GRANITE STATE
DESIGNERS & INSTALLERS
New Hampshires Association of Septic System Professionals

ANAEROBIC VS AEROBIC TREATMENT

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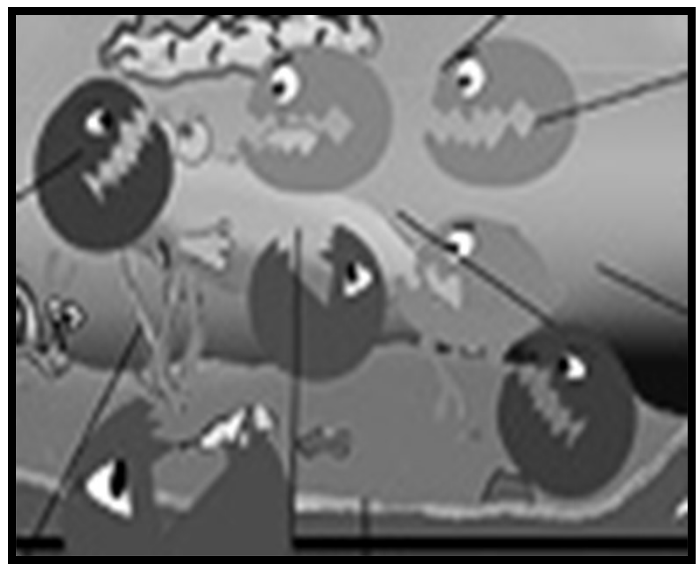
ONSITE SEWAGE TREATMENT PROGRAM

Presentation Overview

- Biological treatment
- Anaerobic treatment
- Aerobic treatment
- Oxygen states
- Applications in onsite systems
  - Anaerobic
    - Septic tanks
    - Processing tanks
  - Aerobic
    - ATUs, Media filters
    - Soil treatment systems
  - Microbe removal

Biological Treatment in Septic Systems

- Uses the microorganisms present
- Different applications
- Biological population and processes dependent on system conditions
  - Aerobic
  - Facultative
  - Anaerobic



Biological Treatment Processes (cont.)

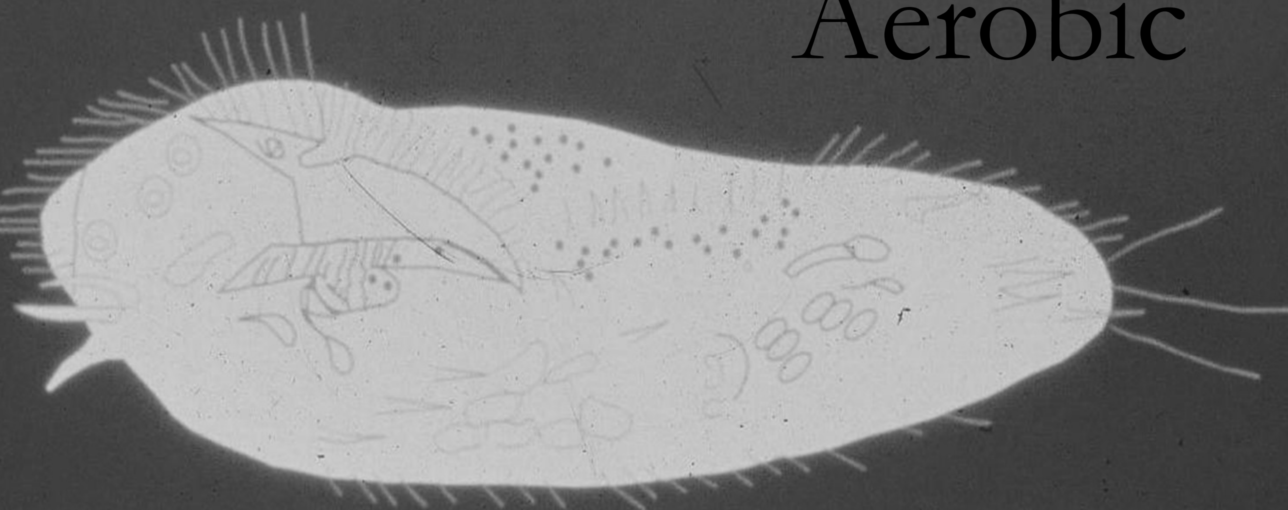
- Biological oxidation
  - Bacteria break down organic matter into water and CO_2
  - Reduces BOD, pathogens
  - Works most efficiently in aerobic conditions

MICROORGANISM SIZE COMPARISON

Anaerobic

A single bacteria is 1.0 µm in length
(Bacillus)

Aerobic



A Single protozoa is 50.0 µm in length
(Stylonchia)

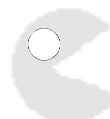
Anaerobic Microbes

- Anaerobic bacteria grow in absence of free oxygen, O_2
- Most anaerobic organisms are bacteria
- Anaerobic treatment processes split oxygen bound,
  - Ex. $SO_{4:} \rightarrow H_2S$, $NO_3 \rightarrow N_2$
- Common condition in:
  - Septic tanks,
  - Processing tanks,
  - Constructed wetlands
  - Other saturated environments

Anaerobes Cont’d

- They are not able to get as much energy from their food
- Advantages:
  - Microbes that do not require oxygen are able to live in places where aerobes cannot survive, such as the human gut, and many other places where oxygen is in low supply
  - For pathogenic microbes (those that cause disease), this ability is a huge advantage, allowing anaerobic pathogens to cause disease in areas of the body that are not exposed to oxygen

