

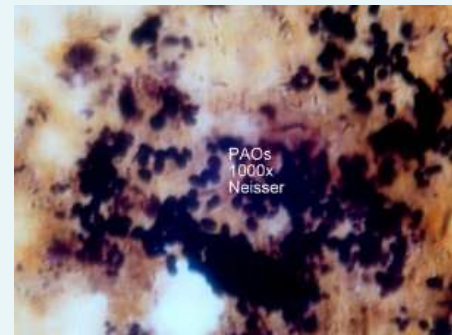
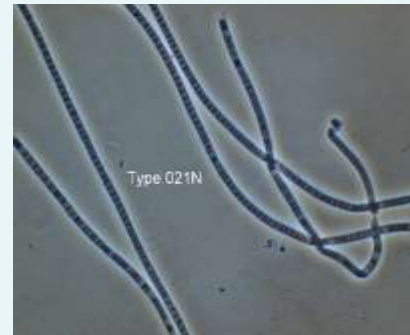
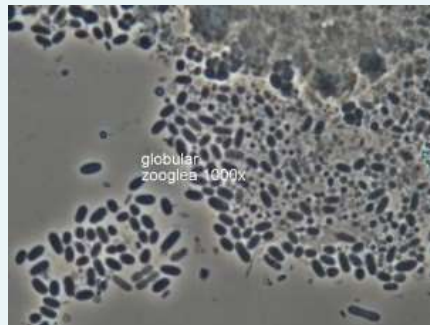
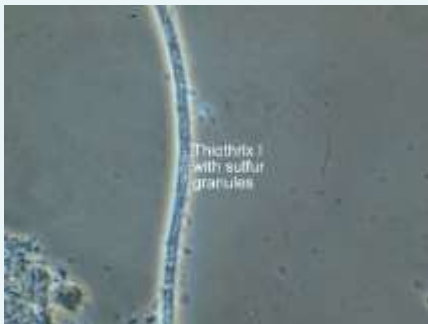


Septicity

(Organic Acids/ Sulfide)

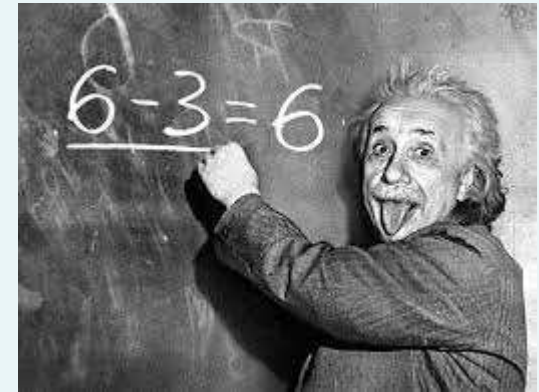
Presented by: Ryan Hennessy

Midwest Contract Operations



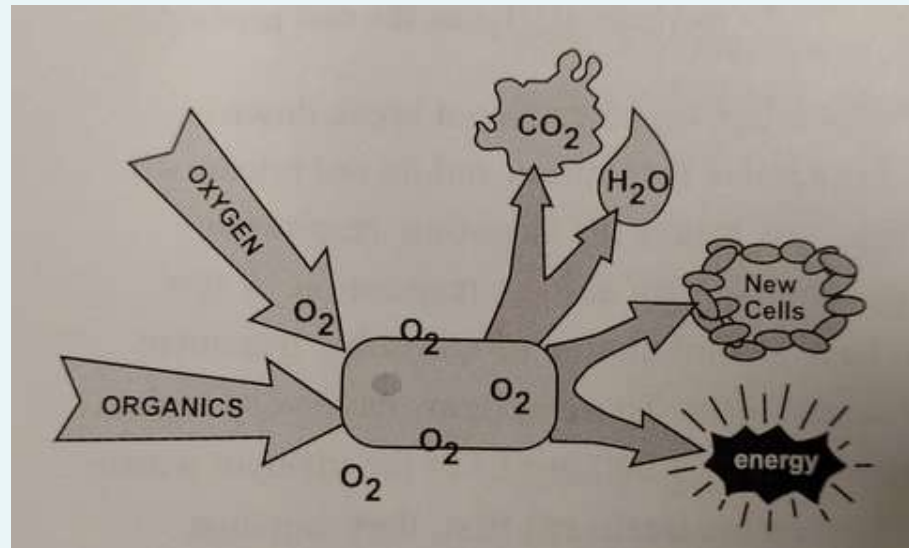
Types of Organisms

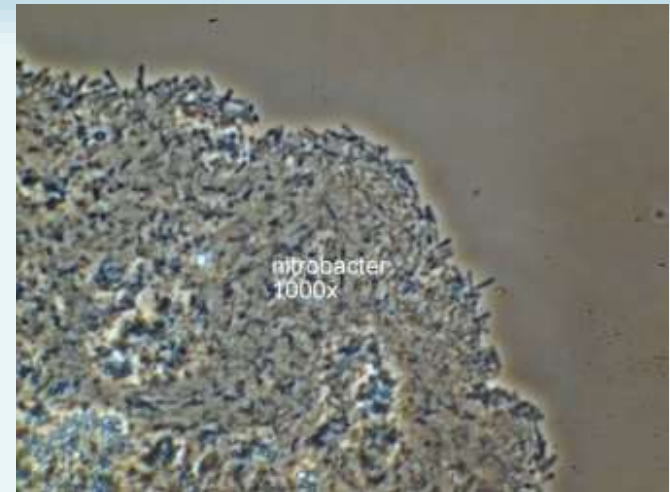
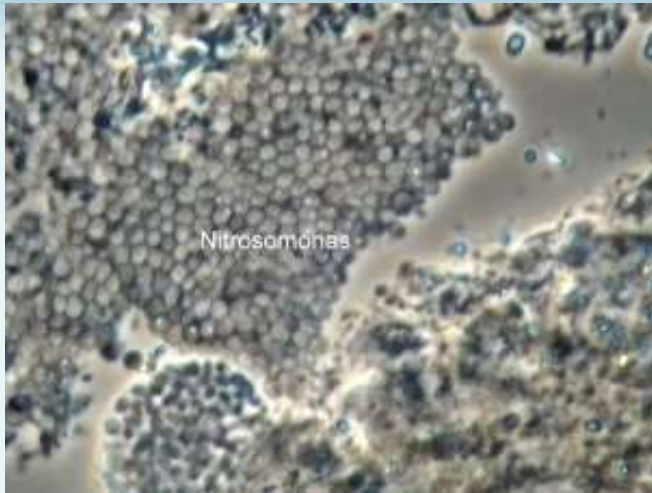
- Microorganisms can be classified by the type of respiration they use
- **Aerobes** use aerobic respiration
- **Anaerobes** have a different metabolism and oxygen (free and combined) is toxic to them
- **Facultative** organisms can possess both enzyme systems, but function aerobically if oxygen is available



Types of Respiration

- **Aerobic Respiration:** oxygen is involved in the last step (as an electron acceptor)
- Organics + Oxygen yield carbon dioxide, water, new cells, and energy





Respiration and Enzymes

- Respiration is a process controlled by enzymes that creates usable energy from food molecules
- **Enzymes are critical to the process**
 - These are protein molecules that are manufactured by cells
 - Each reaction sequence needs a certain set of active enzymes
 - The reason extremes in temperature, pH, and the presence of toxic materials disrupt treatment is due to the failure of enzymes

“Build it and they will come”.

