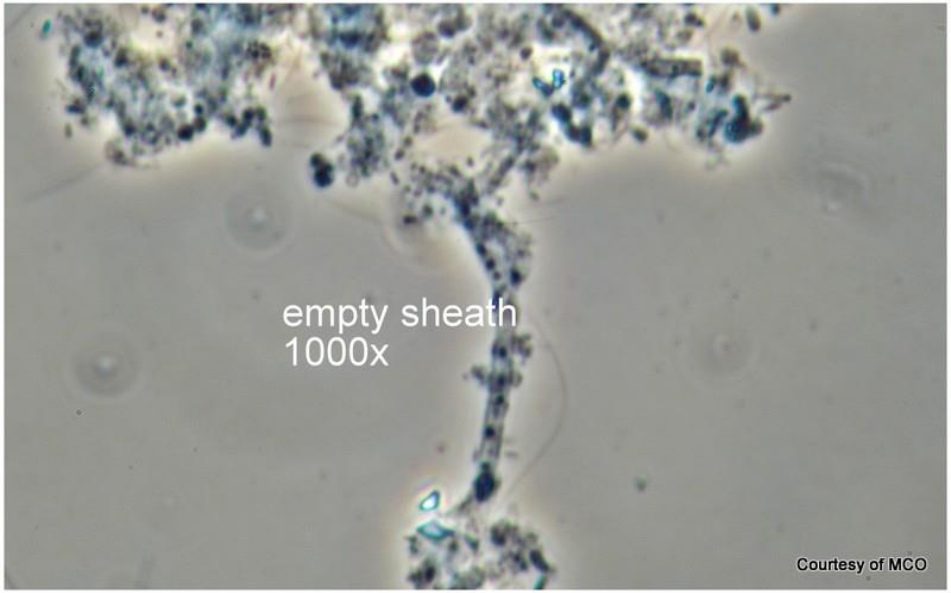
Stress, Inhibition, and Toxicity In Wastewater Systems

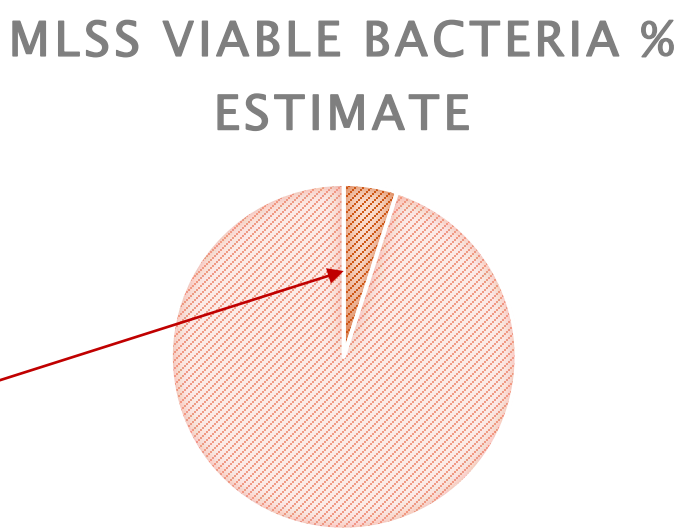


MCO
Midwest Contract Operations

Presented by: Ryan Hennessy
Midwest Contract Operations

MLSS

- 40%: Non-Viable Bacteria and Others
- 25%: Inert Materials
- 20%: Polysaccharide
- 10% Higher Life Forms
- **5% Viable Bacteria**
- *Ballpark Estimates