Anaerobic Digestion



ORGANIC MATTER → GASES + HUMUS

CO_2
CH_4
H_2S
NH_3

Denitrification – Anaerobic Microbes

Denitrification Process

$$NO_3^- + \text{organic carbon} \xrightarrow{\text{carb. bacteria}} N_2 + CO_2 + OH^- + H_20$$

$$CO_2 + OH^- \longrightarrow HCO_3^-$$

$$NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$$

- **2.86 lbs oxygen recovered per lb NO3-N**
- **3.57 lbs alkalinity recovered per lb NO3-N**
- ≥ 3 mg $cBOD_5$ / mg NO_3-N

Basic Design Considerations for Nitrogen Removal Systems

- Anoxic Zone
  - D.O. <0.5 mg/L
  - BOD:NO3-N Ratio
  - Hydraulic retention time
  - Mixing
  - pH (6.5-7.5 ideally)

Denitrification

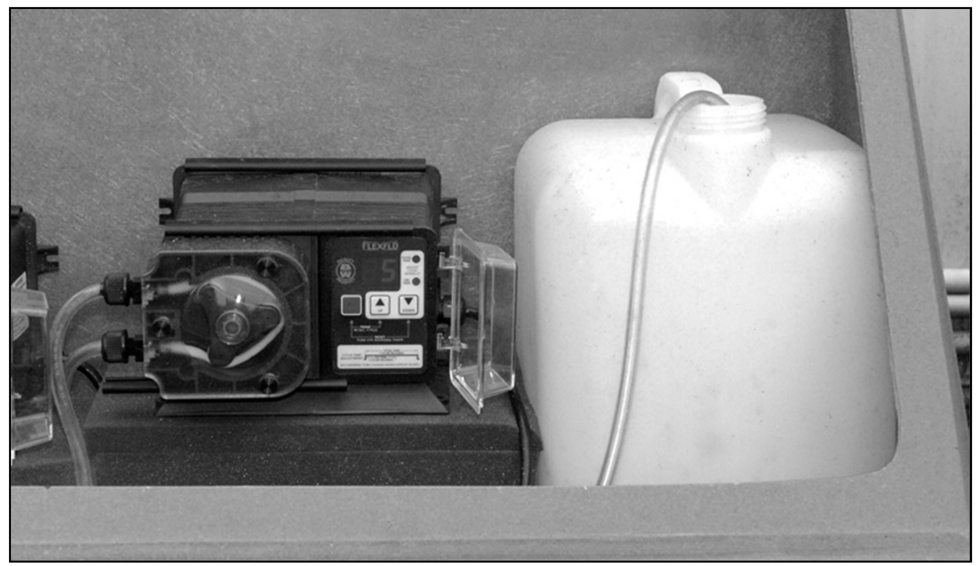
- Heterotrophic bacteria can
  - use nitrate instead of oxygen to break organic matter
  - anoxic conditions
- If oxygen is present:
  - the bacteria will use it instead of NO_3^-
  - Anoxic conditions must exist
- A carbon source is needed for denitrification to occur

Biological Denitrification

- Heterotrophic Denitrification: Wastewater as the Carbon Source
- The reduction of 1 mg of NO3- is equivalent to 2.86 mg of O_2
- Wastewater with an ultimate BOD (BODL) of 200 mg/L could potentially reduce almost 70 mg/L of NO3-
  - if the wastewater were used as the carbon source
  - Does NOT happen in practice as a portion of the carbon in the wastewater must be used for cell synthesis