- pH
 - Alkalinity
 - Temperature
 - Hydraulic Retention Time
 - Sludge Retention Time
 - Dissolved Oxygen
 - Nutrients
-
- Additional Variables
 - Fats, Oils, Grease
 - Septicity/ Organic Acids
 - Inhibitory Compounds



Anaerobic Respiration

- **Anaerobic Respiration:** no free or dissolved oxygen, but uses oxygen combined in other compounds such as Nitrate and Sulfate.
 - Nitrate will be used before sulfate
 - When nitrate (NO_3^-) is used, nitrogen gas is the end product
 - Denitrification
 - When sulfate (SO_4^{2-}) is used, end products are hydrogen sulfide
 - Sulfide formation
 - When carbonate is used, methane is produced
 - Anaerobic treatment

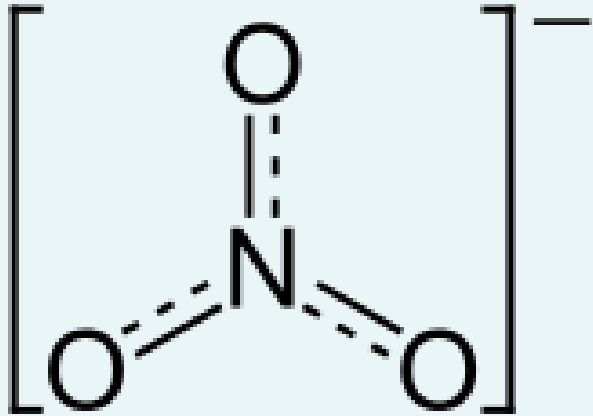


Facultative Bacteria Option #1



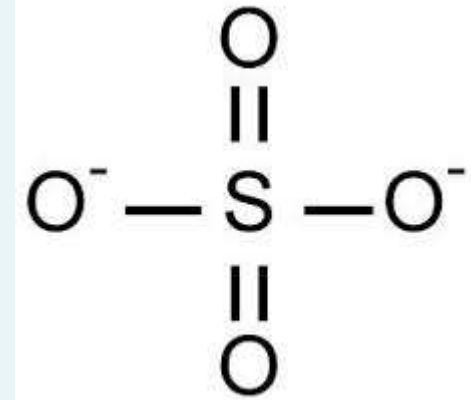
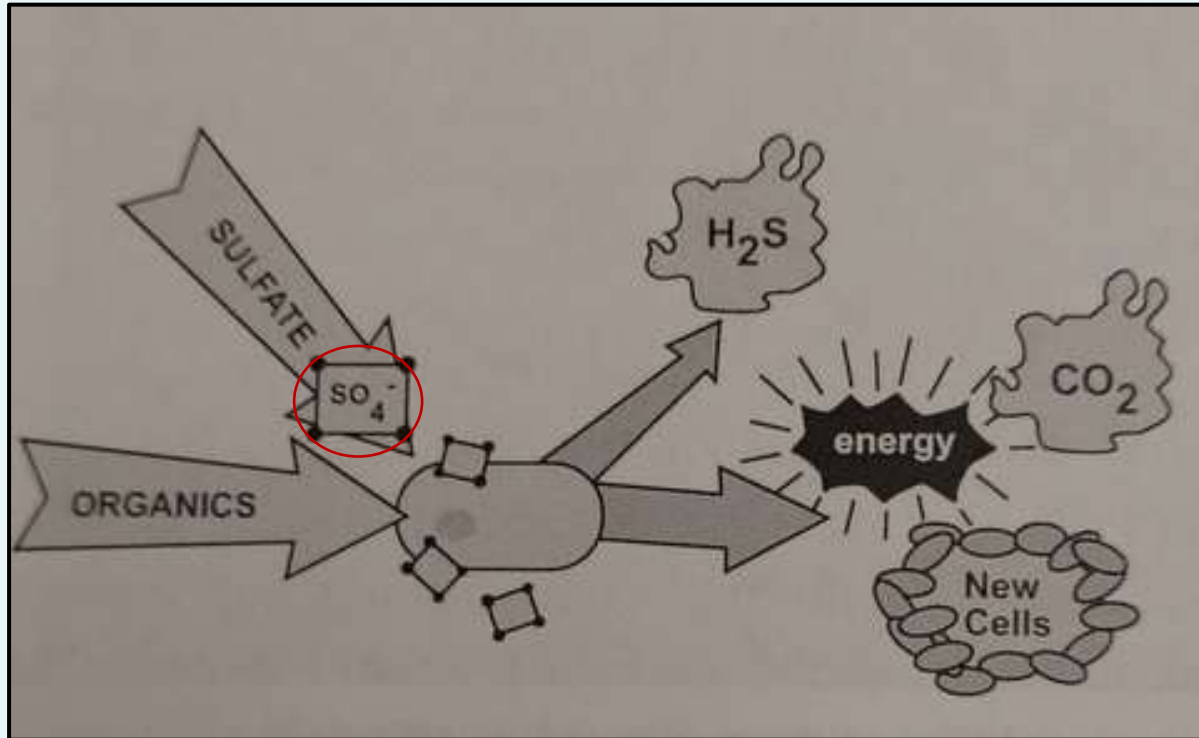
Dissolved Oxygen (preferred)

Option #2 “Nitrate”



Nitrate + **carbon source** + facultative bacteria =
Nitrogen gas, carbon dioxide, water, alkalinity,
and new bacterial cells

