SYSTEM TROUBLESHOOTING BASED UPON WASTEWATER CHARACTERISTICS

NOWRA
National Onsite Wastewater Recycling Association
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RCAP

PRESENTED BY

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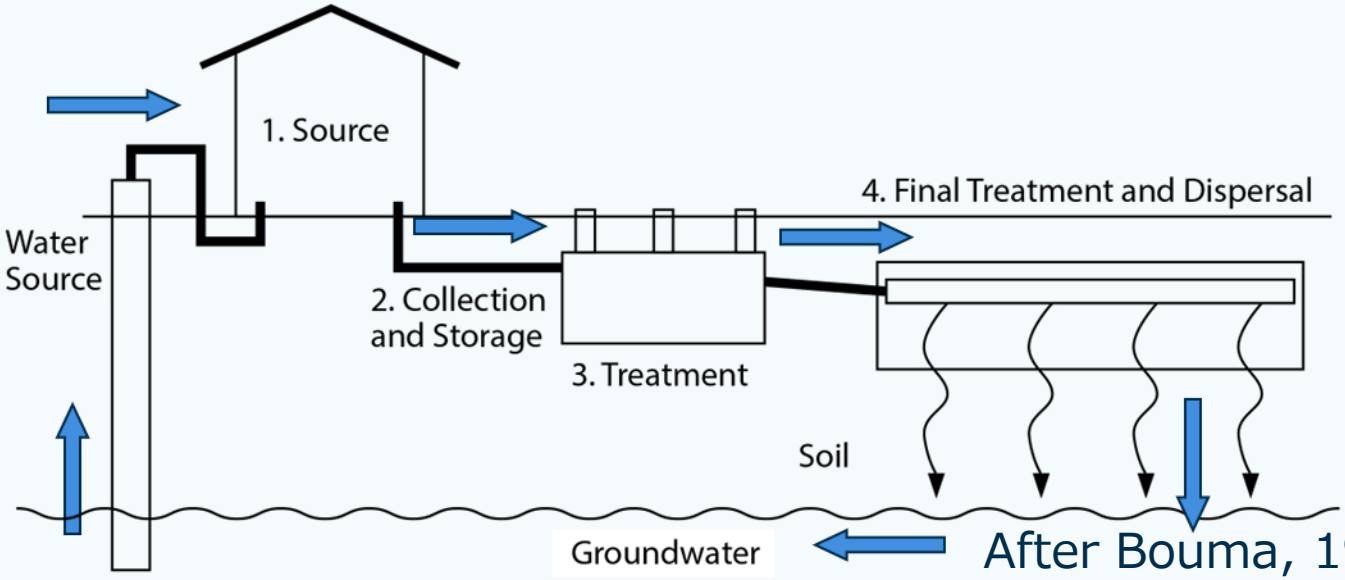
Overview

- First step: Identify the root cause of malfunction
- Solids removal is essential and fundamental
- Treatment trains designed with capacity to remove ***specific*** hydraulic, organic and nutrient load
- Peak or excessive loads moves contaminants downstream
- Investigating excessive loading and potential fixes
- Investigating microbial inhibition and potential fixes

Onsite wastewater treatment system

- Purpose of treatment: prepare effluent for final treatment and dispersal in the soil
- Purpose of soil treatment area: accept, treat and disperse effluent



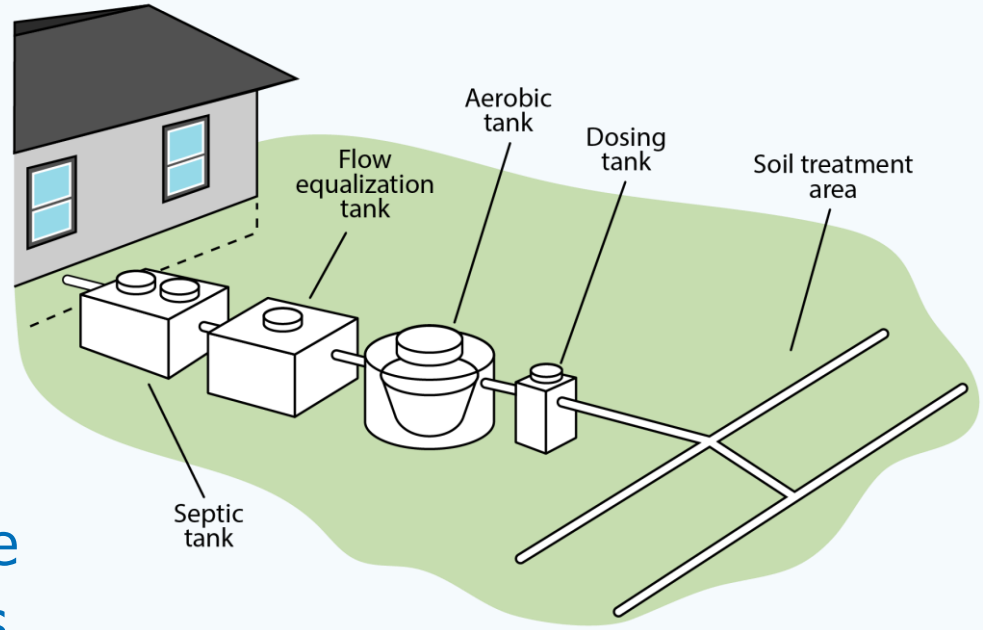
After Bouma, 1979

Root causes of performance issues

- Structural & mechanical issues - Identified with operational checklists
- Treatment issues
  - Hydraulic loading
  - Contaminant mass loading
  - Microbial inhibition

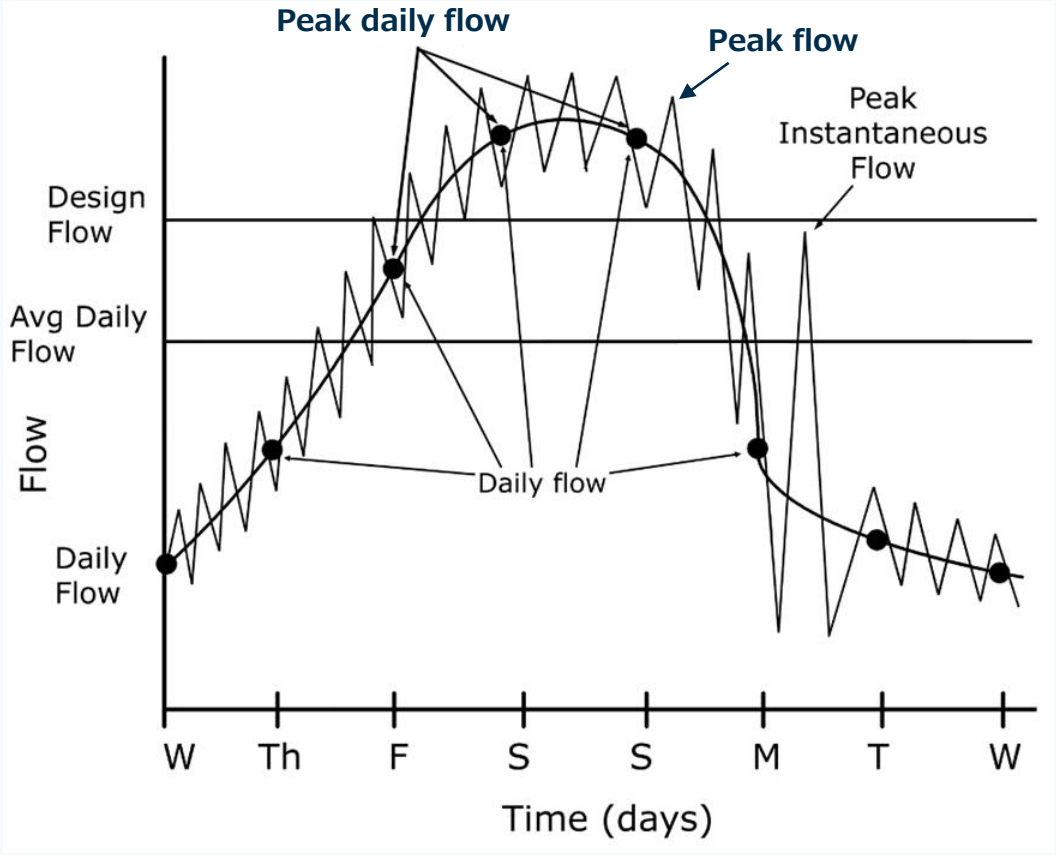
Where to start…

- Start downhill and work backward: Focus on effluent quality in the dosing tank
  - Clear, clarified effluent indicates contaminant reduction
  - Cloudy, yellowish effluent indicates presence of suspended solids, nutrients and FOGs
- Poor quality suggests contaminants are moving downstream of treatment units



