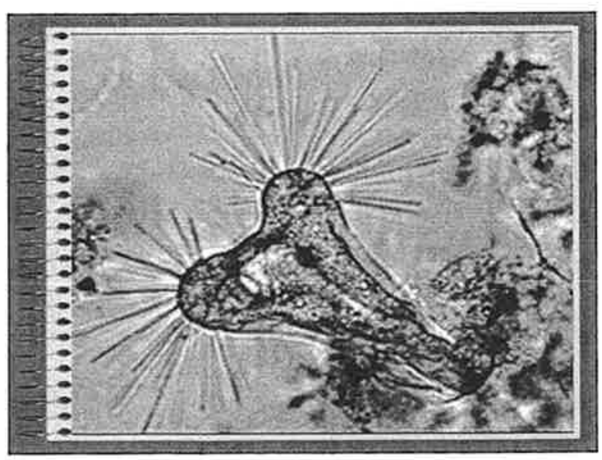

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Metazoa

As with the protozoans, we use these Metazoans to indicate process stability and age.

- Rotifer
- Nematode
- Copepod
- Water mites
- Ostracod (seed shrimp)
- Tardigrade (water bear)
- Water fleas (Ceriodaphnia)
- Annelid (bristle worm)

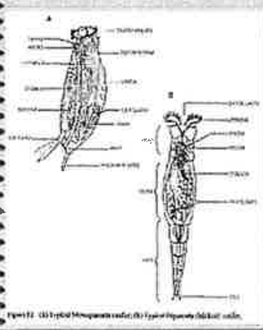
253

Rotifers

- Feed on bacteria and small protozoans
- Cilia on head resemble wheels
- Help keep bacterial population healthy
- Secrete mucus which aids in floc formation
- Strict aerobes
- Indicate process stability

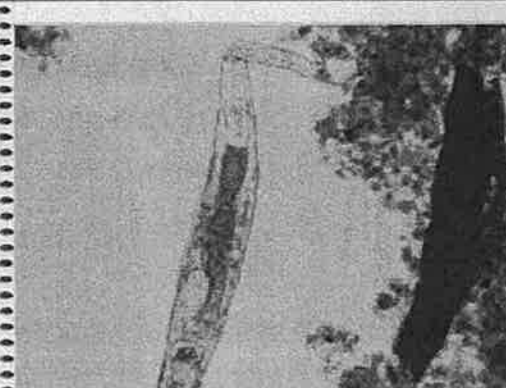
254

Rotifers



- The phylum Rotifera is divided into two classes:
  - Monogononta
  - Digononta
- Rotifers range in size from 40 to 500 microns and have an average life of 6 to 45 days

255



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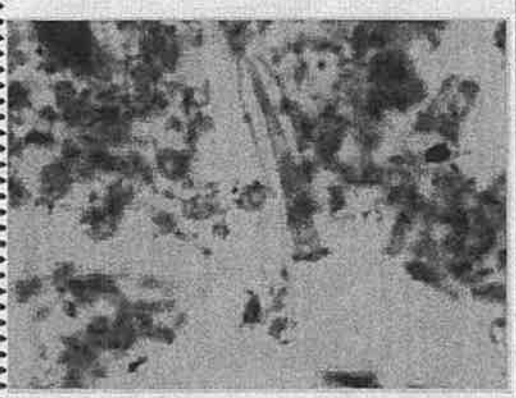

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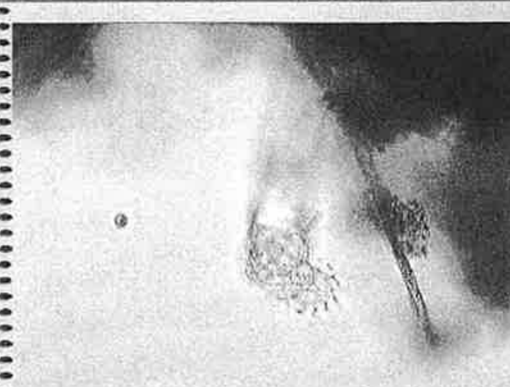
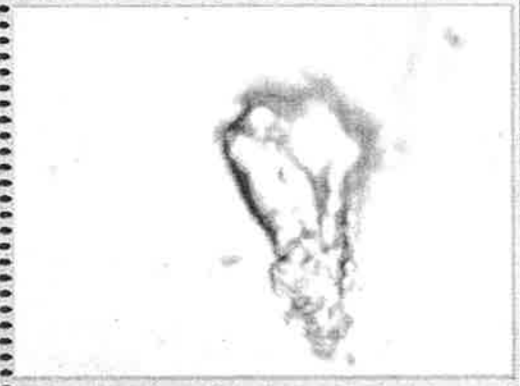


258

Nematodes

- Infest soils
- Common in trickling filters and RBC's
- Indicate old, over-oxidized sludge
- Will eat protozoans, rotifers and decaying plant and animal matter
- Whip-like motion may cause floc to break-up

259



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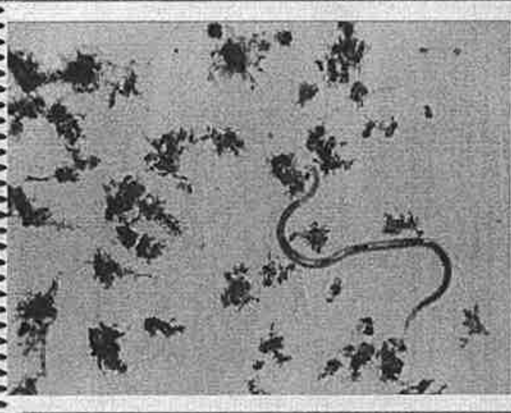


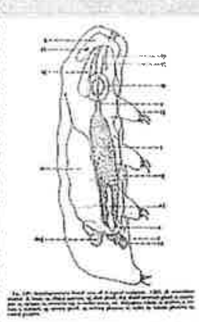
261

Tardigrades (Water Bears)

- Uncommon in most activated sludge systems
- Common in extended aeration systems
- Shed skin several times during lifetime
- Very sensitive to ammonia and other toxic substances
- Indicate a stable, well nitrified effluent

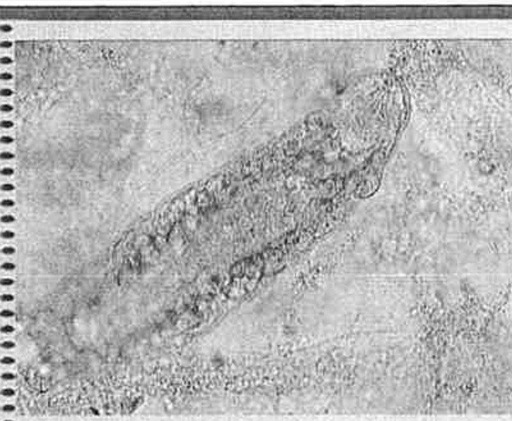
262

Tardigrades (Water Bears)



- Tardigrades are preyed upon by amoeboid protozoans, nematodes and each other.
- They have been discovered in lake bottoms 100 meters deep to mountain tops 6,000 meters high.

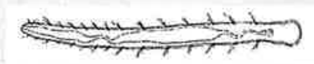
263



264

Annelids (Aeolosoma Worms)

- AKA Bristleworms
  - These aquatic earthworms feed on about anything including the MLSS solids used for secondary treatment. These can sometimes be seen as a red tint laying on the surface of the sludge blanket in a settleometer.



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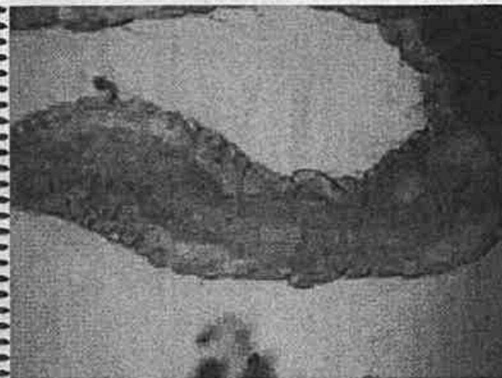


266

Other Metozoans

- Some other types of Metozoans are:
  - Ostracods
  - Copepods

Water Mites
Water Fleas

- These organisms are rare in activated sludge systems, but may be found in lagoon systems. If found in your system, they would indicate a stabile, non-toxic environment.

267

Other Metozoans

Copepod

Ostracod

Ceriodaphnia

268

How Do The Bacteria Eat?

- Adsorption
- Absorption
- Exocellular Digestion

269

Adsorption/Absorption

- Adsorption
  - Organisms contact and stick to food particles.
- Absorption
  - Dissolved nutrients are brought into the cell
  - Used for various growth and reproductive activities

270

Exocellular Digestion

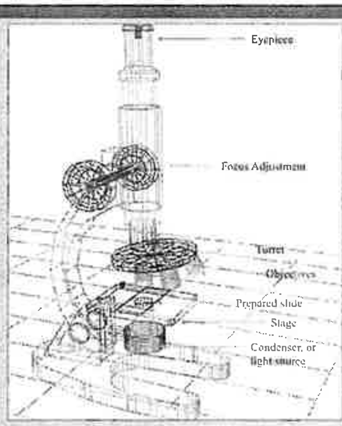
- Exocellular Digestion
  - Organisms secrete enzymes though cell walls
  - Enzymes begin dissolving the adsorped food
  - These enzymes aid in floc formation

271

Microscopes

Types of microscopes:
- Compound
- Dark field
- Phase Contrast
- Interference contrast
- Electron
- Fluorescent microscopy

272



273

Summary Q & A

- Who are the "workhorses of treatment"?
- We call protozoans "_____" organisms.
- What organism has hollow tentacles?
- What is the "wheeled animal"?

274

Summary Q & A

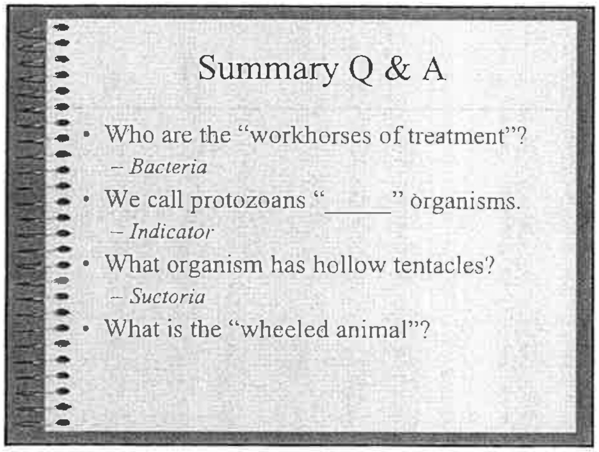
- Who are the "workhorses of treatment"?
  - *Bacteria*
- We call protozoans "_____" organisms.
- What organism has hollow tentacles?
- What is the "wheeled animal"?

275

Summary Q & A

- Who are the "workhorses of treatment"?
  - *Bacteria*
- We call protozoans "_____" organisms.
  - *Indicator*
- What organism has hollow tentacles?
- What is the "wheeled animal"?

276



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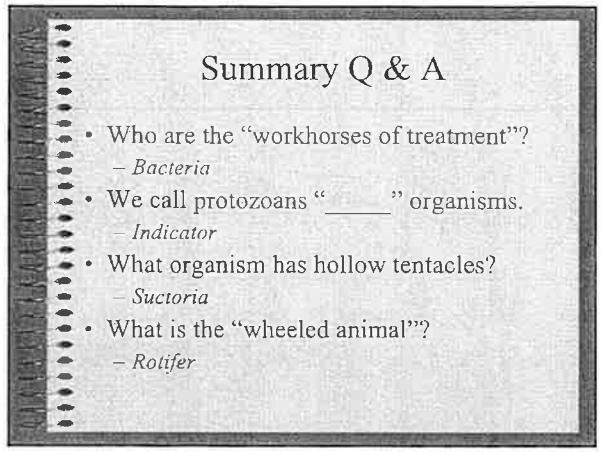

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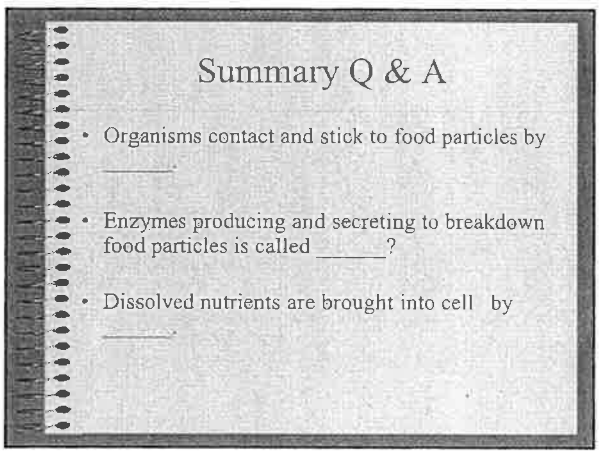

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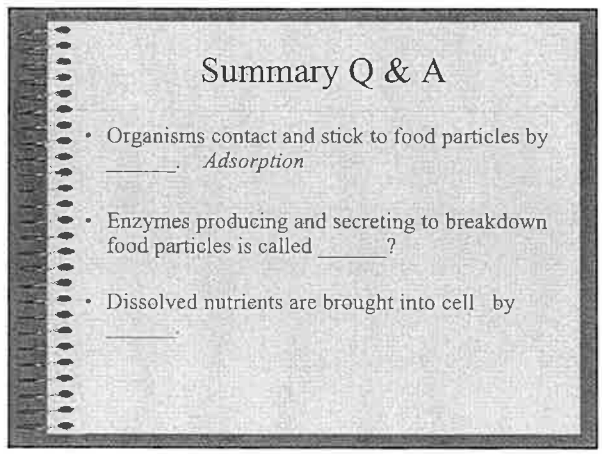

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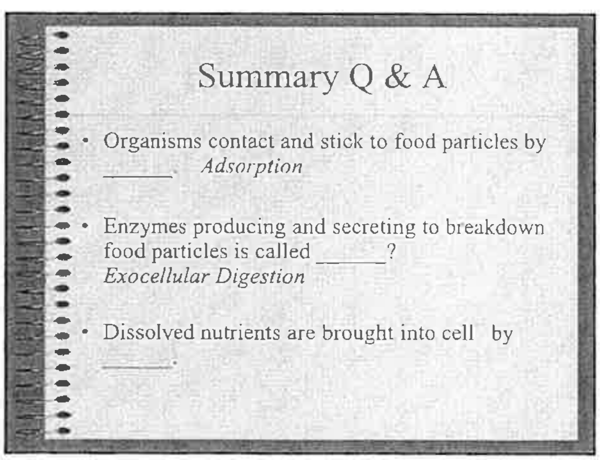

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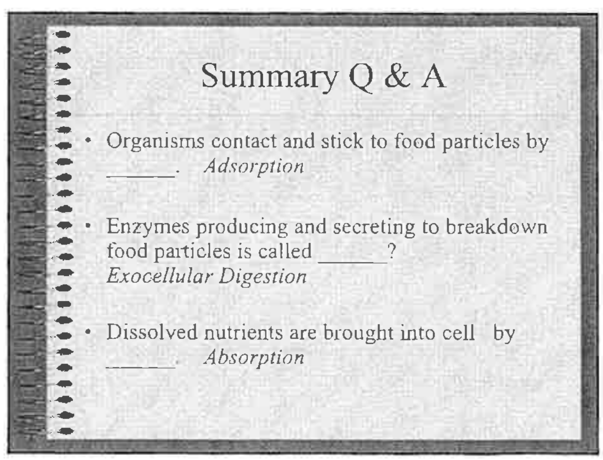

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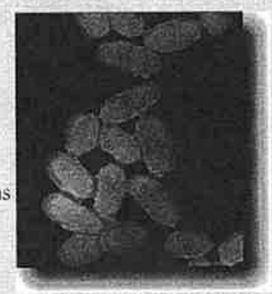
DISINFECTION

283

Disinfection

- Disinfection - destroys pathogenic organisms
- Sterilization - destroys all organisms



284

Purpose of Disinfection

- Protect human beings and other animals from disease-causing pathogens
- These pathogens will threaten the quality of drinking water supplies, water-contact recreation areas and shellfish-growing areas

285

Disinfection Agents

- Heat energy
- Radiant energy – UV
- Chemical Agents

286

Choosing a Disinfectant

- Process should be
  - economical
  - operationally practical
  - reliable
  - environmentally acceptable

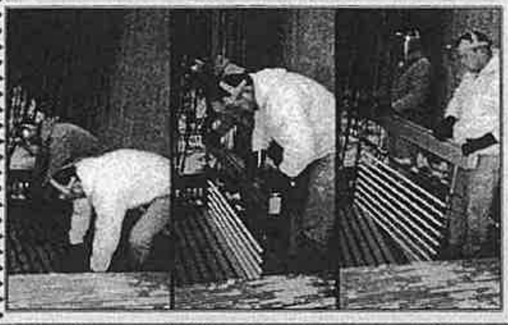
287

UV Disinfection

- High initial capital costs
- High O&M costs
- Must have low effluent TSS
- No residual to measure

288

UV equipment



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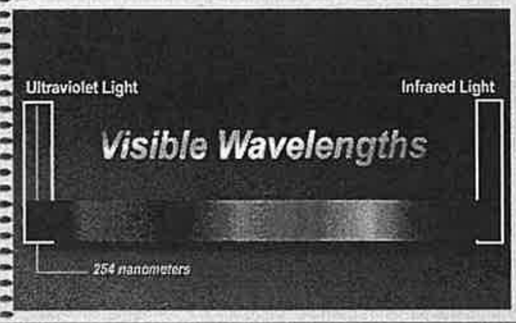
Light Spectrum



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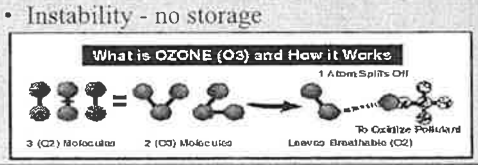
Chemical Agents

- Chlorine Gas or Liquid (Cl_2)
- Sodium or Calcium Hypochlorite
- Ozone (O_3)
- Chlorine Dioxide
- Paracetic Acid

291

Ozone

- Unable to measure residual
- Requires on-site generation
- Utilizes sensitive equipment which requires careful monitoring
- Instability - no storage



292

Chlorine Dioxide

- Used to replace both Chlorine and Sulfur Dioxide in wastewater
- No disinfection by products

293

Paracetic Acid

- Requires shorter contact time
- Replaces Chlorine and Sulfur Dioxide
- No disinfection by products
- Currently under review for NSF certification for water.
- St. Augustine WWTP a 5 MGD plant

294

Choosing Chlorination

- Relatively low dosages
- Simple feed and control procedures
- Low cost compared to other substances

295

Chlorine in the United States

- Low cost can be contributed to the large total production of chlorine in the U.S.
- Water and Wastewater facilities use about 5% of total chlorine produced

296

Chlorine Disadvantages

- Lasting toxic effect on aquatic life
- Toxic effect on human life
- Regulatory agencies placing tightening restrictions on storage and use (Risk management plan req'd for 2500 lbs)

297

Chlorine

- Liquid/gas chlorine (Cl_2) - pressurized containers that keep the chlorine in a liquid state
- Calcium hypochlorite [$Ca(OCL)_2$] - white powder
- Sodium hypochlorite (bleach) (NaOCL) - a pale yellow liquid

298

Physical and Chemical Properties

- Under normal atmospheric pressure at room temperature, chlorine is a yellow-green gas
- 2.5 times heavier than air
- Chlorine gas becomes a liquid at - 30° F
- Liquid to gas expansion ratio=460:1

299

Physical and Chemical Properties

- Dry gaseous or liquid chlorine (less than 150 mg/L moisture) is 100% available chlorine
- Calcium hypochlorite 65 to 75% available chlorine

300

Physical and Chemical Properties

- Sodium hypochlorite is normally a 15% solution or 15% available chlorine - each 100 mL contain 15 grams of available chlorine or 150 g/L or 150,000 mg/L of available chlorine

301

Hazard

- Chlorine gas/liquid - extremely hazardous substance
- Calcium hypochlorite and sodium hypochlorite - hazardous substance
- Disinfection agents kill living organisms and tissue

302

Chlorination Methods

- Gas chlorination
- Liquid chlorination
- Hypochlorination

303

Chlorination Effectiveness

- Chlorine concentration and type
- Effluent pH
- Effluent temperature
- Contact time
- Effluent suspended solids

304

Reactions with Water

- When chlorine gas/liquid, sodium hypochlorite or calcium hypochlorite are added to water, hypochlorous (HOCl) or hydrochloric (HCl) acid is formed
- Higher pH makes Cl2 less effective

305

The Effect of Temperature on Disinfection Efficiency

- Disinfection happens quicker at higher water temperatures.
- However, disinfection strength is reduced at higher temperatures.

306

Contact Time

- Contact time is in many cases more important than dose
- For basic disinfection the State of Florida requires a minimum total chlorine residual of 0.5 mg/L after 15 minutes contact time at Peak Hourly Flow

307

Effluent Suspended Solids

- Effluent suspended solids normally consist of small nonsettleable or colloidal solids or settleable solids which have been hydraulically discharged
- Flocs consist of bacteria - some of these bacteria may be in the fecal coliform group or pathogenic
- The disinfectant may not penetrate the floc particle and may result in incomplete disinfection

308

Chlorine Demand

- Reducing agents (H_2S)
- Organic material
- Inorganic metals - Fe and Mn
- Nitrite (5:1 ratio)
- All react with chlorine and reduce it to the chloride ion
- No chlorine residual is realized

309

Forms of Chlorine

- Cl_2 existing in forms of hypochlorous acid and hypochlorite ion are defined as *free available chlorine*

310

Reactions of Hypochlorous acid with Ammonia

NH_3 + HOCl > NH_2Cl (monochloramine) + H_20

NH_2Cl + HOCl > NHCl2 (dichloramine) + H_20

NHCl2 + HOCl > NCl3 (nitrogen trichloride) + H_20

311

Formation of Combined Chlorine

- Monochloramine (NH_2Cl)
- Dichloramine ($NHCl_2$)
- Trichloramine (NCl_3)

312

Chlorine Residual

- Free Chlorine - aqueous chlorine, hypochlorite ion and hypochlorous ion
- Combined Chlorine - compounds formed by reactions of hypochlorous acid and ammonia (chloramines)
- Total Chlorine - sum of free and combined chlorine

313

Chlorine Relationships

- Chlorine Residual =

  Chlorine Dose - Chlorine Demand

314

Chlorine Demand

- The amount of chlorine that is not available because of side reactions
- The difference between chlorine dosage and chlorine residual

315

Feed Rate and Dosage

- Feed Rate - lb/day of Cl_2 applied
- Chlorine dose - the amount of chlorine that is added to the effluent
- Chlorine – expressed in mg/L

316

Chlorine Dosage (mg/L)

- Chlorine Dosage (mg/L) =

$$\frac{\text{Feed Rate (lb/day)}}{\text{Eff Flow, MGD} \times 8.34\ \text{lb/gal}}$$

317

Typical Chlorine Dosages
Wastewater

- Trickling Filters - 3 to 10 mg/L
- Activated Sludge - 2 to 8 mg/L

318

Maximum Draw-Off Rates

150 lb cylinders - approximately 40 lbs/day

1-ton containers - approximately 400 lbs/day

- Temperature of remaining chlorine decreases as the rate of withdrawal increases
- When temperature of chlorine is low enough it will not evaporate

319

Chlorine Use Limit

- 40 lb/day from each 150-lb cylinder
- 400 lb/day from each 1-ton container
- Temperature of remaining chlorine decreases as the rate of withdrawal increases
- When temperature of chlorine is low enough it will not evaporate

320

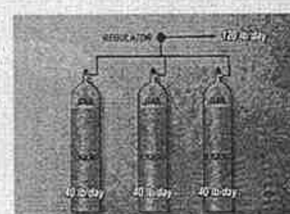
What happens when we try to feed more than these limits

CHLORINE ICING

321

Prevent Chlorine Icing

- When attempting to feed more than the allowable amount from any container, manifolding is required



322

Checks on Effectiveness

- Chlorine residual analysis - residual after a minimum contact time (i.e. for basic disinfection, 0.5 mg/L total chlorine residual after 15 minutes contact time at peak hourly flow)
- Concentration of Fecal Coliform Organisms
  - MPN -most probable number method
  - MF -membrane filter method

323

Effect on Treatment

- Disinfection
- Oxidizes solids further reducing BOD
- Oxidation of ammonia-N

324

A Look at Chlorine Equipment

325

Hoisting a 1-Ton Container

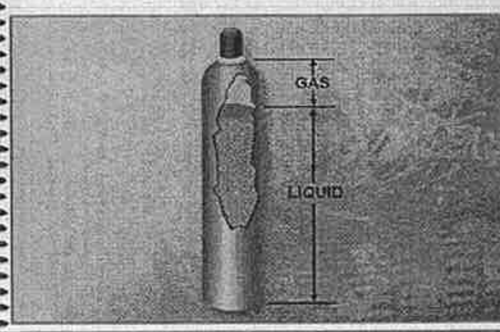
326

Chlorine Cylinders

- Fusible Plugs—designed to melt at 158-165 deg F.
- 6 Plugs on a ton cylinder
- 1 on a 150 lb cylinder

327

150 lb Chlorine Container



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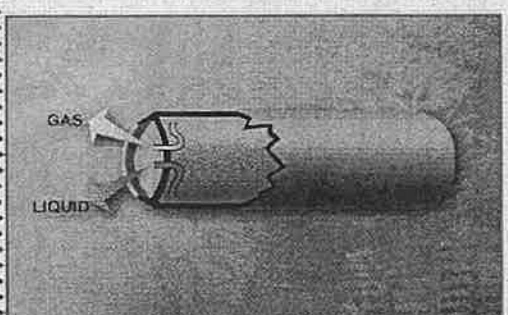
1-Ton Chlorine Container



329

Ton Container Storage

330

Chlorine Storage

- Storage is limited to 2500 pounds at one site
- If exceeded a Risk Management Plan is required

331

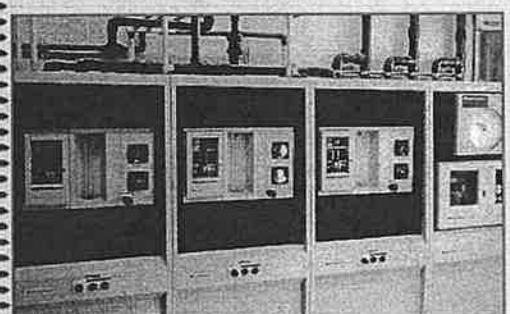
Manifolding More Than One

332

Chlorine Weights

333

Chlorine Feed Equipment



334

Disinfection Systems

Safety Hazards

335

Chlorine Safety

336

Detecting a Chlorine Leak

337

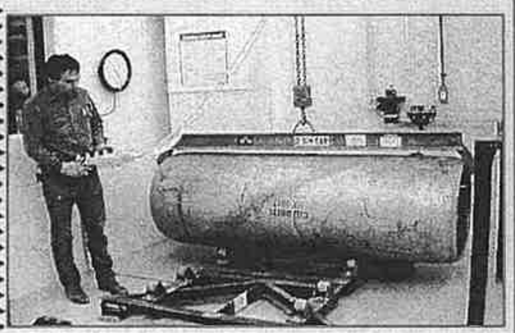
Effects of Chlorine on Humans

- Chlorine Concentrations

- 1 mg/l detectable by smell
  2-3 mg/L considered health haz
  25 mg/l immediate life hazard
- 1000 mg/l rapidly kills

338

Safe Handling of 1-Tons



339

Sludge Digestion

Principles of Operation

Troubleshooting and Correcting Problems

340

Purposes of Digestion

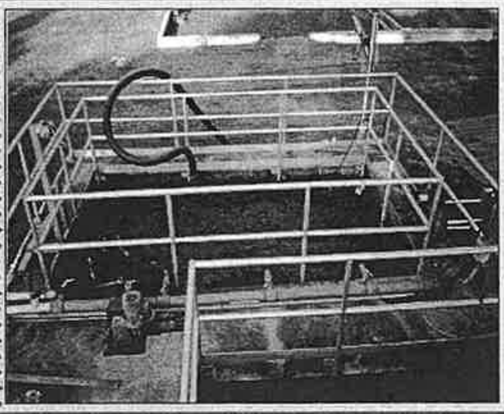
- Protect public health and the environment
  - Primary and secondary sludge both contain large amounts of biodegradable material, which must be stabilized before final disposal.
  - Digestion stabilizes biodegradable solids concentrated from wastewater.

341

Purposes of Digestion

- Protect public health and the environment *(continued)*
  - Reduces possibility of sludge becoming a food source and breeding ground for disease-causing insects and rodents (vectors).
  - Makes sludge relatively inert, reduces odor and bacteria.