Option #3 Sulfate as Electron Receptor



Four Steps of Anaerobic Digestion

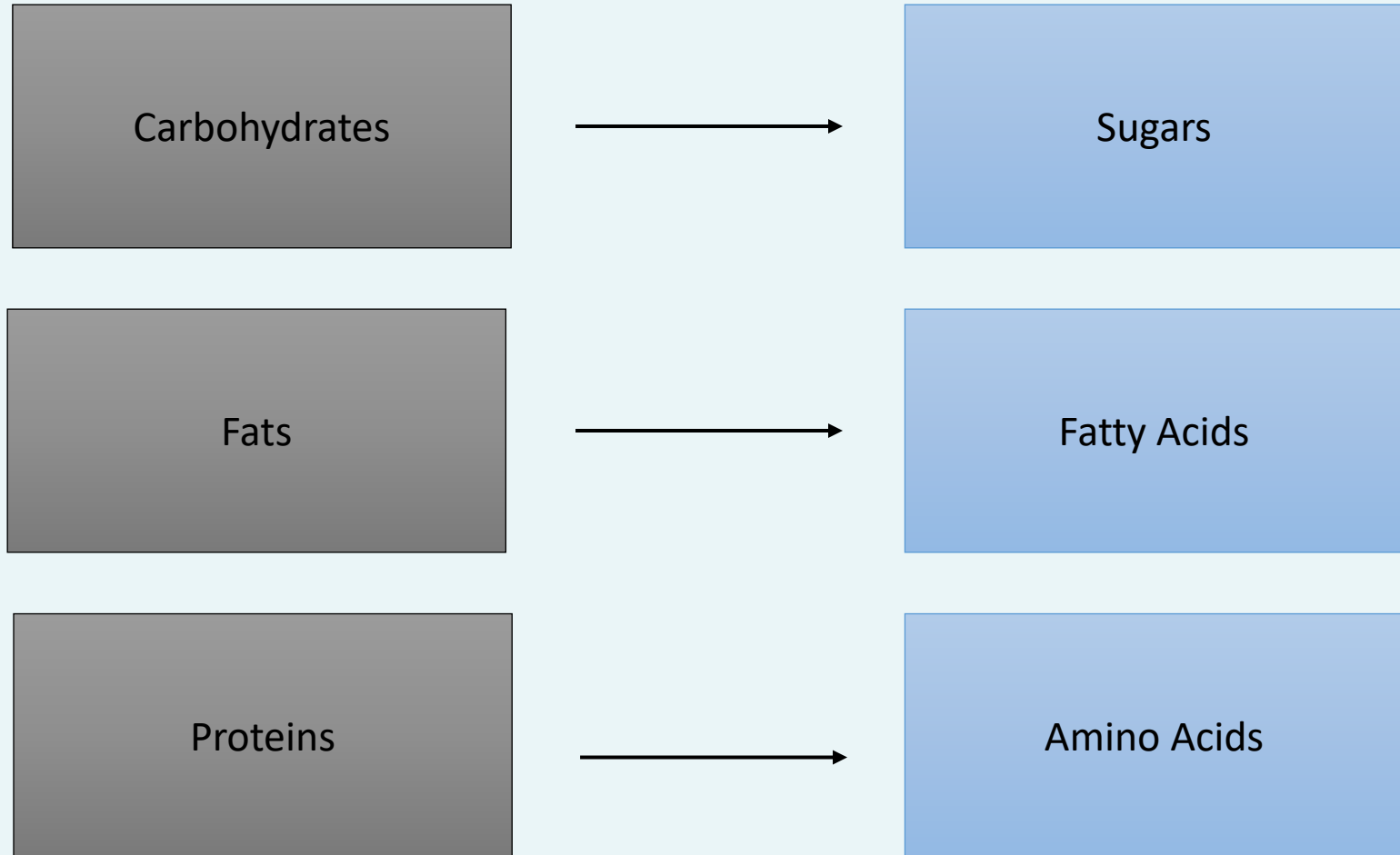
1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis



Egg-shaped gas storage

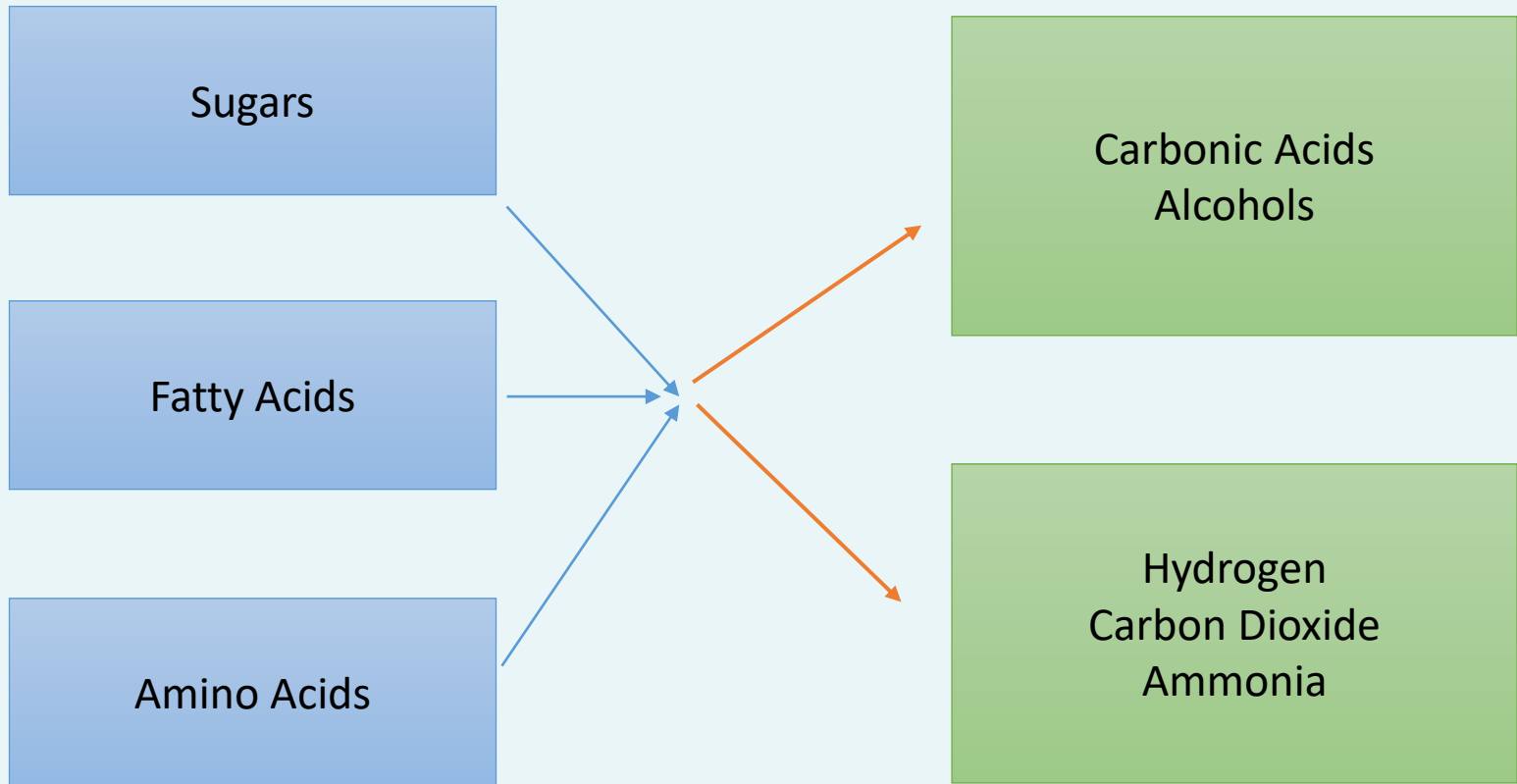
Hydrolysis-Large Polymers To Smaller Parts

