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Kentucky Water & Wastewater Operators Association

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North Central &
Eastern Chapters

Optimizing Aerobic Digestion

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Optimizing Aerobic Digestion

Agenda

- Define Aerobic Digestion
- Do’s and Don’ts of Aerobic Digestion
- Compare Aerobic Digestion and on-line treatment
- Provide strategies for optimizing digestion performance.
- Provide process knowledge to assist in digestion and dewatering troubleshooting.
- Improve skills in plant operation.
- Closing / Questions

Optimizing Aerobic Digestion

What is Aerobic digestion?

… the destruction of degradable organic components and the reduction of pathogen organisms by aerobic, biological mechanisms…Aerobic digestion is based on the biological principle of endogenous respiration (MOP FD-9).

Aerobic digestion will be slightly re-defined……

Aerobic Digestion – re-defined

Some fundamental changes to aerobic digestion:

- The aerobic digester will be "off" longer than "on" (aerating). 25% or less than facilities operating as traditional aerobic digestion.
- Aeration is supporting endogenous respiration AND nitrification.
- The primary goal of the aeration is not just solids destruction and is controlled by changes in pH.
- An effective aeration cycle is controlled by nitrification parameters and any change caused by the reduction in alkalinity.
- Off cycling will stress the aerobic biological solids and cause lysing with the conditioning of the biological EPS into readily biodegradable COD.

Cell Lysing and EPS Conditioning

- Off cycling, rather than continued aeration, allows EPS material and cells (lysing to expose cellular content) in the biomass to become biodegradable (as shown in the gravity thickening process evaluation later in the presentation).
- Glycocalyx: many bacterial cells have an external coating excreted onto the outside of the cell. There are two types of glycocalyx, capsules and slime layers.
- Glycocalyx is a general term for any network of carbon or protein containing material extending outside of the cell. A difference in terms for a general term: a capsule is closely associated with cells and does not wash off easily. A slime layer is more diffuse and is easily washed away.

Cell Lysing and EPS Conditioning

The function of the slime layer:

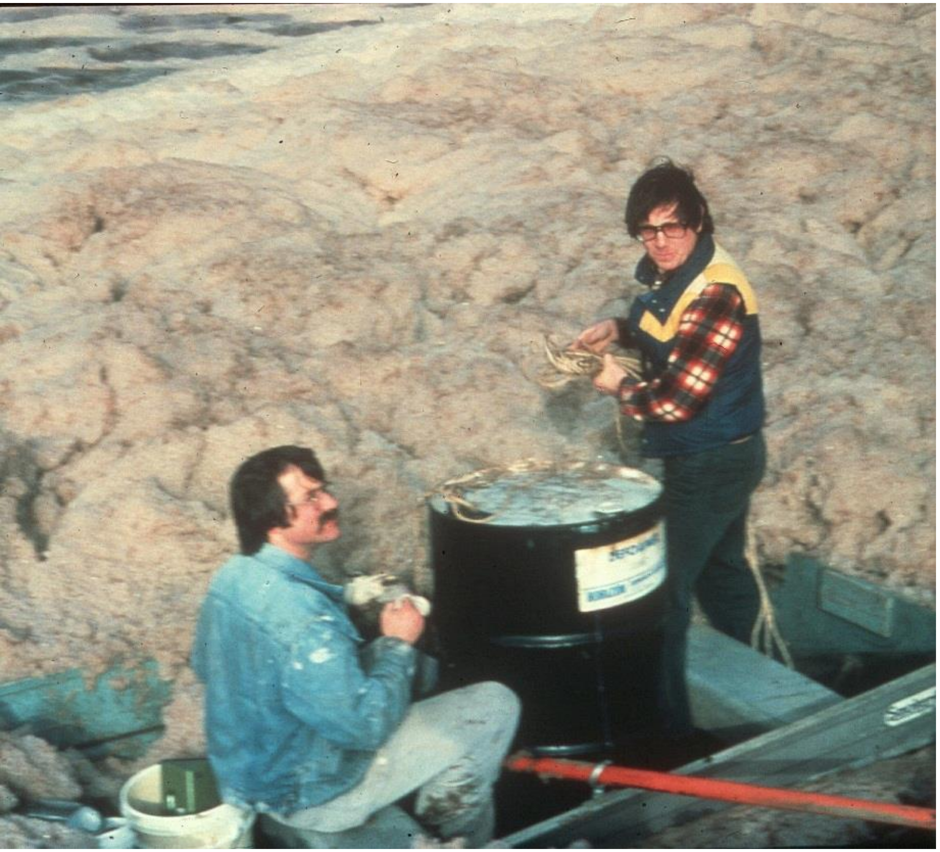
- Attachment as a colony
- These structures are thought to help cells attach to their target environment.
- Resistance to drying. Capsules and slime layers inhibit water from escaping into the environment.
- Reservoir for nutrients. Glycocalyx will bind certain ions and molecules.
- Deposit waste products. Waste products of metabolism are excreted from the cell and will accumulate in the slime layer. This binds waste products and prevents the waste from interfering with cell metabolism.
- A general term for the slime layer is EPS (exopolymer substances).