342



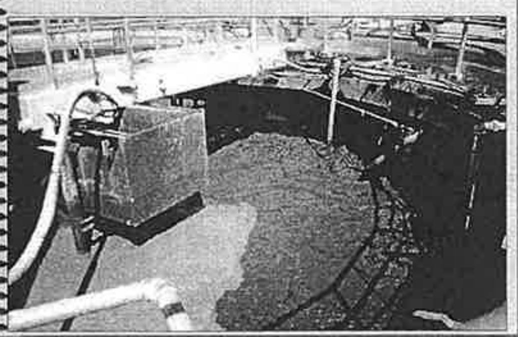
343

Purposes of Digestion

- Reduces cost of disposal
  - Digestion reduces volume and weight of sludge

344

Aerobic Sludge Digestion



345

Aerobic Sludge Digestion

- Operates under Endogenous Respiration principle, similar to extended aeration.
- Sludge is aerated until volatile suspended solids are reduced to stable level, readily dewaters and does not create nuisance odors.
- "Digests" waste activated sludge, primary sludge and clarifier skimmings.

346

Aerobic Sludge Digestion

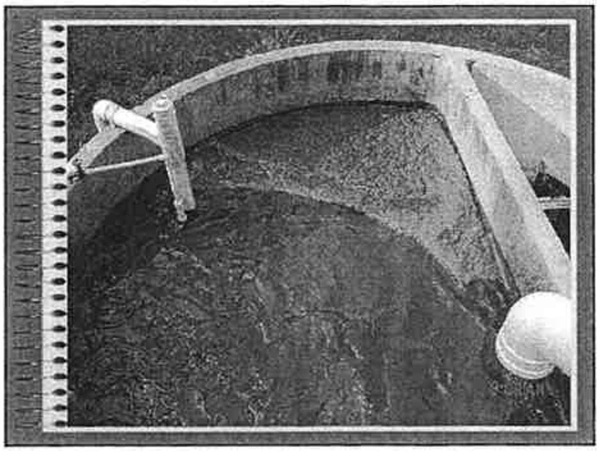
- Most common method of sludge digestion in Florida
- High Operating Costs (Energy)
- Easy operation
- No special training required by operators
- Covered in colder climates (Keep heat in)

347

Aerobic Sludge Digestion

- Supernating / Decanting
  - Aeration is ceased, sludge allowed to settle
  - Clear liquid (supernate) is drawn off, sent to aeration tank or head of plant
  - Aeration is restarted
  - Waste more sludge
  - Repeat process until sludge will not settle then haul sludge

348



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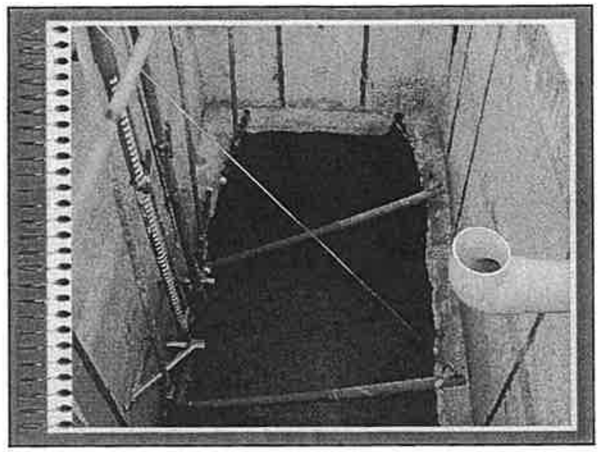


350

Aerobic Sludge Digestion

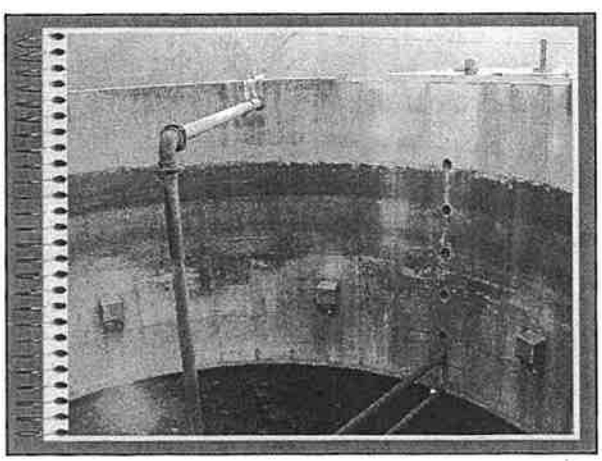
- Operational Controls
  - – DO should be maintained at 1.0 to 2.0 mg/L
  - – pH should be around 7.0
  - – Monitor waste sludge flow and digested sludge withdrawal rates
  - – Reduce aeration after sludge is withdrawn to prevent over aeration that leads to foaming

351

Aerobic Sludge Digestion

- Operational Concerns
  - – Supernatant is usually high in nitrate.
    - Return aerobic digester supernatant during day time flow
  - – A drop in digester pH usually indicates an increase in nitrification.
  - – May be accompanied by large amounts of foaming and high DO levels.
    - Try reducing DO in digester, and/or add lime or sodium hydroxide to raise pH.

352



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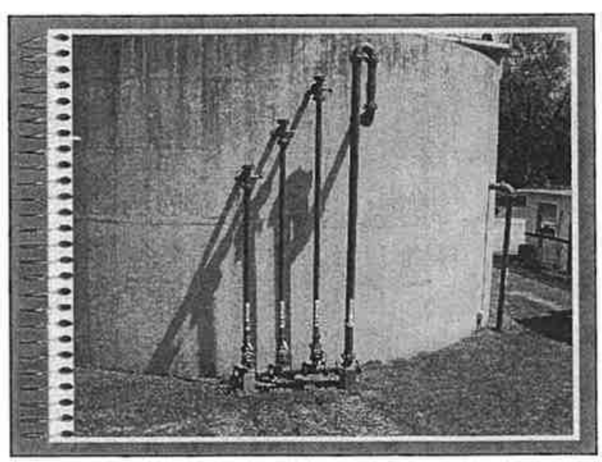

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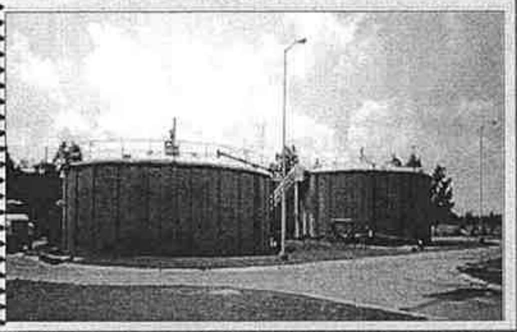
Anaerobic Sludge Digestion



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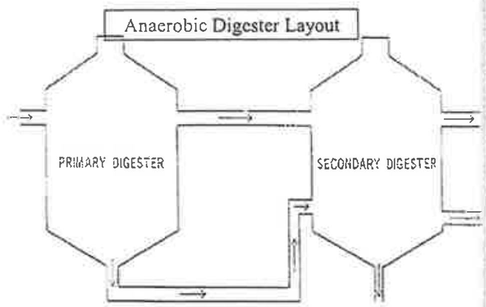

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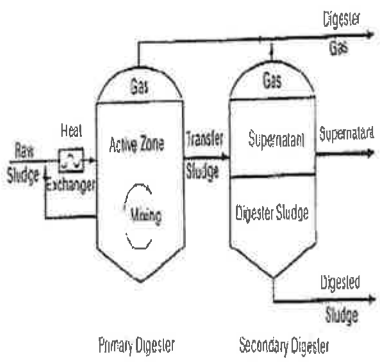

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Anaerobic Sludge Digestion

A multistage process

- Anaerobic digestion is accomplished in two stages …

358

Stage One

- Complex organics, cellulose, proteins and lipids are broken down into soluble (liquid) forms.
- These forms include organic fatty acids, alcohols, carbon dioxide and ammonia.

359

Stage One

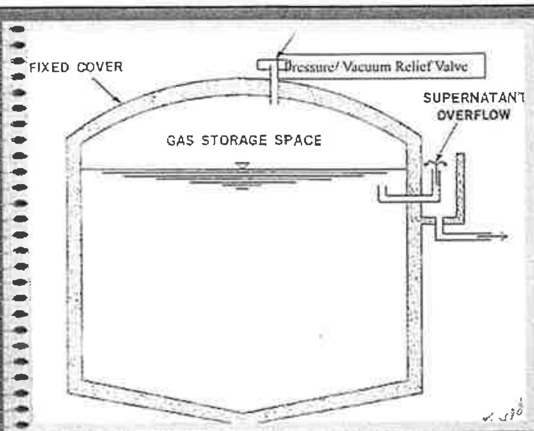
- Products of the first stage are converted to acetic acid, propionic acid, hydrogen, carbon dioxide and other organic acids.
- Microorganisms responsible for these conversions are referred to as acid formers (acetogenic bacteria).
- Acid formation phase

360

Stage Two

- Two groups of methane-forming bacteria begin work.
  - First group converts hydrogen and carbon dioxide to methane.
  - Second group converts acetate to methane and bicarbonate.
  - Methane formation phase

361



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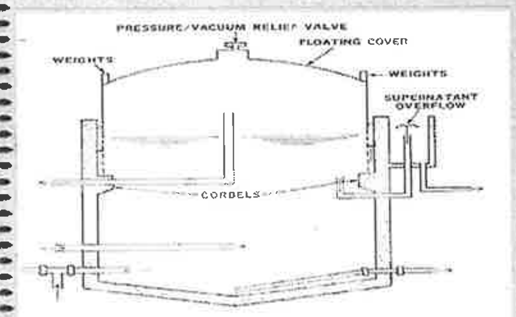
Fixed Cover Anaerobic Digester

363

Floating Cover Digester



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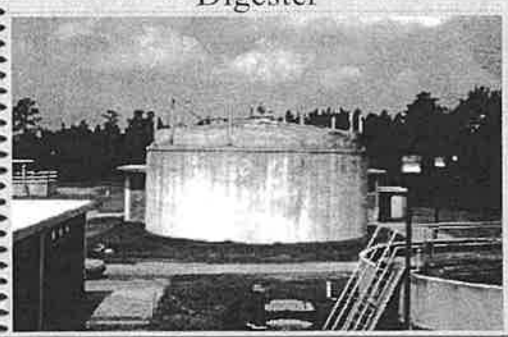
Floating Cover Anaerobic Digester



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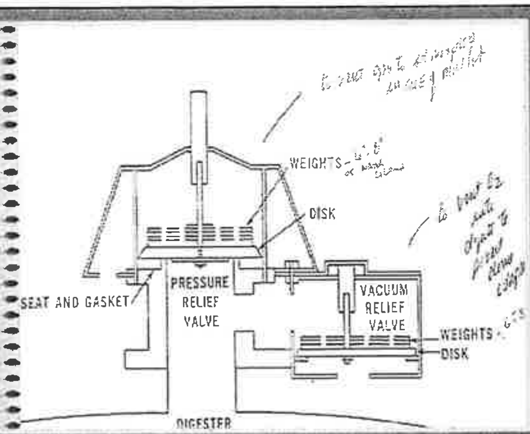

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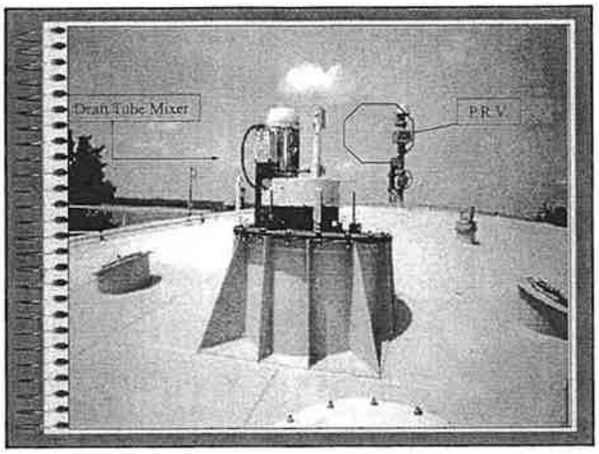

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Anaerobic Sludge Digestion

- Digester Mixing
  - Mixing serves three purposes:
    - Keeps solids in suspension
    - Keeps grit from accumulating and scum layer from forming
    - Keeps sludge temperature uniform
    - Mesophlic 85-105 Fahrenheit
    - Thermophlic 110-125 Fahrenheit

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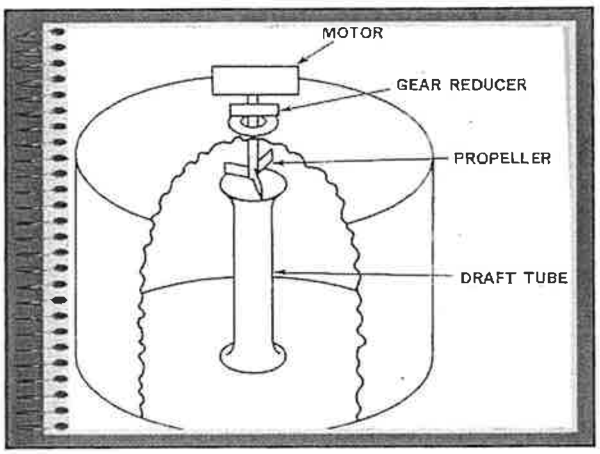

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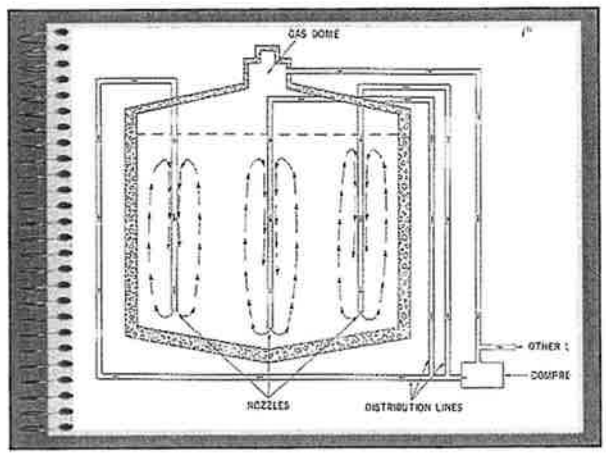

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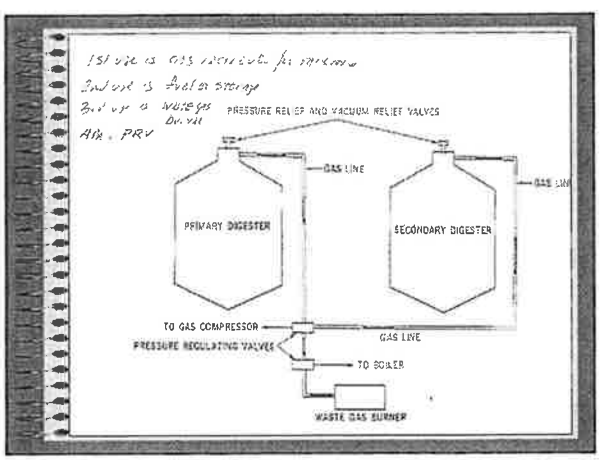

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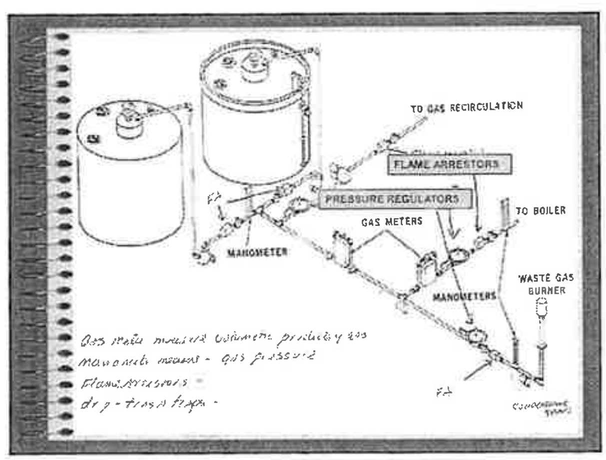

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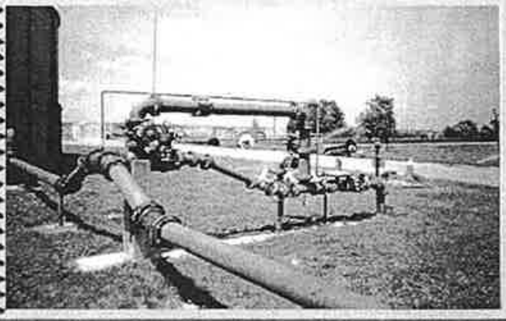
Methane Gas Piping



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Methane Gas Piping

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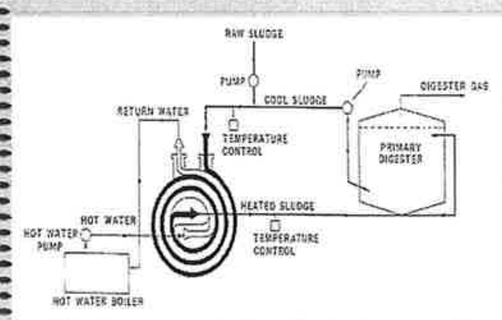
Methane Condensate Trap

375

Digester Sludge Heating



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Sludge Heat Exchanger

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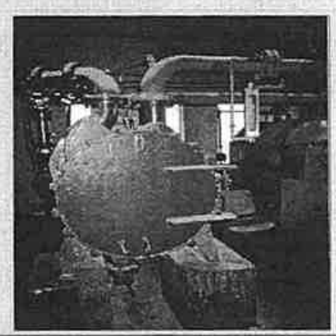
Sludge Heat Exchanger



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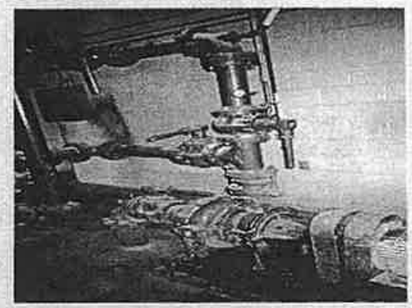
Sludge Recirculating Pump



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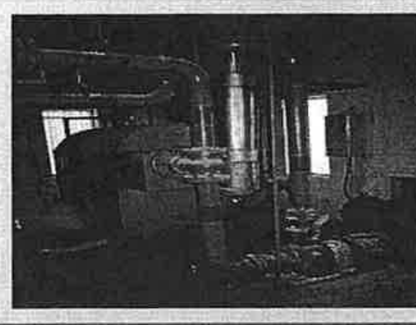
Methane-Fueled Boiler



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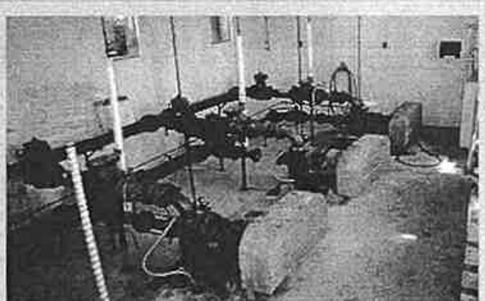
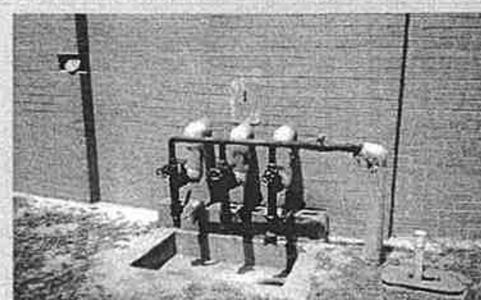
Digester Sludge Transfer Pumps



381

Sludge and Supernatant Ports



382

Anaerobic Sludge Digestion

- Operational Controls
  - Never change digester temperature more than one degree per day.
  - Digester gas is normally 70% methane and 30% carbon dioxide.
- Digester gas and oxygen is ***very*** explosive!!!

383

Anaerobic Sludge Digestion

- Volatile acid/Alkalinity ratio is key to operation
  - When VA/Alk ratio gets out of balance, upset (sour) digester occurs.
  - When VA/Alk ratio rises, digester gas may be unburnable.
  - When VA/Alk ratio finally gets too high, pH begins to drop.
  - If pH is only process control tool used, digester can sour before operator is aware.

384

Anaerobic Sludge Digestion

- Volatile acid/alkalinity ratio
  - 0.1:1 - considered good balance
  - 0.3:1 - needs attention, keep mixing slow feeding
  - 0.5:1 - stop feeding, keep mixing, add some seed sludge
  - 0.8:1 - gas unburnable, pH drops. Stop feeding, keep mixing, add alkalinity
  - 1.0:1- Too late!

385

Anaerobic Sludge Digestion

- Sour Digester Recovery
  - When digester becomes sour, several methods can be used to recover
    - Seed sludge from another digester can be used
    - Lime or soda ash can be added to raise pH

386

Anaerobic Sludge Digestion

- Digester Supernatant
  - Anaerobic digester supernatant is usually high in ammonia (NH_3) and BOD
  - Return anaerobic digester supernatant to head of plant during low flow periods

387

Rules

- In Florida, biosolids must meet either class A or B limits, as per EPA 40 cfr Part 503 and FDEP 62-640
- Must meet Pathogen Reduction requirements and Vector Attraction Reduction requirements
- Three methods to meet Pathogen limits, 10 ways to meet Vector Attraction Reduction limits

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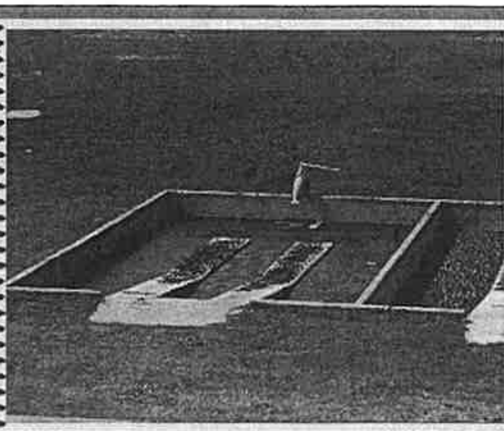

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Pathogens and Vectors

- Fecal Coliform is the pathogen indicator
- Vectors are described as flies, mosquitoes, rats and other disease carrying organisms.
- All wastewater plants are considered generators of biosolids.

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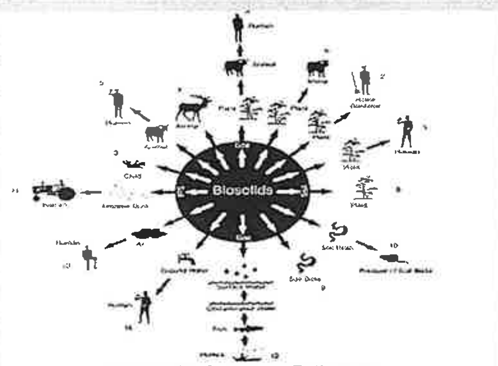


Biosolids Exposure Pathways

391

Sludge Analysis

- All plants must also perform sludge analysis testing at least annually.
- This includes metals testing, nitrogen, phosphorus, potassium, total solids and pH tests

392

Florida Department of Environmental Protection

Rules

393

Objective

- Overview of DEP Rules for Domestic Wastewater
- Rules of Concern for Certified Operators

394

Florida Administrative Code

- Chapter 62-4 - Permits
- Chapter 62-302 - Surface Water Quality Standards
- Chapter 62-600 - Domestic Wastewater Facilities

395

Florida Administrative Code

- Chapter 62-601 - Domestic WWTP Monitoring
- Chapter 62-602 - Drinking Water and Domestic Wastewater Treatment Plant Operators
- Chapter 62-604 - Collection Systems and Transmission Facilities

396

Florida Administrative Code

- Chapter 62-610 - Reuse of Reclaimed Water and Land Application
- Chapter 62-611 - Wetlands Application
- Chapter 62-620 - Wastewater Facility Permitting

397

Florida Administrative Code

- Chapter 62-640 - Domestic Wastewater Bio-Solids
- Chapter 62-650 - Water Quality Based Effluent Limitations
- Chapter 62-699 - Treatment Plant Classification and Staffing

398

Chapter 62-4

Permits

- General Prohibition
  - Facility shall not be operated, maintained, constructed, expanded, or modified without the appropriate DEP permit
- Procedure to Obtain Permits
  - Application shall be certified by a Florida Professional Engineer
  - Permit fees
    - Collection System Construction
    - WWTF Operation
    - Modifications (Revision)

399

Chapter 62-4

Permits

- Surveillance Fees for Surface Water Discharge
  - Annual fee due by January 15
- Permit Application Renewals
  - At least 180 days before expiration of current permit
- Mixing Zones
  - Limited, defined area allows some relief for effluent limits
    - Calculated by dilution

400

Chapter 62-302

Surface Water Quality Standards

- Classification of Surface Waters
  - Class I - Potable water supplies
    - Lake Okeechobee, Hillsborough River, Upper St. Johns River
  - Class II - Shellfish propagation or harvesting
    - Indian River, Matanzas River, Tampa Bay
  - Class III - Recreation, propagation of a healthy, well-balanced population of fish and wildlife
    - Most other surface waters

401

Chapter 62-302

Surface Water Quality Standards

- Outstanding Florida Waters, National Resource Waters
  - Receives highest protection
    - Surface waters in National Parks, Preserves, Memorials, Wildlife refuges and Wilderness Areas
      - Everglades National Park, Caloosahatchee Wildlife Refuge, Suwannee River
- Criteria for Surface Water Quality Classifications
  - Table of water quality limits

402

Chapter 62-600
Domestic Wastewater Facilities

- Definitions
  - General terms
  - Common parameters
  - Facility types
- Design Requirements
  - Fenced
  - Easy, dry, safe access for obtaining samples
- Planning for Expansion
  - Capacity Analysis Report
    - Must have accurate flow measurements

403

Chapter 62-600
Domestic Wastewater Facilities

- Operation and Maintenance Requirements
  - Operation by a certified operator
  - Equipment shall be maintained so as to function as intended
  - Permittee shall provide operating data to DEP
  - Permit, drawings, O&M manual and operating data shall be kept available for use by plant operators and inspection by DEP

404

Chapter 62-600
Domestic Wastewater Facilities

- Treatment Standards
  - Secondary/Advanced Treatment
    - Minimum treatment: 20mg/L $CBOD_5$ and 20 mg/L TSS
- Disinfection
  - Concentration and contact time at peak hourly flow
    - Minimum contact time 15 minutes at peak hourly flow
    - Minimum concentration
      - Basic disinfection - 0.5 mg/L
      - High-level disinfection - 1.0 mg/L, additional TSS control
      - 200 An. Avg Fecal 800 max sample

405

Chapter 62-600
Domestic Wastewater Facilities

- Operation and Maintenance Manual
  - Must be on-site and current
  - Provide the operator with information and description regarding design, operation and maintenance
  - Revise to reflect any facility alterations or reflect experience resulting from facility operation

406

Chapter 62-600
Domestic Wastewater Facilities

- O & M Performance Report
  - Included with new permit application
  - Evaluate physical condition and identify deficiencies
  - Prepared by engineer, operator and owner

407

Chapter 62-600
Domestic Wastewater Facilities

- Reporting, Compliance and Enforcement
  - Violations
    - Release or disposal without proper permit
    - Failure to maintain equipment
    - Planned bypassing of critical components without DEP notification
    - Submission of misleading, false or inaccurate info either knowingly or through neglect
    - Owner shall not allow or encourage operator to violate rules

408

Chapter 62-601
Domestic WWTP Monitoring

- Definitions
  - Lead or chief operator
- General Requirements
  - Submit reports by 28th of month for previous month

409

Chapter 62-601
Domestic WWTP Monitoring

- Sampling and Testing Methods
  - Methods must be approved by DEP and EPA
    - Field testing, sample collection and preservation, and laboratory testing
  - Laboratory must be certified by DOH for specified test
  - On-site tests may be run under direction of certified operator

410

Chapter 62-601
Domestic WWTP Monitoring

- Sampling Schedules, Locations, Methodology
  - Minimum schedule for sampling – Table
  - Grab samples, composite samples
  - Flow-proportioned samples taken @ hourly intervals

411

Chapter 62-602
Drinking Water and Domestic Wastewater Treatment Plant Operators

- Qualifications for Operator License
  - Class D
    - High school diploma or equivalent
    - Minimum 3 months experience or complete training course and 1 hour experience
  - Class C, B and A
    - High school diploma or equivalent
    - Minimum 1 year, 3 year, 5 year experience
    - Complete required training course
    - Must have previous level license for A and B

412

Chapter 62-602
Treatment Plant Operators

- Qualifications for Operator License *(continued)*
  - Must meet qualifications and submit 90 days prior to requested exam date
  - Exam (70% or better passing grade)
  - Experience (2080 hours = 1 year)
  - Training courses - residence or correspondence

413

Chapter 62-602
Treatment Plant Operators

- *New* License Fees
  - A, B, or C level: $100
    - $50 application fee (non-refundable)
    - $50 license fee
    - $75 renewal fee
  - D level: $50
    - $25 application fee (non-refundable)
    - $25 license fee
    - $50 renewal fee

414

Chapter 62-602
Treatment Plant Operators

- Renewal of Operator Licenses
  - Requires renewal every two years
  - Renewal notices sent to last known address
    - Failure to receive notice does not excuse licensee from timely renewal

415

Chapter 62-602
Treatment Plant Operators

- Renewal of Operator Licenses *(continued)*
  - CEU (Continuing Education Unit) documentation
    - Required for next renewal cycle
    - One CEU equals 10 hours of continuing education contact time
    - Two CEUs required for Class A or B renewal
    - One CEU required for Class C renewal
    - 0.5 CEU for Class D

416

Chapter 62-602
Treatment Plant Operators

- CEU documentation for double license
  - A portion of the CEUs must apply to each type of license
    - must be identified on the certificate
    - table of license levels and hours needed for double license

417

Chapter 62-602
Treatment Plant Operators

- Suspension and Revocation of Licenses
  - Suspension for up to 2 years
    - Submitting false data in license application
    - Cheating on exam
    - Incompetence in treatment plant operation
    - No re-test required to resume license

418

Chapter 62-602
Treatment Plant Operators

- Suspension and Revocation of Licenses *(continued)*
  - Permanent revocation
    - Fraud in the submission of documents for license
    - Falsified or misrepresented reports, logs, lab sheets
    - Negligence in treatment plant operation
    - Suspension of license more than twice
    - Short term revocation - complete course and take exam

419

Chapter 62-602
Treatment Plant Operators

- Duties of Operators
  - Submit required reports to permittee
  - Report to permittee and Department within 24 hours any:
    - Unsafe treatment plant operation
    - Unpermitted discharge
    - Major interruption in service

420

Chapter 62-602
Treatment Plant Operators

- Duties of Operators *(continued)*
  - Perform responsible and effective on-site management
  - Maintain operation and maintenance logs on site
    - Hard bound books with consecutive page numbers
    - Contain a minimum of three months of data
    - Partial electronic logging acceptable if approved by DEP

421

Chapter 62-602
Treatment Plant Operators

- Duties of Operators *(continued)*
  - O & M logs shall include the following:
    - Identification of plant
    - Signature and license number of operator
    - Signature of the persons making any entries
    - Date and time in and out
    - Specific operation and maintenance activities
    - Tests performed, samples taken (unless documented on lab sheet) and repairs made
    - Preventive maintenance and repair requests

422

Chapter 62-604
Collection Systems and Transmission Facilities

- Prohibitions
  - Deliberate introduction of stormwater
  - Acceptance of discharges without pretreatment
- Operation and Maintenance
  - Provide uninterrupted service
- Abnormal Events
  - Verbal notification within 24 hours, written report within 72 hours

423

Chapter 62-610
Reuse of Reclaimed Water and Land Application

- Rapid-Rate Land Application Systems
  - Rapid infiltration basins, absorption fields (percolation ponds, drainfields)
  - Effluent Nitrate limit = 12 mg/L
  - maintain ponds to control vegetation

424

Chapter 62-610
Reclaimed Water and Land App.