Hydraulic considerations

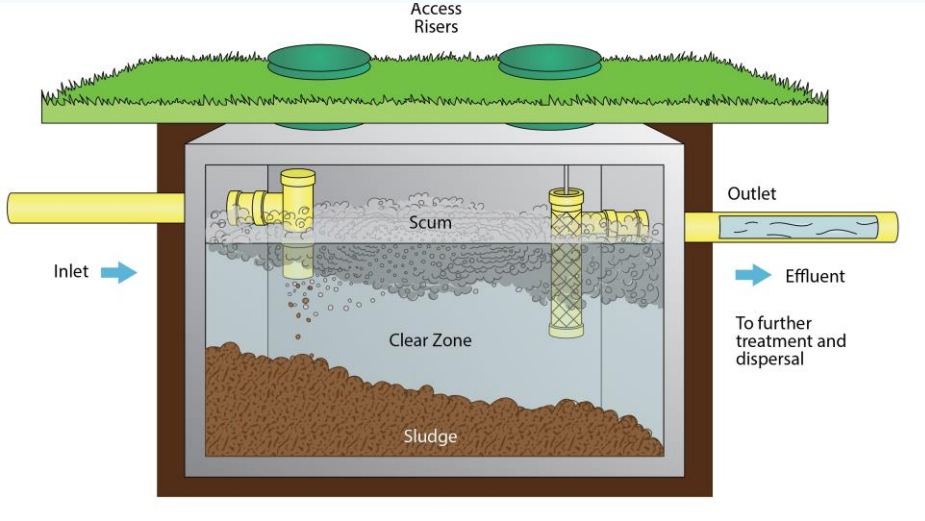
- Flow rate
  - Average - GPD
  - Peak – GPD, GPH
  - Peak instantaneous – GPM
- What hydraulic loading is the issue?



Contaminant loading: Organics and Nutrients

Excess contaminants remain after treatment

1. Current influent mass loading
   - Organics – suspended and dissolved
   - Nutrients – nitrogen and phosphorus
2. Excess biomass accumulation
   - Biomass and sludge in the units
   - Identified with operational checklists



What's in wastewater?

- 99.9% water
- 0.1% constituents of concern
  - Organics / inorganics
  - Solids
  - Fats, oils, and grease
  - Pathogens
  - Nutrients (Nitrogen and Phosphorus)
  - Metals
  - Persistent organic chemicals
  - Salt

Organic material

- BOD
  - Biochemical oxygen demand
- TSS
  - Total suspended solids
- FOG
  - Fats, oils & grease

Inorganic material

- Stable compounds
  - Not broken down by microorganisms
- Minerals, metals, dissolved salts
  - Sand, silt, cadmium, copper, lead, zinc, sodium
- Residential flows have low metal content
- Stormwater, inflow and infiltration
  - Cracked pipes, leaky manhole covers

Solids

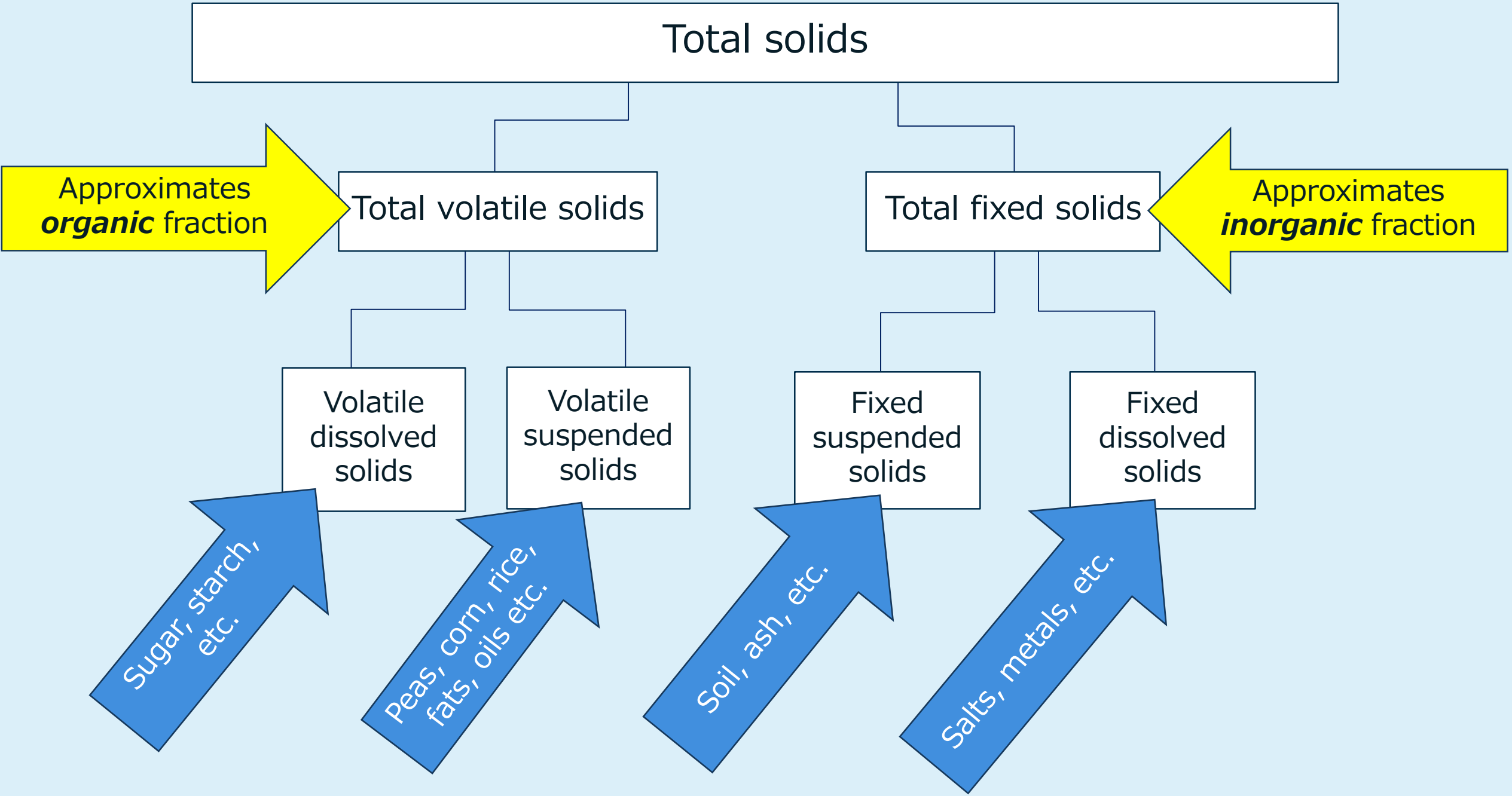
- Total solids
  - Any suspended or dissolved material
  - The residue left after evaporation
  - May be organic and inorganic
- Two broad categories
  - Total suspended solids (TSS) and total dissolved solids (TDS)
  - Total volatile solids and total fixed solids
- *Settleable solids* are heavier suspended particles that settle out during primary treatment