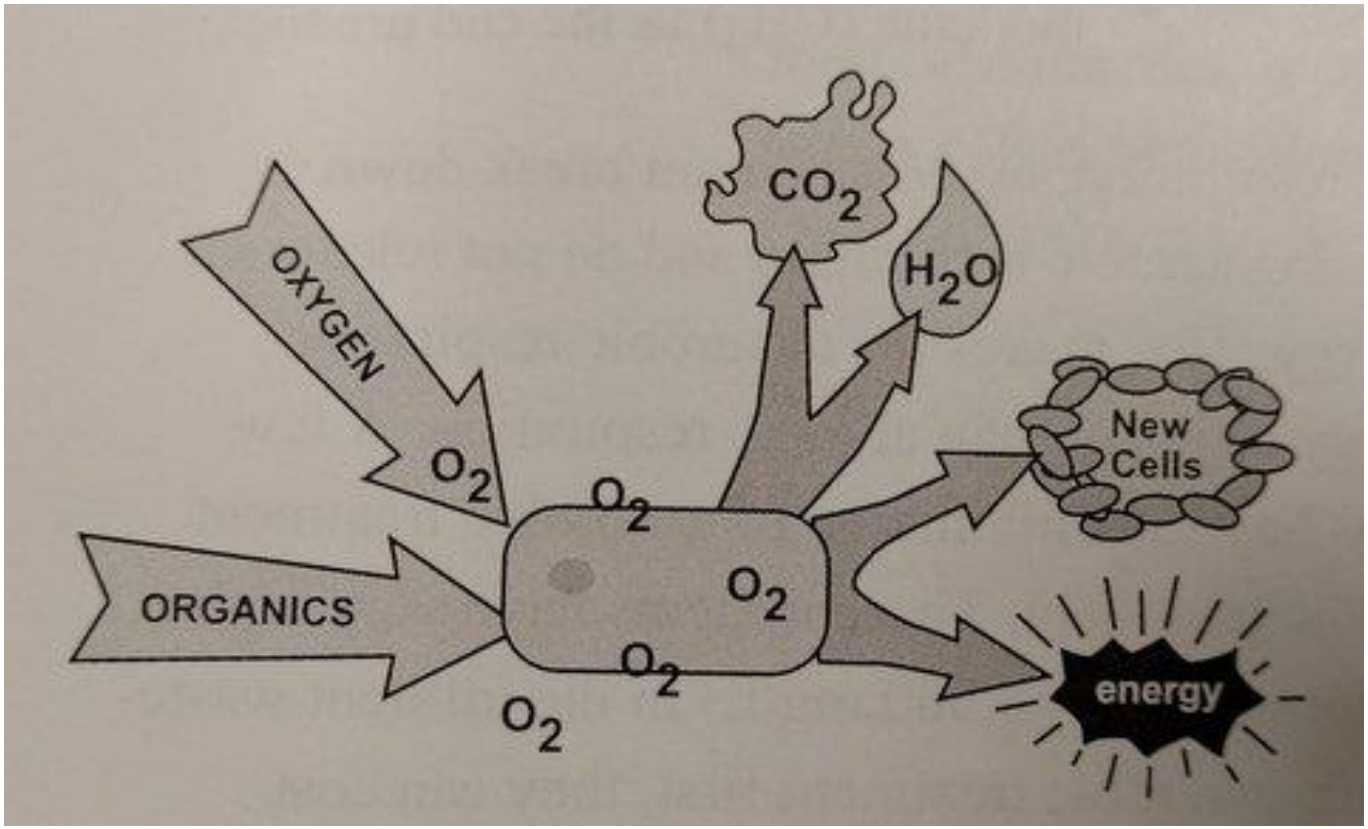


Types of Organisms/ Who are the Players?

- 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 (80% in activated sludge)