Gravity Thickening prior to Aerobic Digestion….. too much of a good thing in Brookfield, OH.

A case study concerning the impact of gravity thickening on aerobic digestion (the ultimate off cycle) to initiate the digestion process:

- VLR plant with effluent ammonia less than 1 mg/L, BOD5 and TSS near detection.
- Effluent MLSS oxygen uptake rate (OUR) was 9.2 mg/L/hr.
- MLSS was high at 4,700 mg/L, but very stable with a Specific Oxygen Uptake Rate of 3 mg/L/hr/gm VS (SOUR).
- Gravity thickener provided solids concentration from 0.47% to 3.58% TS while the Volatile Solids were reduced from 64.3% to 59.9%.
- Solids increased by a factor of 7.6 times while the biological solids were “conditioned” to increase the rate of oxygen consumption by 37 times:
  - ✓ OUR: 9.2 mg/L/hr to 336 mg/L/hr – factor of 37
  - ✓ SOUR: 3.0 mg/L/hr/gm VS to 16 mg/L/hr/gm VS – factor of 5.3

Cell Lysing and EPS Conditioning



- The gravity thickening process caused significant conditioning of the EPS and cell lysing to change the oxygen uptake rate.
- Rule of thumb is that 80 mg/L/hr or higher simulated a nutrient deficient process (nitrogen) wastewater and foam. Paper Mill wastewater "high carbon" or polysaccharide foam to the left.

- The domestic biology simulates a nutrient deficiency and shunts the high carbon waste as foam since nitrogen cannot be incorporated at this rate into cellular material (when processed through gravity thickening or belt thickening).
- Primary sludge can also provide a similar uptake if allowed to solubilize in high blankets and/or gravity thickeners.

Primary Sludge as feed solids

- Off-cycling creates a similar breakdown of the aerobic biomass, but under controlled conditions so as not to reach “nitrogen assimilation” problems with excessive Oxygen Uptake conditions.
- Primary sludge would also impact oxygen uptake conditions. This would be an excellent “tool” to continue to drive the process for a rapid drop in ORP.
- Facilities with primary sludge maintain a seed inventory in the digester to assimilate the fresh feed solids and control odors and oxygen uptake rate.
- The additional carbon allows for denitrification. Mixing allows solids to contact supernatant that may be a reservoir of nitrates.

Do’s and Don’ts for Aerobic Digestion

Do’s and Don’ts for Aerobic Digestion

1. The oxygen residual should be maintained at 1 mg/L or above, under all aerobic digestion operating conditions (Metcalf &Eddy).
    - *DO NOT operate an aerobic digester in a continuous aerobic condition.*
2. Non-degradable materials from the main aeration process suddenly become degradable.
    - *Energy used for digestion is a function of time, conditions and biological acclimation. If not degradable with the on-line process, conditions should be changed, cycled or modified to improve degradability……much will remain non-degradable if just repeating the aeration process environment.*
    - *Grissom Air Force Base Example*

Do's and Don'ts for Aerobic Digestion

3. Volatile solids (burning the TSS sample) is a measurement of the "active biological" portion of the sample and/or digestion efficiency.

