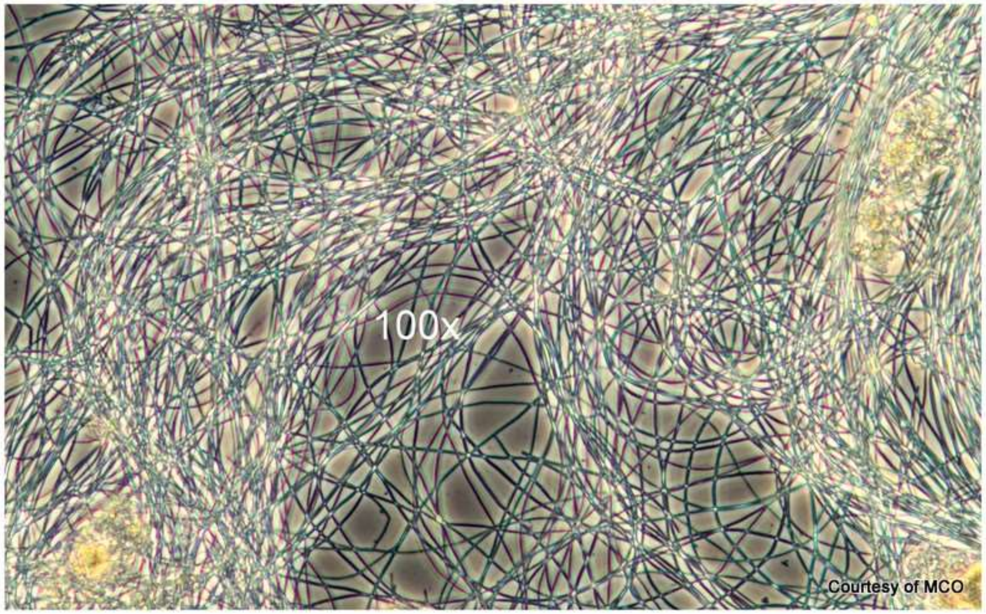
Wastewater Microbiology

Causes vs. Problems



WWOA Weyauwega Meeting 2019

MCO
Midwest Contract Operations

Presented by: Ryan Hennessy
Midwest Contract Operations

Agenda

- Identify and discuss common issues encountered in wastewater treatment processes.
- Identify common remedial actions for various issues.
- Conditions vs. Problems– when to act.

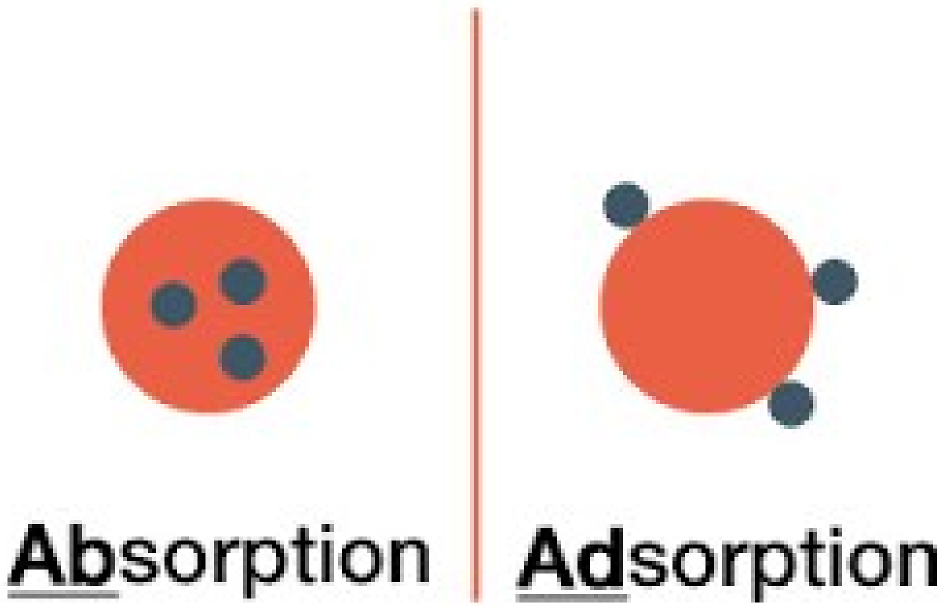
Treatment Goals

- Permit Compliance
- Consistency
- Efficiency
  - Cost
  - Labor

Treatment/ How is BOD Removed?

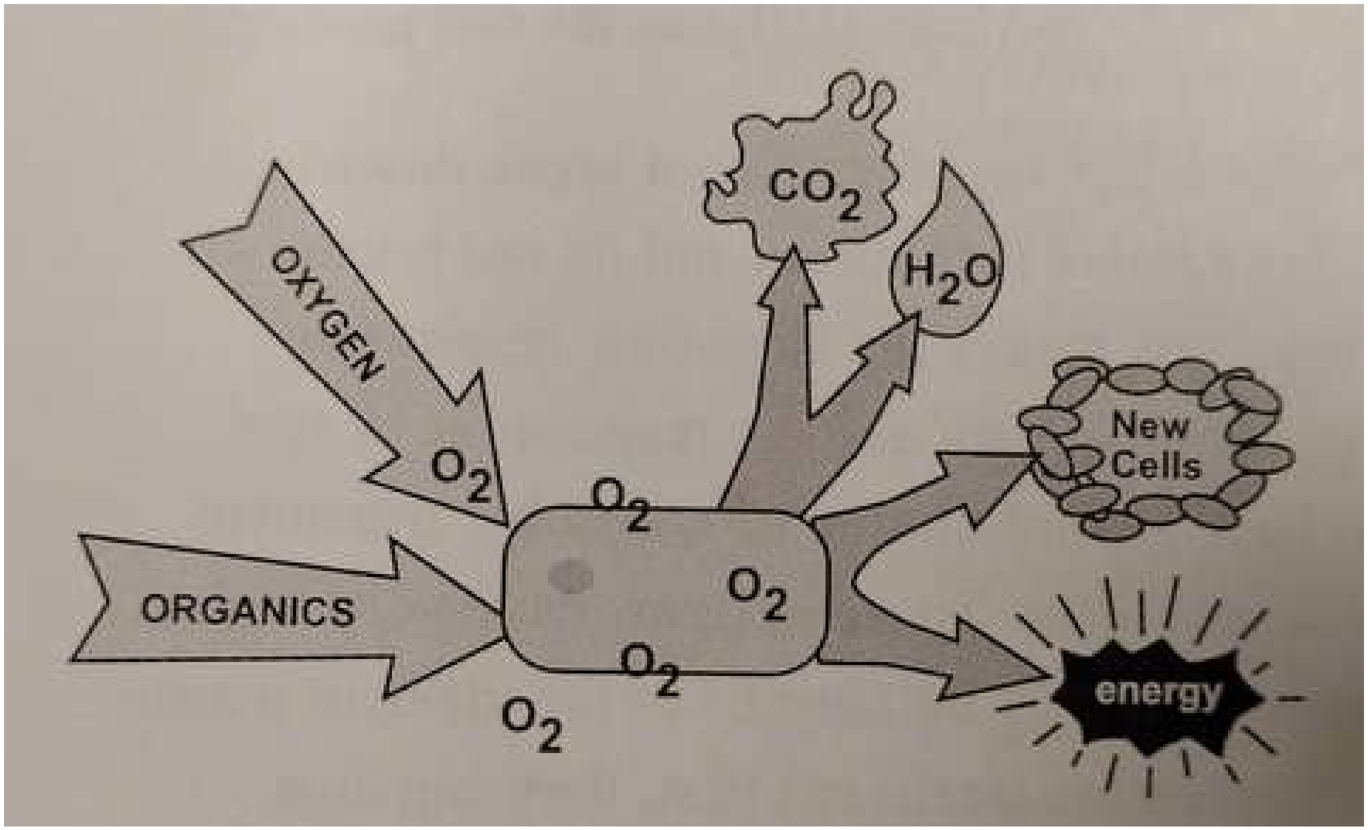
- BOD (food) can either be particulate or soluble
- If soluble, passes through the cell membrane (absorption)
  - These reactions are very quick, often 30-60 minutes
- If particulate, the material is captured by the cell (adsorption) and broken down first
  - This may take several hours or longer

Absorption vs Adsorption



F/M Ratio

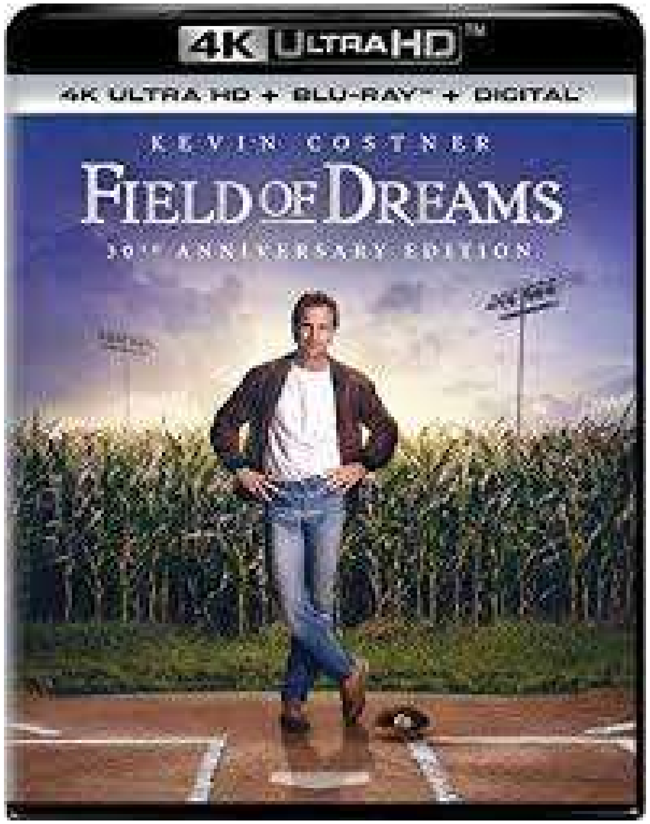
Treatment 101



"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



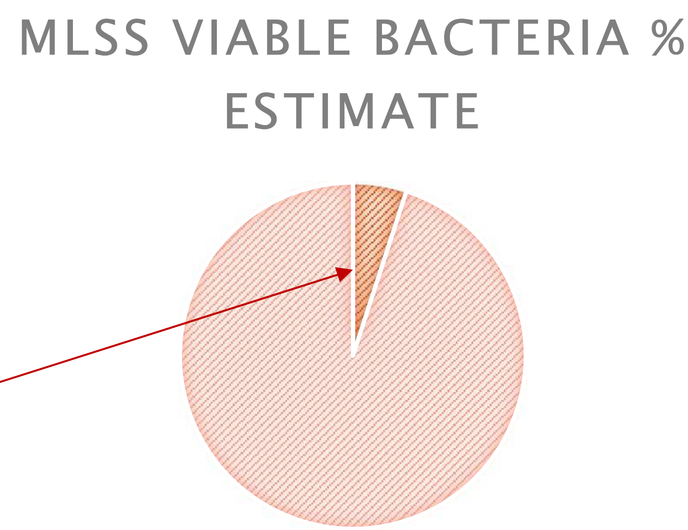
Types of Organisms/ Who are the Players?