Treatment 101



Respiration and Enzymes

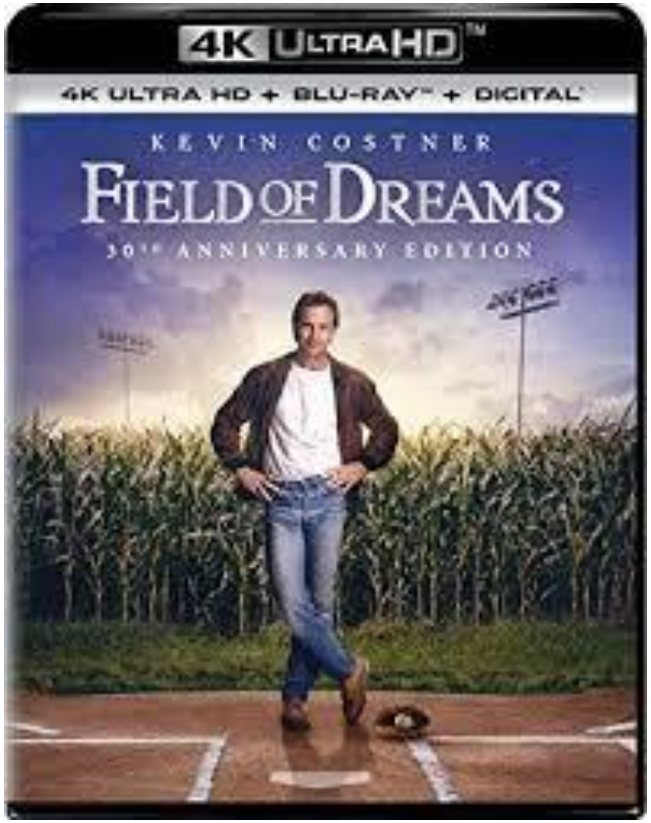
- Respiration is a process controlled by enzymes that creates usable energy from food molecules (creating new cell growth)

- **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

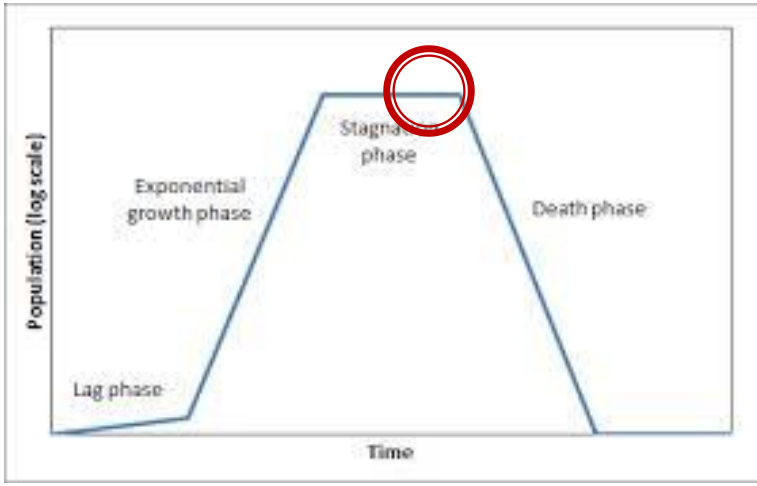


Cell Growth and Respiration

- **Binary Fission:** After a cell reaches its maximum size, it divides into new cells
- Binary Fission can occur every 20-30 minutes under optimum growth conditions
- In Activated sludge, it is ideal to have much slower growth rates and a consistent amount of food to mass (F/M)
  - This keeps systems more stable