- *Significant levels of trash and inerts will be oxidized at 550°C. Paper mill wastewater operations uses increasing volatile solids concentrations as a "lowering of viability".*
- *Concrete, for example, shows 38% volatile solids when heated under the same test protocol. As Phosphorus control becomes more widespread, the "water of hydration" will become a more significant source of problems using the volatile solids test.*
- *Significant amounts of structural water are lost at temperatures above 103°C (drying oven for total solids) up to 550°C (Muffle furnace for volatile solids).*

Do’s and Don’ts for Aerobic Digestion

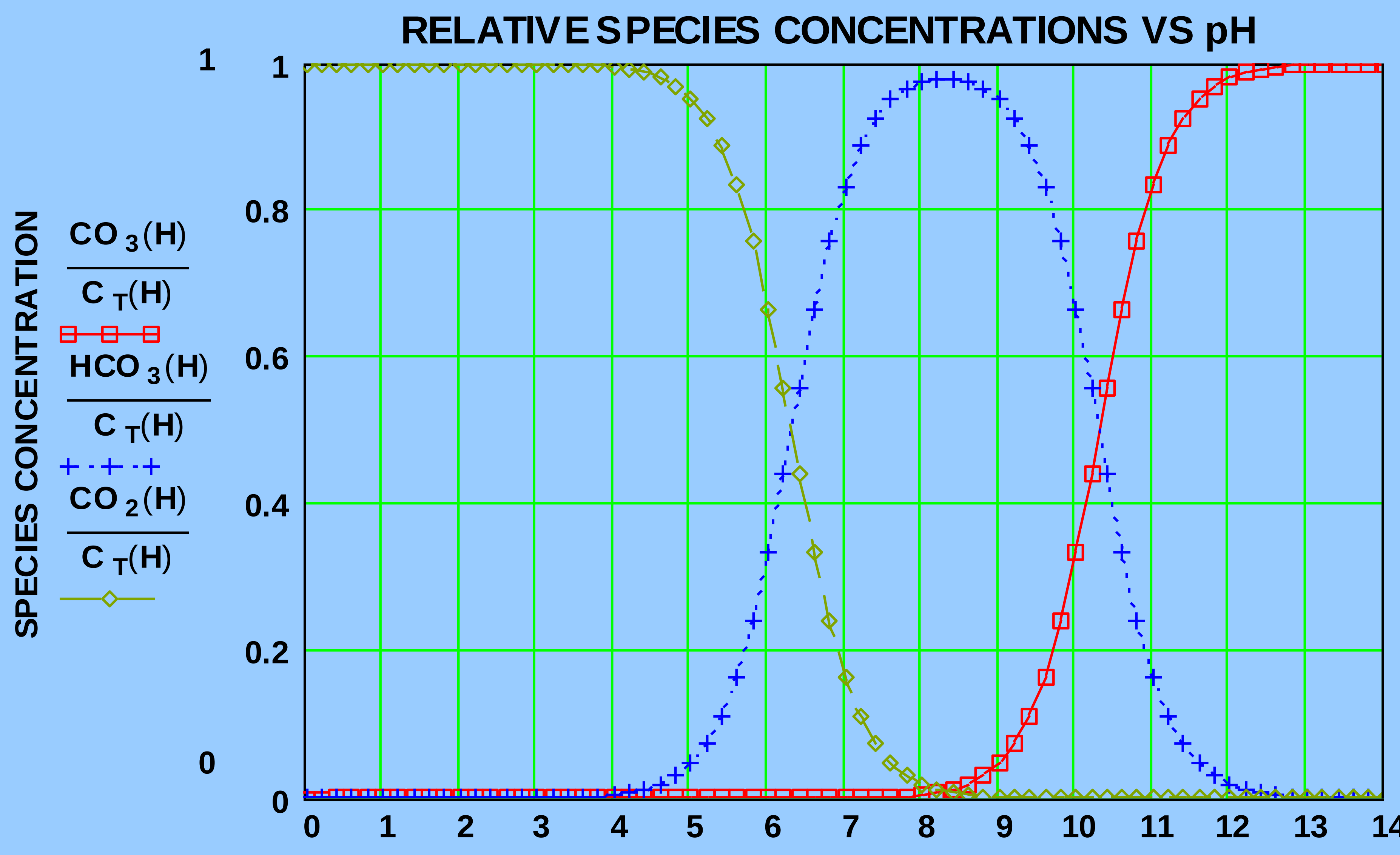
4. “Although not a goal of aerobic digestion, the digestion process is capable of nitrification” (WEF MOP 11)
    - *Nitrification should be a goal in the aerobic digestion process.*

5. The digestion process works best with the greatest concentration of feed solids possible
    - *Accompanying water chemistry is limited relative to the small volume of flow. Water chemistry and is not replenished “automatically” through influent flows in the main treatment process. Water chemistry is typically the controlling variable in aerobic digestion – NOT solids.*

