WISCONSIN WASTEWATER
OPERATORS' ASSOCIATION

WWOA

Virtual Operator Training Series

• April 30th	Activated Sludge 9am –Noon
• May 6th	Anaerobic Digestion 9am –Noon
• May 14th 9am –Noon	Collection System Long-Range Planning
• May 21st	WI DNR Updates 11am-1pm
• May 26th	Water Quality Trading 9am – Noon
• June 4th	Submersible Pump O&M 9am – Noon
• June 10th	Biosolids Handling Case Studies 9am – Noon
• June 18th	Process Control 9am - Noon

Webinar Meeting Details

Welcome from the WWOA, thank you for continuing your education with us during these historically unique times.

- Find the chat function, you will need that to answer simple questions designed to confirm that you are still participating.
  - This is necessary to get credits.
- Breaks will be 5 minutes, we will start promptly following each break.
- Questions can be asked through the Q&A feature, we will check in on them periodically.
- A short survey will be included at the conclusion.
  - We need feedback to improve this approach to continued educational opportunities.

Wisconsin Wastewater Operators' Association

Wisconsin Wastewater Operators' Association

WWOA would like to thank our generous sponsors and partners for their support of our mission to provide training and education opportunities for our members and others working in the water and wastewater profession.

2020 WWOA Virtual Operator Training Series

Accessible ~ Affordable ~ Informative

Process Control & Monitoring: What's Really Important
Virtual Operator Training ~ June 18, 2020

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Launch Poll Q1

June 18, 2020

Process Control & Monitoring: What's Really Important

WWOA Virtual Training Series

DONOHUE

Introductions

Nicole Ringle

Wastewater Operations Specialist

Donohue & Associates

Bill Marten

Wastewater Engineer

Donohue & Associates

Nathan Cassity

Wastewater Engineer

Donohue & Associates

Outline

- Preliminary Treatment
- Primary Clarification
- Fixed Film Secondary Treatment

Break

- Activated Sludge Secondary Treatment
- Tertiary Treatment
- Disinfection

Break

- Digestion
- Sludge Thickening / Dewatering

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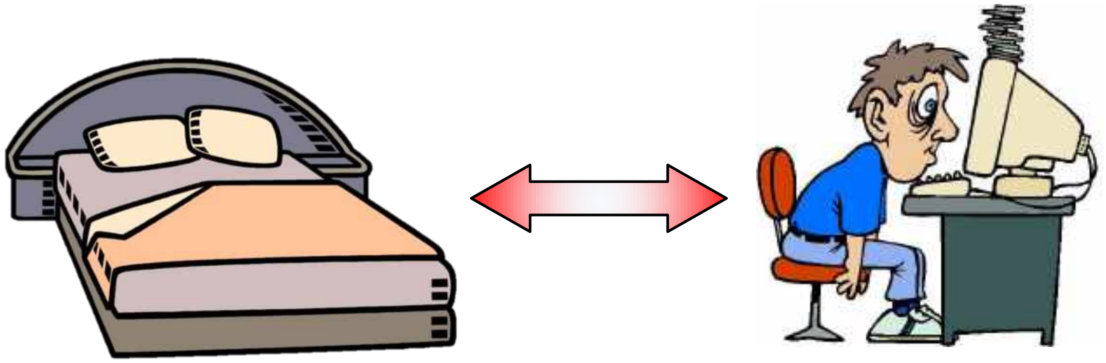
The ABC'S for Successful Process Control

- **A**dopt Control Strategies That Work Best For You
- **B**e Consistent in All Monitoring and Control
- **C**ollect As Much Information As You Can, and Use It to Evaluate Performance, Develop Trend Charts and Historical Records
- **S**hare What You Learn and Experience With Others

Monitoring and Sampling

Sampling Frequency (More = Better)

- Why sample more frequently???
  - To Better Understand Loadings, Their Potential Impacts, and How to Prepare For Them
  - To Better Understand Our Plant Processes – How They're Being Loaded and How They're Performing



What to Monitor & Sample – Liquid Train

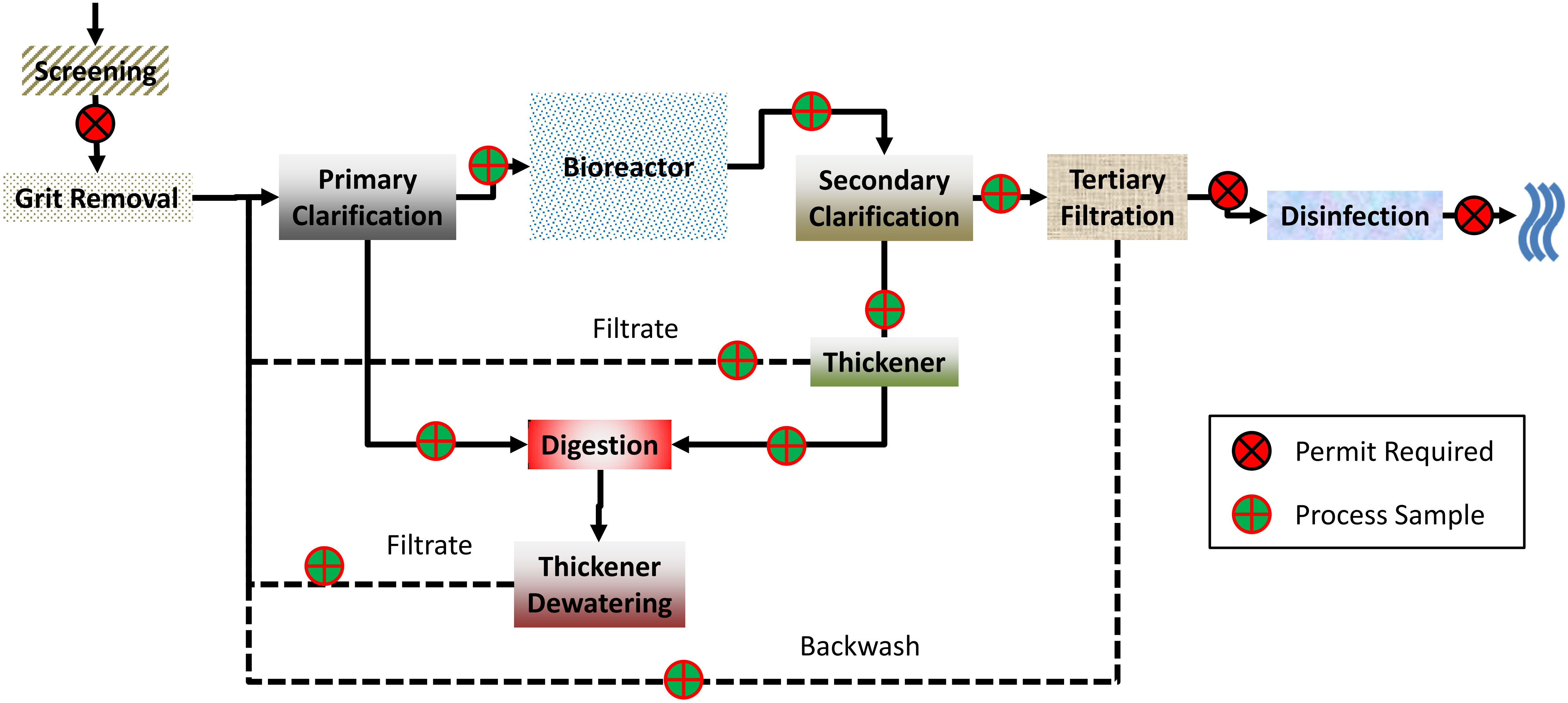
- Flow, BOD, TSS, VSS, TKN, NH_3, TP & SP, pH & alkalinity
  - Influent
  - Primary Effluent
  - Effluent
  - Recycles/Sidestreams
    - Sludge Thickening / Dewatering
    - Filter Backwash
    - Supernatant
    - Tank Draining

What to Monitor & Sample – Solids Train

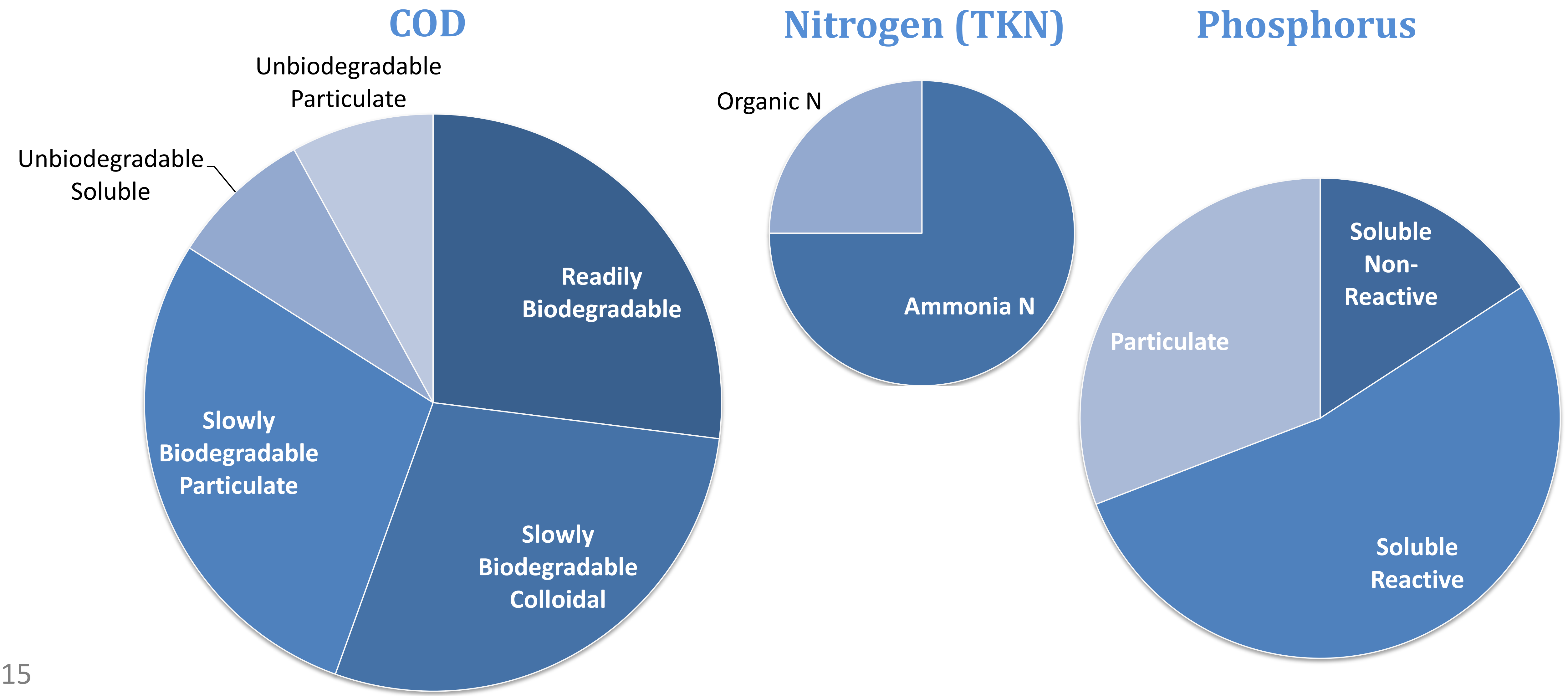
- Sludge Flows, TS, VS
  - Produced From Liquid Treatment Processes
  - Fed to Solids Handling Processes (Thickening, Dewatering)
  - Fed to Stabilization Processes (Digestion)
  - Produced by Solids Handling & Stabilization Processes