- <u>Microorganisms can be classified by the type of respiration they use</u>

- 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)

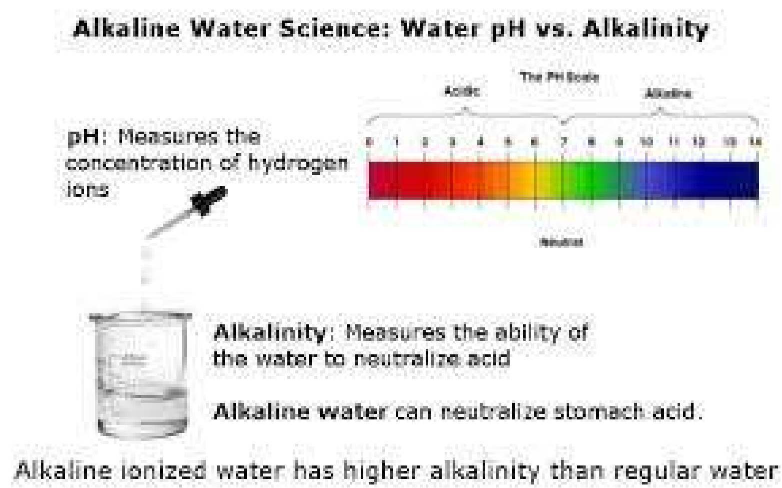
MLSS

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



pH and Alkalinity

- Low or high pH destroys bacterial enzyme structure (becomes toxic)
- General recommended operating ranges are 7.0–8.5 pH
- An alkalinity residual of 75 mg/L or more at the end of activated sludge treatment is desired to prevent decrease in the pH



Hydraulic Retention Time

- Hydraulic Retention Time
  - This is the amount of time the water stays in a particular area
  - In the activated sludge processes, this can be several hours to days, depending on design
  - This is mostly controlled by influent flows and often there is little control over this from an operational standpoint

$$HRT = \frac{Volume\ of\ aeration\ tank}{influent\ flowrate}$$

Sludge Retention Time (SRT)

- This may also be referred to as sludge age, or mean cell residence time (MCRT)
- The purpose of this calculation is for operational control and indicates the average number of days an average microbe stays in the system
- Due to growth rates of different bacteria, some species (such as nitrifying bacteria) require longer sludge retention times
- Operational adjustments can be made by changing the SRT (the amount of sludge wasted per day)

Temperature

- As temperatures increase, so does the rate of biochemical reactions (treatment)

- As a general rule, for every 10 degree C change in temperature, reaction rates double or decrease by a factor of 2

- In warmer months, less bacteria is often needed to treat the same amount of waste, and vice versa in the winter time

Dissolved Oxygen

- For aerobic treatment, adequate dissolved oxygen is needed
- Typically a DO (dissolved oxygen) residual of 1-2 mg/L is recommended

Nutrients

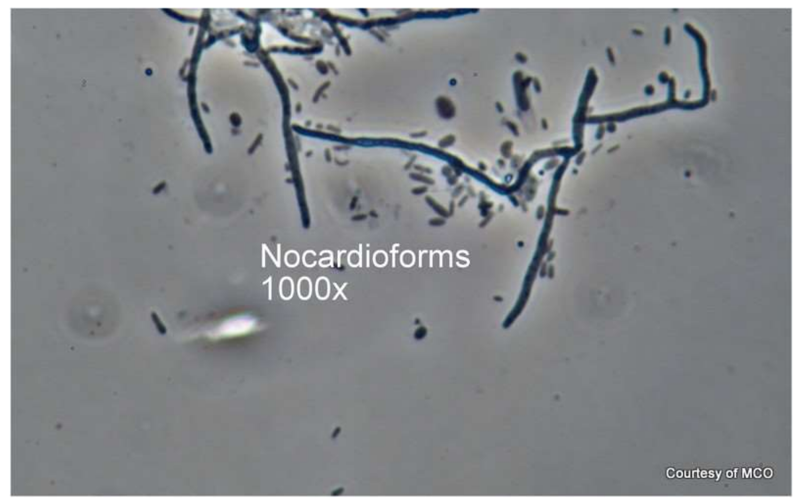
- The key macronutrients that are essential for bacteria to function in activated sludge are phosphorus and nitrogen
- Generally, a ratio of 100BOD:5N:1P is recommended
  - There are other trace minerals (micronutrients) that are essential
    - These are normally found in sufficient quantities in water

Element	Bacterial Composition % by weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1
Potassium	1
Sodium	1
Magnesium	0.5
Chlorine	0.5
Others	0.3

Reference: Kenneth Todar, PhD

Fats, Oils, and Grease (FOGs)

- It is recommended to limit these at the source or remove in primary treatment in wastewater
- If present in plant effluent, these can result in floating material in the receiving water
- High concentrations (commonly >100 mg/L) can cause foaming and settling problems in activated sludge

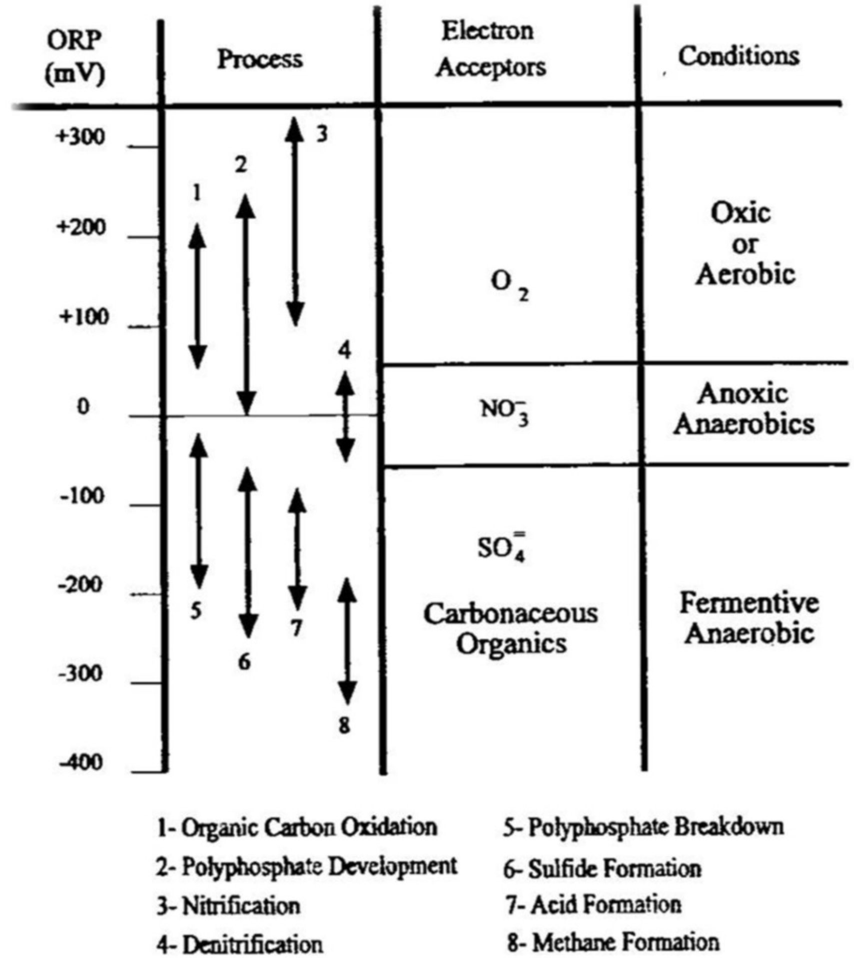


Septicity/ Organic Acids

- Septicity
  - Defined as when wastewater becomes anaerobic
  - Sulfate reducing bacteria reduce sulfate to hydrogen sulfide
  - Anaerobic bacteria ferment organic materials to organic acids
    - Acetic, propionic, butyric, valeric