Carbon Source for Denitrification

- Influent BOD
- Organic material in soil or filter
- External Source

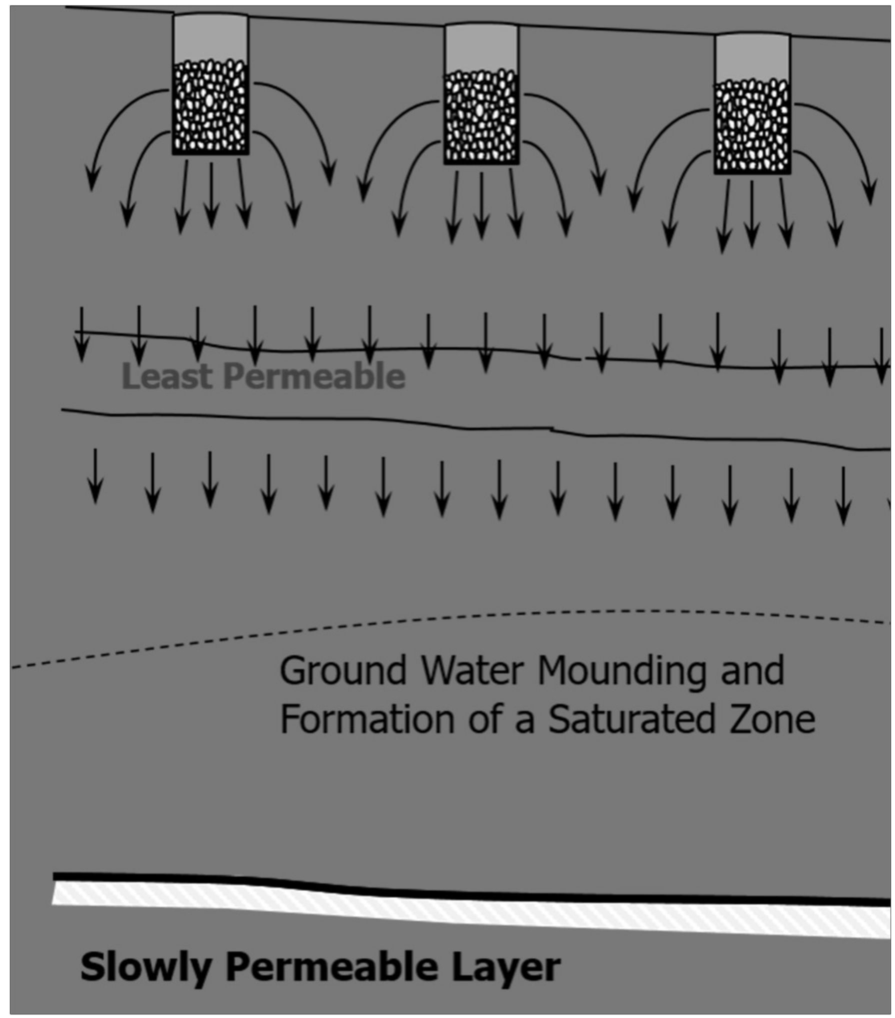


Denitrification in the Soil

1. $NH_4+ \rightarrow NO_3^-$

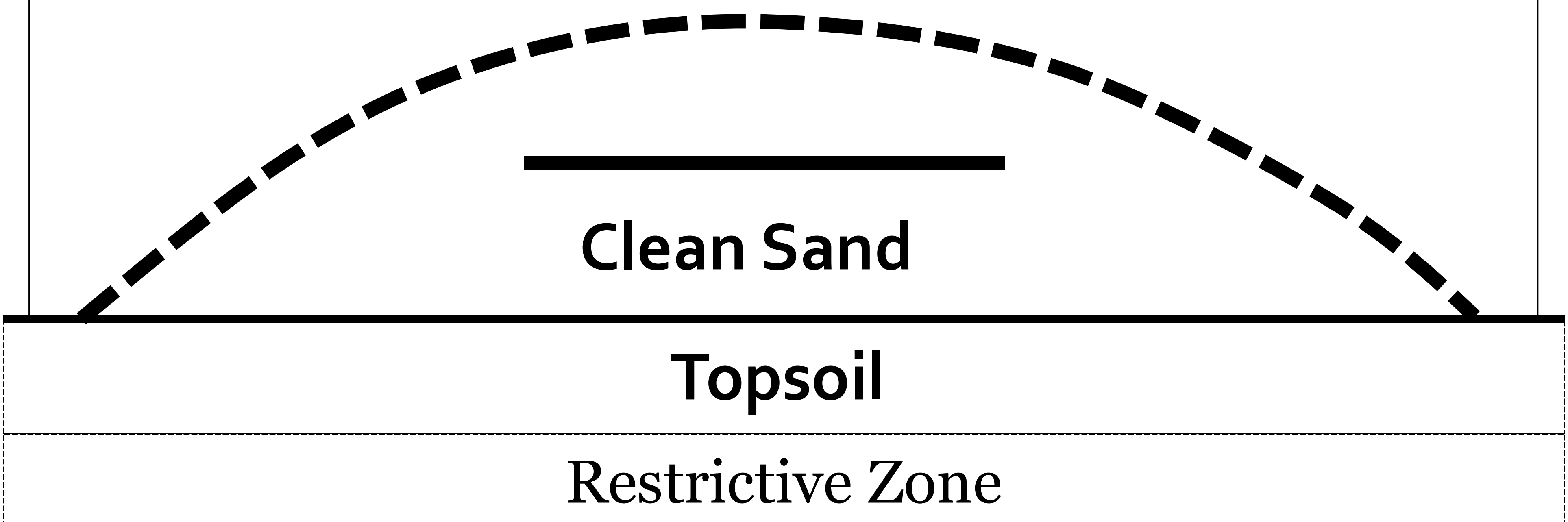
   If carbon source, microbes & anaerobic conditions exist

2. $NO_3- \rightarrow N_2$



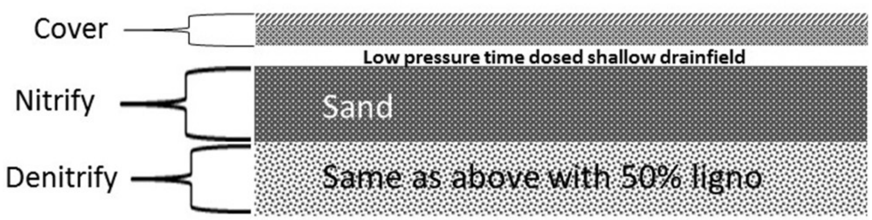
Mound system denitrification

- As ammonia passes through clean sand it is nitrified → converted to nitrate
- Topsoil serves as food source for natural soil microorganisms to use the nitrate as oxygen source if zones of saturation occur



What are nitrogen reducing biofilters?

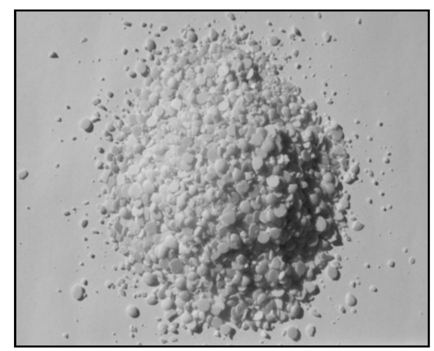
- Nitrogen reducing biofilters (NRBs) are in-ground, layered septics that reduce effluent N using reactive media for denitrification
- Two stage biofiltration process:
  - Stage 1: "nitrify" nitrogen compounds to NO_3 (nitrification)
  - Stage 2: "denitrify" NO_3 to nitrogen gas (denitrification)