- Other Parameters May Also Be of Interest on a Process Specific Basis

Required Sampling vs Process Sampling



Special Sampling (Speciation)



Preliminary Treatment

Influent Pumping

- Lead-Lag – Rotate pump operation
- On-Off Level Control
  - Pumps operate at full speed. Pumps turn on at set high level pump start, turn off at low level pump stop
- Constant Level Control
  - Maintain wet well level with VFDs and level element
- Flow Metering
  - Ensure accurate, reliable
  - Capable of reading full range of flows (minimum flow to peak hour flow)

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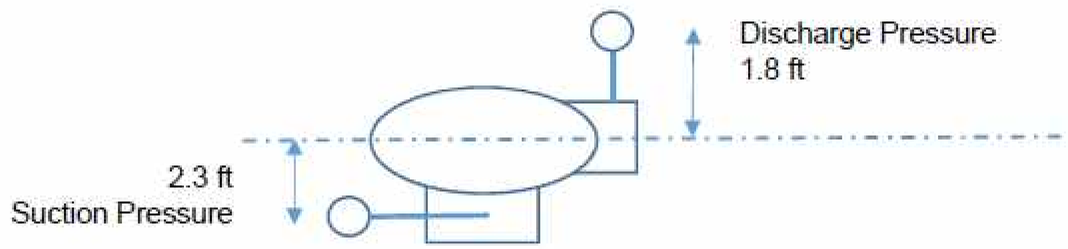
Influent Pumping

- Performance Monitoring
  - Record suction pressure, discharge pressure, pump speed and flow
    - 1.5 psig, 11.2 psig, 100% speed (444 rpm), 22,000 gpm
  - Calculate head (ft)
    - Convert pressures to ft: 1.5 psig->3.5 ft, 11.2 psig->25.9 ft
    - Add or subtract distance from pressure gauge to centerline of pump discharge

      3.5 ft – 2.3 ft = 1.2 ft

      25.9 ft + 1.8 ft = 27.8 ft



    - Subtract suction pressure from discharge pressure to obtain head

      27.8 ft – 1.2 ft = 26.6 ft of head

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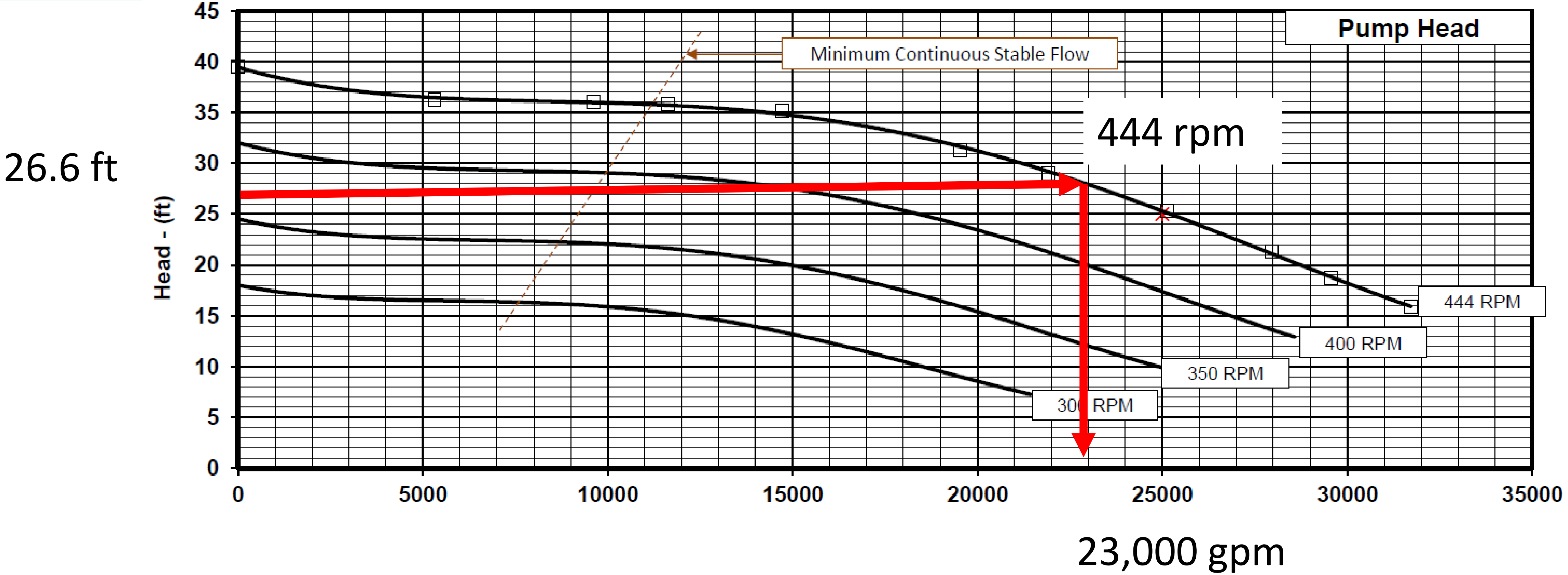
Influent Pumping



- 23,000 gpm field estimated vs 22,000 gpm flow meter reading – Good
- Use results to troubleshoot issues – flow metering, suction issues, pump performance, check valve issues

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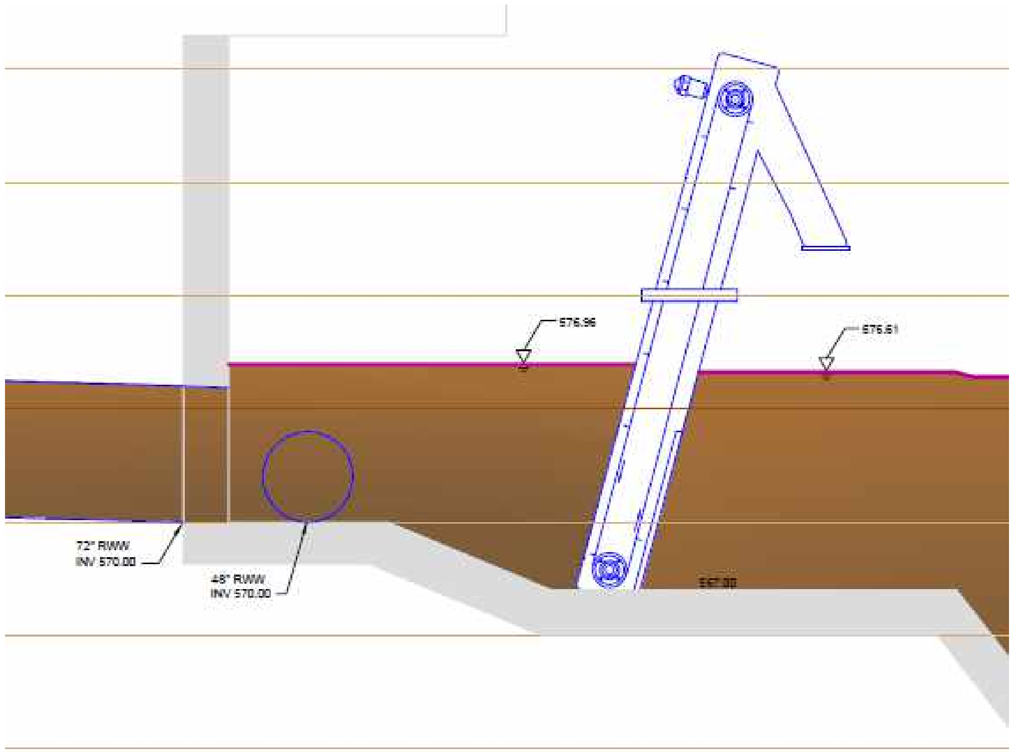
Screening

- Modes of Operation
  - Normal Flow: Operate screen on-off
  - High Flow: Operate screen continuously
  - Speed adjustment also possible
- On-Off Control
  - (1) Cycle time initiated cleaning
  - (2) Level transducer on each side of screen to initiate cleaning based on differential level



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Screening

- Brush or spray bars operate when screen operates
- Keep cleaning cycle time low during dry weather to build screenings mat
- Minimize velocity through the screen to avoid pushing material through openings. Less than 2 ft per second is recommended.
- Control number of screens in-service with automated gates
- Jog reverse available to clear jams

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Screenings Washer-Compactor

- Washer-compactor operates after screens operated for certain amount of time
- Washer-compactor cycle varies by manufacturer and install
- Generally includes washing cycle followed by compaction. Reversing function available to lengthen washing cycle and remove more organics.