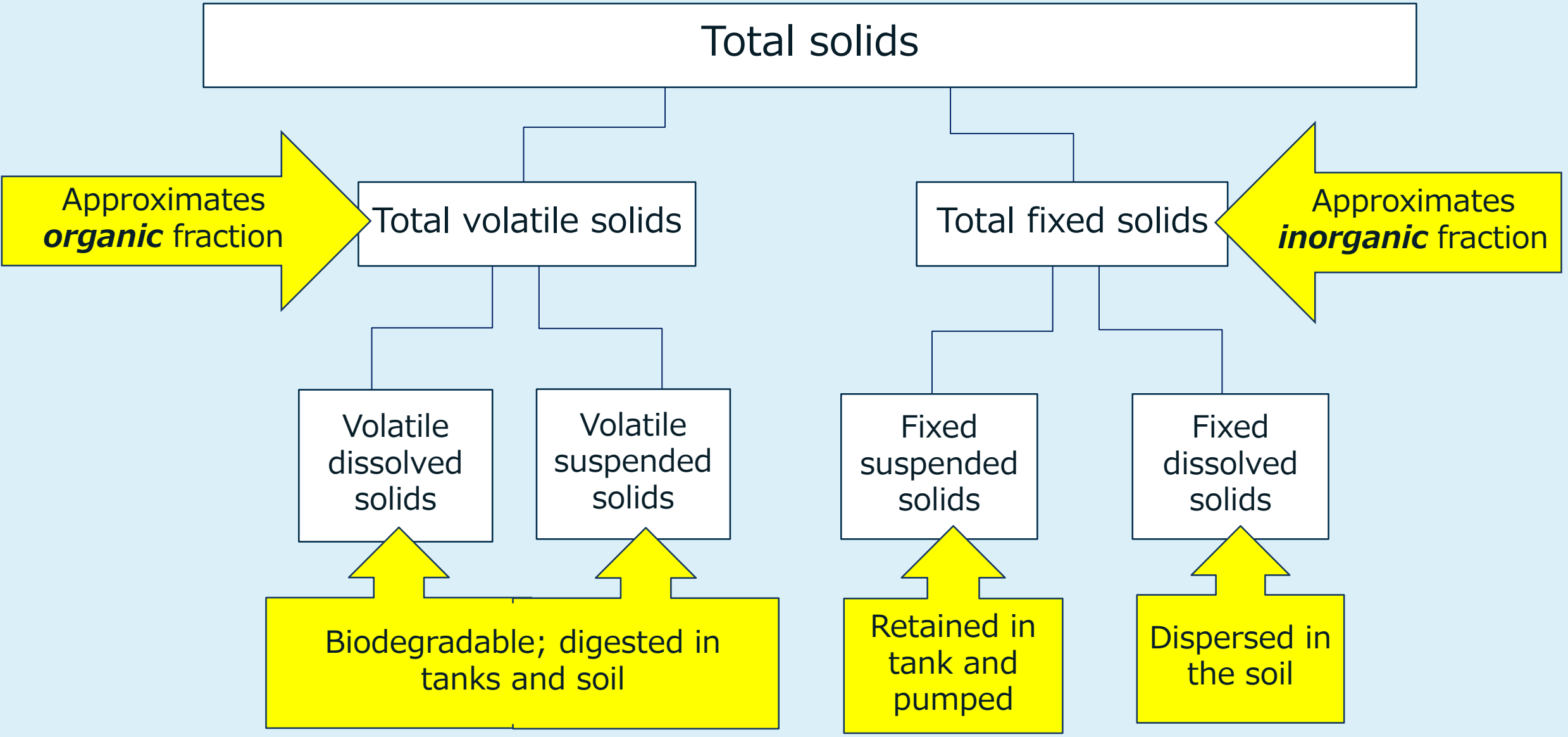
Suspended & Dissolved Solids

- *Total suspended solids* are that part of a sample retained by a 1.5 µm filter
- *Total dissolved solids* are that part of a sample that will pass through the filter

Volatile & Fixed Solids

- *Total volatile solids* is that portion of a sample lost after heating the sample to 550ºC.
  - An approximation of the organic fraction
- *Total fixed solids* is that portion of a sample remaining after heating the sample.
  - An approximation of the mineral (inorganic) fraction


Total solids
Approximates *organic* fraction
Total volatile solids
Total fixed solids
Approximates *inorganic* fraction
Volatile dissolved solids
Volatile suspended solids
Fixed suspended solids
Fixed dissolved solids
Sugar, starch, etc.
Peas, corn, rice, fats, oils etc.
Soil, ash, etc.
Salts, metals, etc.


Total solids
Approximates *organic* fraction
Total volatile solids
Total fixed solids
Approximates *inorganic* fraction
Volatile dissolved solids
Volatile suspended solids
Fixed suspended solids
Fixed dissolved solids
Biodegradable; digested in tanks and soil
Retained in tank and pumped
Dispersed in the soil

Microbial inhibition

- Temperature
- pH
- Oxygen state
- Alkalinity
- Low or excessive nutrient concentrations
- Chemicals or strong disinfectants
- Medications

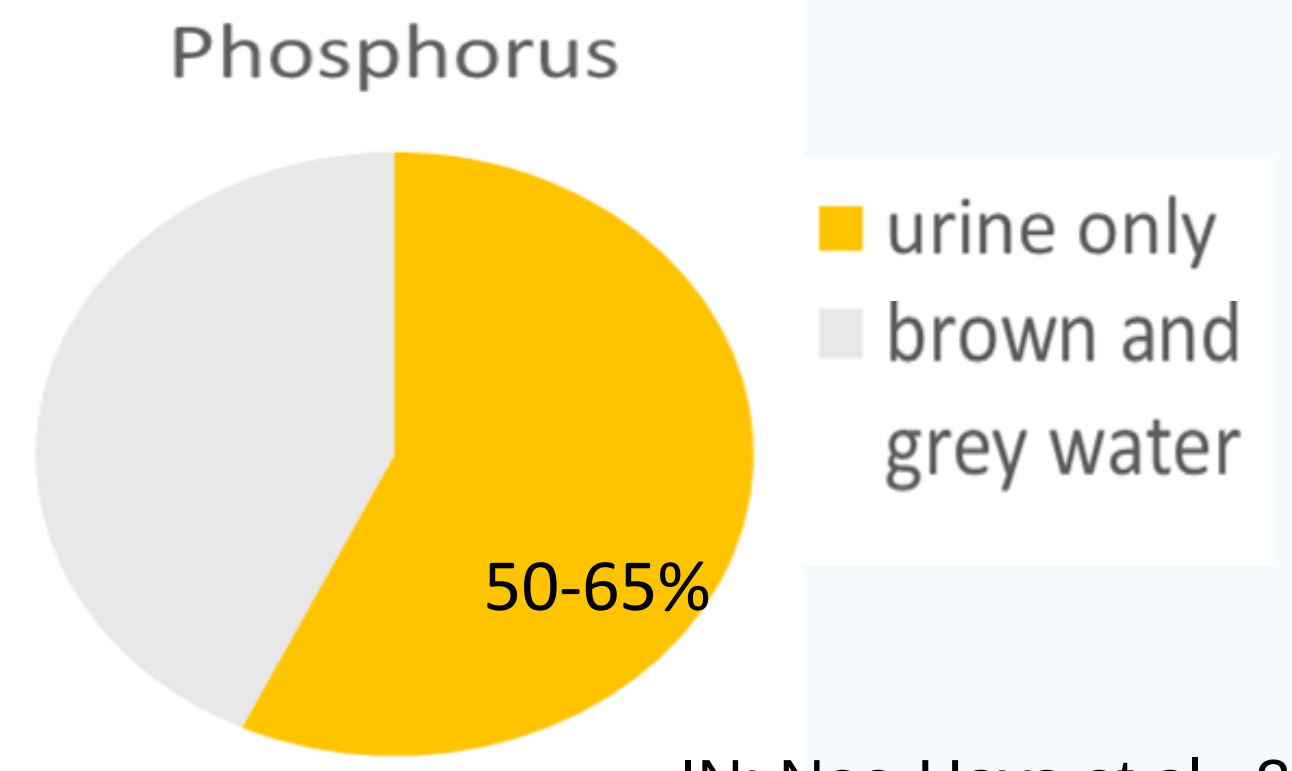
Nutrients

Essential for growth of living organisms

- Major nutrients
  - N, P, K
- Secondary nutrients
  - Mg, Ca, S
- Micronutrients
  - Cu, Zn, Mn, Mo, B, Se

- Building blocks for living organisms
  - Carbon
  - Nitrogen
  - Phosphorus
- Ratio: C / N / P
  - 106 / 16 / 1

Phosphorus – sources

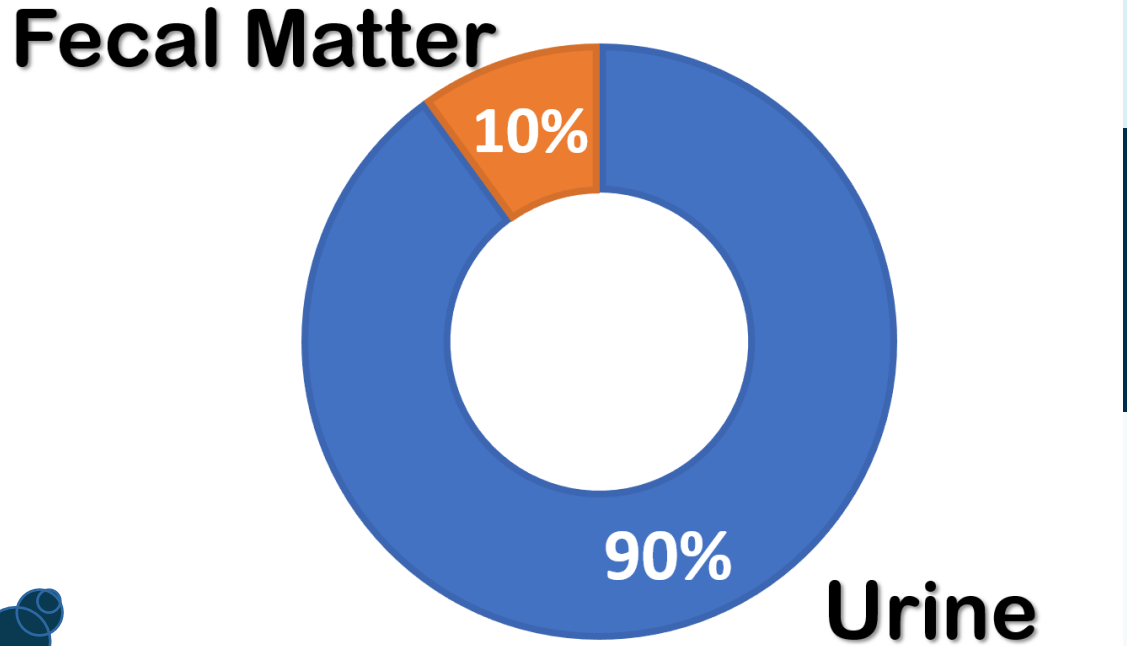


IN: Noe-Hays et al., 2020

Sources of Nitrogen

- Human waste
- Food waste
- Cleaning products

Quaternary Ammonia Compounds



Robust system designs

- Robust designs consider or incorporate:
  - Inherent capacity of each component to process peak loads
  - Appropriate safety factors included in design calculations
  - Treatment systems tailored to specific parameters
  - Flow equalization/time dosing of components
  - Use (or not) of pressure distribution in soil treatment area