- Slow-Rate Land Application Systems - *Public Access*
  - Golf course, residential and food crop irrigation
  - TSS limit = 5 mg/L
  - 15 days for food crops
- Slow-Rate Land Application Systems - *Restricted Public Access*
  - Spray irrigation (hay field)
  - TSS limit = 10 mg/L

425

Chapter 62-610
Reclaimed Water and Land App.

- Ground Water Recharge and Indirect Potable Reuse
  - Injection wells
  - Surface water augmentation for public water supply
- Overland Flow Systems
  - Sod farms, fodder crops
- Industrial Uses
  - Cooling water, wash-water or process water

426

Chapter 62-611
Wetlands Application

- Discharge Limits
  - Treatment wetland
    - Secondary treatment with nitrification
  - Receiving wetland
    - High level treatment 5-5-3-1
  - Total ammonia < 2 mg/L

427

Chapter 62-611
Wetlands Application

- Man-made Wetlands
  - Exempted from wetlands rule
  - Discharge must meet requirements
- Monitoring Requirements
  - Baseline monitoring
  - Nutrient monitoring
  - May request modification after 3 years

428

Chapter 62-620
Wastewater Facility Permitting

- General Prohibitions
  - Must have a permit to operate, construct or modify
- Renewals
  - Application must be submitted 180 days prior to expiration
- Recordkeeping
  - Maintain all records on site for 3 years

429

Chapter 62-620
Wastewater Facility Permitting

- Signatories to Permit Applications and Reports
  - Corporate officer
  - General partner or proprietor
  - Executive officer (city manager, public works director)
  - Authorized representative (must be documented)

430

Chapter 62-620
Wastewater Facility Permitting

- General Conditions for All Permits
  - All results must be reported and included in calculations
  - Must use certified laboratory for all tests
    - On-site tests for DO, Temperature, Turbidity, pH and Cl2 may be performed under the direction of a certified operator

431

Chapter 62-640
Domestic Wastewater Bio-Solids

- Provisions adopted from 40 CFR Part 503
- Applicability
  - domestic wastewater treatment facilities
  - residuals management facilities
  - septage management facilities
    - >10,000 gpd monthly average or 20,000 gpd in a single day

432

Chapter 62-640

Domestic Wastewater Bio-solids

- Permit Requirements
  - Valid permit and approved agricultural use plan
  - Responsibility for treatment and proper use
    - Permittee - unless applier has legally agreed
- Nutrient Management Plan (NMP)
  - Shall consider nutrient content of all residuals, reclaimed water, and other sources

433

Chapter 62-640

Domestic Wastewater Bio-Solids

- Pathogen Reduction - Class A
  - Specific density requirements for fecal coliform or Salmonella in addition to one of six alternatives
  - Six alternatives
    - Examples: Thermal treatment, High pH - high temperature
- Pathogen Reduction - Class B
  - Three alternatives
    - Examples: Fecal coliform density, Process to Significantly Reduce Pathogens (PSRP), Equivalent PSRP

434

Chapter 62-640

Domestic Wastewater Bio-Solids

- Vector Attraction Reduction
  - Ten options
    - Examples: Volatile solids reduction, SOUR test, lime addition, moisture reduction, soil injection or soil incorporation
- Monthly Distribution and Marketing Report
  - Class AA only
  - Sent to Tallahassee
  - Residuals monitoring report still applies

435

Chapter 62-640

Domestic Wastewater Bio-Solids

- New Site
  - NMP along with permit application
  - Aerial maps
  - Soil conservation information
  - Pending site inspection
  - Liability agreement
  - Other pertinent information may be required (i.e. setbacks)
  - Cumulative metals loading rates
  - Site life determination
  - Nitrogen loading rate, Plant Available Nitrogen (PAN) determination, etc.

436

Chapter 62-640

Domestic Wastewater Bio-Solids

- Site Requirements
  - Inspection
    - Piezometer
      - At least 2" in diameter, 36" deep and 24" above ground
      - Located at area where it is easy to see
      - Maintain water table readings ready for inspection
    - Aerial Maps
      - Scale zones
      - Crop type
      - Area of zone
      - Zone ID

437

Chapter 62-640

Domestic Wastewater Residuals

- Site Requirements
  - Setback Distances
    - To buildings - 300 feet if occupied
    - To water bodies - 1000 feet to Class I, 200 feet all other
    - To potable water wells - private is 300 feet, public is 500 feet

438

Chapter 62-640

Domestic Wastewater Residuals

- Site Requirements
  - Soil/residuals mixture must be pH 5.0 or greater
  - Runoff prevention
    - No application during rain that causes runoff or when soil is saturated
    - Topographic grades less than 8%
    - Topographic grades greater than 2% require a conservation plan. Contact the Soil Conservation Service at (904) 328-6522

439

Chapter 62-640

Domestic Wastewater Residuals

440

Chapter 62-650

Water Quality Based Effluent Limitations

- WQBEL Level I Process
  - Water body meets standards
- WQBEL Level II Process
  - Insufficient water quality data
  - Available assimilative capacity of water body is utilized

441

Chapter 62-699

Treatment Plant Classification and Staffing

- Classification and Staffing of Plants
  - Permittee shall employ certified operator as required

442

Chapter 62-699

Plant Classification and Staffing

- Additional Classification and Staffing Requirements
  - Operator shall be on call when plant is unattended
  - Daily checks shall be performed
  - Electric surveillance
  - Lead/chief operator shall be on duty each duty day

443

For More Information …

- www.dep.state.fl.us
  - For DEP Rules check side bar under Resources
- www.epa.gov
- contact your local district office:
  - Your Local District – Domestic Waste Section

444

Safety at WWTFs

445

Types of Hazards at the WWTF

- Physical injuries
- Infections/infectious diseases
- Confined space
- Oxygen deficiency
- Toxic or suffocating gases or vapors

446

Types of Hazards at the WWTF

... continued

- Explosive gas mixtures
- Electrical shock
- Noise
- Dusts, fumes, mists, gases, and vapors

447

Physical Injuries

Most common:
Cuts - Strains
Bruises - Sprains

Can be caused by improper lifting techniques or slippery surfaces

Falls from or into tanks, wet wells, or catwalks

448

Infections and Infectious Diseases

- General Definitions
  - Infection: The invasion of a host by an infectious microorganism.
  - Pathogenicity: The ability of an infectious agent to cause disease and injure the host.
  - Pathogenic organisms or "Pathogens": Bacteria, viruses, or cysts which can cause disease *(such as typhoid, cholera, dysentery)* in a host *(such as a human)*.

449

Infections and Infectious Diseases

- Personal hygiene is the best protection against the risk of infections and disease.
- *Types:* Typhoid fever, Dysentery, Hepatitis and Tetanus
- Immunization shots are a necessity against Tetanus, Polio, and Hepatitis B.

450

Infections and Infectious Diseases

- There are many "Modes of Transmission" of infectious agents:
  - *Person-to-person:* This is the most common mode. By direct person-to-person contact, coughing, or sneezing.
  - *Waterborne:* From consumption of contaminated water.
  - *Foodborne:* Food contaminated from unsanitary practices during production or preparation.

451

Infections and Infectious Diseases

- Modes of Transmission *(continued)*
  - *Airborne:* Transmission of biological aerosols generated by WWTFs or by spray irrigation of wastewater effluents.
  - *Vector-borne:* Transmission by arthropods (fleas, insects) or vertebrates (cats, dogs)
  - *Fomites:* Pathogens transmitted by nonliving objects or fomites (clothes, utensils, toys).

Reference summary chart of some diseases associated with wastewater environments.

452

Infections and Infectious Diseases

- Pathogenic Bacteria Infections Include:
  - *Salmonella spp*: Acute Gastroenteritis, Typhoid Fever, Paratyphoid Fever, Salmonellosis.
  - *Shigella spp*: Shigellosis (bacillary dysentery)
  - *Vibrio spp*: Asiatic Cholera
  - *Clostridium spp*: Tetanus

453

Infections and Infectious Diseases

- Pathogenic Bacteria Infections Include:
  - *Mycobacterium*: Tuberculosis
  - *Yersinia*: Acute Gastroenteritis
  - *Escherichia coli (E-coli)*: Usually considered nonpathogenic, several strains may cause Gastroenteritis.

454

Infections and Infectious Diseases

- **Personal Protection**
  - *Gloves* Always wear a good, heavy duty rubber glove when cleaning bar racks, weirs, or while conducting any other scrubbing duty. Be sure there are no holes in them. Always wear gloves if your hands may come in direct contact with wastewater or sludge.
  - *Footwear* If you have to walk in sewage, wear rubber boots. Rubber boots will not soak up sewage fluids.

455

Infections and Infectious Diseases

- Personal Protection *(continued)*
  - *Hygiene* If you smoke or break for a snack, clean your hands first. Be sure to use a disinfectant soap.
  - Spray your shoes with a disinfectant or change your shoes before going home. Don't mix your work clothes with the family wash, and wash them in hot water.

456

Infections and Infectious Diseases

- Safety At The Plant Site
  - *DO NOT* store your lunch in the same refrigerator as sludge or any other wastewater samples. Freezing will not kill viruses, *only extremely high heat.*
  - When cleaning with a high pressure water hose (hose with nozzle), wear a full face shield and apron to stop any splash back.

457

Infections and Infectious Diseases

- Safety At The Plant Site *(continued)*
  - While conducting lab work, or when wearing latex gloves while sampling, consider doubling or tripling the glove. Latex is laced with five micron channels, the HIV virus is .1 micron in size and Hepatitis B is 1.5 microns in size.

458

Infections and Infectious Diseases

- Safety At The Plant Site *(continued)*
  - Bandages covering wounds should be changed frequently.
  - You should always wear long pants when climbing on or around a WWTF.

459

Confined Space

- Space that is large enough and configured so that an employee can enter and perform assigned work.
- Space that has limited or restricted means for entry or exit.
- Space that is not designed for continuous employee occupancy.

460

Confined Space

Examples of Confined Spaces

- Tanks
- Vessels
- Storage Bins
- Hoppers
- Vaults
- Pits
- Manholes
- Lift Stations

461

Oxygen Deficiency

- Low oxygen levels may exist in poorly ventilated areas where gases, such as hydrogen sulfide, gasoline vapor, carbon dioxide and chorine, may be produced or accumulated.
- *Hydrogen Sulfide and Chlorine* collect in low places because they are heavier than air.
- The weight of a gas is indicated by its specific gravity as it is compared to an equal volume of air.

462

Oxygen Deficiency

- The specific gravity of air is 1.0.
- Therefore, any gas with a specific gravity of >1 will sink to low lying places.

(Methane rises out of manholes because it's specific gravity is < 1. Therefore, it is lighter than air.)

463

Chlorine Facts

- When changing chlorine cylinders or handling chlorine, ALWAYS do the following
  - Have a standby person present with a respirator available.
  - Remove the old lead washer from the pig-tail or chlorinator, use one new lead washer.
  - Have an emergency repair kit on-site and be familiar with how to use if BEFORE the need arises. Make sure the kit is complete and no tools or parts are missing.

464

Toxic or Suffocating Gases

- They originate from industrial waste dischargers, process chemicals, or decomposition of domestic wastewater.
- Become familiar with waste dischargers in your system.

465

Toxic or Harmful Chemicals

- Strong acids, bases, and liquid mercury are types of harmful chemicals that operators may encounter.
- All hazardous chemicals should be clearly labeled
- Health and safety data (MSDS) about the specific chemicals should be read before handling.

466

Explosive Gas Mixtures

- *Explosive Gases* develop in areas where air and methane, natural gas, manufactured fuel gas, hydrogen, or gasoline vapors mix.
  - Explosion-proof electrical equipment and fixtures should be used in these areas.
  - Explosions can be avoided by eliminating sources of ignition in these type areas. *(examples: influent/bar screen rooms, gas compressor areas)*

467

Explosive Gas Mixtures

- Also, adequate ventilation should be provided

***Note:* Methane and oxygen combined are highly explosive.**

Always use Non-Sparking tools when working around anaerobic digesters.

468

Electrical Shock

- *DO NOT* attempt electrical repairs unless you are qualified and know what you are doing.
- Ordinary 120 Volt electricity may be fatal.
- 12 Volts can cause injury.

469

Electrical Shock

- Any electrical system should be considered dangerous unless you know *for sure* it has been de-energized.
- Always use a lock-out tag-out procedure to prevent accidental re-energizing of power.

470

Noise

- Some WWTF equipment produce high noise levels. Ex: blowers
- Hearing protection devices should be used if you have to shout or cannot hear someone talking to you in a normal tone of voice.

471

Dust, Fumes, Mists, Gases, and Vapors

- The ideal way to control diseases from breathing air contaminated with harmful dusts, fumes, mists, gases, and vapors is to prevent the atmospheric contamination from occurring.
- This can be achieved through *engineering control measures*. It is not always economically feasible, therefore *respirators should be provided/used* in these atmospheres.

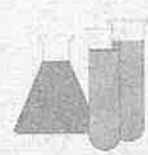
472

References

- Operation of Wastewater Treatment Plants California State University, Sacramento, Volume II, Third Edition 1998.
- Wastewater Microbiology, University of Florida, Gainesville, Gabriel Bitton, 1994.
- Wastewater Engineering Treatment, Disposal, and Reuse, Metcalf and Eddy, Inc., Third Edition, 1991.

473

Laboratory Procedures and Chemistry



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Agenda

- **Sample Collection**
  - Terminology
  - Procedures
- **Laboratory**
  - Safety
  - Terminology
  - Measurements

475

Sample Collection

- The result of any testing method can be no better than the sample on which it is performed.
- **Objective** - to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled to demonstrate compliance with regulatory requirements.

476

Sample Collection

- **Why?**
  - Used to control wastewater processes
    - Find problems before they become problems
    - Used for basic wastewater operations parameters
  - Used to monitor treatment effectiveness
    - Tests required by regulation
    - For determining effectiveness for budget issues

477

Sample Collection Terminology

- **Grab Sample** - a single sample collected at a particular time and place which represents the composition only at that time and place

- **Composite Sample** - a collection of individual samples obtained at regular intervals

478

Sample Collection Terminology

- **Flow Proportioned Sample** - a collection of individual samples obtained at regular intervals. Sample size based upon flow
- **Representative Sample** - a sample portion of material that is as nearly identical in content and consistency as possible to that in the larger body of material being sampled

479

Sample Collection Procedures

- **Most errors occur due to**
  - Improper sampling
  - Poor preservation
  - Lack of mixing during compositing and testing

480

Sample Collection Procedures

- **Proper sampling technique**
  - Have access to safe sampling location
  - Use clean and proper sampling equipment and containers
  - Collect a representative sample
    - Approved location and sample type (grab or composite)
    - Appropriate collection time and frequency

481

Sample Collection Procedures

- **Automatic samplers** - clean sample lines and verify proper programming
- **Sample containers & preservation**
  - Use type of container specified in method
  - Preserve as specified in method
  - Keep refrigeration ≤ 4 degrees C
  - Properly label all sample containers
  - Record sample collection time

482

Laboratory Safety

- Chemical hygiene plan
- Safety Data Sheets (SDSs)
- Blood borne pathogens
- Never pipet by mouth
- Always add acid to water
- PPE

483

Laboratory Safety

- **Corrosive Chemicals**
  - H_2SO_4 (Sulfuric Acid)
  - HNO_3 (Nitric Acid)
  - HCl (Hydrochloric Acid)
  - NaOH (Sodium Hydroxide)
  - KOH (Potassium Hydroxide)
  - Phenylarsine oxide

484

Laboratory Safety

- **Safety equipment in the laboratory**
  - Fume hood
  - Spill clean up kits
  - Safety eyewash and shower
  - Fire extinguisher
  - Fire blanket
  - First aid kit

485

486

Laboratory Terminology

- **Aliquot** - portion of a sample, usually an equally divided portion
- **Aseptic** - free from living germs, sterile
- **Buffer** - a solution or liquid that neutralizes acids or bases with minimal change in pH

487

Laboratory Terminology

- **Chain-of-Custody** - the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition
- **Compound** - a pure substance composed of two or more elements
- **Element** - a substance which cannot be separated into its parts

488

Laboratory Terminology

- **Gram Molecular Weight** - molecular weight of compound in grams
- **Meniscus** - the curved surface of a column of liquid in a small tube
- **Molar (M)** - solution consists of one gram molecular weight of a compound dissolved in enough water to make 1 liter

489

Laboratory Terminology

- **Molecular weight** - the sum of the atomic weights of the elements in a compound
- **Normal (N)** - solution contains one gram equivalent weight of a compound per liter of solution

490

Laboratory Terminology

- **Quality Assurance** - a set of operating principles that, if strictly followed during sample collection and analysis, will produce data of known and defensible quality
- **Quality Control** - ability to produce credible results

491

Laboratory Terminology

- **Reagent** - a pure chemical substance that is used to make new products or is used in chemical test to measure, detect, or examine other substances
- **Solution** - a liquid mixture of dissolved substances
- **Titrate** - a chemical solution of known strength is added drop by drop until a change in the sample is observed (end point)

492

Laboratory Terminology

- **Volatile** - capable of being evaporated or changed to a vapor. In solids analysis, materials lost at 550 deg. C for 60 minutes in a muffle furnace.
- **Volatile acids** - fatty acids produced during digestion that are soluble in water and can be steam distilled at atmospheric pressure.

493

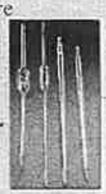
Laboratory Measurements

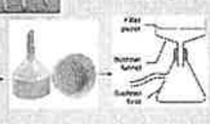
- Metric
  - Liter (volume) - L
  - Gram (weight) - g
  - Meter (length) - m
    - micro( ) = 1/1,000,000 or 0.000001 X
    - milli (m) = 1/1000 or 0.001 X
    - centi (c) = 1/100 or 0.01 X
  - Temperature
    - C° = 5/9 (F° - 32)
    - F° = C°(1.8) + 32

494

Laboratory Equipment

- Use of class "A" labware
- Burets
- Graduated cylinders
- Flasks
- Beakers
- Pipettes (Most Accurate)
- Crucibles
- Funnels (Buchner Funnel is used for TSS)





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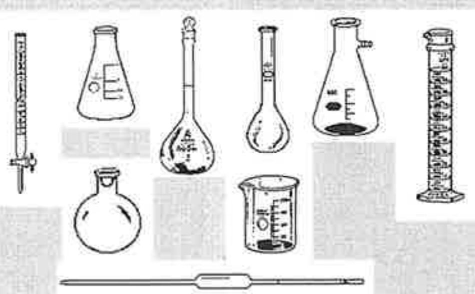
Laboratory Equipment



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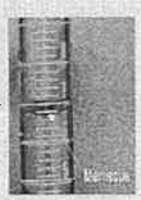
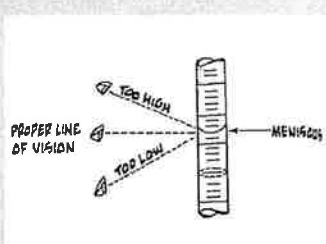
Laboratory Equipment

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Laboratory Equipment

- Hot Plate
- Magnetic Stirrer
- Dessicator
- Drying Oven
- Muffle Furnace
- Water Bath
- Incubator
- Petri dishes

498

Laboratory Equipment

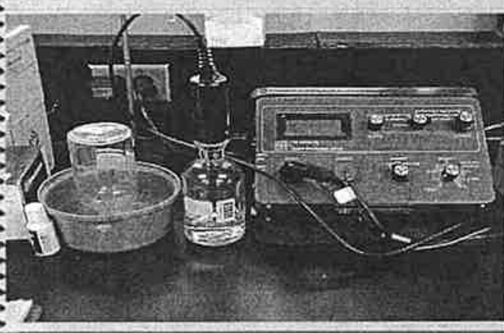
499

Laboratory Equipment

- Analytical balance
- Triple beam balance
- Ion meter (pH)
- Spectrophotometer
- D.O. meter
- Microscope
- Autoclave
- Fume hood

500

Laboratory Equipment



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Laboratory Records

- **Bench sheets and notebooks**
  - Bench sheets must have all information required by DEP
    - Name of laboratory
    - Name of sampler(s)
    - Date & time of analysis
    - Date, time & location of sample
    - Method used
    - Name of technician performing analysis
    - Calculations used

502

Laboratory Records

- **Accurate, complete records are a must!**
  - Used to record data and arrange in orderly manner
  - All information must be recorded
  - If you make a mistake, one line & initial, no white out!
  - Keep accurate calibration and temperature logs
  - Make sure information is legible!

503

Laboratory Records

504

Laboratory Records

- **Quality Assurance/ Quality Control**
  - All certified labs must have a DEP approved QA Plan
  - Without good QA/QC, data is not considered reliable

505

Laboratory Analyses

- **Titrations**
  - Adding one solution to another until end point
- **Gravimetric**
  - Using weight to determine concentration

506

Laboratory Analyses

- **Electrode**
  - Using ion selective electrodes to measure
- **Spectrophotometer or Colorimeter**
  - Measure intensity of color at particular wavelength

507

Laboratory Analyses

- Carbonaceous Biochemical Oxygen Demand
- Total Suspended Solids
- Chlorine Residual
- pH
- Fecal Coliform

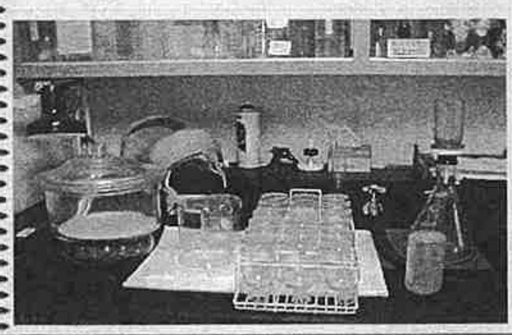
508

Laboratory Analyses

- **Carbonaceous BOD**
  - Disadvantage- results take 5 days to obtain
  - Bioassay
  - 5 day test at 20 deg. C
  - Nitrification inhibitor
  - Initial dissolved oxygen
  - Oxygen five days later
  - Calculate CBOD
  - Rate of oxygen-use expressed as mg/L

509

Laboratory Analyses



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Laboratory Analyses

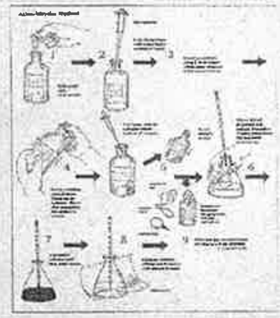
- **Total Suspended Solids (Total Non-Filterable Solids)**
  - Gravimetric method
  - Use fine filter to capture solids
  - Weigh clean filter
  - Pour sample through filter
  - Dry in drying oven at 103-105 C
  - Weigh again to determine mg/L

511

Dissolved Oxygen Analysis

DO Meter

Winkler Method



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Laboratory Analyses

- **Chlorine residual** (Chlorine must be read immediately)

  - DPD Spectrophotometric
    - Use standards to calibrate meter
    - Add DPD reagent. Color intensity corresponds to residual chlorine (For Total Chlorine this takes 3 minutes)

  - Amperometric Titration
    - Uses electronic value to read chlorine level

513

Laboratory Analyses

- pH
  - Meter or ion meter
  - Calibrate with at least 2 buffer solutions that bracket the expected range
  - Take reading immediately, pH can change quickly (Immediately means within 15 min.)

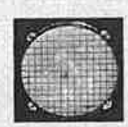
514

Laboratory Analyses

515

Laboratory Analyses

- **Fecal coliform**
  - Membrane Filter Method
    - Uses very fine porous filter to capture bacteria
    - Maintain sterile conditions during sampling and testing
    - Pour samples through filter
    - Place filter in petri dish with broth
    - Incubate 24 hours at 44.5 deg. C



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Laboratory Analyses

- **Fecal coliform**
  - MPN Method (Most Probable Number)
    - Inoculate tubes of broth with several dilutions of sample
    - Calculate density based on number of tubes gas-negative and gas-positive

517

Additional Terminology

- **Bioassay -** measuring effect of biological process. Determining toxic effects by using live organisms.
- **Biomonitoring -** measuring effects of toxic substances
- **Biosurvey** - site survey upstream and down. Used to determine effect downstream

518

Additional Terminology

- **Facultative** - can survive in aerobic or anaerobic conditions
- **Oxidation** - addition of oxygen, removal of hydrogen (aerobic)

519

Additional Terminology

- **Reduction -** addition of hydrogen, removal of oxygen (anaerobic)
- **Surfactant** - surface active agent. Agent in detergents that has good cleaning ability.

520

WATER AND WASTEWATER MATH

521

CONVERSION FACTORS

- VOLUME :

522

CONVERSION FACTORS

- VOLUME :

7.48 gal = 1 cu ft

7.48 gal/cu ft

1 cu ft / 7.48 gal

523

CONVERSION FACTORS

- DENSITY OF WATER

524

CONVERSION FACTORS

- DENSITY OF WATER

8.34 LBS = 1 GAL

8.34 LBS / GAL

1 GAL / 8.34 LBS

525

CONVERSION FACTORS

- CONCENTRATION

526

CONVERSION FACTORS

- CONCENTRATION

CONCENTRATION MAY ALSO BE REFERED TO AS DOSAGE.