Example of layered system

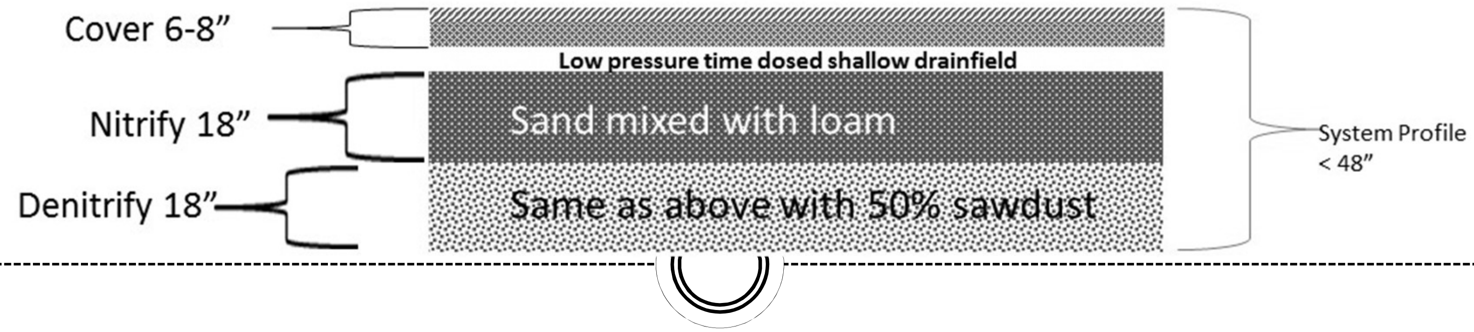
REACTIVE MEDIA

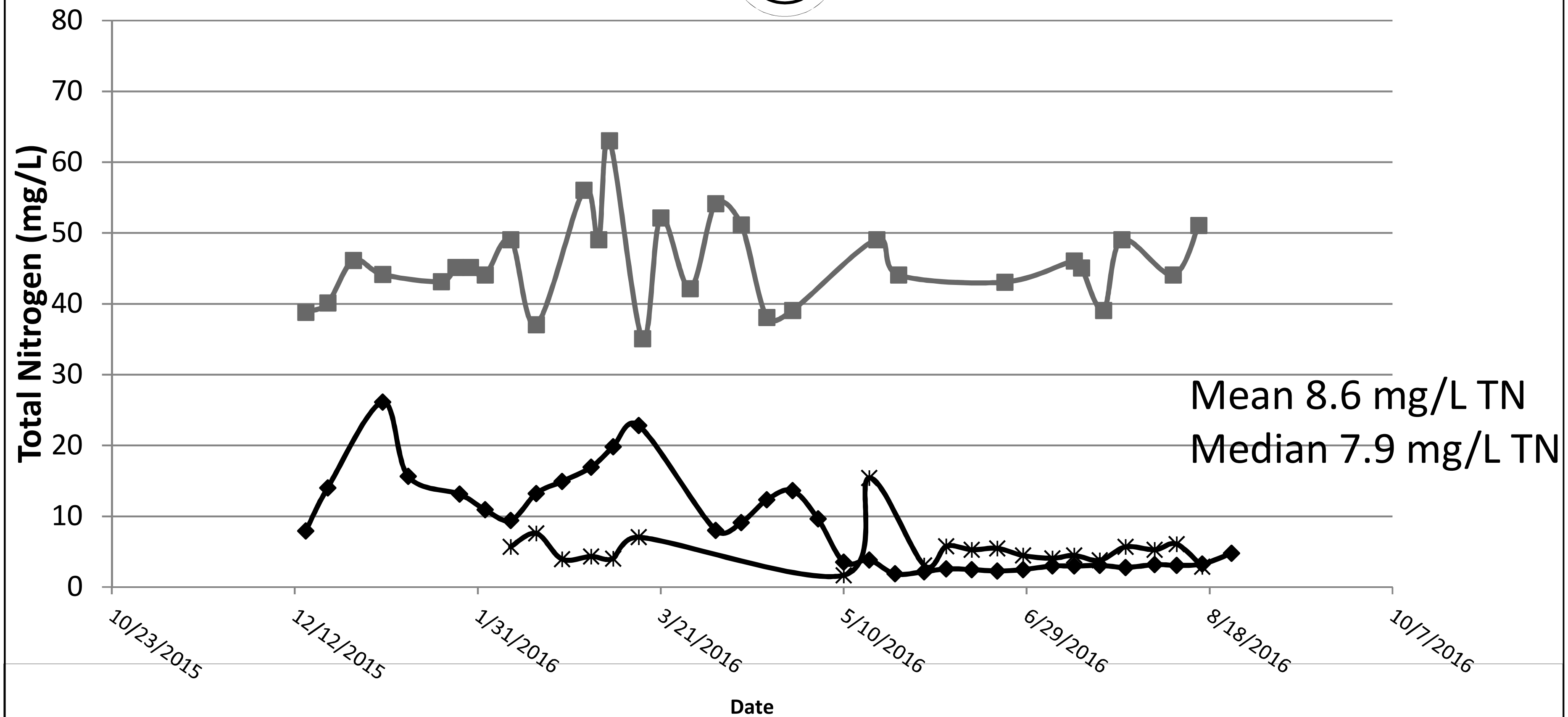
denitrification media: lignocellulosics



denitrification media: elemental sulfur

Lower Profile Unsaturated Denitrification





Denitrification Rate

- It varies with the source of carbon
- It varies with temperature
  - Denitrification rates affected by temperature drops below 68°F
  - Denitrification rate at 50°F will be less than half of those at 68°F