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Grit Removal

- Aerated Grit Chambers
  - Airflow control – adjusted to maximize grit removed and minimize organics removed
- Vortex Grit Chambers
  - Only control – number of units in service
  - Mechanisms run continuously
- Grit Settling Basins
  - Constant velocity control
  - Downstream valves throttled to control velocity

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Grit Fluidizing

- Grit Fluidizing Water Control
  - Added prior to pump start up and during pump operation
  - Control to provide sufficient water to avoid plugging, but do not provide too much water to overwhelm grit processing equipment
  - Grit slurry with less than 1% solids best for pumping

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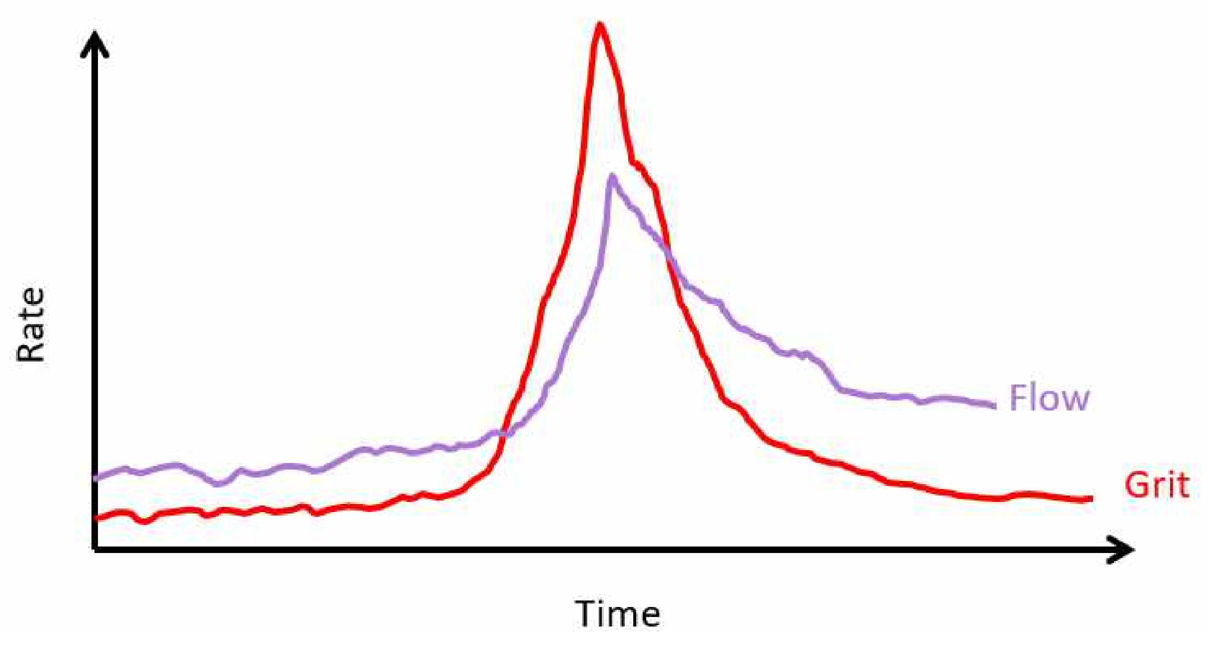
Grit Pumping

- Grit Pumping/Removal Control
  - Intermittent pump operation during normal flows
  - More frequent or continuous pump operation during high flows or starting at flow rise to prepare for first flush events
  - Discharge pressure monitoring to identify pipe plugging and shut down pumps



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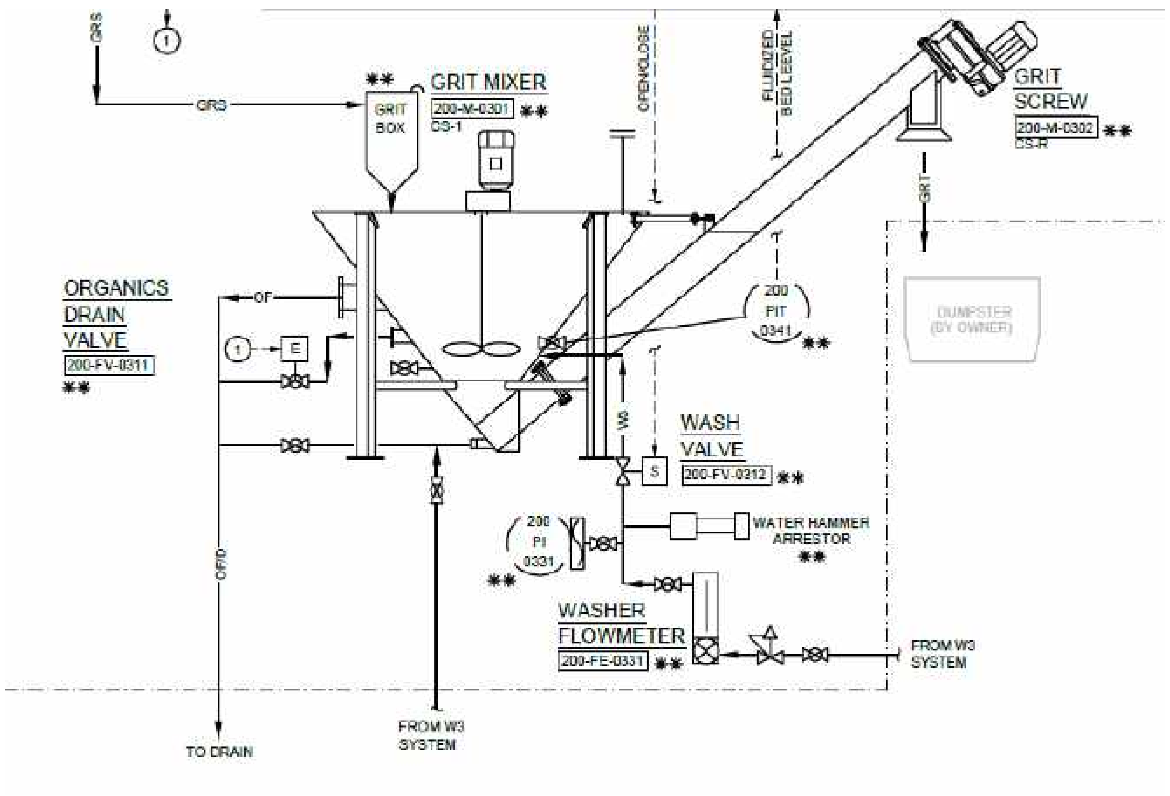
Grit Processing

- Control is vendor specific, systems operate when grit pumps are running
- Washing for organics removal
  - Wash water begins, then mixer runs, both operate as long as pump is running.
  - Organics drain valve operated intermittently
  - Adjust sequence timing to optimize organics removal



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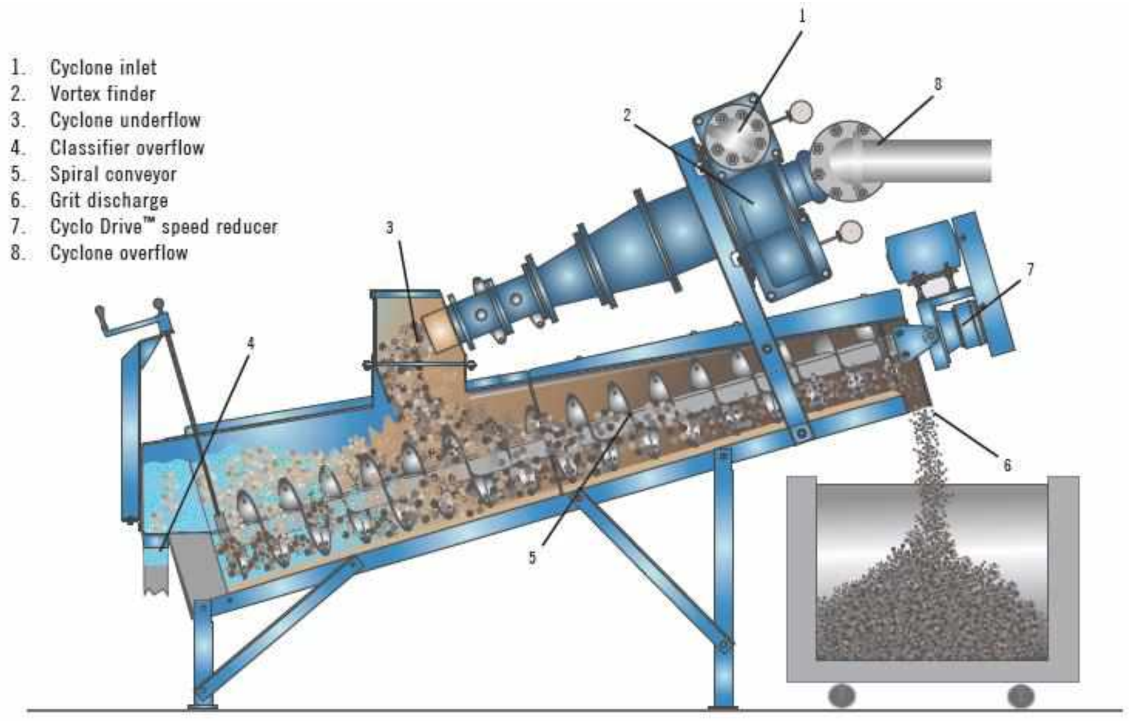
Grit Processing

- Concentrating/cyclone
  - Speed dictates separation of grit from water
- Classification/Dewatering Screw
  - Speed of dewatering screw set to remove grit fast enough, but operate slow enough to provide dewatering