1 ppm = 1 mg/l

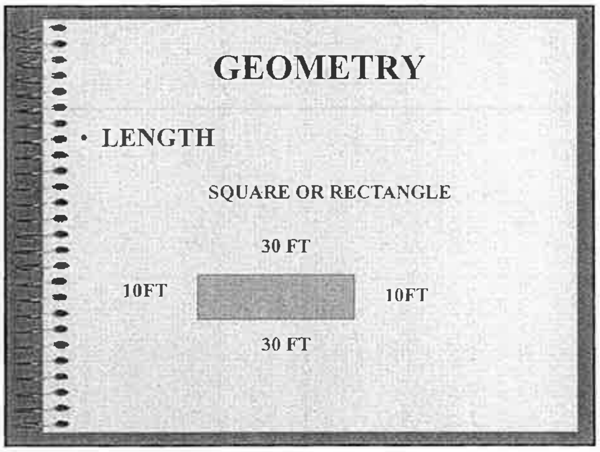
1% = 10,000 mg/l

527

GEOMETRY

- LENGTH

528



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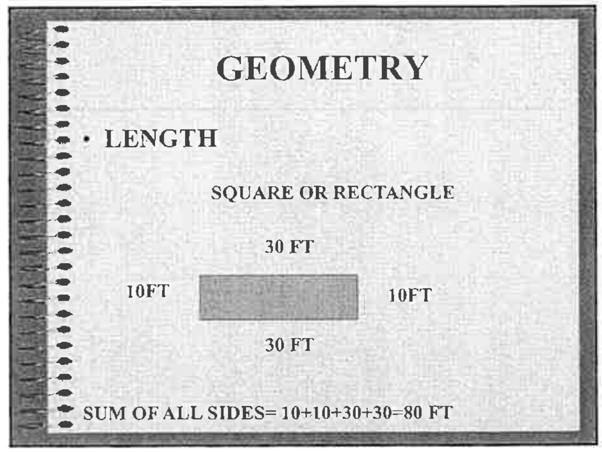

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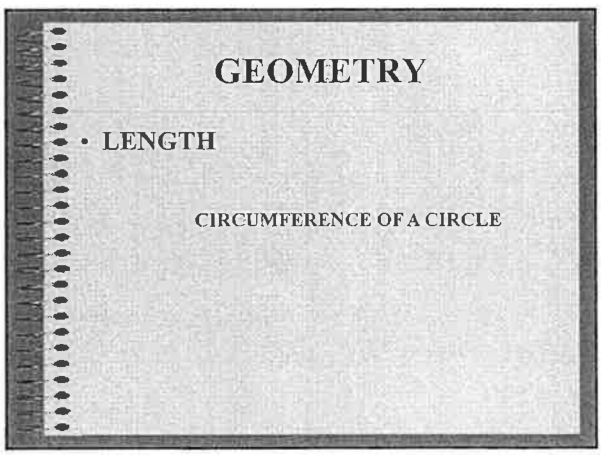

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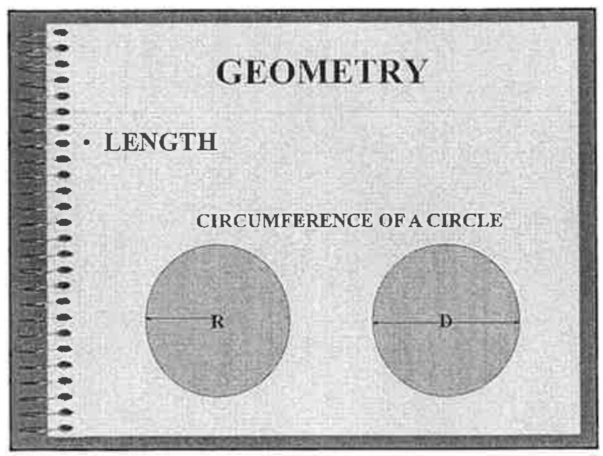

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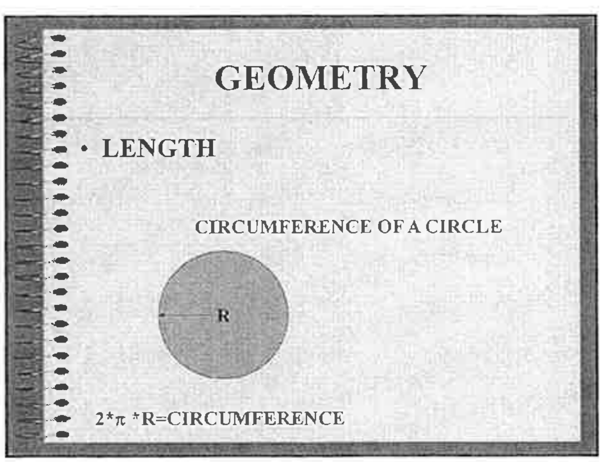

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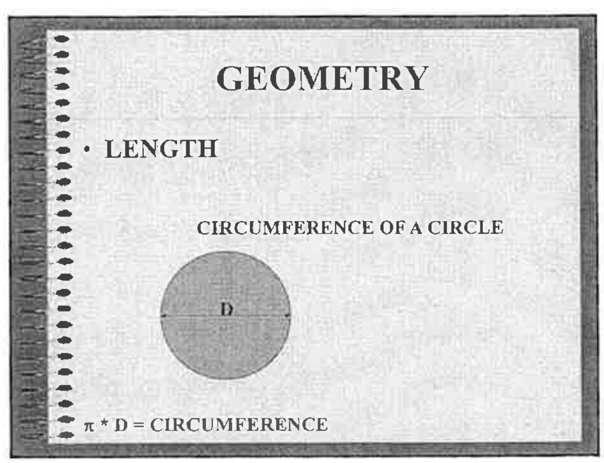

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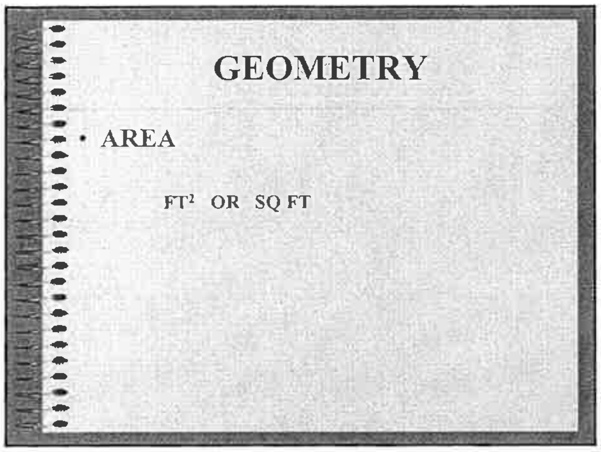

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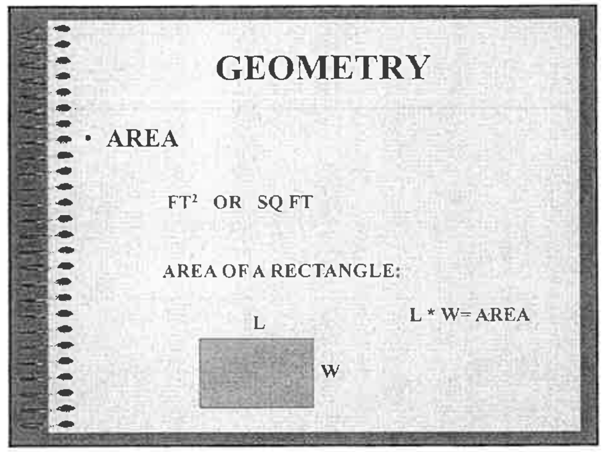

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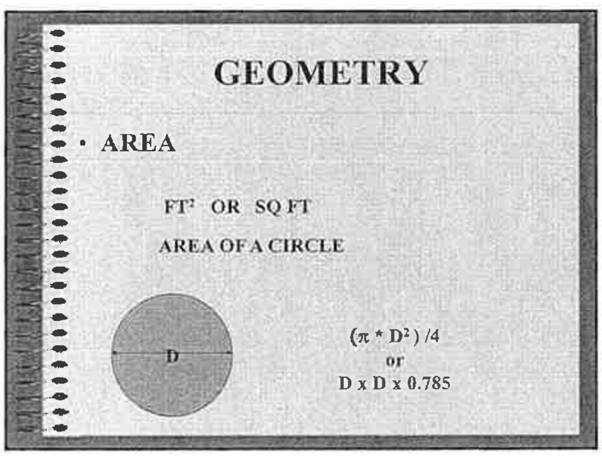

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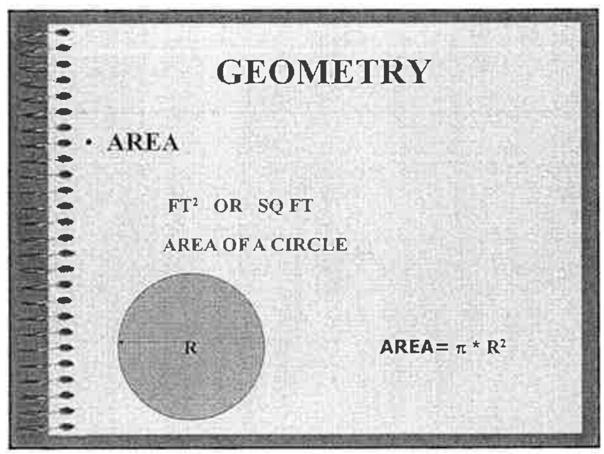

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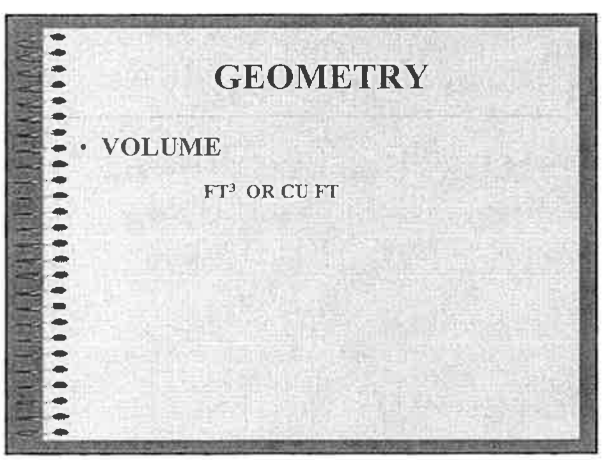

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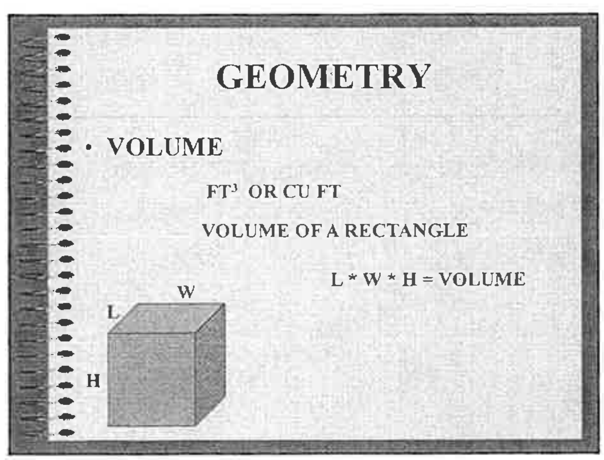

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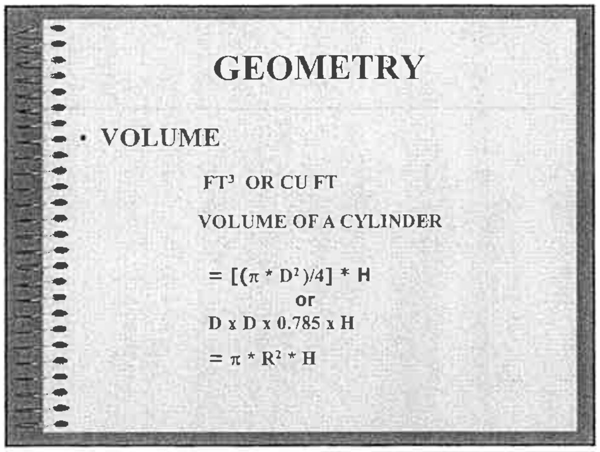

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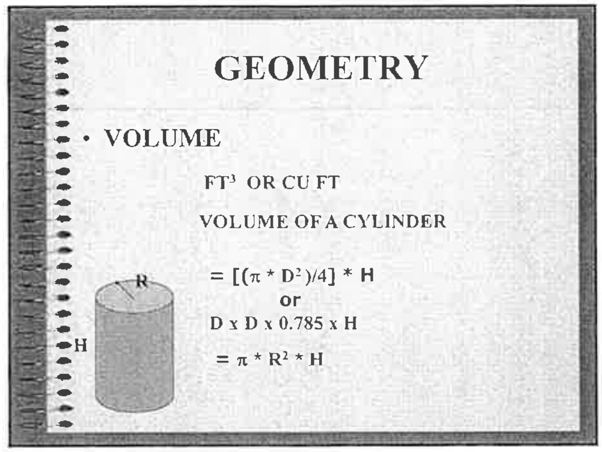

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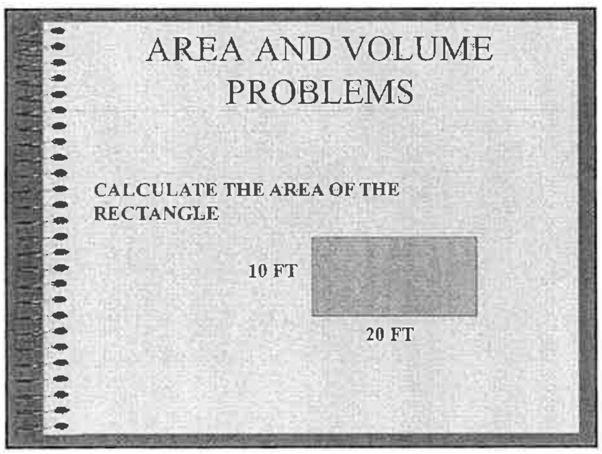

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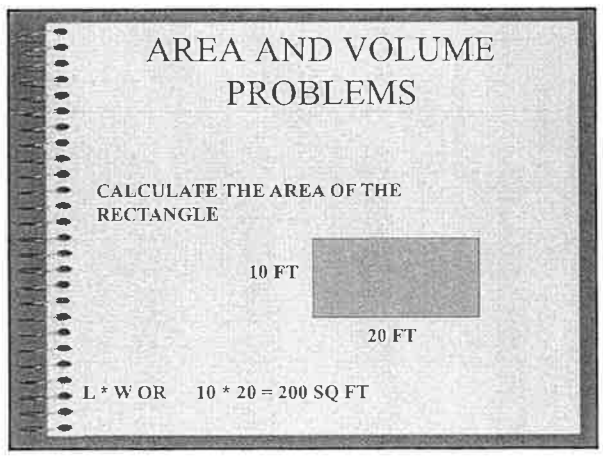

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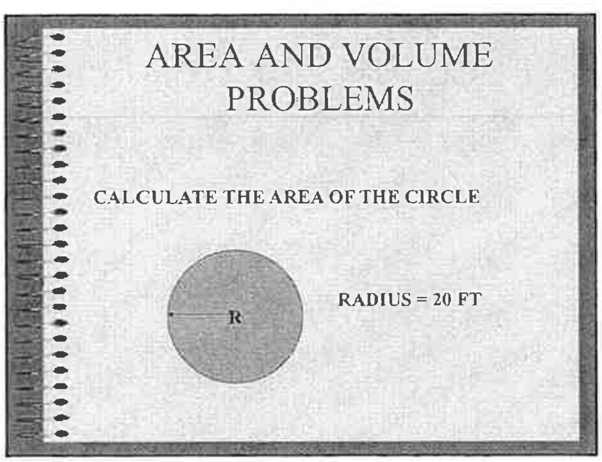

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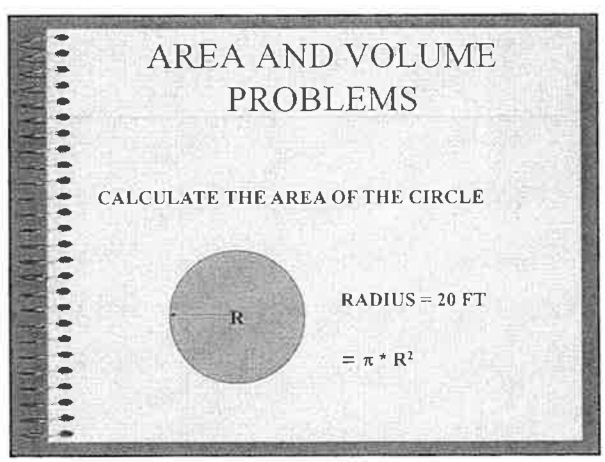

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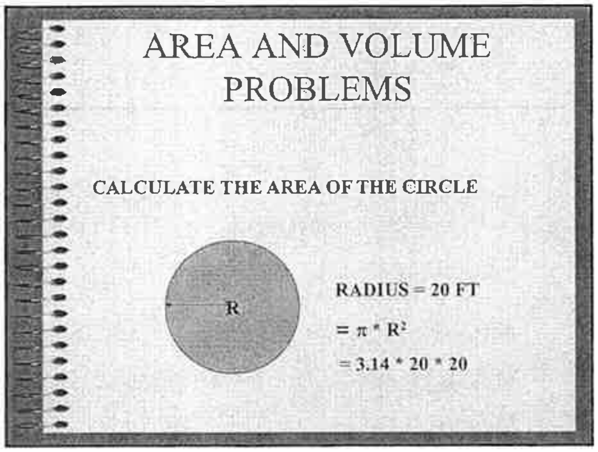

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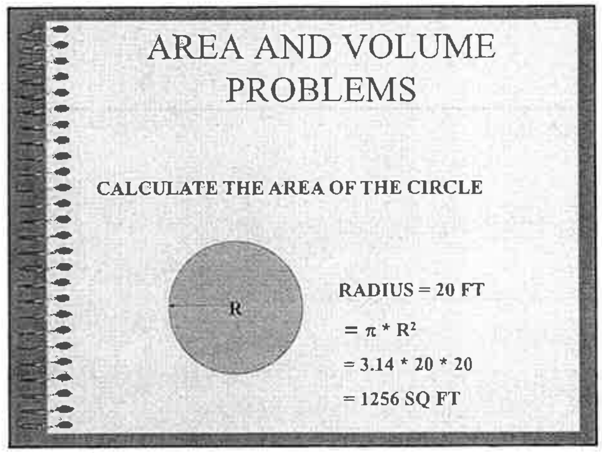

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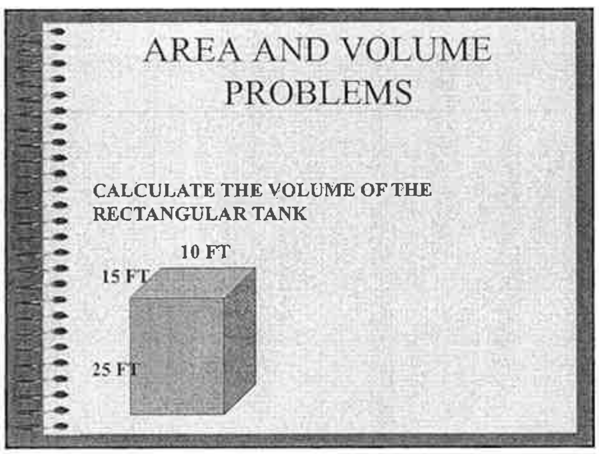

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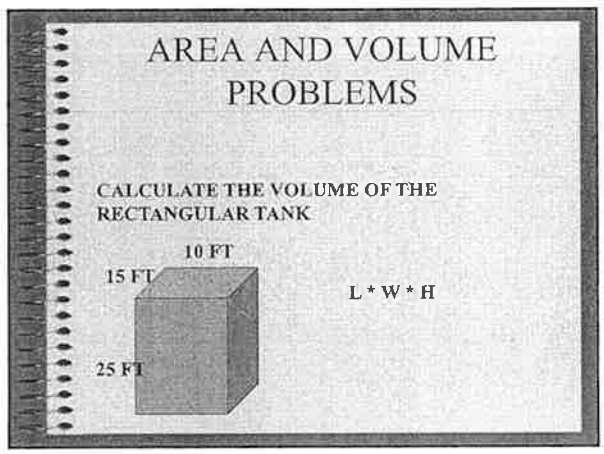

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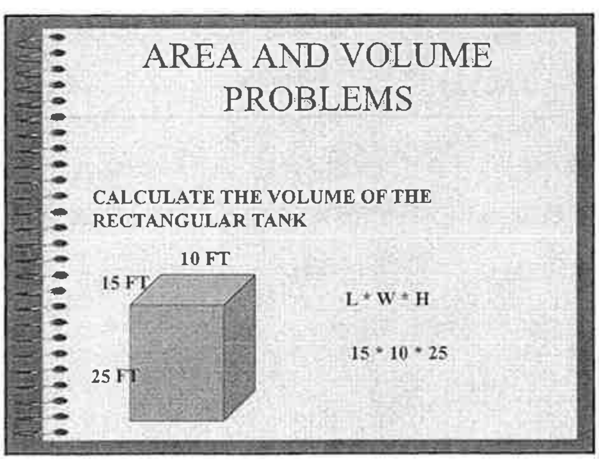

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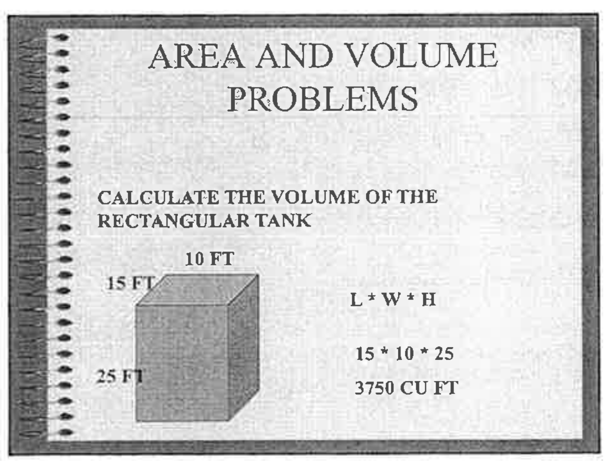

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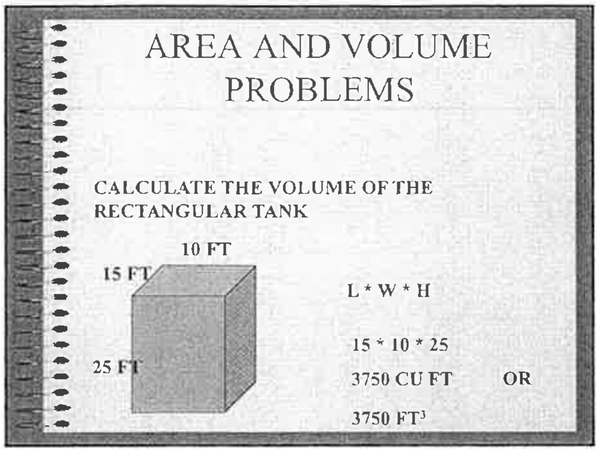

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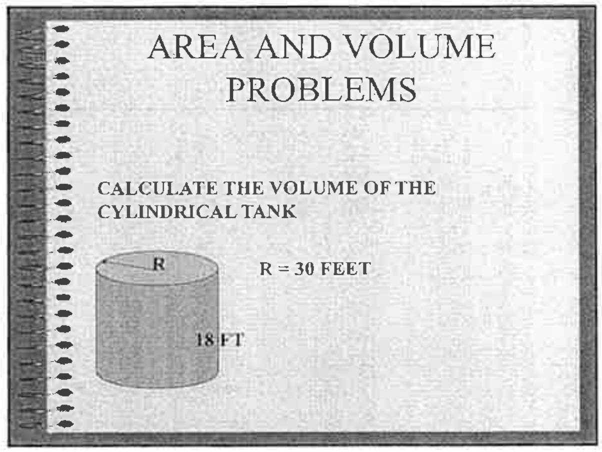

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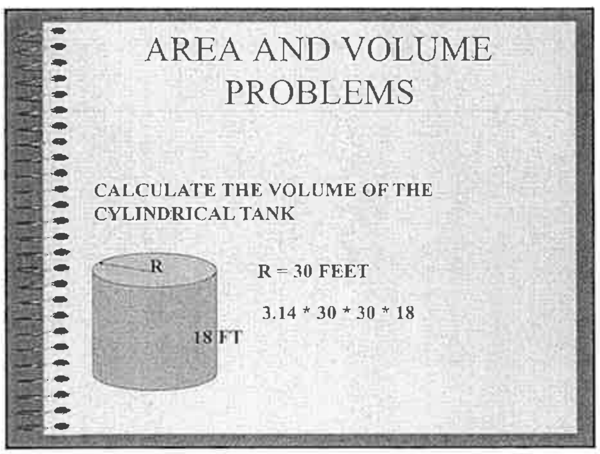

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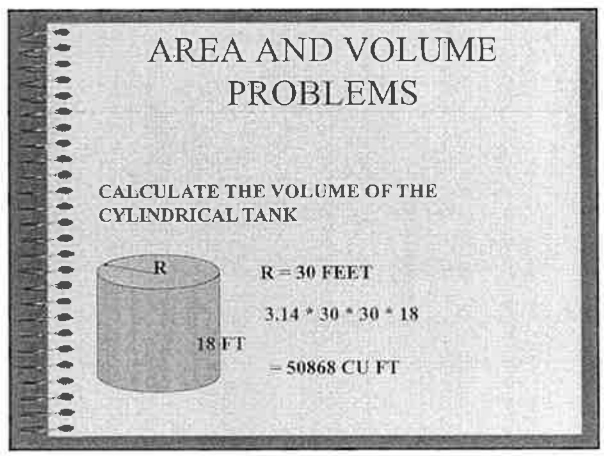

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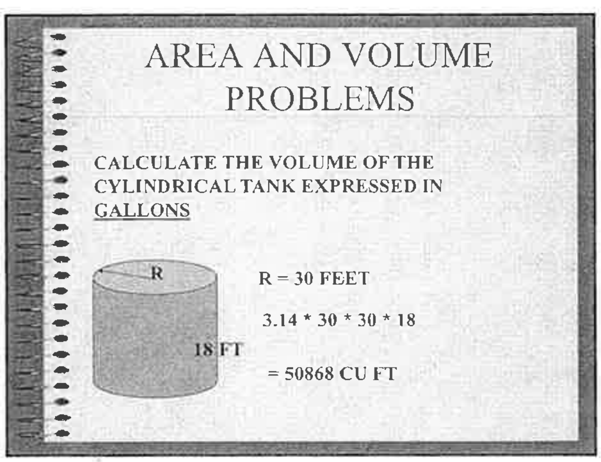

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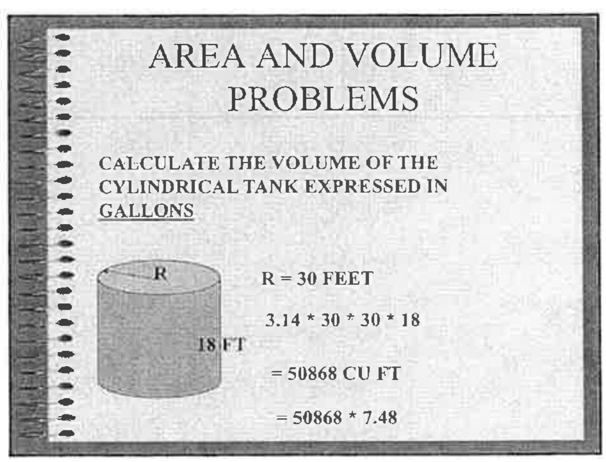

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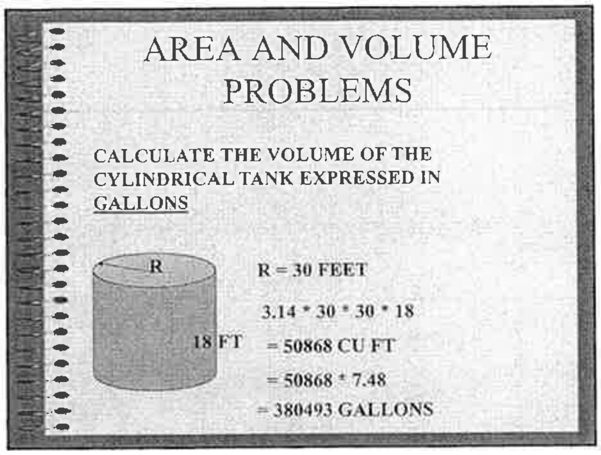

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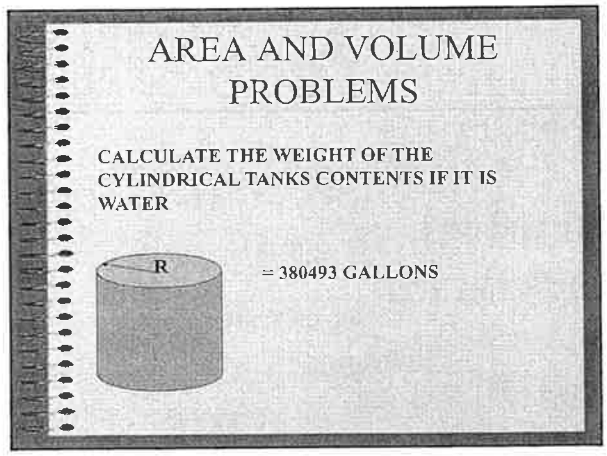