Challenges of Nitrogen Removal for Onsite Applications

- Periodic and non-uniform influent Flow
- Adverse impact of high and low loading rates on nitrogen removal
- Typically non-optimum influent BOD:TKN for denitrification process
- Potential for unexpected toxicity in the influent
- Temperature limitations in our environment

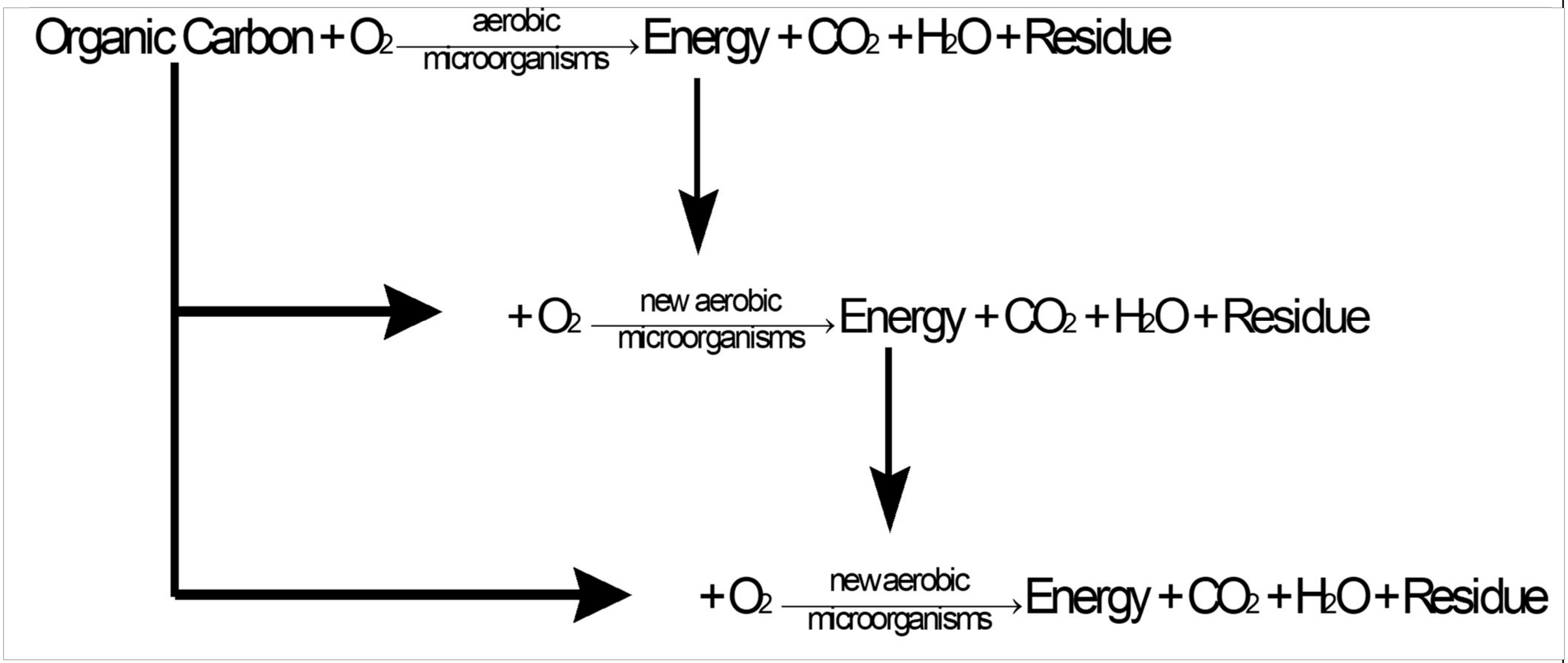
Facultative Microbes

- Can develop in the presence of oxygen but does not require it
- The concentrations of oxygen and fermentable material in the environment influence the organism's use of aerobic respiration vs. fermentation to derive energy
- If given the choice they prefer to have access to oxygen, in order to get the maximal amount of energy from metabolizing their food

Aerobic Microorganisms

- Aerobic bacteria require O2 to live and grow
- Aerobic bacteria manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium
  - The ammonium is further converted by bacteria into nitrate
- Common condition in
  - Soil treatment systems
  - Media filters
  - ATUs

Basic Equation – Carbon Removal



Respiration

Processes Occurring Under Aerobic Conditions

- Nitrification: Transformation of NH_4 to NO_3
- Nutrient reduction
- Pathogen removal
- TSS and BOD reduction

Microbes Minimal Requirements

- Temperature must be life-sustaining
- Steady supply of food to maintain stable microbial population
- pH needs to be controlled
- Limited biocides

Toxic Chemicals

- Liquid fabric softeners – petroleum based and act as emulsifier
- Pine oil and drain cleaners
- Strong sanitizers or quaternary ammonia
- Floor stripping waste (Zinc)
- Pesticides
- Acid and caustic materials

Oxygen States - Dissolved

- Dissolved
  - Free O_2
  - Oxygen that has been incorporated into water
  - Oxygen source for aerobic and facultative microbes
  - Under aerobic conditions, bacteria rapidly consume organic matter and convert it into carbon dioxide

Dissolved Oxygen (DO)

- Concentration of O_2 dissolved in water
  - Measure with meter and probe or colorimetric kit in field
  - DO expressed as mg/L
  - DO low in septic tank <1 mg/L
  - DO in denitrification ntanks <0.5 mg/L
  - DO >2 mg/L from advanced treatment systems

Colorimetric kit for dissolved oxygen

Options and Challenges for Oxygen Transfer?