Design criteria

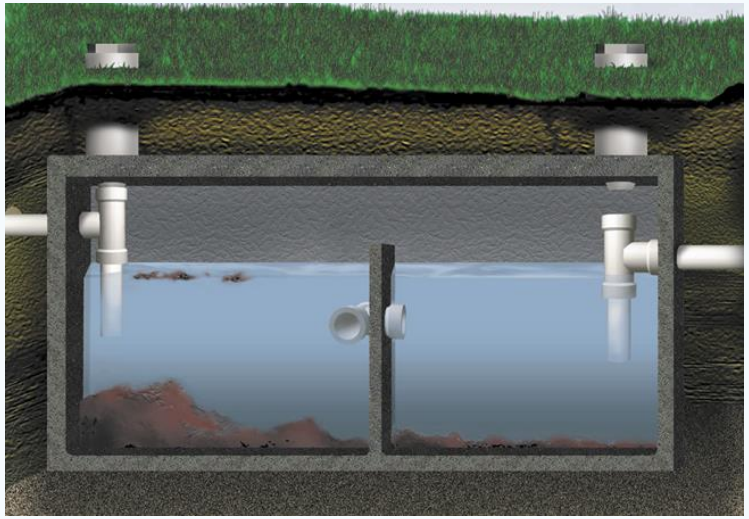
- Treatment components: hydraulic and organic loading
- Receiving environment: mass loading
- Basis of specific requirements
  - Indirect: Concentration loading
    - *Depends on the volume of liquid*
  - Direct: Mass loading
    - *Mirrors the criteria used for treatment and dispersal of contaminants*

OWTS sensitivity to hydraulic loading

- Component response to peak hydraulic loading
  - Septic tank with effluent screen
  - Tank surface area
- Design – robust treatment capacity with safety factor
- Flow attenuation – restrict liquid movement through system
- Flow equalization / dosing tank with time dosing
- Restrict/limit flow bypass

Septic/trash tank operation

- Septic tank is a wide space in pipe
- Effluent enters tank, spreads across tank surface area
- Liquid level rises in tank resulting in effluent leaving tank
- Rate effluent leaves tank is proportional to increase in water surface



Calculating gallons per inch

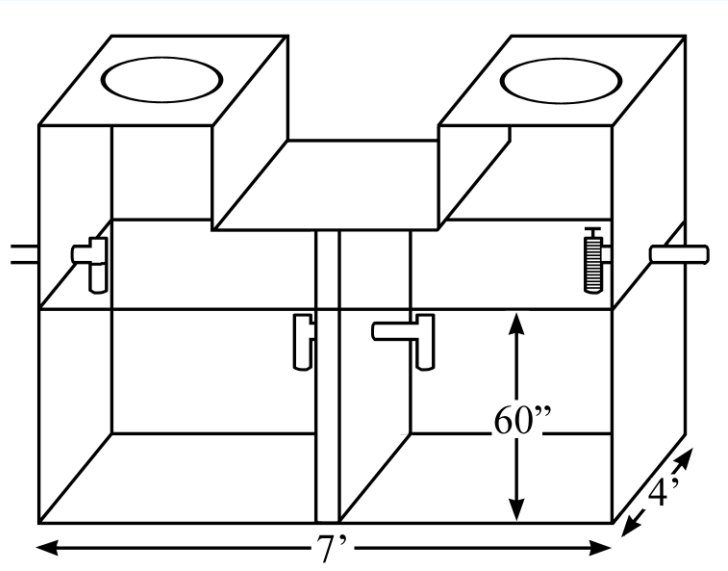
- Tank INSIDE dimensions
- Operating depth is measured to the OUTLET

4’ x 7’ x 60”

4’ x 7’ x [60”÷12] = 140 ft^3

140 ft^3 x 7.5 gal/ft^3 = 1050 gal.

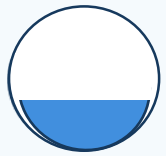
1050 gal ÷ 60 inches = 17.5 gal./in.

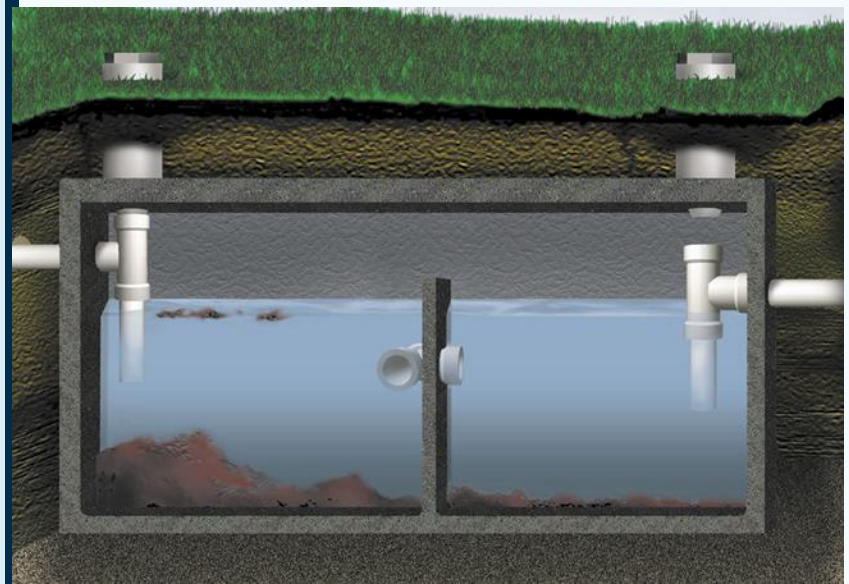


V = Q/A

GPI is the critical factor for discharge rate.