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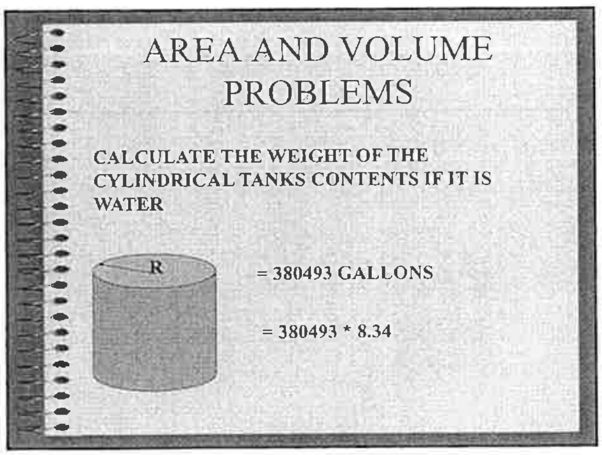

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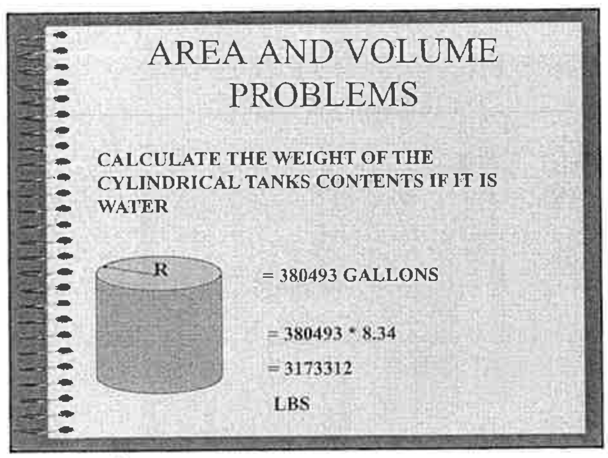

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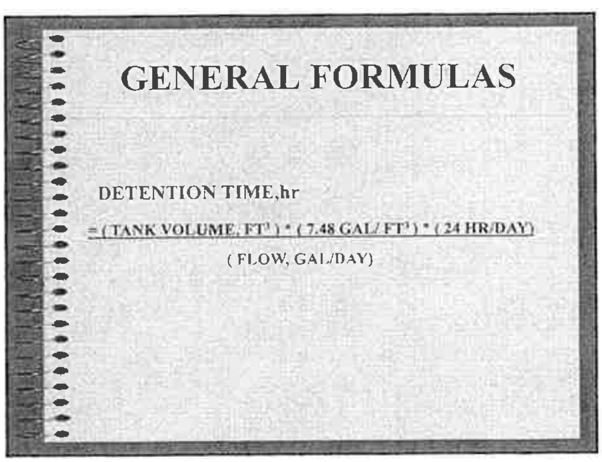

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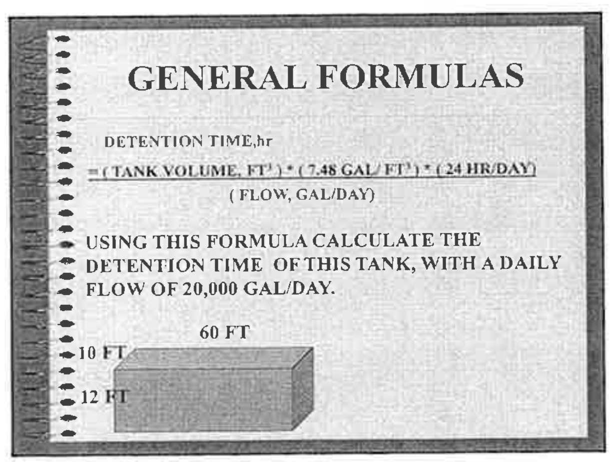


564

GENERAL FORMULAS

DETENTION TIME,hr

$$= \frac{(\text{TANK VOLUME, FT}^3) * (7.48\ \text{GAL/FT}^3) * (24\ \text{HR/DAY})}{(\text{FLOW, GAL/DAY})}$$

$$\frac{(10 * 60 * 12) * 7.48 * 24}{20{,}000} = \frac{7200\ \text{FT}^3 * 7.48 * 24}{20{,}000}$$

$$= 64.6\ \text{HRS}$$

565

GENERAL FORMULAS

PLANT EFFICIENCY

$$\text{PLANT EFFICIENCY, \%} = \frac{(\text{IN - OUT}) * 100\%}{\text{IN}}$$

566

GENERAL FORMULAS

PLANT EFFICIENCY

$$\text{PLANT EFFICIENCY, \%} = \frac{(\text{IN - OUT}) * 100\%}{\text{IN}}$$

EXAMPLE: RAW WATER COMING INTO THE PLANT HAS A TSS OF 120 MG/L, LEAVING THE PLANT AFTER FILTRATION IT IS 5 MG/L. WHAT IS THE EFFICENCY OF THE FILTER?

567

GENERAL FORMULAS

PLANT EFFICIENCY

$$\text{PLANT EFFICENCY, \%} = \frac{(\text{IN - OUT}) * 100\%}{\text{IN}}$$

EXAMPLE: RAW WATERCOMING INTO THE PLANT HAS A TSS OF 120 MG/L, LEAVING THE PLANT AFTER FILTRATION IT IS 5 MG/L. WHAT IS THE EFFICENCY OF THEFILTER?

$$\frac{(120 - 5) * 100\%}{120} = 95.8\%$$

568

GENERAL FORMULAS

PLANT EFFICIENCY

$$\text{PLANT EFFICENCY, \%} = \frac{(\text{IN - OUT}) * 100\%}{\text{IN}}$$

CAN ALSO BE USED FOR MANY OTHER APPLICATIONS:

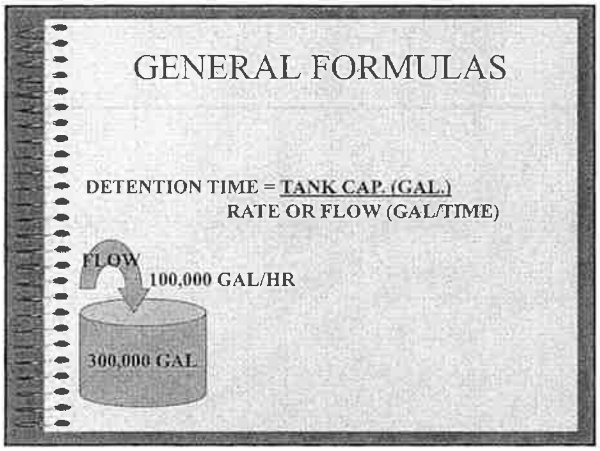
- BOD
- TSS
- REMOVAL OF CHEMICALS

569

GENERAL FORMULAS

$$\text{DETENTION TIME} = \frac{\text{TANK CAP. (GAL.)}}{\text{RATE OR FLOW (GAL/TIME)}}$$

570



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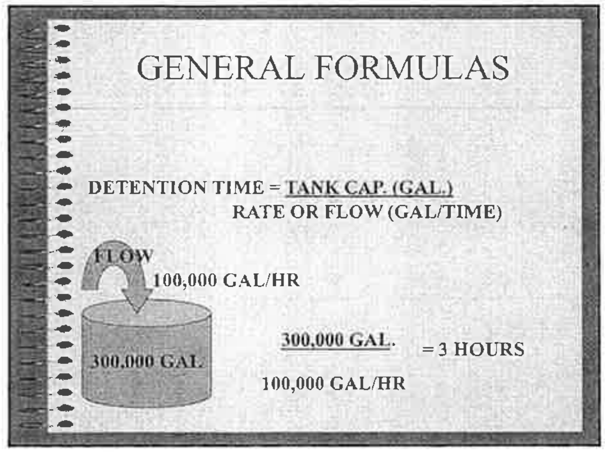

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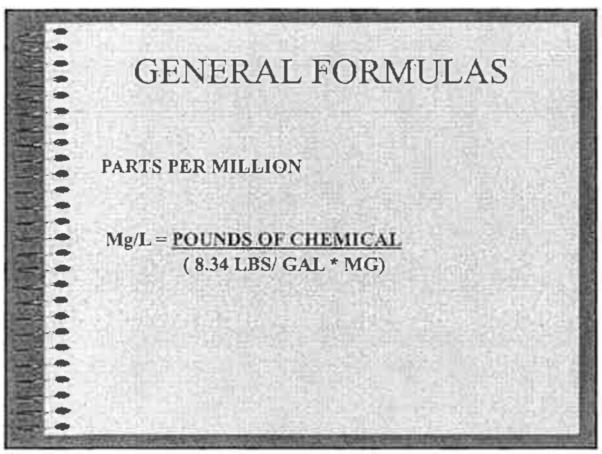

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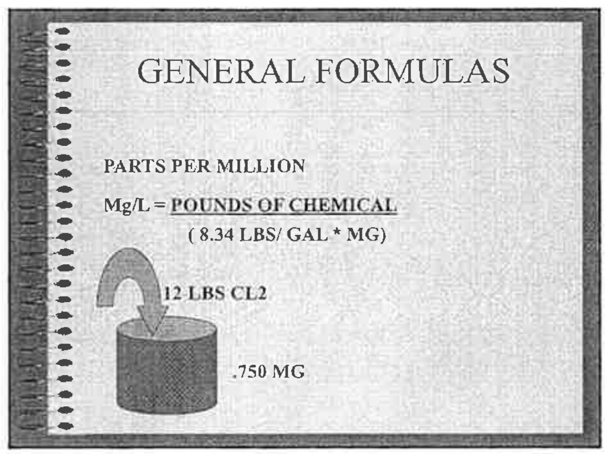

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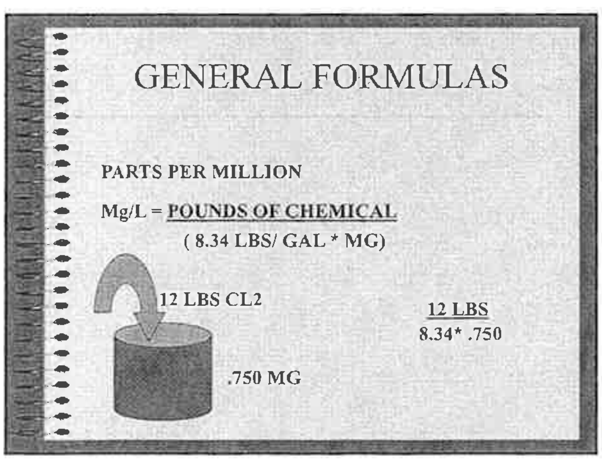

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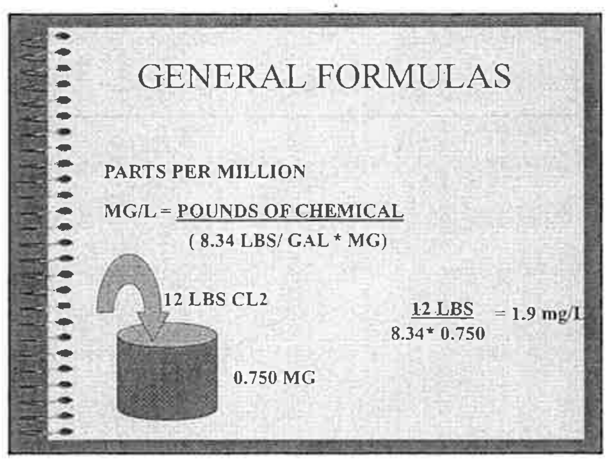


576

GENERAL FORMULAS

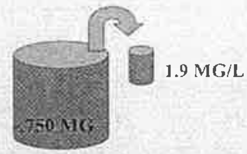
POUNDS

LBS = 8.34 LBS/ GAL * mg/L * MG

577

GENERAL FORMULAS

POUNDS
LBS = 8.34 LBS/ GAL * mg/L * MG



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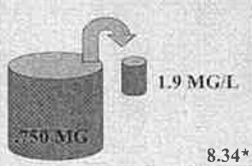
GENERAL FORMULAS

POUNDS
LBS = 8.34 LBS/ GAL * Mg/L * MG

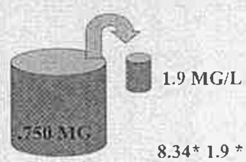


8.34* 1.9 * .750 =

579

GENERAL FORMULAS

POUNDS
LBS = 8.34 LBS/ GAL * Mg/L * MG



8.34* 1.9 * .750 = 11.88 OR 12 LBS

580

ACTIVATED SLUDGE

SOLIDS INVENTORY or
POUNDS UNDERAERATION

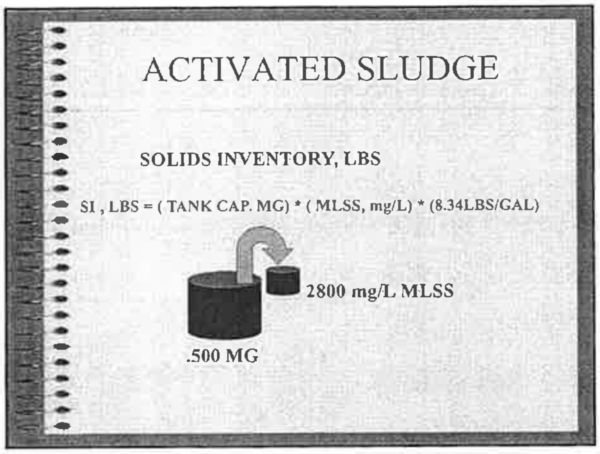
581

ACTIVATED SLUDGE

SOLIDS INVENTORY, LBS

SI , LBS = (TANK CAP. MG) * (MLSS, Mg/L) * (8.34LBS/GAL)

582



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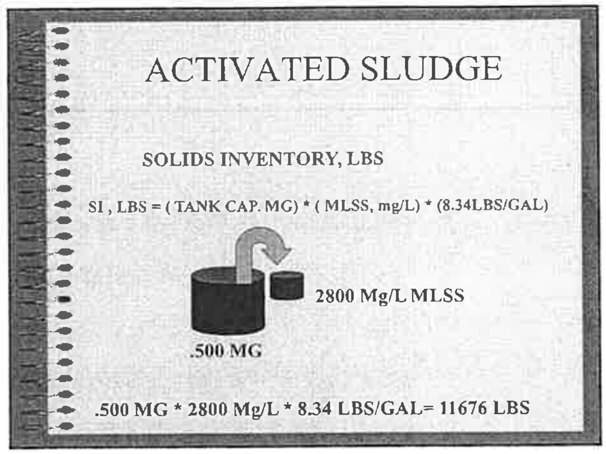

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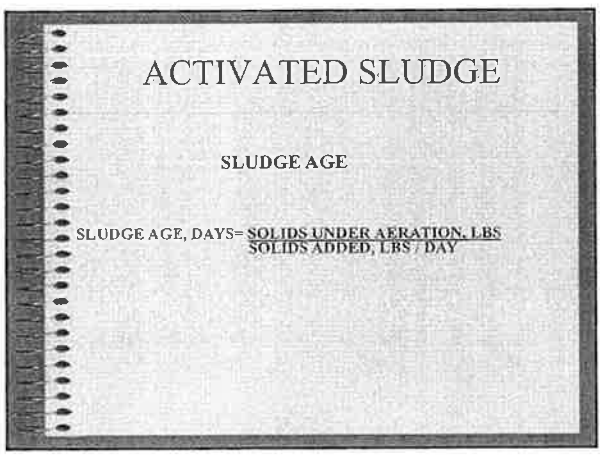

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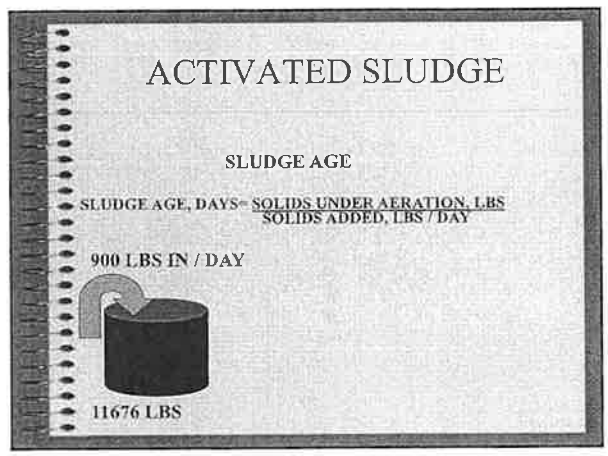

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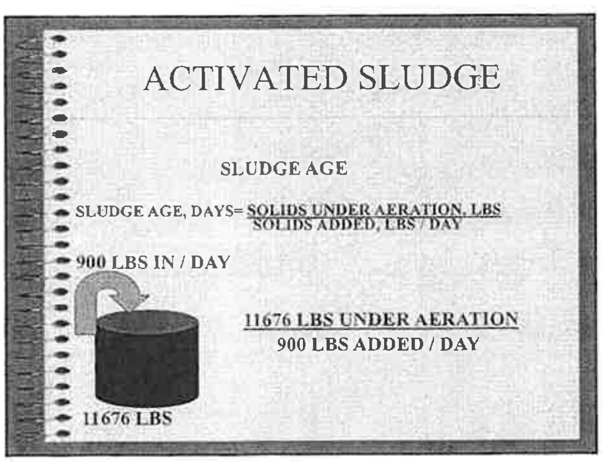

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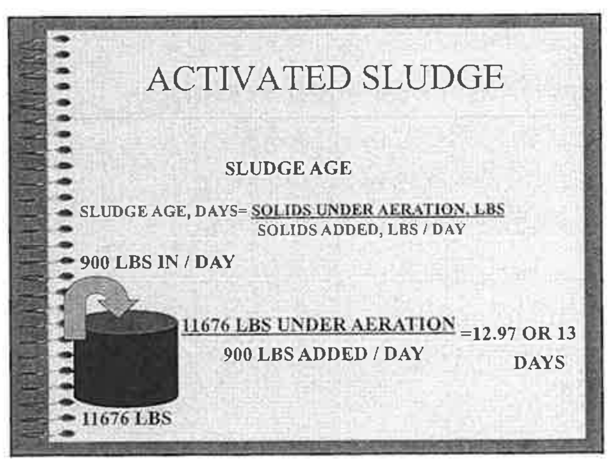

588

ACTIVATED SLUDGE

- INFLUENT FLOW 0.500 MGD
- INF TSS 200 Mg/L
- INF CBOD 250 Mg/L
- AERATION TANK VOL. 0.300 MG
- MLSS 2800 Mg/L
- EFF TSS 20 Mg/L
- EFF CBOD 12 Mg/L
- MLVSS 2600 Mg/L
- WAS CONC. 5500 Mg/L
- WAS 10,000 gal.

589

ACTIVATED SLUDGE

F/M

F = FOOD OR CBOD, MEASURED IN LBS.

590

ACTIVATED SLUDGE

F/M

F = FOOD OR CBOD, MEASURED IN LBS.

M = MICROORGANISMS MEASURED IN LBS.
MLVSS ARE THE BUGS

591

ACTIVATED SLUDGE

F/M =

(INF CBOD, Mg/L) * (FLOW, MGD) * (8.34 LBS/GAL)
(AERATION TANK CAP.,MG) * (MLVSS,mg/L) * (8.34LBS/GAL

592

ACTIVATED SLUDGE

F/M =

(INF CBOD, Mg/L) * (FLOW, MGD) * (8.34 LBS/GAL)
(AERATION TANK CAP.,MG) * (MLVSS,Mg/L) * (8.34LBS/GAL

250 Mg/L * 0.500 MGD * 8.34 LBS/ GAL
0.300 MG* 2600 Mg/L * 8.34 LBS/GAL

593

ACTIVATED SLUDGE

F/M =

(INF CBOD, Mg/L) * (FLOW, MGD) * (8.34 LBS/GAL)
(AERATION TANK CAP.,MG) * (MLVSS Mg/L) * (8.34LBS/GAL

250 Mg/L * 0.500 MGD * 8.34 LBS/ GAL = .16
0.300 MG* 2600 Mg/L * 8.34 LBS/GAL

594

ACTIVATED SLUDGE

MCRT: MEAN CELL RESIDENCE TIME

595

ACTIVATED SLUDGE

MCRT: MEAN CELL RESIDENCE TIME

•MCRT= SOLIDS INVENTORY , LBS
(EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

596

ACTIVATED SLUDGE

•MCRT= SOLIDS INVENTORY , LBS
(EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

SI, LBS = TANK CAP MG * MLSSMg/L * 8.34 LBS GAL

EFF SOLIDS, LBS = FLOW MG * EFF TSS Mg/L * 8.34LBS/GAL

WAS SOLIDS, LBS = WAS Q * WAS CONC. Mg/L * 8.34 LBS/GAL

597

ACTIVATED SLUDGE

•MCRT= SOLIDS INVENTORY , LBS
(EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

0.300 MG * 2800 mg/L * 8.34 LBS/GAL

0.500 MG * 20 mg/L * 8.34 LBS/ GAL +

0.010 MG * 5500 mg/L * 8.34 LBS/GAL

598

ACTIVATED SLUDGE

•MCRT= SOLIDS INVENTORY , LBS
(EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

0.300 MG * 2800 mg/L * 8.34 LBS/GAL = 7005.6

0.500 MG * 20 mg/L * 8.34 LBS/ GAL + = 83.4 +

0.010 MG * 5500 mg/L * 8.34 LBS/GAL = 458.7

599

ACTIVATED SLUDGE

•MCRT= SOLIDS INVENTORY , LBS
(EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

0.300 MG * 2800 mg/L * 8.34 LBS/GAL = 7005.6

0.500 MG * 20 mg/L * 8.34 LBS/ GAL + = 83.4 +

0.010 MG * 5500 mg/L * 8.34 LBS/GAL = 458.7

$\frac{7005.6}{83.4 + 458.7}$ $\frac{7005.6}{542.1}$ = 12.92 OR 13 DAYS

600

Sprayfield Zones

You operate an extended air plant with a permitted capacity 750,000 gallons per day. Your average daily flow is 400,000 gallons per day. You discharge to a spray field that has 7 zones. Each zone is 5 acres. You are allowed to apply 3 inches to a zone. One acre is 43,560 sq. ft.

How long can you spray to a zone before switching zones?

601

Sprayfield Zones

You operate an extended air plant with a permitted capacity 750,000 gallons per day. Your average daily flow is 400,000 gallons per day. You discharge to a spray field that has 7 zones. Each zone is 5 acres. You are allowed to apply 3 inches to a zone. One acre is 43,560 sq. ft.

How long can you spray to a zone before switching zones?

3 inches/12 inches = 0.25 ft.

602

Sprayfield Zones

You operate an extended air plant with a permitted capacity 750,000 gallons per day. Your average daily flow is 400,000 gallons per day. You discharge to a spray field that has 7 zones. Each zone is 5 acres. You are allowed to apply 3 inches to a zone. One acre is 43,560 sq. ft.

How long can you spray to a zone before switching zones?

3 inches/12 inches = 0.25 ft.

43,560 X 0.25ft= 10,890cubic ft. X 7.48 = 81,457 gallons

603

Sprayfield Zones

You operate an extended air plant with a permitted capacity 750,000 gallons per day. Your average daily flow is 400,000 gallons per day. You discharge to a spray field that has 7 zones. Each zone is 5 acres. You are allowed to apply 3 inches to a zone. One acre is 43,560 sq. ft.

How long can you spray to a zone before switching zones?

3 inches/12 inches = 0.25 ft.

43,560 X 0.25ft= 10,890cubic ft. X 7.48 = 81,457 gallons

81,457 X 5 acres = 407,286 gallons/400,000 = 1 day

604

Sprayfield Zones

You operate an extended air plant with a permitted capacity 750,000 gallons per day. Your average daily flow is 400,000 gallons per day. You discharge to a spray field that has 7 zones. Each zone is 5 acres. You are allowed to apply 3 inches to a zone. One acre is 43,560 sq. ft.

How long can you spray to a zone before switching zones?

3 inches/12 inches = 0.25 ft.

43,560 X 0.25ft= 10,890cubic ft. X 7.48 = 81,457 gallons

81,457 X 5 acres = 407,286 gallons/400,000 = 1 day

Answer: Daily

605

Positive Displacement Pump

You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

How long will it take to raise the level of a digester 20%, if it has a diameter of 20 feet and a height of 10 feet?

606

Positive Displacement Pump

You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

How long will it take to raise the level of a digester 20%, if it has a diameter of 20 feet and a height of 10 feet?

9 inches/12 = 0.75 feet and 6 inches/ 12 = 0.5 feet

607

Positive Displacement Pump

You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

How long will it take to raise the level of a digester 20%, if it has a diameter of 20 feet and a height of 10 feet?

9 inches/12 = 0.75 feet and 6 inches/ 12 = 0.5 feet

0.75X0.75X0.785= .44 X 0.5 = 0.22 cubic feet X 7.48 = 1.65 gallons

608

Positive Displacement Pump

You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

How long will it take to raise the level of a digester 20%, if it has a diameter of 20 feet and a height of 10 feet?

9 inches/12 = 0.75 feet and 6 inches/ 12 = 0.5 feet

0.75X0.75X0.785= .44 X 0.5 = 0.22 cubic feet X 7.48 = 1.65 gallons

1.65 X 89 = 147 gallons per minute

609

Positive Displacement Pump

You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

How long will it take to raise the level of a digester 20%, if it has a diameter of 20 feet and a height of 10 feet?

9 inches/12 = 0.75 feet and 6 inches/ 12 = 0.5 feet

0.75X0.75X0.785= .44 X 0.5 = 0.22 cubic feet X 7.48 = 1.65 gallons

1.65 X 89 = 147 gallons per minute

20 X 20 X .785 X 2 = 628 cubic feet X 7.48 = 4697 gallons

610

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You have a positive displacement pump that has a 9 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump?

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1.65 X 89 = 147 gallons per minute

20 X 20 X .785 X 2 = 628 cubic feet X 7.48 = 4697 gallons

4697/147 gpm = 32 minutes

611

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

612

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

40 X 60 = 240 sq. feet

613

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

40 X 60 = 240 sq. feet

6"/12" = 0.5'

614

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

40 X 60 = 240 sq. feet

6"/12" = 0.5'

240 X 0.5 = 120 cubic feet

615

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

40 X 60 = 240 sq. feet

6"/12" = 0.5'

240 X 0.5 = 120 cubic feet

120/27=4.4 cubic yards

616

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. The sand cost is $60.00 per cubic yard. How much will it cost to rehab the drying bed?

40 X 60 = 240 sq. feet

6"/12" = 0.5'

240 X 0.5 = 120 cubic feet

120/27=4.4 cubic yards

4.4 X $60= $264

617

Water Horse Power

You have an effluent pump that pumps 250 gpm at 75 feet of head.

What is the Water Horse Power of the pump?

618

Water Horse Power

You have an effluent pump that pumps 250 gpm at 75 feet of head.

What is the Water Horse Power of the pump?

$$\frac{250\text{gpm X } 75\text{ft of head}}{3960}$$

619

Water Horse Power

You have an effluent pump that pumps 250 gpm at 75 feet of head.

What is the Water Horse Power of the pump?

$$\frac{250\text{gpm X } 75\text{feet of head}}{3960}$$

4.73 WHP

620

Brake Horse Power

You have an effluent pump that pumps 150 gpm at 55 feet of head.
The pump efficiency is 85%

What is the Brake Horse Power of the pump?

621

Brake Horse Power

You have an effluent pump that pumps 150 gpm at 55 feet of head.
The pump efficiency is 85%

What is the Brake Horse Power of the pump?

$$\frac{150\text{gpm X } 55\text{feet of head}}{3960 \text{ X } .85}$$

622

Brake Horse Power

You have an effluent pump that pumps 150 gpm at 55 feet of head.
The pump efficiency is 85%

What is the Brake Horse Power of the pump?

$$\frac{150\text{gpm X } 55\text{feet of head}}{3960 \text{ X } .85}$$

2.5 Brake Horse Power

623

Motor Horse Power

You have an effluent pump that pumps 300 gpm at 45 feet of head.
The pump efficiency is 80 percent and the motor efficiency is 85 percent.

What is the Motor Horse Power of the pump?

624

Motor Horse Power

- You have an effluent pump that pumps 300 gpm at 45 feet of head. The pump efficiency is 80 percent and the motor efficiency is 85 percent.
- What is the Motor Horse Power of the pump?