- Passively through natural diffusion through soil and media
  - Dosing and resting
- Actively through the use of a blower, compressor, etc
- Through infiltration from leaks in home or leaks in components

→ Compaction
→ Smearing
→ Depth
→ Electricity
→ Maintenance
→ Homeowner repairs
→ Watertight components

Amount of Dissolved Oxygen

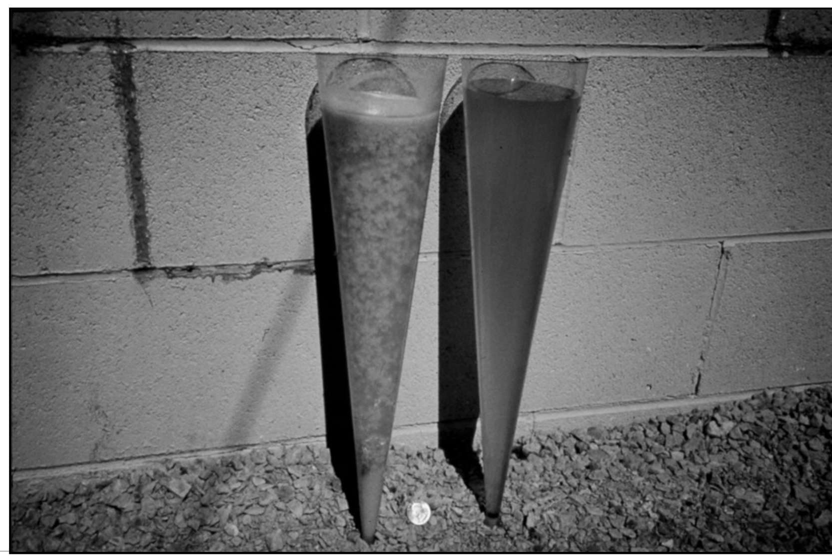
- Temperature:
  - Greater temperature → Lower saturated DO
  - Lower temperature → Greater saturated DO

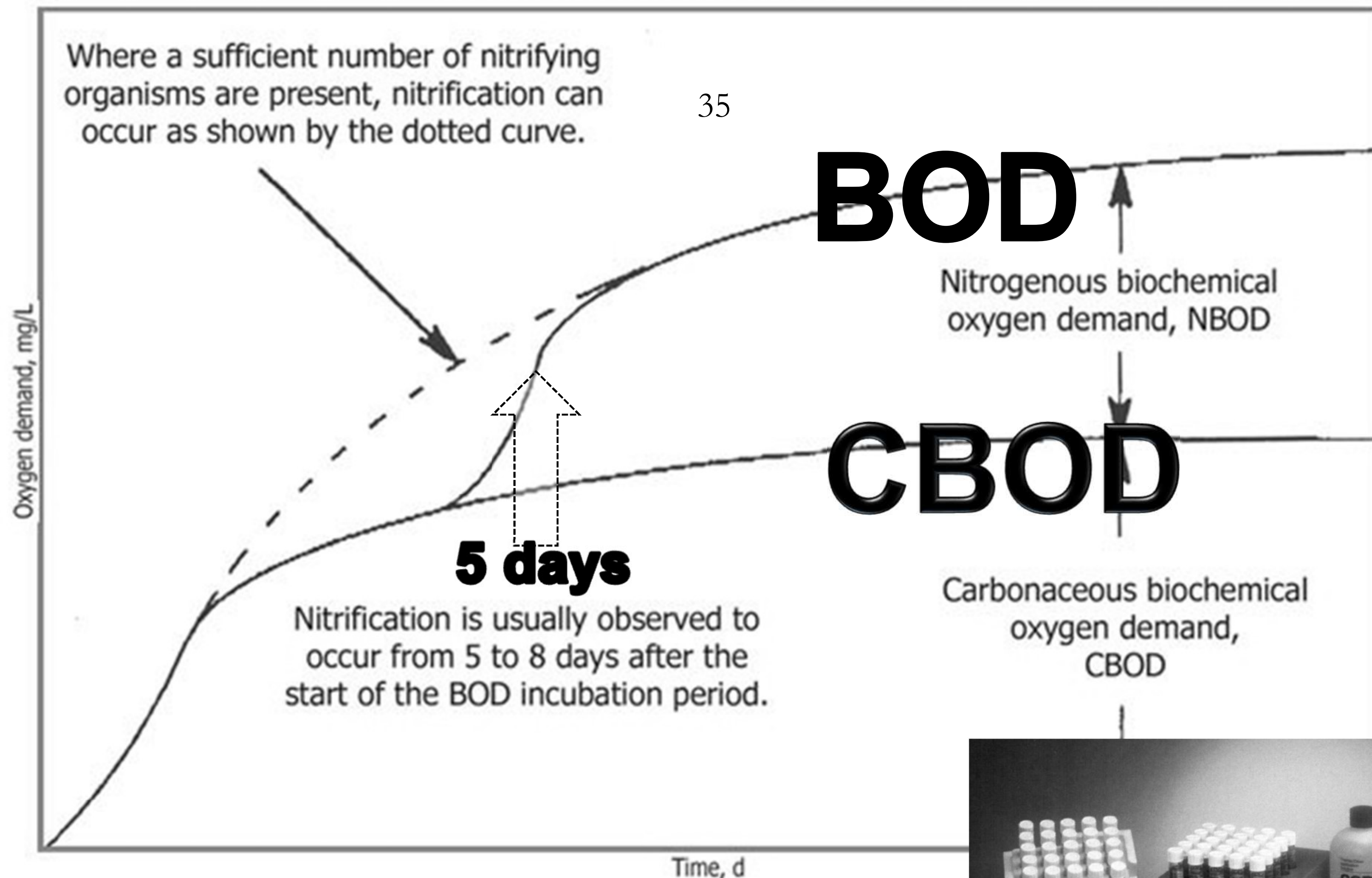
Amount of Dissolved Oxygen

- Organic material
  - If oxygen is available, organic material requires oxygen to decompose
  - Organic material may also decompose in the absence of oxygen
  - More organic material requires more DO, and will tend to deplete water of DO
- Oxygen demand
  - The oxygen demand is the amount of oxygen required to aerobically oxidize a material