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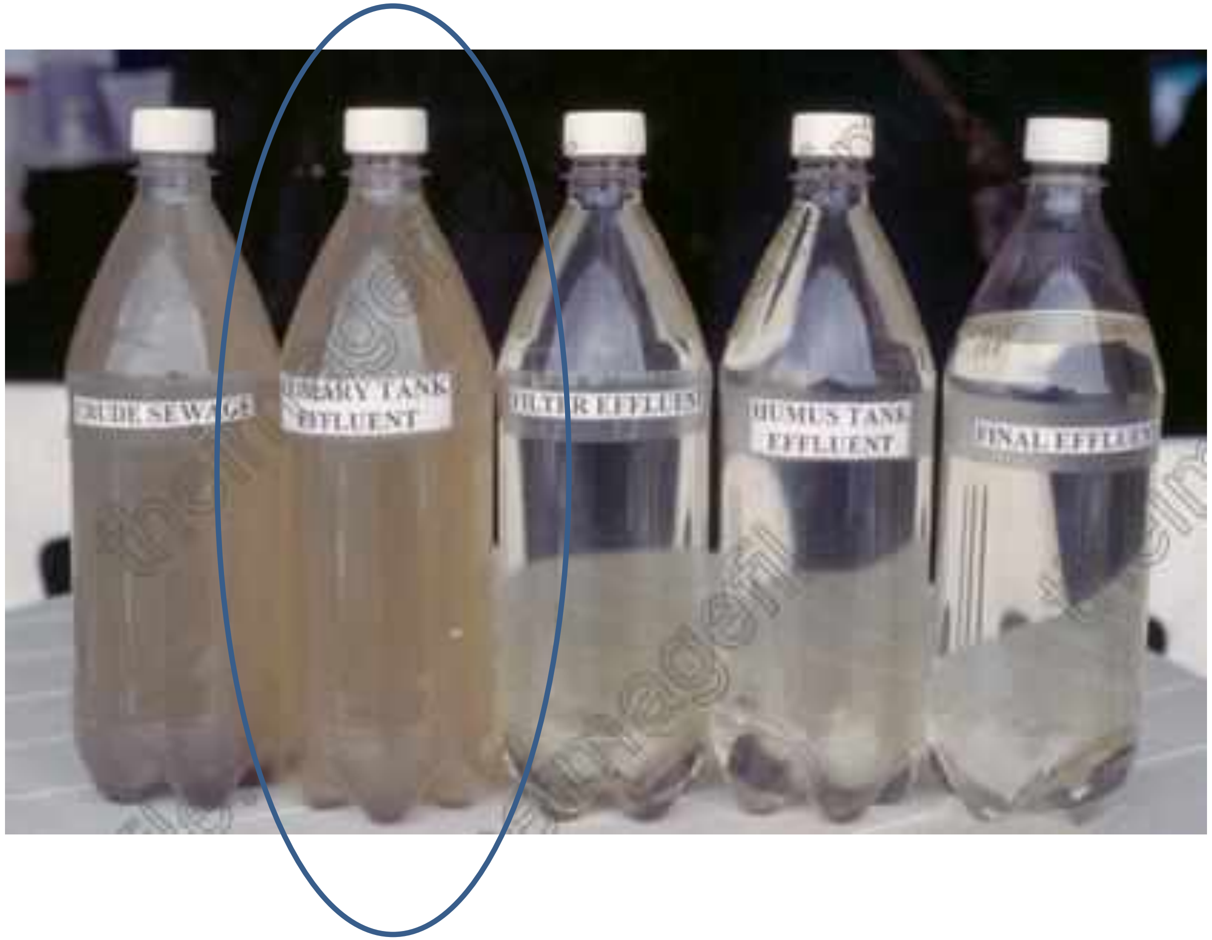
Primary Clarification

Primary Clarification



Primary treatment: removes stuff that already settles

Activated sludge: converts non-settleable to settleable, then settles it out

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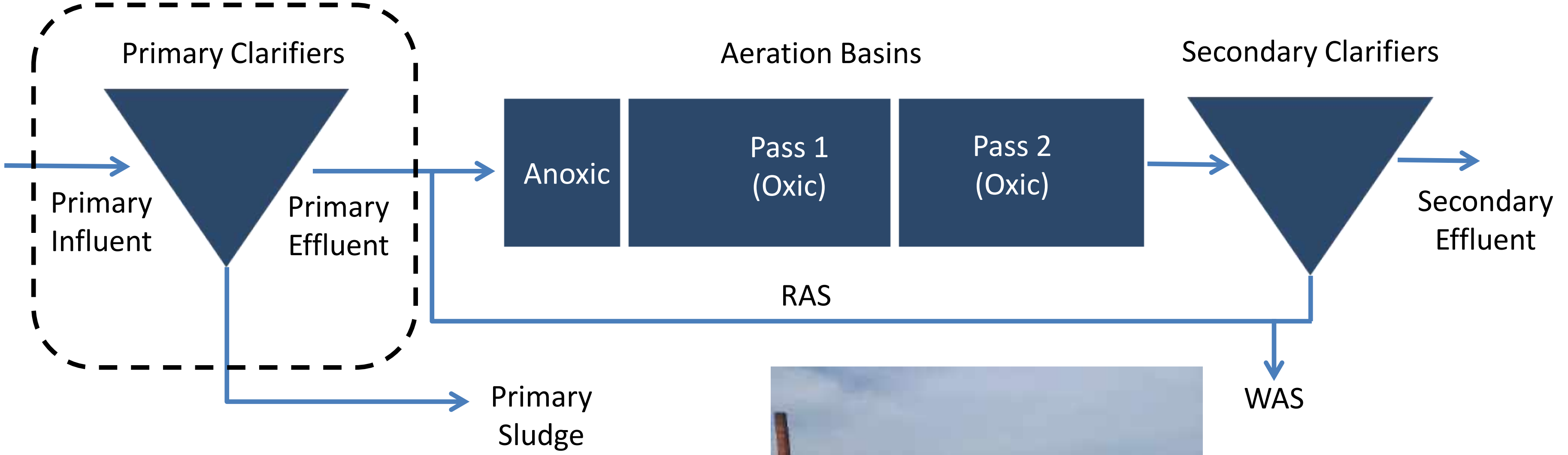
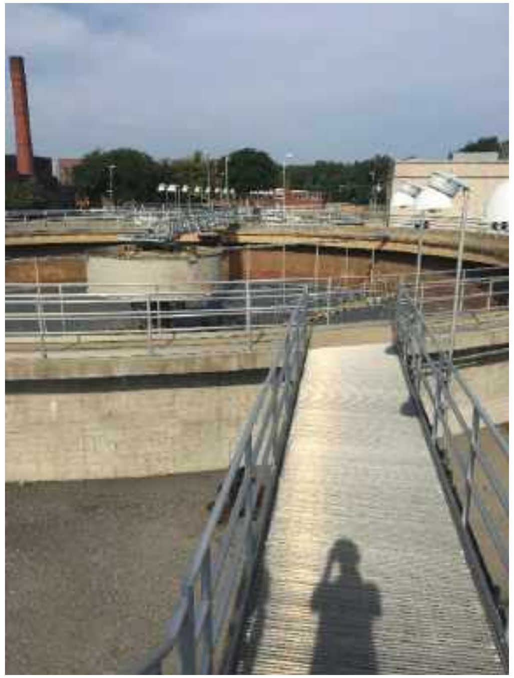
Primary Clarification



1. Remove solids by gravity (low cost).

2. Primary solids have higher volatile concentration and are more easily digested than biological solids.



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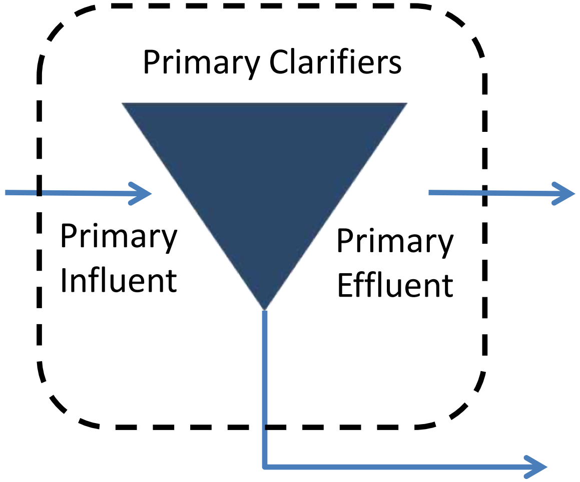
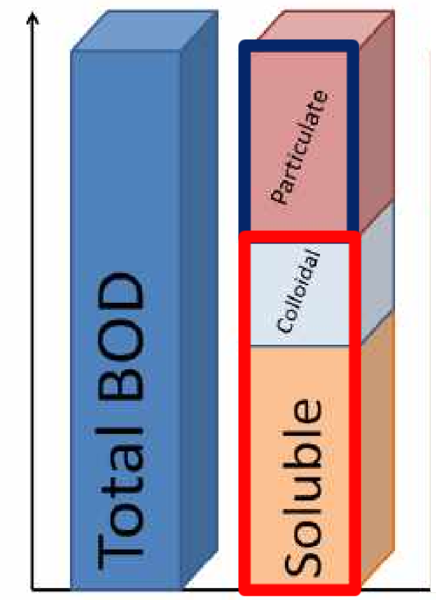
Primary Clarification Performance Measures



1. Surface Overflow Rate
2. Sludge Blanket
3. Hydraulic Capacity
4. BOD/TSS Removal Efficiency



Settles

Passes to Secondary Treatment

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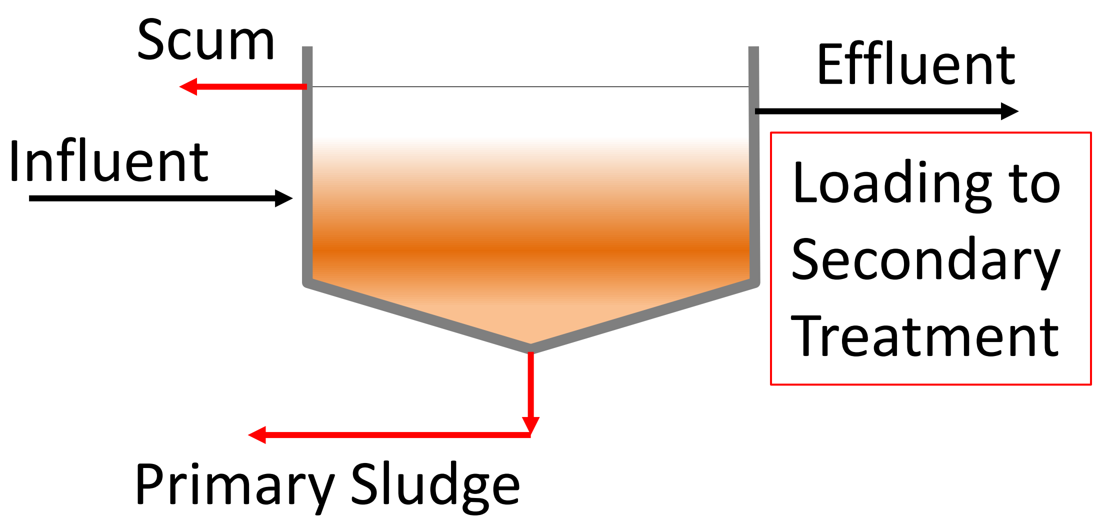
Primary Clarification

- Primary Operation Questions
  - Size and number?
  - What peak flow are they sized for?
  - Keep all in service or place some on-line for peak flows?



Primary Clarification

- Primary Sludge Control
  - Feedback from sludge judge
    - Blanket level goal
    - Similar between clarifiers
  - Pumping schedule
    - Intermittent or continuous
  - Downstream dependency
    - Do you have a thickening process?