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



ORP & Metabolic Processes.
Goronszy, M, et al 1992

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

Respiration and Enzymes

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

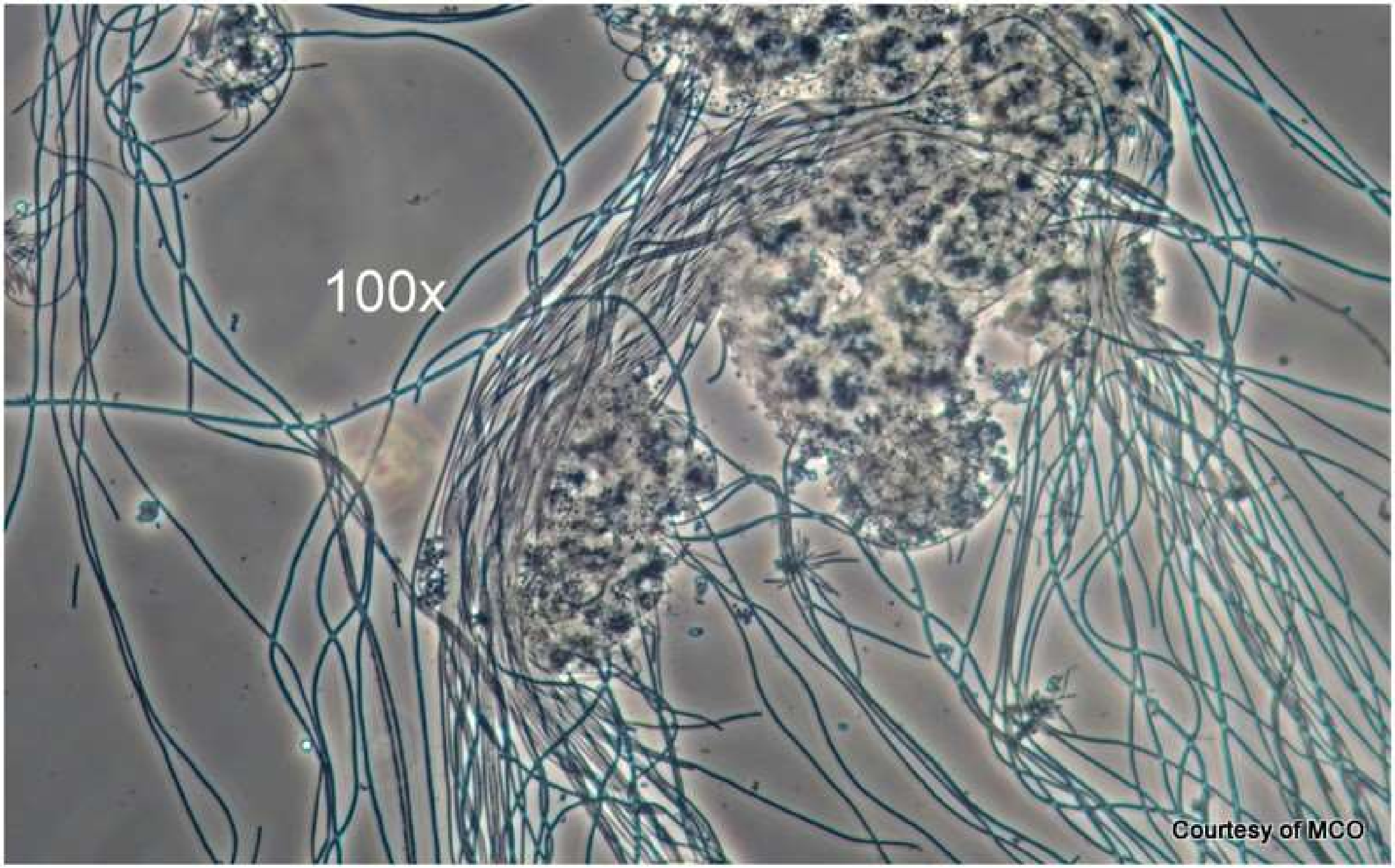
- Enzymes are critical to the process
  - These are protein molecules that are manufactured by cells
  - Each reaction sequence needs a certain set of active enzymes
  - The reason extremes in temperature, pH, and the presence of toxic materials disrupt treatment is due to the failure of enzymes

Summary: Proper Environment for bugs

- 1)pH (7–9)
- 2) Alkalinity (>50 mg/L)
- 3) Time (HRT and SRT)
- 4) Temperature
- 5) Dissolved Oxygen
- 6) Nutrients
- 7) FOGs (limited)
- 8) Septicity (limited)

Sludge doesn't settle: Why?

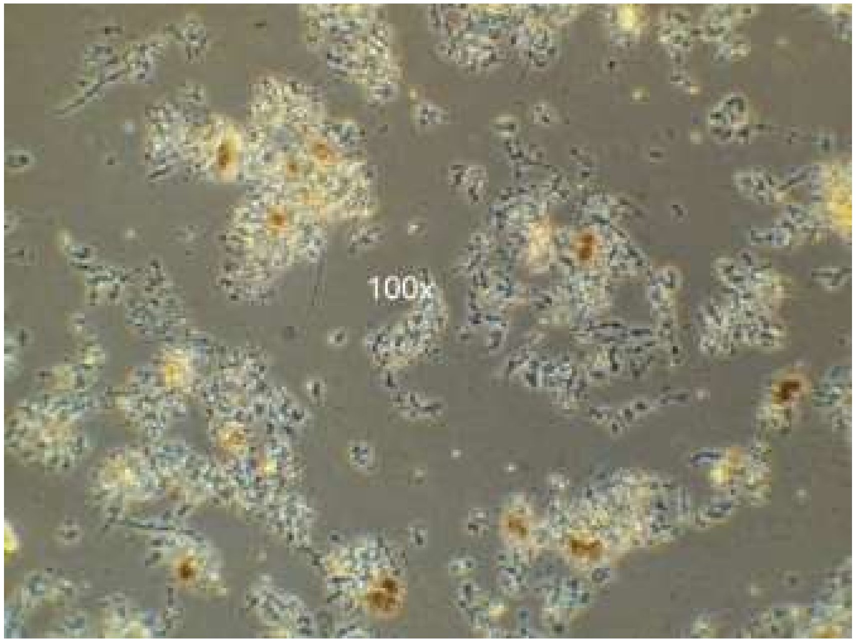
Filamentous Bulking

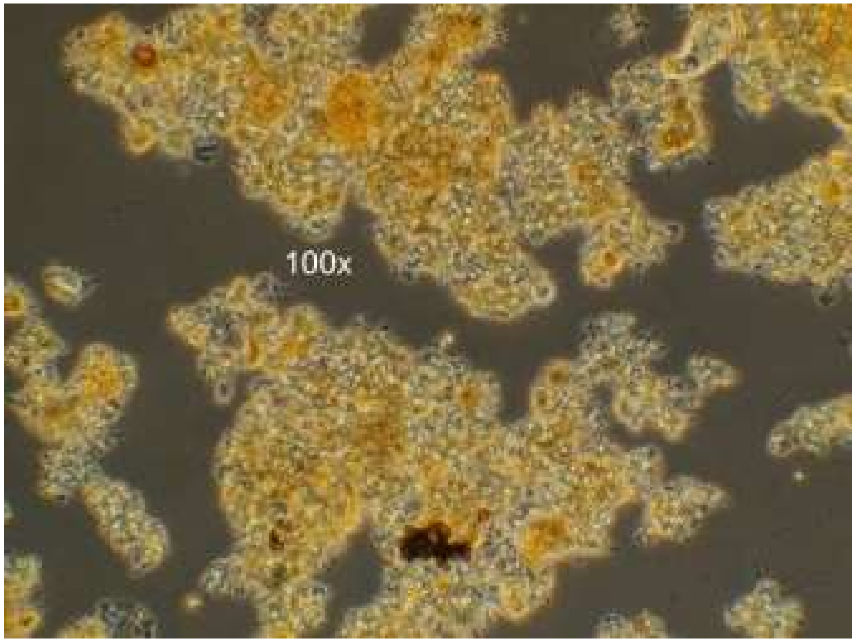


Filament Causes

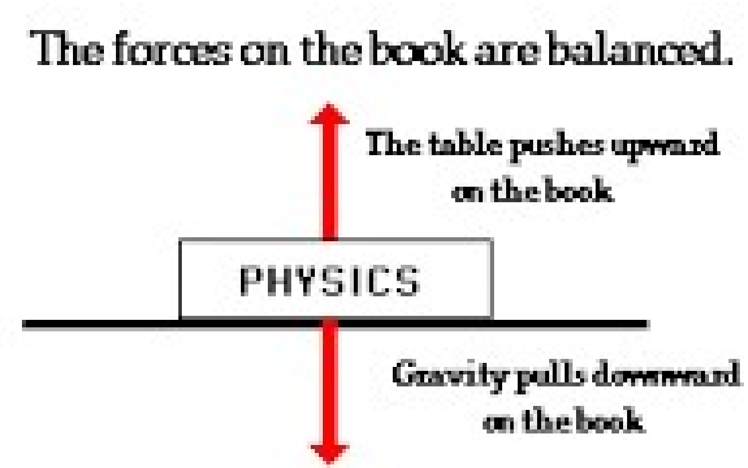
Cause	Filaments
Low DO	*Spaeroltius natans* Type 1701 *Haliscomenobacter hydrossis*
Low F/M ratio	Type 0041 Type 0675 Type 1851
Septicity	Type 021N *Thiothrix* I and II *Nostocoida limicola* I, II, III Type 0411 Type 0961 Type 0581 Type 0092
Oil and Grease	Nocardia spp. *Microthrix parvicella* Type 1863
Nutrient Deficiency	Nitrogen: *Thiothrix* I, II, type 021N Phosphorus*: N limicola* III, *H. hydrossis, S. natans*
Low pH	Fungi
***Source**: Dr. Michael G Richard; used with his authorization.*	