Performed by bacteria, protozoa, and exocellular enzymes



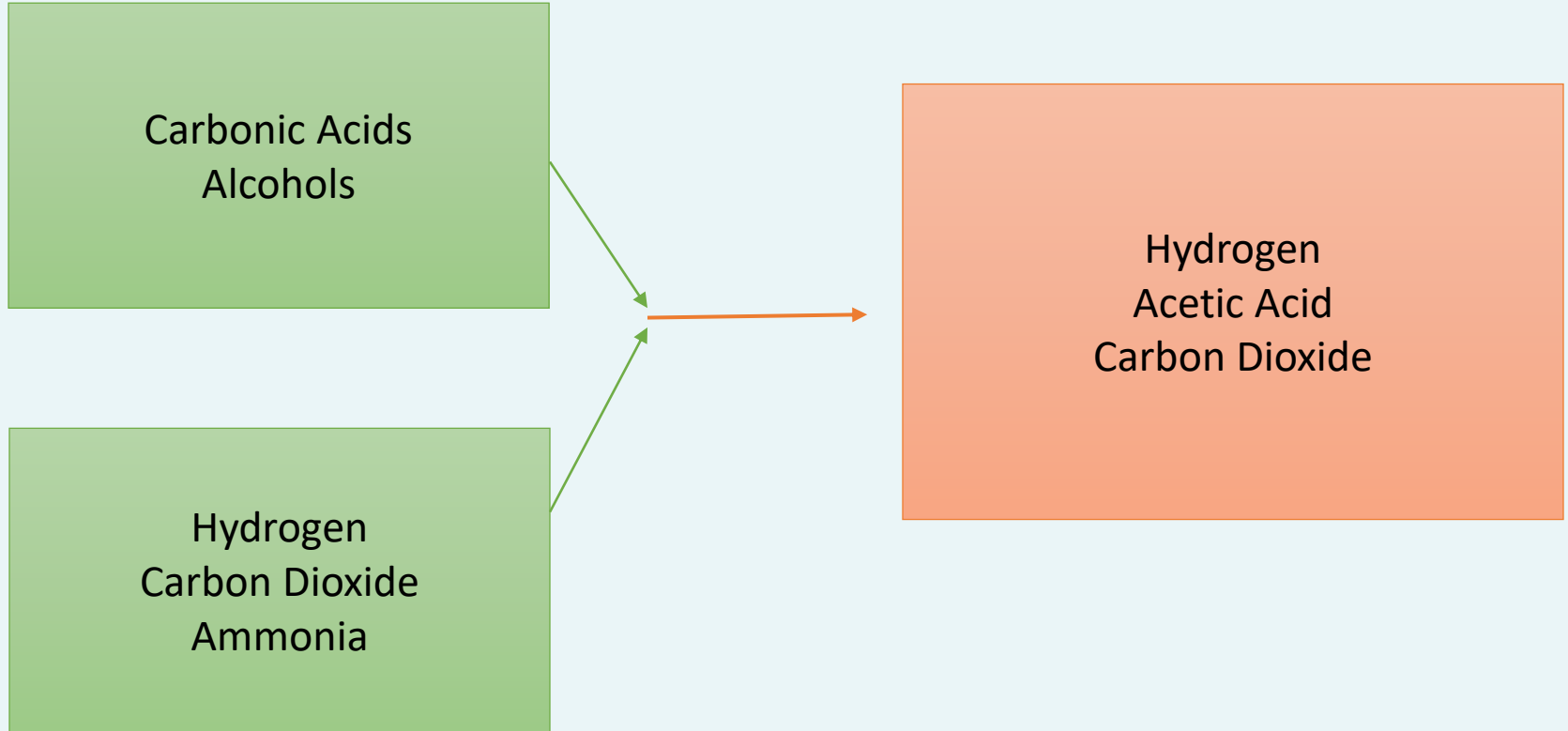
Acidogenesis

Done by Acid Forming Bacteria



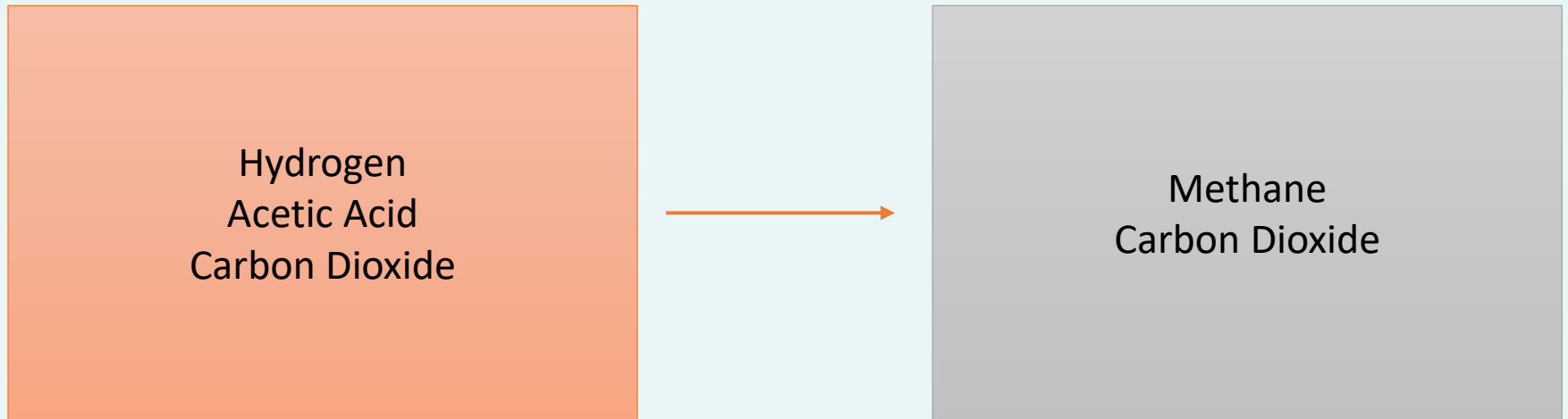
Acetogenesis

Done by Acid Forming Bacteria

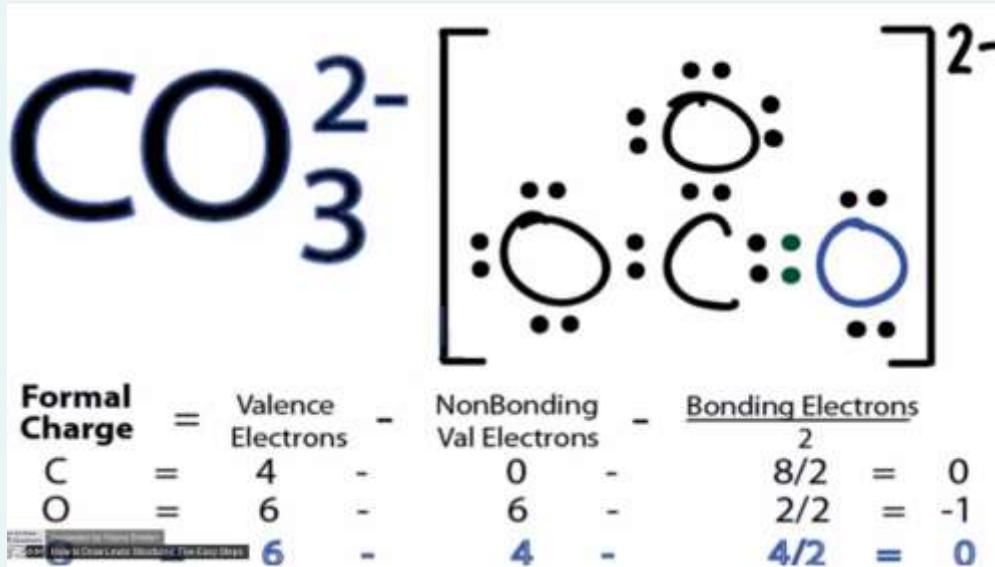


Methanogenesis

Done by Methanogens

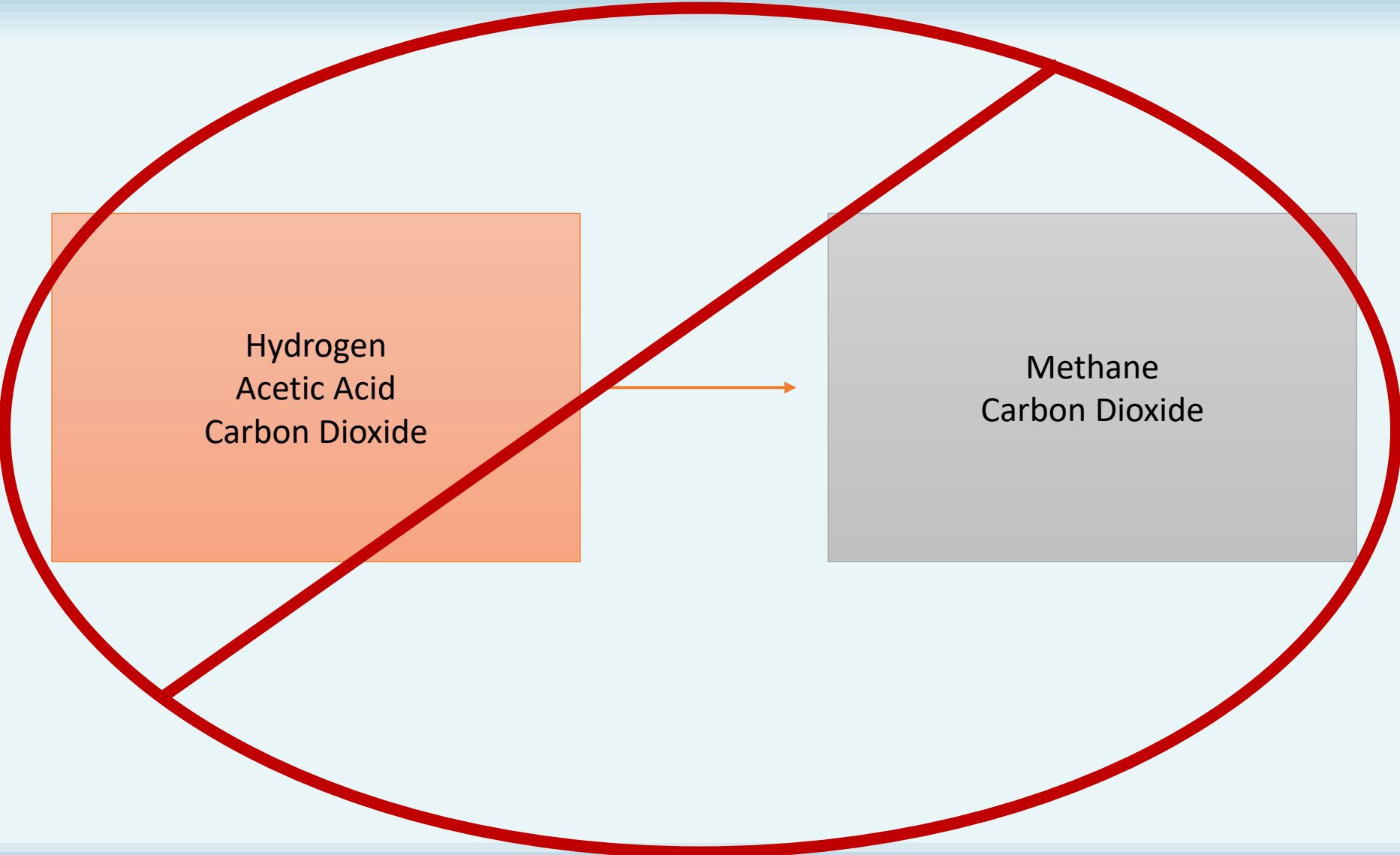


Anaerobic Treatment: Carbonate Reduction



Carbon Dioxide and Methane as end products

Fermentation