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Primary Clarification

- Sludge Blanket Control
  - Down stream EBPR can benefit from VFA production in higher sludge blankets
  - Removals during peak flow can benefit from minimal sludge blankets
  - Prioritize and know your clarifier limitations

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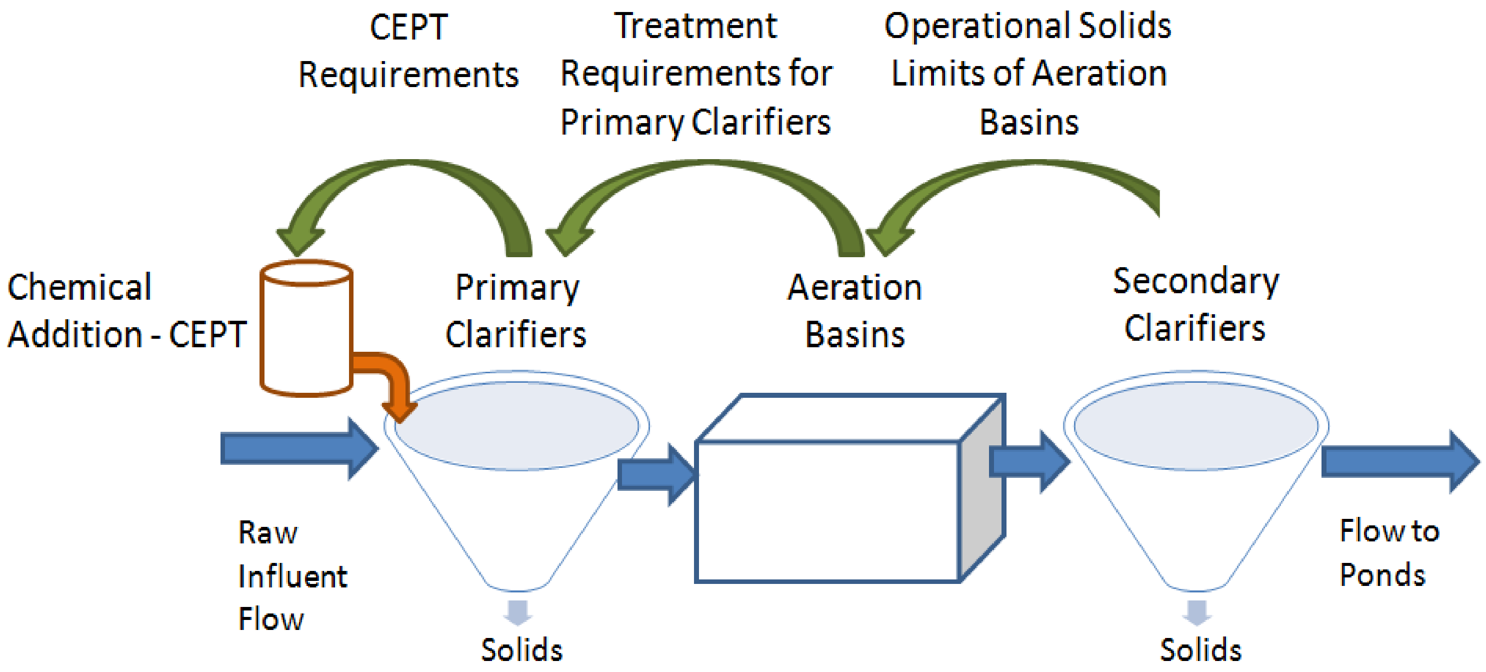
Chemically Enhanced Primary Treatment

- Coagulant dosing upstream of primary clarifiers to enhance removal of BOD, TSS, and phosphorus

Use Chemicals(Ferric Chloride Fe+3, Aluminum (Al+3) and polymer to improve BOD/TSS/P Removal Efficiency

Manage Organic Load to Secondary Treatment

Improve anaerobic digester performance/reduce aeration



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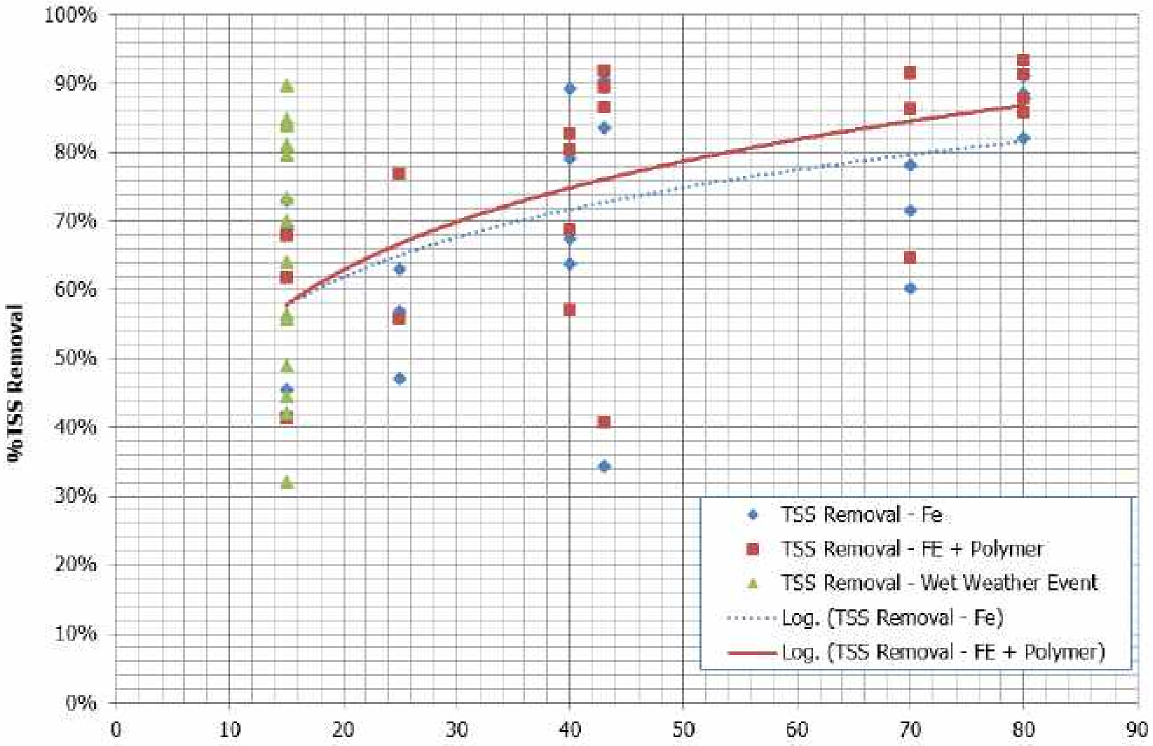
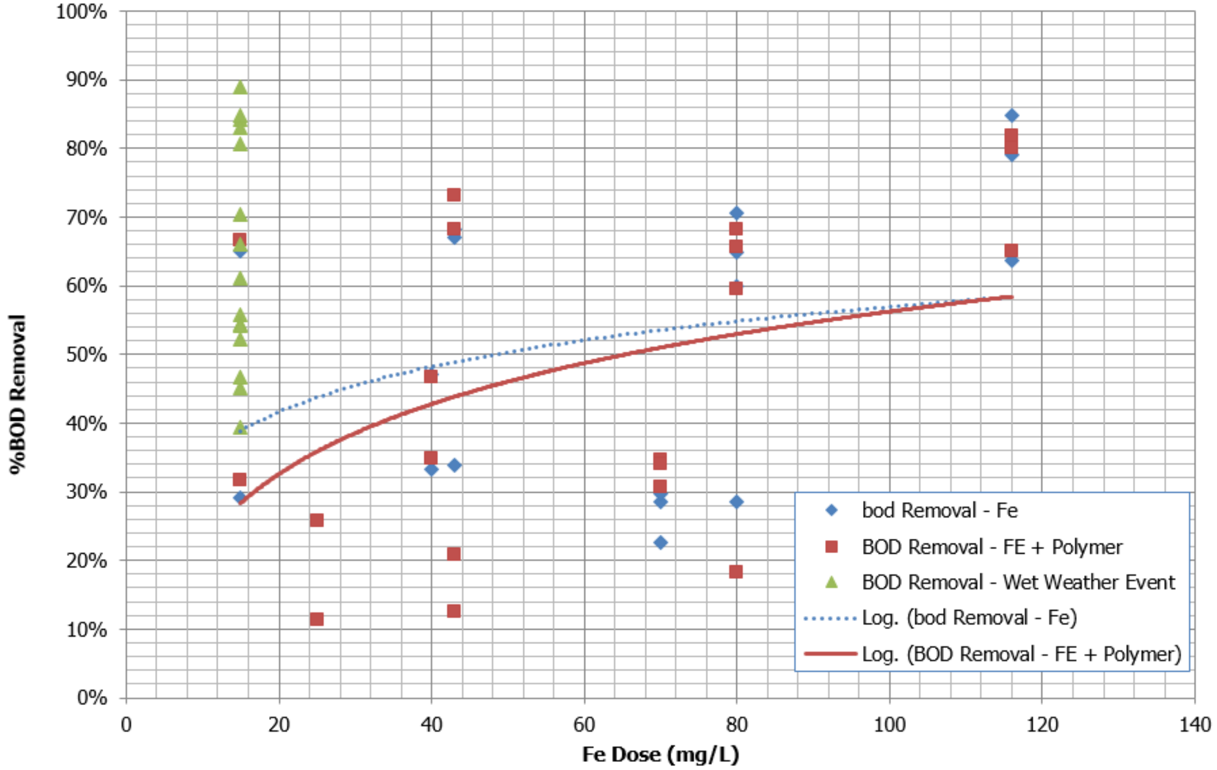
CEPT Doses and Removal Efficiency





Chemicals	Unit cost (€/ton)	Average dose (g/m³)
Alum	175–200	15–45
Polyaluminum chloride (PACl)	250–400	15–40
Calcium hydroxide (lime)	50–80	100–250
Ferric chloride	250–350	30–60
Ferric sulfate	200–280	45–60
Polymer (Polyelectrolyte)		
–cationic	2200–3080	0.1–2.0
–anionic	2000–2300	0.5–3.0

Source: CH2MHill (2009), Metcalf and Eddy (2014), U.S. EPA (2000).