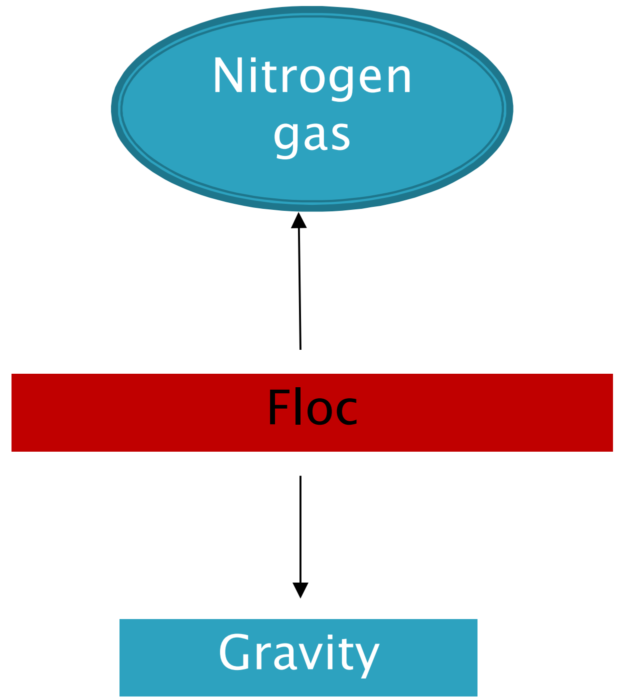
Hindered Settling and/or Weak Flocs





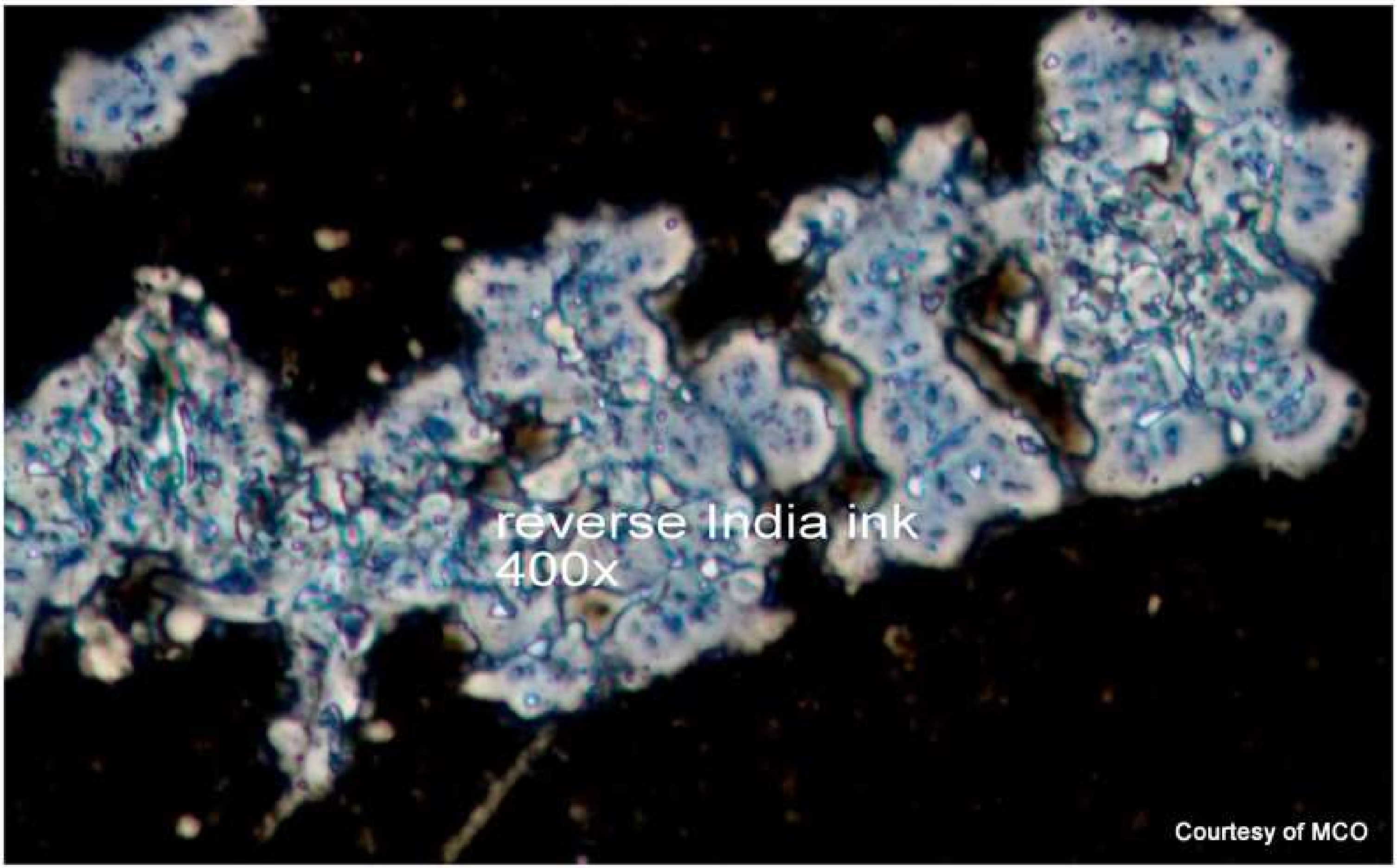
Settling Issues can be Denitrification related





Slime Bulking-zoogloea

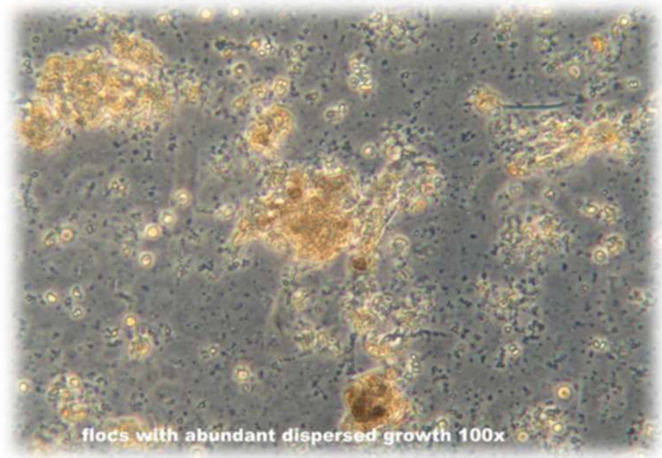
Slime Bulking-low nutrients



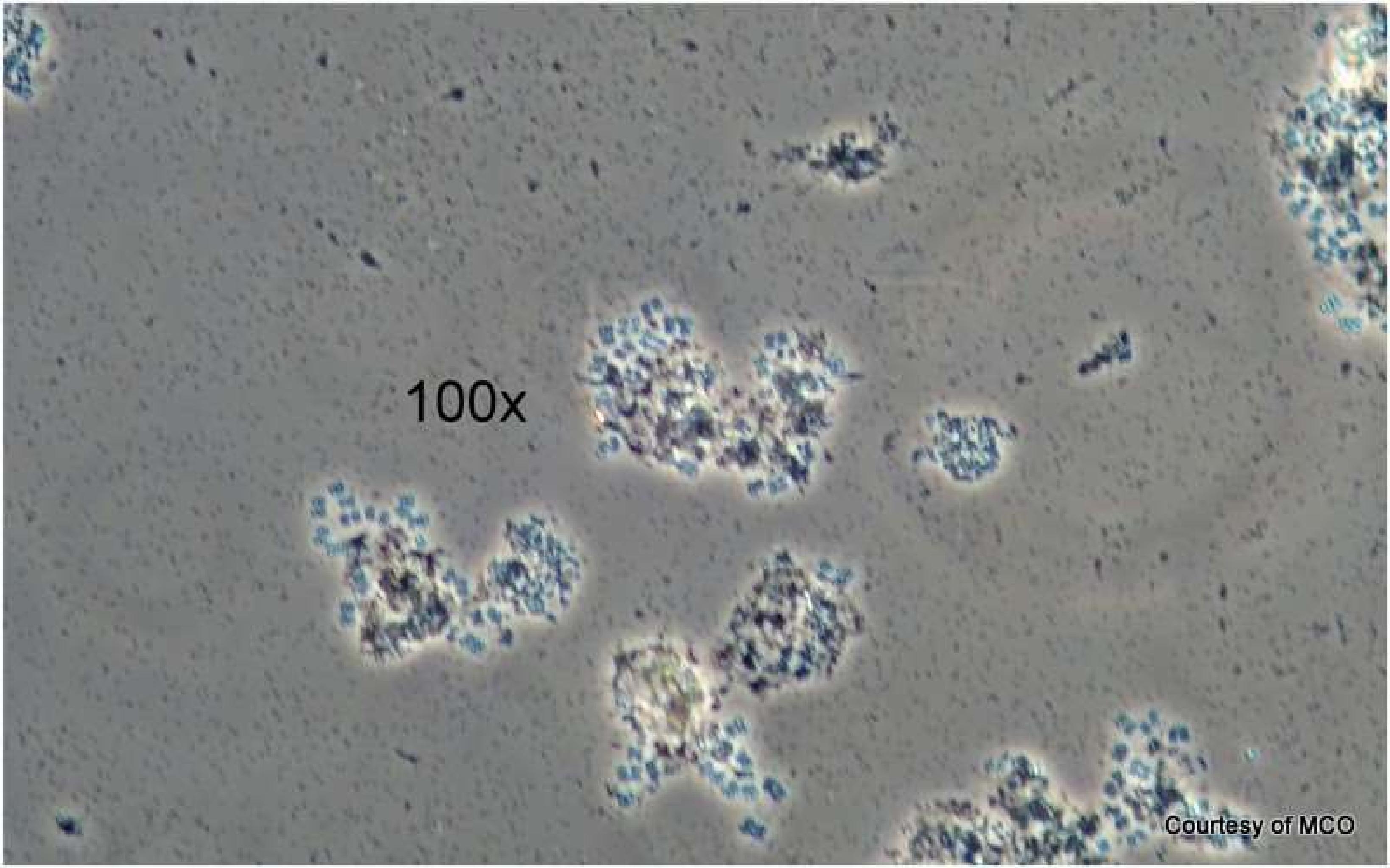
Turbid Supernatant: Why?

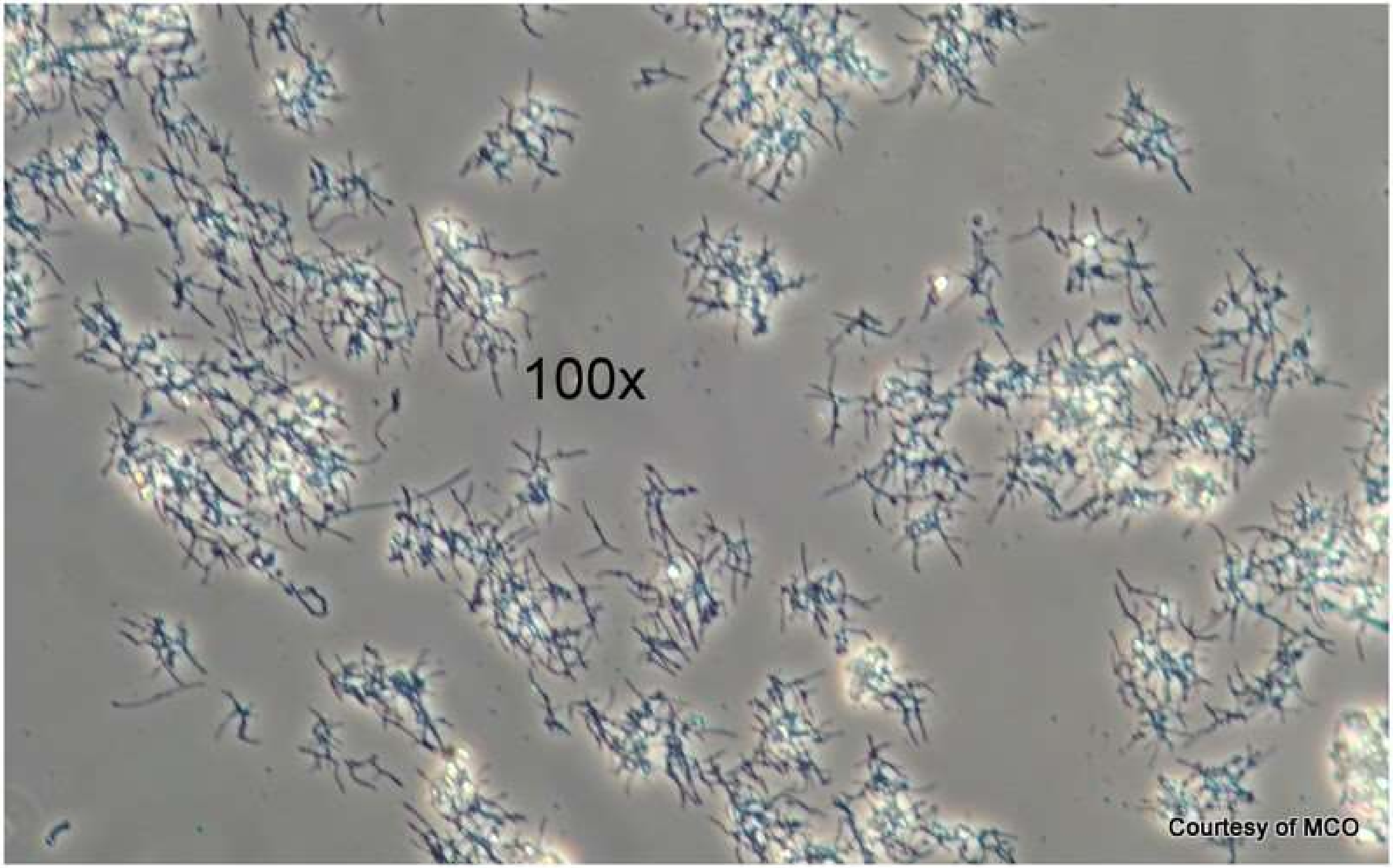
Dispersed Growth

- Selection of single cells or filaments at high growth rates (high F/M)
- High concentrations of monovalent cations (like potassium and sodium)
- High temperatures (>40 degrees C)
- Rapid temperature change
- De-flocculation
  - Poorly biodegradable surfactants
  - Toxic materials