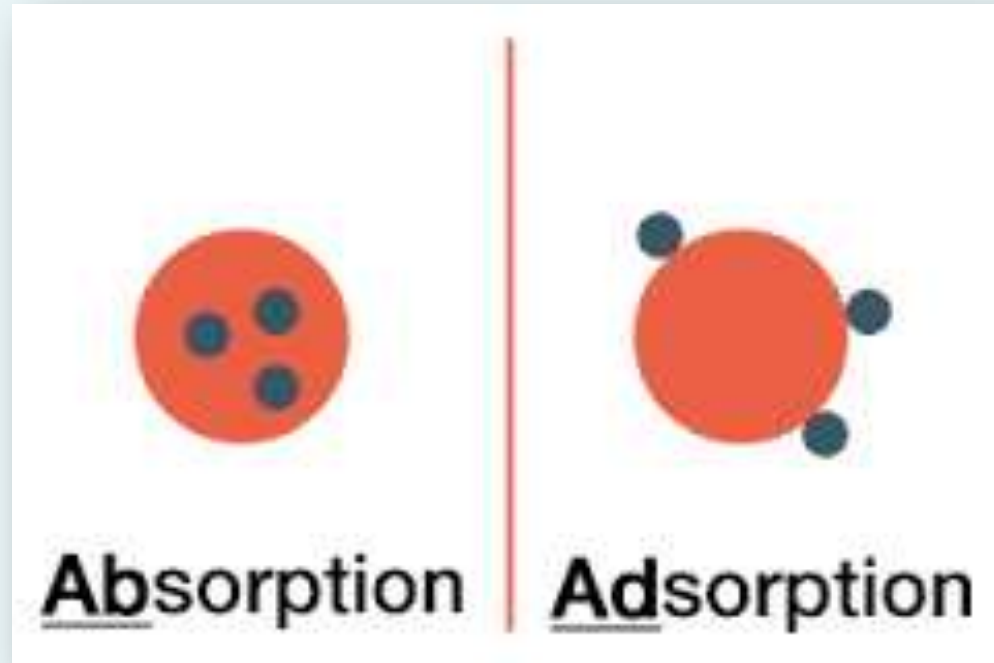


The diagram illustrates the fermentation process. It features a large red oval that encloses two rectangular boxes. The box on the left is orange and contains the text 'Hydrogen', 'Acetic Acid', and 'Carbon Dioxide'. An orange arrow points from this box to a gray box on the right, which contains the text 'Methane' and 'Carbon Dioxide'. A diagonal red line also crosses the oval from the top right to the bottom left.