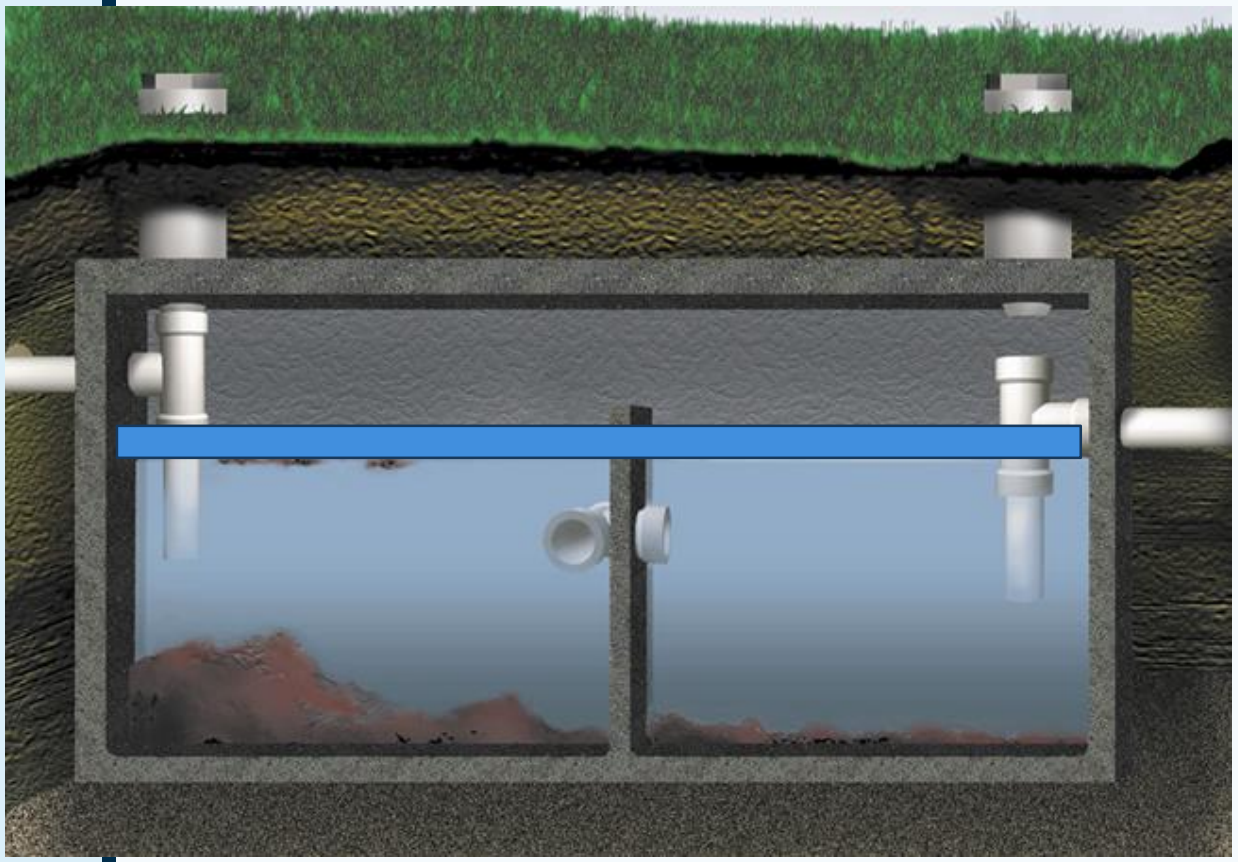
Pipe discharge flow

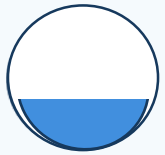




- Discharge rate determined by
  - Cross-sectional area of flow within pipe
  - Slope of pipe
    - *Increasing values increase discharge rate*
- Rise in the liquid level in the tank directly determines:
  - The liquid level in the pipe
  - The cross-sectional area of flow

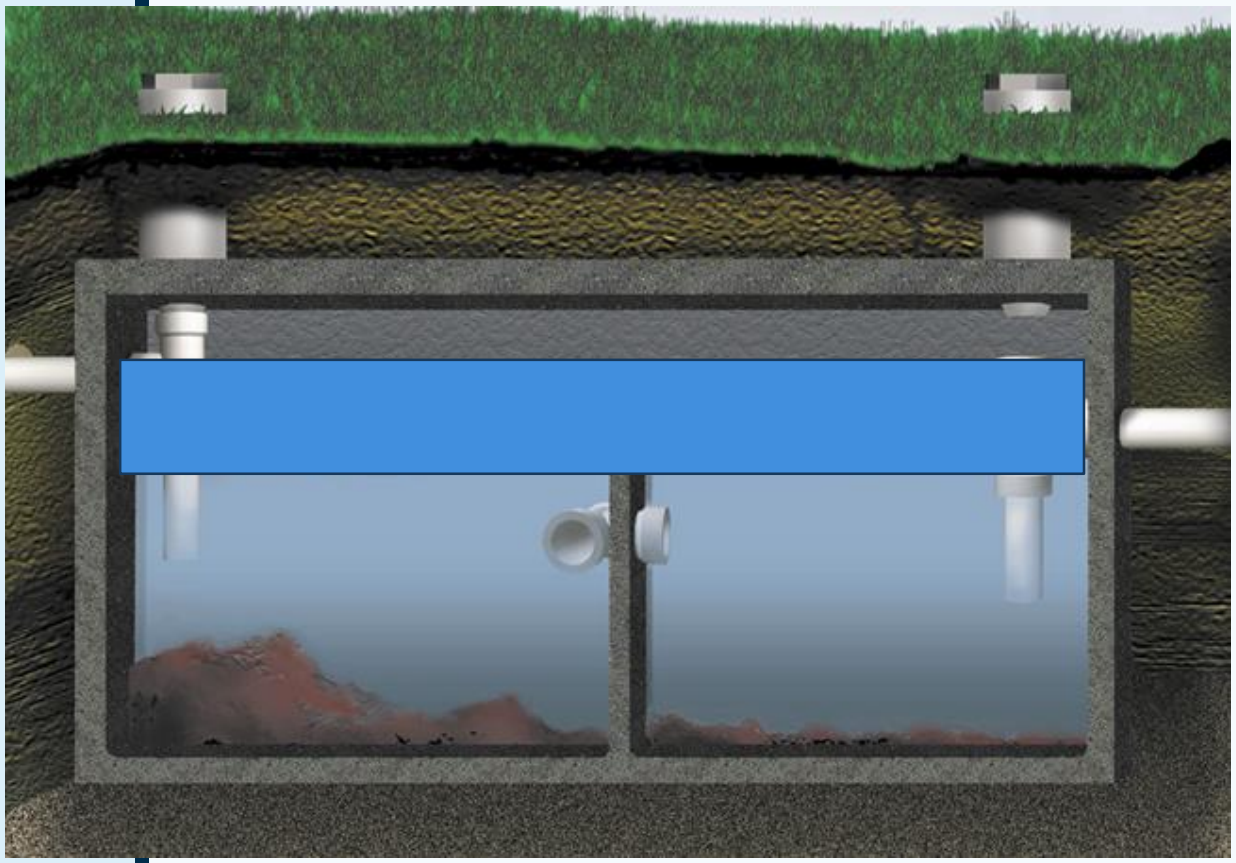
Liquid entry & exit





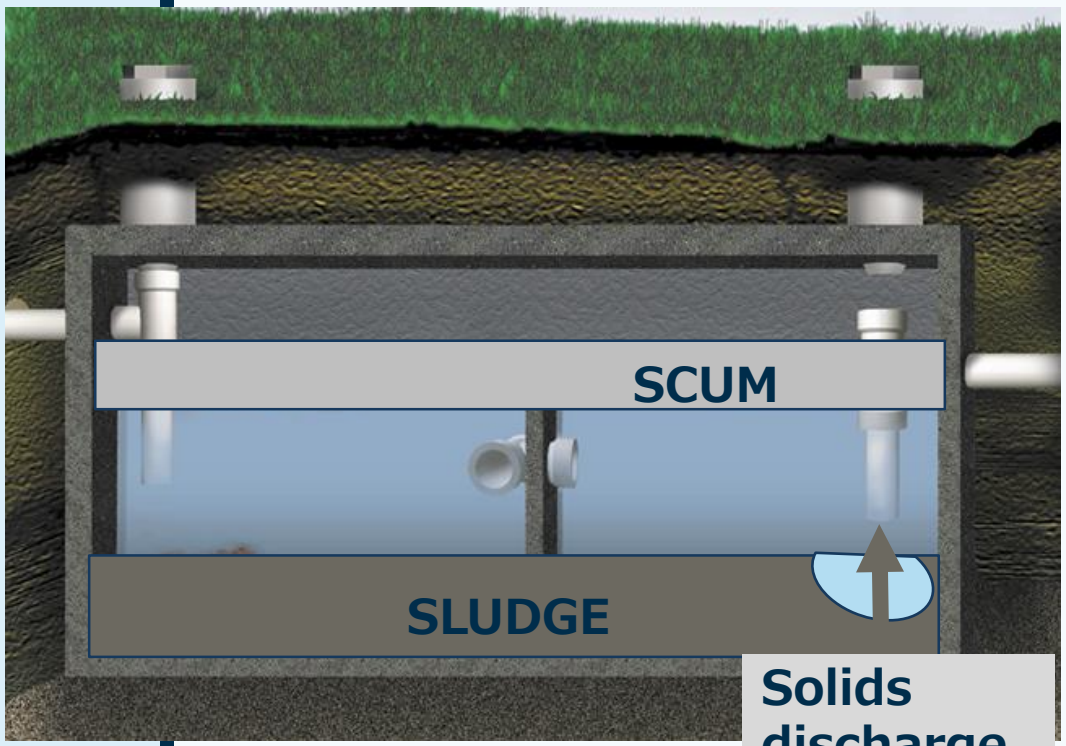
- Washing machine: 35-gallon tub capacity
- 35 gallons/17.5 gal/inch
- Two (2) inch increase in liquid surface elevation

Liquid entry & exit



- Large garden tub: 123-gallon capacity
- 123 gallons/17.5 gal/inch
- Seven (7) inch increase in water surface
- Rapid water movement through tank
- Disrupts settling process
- Extreme condition – scum exits the baffle