Flocs with Abundant Dispersed Growth


100x
Courtesy of MCO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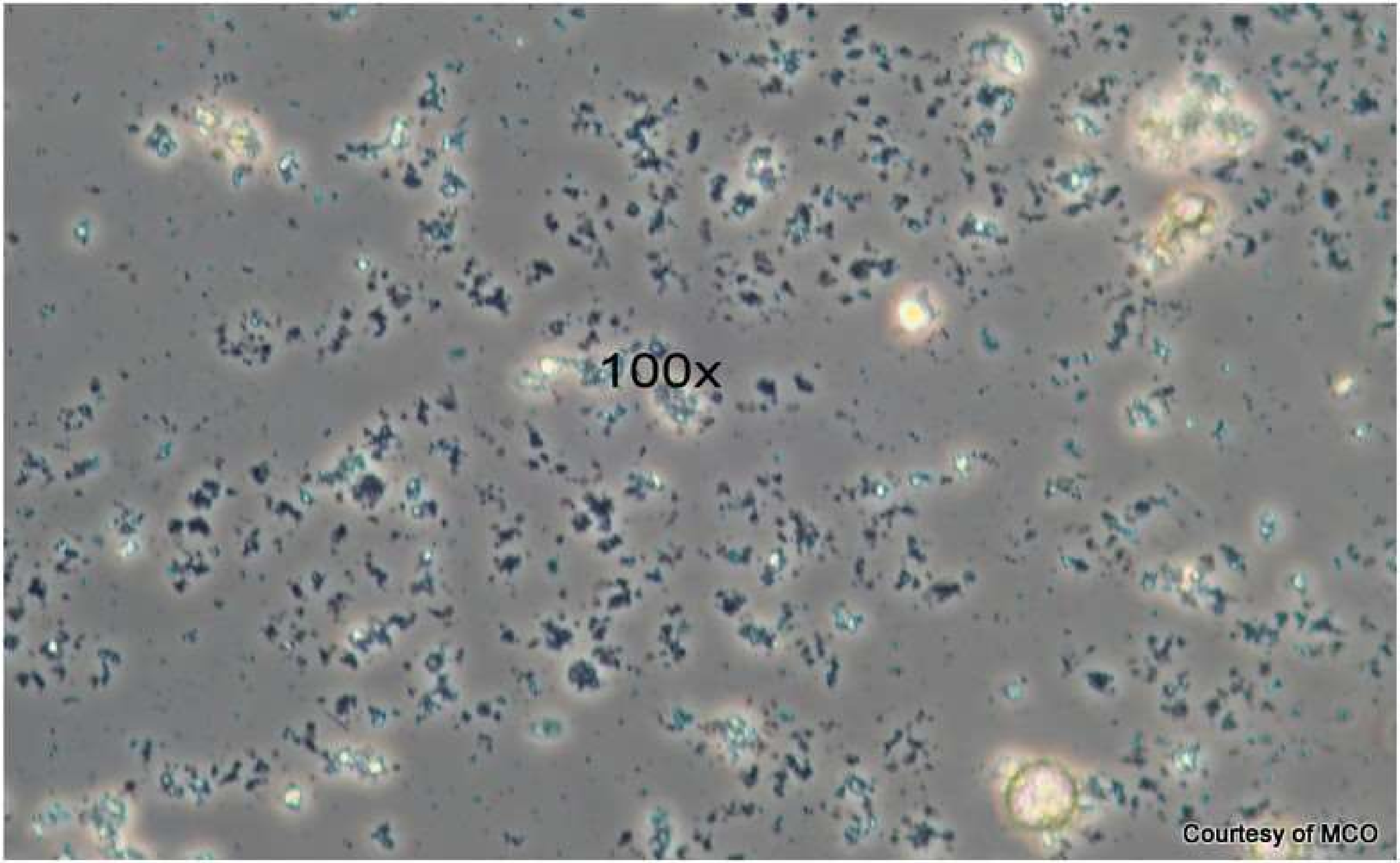
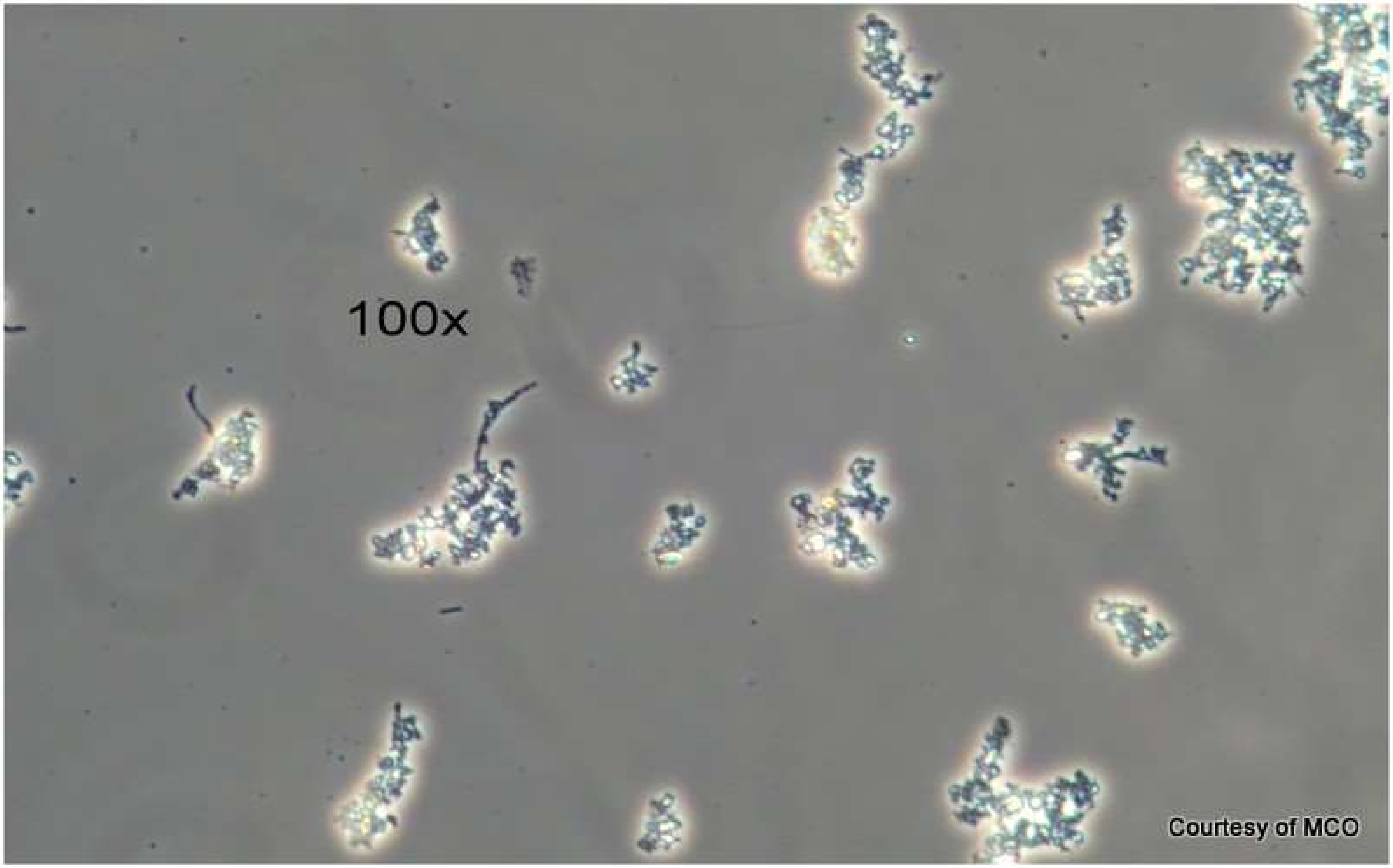

100x
Courtesy of MCO

Pin Floc

- Pin floc (<100um) is known to occur at starvation conditions associated with very low F/M ratio
- In these instances small dense flocs settle rapidly
  and leave behind a turbid supernatant
- Chronic toxicity is also a cause of pin floc
- Pin flocs at high MLSS concentration can cause hindered settling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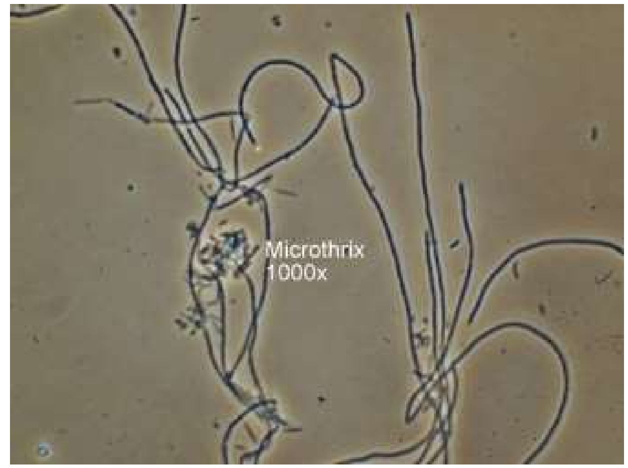
Courtesy of MCO