Bacterial Growth Curve

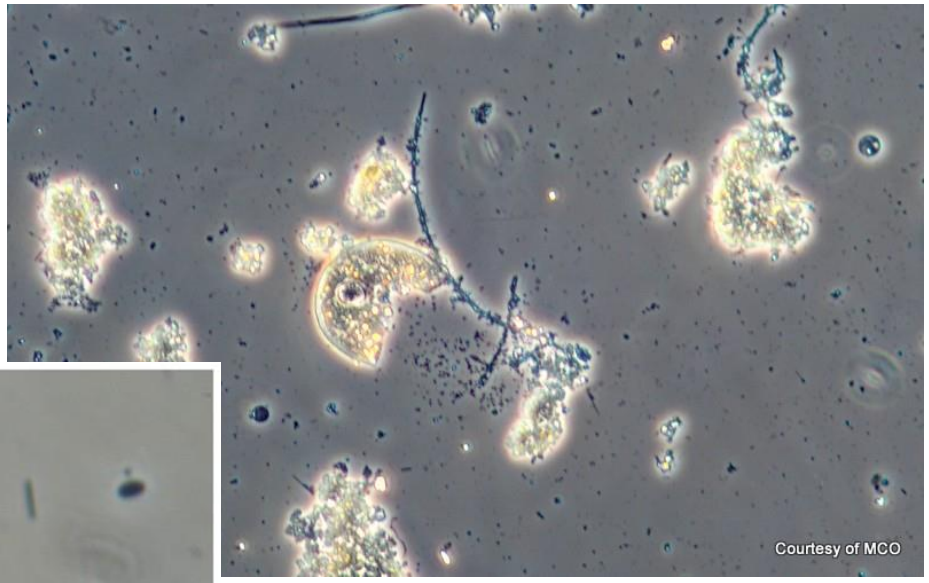
- **Lag**
  - Acclimatization, no reproduction
- **Logarithmic (log)**
  - Bacteria are multiplying by their greatest rate
  - F/M is high
  - High single celled bacteria/ dispersion rates
- **Stationary Phase**
  - Growth= death
  - F/M decreasing F/M <1
- **Declining Growth Phase (death log)**
  - Logarithmic Death
  - Endogenous Respiration
  - F/M at it's lowest point
  - Old sludge
- **Death**
  - no viable cells



Cell Life

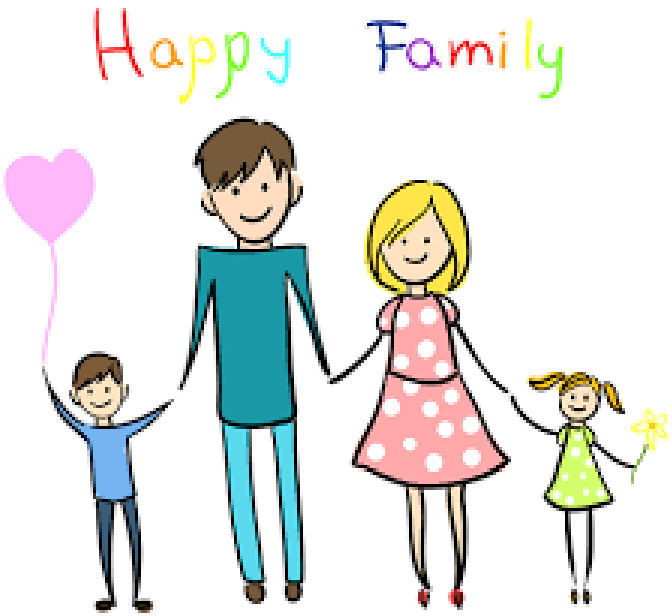
- As cells grow, they must maintain themselves
- Energy is released from food molecules taken inside the cell and used for cell growth, repair, and maintenance
- Enzymes are manufactured by the cell to help break down the organics
- Waste products are produced
  - Carbon Dioxide
  - Water
- **Eventually a cell dies when it can no longer maintain itself**

Diagnosing Stress (Often the Easy Part)



Causes of Stress (When one of these isn't right)

- pH
- Alkalinity
- Temperature
- Hydraulic Retention Time
- Sludge Retention Time
- Dissolved Oxygen
- Nutrients



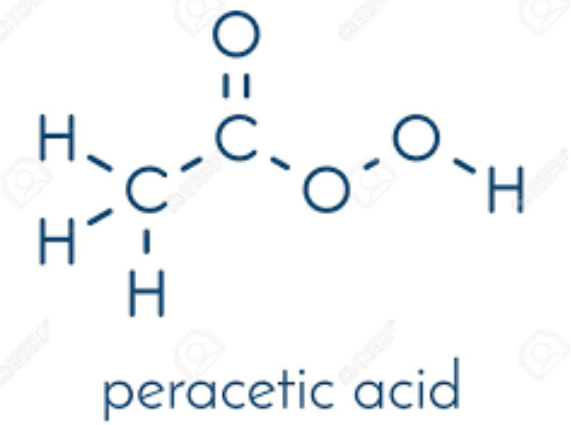
- Additional Variables
  - Inhibitory Compounds