<u>300gpm X 45feet of head</u>

3960 X .8 X .85

625

Motor Horse Power

- You have an effluent pump that pumps 300 gpm at 45 feet of head. The pump efficiency is 80 percent and the motor efficiency is 85 percent.
- What is the Motor Horse Power of the pump?

<u>300gpm X 45feet of head</u>

3960 X .8 X .85

5.0 MHP

626

PROCESS CONTROL MATH

for

WASTEWATER PLANT OPERATORS

Third Edition

1998

CONTENTS

INTRODUCTION

Welcome to Process Control Math for Wastewater Plant Operators. This workbook should be used after successful completion of the Water and Wastewater Technologies Core Program. In the Core Program, students were introduced to a process where problems were solved by organizing them into simple steps. Students were encouraged to follow each step, assign units to each value, and draw a diagram of the situation given.

The method of problem solving introduced in the Core Program will be used in solving more complex problems dealing with process control of drinking water facilities. These problems can sometimes involve multiple formulas, so it is extremely important that the steps introduced in the Core Workbook be adhered to.

As in the Core Workbook, examples will be given for each type of problem. The steps in the examples given are not labeled as in the Core Workbook, however, and many of the diagrams have been eliminated for simplicity. In the appendix, there are sample tests that represent each type of problem. The appendix also contains an answer key. Use the formula sheet and the table of equivalents provided in the appendix in completing the sample tests.

Remember that most students make errors in the actual setup of the problem. Take your time. Keep organized. Write down all information given that concerns the problem, draw a diagram if necessary, keep track of the units, and use the four steps:

1. Write the formula.
2. Substitute knowns for unknowns.
3. Simplify by canceling and calculating.
4. Write that answer in the units called for.

CHAPTER ONE

LOADING PROBLEMS

Weir Overflow Rates

Clarifiers or sedimentation tanks used to settle raw wastewater are known as *primary tanks*. *Final clarifiers* are settling tanks following secondary aerobic treatment. Sedimentation basins in wastewater treatment are designed with certain overflow, or loading rates. If the loading rates are exceeded, the efficiency of the sedimentation process diminishes greatly.

Weir overflow rates (sometimes called weir loading rates) are how many gallons of effluent flow over one foot of weir in a certain time period. They involve the total length of the weir and the total flow rate. Sometimes the weir length is given, and other times it must be calculated, such as in circular clarifiers where only the diameter of the clarifier is given. In all cases, the length of weir is in linear units (a single dimension resembling a straight line), usually feet. The flow rate can be given in any combination of gallons and time units and can be written as such in the formula.

The formula for calculating weir overflow rates in gallons per day per foot is:

- **Weir overflow rate, gal/day/ft =** $\frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$

<u>Example</u>

Determine the weir overflow rate of a circular clarifier whose diameter is 60 feet and a flow of 1.5 MGD.

In this case, the length of the weir is not given. Knowing that the clarifier is circular, it is easy to calculate the weir length by using the circumference formula:

$C = \pi \times D$

$C = 3.14 \times 60$ ft

C = 188.4 feet, the length of the weir

Weir overflow rate, gal/day/ft= $\frac{\text{total flow rate, gal/day}}{\text{length of weir,ft}}$

Weir overflow rate, gal/day/ft= $\frac{\text{1,500,000 gal/day}}{\text{188.4 ft}}$

Weir overflow rate, gal/day/ft= 7, 962 gal/day/ft

Notice that none of the units cancel out. The new units for the weir overflow rate are in gallons per day per (linear) foot.

Surface Loading Rates

Surface loading is an important guideline used in the design of sedimentation tanks. In order to perform the calculations, the tank influent flow and the total surface area of the sedimentation tank or clarifier are needed. Sometimes the areas are given, and other times a calculation is required. Determine surface areas by the area formulas in the Core Workbook. Notice that the time units in the following formula are in days. The formula can be written with minutes or hours as the time unit. The calculations are performed in the same way.

The formula for surface loading rates in gallons per day per square foot is written:

- **SLR, gal/day/ft^2**= $\frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$

Example

What is the surface loading rate of a clarifier with a diameter of 55 ft and an influent flow of 1.152 MGD?

The clarifier is circular. Use the formula for the area of a circle.

A= $\pi\ x\ R^2$

A= 3.14 x 27.5 ft x 27.5 ft

A= 2, 374.6 ft^2

After the surface area has been determined, substitute all the known values into the surface loading rate formula.

SLR, gal/day/ft^2 = $\frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$

SLR, gal/day/ft^2 = $\frac{\text{1,152,000 gal/day}}{\text{2,374.6 ft}^2}$

SLR, gal/day/ft^2 = 485 gal/day/ft^2

The units are particular to surface loading rates. Notice that none of the units cancel out in the example, so all of the units must be kept.

Sometimes the answer must be in gallons per minute per square foot (gal/min/ft^2) as well as gallons per day per square foot (gal/day/ft^2). As stated previously, this can also apply to weir overflow rates. Just use the appropriate conversion factors as in the example given below.

$\frac{\text{485 gal/day/ft}^2}{\text{1,440 min/day}}$ = 0.34 gal/min/ft^2

Solids Loading

Another calculation that wastewater plant operators may be required to perform is solids loading of clarifiers or sedimentation tanks. Clarifiers are designed to remove a certain amount of solids per square foot of surface area. In order to perform this calculation, the amount of solids, in pounds, that are applied to the clarifier daily, the surface area of the clarifier, and the daily flow must be known.

Sometimes a laboratory result in mg/L for the solids concentration being applied to the clarifier is given. In this case, use the pounds formula introduced in the Core Workbook to calculate the pounds of solids applied to the clarifier daily.

The formula for solids loading, in pounds per day per square foot, is written:

- **Solids loading, lbs/day/ft^2 =** $\frac{\text{solids applied, lbs/day}}{\text{surface area, ft}^2}$

Example

A primary clarifier has a diameter of 80 feet and treats a flow of 3.75 MGD. Laboratory results show that the total suspended solids concentration entering the clarifier is 265 mg/L. What is the solids loading in lbs/day/ft^2?

In solving this problem, the solids applied, in pounds per day, are needed. Use the pounds formula:

Solids, lbs/day = flow, MGD x mg/L x 8.34 lbs/gal

Solids, lbs/day = 3.75 MGD x 265 mg/L x 8.34 lbs/gal

Solids, lbs/day = 8,288 lbs/day

Now, the surface area of the clarifier must be calculated. It is circular, so use the appropriate area formula:

$A = \pi \times R^2$

A = 3.14 x 40 ft x 40 ft

A = 5,024 ft^2

Now, use the above information in the solids loading formula:

Solids loading, lbs/day/ft^2 = $\frac{\text{solids applied, lb/day}}{\text{surface area, ft}^2}$

Solids loading, lbs/day/ft^2 = $\frac{\text{8,288 lbs/day}}{\text{5,024 ft}^2}$

Solids loading, lbs/day/ft^2 = 1.65 lbs/day/ft^2

Efficiency Calculations

Efficiency calculations are dependent upon laboratory test results of the particular water quality indicator of interest. Efficiency compares what is entering a treatment unit with what is leaving that unit. The lab results are given in milligrams per liter (mg/L). The unit used in efficiency problems is percent (%).

The formula for any type of efficiency, in percent, is written as follows:

- **Efficiency, %** $= \dfrac{\text{(in, mg/L)} - \text{(out, mg/L)}}{\text{(in, mg/L)}}$ **x 100 %**

Example

A secondary clarifier in an activated sludge treatment plant receives a total suspended solids concentration of 3,550 mg/L. The effluent suspended solids concentration for this clarifier is 55 mg/L. What is the efficiency of this clarifier in percent?

$$\text{Efficiency, \%} = \frac{\text{(in, mg/L)} - \text{(out, mg/L)}}{\text{(in, mg/L)}} \times 100\%$$

$$\text{Efficiency, \%} = \frac{\text{(3,550 mg/L)} - \text{(55 mg/L)}}{\text{(3,550 mg/L)}} \times 100\%$$

$$\text{Efficiency, \%} = \frac{3{,}495}{3{,}550} \times 100\%$$ *(notice that the mg/L units cancel out, leaving %)*

Efficiency, % = 98%

Organic Loading

Another type of loading problem that may be encountered in wastewater treatment, primarily in attached growth facilities, is the organic loading rate problem. BOD loading on a trickling filter is calculated using the BOD in the primary clarifier effluent which is then applied to the trickling filter, *without regard to the BOD in the recirculation flow.*

This calculation is important in that as the BOD load increases on a trickling filter, the amount of biological growth developed in the filter bed increases significantly, thus filling the voids in the bed and impeding the passage of liquid and air. BOD loadings are expressed in terms of pounds of BOD applied per day per unit of volume as 1,000 ft^3.

The formula for calculating the organic loading rate is written as follows:

- **Organic loading, lbs BOD/day/1000** ft^3 $= \dfrac{\text{BOD applied, lbs/day}}{\text{volume of media (in 1000 ft}^3\text{)}}$

Example

What is the organic loading rate in pounds of BOD per day per 1,000 ft^3 on a trickling filter that has a depth of 5 feet and a diameter of 60 feet if the influent to the filter has a BOD of 180 mg/L and the flow is 1,500,000 gallons per day?

In solving this problem, first determine how many pounds of BOD per day are applied to the filter. Use the pounds formula.

BOD, lbs/day = Flow, MGD x BOD, mg/L x 8.34 lbs/gal

BOD, lbs/day = 1.5 MGD x 180 mg/L x 8.34 lbs/gal

BOD, lbs/day = 2,252 lbs/day

Now, the next step is to calculate the volume of the trickling filter in 1,000 cubic foot units. Use the appropriate formula for the volume of a cylinder.

$V = \pi \times R^2 \times H$

V = 3.14 x 30 ft x 30 ft x 5 ft

$V = 14{,}130\ ft^3$

$\text{Volume, in } 1000\ ft^3 = \frac{14{,}130\ ft^3}{1000}$

$\text{Volume, in } 1000\ ft^3 = 14.13/1000\ ft^3$

Now, use the organic loading formula, substituting with the values previously calculated:

$\text{Organic loading, lbs BOD/day/1000 } ft^3 = \frac{\text{BOD applied, lbs/day)}}{\text{volume of media (in 1000 } ft^3)}$

$\text{Organic loading, lbs BOD/day/1000 } ft^3 = \frac{2{,}252\ \text{lbs/day}}{14.13/\ 1000\ ft^3}$

$\text{Organic loading, lbs BOD/day/1000 } ft^3 = 159\ \text{lbs BOD/day/1000 } ft^3$

RBC Loadings and Soluble BOD Calculations

There are two basic differences from trickling filters in calculating the organic loading for a rotating biological contactor. The formula is nearly the same, with the exception being that the media is expressed in square feet of media surface. This is usually given. The loadings on rotating biological contactors are based upon *soluble* BOD, which is sometimes given in a problem. Soluble BOD is the BOD of the filtrate from the standard suspended solids test. If calculating the soluble BOD is required, use the following formula:

- **Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)**

("K" is equal to 0.5 to 0.7 for most domestic wastewaters. This number is given in a test situation.)

Example

A rotating biological contactor has a media surface area of 834,000 sq ft, treats a domestic wastewater having a BOD of 330 mg/L, a total suspended solids of 310 mg/L, and receives an average daily flow of 2.0 MGD. What is the organic loading of this facility if the K factor is 0.65?

First, calculate the soluble BOD:

Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

Soluble BOD, mg/L = 330 mg/L – (0.65 x 310 mg/L)

Soluble BOD, mg/L = 330 mg/L – 201.5 mg/L

Soluble BOD, mg/L = 128.5 mg/L

Now, calculate how many pounds of soluble BOD are applied per day using the pounds formula.

Soluble BOD, lbs/day = Flow, MGD x soluble BOD, mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2.0 MGD x 128.5 mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2,143 lbs soluble BOD/day

Now, use the organic loading formula. Remember to use square feet of media surface instead of cubic feet of media.

$$\frac{834{,}000\ ft^2}{1000} = 834/1000\ ft^2$$

$$\text{ORL, lbs soluble BOD/day/1000 } ft^2 = \frac{\text{soluble BOD applied,lbs day}}{\text{surface area of media (in 1000 } ft^2)}$$

$$\text{ORL, lbs soluble BOD/day/1000 } ft^2 = \frac{2{,}143\ lbs/day}{834/1000\ ft^2}$$

$$\text{ORL, lbs soluble BOD/day/1000 } ft^2 = \text{2.6 lbs soluble BOD/day/1000 } ft^2$$

Hydraulic Loading

Another type of loading problem that involves attached growth units is that of hydraulic loading. It is very similar to the surface loading rate problem that was demonstrated at the beginning of the section. When applied to the attached growth facilities, however, the recirculation flow must be considered. The total flow applied to the treatment plant is the average daily flow to the plant plus the recirculation flow.

The formula for hydraulic loading, in gal/day sq ft, is written:

- **Hydraulic loading, GPD/sq ft =** $\frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

Example

What is the hydraulic loading, in GPD/sq ft, for a tickling filter plant that has a diameter of 120 feet and a depth of 6 feet if the plant has a daily flow of 1.25 MGD and a 65% recirculation rate?

In figuring the new flow (the average daily flow plus the recirculation flow), if the recirculation flow is given as a percent of the average daily flow, simply multiply the average daily flow by 1 and the decimal equivalent of the percent. This automatically adds in the recirculation flow.

1.25 MGD x 1.65 = 2.0625 MGD (the daily flow plus recirculation flow)

Now, calculate the surface area of this filter using the appropriate area formula:

$A = \pi \times R^2$

A = 3.14 x 60 ft x 60 ft

A = 11,304 sq ft

Now, use the hydraulic loading formula and the information that has been calculated, above:

$$\text{Hydraulic loading, GPD/sq ft} = \frac{\text{flow rate, gal/day}}{\text{surface area,sq ft}}$$

$$\text{Hydraulic loading, GPD/sq ft} = \frac{2{,}062{,}500 \text{ gal/day}}{11{,}304 \text{ sq ft}}$$

Hydraulic loading, GPD/sq ft = 182 gal/day/sq ft

This concludes the LOADINGS portion of this workbook. In the appendix, there is a multiple-choice test which covers all of the information in this chapter. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key. Use the formula sheet provided at the end of this workbook. Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER TWO

ACTIVATED SLUDGE

Traditionally, operators have the most difficulty understanding the activated sludge process control calculations. One reason is because most of the problems require the use of several formulas and calculations. Most students do not take the time to set the problem up correctly and become confused while performing the calculations. Use the process introduced in the Core workbook – draw a diagram if necessary, set the problem up in steps, and be sure to label each number with the appropriate units.

Sludge Volume Index (SVI)

The sludge volume index is an operational parameter for the activated sludge process. It is a calculation of which the result is used to indicate the settling ability of activated sludge in secondary clarifiers. It compares the volume of the sludge to its weight. In order to make this calculation, laboratory results for the 30 minutes settleable solids test and the mixed liquor suspended solids test are needed.

The formula for the SVI is written as follows. The units for SVI are mL/mg.

- **$\text{SVI} = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$**

Example

What is the SVI for a conventional activated sludge facility when the 30 minute settling is 420 mL/L and the MLSS is 3,300 mg/L?

$$\text{SVI} = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$$

$$\text{SVI} = \frac{\text{420 mL/L}}{\text{3,300 mg/L}} \times 1{,}000$$

SVI = 127 mL/mg *(in SVI calculations, the units mL/mg are usually left off)*

Sludge Density Index (SDI)

A calculation that is used similarly to SVI is the *sludge density index*, or SDI. SDI is the weight, in grams, of one mL of sludge after settling for 30 minutes.

The formula for sludge density index is written:

- **$\text{SDI} = \frac{100}{\text{SVI}}$**

Example

What is the SDI of the conventional activated sludge plant described in the previous example?

$$SDI = \frac{100}{SVI}$$

$$SDI = \frac{100}{127}$$

SDI = 0.79

Solids Inventory

The solids inventory is a basic calculation that is required for operational control in activated sludge treatment plants. The formula used in the pounds formula from the Core Workbook. However, since the pounds desired are located in the aeration tank, the capacity of the tank in MG is needed.

The tank volume and capacity may have to be calculated in solids inventory problems, and for this, use the appropriate volume formulas introduced in the Core Workbook. The mixed liquor suspended solids (MLSS), in mg/L, is a laboratory result, and is given in the problems.

The formula for solids inventory, or pounds of solids in the aeration tank, is written:

- **Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)**

<u>Example</u>

What is the solids inventory of a treatment plant with an aeration tank capacity of 0.220 MG and an MLSS of 2,800 mg/L?

Since the tank capacity is given, just substitute the known values into the formula:

Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.220 MG) x (2,800 mg/L) x (8.34 lbs/gal)

Solids, lbs = 5,137 lbs

Another type of solids inventory operators should be familiar with is the volatile solids inventory. This is done in the exact same way as the solids inventory above, except that the volatile solids or MLVSS in mg/L, is used in place of the MLSS.

The volatile solids may be given as a percentage of the MLSS. In order to get MLVSS from this, just multiply the MLSS by the decimal equivalent of the percent given. This is demonstrated in the example below.

<u>Example</u>

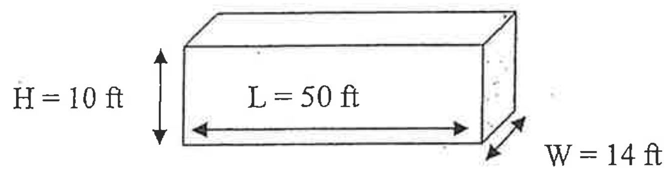
What is the volatile solids inventory of an activated sludge plant with an aeration tank that has a length of 50 feet, a width of 14 feet, and a depth of 10 feet if the average daily flow through the tank is 0.0650 MGD and the MLSS is 3,550 mg/L? Assume the volatiles to be 65 percent of MLSS.

In setting this problem up, notice that a flow is given. This is NOT needed in the calculation. However, the tank capacity in MG and the MLVSS are needed. Calculate those values as shown below:

V = L x W x H

V = 50 ft x 14 ft x 10 ft

V = 7,000 ft^3



7,000 ft^3 x 7.48 $\frac{gal}{ft^3}$

capacity, gal = 52,360 gal

capacity, MG = 0.05236 MG

Now, the given MLSS is 3,550 mg/L

3,550 mg/L x 0.65 = 2,308 mg/L *(the 0.65 is the decimal equivalent of the percent volatile solids)*

Volatile solids, mg/L = 2,308 mg/L

In substituting:

Volatile solids, lbs = (tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = (0.05236 MG) x (2,308 mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = 1,008 lbs

Sludge Age

Another important process control calculation is the sludge age. It is a measure of the length of time (in days) that suspended solids remain in the activated sludge process. It is calculated by dividing the weight of suspended solids added per day to the aeration tank into the weight of suspended solids under aeration (the solids inventory).

The formula for sludge age is written:

- **Sludge age, days** = $\frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

This is the same as writing the formula as:

- **Sludge age, days** = $\frac{\text{(Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)}}{\text{(Flow, MGD) x (TSS influent, mg/L) x (8.34 lbs/gal)}}$

If either the solids inventory, in pounds, or the pounds of solids being added daily are given, or possibly both, it is easier to substitute those values into the first formula. If calculations are necessary to obtain the values needed to substitute into the formulas, it is less confusing to use the second formula given above. The tank capacity may have to be calculated, however, and this should be treated as a separate problem altogether, as will be shown in the example.

Example

What is the sludge age for the activated sludge plant described below?

Aeration tank:	80 ft = L, 20 ft = W, 15 ft = D
MLSS:	4,025 mg/L
TSS, influent:	235 mg/L
Daily flow:	525,000 gpd
Volatile solids:	68 % of MLSS

First, calculate the aeration tank capacity using the appropriate volume formula. The dimensions are all in feet, so no conversions are necessary.

V = L x W x H

V = 80 ft x 20 ft x 15 ft

V = 24,000 ft^3

Capacity, gallons = $24{,}000\ ft^3 \times 7.48\ \frac{gal}{ft^3}$ =

179,520 gallons or 0.180 MG

Notice that a percentage of volatiles is given. This is not necessary in calculating the sludge age, so just disregard it.

$$\text{Sludge age, days} = \frac{(\text{Tank cap, MG}) \times (\text{MLSS, mg/L}) \times (8.34\ \text{lbs/gal})}{(\text{Flow, MGD}) \times (\text{TSS influent, mg/L}) \times (8.34\ \text{lbs/gal})}$$

$$\text{Sludge age, days} = \frac{(0.18\ \text{MG}) \times (4{,}025\ \text{mg/L}) \times (8.34\ \text{lbs/gal})}{(0.525\ \text{MGD}) \times (235\ \text{mg/L}) \times (8.34\ \text{lbs/gal})}$$

$$\text{Sludge age, days} = \frac{724.5}{123.4\ \text{days}}$$

Sludge age, days = 5.9 days *(notice that all units except for days cancel)*

F/M Ratios

The F/M, or food to microorganism ratio, is an operational control parameter based upon the pounds of food available (pounds of BOD) and the pounds of microorganisms (volatile solids) present to consume this food. Metabolism of the microorganisms results in an increased mass of microorganisms in the system. The excess microorganisms are removed (wasted) from the system to maintain the proper balance between food supply and the mass of microorganisms in the aeration tank.

A high F/M ratio is characterized by excess food and poor settling characteristics. The settling tank is not as effective in separating microorganisms form the effluent, and there is excess unused organic matter in solution which will not be consumed by the microorganisms and consequently will pass out in the effluent, contributing to poor overall treatment.

At a low F/M ratio, overall metabolic activity in the aeration tank may be considered near the endogenous stage in that competition for the small amount of food available to the large mass of microorganisms results in near-starvation conditions in a very short time. Under these conditions, even though the rate of metabolism of the microorganisms is relatively low, settling characteristics in the sedimentation tank is quite good and the consumption of the food in nearly complete.

The formula for calculating F/M ratios is written as follows:

- **F/M, lbs/day/lb =** $\frac{\text{(inf. BOD, mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

Notice that the formula is just two pounds formulas, the top being the pounds of BOD added per day, and the bottom being the volatile solids inventory in pounds. Remember that the volatile solids are representative of the amount of microorganisms present. The units will be lbs/day/lb, but are usually left off.

Example

What is the F/M ratio for a treatment plant if the following information is given?

Aeration tank capacity:	0.220 MG
Influent BOD:	205 mg/L
Daily flow:	0.300 MGD
MLVSS:	1,700 mg/L

F/M, lbs/day/lb = $\frac{\text{(inf. BOD,mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{(205 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}{\text{(0.220 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{512.9 lbs/day}}{\text{3,119 lbs}}$

F/M = 0.16

(this means that for every hundred pounds of microorganisms, there are 16 pounds of food)

As stated previously, F/M ratios are usually expressed without any units.

Mean Cell Residence Time

MCRT, or mean cell residence time, is another way that the theoretical amount of time that microorganisms spend in the activated sludge process can be calculated. Solids retention in activated sludge systems is measured in days whereas liquid retention is measured in hours. Remember that the solids are recycled in the system from the final clarifier back to the aeration tank, while the liquid flows through the aeration tank, into the clarifier, and out of the process as effluent.

MCRT involves three pounds formulas – the first is the solids inventory, which measures the pounds of MLSS in the aeration tank. On the bottom of the formula, the effluent solids in pounds is a function of the daily flow and the total suspended solids (TSS), in mg/L, of the effluent. Also on the bottom, the WAS, or waste activated sludge in pounds is a function of the sludge intentionally wasted in MG and the concentration of this sludge in mg/L.

The MCRT formula is written as follows:

- $$\text{MCRT} = \frac{\text{solids inventory, lbs}}{\text{(effluent solids, lbs)} + \text{(WAS solids, lbs)}}$$

You may also see the formula written as follows. Both formulas are the same.

$$\text{MCRT} = \frac{\text{(Aeration tank cap, MG)} \times \text{(MLSS,mg/L)} \times \text{(8.34 lbs/gal)}}{[\text{(Flow, MGD)} \times \text{(TSS eff, mg/L)} \times \text{(8.34 lbs/gal)}] + [\text{(WAS flow, MGD)} \times \text{(WAS,mg/L)} \times \text{(8.34 lbs/gal)}]}$$

In working MCRT problems, it is less confusing if the first formula is used. If calculations are necessary in order to substitute numbers in the formula, just treat each calculation as a separate pounds problem, then substitute the values into the MCRT formula as in the example shown below.

Example

What is the MCRT of the activated sludge plant described?

Aeration tank capacity:	150,000	gallons
MLSS:	2,250	mg/L
Daily flow:	820,000	gallons per day
TSS, effluent:	5.0	mg/L
WAS, mg/L:	10,500	mg/L
WAS flow, daily:	6,000	gallons per day

First, determine the amount of solids in the aeration tank, or solids inventory.

Solids, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.150 MG) x (2,250 mg/L) x (8.34 lbs/gal)

Solids, aeration, lbs = 2,815 lbs

Now, determine the amount of solids lost in the effluent daily.

Solids, effluent lbs/day = (Flow, MGD) x (TSS effluent, mg/L) x (8.34 lbs/gal)

Solids, effluent lbs/day = (0.82 MGD) x (5 mg/L) x (8.34 lbs/gal)

Solids, effluent, lbs/day = 34 lbs

Finally, determine the pounds of solids wasted daily.

WAS, lbs = (WAS, MG) x (WAS, mg/L) x (8.34 lbs/gal)

WAS, lbs = (0.006 MG) x (10,500 mg/L) x (8.34 lbs/gal)

WAS, lbs = 525 lbs/day

Now that all of the information is available and ready to substitute, proceed with the formula.

$$\text{MCRT} = \frac{\text{solids inventory, lbs}}{(\text{effluent solids, lbs}) + (\text{WAS solids, lbs})}$$

$$\text{MCRT} = \frac{2{,}815 \text{ lbs}}{(34 \text{ lbs/day}) + (525 \text{ lbs/day})}$$

MCRT = 5 days

WAS Pumping Rates

If a plant runs well in a certain MCRT, and that MCRT is to be maintained, a certain amount of sludge must be wasted daily. If a new MCRT must be met, the following formulas can be used to calculate a wasting rate to achieve that desired MCRT.

- **WAS, lbs/day** $= \frac{\text{(solids inventory, lbs)}}{\text{desired MCRT, days}}$ **- (solids lost in effluent, lbs/day)**
- **WAS flow, MGD** $= \frac{\text{WAS, lbs/day}}{(\text{WAS, mg/L}) \times (8.34 \text{ lbs/gal})}$

<u>Example</u>

An activated sludge plant was determined to have a MCRT of 5 days under present operating conditions. The desired MCRT for this facility is 8 days. The amount of solids lost in the effluent daily is 34 pounds. The solids inventory of the plant is kept at 2,815 pounds. The WAS concentration is 10,500 mg/L. What WAS pumping rate is necessary to achieve the desired MCRT?

$$\text{WAS, lbs/day} = \frac{\text{(solids inventory, lbs)}}{\text{desired MCRT, days}} - \text{(solids lost in effluent, lbs/day)}$$

$$\text{WAS, lbs/day} = \frac{\text{(2,815 lbs)}}{\text{8 days}} - \text{(34 lbs/day)}$$

WAS, lbs/day = 351.9 lbs/day - 34 lbs/day

WAS, lbs/day = 318 lbs/day

Now, use the second formula to get these units into a flow:

$$\text{WAS flow, MGD} = \frac{\text{WAS, lbs/day}}{\text{(WAS, mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{\text{318 lbs/day}}{\text{(10,500 mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{318}{(87{,}570)}$$

WAS flow, MGD = 0.0036 or 3,600 gallons per day

Changing Sludge Pumping Rates

The *constant MLSS* method technique of process control is simple to understand and requires a minimum amount of laboratory work. As long as the incoming wastewater characteristics remain fairly constant with minimal variations in flow rates, a good quality effluent can be produced using this method. When the MLSS begins to rise, it is time to change the sludge pumping rate. The present sludge pumping rate should already be known.

The control technique is implemented by choosing an MLSS concentration which has been found to produce a high quality effluent. Therefore, before an operator begins to use this method, the plant's past operation records and process control data must be researched.

This method has its drawbacks, however. It does not account for variations in flow, influent BOD, amount of solids remaining in the secondary clarifier, and microorganism growth rates.

This method can also be used with the MLVSS instead of MLSS. The results will be the same, but choose either MLSS or MLVSS. NEVER combine the two in the formula.