Biochemical Oxygen Demand

- Biochemical oxygen demand, or BOD is the amount of oxygen used by organisms during the breakdown of organic material and convert ammonia to nitrate
- BOD is considered an indirect measure of the organic content of a sample





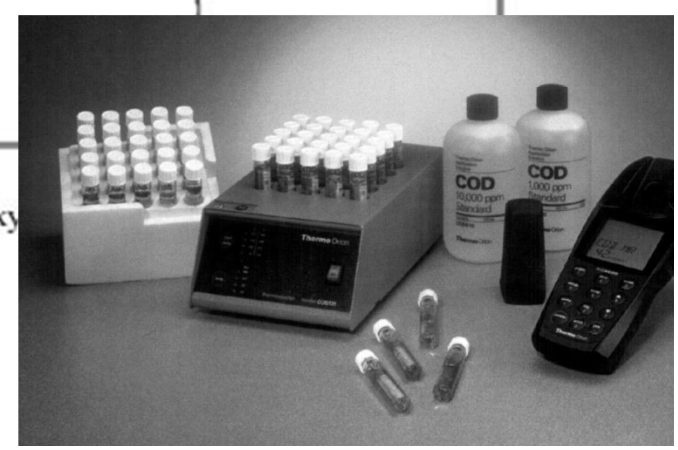


Figure 3: Carbonaceous and Nitrogenous Biochemical Oxy
Adapted from Metcalf and Eddy (1991)

Chemical Oxygen Demand

- Another means of measuring oxygen demand needed to oxidize organics and reduced nitrogenous compounds
- Faster than BOD
- Always higher than BOD
  - COD is much higher than BOD in raw wastewaters
  - COD:BOD ratio is usually less than 2:1 in treated effluents
- COD:BOD ratio is dependent on circumstances and reduces with treatment

DO ranges for Microbes

Ideal Dissolved Oxygen Range in Wastewater			
Microbes	**Anaerobe**	**Facultative**	**Aerobe**
Low DO (mg/L)	0	0	0.5
High DO (mg/L)	0.5	5	5
Typical (mg/L)	0-0.3	0-1	1-3

Troubleshooting - High DO

- Cause
  - Leaking fixtures
  - High DO in source water
  - Sampling method
  - Water infiltration – plumbing, ground and surface water
  - Dead bacteria (chemical addition)
  - Aerator startup
- Effect
  - Mainly and indicator of its cause
  - May be used to recover a system that has a thick biomat
  - Can limit denitrification in processing tanks

Troubleshooting - Low DO

- Cause
  - Low oxygen levels in the water source
  - Excess organic material
- Effect
  - Indicator of anaerobic conditions
  - Increased buildup of biomat
  - More strain on subsequent aerobic step(s)

Temperature

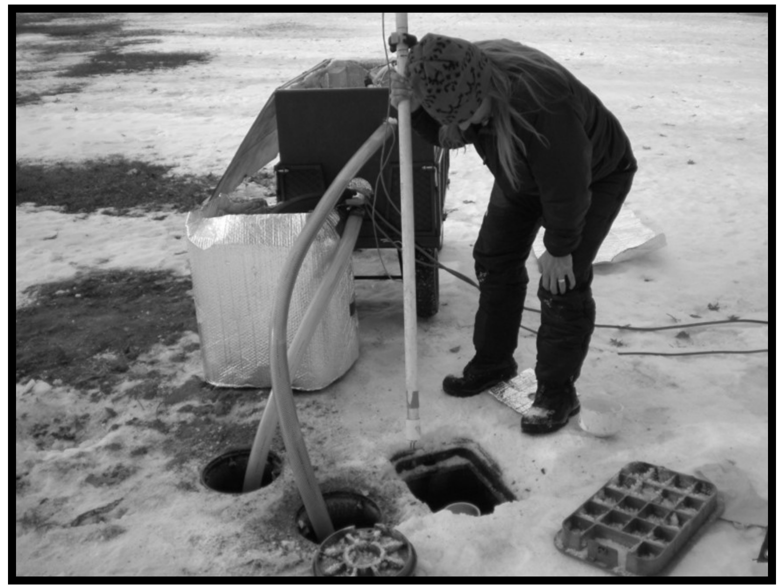
- Typical range: 48 – 70˚F
- Typical value: 59˚F
- Low end concerns
  - Microbes become dormant below 39°F
  - Nitrification impacted by temps below 50°F
- High end concerns
  - < 75°
  - Fats solidify

Temperature and Growth

- Growth rates increase with increasing temperature (0 to 55 ^{o}C)
- Growth rates approximately double for a 10 ^{o}C rise in temperature
- Temperature extremes may interfere with metabolic processes or harm the organisms