Solids discharge

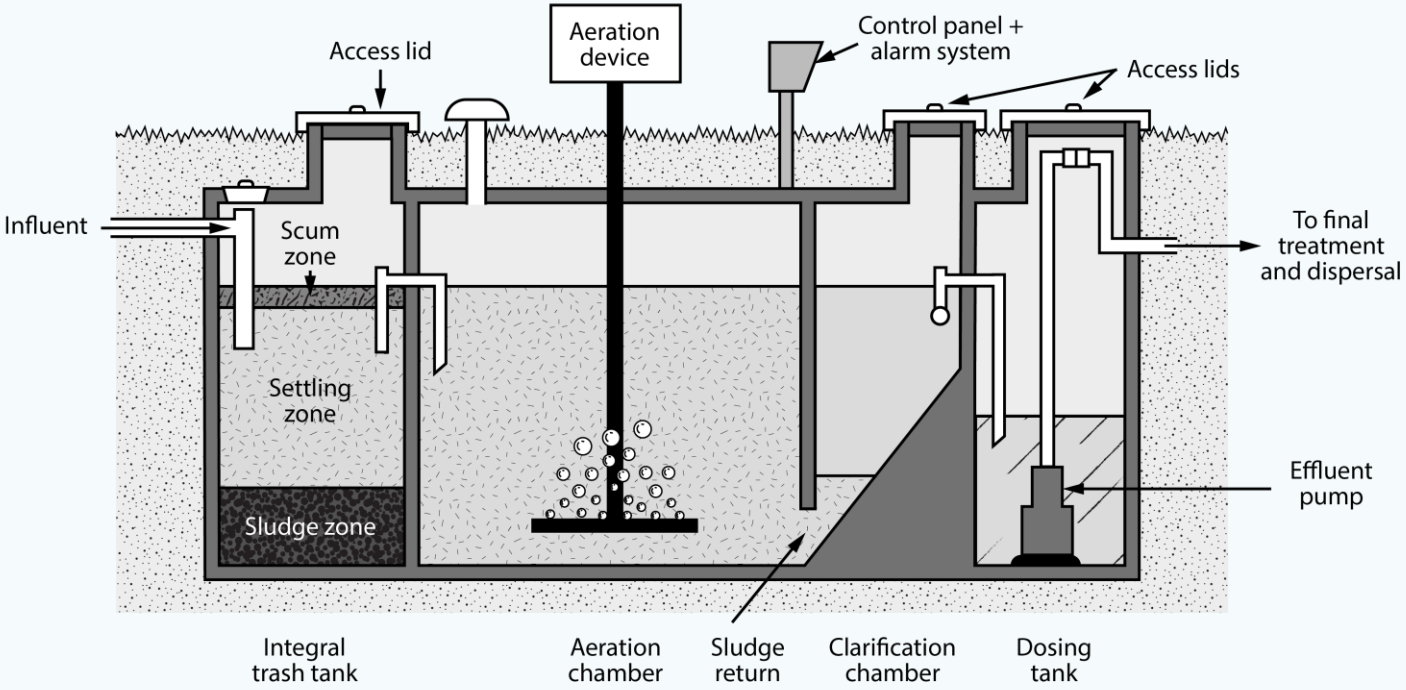


- Solids accumulate in septic tank
- Scum level approaches outlet baffle
  - *Within 3 inches*
- Sludge level approaches outlet baffle
  - *Within 12 inches*
- Increasing water velocity at outlet creates a vortex
  - *Carries solids out of tank*

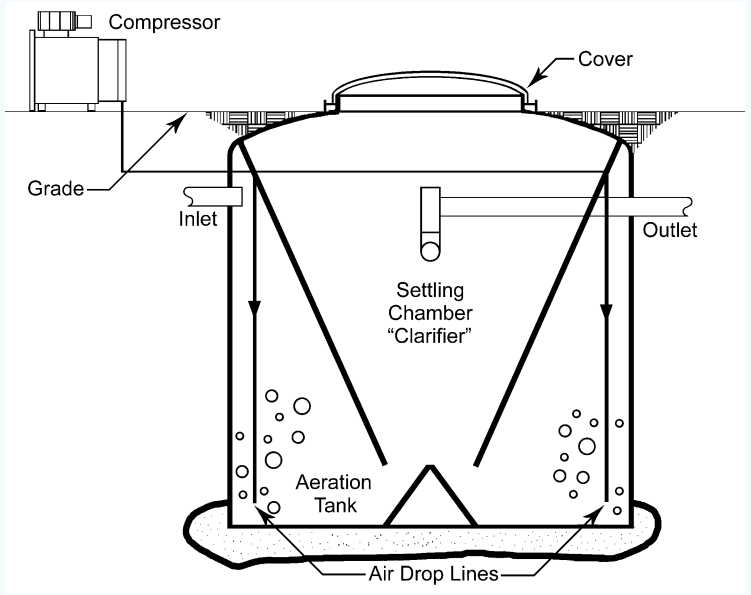
Effluent screens

- Screen solids from effluent exiting septic tank
- Plug when solids discharge from septic tank
- Indicators of plugged screens:
  - Slow drainage from building
  - High-water alarm condition in septic tank
- Excellent warning system for maintenance

Clarification Chamber



Surface area connected across three chambers
Entering liquid spreads over all tanks.

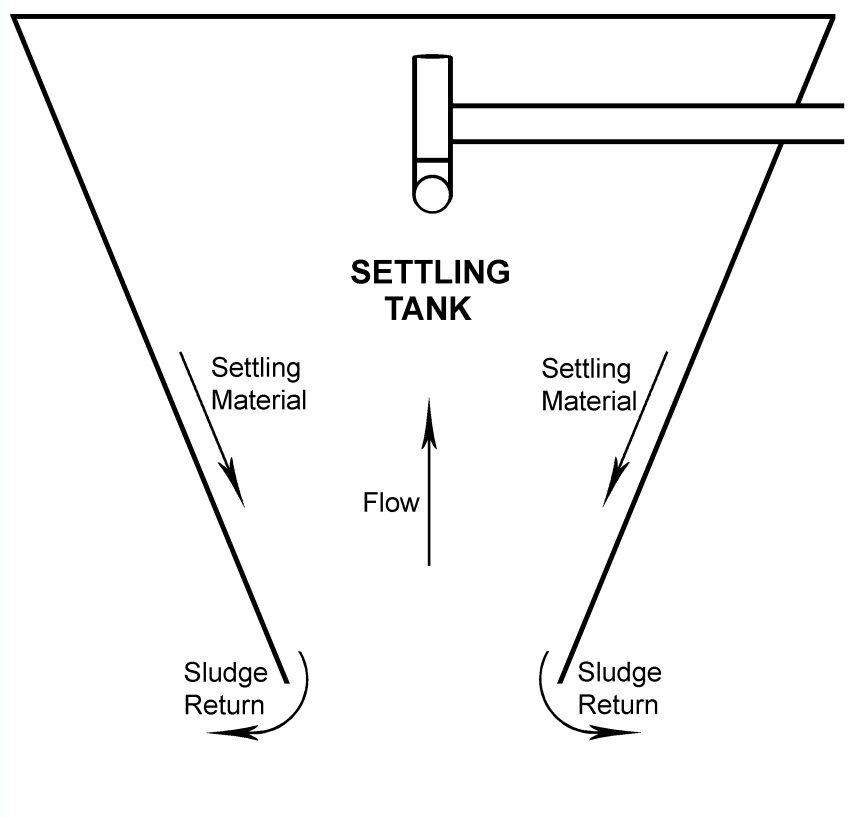


Tank with integrated clarifier.
Most surface area is in clarifier

Vertical Settling Chamber

- Vertical flow through the chamber
- Upward flow rate must be less than the settling rate

$$V = Q / A$$



OWTS sensitivity to organic mass loading

- Component response to variable organic mass loading
  - *Septic tank – effluent screen*
  - *Treatment – suspended growth, biofilm growth*
- Design
  - Robust treatment capacity with safety factor
- Flow equalization / dosing tank with time dosing
  - Distributes the organic load over 24 hours

OWTS sensitivity to nutrient mass loading

- Nitrogen and phosphorus remain in solution and move through the system
- Addressed based upon concentration
- Robust designs with flow equalization
  - High storage volume allows reduction in concentration
- Diligent operation and maintenance

Mass Loading Values – per person

Item	Range (lb./cap./day)	Typical without ground up Kitchen waste (lb./cap./day)	Typical with ground up Kitchen waste (lb./cap./day)	Common Value (lb./cap./day)
BOD	0.11 - 0.26	0.17	0.22	0.25
TSS	0.13 - 0.33	0.2	0.25	0.25
NH^3 as N	0.011 - 0.026	0.017	0.019	0.03
Flow (GPD/cap.)	20 - 200			75

Metcalf and Eddy, 4th Edition, Table 3-12

Water conservation – ten marble example

Scenario	10 Marbles in a 2-liter bottle	10 Marbles in a 1-liter bottle
Hydraulic loading	2-liters	1-liter
Organic loading	10 marbles	10 marbles
Concentration	5 marbles per liter	10 marbles per liter
Sizing of OWTS	10 marbles	10 marbles
Controlling loading	Organic	Organic

Water conservation removes liquid, not waste

Concentration vs Mass Loading

- Contaminant loading
  - Concentration: mass per volume, mg/L
  - Mass: pounds per day

- Mass (lb.) = C (mg/L) x Q (GPD) x 8.34/1,000,000
- Mass (lb.)= 300 mg/L x 500 GPD x 8.34/1,000,000 = 1.25 lb./day
- Mass (lb.)= 600 mg/L x 500 GPD x 8.34/1,000,000 = 2.5 lb./day

HOW DO I USE ALL THIS INFORMATION?