To change, or adjust the sludge pumping rate, use this formula:

- **Change, WAS rate, MGD** $= \frac{\text{(current SI)} - \text{(desired SI)}}{\text{WAS}, \frac{mg}{L} \times 8.34 \frac{lbs}{gal}}$

Example

An extended aeration plant has been observed to produce an excellent effluent over a period of time with an MLSS concentration of 2,555 mg/L and a WAS pumping rate of 18 gallons per minute. Currently, the effluent quality has deteriorated and the MLSS under aeration has risen to 3,350 mg/L. The WAS has a value of 10,500 mg/L. If the aeration tank capacity is 440,000 gallons, what is the change in sludge pumping rate in order to achieve the desired MLSS and the NEW sludge pumping rate?

First, calculate the CURRENT solids inventory.

SI, current = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, current = (0.440 MG) x (3,350 mg/L) x (8.34 lbs/gal)

SI, current = 12,293 lbs

Now, calculate the DESIRED solids inventory.

SI, desired = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, desired = (0.440 MG) x (2,555 mg/L) x (8.34 lbs/gal)
SI, desired = 9,376 lbs

Now, use the change in WAS flow formula, substituting the values that have just been calculated:

$$\text{WAS change, MGD} = \frac{(\text{current SI}) - (\text{desired SI})}{\text{WAS, mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{(12{,}293\ \text{lbs}) - (9{,}376\ \text{lbs})}{10{,}500\ \text{mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{2917\ \text{lbs}}{87{,}570\ \text{lbs/gal}}$$

WAS change, MGD = 0.033 MGD or 33,000 gal/day

Now the pumping rate can be changed to gallons per minute by using the following conversion:

$$\frac{33{,}000\ \text{gal/day}}{1{,}440\ \text{min/day}} = 22.9 \text{ or } 23 \text{ gal/min}$$

The old WAS pumping rate was 18 gal/min, and the change, as calculated, is 23 gal/min. The new pumping rate is equal to the OLD plus the NEW.

23 gal/min + 18 gal/min = 41 gal/min

Return Sludge Rate

A simple way to estimate the proper return sludge pumping rate for an activated sludge facility is by using the results from the 30 minute settleable solids test.

The formula is written:

- **Return sludge rate, MGD =** $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) − (set. solids, mL)}}$

Example

What is the proper return sludge rate in gallons per minute for an activated sludge plant that has an average daily flow of 2.0 MGD and a settleable solids concentration of 350 mL?

Return sludge rate, MGD = $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) − (set. solids, mL)}}$

Return sludge rate, MGD = $\frac{\text{(350 mL) x (2.0 MGD)}}{\text{(1,000 mL) − (350 mL)}}$

Return sludge rate, MGD = $\frac{\text{700 MGD}}{\text{650}}$

Return sludge rate, MGD = 1.08 MGD

Now the MGD can be changed to gallons per minute:

$\frac{\text{1,080,000 gal/day}}{\text{1,440 min/day}}$ = 750 gal/min

This concludes the activated sludge process control portion of this program. In the appendix, there is a multiple-choice test which covers all of the information in this section. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key.

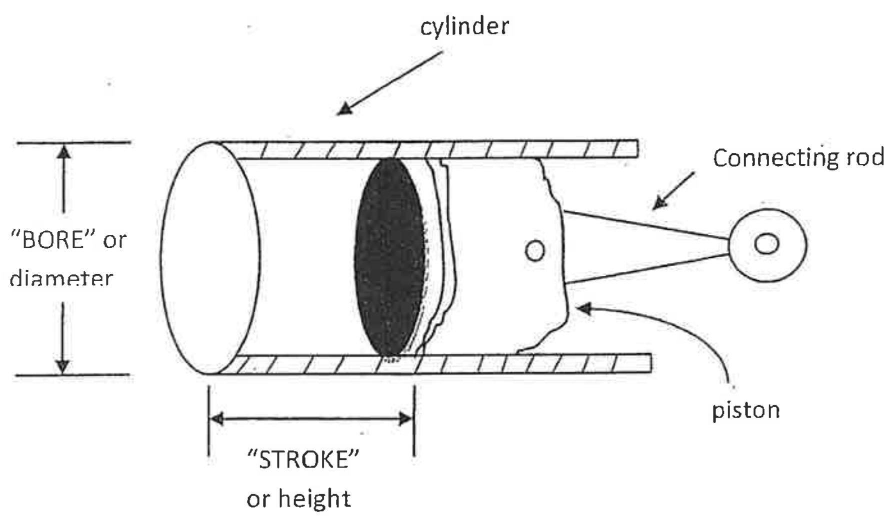
Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER THREE

SLUDGE DIGESTION

Sludge Pumping

Positive displacement pumps are used in wastewater to handle sledges. One type of positive displacement pump is the piston pump. Sometimes operators must calculate the capacity of piston pumps and how many gallons of sludge will be pumped over a period of time. As shown in the diagram below, a piston moves back and forth over a distance called the *stroke*. The width of the piston, or its diameter, is called the *bore*. Every time the piston moves upward and downward in the cylinder (*called a revolution*) it pumps the volume of water contained in the cylinder.



Calculating the capacity of piston pumps is similar to calculating the volume of a cylinder.

Example

What is the capacity, in gallons per minute, of a piston pump that has a bore of 4 inches and a stroke of 8 inches if it pumps 30 revolutions (rev) per minute?

Calculate the volume of the cylinder in the pump using the volume of a cylinder formula:

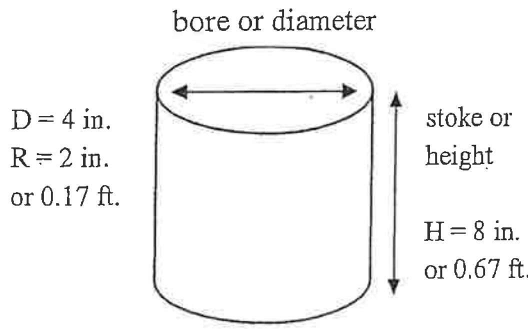
$V = \pi \times R^2 \times H$

$V = 3.14 \times 0.17\ ft \times 0.17\ ft \times 0.67\ ft$

$V = 0.061\ ft^3$

$0.061\ cu\ ft \times 7.48\ gal/ft^3 =$

Capacity = 0.46 gal



This means that for every revolution, the pump pumps 0.46 gallons of sludge.

0.46 gal/rev x 30 rev/min = 13.8 gal/min

The units "rev" cancel out and gal/min is left.

Dry Solids

If the percent total solids in sludge is known, the pounds of dry solids that are handled can be calculated.

The formula for dry solids, in pounds, is written:

- **Dry solids, lbs** = $\frac{\text{(raw sludge, gal) x (raw sludge, \% solids) x (8.34 lbs/gal)}}{\text{100 \%}}$

Example

Each day, 6,500 gallons of raw sludge are pumped to a disposal area. This sludge contains 6.0% total solids. How many pounds of dry sludge are handled per day?

Dry solids, lbs = $\frac{\text{(6,500 gal) x (6.0 \%) x (8.34 lbs/gal)}}{\text{100 \%}}$

Dry solids, lbs = $\frac{\text{325,260 lbs}}{100}$

Dry solids, lbs = 3,253 lbs

Sometimes the pounds of volatile solids (VS) contained in a known volume of sludge must be calculated. The percentage of volatile solids in the sludge will be given in this case. Multiply the pounds of total solids by the decimal equivalent of the percent volatile solids are shown below.

Example

Using the dry solids example above, if the lab has determined that the volatile solids content of the sludge being disposed of is 72%, how many pounds of volatile solids are being disposed of daily?

3,253 lbs x 0.72 =

Volatile solids, lbs = 2,342 lbs

Seed Sludge, Volatile and Suspended Solids Pumping

In startup of anaerobic digesters, seed sludge is sometimes required. The seed sludge can be added based upon the capacity of the digester tank, or by the amount of raw sludge which will be added to the digester.

If the sludge is added based upon the capacity of the digester, just multiply the capacity of the digester by the percentage of seed sludge that is necessary.

Example

A digester measures 14 feet in depth and has a diameter of 24 feet. In starting this digester, it is recommended that the digester be filled to 25% of the tank volume in seed sludge. How many gallons of seed sludge must be added?

First, calculate the digester capacity in gallons. It is a circular tank, so the volume of a cylinder formula is used:

$V = \pi \times R^2 \times H$

V = 3.14 x 12 ft x 12 ft x 14 ft

$V = 6{,}330 \text{ ft}^3$

$6{,}330 \text{ cu ft} \times \frac{7.48 \text{ gal}}{\text{ft}^3} =$

47,350 gallons *(digester capacity)*

47,350 gal x 0.25 = 11,838 gallons of seed required

(NOTE: the 0.25 is the decimal equivalent of the percent of tank volume required to be filled.)

Another method of calculating seed sludge (SS) depends upon the gallons of raw sludge (RS) that will be added initially, the solids content of the raw sludge (RSS), and the percent volatiles of the raw sludge (RSV). A loading factor will also be given, which will usually be between 0.03 and 0.10, and this means that there can be 0.03 to 0.10 pounds of raw volatile solids (RSV) added for every pound of volatile solids (VS) already under digestion.

The formulas necessary to accomplish this are written using the abbreviations above:

- **VS pumped, lbs/day** $= \dfrac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\ \text{lbs/gal})}{(100\ \%)\quad(100\ \%)}$

- **Seed sludge, lbs VS** $= \dfrac{\text{VS pumped, lbs VS / day}}{\text{Loading factor, lbs VS/day/lb VS in digester}}$

- **Seed sludge, gallons** $= \dfrac{\text{Seed sludge, lbs VS}}{(\text{SS, lbsgal})\left(\dfrac{\text{Solids \%}}{100\ \%}\right)\left(\dfrac{\text{VS \%}}{100\ \%}\right)}$

Example

A new digester is going on line as part of a plant expansion. How many pounds of volatile solids will be pumped to the digester per day and how many gallons of seed sludge will be necessary to start this digester if the following information is given?

• Raw sludge, gal/day:	650
• Raw sludge solids, %	5.5 %
• Raw sludge volatiles, %	70 %
• Seed sludge solids, %	8.5 %
• Seed sludge volatiles, %	58 %
• Wt. of seed sludge, gal:	9.5 lbs/gal
• Loading factor:	0.05 lbs VS/day per lb VS under digestion

First, calculate the pounds of volatile solids that will be pumped to the digester daily.

$$\text{VS pumped, lbs/day} = \frac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\ \text{lbs/gal})}{(100\ \%)\ (100\ \%)}$$

$$\text{VS pumped, lbs/day} = \frac{(650\ \text{gal/day})(5.5\ \%)(70\ \%)(8.34\ \text{lbs/gal})}{(100\ \%)(100\ \%)}$$

$$\text{VS pumped, lbs/day} = \frac{2{,}087{,}085\ \text{lbs/day}}{10{,}000}$$

VS pumped, lbs/day = 209 lbs VS/day

Now, find the pounds of seed volatile solids needed:

$$\text{SS, lbs volatile solids} = \frac{\text{VS pumped, lbs VS / day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$$

$$\text{SS, lbs volatile solids} = \frac{209\ \text{lbs VS / day}}{0.05\ \text{lbs VS/day/lb VS in digester}}$$

SS, lbs volatile solids = 4,180 lbs VS

In order to seed the digester with 4,180 pounds of volatile solids, it is necessary to convert the pounds of VS to gallons of seed sludge.

$$\text{SS, gal} = \frac{\text{SS, lbs VS}}{(\text{SS, lbs/gal})\left(\frac{\text{solids \%}}{100\ \%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\left(\frac{8.5\ \%}{100\ \%}\right)\left(\frac{58\ \%}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\ (0.085)\ (0.58)}$$

$$\text{SS, gal} = \frac{4{,}180}{0.47}$$

SS, gal = 8,894 gallons of seed sludge

Neutralizing Upset Digesters

If an anaerobic digester becomes upset, sometimes it is necessary to add lime to neutralize it. The lime required to neutralize an upset digester is estimated using the pounds formula.

The formula for neutralizing a sour or upset digester using lime is written:

- **Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)**

<u>Example</u>

An anaerobic digester is upset and should be neutralized with lime. If the digester contains 45,000 gallons of sludge and the volatile acids content is 2,980 mg/L, how many pounds of lime are required?

lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

lime req'd, lbs = (0.045 MG) x (2,980 mg/L) x (8.34 lbs/gal)

lime req'd, lbs = 1,118 lbs of lime

Percent Reduction of Volatile Solids

The percent reduction of volatile solids in a digester as the result of digestion is a calculation that operators need to perform.

The formula for percent reduction of volatile solids is written as follows:

- **% reduction** $= \frac{\textbf{(in−out) x (100\%)}}{\textbf{in − (in x out)}}$

Example

An anaerobic digest is operating properly. The raw sludge has a volatile solids content of 72% and the digested sludge has a volatile content of 47%. What is the percent reduction of volatile solids accomplished by this digester?

$$\% \text{ reduction} = \frac{(\text{in}-\text{out}) \times (100\,\%)}{\text{in}-(\text{in} \times \text{out})}$$

$$\% \text{ reduction} = \frac{(0.72 - 0.47) \times (100\,\%)}{0.72 - (0.72 \times 0.47)}$$ *(NOTE that the percentages are expressed as decimals)*

$$\% \text{ reduction} = \frac{0.25\ (100\,\%)}{0.72 - 0.338}$$

$$\% \text{ reduction} = \frac{25\,\%}{0.382}$$

$$\% \text{ reduction} = 65\ \%$$

Volatile Solids Destroyed

The information used in calculating volatile solids percent reduction can be used to calculate the pounds of volatile solids destroyed per day per cubic foot of digester space.

The formula for estimating pounds of volatile solids destroyed in written:

- **VS destroyed, lbs/day/cu ft** $= \frac{\textbf{(VS added, lbs/day) (VS reduction, \%)}}{\textbf{(digester volume, cu ft) (100 \%)}}$

Example

How many pounds of volatile solids are destroyed per day if a digester has a volume of 22,750 cubic feet and 8,800 pounds of volatiles are added per day with a percent reduction due to digestion of 65%?

$$\text{VS destroyed, lbs/day/cu ft} = \frac{(\text{VS added, lbsday})\ (\text{VS reduction, }\%)}{(\text{digester volume, cu ft}) \times (100\,\%)}$$

$$\text{VS destroyed, lbs/day/cu ft} = \frac{(8{,}800 \text{ lbs/day})\ (65\,\%)}{(22{,}750 \text{ cu ft})\ (100\ \%)}$$

$$\text{VS destroyed, lbs/day/cu ft} = \frac{(572{,}000 \text{ lbs / day})}{(2{,}275{,}000 \text{ cu ft})}$$

$$\text{VS destroyed, lbs/day/cu ft} = 0.25 \text{ lbs/day/cu ft}$$

A precaution that should be taken in this type of problem is that the volume of the digester may need to be calculated. *Remember that cubic feet are required, not the capacity in gallons*. Also, volatiles may be given in gallons added instead of pounds. In this case, the weight of one gallon of the volatiles will be given so a calculation *from gallons to pounds* can be made.

Digester Gas Production

Another digestion problem involving anaerobic digestion is the amount of gas production as related to the volatile solids destroyed. Gas production is dependent upon the amount of volatiles destroyed per day per cubic foot of digester space, as described in the example illustrated above.

The formula for calculating gas production is written as follows:

- **Gas production, cu ft/ lb VS =** $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Example

An anaerobic digester destroys 988 pounds of volatile solids daily. The gas meter indicates that 12,750 cubic feet of gas are produced each day. How many cubic feet of gas are produced per pound of volatile solids destroyed?

Gas production, cu ft/lb VS = $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Gas production, cu ft/lb VS = $\frac{\text{(12,750 cu ft/day)}}{\text{(988 lbs/day)}}$

Gas production, cu ft/lb VS = 13 cu ft gas / lb of VS destroyed

This concludes the sludge digestion portion of the program. A 10 question multiple choice test can be found in the appendix. Do your work on a separate sheet of paper, and feel free to refer to the formula sheet at the beginning of this workbook.

CHAPTER FOUR

HORSEPOWER, FORCE, FEED PUMPS

Horsepower

One horsepower is equal to 33,000 ft-lbs per minute. This means that one horsepower is the same as lifting one pound of a vertical distance of 33,000 feet in a period of one minute. If the discharge from a pump is converted into the weight of water and this weight is multiplied by the vertical distance it is lifted (head), and it is known that 1 horsepower is equal to 33,000 ft-lbs/min, a formula for water horsepower can be written. Water horsepower is the *horsepower required to lift water*.

The formula for water horsepower is written:

- **Water HP** $= \dfrac{\text{(flow, gal/min) x (head, feet)}}{\text{(3,960 gal/min/ft}}$

The 3,960 at the bottom of the formula is derived from dividing 33,000 ft-lbs per minute, which is the equivalent of one horsepower, by 8.34 lbs/gal, which is the weight of one gallon of water. The units for the 3,960 are gal/min/ft, which cancel out with the units in the numerator of the formula.
(The units are usually left off the 3,960 in the formula to avoid confusion.)

Each pump has its own characteristics relative to power requirements and efficiency. No pump is 100 percent efficient, with the normal range of efficiency being between 50% and 85% for centrifugal pumps. Pump efficiency usually increases with the size and capacity of the pump.

The horsepower applied from the motor to the pump is called the Brake Horsepower, or BHP. The formula for brake horsepower takes into account the pump efficiency, or Ep. *The Ep is always expressed in the formula as a decimal.*

The BHP formula is written:

- **BHP** $= \dfrac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960 gal/min/ft) x (Ep)}}$

The motors that drive pumps are also not 100 percent efficient. Motor efficiency is usually in the range of 80 to 90 percent, and this is expressed as Em. *In the formula, the motor efficiency percent is always expressed as a decimal.*

The formula for motor horsepower is written:

- **Motor HP** $= \dfrac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960) x (Ep) x (Em)}}$

The above formulas work well when pumping water with a specific gravity of 1.0. If liquids with a greater specific gravity such as sludge are being pumped, more horsepower will be required. In this case, multiply the calculated horsepower by the specific gravity of the liquid being pumped. Sludges are heavier than water and have a specific gravity of greater than one. Therefore, multiplying the calculated horsepower by a number greater than one will cause the horsepower number to increase.

Example

An effluent pumping station is to be designed for a capacity of 1,200 gallons per minute at a total head of 80 feet. What is the pump horsepower and the motor horsepower that will be required if Ep is 65% and the Em is equal to 82%?

$$\text{BHP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep})}$$

$$\text{BHP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65)}$$

$$\text{BHP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}574}$$

$$\text{BHP} = 37$$

In solving for motor HP:

$$\text{Motor HP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep}) \times (\text{Em})}$$

$$\text{Motor HP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65) \times (0.82)}$$

$$\text{Motor HP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}111}$$

$$\text{Motor HP} = 45 \text{ HP}$$

Force

In the Core Workbook, pressure and head were introduced. Pressure creates a force. Force calculations can become very important to wastewater plant operators when applied to tank bottoms and tank walls. If a tank is emptied during periods where the ground water table is very high, the pressure exerted on the tank bottom by the ground water can float the tank out of the ground.

The formula for calculating the upward force on a tank bottom is written:

- **Force, lbs = 62.4 lbs/cu ft x height, ft x area, sq ft**

NOTE: the 62.4 lbs/cu ft represents the weight of one cubic foot of water (8.34 lbs/gal x 7.48 gal/cu ft)

Example

What is the upward force, in pounds, on the bottom of an empty tank when the groundwater is 6 feet above the tank bottom and the tank is 40 feet long, 20 feet wide, and 16 feet in depth?

In the text of the problem, a depth is given. It is not necessary in solving this problem. Calculate the area of the tank bottom first.

A = L x W

A = 40 ft x 20 ft

A = 800 sq ft

Now, use the force formula:

Force, lbs = 62.4 lbs/cu ft x Height, ft x Area, sq ft

Force, lbs = 62.4 lbs/cu ft x 6 ft x 800 sq ft

Force, lbs = 299,520 lbs

(Notice how the units cancel, leaving pounds)

Another calculation concerning force and pressure is that of the force created by water on the side wall of a tank. The pressure at the bottom of the wall is different from the pressure at the water level, or top of the wall. The pressure at the surface is 0 psi, but the pressure at the bottom of the tank is equal to 0.433 times the height of the water in the tank.

The formula for calculating the force acting on the side wall of any tank is written:

- **Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)**

Example

A tank is 40 feet long, 10 feet deep, and 16 feet in width. What is the force, in pounds, acting along the length of this tank wall when it is full?

Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)

Force, lbs = (31.2 lbs/cu ft) x (10 ft)^2 x (40 ft)

Force, lbs = 31.2 lbs/cu ft x 10 ft x 10 ft x 40 ft

Force, lbs = 124,800 lbs

Chemical Solutions and Feed Pumps

Sometimes in wastewater treatment the setting in percent stroke of a chemical feeder must be determined. The chemical solutions come in various solution strengths and are fed in doses measured in milligrams per liter.

Usually, adjusting feeders is accomplished by turning a knob or hand crank on the feeder itself. The feeder has a rate scale with a pointer, calibrated over a range from 0 to 100 percent.

In order to calculate the setting of a solution chemical feeder, it may be necessary to convert a solution strength in percent into pounds of chemical per gallon of solution. The formula for this is written:

- **Chemical sol'n, lbs/gal** $= \frac{(\text{sol'n }\%) \times (8.34\text{ lbs/gal})}{100\ \%}$

The desired flow, in gallons per day, may also have to be calculated.

The formula is written as shown:

- **Feed pump gal/day** $= \frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

The time unit gal/day could just as well be gal/hr or gal/min. Be sure that you keep track of the time units and do the unit conversions properly.

Now that the amount of solution needed (in gallons per time unit) has been established, it is easy to set the pump.

The formula for solution chemical feeders is written:

- **Scale setting, %** $= \frac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$

The chemical required, in pounds per day, pounds per hour, or whatever time unit is being used, may also have to be estimated. For this, the pounds formula is used. It is written below.

- **Chemical req'd, lbs/day = (Flow, MGD) x (dose, mg/L) x (8.34 lbs/gal)**

Example

A solution feeder has a scale that reads in percent. The maximum output of this feeder is 40 gallons per day. A polymer solution must be fed which will result in a chemical dose of 2.5 mg/L to a flow of 0.450 MGD. At what percent should the chemical feeder be set if the polymer being fed is in a 6 percent solution?

In solving this problem, notice that the pump output is in gallons per day and the flow is given in gallons per day. Therefore, it is best to set up the formulas using days as the time unit.

First, calculate how many pounds per gallon are contained in a 6% chemical solution.

$$\text{Chemical sol'n, lbs/gal} = \frac{(\text{sol'n\%}) \times (8.34 \text{ lbs/gal})}{100\ \%}$$

$$\text{Chemical sol'n, lbs/gal} = \frac{(6\ \%) \times (8.34 \text{ lbs/gal})}{100\ \%}$$

$$\text{Chemical sol'n, lbs/gal} = \frac{50 \text{ lbs/gal}}{100}$$ *(NOTE: The % units cancel out.)*

Chemical sol'n, lbs/gal = 0.5 lbs/gal

Now, figure the chemical requirement in milligrams per liter.

Chem. req'd, lbs/day = Flow, MGD x dose, mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 0.450 MGD x 2.5 mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 9.4 lbs/day

Now, calculate the output required of the feed pump.

$$\text{Feed pump, gal/day} = \frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$$

$$\text{Feed pump, gal/day} = \frac{9.4 \text{ lbs/day}}{0.5 \text{ lbs/gal}}$$

Feed pump, gal/day = 18.8 gal/day

Now, use the *scale setting* formula.

$$\text{Scale setting, \%} = \frac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$$

$$\text{Scale setting, \%} = \frac{(18.8 \text{ gal/day})\ (100\ \%)}{40 \text{ gal/day}}$$

$$\text{Scale setting, \%} = \frac{1{,}800\ \%}{40}$$ *(NOTE: the units 'gal/day' cancel)*

Scale setting, % = 47 %

This concludes this section of the workbook. A ten question test in is in the appendix, covering all subjects contained in this section, and some possible review questions from previous sections. Some of the problems in the test will require several calculations. Be sure to set these problems up using the steps as outlined in the examples. Draw a simple diagram where necessary.

CHAPTER FIVE

LAB PROCEDURES AND MEASUREMENTS

Suspended Solids Calculations

In order to calculate suspended solids concentrations from laboratory results, the follow information must be known:

- Sample volume, mL
- Wt. of crucible, grams
- Wt. of crucible and dry residue, grams
- Wt. of crucible and ash, grams

When the above information is given, the following parameters can be calculated:

- Total suspended solids, mg/L
- Volatile suspended solids, mg/L
- Volatile suspended solids, %
- Fixed suspended solids, mg/L
- Fixed suspended solids, %

To calculate the total suspended solids, the formula is written:

- **TSS, mg/L =** $\frac{(\text{RDD}-\text{DD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
1 M = 1 million

The formula for calculating fixed suspended solids, a subtraction is necessary:

- **VSS, mg/L =** $\frac{(\text{RDD}-\text{FDD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
FDD = fired residue + dish + disc, grams
1 M = 1 million

To calculate fixed suspended solids, a subtraction is necessary:

- **Fixed solids, mg/L = TSS, mg/L – VSS, mg/L**

TSS = total suspended solids
VSS = volatile suspended solids

In order to calculate the percent of volatile and fixed solids, use these formulas:

- **Volatile solids, %** = $\frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}}$ x **100%**

- **Fixed solids, %** = $\frac{\text{fixed solids, mg/L}}{\text{TSS, mg/L}}$ x **100%**

<u>**Example**</u>

A lab technician obtains the following results from a suspended solids test. What are the total suspended solids, volatile suspended solids, and percent of volatile suspended solids?

Sample volume:	10 mL
Wt. of dish + filter:	21.7319 grams
Wt. of dish + filter + dry residue:	21.7714 grams
Wt. of dish + filter + ash:	21.7387 grams

TSS, mg/L = $\frac{\text{(RDD−DD) x 1 M}}{\text{sample vol, mL}}$

TSS, mg/L = $\frac{(21.7714\text{ g} - 21.7319\text{ g})}{10\text{ mL}}$ x 1,000,000

TSS, mg/L = 3,950 mg/L

VSS, mg/L = $\frac{\text{(RDD−FDD)}}{\text{sample volume, mL}}$ x 1 M

VSS, mg/L = $\frac{(21.7714\text{ g} - 21.7387\text{ g})}{10\text{ mL}}$ x 1,000,000

VSS, mg/L = 3,270 mg/L

Volatile solids, % = $\frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}}$ x 100 %

Volatile solids, % = $\frac{3{,}270\text{ mg/L}}{3{,}950\text{ mg/L}}$ x 100%

Volatile solids, % = 83 %

Biochemical Oxygen Demand

If a sample contains high levels of organic material, the BOD result will be high and small portions of the sample should be used in the dilution. If a sample has a low BOD, such as a final wastewater effluent or a lake, larger portions of sample will be necessary. When using the standard 300 mL BOD bottles, the amount of sample to add can be calculated if an estimate of the BOD can be made.

The formula for BOD sample size is written:

- **Size of sample, mL** = $\frac{1{,}200\ (mg/L)\ (mL)}{\text{estimated BOD, mg/L}}$

(The '1,200' comes from the most valid BOD oxygen depletion, 4 mg/L, times the standard BOD bottle volume, 300 mL)

Example

The BOD of an industrial waste treatment facility is estimated to be 470 mg/L. How many mL of actual sample should be added to the standard BOD bottle in preparation of the BOD test?

Size of sample, mL = $\frac{1{,}200}{\text{estimated BOD, mg/L}}$

Size of sample, mL = $\frac{1{,}200}{470\ mg/L}$

Size of sample, mL = 2.6 mL or 3 mL

When the BOD cannot be estimated, select more than one sample size. Use a range of samples such as 1 mL, 3 mL, 6 mL, and 12 mL.

When testing a BOD sample that has been chlorinated, such as in a wastewater final effluent, a seed must be added. The calculations for the BOD test with seed vary slightly from the BOD test without the use of seed. Both formulas and information necessary are below.

In order to calculate a 5-day BOD that is unseeded, the following information is necessary.

- Sample volume, mL
- Initial dissolved oxygen, mg/L
- Final dissolved oxygen, mg/L
- Bottle volume, mL

To calculate a 5-day BOD using seed, the information above *and* the additional information below is used.

- Seed added to sample, mL
- Seed added to blank, mL
- Initial seed dissolved oxygen, mg/L
- Final seed dissolved oxygen, mg/L
- Seed correction factor, mg/L

When using seed, a *seed correction factor* must be calculated first. The *seed correction factor* is determined by actually conducting a separate BOD test on the seed itself. A measured amount of seed material is placed in a blank of dilution water and incubated for 5 days.