Do's and Don'ts for Aerobic Digestion

6. The pH will decrease and will require displacement of liquid volume to maintain buffering or alkalinity addition is necessary.
   - *pH buffering can be restored through off cycling and carbon dioxide stripping. Off-cycles can reduce restore alkalinity through nitrate destruction.*
7. Aerobic sludge cannot dewater well.
   - *Low pH creates cation site competition, forces polymer overfeeding, causes CO_2 to come out of solution as pH continues to decrease. Gas would not allow for proper concentration of solids prior to dewatering.*
   - *The aerobic digestion process has been operated to create a reduced biological mass with sludge cake solids in excess of 20% total solids. (Buffalo Toyota Plant, West Virginia)*

pH effect on Distribution of CO_2 Ions in Solution



Do's and Don'ts for Aerobic Digestion

8. Nitrifiers cannot withstand long periods of zero dissolved oxygen.

    - *Nitrosomonas was mistakenly identified as the primary AOB (ammonia oxidizing bacteria). Nitrobacter was mistakenly identified as primary NOB (nitrite oxidizing bacteria). Nitrification was assumed to be driven by the requirements of these organisms.*
    - *Dye tagging specific to DNA (FISH -* (fluorescence in situ hybridization) *has allowed microbiologists to provide a much more detailed analysis of the populations.*
    - *Bacteria in the genus Nitrosospira are significant AOBs while bacteria in the genus Nitrospira have been shown to be the dominant organisms in nitrite to nitrate (NOB) for many facilities (oxidation ditches and pulsed aeration).*

Do’s and Don’ts for Aerobic Digestion

9. Nitrification requires high dissolved oxygen levels before the nitrifiers can oxidize ammonia. Nitrification cannot proceed until the carbonaceous oxygen demand is satisfied.
   - *Some of the misconceptions of nitrification were due to this misunderstanding regarding population dynamics.*
   - *Research has shown that simultaneous nitrification and denitrification is dominant in many pulsed aeration processes (oxidation ditches, vertical loop reactors, aerobic digestion) that are operated aggressively with low ORP.*

Do’s and Don’ts for Aerobic Digestion

- *“Aerobic denitrification” is the rule rather than the exception as oxygen is provided under enough loading to drive denitrification.*
- *Long off-cycles results in 0 dissolved oxygen throughout the aerobic digestion biology.*
- *Starting up the aeration after a long off cycle may show zero dissolved oxygen residuals, but that condition can be responsible for significant amounts of ammonia removal.*
- *Nitrification uses alkalinity (7.14 mg/L of alkalinity for each mg/L of ammonia oxidized).*
- *Denitrification is responsible for returning half of the alkalinity when nitrates are reduced to nitrogen gas (denitrification).*

Do’s and Don’ts for Aerobic Digestion

10. Cell walls (bug bones) are persistent in the wastewater environment and cannot be broken down. Sometimes characterized as low BOD_5 pin floc/cell debris.

    - *Low load pin floc is usually due to the release of inerts content, not cellular material.*

    - *Deep cycling an aerobic biomass puts stress on the cell wall. Cell destruction, lysing through cell wall stress) is a method of biological destruction caused by off-cycling.*

    - *The cell wall is a critical structure in bacterial cells. Inside of the bacterial cell there is a high solute concentration and pressure on the cell membrane (75 lb/in^2).*

    - *Outside of the cell there is a low solute concentration. Mother nature will tend to flow water into a cell to equilibrate the amount of water inside and outside of the cell. Cell membranes prevent most other molecules from crossing them, but water can. Without something supporting the membrane the cell would swell and burst. A cell wall protects bacteria from lysis.*

How Does Digestion Differ from On-Line Biological Treatment?

Water Chemistry

- Digestion has a limited exchange of water chemistry.
- Volume exchange is typically maintained at a minimum by concentrating primary and WAS solids.
- Toxicity and inhibition are common in digestion due to biological byproducts accumulating in high concentrations. Alkalinity inhibition of nitrification most common.
- Solids separation is typically poor due to limited water chemistry and high solids.
- The clarity of the discharged water chemistry is not primary objective (supernatant versus effluent).
- Biological decay predominates water chemistry (rather than growth). Dissolved solids increasing rather than decreasing.

How Does Digestion Differ from On-Line Biological Treatment?