What Influences Temperature

- Water temperature
- Holding time
- Air temperature
  - Venting

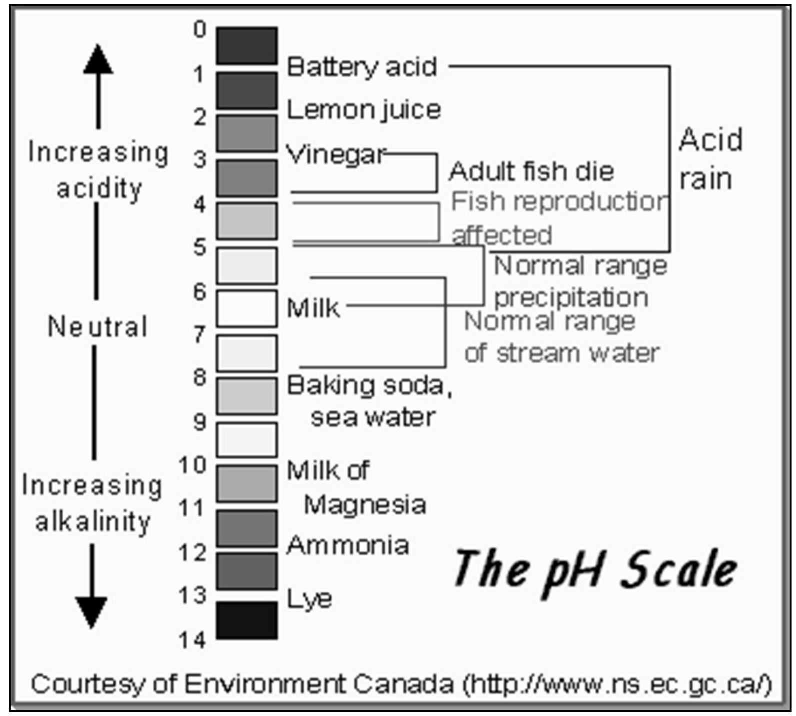


pH ranges for Microbes

Ideal Range in Wastewater	
Low pH	**< 6.5**
Ideal	7
High pH	**>7.2**

pH

- pH is the negative log of the hydrogen ion concentration
- It can have a major impact on biological and chemical reactions
- Neutral range best for microbial growth
  - Typically 6.5 – 7.5 in our systems



Where Does It Come From?

- Low pH: Acids
  - Coffee, soda
  - Acid cleaners
  - Nitrification process
- High pH: Bases
  - Ammonia based cleaners
  - Lye

Aerobic Microbes as Workhorses

- Microorganisms are used
  - aerobic process is 10 - 20 times faster than anaerobic
  - to convert colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue
    - gases evolve (CO_2, N_2, and others)
    - new cells can be settled – thus carbon is removed
  - break other nutrients out of organic compounds
    - nitrogenous compounds
    - phosphorous species

Organics, Microbes & Oxygen

- Bioavailable organic compounds provide food and energy to microbes
  - Naturally-occurring microorganisms consume food, and create more microorganisms
  - The more microorganisms, the more food consumed
  - The more food consumed, more dissolved oxygen is required

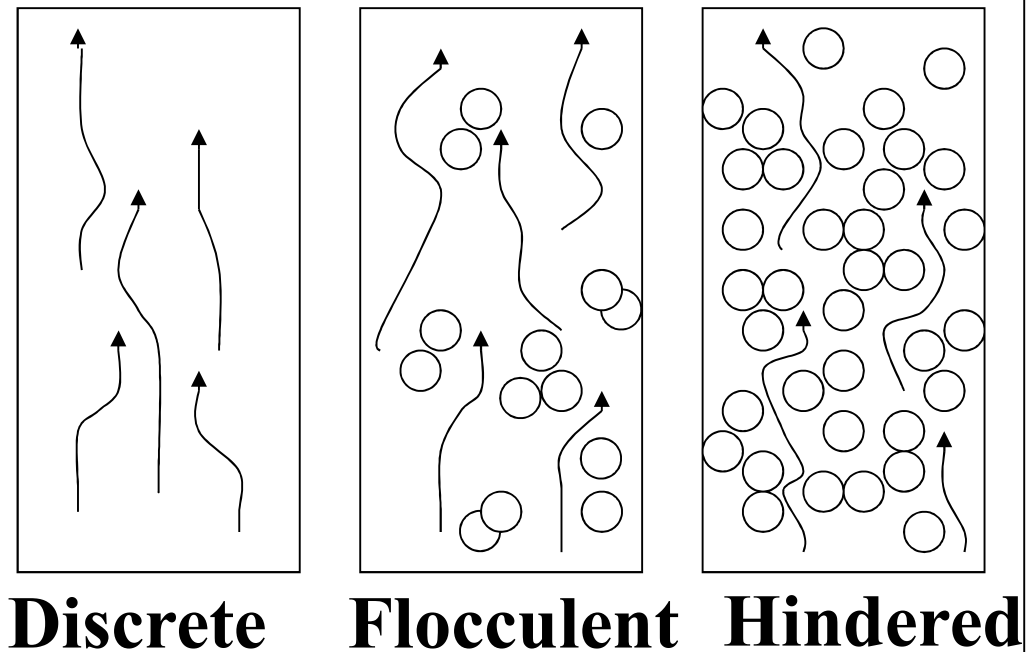
What Happens to the Microbes?

- Flocculate
- Slough
- Settle out
  - Storage
  - Wasting - Eventually need to be removed

Types of Settling

Four types of sedimentation:

- Discrete settling
- Flocculent settling
- Hindered settling
- Compression



Summary

- Aerobic and anaerobic treatment are both critical to onsite wastewater treatment
- Microbes will thrive in the correct environments
- At some point microbes die off and need to be removed

Questions

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