“Low Hanging Fruit”

- pH
- Alkalinity
- Temperature
- Hydraulic Retention Time
- Sludge Retention Time
- Dissolved Oxygen
- Nutrients

Not always Easy

- Additional Variables
  - Inhibitory Compounds



Inhibition vs. Toxicity

Oxygen Uptake Rate

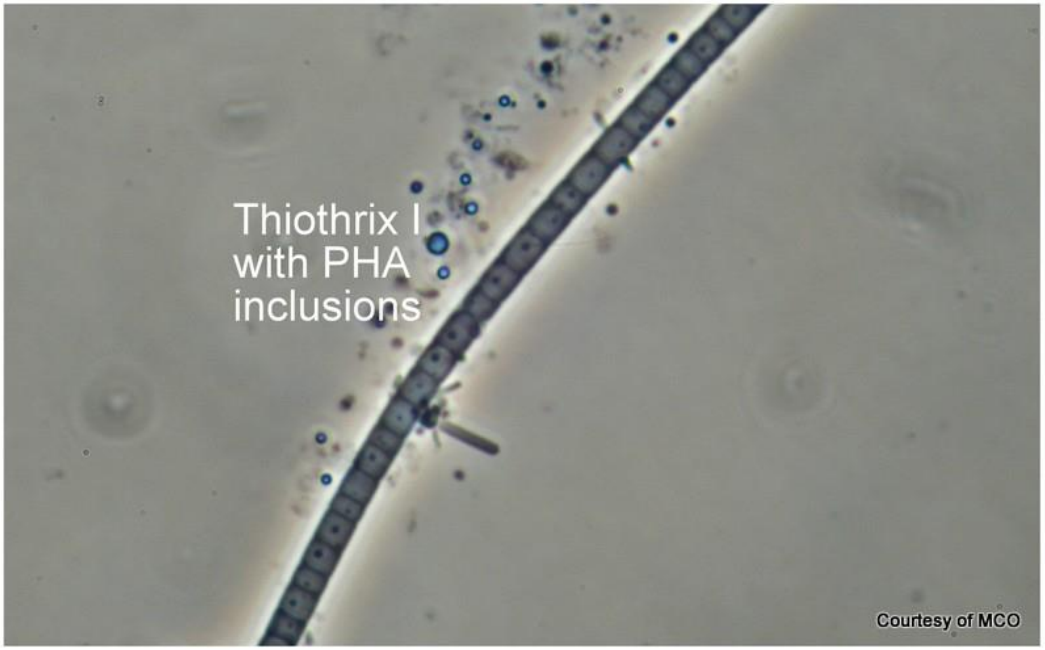
- Basic Equipment Needs
  - Dissolved Oxygen Meter
  - Lab DO Probe and Stirrer
  - Stop watch
  - 300 mL BOD Bottle
  - Air pump and stone for aerating samples

Oxygen Uptake Rate Guidelines

Generally problems such as dispersed growth develop at OUR values over 60 mg/L/hour.

Oxidation and Storage

- The bacteria will oxidize as much food as possible and also store as much as possible initially.
- When there is higher organic acids concentrations the food is more readily available. (Acetic acid taken up within initial 15 minutes- reference Dr. Michael Richard).