The formula for finding the seed correction factor is written:

- **Seed correction for 1 mL of seed =** $\frac{\text{initial D.O.} - \text{final D.O.}}{\text{mL of seed added to blank}}$

If more than 1 mL of seed is to be used in any BOD bottle, multiply the calculated *seed correction factor* for that particular seed material by the mL of seed being used in that BOD bottle.

The formula for calculating BOD with a *seed* is written:

- **BOD, mg/L =** $\frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

The formula for calculating BOD *without seed* being added is written:

- **BOD, mg/L =** $\frac{[(\text{Initial D.O.}) - (\text{Final D.O.})] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

<u>Example</u>

A BOD sample is run for a chlorinated effluent from a conventional activated sludge plant. What is the BOD if the following information is known?

Sample volume	225 mL
Initial D.O.	8.2 mg/L
Final D.O.	4.2 mg/L
Bottle volume	300 mL
Seed added to BOD sample	1 mL
Seed added to blank	3 mL
Initial seed D.O.	7.9 mg/L
Final seed D.O.	3.8 mg/L

Seed correction for 1 mL of seed = $\frac{\text{Initial D.O} - \text{Final D.O.}}{\text{mL of seed added to blank}}$

Seed correction for 1 mL of seed = $\frac{7.9 \text{ mg/L} - 3.8 \text{ mg/L}}{3 \text{ mL}}$

Seed correction for 1 mL of seed = 1.4 mg/L

Since only 1 mL of seed has been added to the BOD bottles, the correction factor will be 1.4 mg/L.

Now, use the BOD formula with seed correction:

BOD, mg/L = $\frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

BOD, mg/L = $\frac{[(8.2 \text{ mg/L} - 4.2 \text{ mg/L}) - 1.4 \text{ mg/L}] \times (300 \text{ mL})}{225 \text{ mL}}$

$$\text{BOD, mg/L} = \frac{780\ \text{mg}}{225\ \text{mL}}$$

BOD, mg/L = 3.5 mg/L

Data Analysis

Sometimes operators may be required to analyze and calculate data from laboratory results, flows, or other groups of measurements. The *average, or arithmetic mean*, is adding all of the measurements and dividing by the total number of measurements. The formula for finding an average or mean is written:

- **Average =** $\frac{\textbf{sum of all measurements}}{\textbf{number of measurements}}$

In a wastewater facility that operates 7 days per week, *moving averages* may be used. They are calculated the same way that averages are, except that each day the oldest measurement is replaced with the newest measurement. Moving averages are used to better reveal trends in treatment plant operation.

A useful method of indicating a spread in a series of measurements is the *range*. The range is calculated by the smallest measurement from the largest measurement.

- **Range = largest value – smallest value**

<u>**Example**</u>

The laboratory submits the following influent TSS values for one week. What is the *mean and range* of these values?

DAY	*TSS, mg/L*
1	190
2	220
3	225
4	195
5	208
6	210
7	204

$$\text{Average} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

$$\text{Avcragc} = \frac{1{,}452}{7}$$

Average = 207 mg/L

Range = largest value – smallest value

Range = 225 - 190

Range = 35 mg/L for the 7-day period

In analyzing data, high values in a list of numbers may sometimes be encountered. In this case, the *median* value may be better to use than the mean, or average value.

To calculate the median, first rank all of the measurements in ascending to descending order, and then pick the middle measurement.

Example

What is the median value of the weekly data for flows shown below?

DAY	FLOW, MGD
1	2.7
2	1.9
3	3.4
4	5.6
5	1.9
6	1.8
7	2.0

First, rank the flows in ascending order.

FLOWS: 1.8 1.9 1.9 2.0 2.7 3.4 5.6

Now, pick the middle measurement:

Median = 2.0 MGD

The next measurement that operators should be familiar with is the *mode*. The mode is the measurement that occurs most frequently in a series of measurements. In the example given above, the mode would be 1.9 MGD, since it is the only measurement that occurs twice in the 7-day period.

This concludes the laboratory mathematics section of this program. A 10 question multiple-choice test can be found in the appendix. Try to adhere to the time limit, keep organized, and set up the problems according to the steps.

Do your work on a separate sheet of paper and feel free to consult the formula sheet and table of equivalents. Be sure to read the problem carefully, and check your answers with the answer key provided at the end of the workbook.

Test No. 1
SEDIMENTATION AND LOADING PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. A clarifier has a depth of 14 feet, a diameter of 35 feet, and receives a flow of 350,000 gal/day. What is the surface loading rate and weir overflow rate of this facility, assuming the weir has the same diameter as the tank?

Surface loading rate	*weir overflow rate*
A: 364 gal/day/ft	6,369 gal/day/ft
B: 364 gal/day/ft	3,185 gal/day/ft
C: 26 gal/day/ft	6,369 gal/day/ft
D: 26 gal/day/ft	3,185 gal/day/ft

2. A primary clarifier has a diameter of 65 feet, a depth of 12 feet and receives a flow of 1.75 MGD. The influent suspended solids concentration is 312 mg/L. What is the solids loading in pounds per day per square foot?

   A: 0.23 lbs/day/ft
   B: 0.66 lbs/day/ft
   C: 1.1 lbs/day/ft
   D: 1.4 lbs/day/ft

3. The clarifier described in problem 2 above has an effluent suspended solids concentration of 55 mg/L. What is the efficiency, in percent, of this clarifier in solids removal?

   A: 121 %
   B: 82 %
   C: 50 %
   D: 25.7 %

4. A trickling filter receives an influent BOD of 285 mg/L. The filter has a diameter of 100 feet and an effective depth of 6 feet. What is the organic loading, in pounds of BOD per day per 1000 cubic feet when the flow is 1.75 MGD?

   A: 91.4 lbs/day/1000 cu ft
   B: 62.4 lbs/day/1000 cu ft
   C: 18.4 lbs/day/1000 cu ft
   D: 0.09 lbs/day/1000 cu ft

5. A domestic wastewater has a 'K' factor of 0.65 when the total suspended solids is 280 mg/L. If the BOD is 205 mg/L, what is the *soluble* BOD?

A: 318 mg/L
B: 210 mg/L
C: 183 mg/L
D: 23 mg/L

6. A trickling filter plant receives a flow of 1.65 MGD. The best recirculation rate is 70 percent of this flow. If the filter is 80 feet in diameter and 7 feet in depth, what is the hydraulic loading on this plant?

A: 558 gal/day/sq ft
B: 328 gal/day/sq ft
C: 230 gal/day/sq ft
D: 80 gal/day/sq ft

7. How many cubic yards of media must be ordered to replace the existing media in a trickling filter plant if the filter is 80 feet in diameter and 7 feet in depth?

A: 65 cu yds
B: 622 cu yds
C: 1,303 cu yds
D: 9,743 cu yds

8. A rotating biological contactor's disk area is 150,000 square feet. The plant's daily flow is 18,750 gal/hr. If the influent BOD is 180 mg/L, the influent TSS is 165 mg/L, and the 'K' factor for this wastewater is 0.6, what is the organic loading in lbs/day/1000 sq ft?

A: 0.002 lbs/day/1000 sq ft
B: 0.08 lbs/day/1000 sq ft
C: 1.28 lbs/day/1000 sq ft
D: 2 lbs/day/1000 sq ft

9. What is the organic load in pounds of BOD per day on a treatment facility that receives a raw wastewater with a BOD of 308 mg/L if the average daily flow is 440,000 gal/day?

A: 113,000 lbs/day
B: 11,300 lbs/day
C: 1,130 lbs/day
D: 1,014 lbs/day

10. A plant clarifier was designed to have a surface loading rate of 400 gal/day/sq ft. The diameter of the clarifier is 50 ft, the depth is 15 ft, and the plant is receiving an average daily flow of 0.980 MGD. How many gal/day/sq ft *over* or *under* the design capacity is this plant operating?

A: 499 gal/day/sq ft over
B: 499 gal/day/sq ft under
C: 99 gal/day/sq ft over
D: 99 gal/day/sq ft under

TEST NO. 2

ACTIVATED SLUDGE

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. A daily lab report shows the settlometer reading to be 330 mL/L after 30 minutes. The lab has also determined the MLSS to be 3,670 mg/L. What is the SVI and SDI at this facility?

	SVI	*SDI*
A:	111	0.89
B:	90	0.90
C:	102	1.11
D:	90	1.11

2. An aeration tank has a diameter of 50 feet and a depth of 12 feet. The lab determines the MLSS to be 4,200 mg/L. What is the solids inventory in this tank?

A: 24,659 lbs
B: 11,220 lbs
C: 6,170 lbs
D: 806 lbs

3. An operator is trying to keep the sludge age of a plant at 8 days. The solids inventory is 5,890 pounds and the average daily flow is 0.225 MGD. The TSS of the influent is 365 mg/L. How many days over or under the operator's target sludge age is the plant operating at presently?

A: 8 days over
B: 0.6 days over
C: 4 days under
D: 0.5 days under

4. What is the F/M ratio of a treatment facility with an influent BOD of 196 mg/L, a MLSS of 3,654 mg/L, an aeration tank capacity of 0.216 MG, and an average daily flow of 1,200,000 gallons per day is 79 percent of the solids are volatile?

A: 0.04
B: 0.14
C: 0.24
D: 0.38

5. Settlometer results indicate that 275 mL/L settled in 30 minutes. The average daily flow of this conventional activated sludge plant is 0.975 MGD. What is the estimated return sludge pumping rate based on the settlometer result?

A: 188 gpm
B: 257 gpm
C: 370 gpm
D: 725 gpm

6. An activated sludge plant produces a desirable effluent using 8 days as a target MCRT. What is the WAS rate of this plant when the following information is known?

solids inventory, lbs	5,960	lbs
SS lost in effluent, lbs/day	180	lbs
WAS suspended solids, mg/L	7,600	mg/L
Desired MCRT, days	8	days

A: 8,914 gal/day
B: 9,720 gal/day
C: 12,706 gal/day
D: 13,710 gal/day

7. What is the MCRT of and activated sludge plant when the following data is known?

aeration tank capacity	325,000	gal
MLSS	3,800	mg/L
daily flow	0.350	MGD
WAS flow	6,500	gal/day
WAS suspended solids	9,750	mg/L
TSS influent	215	mg/L
TSS effluent	4.0	mg/L
volatile solids	65	%

A: 19.1 days
B: 19.8 days
C: 22.0 days
D: 24.1 days

8. An extended aeration plant produces its best effluent when the MLSS is held at 3,200 mg/L and the sludge is pumped at a rate of 21,600 gallons per day. The MLSS has risen to 4,150 mg/L and the effluent has deteriorated considerably. If the WAS concentration is 9,500 mg/L, and the aeration tank capacity is 0.5 MG, what is the new sludge pumping rate that is required in order to achieve the desired MLSS?

A: 50,100 gal/day
B: 55,520 gal/day
C: 71,606 gal/day
D: 82,236 gal/day

9. The specifications and lab results for a water reclamation facility are shown below. What is the present sludge age?

TSS, raw	225	mg/L	
TSS, final	5	mg/L	
aeration tank	L = 130 ft,	W = 24 ft,	D = 15 ft
clarifier	Dia = 60 ft,	D = 15 ft	
MLSS	3,680	mg/L	
30 minute SS	420	mL/L	
daily flow	1.5	MGD	

A: 1.5 days
B: 2.8 days
C: 3.8 days
D: 5.8 days

10. Using the information given in question 9 above, what would be an estimated sludge return rate based on the present flow?

A: 120 gal/min
B: 256 gal/min
C: 754 gal/min
D: 920 gal/min

TEST NO. 3
DIGESTION PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An anaerobic digester must be neutralized with lime. The digester contains 0.015 MG of sludge with a volatile acid level of 2,875 mg/L as acetic acid. How many pounds of lime are necessary for neutralization?

   A: 2,960 lbs
   B: 918 lbs
   C: 360 lbs
   D: 147 lbs

2. If 15,000 gallons of sludge with a solids content of 2.5 percent are pumped to a thickener, what is this expressed as pounds of dry sludge?

   A: 313 pounds
   B: 1,468 pounds
   C: 2,712 pounds
   D: 3,128 pounds

3. How many gallons per hour of sludge can be pumped with a piston pump that has a 6 inch diameter piston and a 4 inch stroke if the pump is operating at 30 revolutions per minute?

   A: 14 gal/hr
   B: 58 gal/hr
   C: 872 gal/hr
   D: 3,487 gal/hr

4. Raw sludge has a volatile solids count of 75 percent. The digester reduces the volatiles to 40 percent. What is the percent reduction accomplished by the digester?

   A: 41 %
   B: 52 %
   C: 78 %
   D: 35 %

5. An anaerobic digester must be started at a plant expansion project. If the digester is 20 feet in depth and has a diameter of 30 feet, how many gallons of seed sludge must be added, based on the recommendation that 20 percent of the digester volume be filled with seed?

A: 11,300 gal
B: 21,138 gal
C: 44,260 gal
D: 84,500 gal

6. A digester receives a raw sludge that has a volatile content of 80 percent. The digester reduces this to 37 percent. How many pounds of volatile solids are destroyed per day per cubic foot of digester space if the digester is 16 feet deep, has a diameter of 24 feet, and 2,250 lbs of volatiles are added daily?

A: 0.12 lbs/day/cu ft
B: 0.26 lbs/day/cu ft
C: 0.33 lbs/day/cu ft
D: 0.41 lbs/day/cu ft

7. A digester destroys 2,275 lbs of volatile solids per day. The digester has an effective volume of 65,250 cubic feet. The gas meter indicated that 27,500 cubic feet of gas are produced daily. How many cubic feet of gas are produced for every pound of VS destroyed?

A: 2.4 cu ft / lb VS
B: 8.9 cu ft / lb VS
C: 12.1 cu ft / lb VS
D: 28.7 cu ft / lb VS

8. An anaerobic digester has gone sour and must be neutralized. The digester is 24 feet in depth and has a diameter of 18 feet. It is presently 1/3 full of sludge containing a VA concentration of 4,225 mg/L. How many pounds of lime are required?

A: 72 lbs
B: 458 lbs
C: 536 lbs
D: 1,609 lbs

9. A new digester must be seeded. How many gallons of seed will be required based on the following information?

Raw sludge, gal/day	2,500
Raw sludge solids, %	2.5
Raw sludge volatiles, %	65
Seed sludge solids, %	5.0
Seed sludge volatiles, %	75
wt. of seed sludge, lbs/gal	9.8
Loading factor	0.05 lbs VS/day

A: 18,449 gal
B: 20,707 gal
C: 26,114 gal
D: 28,800 gal

10. How many pounds of dry sludge are handled if a 5,000 cubic foot capacity digester is pumped to a press and the sludge pumped contains 5 percent solids?

A: 1,625 lbs
B: 2,085 lbs
C: 10,450 lbs
D: 15,596 lbs

TEST NO. 4
HORSEPOWER, FORCE, & CHEMICAL PUMP PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An in-ground sedimentation tank must be drained. The tank has a depth of 15 feet and a diameter of 75 feet. What is the upward force on this tank created by groundwater if the groundwater is 3.5 feet above the tank bottom?

   A: 36,003 lbs
   B: 126,011 lbs
   C: 688,212 lbs
   D: 964,373 lbs

2. A pump must be able to pump against a total head of 135 feet at the rate of 250 gallons per minute. If the pump is 56 percent efficient and the motor is 90 percent efficient, what should the minimum motor horsepower be?

   A: 10 hp
   B: 17 hp
   C: 20 hp
   D: 23 hp

3. How many pounds of chemical are in one gallon of a 10 percent hypochlorite solution?

   A: 0.0834 lbs/gal
   B: 0.834 lbs/gal
   C: 3.2 lbs/gal
   D: 1.8 lbs/gal

4. Hypochlorite is being fed at the rate of 66 gallons per day using a 7 percent solution. What is the dose being fed, in mg/L, if the flow is 2.4 MGD?

   A: 1.2 mg/L
   B: 1.5 mg/L
   C: 1.9 mg/L
   D: 3.0 mg/L

5. A chemical feed pump has a scale that reads from 0 to 100 in percent. The pump has an output of 25 gallons per day when set at 100 percent. A sludge conditioner with a 5.5 percent concentration must be fed to a flow of 1.25 MGD to achieve a dose of 0.5 mg/L. At what percent should the pump be set to achieve this dose?

A: 24 %
B: 35 %
C: 45 %
D: 62 %

6. What is the force in pounds acting on a side wall of a chlorine contact chamber that has a depth of 14 feet and a length of 25 feet?

A: 10,920 lbs
B: 19,500 lbs
C: 152,880 lbs
D: 273,000 lbs

7. An in-ground tank has a depth of 12 feet, a width of 24 feet and a length of 30 feet. What is the upward force on the bottom on this tank exerted by groundwater if the groundwater depth is 8.5 feet below the top of the tank?

A: 157,248 lbs
B: 196,560 lbs
C: 210,200 lbs
D: 381,888 lbs

8. A 6.5 percent solution of polymer must be fed to a flow of 0.440 MGD to result in a chemical dose of 10 mg/L. How many gallons of this chemical will be required for a 30-day period?

A: 37 gal
B: 68 gal
C: 1,402 gal
D: 2,031 gal

9. What is the brake horsepower of a pump that can pump 0.425 MGD at a total head of 110 ft if the pump efficiency if 62 percent?

A: 10 BHP
B: 13 BHP
C: 15 BHP
D: 22 BHP

10. A circular tank is filled to a depth of 20 ft. The diameter of this tank if 32 feet. What is the force, in pounds, acting on the wall of this tank?

A: 149,361 lbs
B: 516,232 lbs
C: 798,720 lbs
D: 1,253,990 lbs

TEST NO. 5

LAB PROCEDURES & MEASUREMENT PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

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1. Results for fecal coliforms have been compiled for one week. What is the range *and* median of these results?

DAY	1	2	3	4	5	6	7
COLONIES/100 mL	22	40	16	4	16	31	28

range	*median*
A: 36	22
B: 36	16
C: 22	26
D: 26	22

2. The following information is from a wastewater lab bench sheet. What is the BOD of the sample?

sample volume	12 mL
initial DO	8.6 mg/L
final DO	3.1 mg/L
bottle volume	300 mL
seed added to sample	1 mL
seed added to blank	2 mL
initial seed DO	7.5 mg/L
final seed DO	4.0 mg/L

A: 88 mg/L
B: 94 mg/L
C: 120 mg/L
D: 128 mg/L

3. An industrial waste influent is estimated to have a BOD of 1,500 mg/L. How many mL of sample must be added to a 300 mL BOD bottle?

A: 2.0 mL
B: 1.3 mL
C: 0.8 mL
D: 0.5 mL

4. A bench sheet has the following data for solids testing. What is the volatile suspended solids in mg/L?

Sample volume	100	mL
Wt. of crucible + filter	23.3819	gr
Wt. of crucible + filter + dry residue	24.0090	gr
Wt. of crucible + filter + ash	23.7272	gr

A: 1,157 mg/L
B: 2,818 mg/L
C: 2,920 mg/L
D: 3,453 mg/L

5. Using the information in question 4 above, what is the percent volatile solids?

A: 45 %
B: 52 %
C: 75 %
D: 81 %

6. TSS results for one week are shown below. What is the median and mode measurements of these results?

DAY	1	2	3	4	5	6	7
TSS, mg/L	308	212	316	286	308	312	318

median	*mode*
A: 312	308
B: 308	312
C: 318	212
D: 308	308

7. A lab bench sheet shows the following information. What is the TSS and VSS of the sample?

Sample volume	1,250 mL
Wt. of dish + filter	19.2752 g
Wt. of dish + filter + residue	19.2823 g
Wt. of dish + filter + ash	19.2799 g

TSS	*VSS*
A: 6.5 mg/L	2.3 mg/L
B: 5.6 mg/L	1.9 mg/L
C: 5.6 mg/L	1.0 mg/L
D: 6.5 mg/L	1.9 mg/L

8. A BOD test is conducted on a stream where wastewater effluent if discharged. What is the BOD if the bench sheet reads as follows?

Sample volume	275	mL
Initial D: O.	8.5	Mg/L
Final D: O.	7.0	Mg/L
Bottle vol.	300	mL

A: 1.0 mg/L
B: 1.6 mg/L
C: 2.7 mg/L
D: 5.0 mg/L

9. A BOD test is conducted on a final effluent where seed must be added. What is the BOD of the data is as follows?

sample volume	250	mL
initial D: O.	8.1	mg/L
final D: O.	4.0	mg/L
seed added to sample	2	mL
seed added to blank	4	mL
initial seed D: O.	7.8	mg/L
final seed D: O.	2.8	mg/L

A: 9.1 mg/L
B: 3.6 mg/L
C: 1.9 mg/L
D: 1.3 mg/L

10. The data for the effluent TSS test is below. How many pounds of solids are discharged in 30 days from this plant if the average daily flow is 1.65 MG?

sample volume	500	mL
wt. of dish + filter	22.7255	g
wt. of dish + filter + residue	22.7380	g
wt. of dish + filter + ash	22.7299	g

A: 345 lbs
B: 2,818 lbs
C: 9,516 lbs
D: 10,321 lbs

ANSWER KEYS

Allow 10 points for each correct answer. The minimum passing score for each test is 70%. If you missed a question, go back to your work and retrace your steps and your unit conversions.

TEST NO. 1

1. B
2. D
3. B
4. A
5. D
6. A
7. C
8. D
9. C
10. C

TEST NO. 2

1. D
2. C
3. B
4. D
5. B
6. A
7. A
8. C
9. C
10. C

TEST NO. 3

1. C
2. D
3. C
4. C
5. B
6. B
7. C
8. C
9. A
10. D

TEST NO. 4

1. D
2. B
3. B
4. C
5. C
6. C
7. A
8. D
9. B
10. D

TEST NO. 5

1. A
2. B
3. C
4. B
5. A
6. D
7. B
8. B
9. C
10. D

APPLIED WASTEWATER MATH FORMULA SHEET AND CONVERSION FACTORS

Below is a list of basic conversion factors and formulas that will be used with throughout this workbook. Feel free to refer to this page when doing the section test.

12 in	= 1 ft	12 in/ft	1000 mg	= 1 gm	1000 mg/gm
3 ft	= 1 yd	3 ft/yd	1000 gm	= 1 kg	1000 gm/kg
144 sq in	= 1 sq ft	144 sq in/sq ft	1000 mL	= 1 liter	1000 ml/L
9 sq ft	= 1 sq yd	9 sq ft/sq yd	1 meter	= 39.37 in	39.37 in/meter
27 cu ft	= 1 cu yd	27 cu ft/cu yd	1 gram	= 0.035 oz	0.035 oz/gram
5,280 ft	= 1 mile	5,280 ft/mi	60 sec	= 1 min	60 sec/min
7.48 gal	= 1 cu ft	7.48 gal/cu ft	60 min	= 1 hour	60 min/hr
8.34 lb	= 1 gal	8.34 lb/gal	24 hr	= 1 day	24 hr/day
62.4 lb	= 1 cu ft	62.4 lb/cu ft	43,560 sq ft	= 1 acre	43,560 sq ft/ac

VELOCITIES and FLOW RATES

1. $V = \frac{\text{distance, feet}}{\text{time, min}}$
2. Q = V x A (Flow rate = velocity, ft/sec x area, sq. ft)

RETENTION TIME

1. $\text{Ret. Time} = \frac{\text{tank cap. (gal)}}{\text{flow, gal/time unit}}$

PARTS PER MILLION / POUNDS

1. $\text{mg/L} = \frac{\text{pounds of chemical}}{\text{(8.34 lb/gal) x (MG)}}$

2. lbs = 8.34 lbs/gal x mg/L x MG

SEDIMENTATION AND LOADINGS

1. $\text{Weir overflow, gal/day/ft} = \frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$

2. $\text{Surface loading, gal/day/sq ft} = \frac{\text{influent flow, gal/day}}{\text{surface area, sq ft}}$

3. $\text{Solids loading, lbs/day/sq ft} = \frac{\text{solids applied, lbs/day}}{\text{surface area, sq ft}}$

4. Efficiency, $\% = \frac{(\text{in mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})} \times 100\%$

5. Organic loading, lbs BOD/day/1,000 cu ft $= \frac{\text{BOD applied, lbs/day}}{\text{vol of media (in 1,000 cu ft)}}$

6. Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

   (where K = 0.5 to 0.7 for most domestic wastewaters)

7. Hydraulic loading, gal/day/sq ft $= \frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

ACTIVATED SLUDGE

1. $\text{SVI} = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

2. $\text{SDI} = \frac{100}{\text{SVI}}$

3. Solids inventory, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

4. Sludge age, days $= \frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

5. $\text{F/M} = \frac{(\text{inf BOD, mg/L}) \times (\text{Flow, MGD}) \times (8.34\ \text{lbs/gal})}{(\text{Aer.tank cap, MG}) \times (\text{MLVSS, mg/L}) \times (8.34\ \text{lbs/gal})}$

6. $\text{MCRT} = \frac{\text{solids inventory, lbs}}{(\text{effluent solids, lbs}) + (\text{WAS solids, lbs})}$

7. WAS, lbs/day $= \frac{\text{solids inventory, lbs}}{\text{desired MCRT, days}}$ - (solids lost in effluent, lbs/day)

8. WAS flow, MGD $= \frac{\text{WAS, lbs/day}}{(\text{WAS, mg/L}) \times (8.34\ \text{lbs/gal})}$

9. Change, WAS rate, MGD $= \frac{(\text{current solids inventory, lbs}) - (\text{desired solids inventory, lbs})}{\text{WAS, mg/L} \times 8.34\ \text{lbs/gal}}$

10. Return sludge rate, MGD $= \frac{(\text{set. solids, mL}) \times (\text{flow, MGD})}{(1{,}000\ \text{mL}) - (\text{set. solids, mL})}$

SLUDGE DIGESTION

1. Dry solids, lbs = $\frac{\text{(raw sludge, gal) x (raw sludge, \% solids) x (8.34 lbs/gal)}}{100\%}$

2. VS pumped, lbs/d = $\frac{\text{(raw sludge, gal/day) (raw sludge solids,\%)(raw sludge vol, \%)(8.34 lbs/gal)}}{\text{(100\%) (100\%)}}$

3. Seed Sludge, lbs volatile solids = $\frac{\text{VS pumped, lbs VS/day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$

4. Seed sludge, gal = $\frac{\text{seed sludge, lbs volatile solids}}{\text{(seed sludge, lbs/gal) x}\left(\frac{\text{solids \%}}{100\%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$

5. Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

6. Percent reduction = $\frac{\text{(in − out) x 100 \%}}{\text{in− (in x out)}}$

7. VS destroyed, lbs/day/cu ft = $\frac{\text{(VS added, lbs/day) (VS reduction, \%)}}{\text{(digester volume, cu ft) (100 \%)}}$

8. Gas production, cu ft/lb VS = $\frac{\text{gas production, cu ft/day}}{\text{VS destroyed, lbs/day}}$

HORSEPOWER, FORCE, CHEMICAL PUMPS

1. Water HP = $\frac{\text{(flow, gal/min) x (head, ft)}}{3{,}960}$

2. BHP = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960 x Ep)}}$

3. Motor HP = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960) x (Ep) x (Em)}}$

4. Upward force, lbs = 62.4 lbs/cu ft x height, ft x Area, sq ft

5. Side wall force, lbs = (31.2 lbs/cu ft) x (height, ft)^2 x (length, ft)

6. Chemical sol'n, lbs/gal = $\frac{\text{(sol'n \%) x (8.34 lbs/gal)}}{100\ \%}$

7. Feed pump flow, lbs/gal = $\frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

8. Scale setting, % = $\frac{\text{(desired flow, gal/day) (100 \%)}}{\text{maximum feed rate, gal/day}}$

LAB PROCEDURES AND MEASUREMENTS

1. TSS, mg/L = $\frac{\text{(RDD} - \text{DD)}}{\text{sample vol, mL}}$ x 1 M

2. VSS, mg/L = $\frac{\text{(RDD} - \text{FDD)}}{\text{sample vol, mL}}$ x 1 M

   Where: RDD = dried residue + dish + disc (filter), grams
   DD = dish + disc, grams
   FDD = fired residue + dish + disc, grams
   1 M = 1,000,000

3. VSS, % = $\frac{\text{volatile solids, mg/L}}{\text{total suspended solids, mg/L}}$ x 100%

4. BOD sample size, mL = $\frac{\text{1,200 (mg/L) (mL)}}{\text{estimated BOD, mg/L}}$

5. Seed correction, mg/L, for 1 mL seed = $\frac{\text{initial DO} - \text{Final DO}}{\text{mL seed added}}$

6. BOD, mg/L = $\frac{\text{[(initial DO} - \text{Final DO)} - \text{(seed correction factor)] x (bottle volume, mL)}}{\text{sample volume, mL}}$