Fort Wayne, IN

- Testing for CEPT
- Impacts of Wet Weather
- Concept to control load to secondary treatment to maximize wet weather capacity
- Concept to manage first flush events in combined sewer system (wet weather events)

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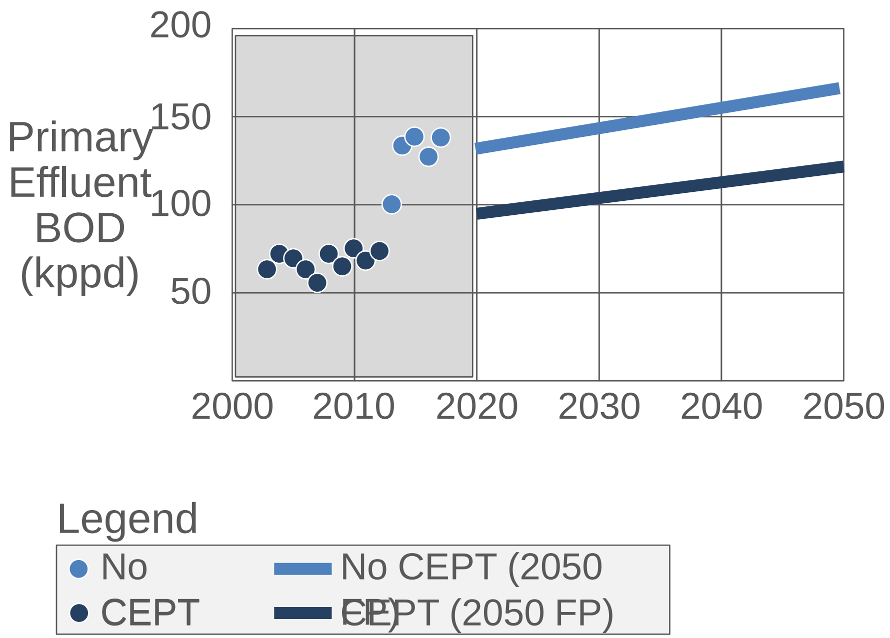
MMSD South Shore Water Reclamation Facility



Used primarily Ferric Chloride for phosphorus removal from 2000 to 2012 (also managed BOD load to secondary treatment). Doses 20 – 30 mg/L as ferric chloride.

Changed to ferrous iron in 2013 and reduced chemical use. Resulted in increased BOD load to secondary treatment.

Future planning based on CEPT and no CEPT conditions. CEPT removal also impacted by influent characteristics.

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Fixed Film Secondary Treatment

Fixed Film Secondary Treatment

- Trickling Filters
- Rotating Biological Contactors (RBC)
- Recirculating Sand Filters
- Biological Aerated Filters (BAF) [not discussed today]

- Solids retention time is based on biofilm layer maintained on media
- Advantage for BOD removal and nitrification (separate)

Trickling Filter Performance and Control

- Performance based on loading rates and design goals
- Low cost soluble BOD removal
- Some nitrification (particular with 2-stage systems, depending on temperature and air flow)
- Trickling Filter Recycle
  - Maintain wetted surface area (wetting rate)
  - Achieve pollutant reduction goals
  - Manage recycle energy

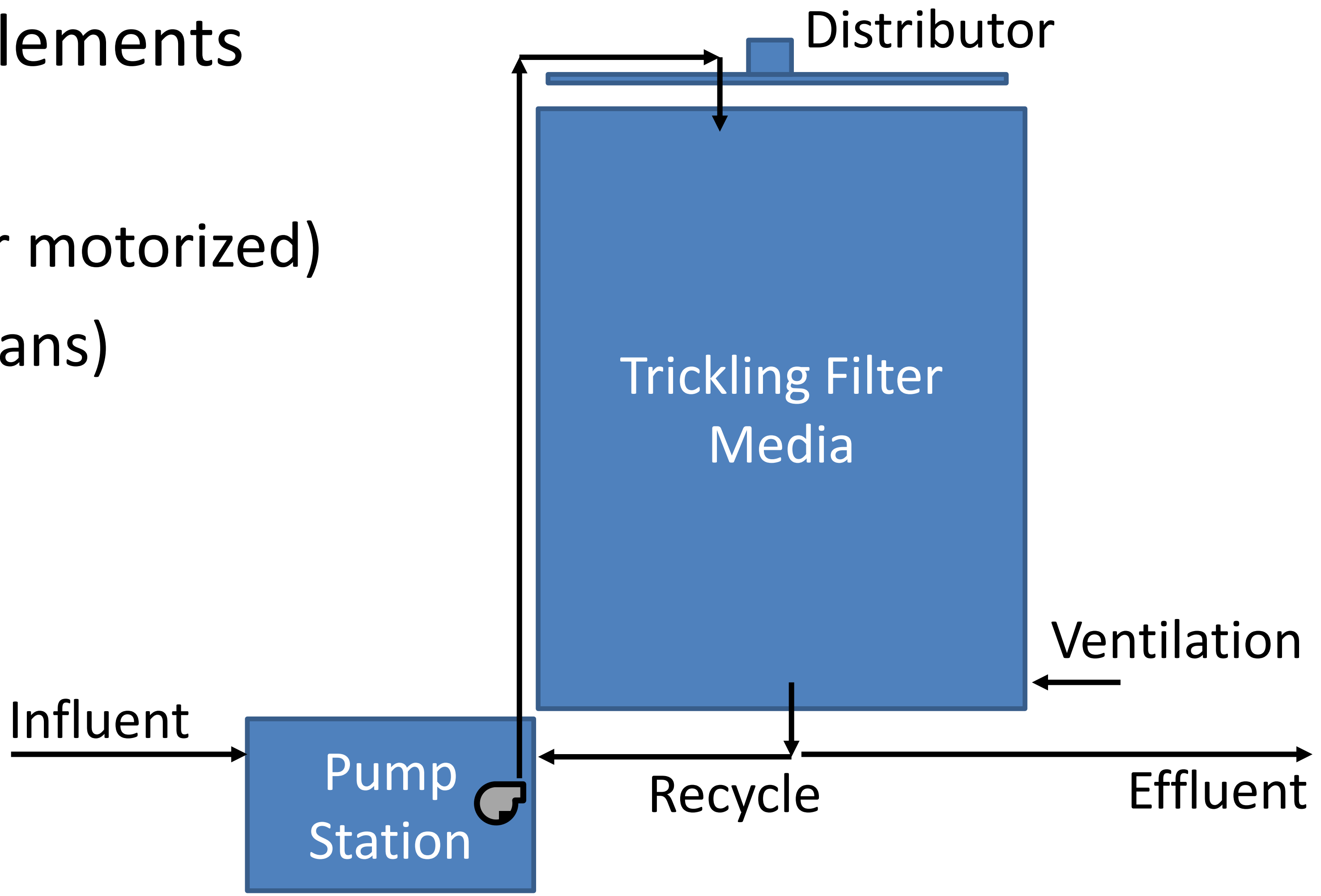
TABLE 1 BOD_5 REMOVAL RATES FOR VARIOUS FILTER TYPES

Filter Type	BOD_5 Removal (%)
Low Rate	80 - 90
Intermediate Rate	50 - 70
High Rate	65 - 85
Roughing Filter	40 - 65

Source: Environmental Engineers Handbook, 1997.

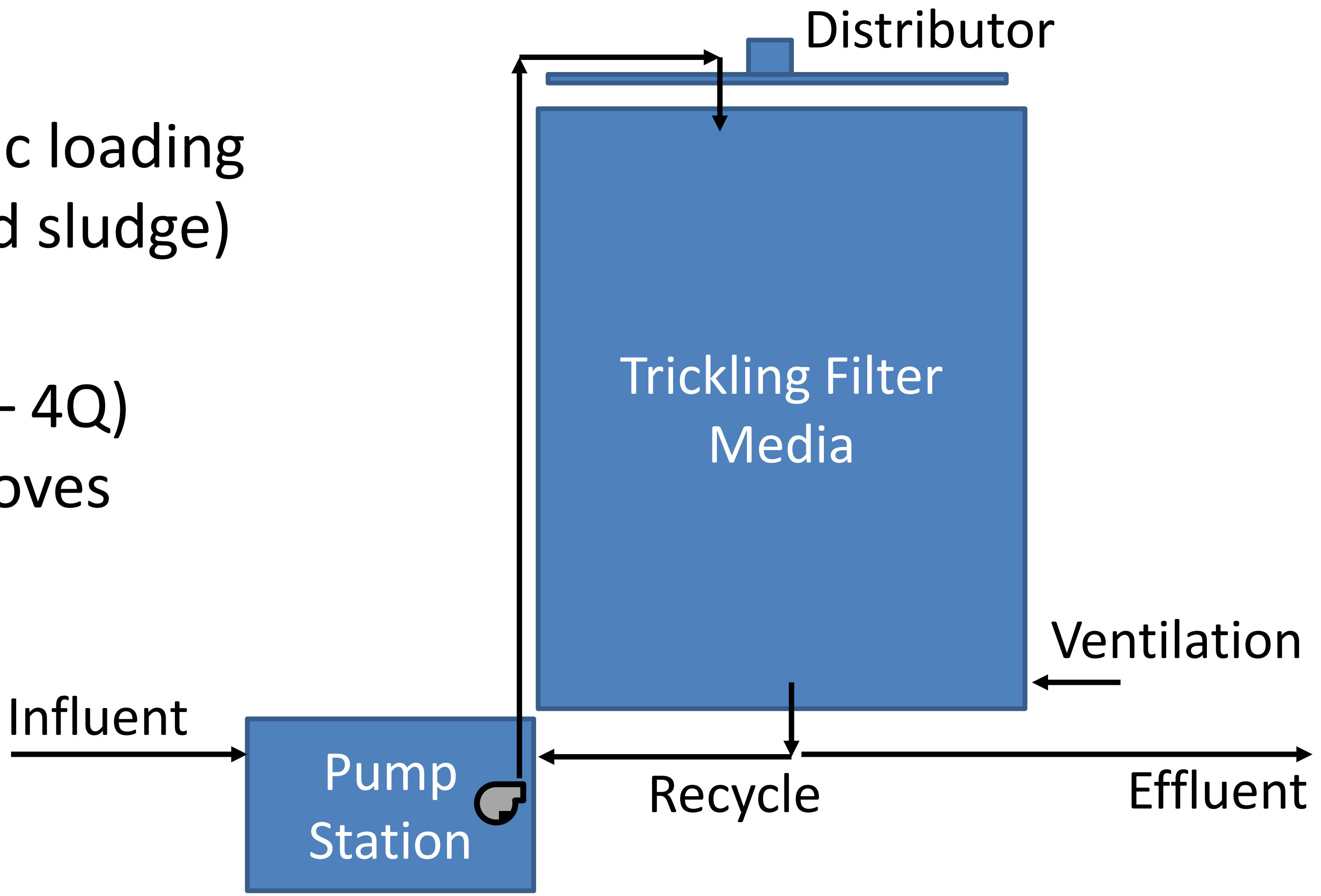
Fixed Film Secondary Treatment

- Trickling Filter Control Elements
  - Pump station
  - Distributor (hydraulic or motorized)
  - Ventilation (passive or fans)