OUR Test Procedure (Reference Rick Marshall of METC)

- Aerate the sample to get the DO level high enough (6-8 mg/L) for the test
- Fill BOD bottle with sample
- Start timing after recording initial DO reading
- Record DO every minute
- Stop once DO nears 1 mg/L (at 1 mg/L or less DO can become a limiting factor for uptake rate).
- Calculate the $\triangle$DO using 3-4 consistent readings
- Convert to mg DO/hr. by multiplying by 60
  - To calculate SOUR divide by the grams of MLVSS
    - (for example if MLVSS is 2,000 mg/L divide by 2.0)

Some Meters can Measure OUR

Can program start and stop DO concentrations/Built in OUR program

Measurement

- Here the △DO gets consistent after a few readings:

Time (Minutes)	D.O. mg/L	△DO
0	8.50	
1	7.29	1.21
2	6.97	0.32
3	6.64	0.33
4	6.31	0.33
5	5.98	0.33
6	5.66	0.32
7	5.33	0.33

Sample Prep

- RAS (dilute down to MLSS concentration)
  - Example: RAS= 9000 mg/L, MLSS= 3000 mg/L use 100 mL of RAS in the 300 mL bottle
- Aeration Basin Influent (food)
- Secondary Clarifier Effluent (no food)

- *In preparing the samples the RAS must be aerated to eliminate initial oxygen demand from not being in aerobic environment*

Fed vs Unfed Test

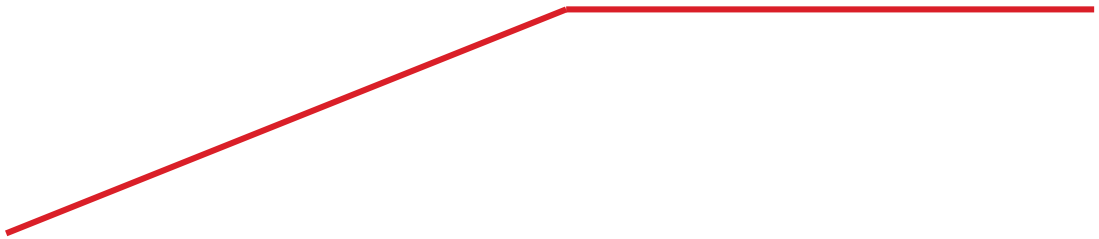
- Fed Test
  - 100 mL RAS
  - 200 mL Influent
    - As bacteria see higher food concentrations uptake rate increases
- Unfed Test
  - 100 mLs RAS
  - 200 mLs Secondary Clarifier Effluent
    - Typically >0.8 mg/L/minute is a high unfed rate which indicates under-oxidized sludge
    - Typically <0.3 mg/L/minute is an over-oxidized sludge
    - *Disclaimer: Every plant is different. Not broke don't fix!

In Situ OUR measurements

Flow
Direction

Healthy OUR curve

- The OUR of an activated sludge fed increasing amounts of a nontoxic waste will initially rise with increasing waste additions
- Eventually it will reach a maximum oxygen uptake rate in which higher waste concentrations can no longer increase OUR value



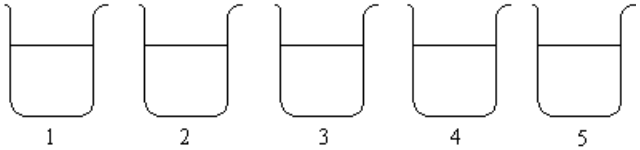
Inhibitory Curve

- OUR of an activated sludge fed an inhibitory waste may increase initially with increasing waste strength, but will decrease quickly at waste additions above the toxicity threshold value

Microbial Death

- Dr. Michael Richard defines microbial death as when the fed OUR is less than the basal endogenous OUR

Bench Scale Testing



<u>Procedure Developed by Ryan Hennessy of MCO</u>

- Each vessel contains 500 mL
- 250 mL known healthy RAS + varying spikes of suspected "inhibitory influent"
  - *Example test #1 = 250 mL RAS + 250 mL known healthy influent. Test #2= 250 mL RAS + 200 mL known healthy influent + 50 mL test influent etc.*
- "Baseline uses known healthy municipal influent"
- Samples aerated for 7 hours and ammonia at beginning and end of test monitored (for nitrification)
- Soluble COD removal% can be tested at various intervals to get an idea of impact on carbonaceous BOD removal
- *Disclaimer: Influent sample/baseline must be healthy for test to be valid. "Spike" amounts vary depending on strength of suspected influent/ goal is to mimic actual plant conditions as best as possible