- Collect and analyze samples from:
  - Outlet of pretreatment tank (septic, trash or flow equalization tank
  - Dosing tank
  - Send samples to environmental laboratory for analysis
- Calculate contaminant mass load for each sample
- Compare actual contaminant reduction figures to manufacturers specified mass reduction capacity

Biomass

- Solids
  - Suspended solids
  - Settleable solids
  - Sludge
- Color indicators
  - Rich brown color – aerobic
  - Dark to black – anaerobic
- Biomass fluctuation and accumulation: F:M ratio

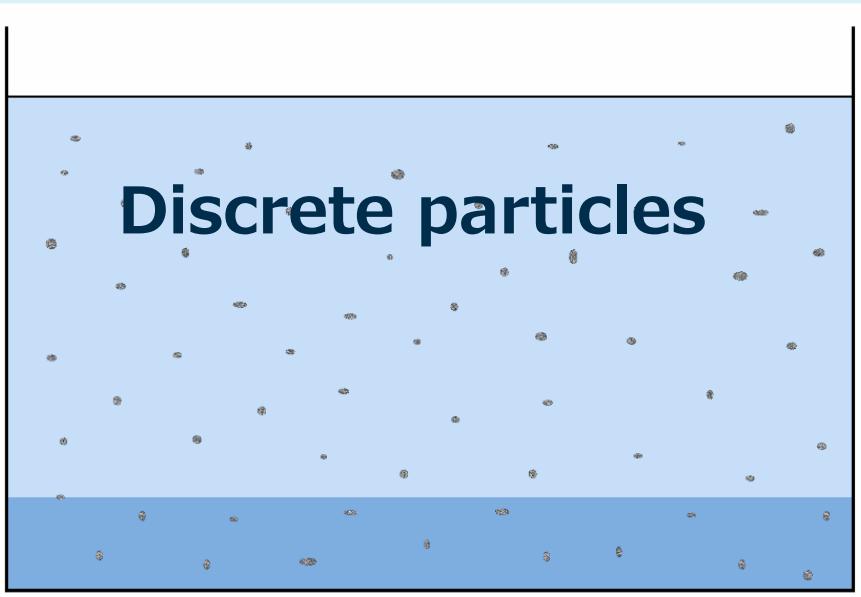
Biomass accumulation

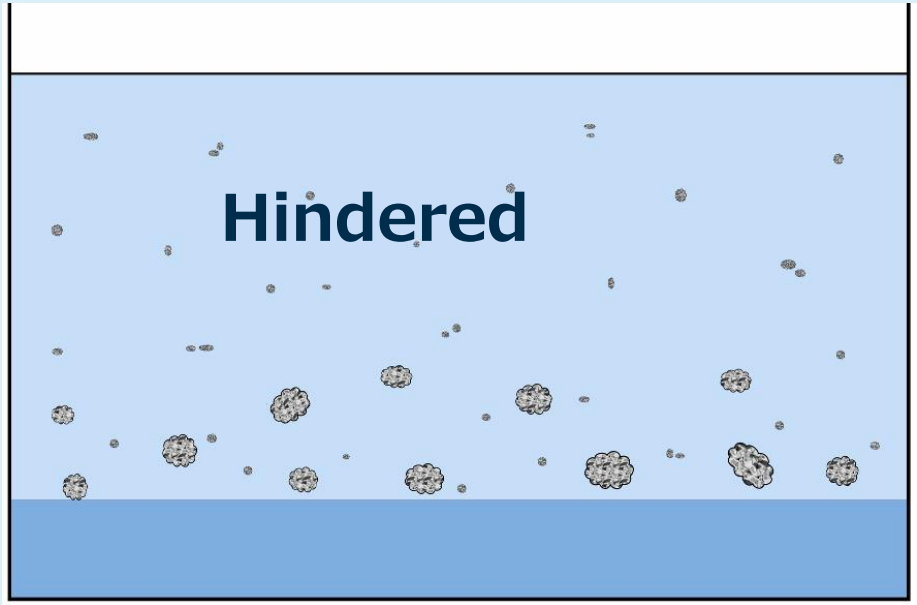
Determine the amount of mixed liquor suspended solids (MLSS)

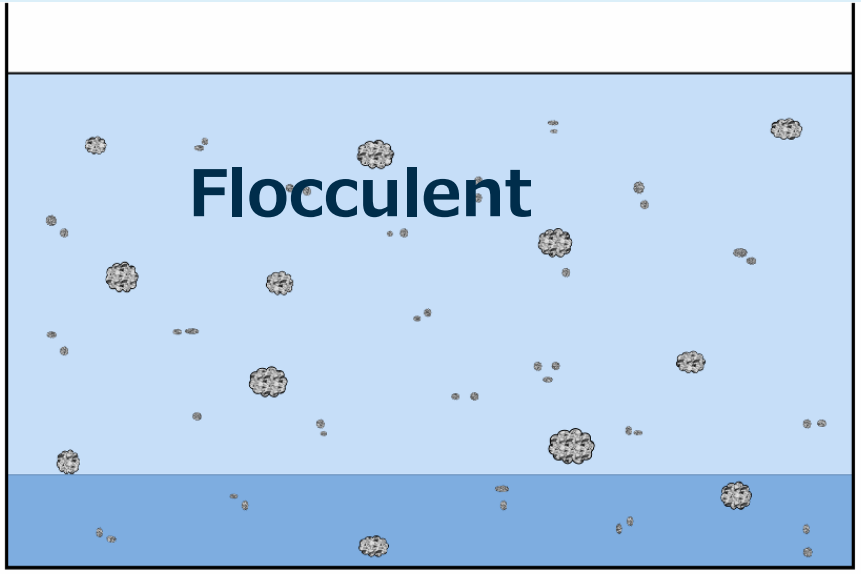
30 Minute Settleability Test

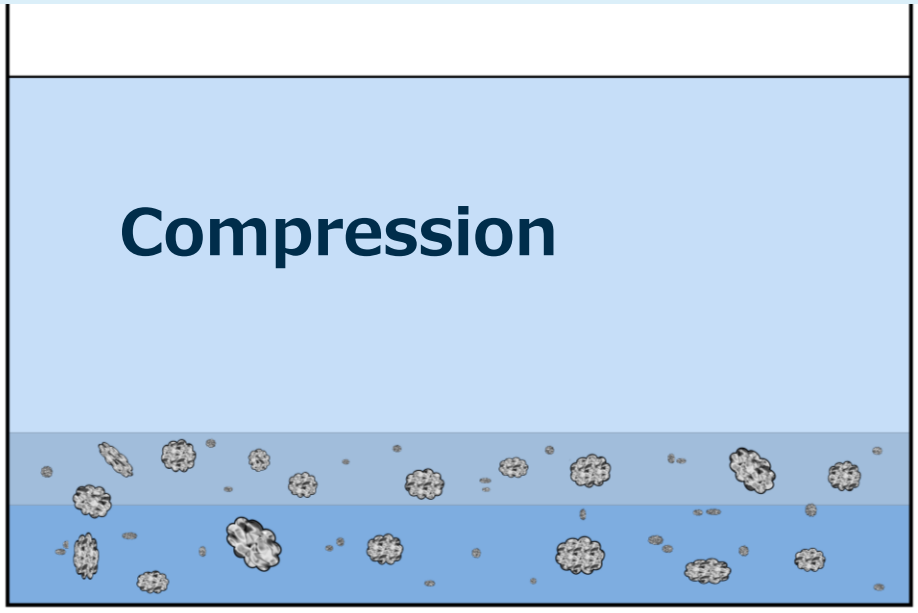
- Beaker with 10 even gradations
- Sample from aeration chamber.
- Let stand for 30 minutes
- Read level of settled solids.
- Indicates remaining biomass accumulation capacity