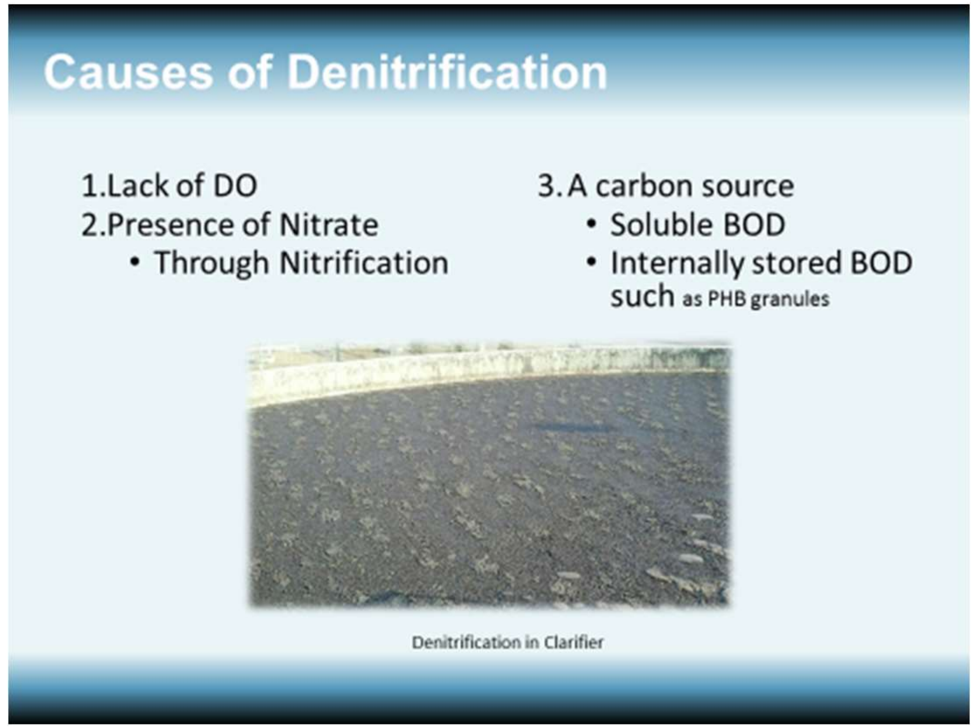
Foam…why?

Nocardia/Microthrix Foam



"Dead Bug Foam"

Denitrification Foam



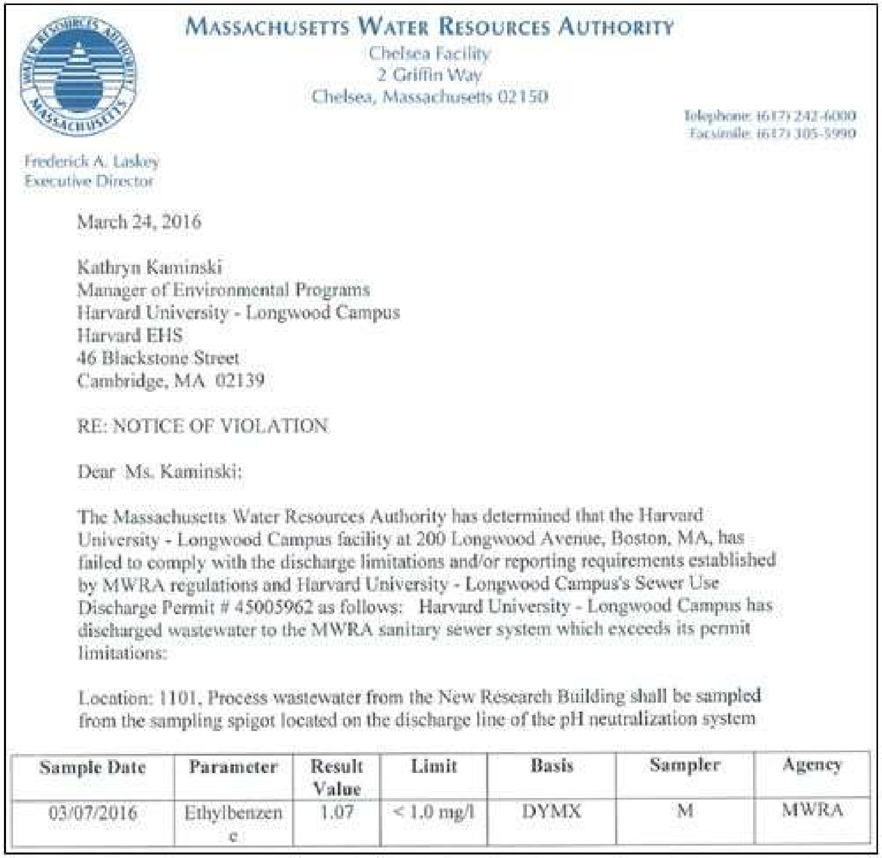
Surfactant Foam

“Excessive Fines Foam”

When to Act

2. Recent Permit Violations

Too late!



MASSACHUSETTS WATER RESOURCES AUTHORITY
Chelsea Facility
2 Griffin Way
Chelsea, Massachusetts 02150

Telephone: (617) 242-6000
Facsimile: (617) 305-5990

Frederick A. Laskey
Executive Director

March 24, 2016

Kathryn Kaminski
Manager of Environmental Programs
Harvard University - Longwood Campus
Harvard EHS
46 Blackstone Street
Cambridge, MA 02139

RE: NOTICE OF VIOLATION

Dear Ms. Kaminski:

The Massachusetts Water Resources Authority has determined that the Harvard University - Longwood Campus facility at 200 Longwood Avenue, Boston, MA, has failed to comply with the discharge limitations and/or reporting requirements established by MWRA regulations and Harvard University - Longwood Campus's Sewer Use Discharge Permit # 45005962 as follows: Harvard University - Longwood Campus has discharged wastewater to the MWRA sanitary sewer system which exceeds its permit limitations:

Location: 1101, Process wastewater from the New Research Building shall be sampled from the sampling spigot located on the discharge line of the pH neutralization system

Sample Date	Parameter	Result Value	Limit	Basis	Sampler	Agency
03/07/2016	Ethylbenzene	1.07	< 1.0 mg/l	DYMX	M	MWRA

HARVARD
Campus Services
ENVIRONMENTAL HEALTH & SAFETY

Plant Observations and Trends

- Changes in the following:
  - Sludge volume index/ 30 minute settling
  - Settlometer test supernatant clarity
  - Foam on aeration basin/clarifier
  - Mixed liquor looks different in color
  - Analytical data/ results reaching key performance indicator targets
  - Weather/ rain/temperature etc.
  - Patterns/Known changes to loading characteristics
    - Industrial activity
    - Tourism

State Point Analysis

- NMSC normal operations

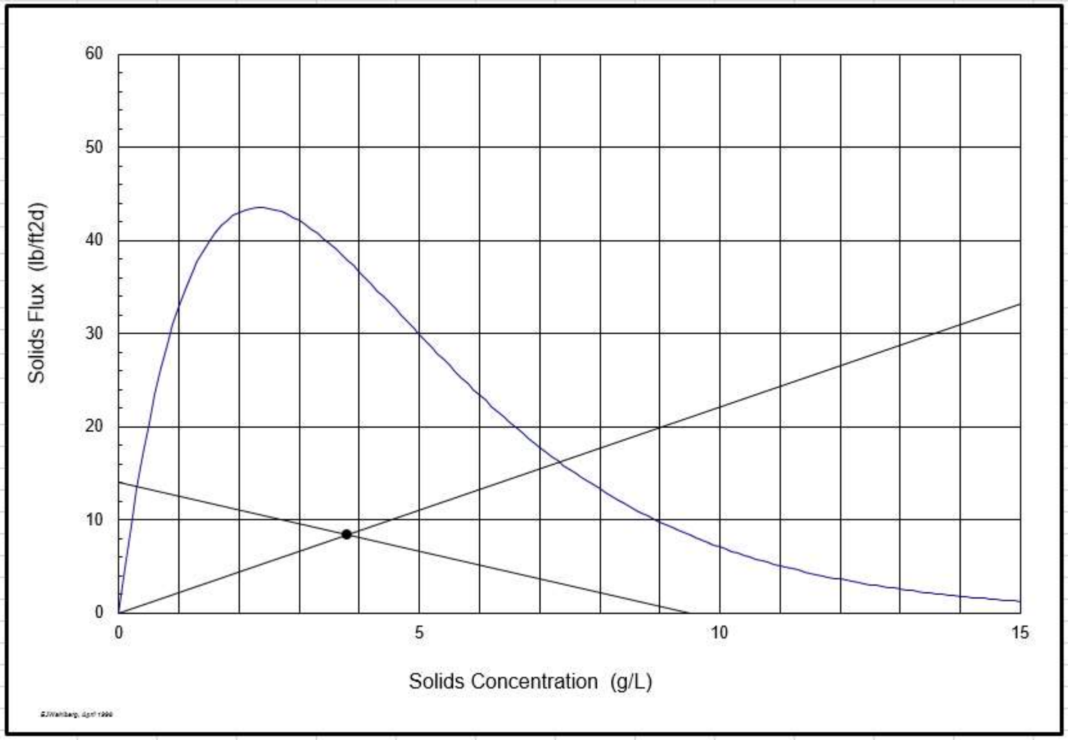
This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	100	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	12	mgd
RAS flow	8	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Cor	Solids Flux (lb/ft2d)
0	0
0.1	4.843265
0.2	9.281622
0.3	13.34046
0.4	17.04375
0.5	20.41412
0.6	23.47295
0.7	26.24038
0.8	28.73542
0.9	30.97603
1	32.97911
1.1	34.76059
1.2	36.33552