Hydrogen
Acetic Acid
Carbon Dioxide

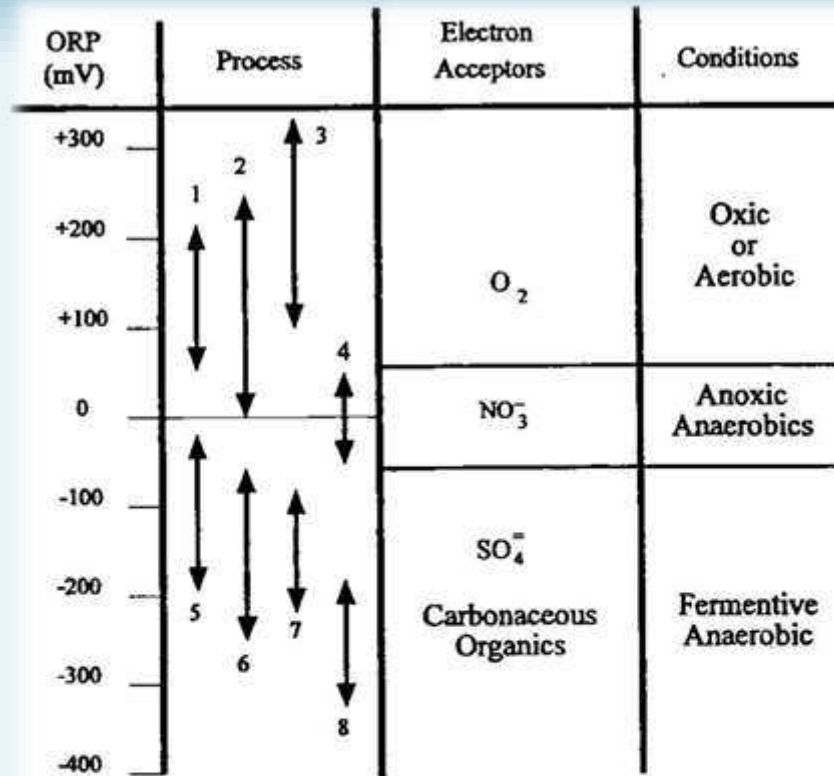
Methane
Carbon Dioxide

Absorption vs Adsorption



What is Septicity?

- Septicity occurs when bacteria ferment organic matter (BOD) to “smaller pieces” in the absence of free dissolved oxygen
 - These “smaller pieces” are known as organic acids



- | | |
|------------------------------|----------------------------|
| 1- Organic Carbon Oxidation | 5- Polyphosphate Breakdown |
| 2- Polyphosphate Development | 6- Sulfide Formation |
| 3- Nitrification | 7- Acid Formation |
| 4- Denitrification | 8- Methane Formation |

ORP & Metabolic Processes.

Goronszy, M, et al 1992

Septicity

- Wastewater becomes/ became anaerobic
- Sulfate reducing bacteria reduce sulfate to hydrogen sulfide
- Anaerobic bacteria ferment organic materials to organic acids
 - Acetic
 - Propionic
 - Butyric
 - Valeric



Septicity Vs. Low DO



Sources of Septicity

- Can occur ahead of the plant
 - Lift stations
 - Long retention time in collection system
- Industrial wastes
 - Dairy, pickling, textile dyeing operations
- Septage
- Treatment Plant
 - Equalization basins
 - Primary clarifiers
 - Sludge processing side-streams
 - Co thickening WAS sludge can be a common cause



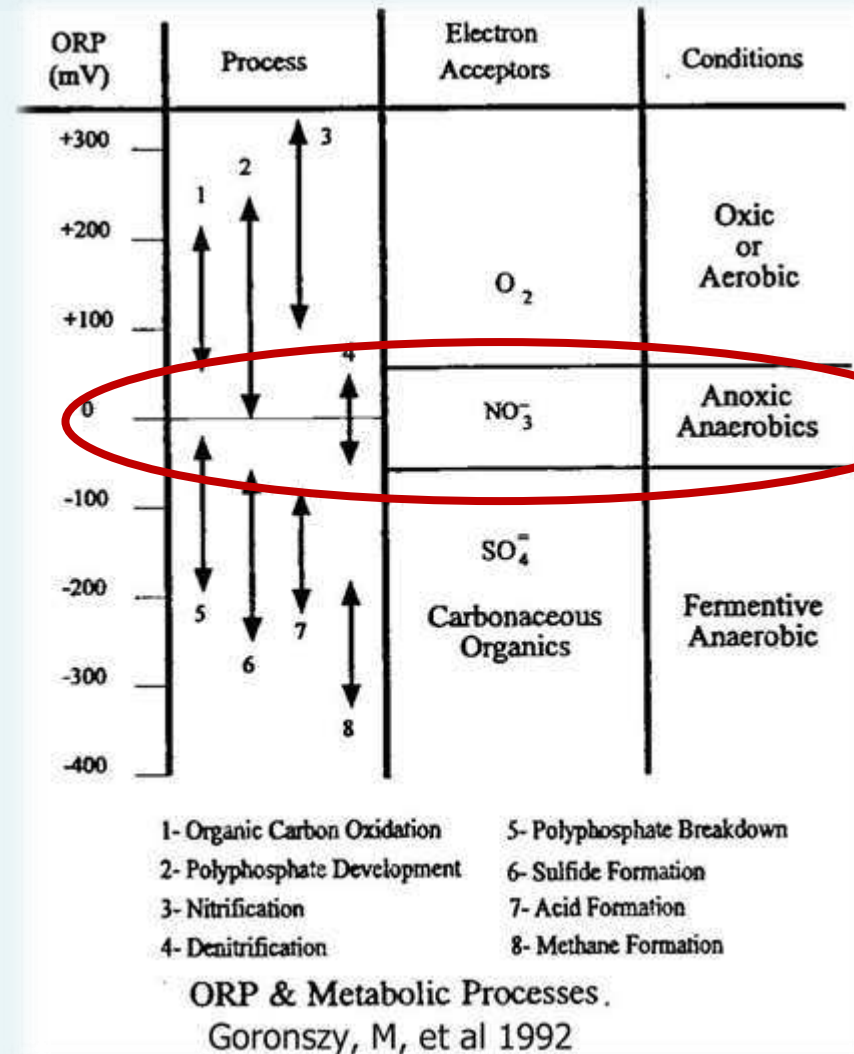
Double Edged Sword

- **Organic Acids (VFA's) are needed for enhanced biological nutrient removal**
 - Denitrification
 - Biological Phosphorus Removal
- To obtain enhanced biological nutrient removal plant must be designed with selector
 - **If VFAs are too high and pass through selector can cause several issues**
 - Filaments
 - Dispersed growth
 - Zooglea
 - Inhibition of nitrification



Organic Acids role in Denitrification

- Nitrate + **carbon source** + facultative bacteria = Nitrogen gas, carbon dioxide, water, alkalinity, and new bacterial cells
 - In denitrification, bacteria reduce nitrate to nitrogen gas. Nitrogen gas is not very water-soluble so it is released into the atmosphere
- Actual requirements of **soluble COD** to nitrate for denitrification are plant specific and can sometimes be as high as 10 mg COD/mg nitrate to denitrify



Causes of Denitrification

1. Lack of DO
2. Presence of Nitrate
 - Through Nitrification
3. A carbon source
 - Soluble BOD
 - Internally stored BOD such as PHB granules



Denitrification in Clarifier

Denitrification Problems

- Can be diagnosed by seeing the settled sludge rise in the settling test jar within 2 hours or less
- Occurs when nitrogen is batch dosed due to high periods of nitrate build up
- Denitrification and nitrification can occur simultaneously in the floc with no residual nitrate