Particle settling processes







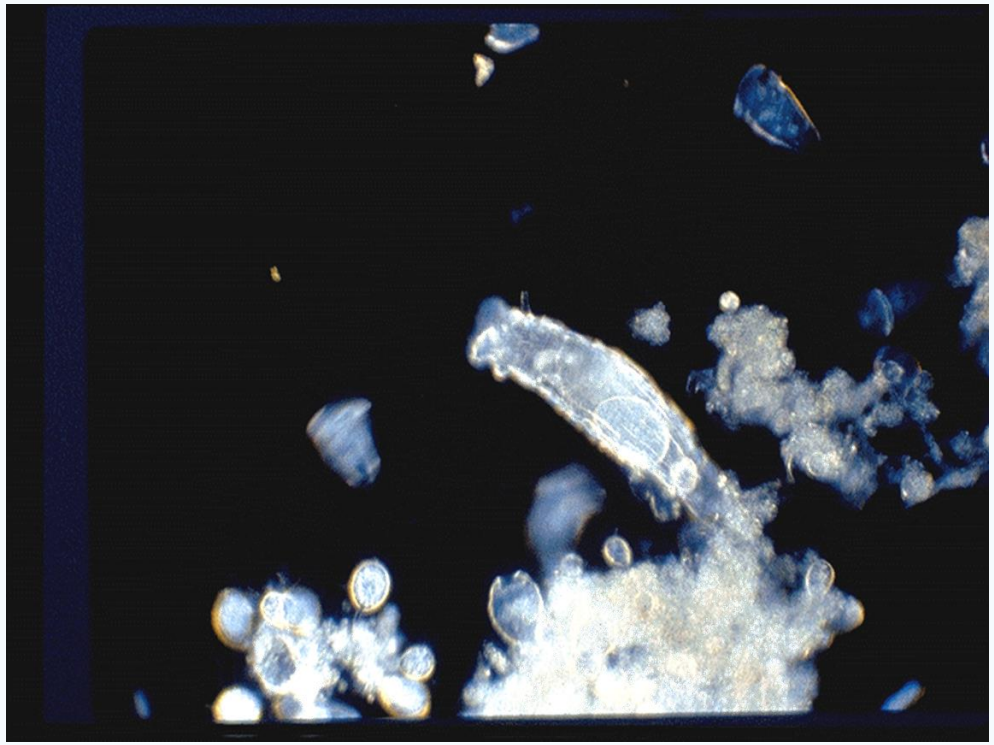


OWTS sensitivity to microbial inhibition

- Effective particle settling depends on healthy microorganisms
- Effective particle settling means effective solids removal
- THEREFORE, a healthy microbial environment is *the basis of good treatment.*
- Troubleshooting: investigate potential microbial inhibitions:
  - Temperature, pH, DO, alkalinity, chemicals, food supply

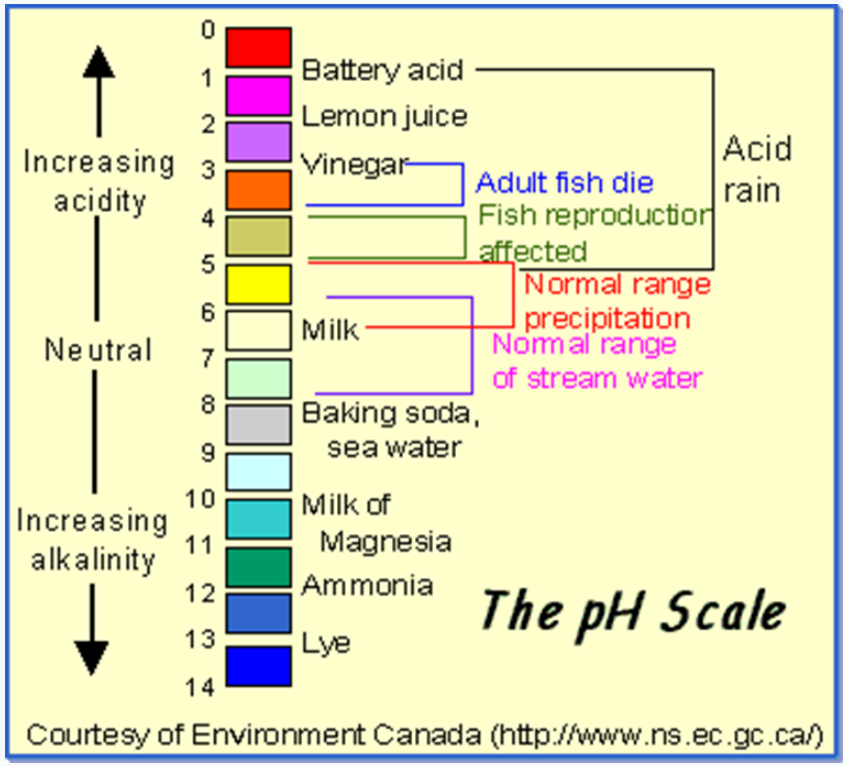
Microbial inhibition: temperature

- Optimal temperature – 68º F plus
- Low temperatures slow microbial degradation of constituents
  - Microbes become dormant below 39.2ºF (4ºC)
- Maximum temperatures
  - FOG emulsification at 95º F
  - Organism survival – 122º F



Microbial inhibition: pH

- Measure of acidity or basicity
- Major impact on biological and chemical reactions
- Neutral value of 7 is best
  - Fluctuations or rapid changes can kill microorganisms
- Range of 6.5 to 8.0 for microbial growth
- Biological life: 4.5 to 9



Microbial inhibition: dissolved oxygen state

- Anaerobic conditions
  - Less than 1.0 mg/L
- Anoxic conditions
  - Less than 0.5 mg/L
  - Better at 0.3 mg/L
- Aerobic conditions
  - Greater than 1.0 mg/L
  - Better at 2.0 mg/L plus
- Microorganisms: Anaerobic, Aerobic, Facultative

Microbial inhibition – Chemicals

- Cleaning products
  - Sanitizing
  - Excess nitrogen loading
  - Quaternary ammonia compounds
- Water source
  - Limited alkalinity
  - Inherent or added salinity
- Medications

Microbial inhibition – Food supply

- Variable or limited food supply
  - Carbon, nitrogen and phosphorous
  - Presence of carbonate for nitrification
- Waste imbalance
  - More urine vs. feces: low carbon/high nitrogen
  - Graywater vs. blackwater
  - Use of urine-separating or incinerating toilets
- Food to microorganism (F:M) ratio

Microbial environment management options

- Remove inhibitors to healthy growth
- Dissolved oxygen management
  - Maintain aeration system
  - Adjust circulation ratios
  - Adjust air flow to air lift pumps
- Alkalinity management – maintain an appropriate pH
  - Limestone in contact with aerated liquid
  - Soda ash dosing

Microbial environment management options

- Enhanced denitrification through carbon management
  - Methanol, ethanol, acetate, glycerol dosing
  - MicroC® dosing
- Enhanced biological phosphorous removal processes
  - MicroC 2000® dosing

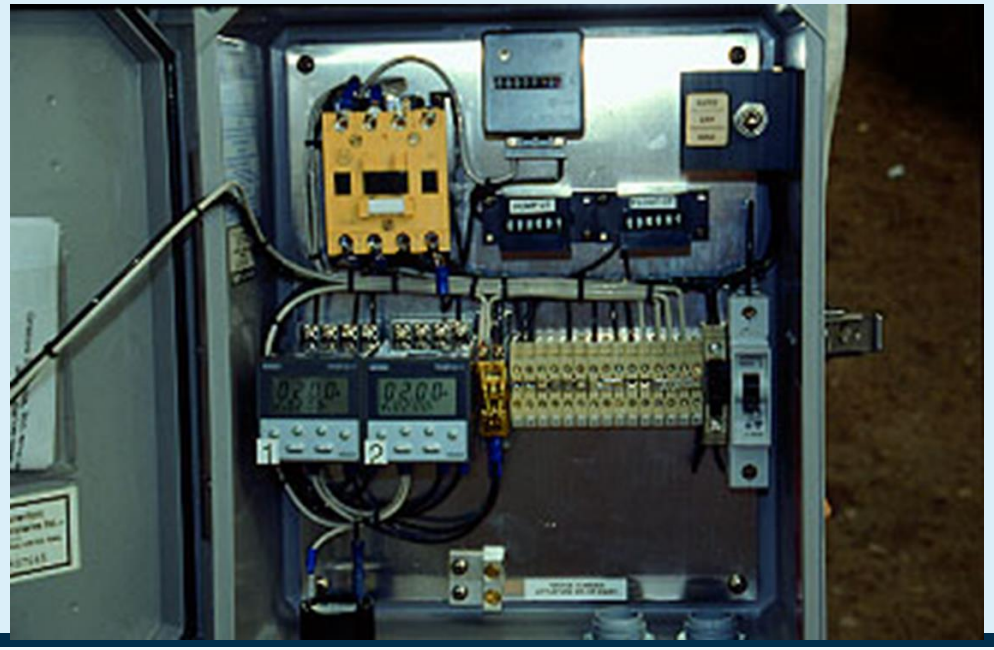
Microbial inhibition management options

- Less toxic alternatives for cleaning and disinfection at source
  - Quaternary ammonium compounds (QUATs)
  - QUAT deactivation chemicals:
    - *Commercially available*
    - *Cyclodextrins, lecithin and Tween 80*

Summary

- First step: Identify the root cause of malfunction
- Solids removal is essential and fundamental
- Treatment trains designed with capacity to remove ***specific*** hydraulic, organic and nutrient load
- Peak or excessive loads causes contaminants to move downstream
- Investigating excessive loading and potential fixes
- Investigating microbial inhibition and potential fixes

QUESTIONS?



Instructor's Contact information here