Normal flows but higher SVI

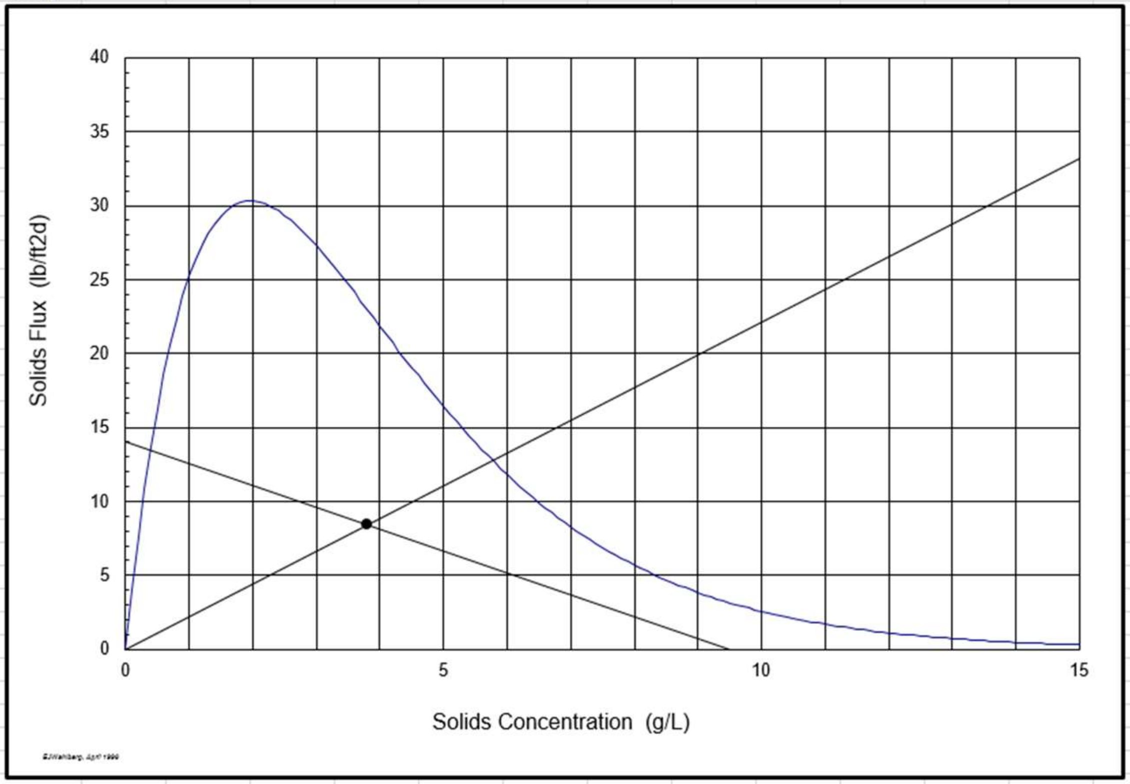
This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	150	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	12	mgd
RAS flow	8	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Co	Solids Flux (lb/ft2d)
0	0
0.1	3.991987
0.2	7.587
0.3	10.81465
0.4	13.70257
0.5	16.27658
0.6	18.56074
0.7	20.57752
0.8	22.34786
0.9	23.89128
1	25.22597
1.1	26.36888
1.2	27.33576
1.3	28.14131



Summary Information

Higher SVI 2x flow rate

This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	150	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	24	mgd
RAS flow	8	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Cor	Solids Flux (lb/ft2d)
0	0
0.1	3.991987
0.2	7.587
0.3	10.81465
0.4	13.70257
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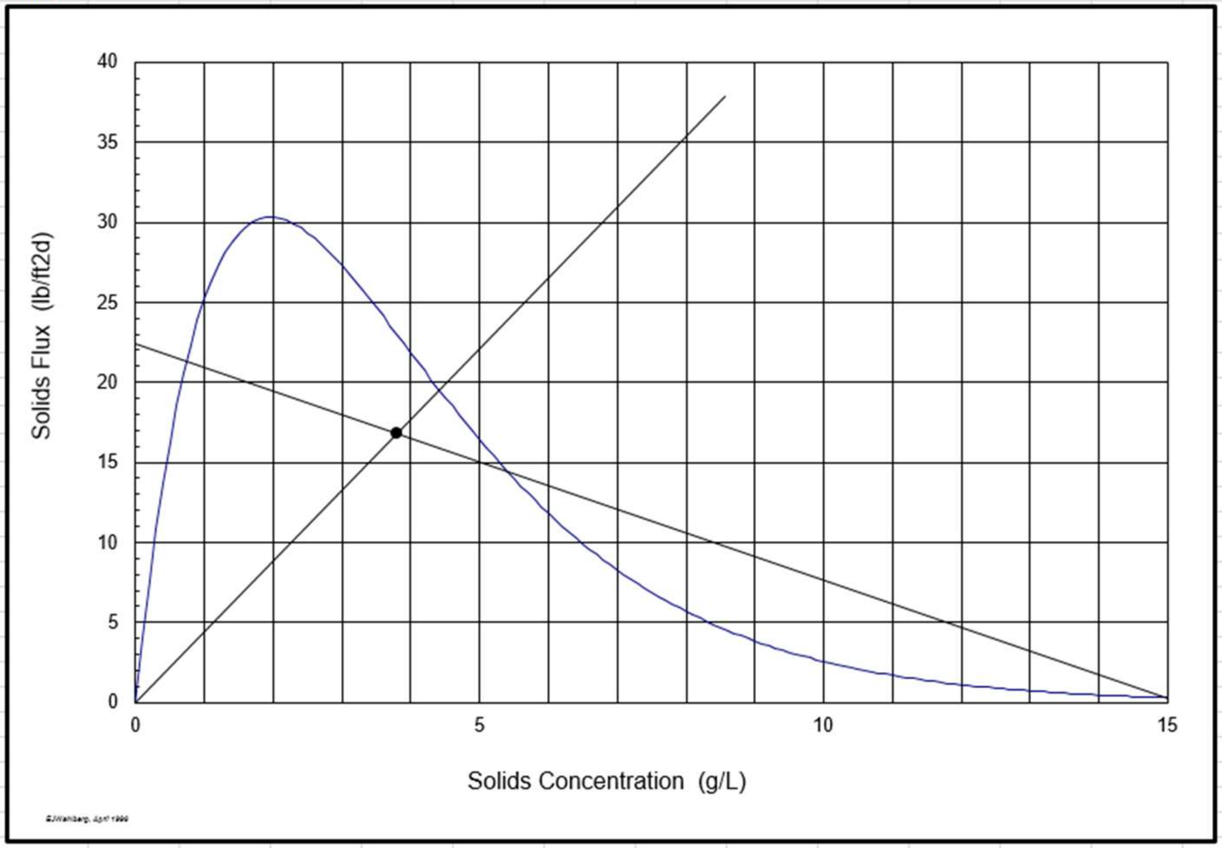


RAS chlorination/knocked down filaments 2x flow rate

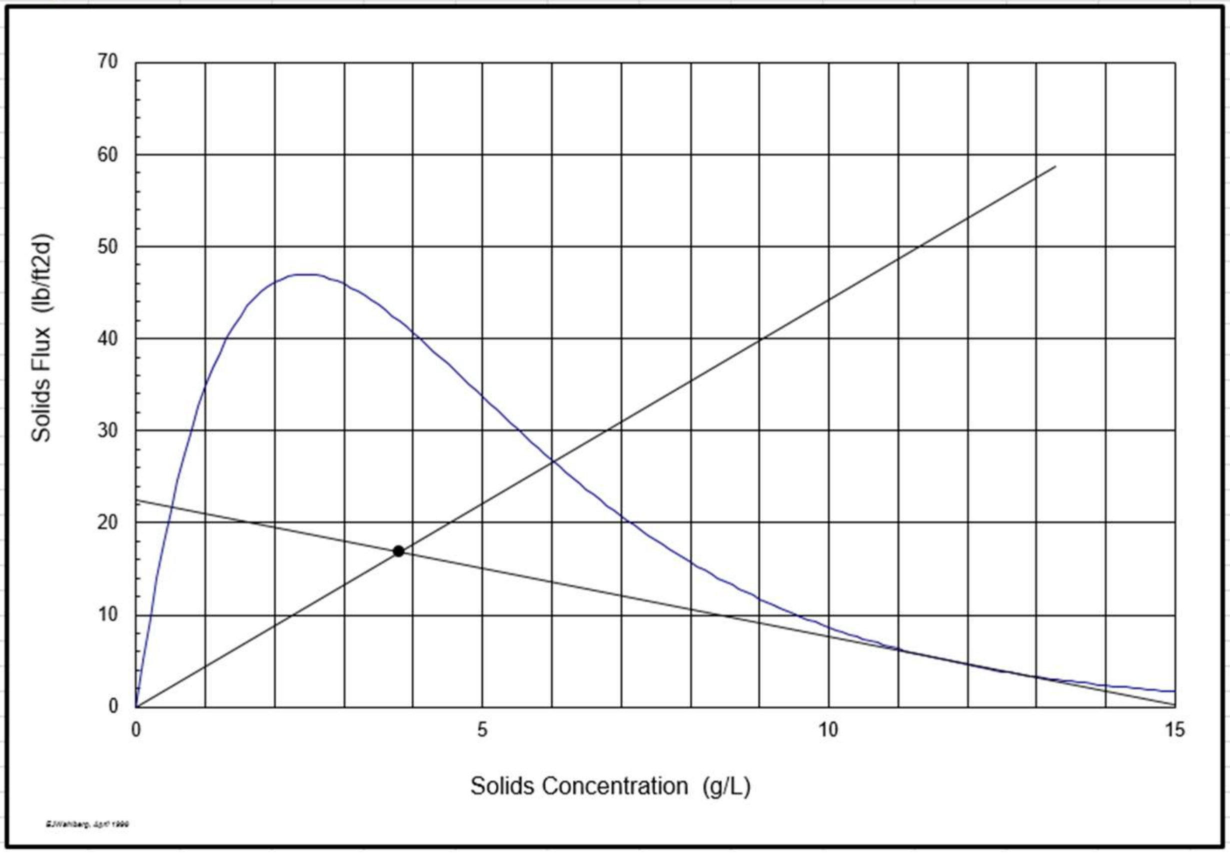
This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	90	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	24	mgd
RAS flow	8	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Co	Solids Flux (lb/ft2d)
0	0
0.1	5.034172
0.2	9.663504
0.3	13.91241
0.4	17.80401
0.5	21.36015
0.6	24.60153
0.7	27.54771
0.8	30.21718
0.9	32.62744
1	34.79502
1.1	36.73553