Interesting Technology Advances

SENTRY™

OVERVIEW BENEFITS PRODUCT PERFORMANCE CONTACT BLOG

Product focus

SENTRY leverages bio-electrochemical sensor technology to relay bio-activity (metabolic activity) of the microbiology to the wastewater system operator. This data allows operators to continually monitor the microbial stability (health) of their wastewater treatment process. Furthermore, this data can be leveraged with other water quality and operational data to improve/optimize system performance.

Data produced from the sensor can be used to:

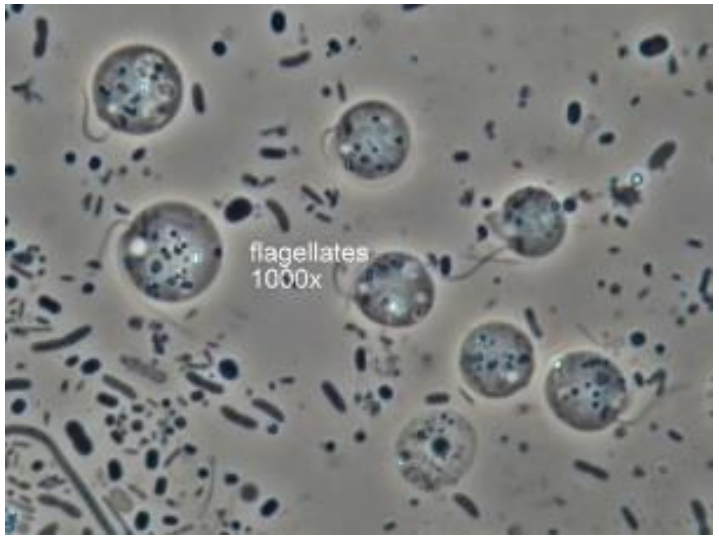
1. Predict process upset via instability in microbial metabolism

2. Correlate fluctuating bio-electrode output to system input / process / operational events

3. Aggregate data to determine daily, weekly, and monthly performance patterns

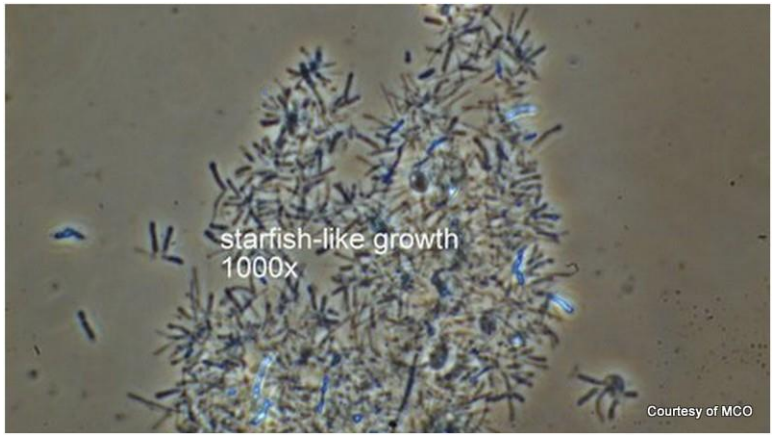
Common Order of Events (Toxicity)