Denitrification

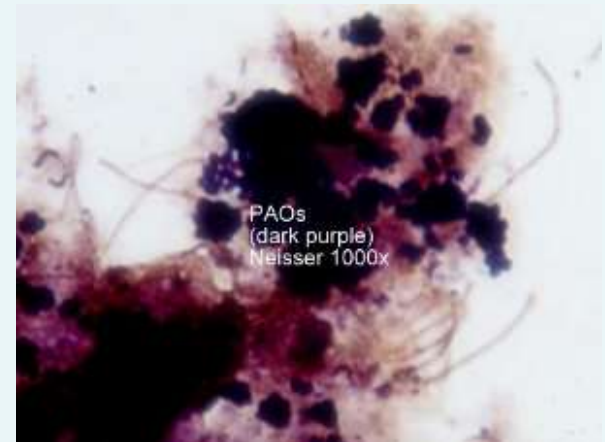
Control Strategies: Denitrification

- Increase DO at end or aeration basin
- Increase RAS rate to limit sludge retention time in the clarifier to a minimum
- Prevent nitrification
 - Usually not possible/ permit
- Improve sludge quality



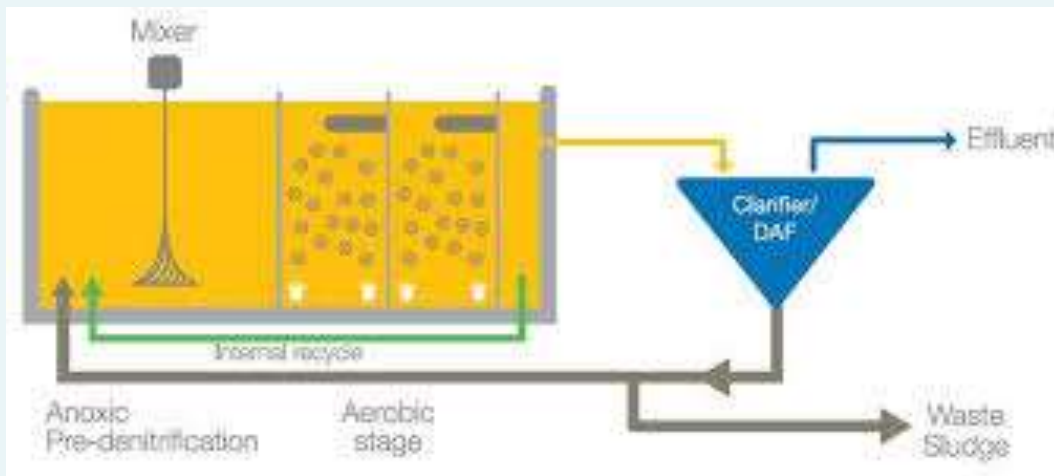
Biological Phosphorus Removal

- In a conventional activated sludge system microorganisms take up soluble phosphorous as a nutrient to generate new biomass
 - These organisms contain about 2% of phosphorous on a dry weight basis
- Polyphosphate Accumulating Organisms consist of roughly 35% phosphorous
- By creating an environment to select PAOs more phosphorous can be taken up by the bacteria
 - Sludges with high percentage of PAOs can contain up to 6% phosphorous on a dry weight basis

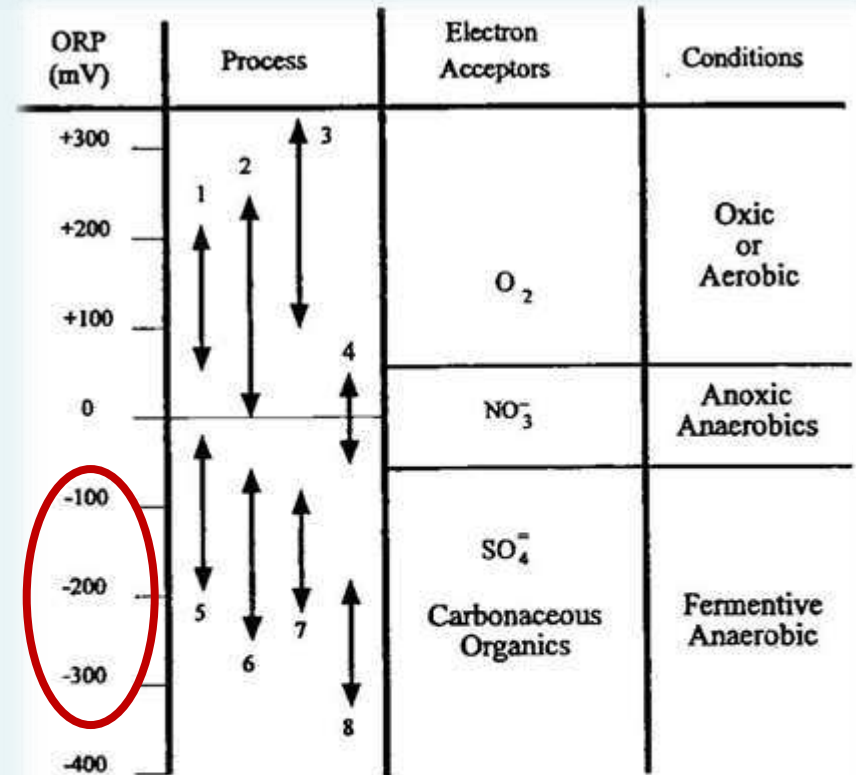


Bio P removal (summary)

- A two step process in which an anaerobic environment is followed by an aerobic one
- In the anaerobic selector PAOs release orthophosphate to obtain the energy to uptake readily biodegradable organics (soluble BOD)
- In the Aerobic zone PAOs grow new biomass and take up phosphorus, typically more than they released in the anaerobic zone



OA's role in Bio P removal



- 1- Organic Carbon Oxidation
- 2- Polyphosphate Development
- 3- Nitrification
- 4- Denitrification
- 5- Polyphosphate Breakdown
- 6- Sulfide Formation
- 7- Acid Formation
- 8- Methane Formation

ORP & Metabolic Processes .

Goronszy, M, et al 1992

Bio P impact Effluent Phos based on TSS

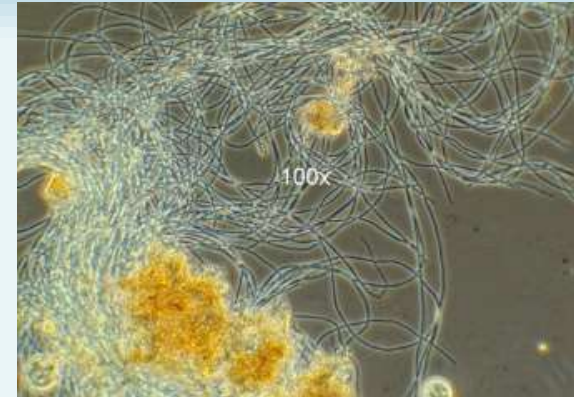
Mg/L TSS	10	15	20	25	30
3%P	0.30	0.45	0.60	0.75	0.90
4%P	0.40	0.60	0.80	1.00	1.20
5%P	0.50	0.75	1.00	1.25	1.50
6%	0.60	0.90	1.20	1.50	1.80



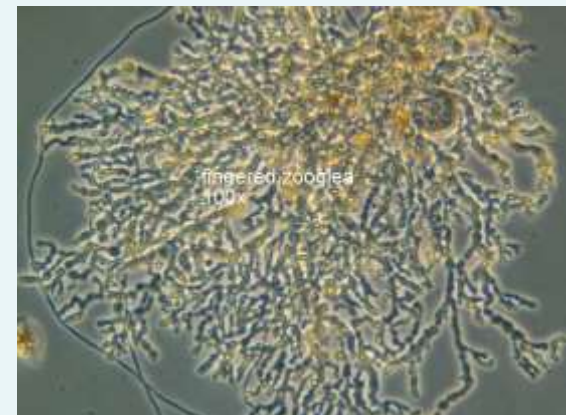
If too many OA's pass through.....