RAS Adjustment

This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	90	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	24	mgd
RAS flow	12	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Cor	Solids Flux (lb/ft2d)
0	0
0.1	5.034172
0.2	9.663504
0.3	13.91241
0.4	17.80401
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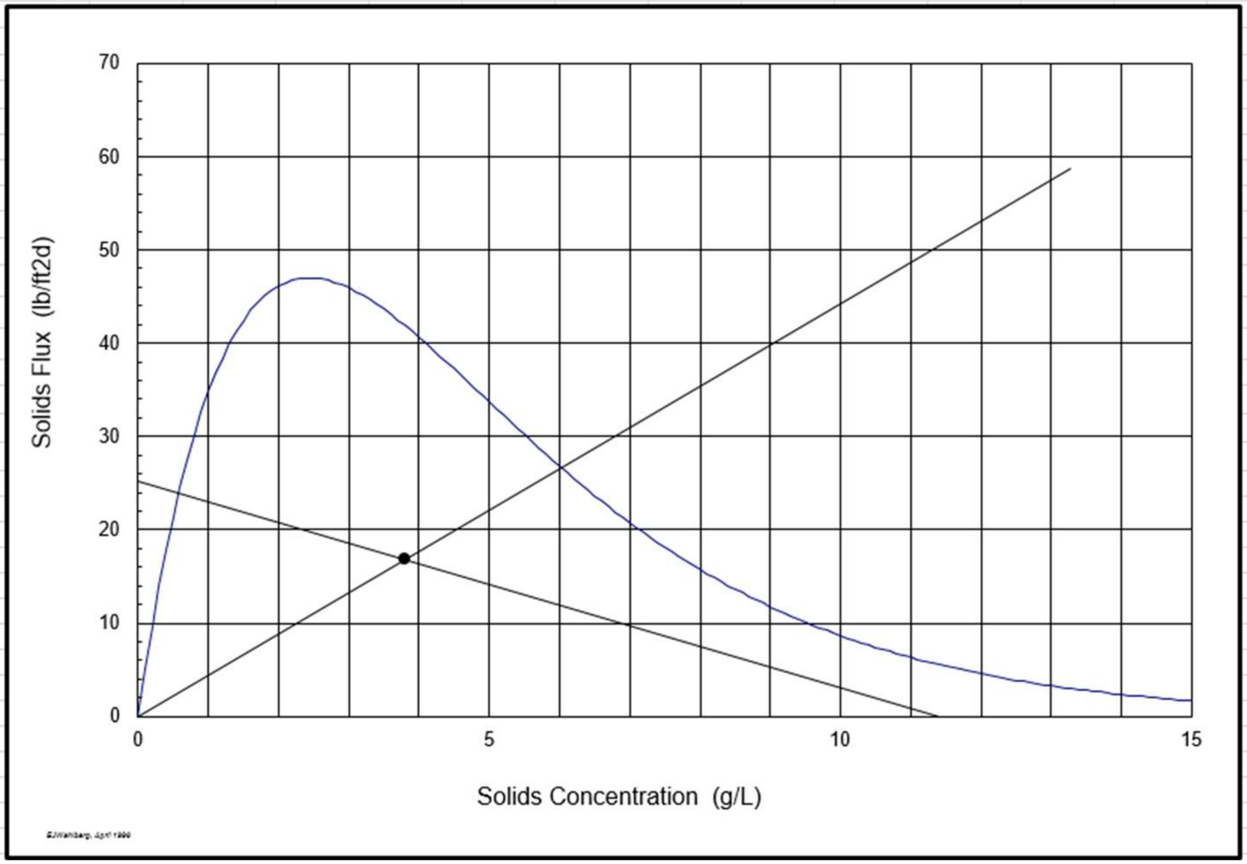


Large Rain Event

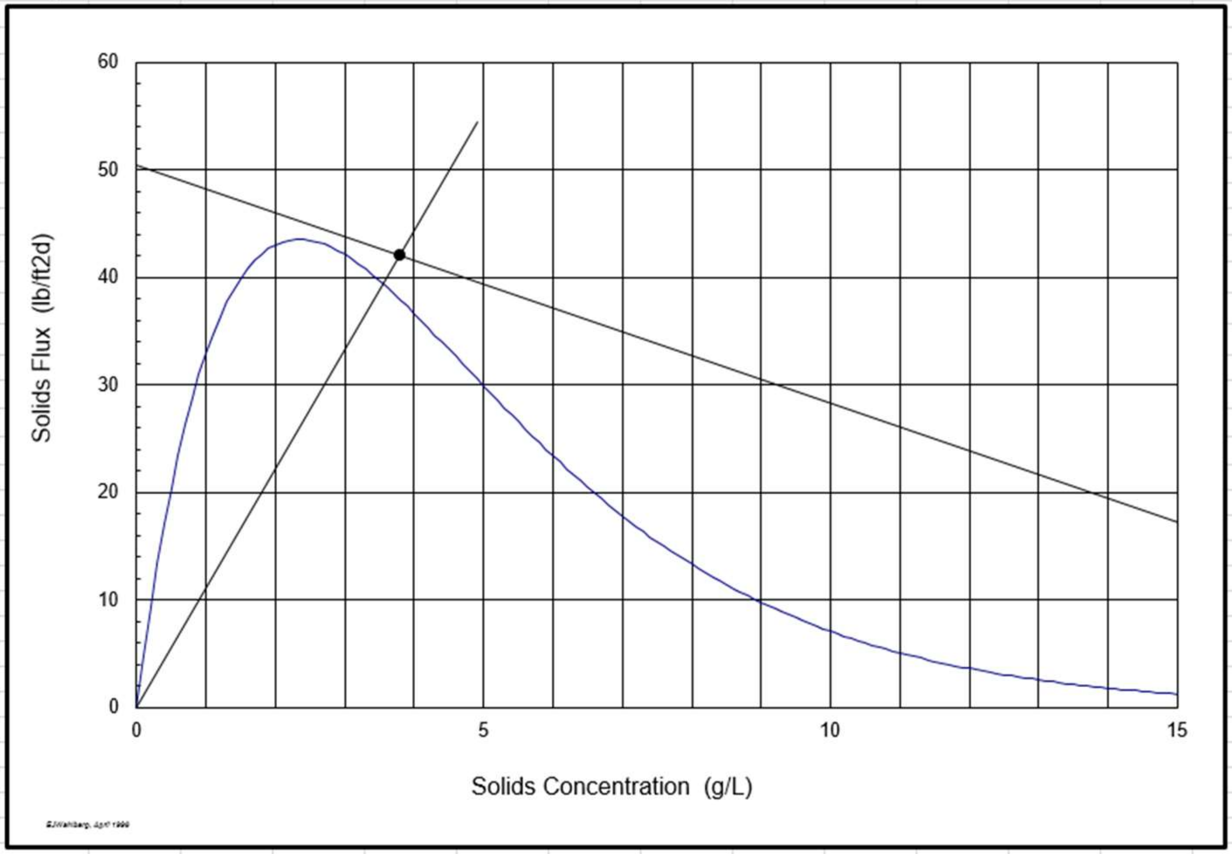
This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	100	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	3.8	g/L
Inf. flow	60	mgd
RAS flow	12	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
Solids Cor	Solids Flux (lb/ft2d)
0	0
0.1	4.843265
0.2	9.281622
0.3	13.34046
0.4	17.04375
0.5	20.41412
0.6	23.47295
0.7	26.24038
0.8	28.73542
0.9	30.97603
1	32.97911
1.1	34.76059
1.2	36.33552



Beware. If only we could run MLSS lower….

This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	100	mL/g
No. of clarifiers	4	
Area of each	11304	ft^2
MLSS	2	g/L
Inf. flow	60	mgd
RAS flow	12	mgd
Alternate inf. flow		mgd
Alternate RAS flow		mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

X	G
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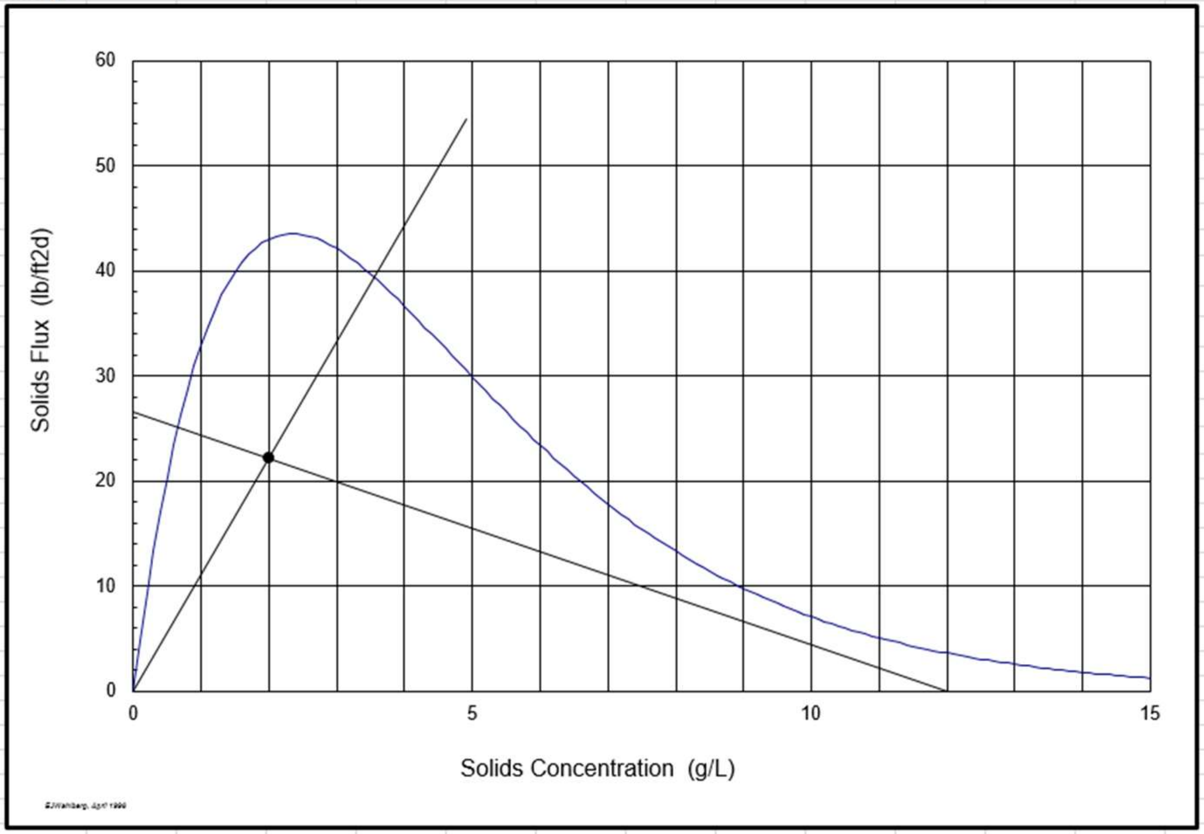

References

- 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?

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