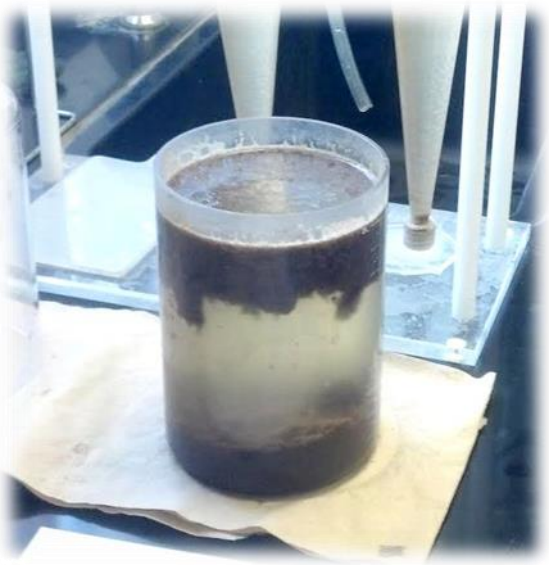
- Initially Flagellate “bloom”
- Subsequent death of protozoa and other higher life form organisms
- De-flocculation/Foaming/ Loss of carbonaceous BOD removal
- Filamentous Bulking upon Recovery



Other Possible Signs of Stress

- Loss of Nitrification/increase of ammonia
- Headless stalked ciliates/ shift in higher life form organisms to flagellates and amoeba
- Dead filamentous bacteria
  - Rapid decrease in 30 minute settling
- Presence of Surfactant-like Foam
- “Irregular Growth Formations”
- Increase in Rise Time





Common Inhibitory Substances

- Sulfide
- Odd # carbon organic acids
- Quaternary ammonium compounds
- Peracetic Acid
- Heavy Metals
- Surfactants
- Phenols/ Hydrocarbons
- Dyes from Textile Processing

Surfactants

- Cationic
  - No direct testing method. TKN comparison/ elevated TKN concentrations associated with these
- Nonionic (CTAS testing)
  - http://www.davylaboratories.com/
  - Approximately $330/sample
  - >25 mg/L considered high
- Anionic (MBAS testing)
  - Most common in municipal
  - A lot of labs test for these
  - Ballpark $90-$100/sample
  - >25 mg/L considered high

Surface Tension Measurements

Measurements of <60 mN/m are an indicator of presence of surface-active agents (surfactants)

*Reference Dr. Jenkins, Dr. Richard 2004

KRÜSS

Surface Tension of Waste Water

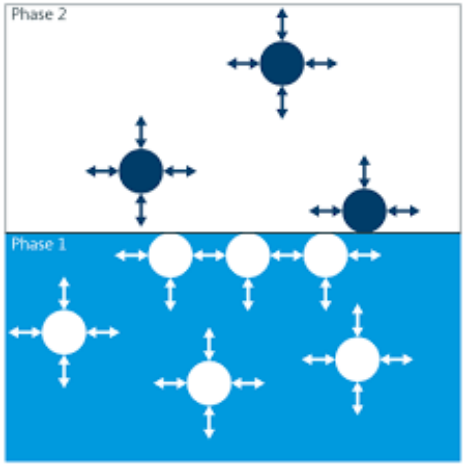
The surface tension of several waste water samples were measured using Wilhelmy Plate Method

Dr. Raymond Sanedrin
Matthews, NC, 01/09/2019

KRÜSS

Instrument

K100 – Surface Tension Measurement



Operational Adjustments

- Diagnosing “stress” is often relatively straight forward.
- Determining potential causes can be more complex.
- Control strategies range significantly depending on individual circumstances
  - Reducing wasting rate/ increasing MLSS
    - Often a successful first approach
      - Note that some toxins do accumulate within the flocs so this does have the potential to worsen things in some instances
  - Addition of healthy mixed liquor
  - Temporary coagulant/polymer addition
  - Wasting and/or reseeding

References

- https://www.kruss-scientific.com/services/education-theory/glossary/surface-tension/
- 3rd Edition Manual on Causes and Control of Activated Sludge Bulking, Foaming, and Other Solids Separation Problems (2004 Jenkins, Richard).
- Industrial Activated Sludge Operations, Rick Marshall METC http://www.metcgroup.com/
- https://www.dec.ny.gov/docs/water_pdf/drrichard1.pdf
- https://www.islandwatertech.com/sentry-2/

Questions?