- Selector should remove 60-80% of soluble BOD



Filamentous Bulking



Floc with abundant zoogloea

Control of Septicity/Organic Acids

- **Pre-aeration**
- **Chemical Oxidation**
 - Oxidizes sulfide and some organic acids
 - Chlorine, hydrogen peroxide, potassium permanganate
- **Chemical Precipitation**
 - Ferric Chloride will precipitate sulfide
- **Calcium Nitrate**
 - An “oxygen source” to raise the redox potential
- **Diluting Influent**
 - Recirculated % of treated effluent back into head of plant
- **Switching modes of Operation**
 - Step Feed
 - Complete-mix

Other Options

- Often it is not possible or economically feasible to treat sources of organic acids
 - Coagulant/polymer addition
 - Chlorination of RAS to selectively destroy filaments

Chlorination

Chlorination is a “Band-Aid” rather than a cure all

It's important to properly diagnose the settling problem

- Chlorine and hydrogen peroxide
- Dose is plant specific
 - Range of 1-10 pounds chlorine/1000 pounds MLVSS/day
- Filaments may grow back rapidly when chlorination is stopped



RAS Line



Chlorination



Polymer jar test



MCO Microscope Setup



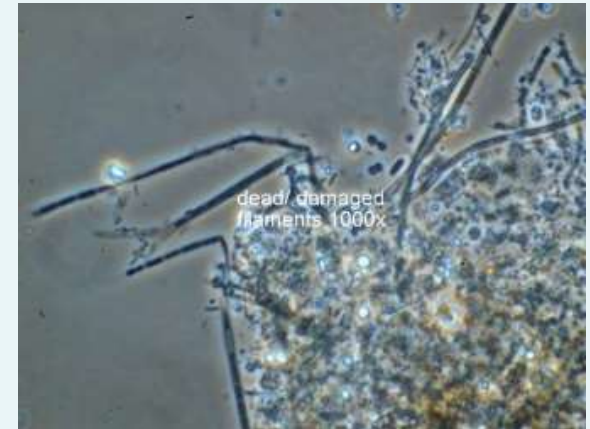
Healthy filaments



MCO staff at microscope



Damaged filaments



Damaged filaments

Chlorination

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RAS Line



Chlorination

RAS Chlorination Dose

GENERAL GUIDELINES

- **2-3 lbs Chlorine/1000 lbs MLVSS/day**
 - A typical maintenance dose when the SVI is generally under control and chlorination is needed to kill newly growing filaments
- **5-6 lbs Chlorine/1000 lbs MLVSS/day**
 - A typical dose that will reduce SVI over several days and have little impact on effluent quality
- **10-12 lbs Chlorine/1000 lbs MLVSS/day**
 - Usually will destroy excess filaments and reduce the SVI rapidly/ Floc structure is likely to deteriorate at this dose

Chlorine Dosing Points

Chlorine must be dosed at a point of excellent initial mixing

- Add where the chlorine demand is at a minimum
 - RAS line (application point of choice)
 - Elbow in a pipe
 - Into/below the rising liquid level in the riser tube of airlift RAS pumps
- Areas NOT to dose chlorine
 - Aeration basin (generally causes floc dispersion and system damage)
 - RAS wet wells
 - Mixed liquor channels
 - Any other point of poor mixing

Contacts of Chlorine/MLSS

- RAS should come into contact with the chlorine 2-3x per day
- In long aeration basins with long hydraulic residence times a second RAS dosing point may be needed to obtain this
- Dose the center well of the clarifier in addition to the RAS line to achieve the necessary contacts between the RAS and the chlorine



Chlorination (continued)

- A microscopic evaluation is recommended daily when chlorinating
- If the proper dose is reached settling usually improves in 1-3 days
- Sheathed filaments take longer to get rid once a target SVI is reached

Chlorination Impacts



Empty Sheaths- *Thiothrix* I

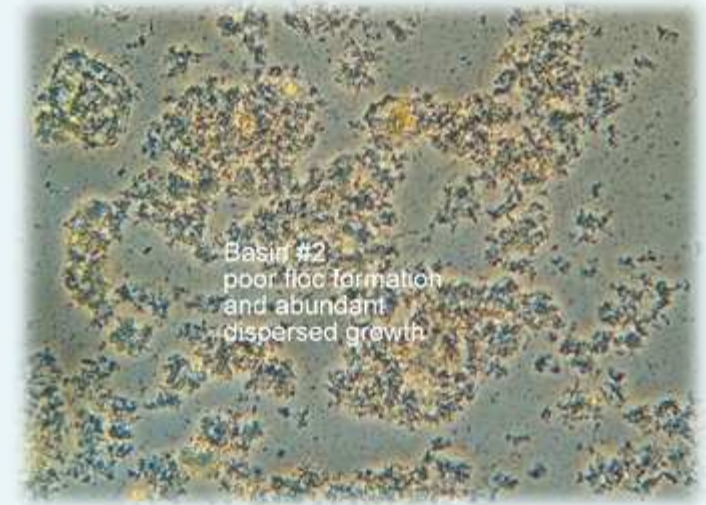


Dead Filament

- Loss of sulfur granules
- Damaged cells, empty sheaths, and cytoplasm shrinkage
- Filament breakup
 - Ceasing chlorination once about 70% of the cells are damaged or missing a filament

Signs of Over-Chlorination

- A turbid milky effluent
- Significant increase in effluent TSS
- Loss of higher life forms (protozoa, metazoa)
- Reduction of BOD removal
- Disruption of nitrification
- Small broken up flocs under the microscope



Over- Chlorination

Take Home Points/ Review

- What are organic acids?
- Where are organic acids formed?
- What is the sequence in which different forms of dissolved oxygen are used?
- What is the main final end product in true anaerobic treatment and what's the difference between true anaerobic treatment and fermentation?
- What are we measuring with negative ORP values?
- Describe denitrification and it's recipe
- Describe biological phosphorus removal principles
- Describe potential ways to reduce septicity or maintain good settling sludge if source reduction is not possible.



References

- Jenkins, D., M.G. Richard and G.T. Daigger, *Manual on the Causes and Control of Activated Sludge Bulking, Foaming, and Other Solids Separation Problems*, 3rd Edition., Lewis Publishers (CRC PRESS), Boca Raton, FL, 2003
- *Activated Sludge Microbiology Problems and Their Control*, 2010 Michael Richard, Ph.D. Michael Richard Wastewater Microbiology LLC Fort Collins, CO www.mrwwm.com
- Water Environment Federation, *Operation of Municipal Wastewater Treatment Plants Volume II: Liquid Processes, Manual of Practice No.11* McGraw Hill Companies, New York, NY 2008
- Industrial Activated Sludge Operations: METC Group Incorporated, 1999
- All microorganism pictures courtesy of Ryan Hennessy, Midwest Contract Operations, 2015 and 2016

Q&A Segment

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Thank you!

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