Fixed Film Secondary Treatment

- Trickling Filters
  - Understand your organic loading rate (similar to activated sludge) lbsBOD/1000cuft/day
  - Recirculation Rate (1Q – 4Q) increases contact, improves wetting and sloughing



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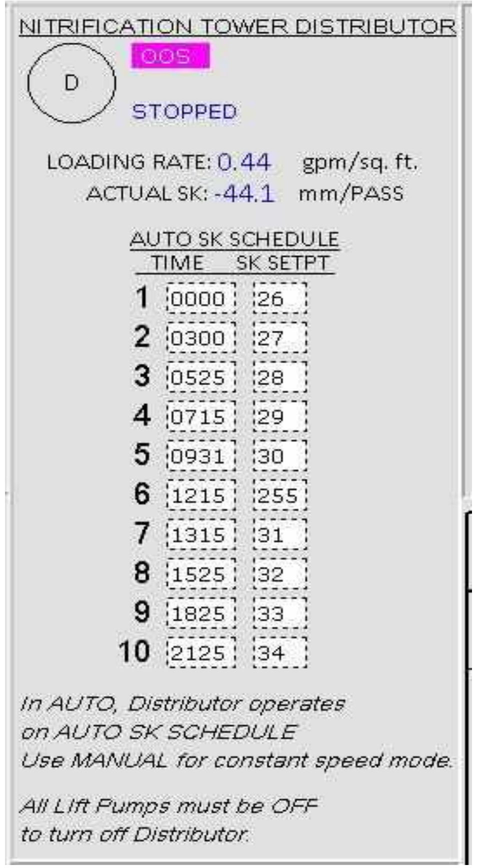
Nitrification Towers

- Designed for ammonia removal
- Flushing Intensity (SK Value)
- Sturgis, MI Nitrification Tower
  - Operator enters SK values throughout day
  - Include flushing period
  - Arm speed is adjusted to maintain SK value based on influent flow



Nitrification Tower Distribution Arm - The nitrification tower distribution system control is based on a flushing intensity (SK) calculation.

The flushing intensity (SK) calculation is:

$$SK\left(\frac{mm}{pass\ of\ arm}\right) = \frac{\frac{mg}{d} * \frac{1{,}000{,}000\ gal}{mg} * \frac{d}{1{,}440\ min} * \frac{1}{2{,}462\ sf} * \frac{\frac{m3}{m2-hr}}{0.41\frac{g}{sf-min}} * \frac{1{,}000\ mm}{m}}{4\ arms * \frac{0.1\ rounds}{min} * \frac{60\ min}{hr}}$$

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Fixed Film Secondary Treatment

- Rotating Biological Contactors
  - Old designs give these a bad reputation
  - Keep organic loading rate low and aerate for reliability
  - Advantageous for second stage nitrification

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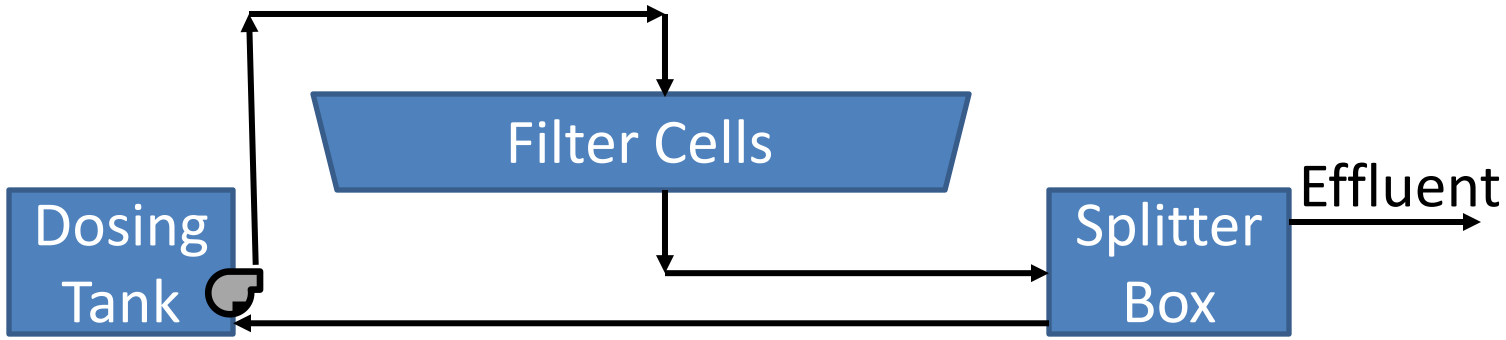
Fixed Film Secondary Treatment

- Recirculating Sand Filters
  - Can treat BOD, TSS, and nitrify (limited)
  - Only mechanical equipment is pumping system in dosing tank
  - Typically pump often with short duration
  - Recirculation rate similar to trickling filter
  - Manual maintenance of bed is required



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Chat
Answer the following:

Are you missing baseball this year?

5 Minute Break

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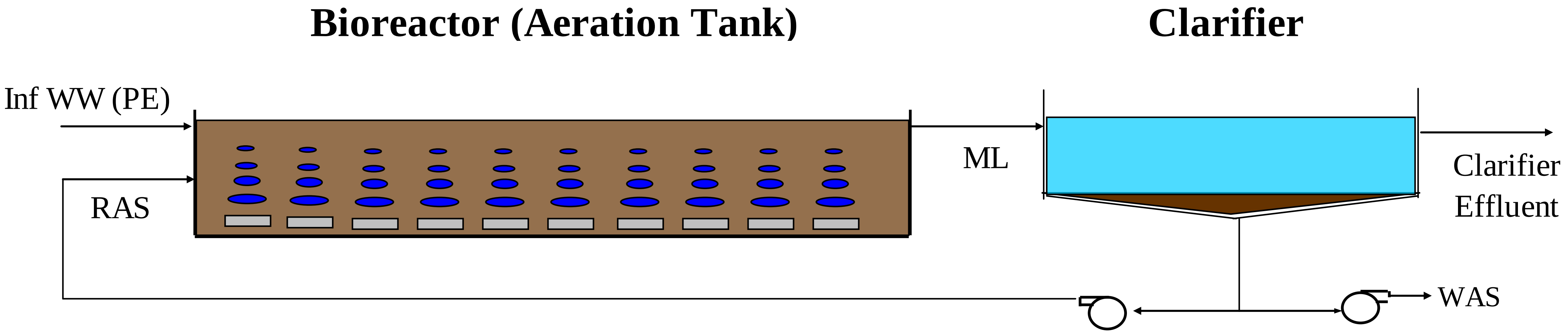
Activated Sludge

Activated Sludge Secondary Treatment

Biological Treatment Involving Two Key Process Components Intertwined



- Key Process Difference – Solids Recycle as Return Activated Sludge (RAS)

Activated Sludge Process Control

- Complex Process – Many Considerations
  - Basic Secondary Treatment
  - Advanced Biological Treatment (Often Involving "Selectors")
- Either way, to "successfully" control the process you've got to understand it and effectively monitor it.

Most of focus will be on Bioreactors, but we'll also discuss Clarifiers.

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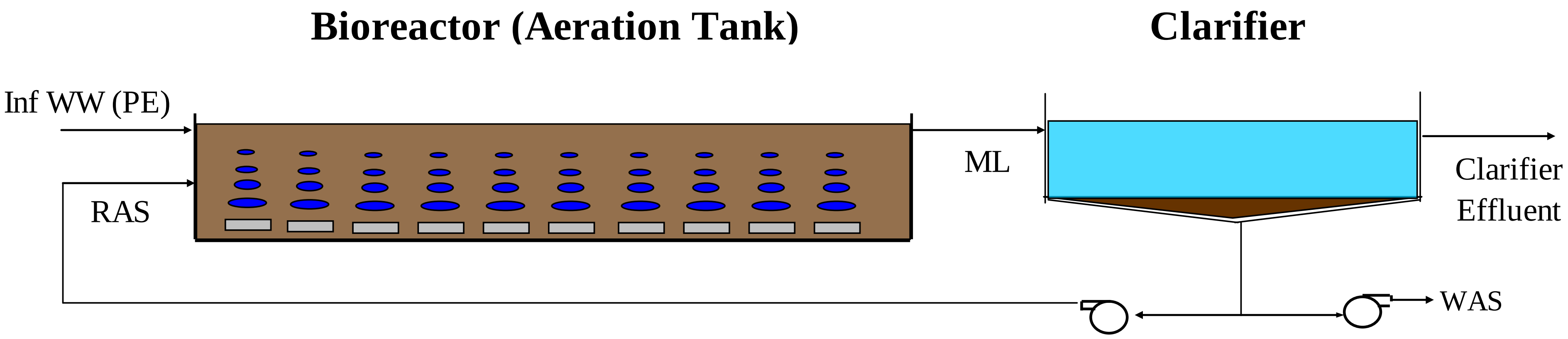
A Few Keys to Successful Operations

- Monitor the System
- Control the System
- Keep Good Records
- Communicate/Network
- Make Use of Resources Available

Effective Monitoring is Critical

- What's Coming In & Going Out
  - (Q, BOD, TSS, TKN, NH3-N, TP, SP)
- What's Going On In System
  - (DO, MLSS/MLVSS, Blankets, Settleability, RAS Q, WAS Q, RAS & WAS TSS, Microscopic Examination, Tank Appearance)