Growth Rates

- Decay is predominant cycle rather than growth.
- Organic and nitrogen loading input is biological based rather than through non-biological loading external to the facility.
- Sludge age or sludge retention time is far greater than the on-line process.

Trash and Debris

- The trash and debris is concentrated in the digestion process as biological solids are destroyed while non-degradable inerts and trash remain.
- Viability of solids is reduced on a unit basis.

Aerobic Digestion Process Drivers

Aerobic Digestion Process Drivers
Water Chemistry

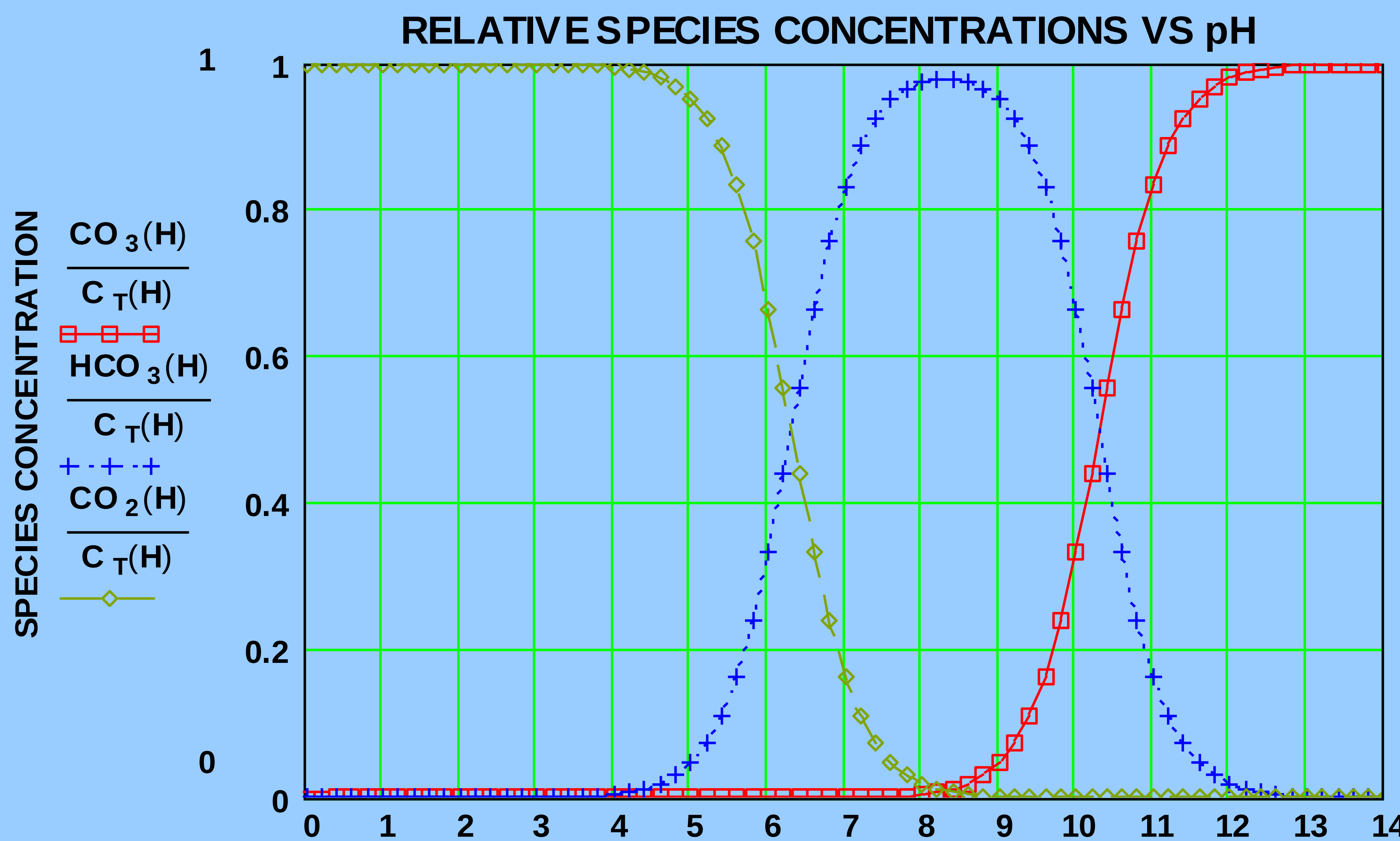
- The accompanying water chemistry is limited relative to the small volume of “sludge” and is not replenished “automatically” through influent flows in the main treatment process.
- Water chemistry must be controlled through the natural process of death and growth in separate zones of biological activity – aerobic, anoxic and anaerobic
- The limited volume of flow into the digester containing a relatively high concentration of nitrogen, carbon and hydrogen in the form of biological material creates an environment the operator must balance with cycling on and off.

Aerobic Digestion Process Drivers
Water Chemistry

- As water chemistry is compressed within the aerobic digestion process, carbon dioxide generation by the biology is an important process variable that can result in significant fluctuations in pH and gas solubility.
- As the pH decreases, carbon dioxide becomes “insoluble” as a gas and will “vapor lock” solids that would otherwise be settleable.

1. If you suspect carbon dioxide is causing a vapor lock on settleability, off-cycle for a long period of time (overnight).
2. Provide a short aeration cycle to mix and strip nitrates and to “off-gas” the carbon dioxide (15 minutes or less).
3. Allow to re-settle at a higher pH.

pH effect on Distribution of CO_2 Ions in Solution



Aerobic Digestion Process Drivers
Nitrification/Denitrification

- Endogenous respiration cannot generate its own carbon source to drive the anoxic reaction and strip nitrates. A carbon source is necessary to drive the anoxic reaction.
- The aerobic digester can generate its own carbon source to drive the anoxic reaction and strip nitrates, but it must “cycle on and off” to do so.
- Cycling between aerobic / anaerobic environments provides for a more rapid and thorough biological decay than through just “aerobic” digestion

Aerobic Digestion Process Drivers
Nitrification

AOBs (ammonia oxidizing bacteria) are responsible for the loss in alkalinity with the production of nitrous acid (destroying approximately 7.14 mg/L of alkalinity for each mg/L of ammonia oxidized).

Nitrification can be stopped with a loss in <u>available</u> alkalinity

Nitrification inhibition due to loss of alkalinity is most often seen in aerobic digestion where limited water chemistry results in high nitrates, high nitrites and high ammonia results.

Typically, dissolved oxygen is mistakenly considered the process limitation.

Aerobic Digestion Process Drivers Denitrification

- Each mg/L of nitrate can provide for 2.86 mg/L of $CBOD_5$ removal.
- Denitrification requires approximately 4 parts of BOD_5 to reduce each part of nitrate nitrogen. Long off cycles may be necessary to generate enough carbon to drive the denitrification process.
- If fresh sludge is provided from a low SRT process, particulate BOD5 provides carbon to the digestion process.

Process Drivers – Control Strategies

Aerobic Digestion
Process Drivers / Control Strategies

- Once acclimated to a facultative operation, the process aeration cycle can aerate for 8 - 12 out of 72 hours on an average basis. Primary sludge (if present) will significantly increase aeration time
- Peak summer conditions may reduce the off-cycle, while winter conditions will extend the off-cycle times.
- As carbon becomes limiting, some operators have used small amounts of influent to serve as a carbon source to drive the anoxic/anaerobic reaction in the digester (without primary sludge).
- Primary sludge will drive the process as a carbon source.

Aerobic Digestion
Process Drivers / Control Strategies

Key Control Parameters of "Aerobic Digestion":

- Seed Sludge: Primary sludge necessitates a minimum seed sludge volume to control oxygen uptake and odors. Typically the seed sludge is mixed while Feed Sludge is first introduced to the digester.

- Feed Sludge Secondary: If the process is operated at a lower SRT, particulate BOD5 may be available initially. The longer the SRT, the deeper cycles are necessary for lysing and EPS solubilization.

- Initial mixing with fresh sludge (while not aerating) will contact nitrates in upper reaches of tank and initiate denitrification.

Aerobic Digestion
Process Drivers / Control Strategies

- Aeration cycles are controlled by pH – aeration can be provided until the alkalinity is lost and pH begins to drop.
- pH control of aeration is necessary to prevent waste of energy with a drop in pH – watch for the ammonia valley. Some operators have ORP setpoints with pH override to shutdown aeration if pH drops.
- Off-cycles are controlled by time and/or ORP (oxidation reduction potential). Timed off cycles are checked and controlled by the operator (odor/foam).
- Mixing independent of aeration for cycle control is a plus.
- Diffusers / blowers must be capable of off-cycles.

Questions???????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