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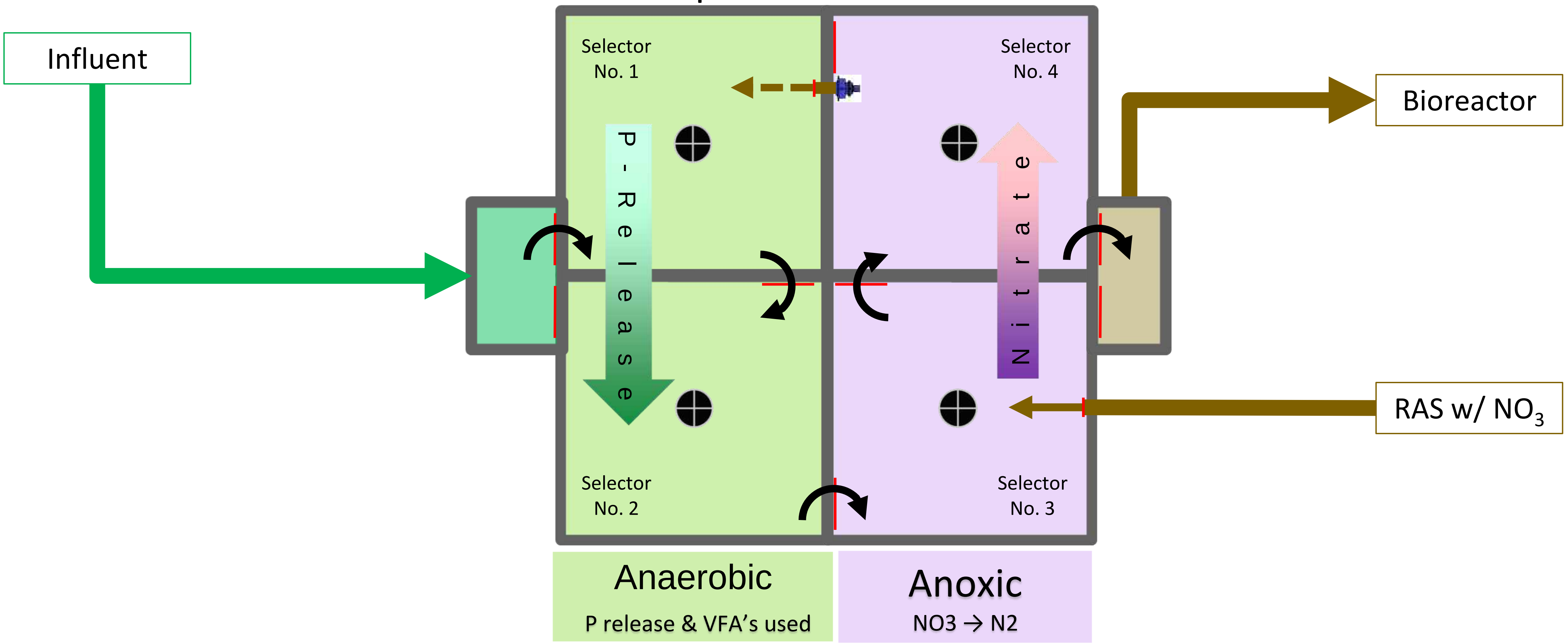
Selectors/BNR Monitoring Considerations

Example: MUCT' Process



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Process “Control” Success Involves

- Achieving Appropriate Loading Rates
- Providing and Maintaining Proper Environmental Conditions
- Controlling Population Dynamics

We as operators must control these to the extent we can, to achieve process success.

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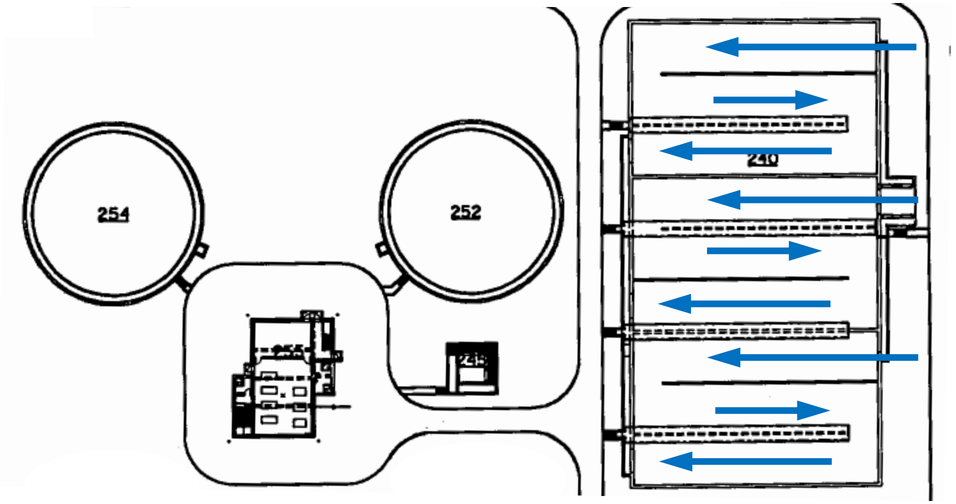
Achieving Appropriate Loading Rates

We often think this is a "design" function, we're given tankage and equipment and need to make it work…but we do have some control ability such as making use of provided flexibility:

- Controlling Tankage Volume in Service
  - e.g., Summer vs Winter
- Adjusting Flow Configurations of That Tankage
  - e.g., Step Feed (particularly for high flows)
- Controlling Mechanical Equipment
  - e.g., Making Use of Variable Speed Pumping – Flow Pacing RAS Pumping



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Achieving Appropriate Loading Rates

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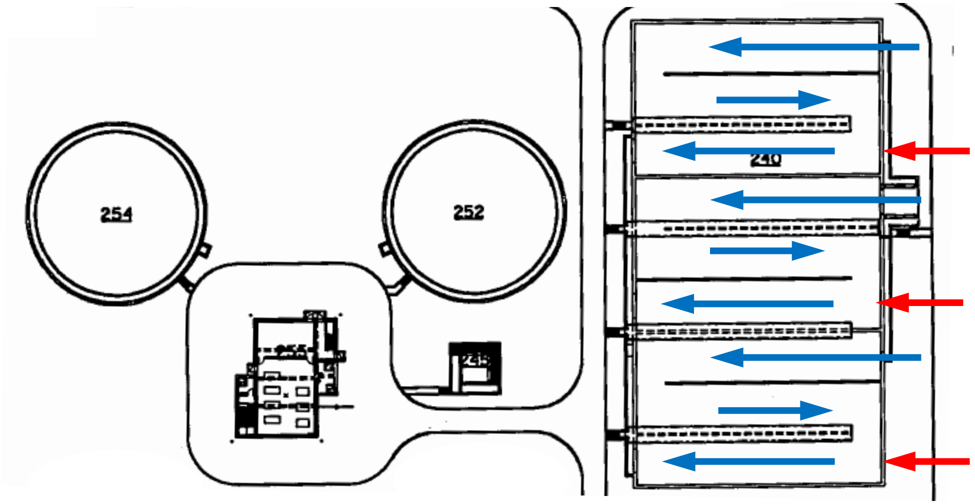

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Providing and Maintaining Proper Environmental Conditions

The ones we typically can control include:

- Dissolved Oxygen (DO)
- pH/Alkalinity
- Adequate Nutrients
- Biomass Available For Treatment
    - Based in part on process goals
    - Inter-related with Controlling Population Dynamics

Aeration Control/Monitoring

- Dissolved Oxygen Monitoring a Must
  - Target 1.5-2 mg/L Near End of Basins
  - Typically Measure ~ 3/4 Length Down the Basin
- Air Supply Control Options
  - Direct Control of Blowers/Mechanical Aerators
  - Indirect Control for Diffused Air Systems
    - Multiple Parallel Aeration Basins
    - Blowers Controlled on Pressure
    - Air Flow to Basins Metered & Controlled by Flow Control Valves (Butterfly Valves)

Common D.O. Control Strategy

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Potential Consequences of Inadequate Aeration

- Undershooting
  - Incomplete Nitrification
  - Filamentous Organisms
  - Insufficient Mixing
  - Diffuser Fouling
- Overshooting
  - Excessive Energy Usage
  - Excessive Turbulence/Shear of Flocs

pH/Alkalinity

- Biological System Requiring ~ Neutral pH (6.8-8.0)
- Alkalinity Buffers Against Changes in pH, With Key Factors
  - Source of Water Supply (Surface Water, Groundwater)
  - Nitrification (7.46 mg alkalinity consumed for each mg N nitrified)
  - Sometimes In-Plant Chemical Use (P Removal)
  - Sometimes Industries Can Have an Impact on pH
- Potential Consequences
  - Treatment Issues (incomplete nitrification, microbial challenges)
  - Effluent pH Violations

Supplemental Alkalinity May Be Required

- Desire 75-100 mg/L Residual Alkalinity in Sec Eff
  - pH Control Often Used
- Lots of Potential Sources
  - Lime, MagLime, Caustic most common
  - Sodium/Calcium Carbonate or Bicarbonate
  - Sodium Aluminate as a P Removal Alternative

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Supplemental Alkalinity May Be Required

- Lots of Potential Sources
  - Lime, MagLime, Caustic most common
  - Sodium/Calcium Carbonate or Bicarbonate
  - Sodium Aluminate as a P Removal Alternative
  - Anoxic Selectors Upstream of Aeration – 3.57 mg alkalinity produced per mg N denitrified

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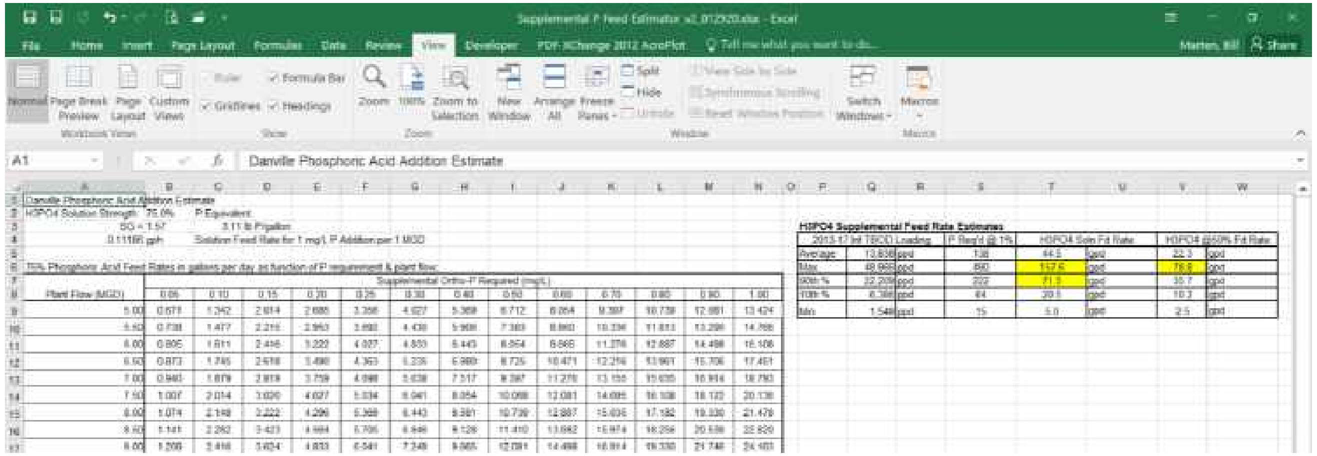
Adequate Nutrients Needed

- Nitrogen & Phosphorus
  - P Deficiency Most Common
  - Industrial Impacts
  - In-Plant Chem Feed
- Other Essential "Nutrients"
  - DO
  - Food
  - Micronutrients



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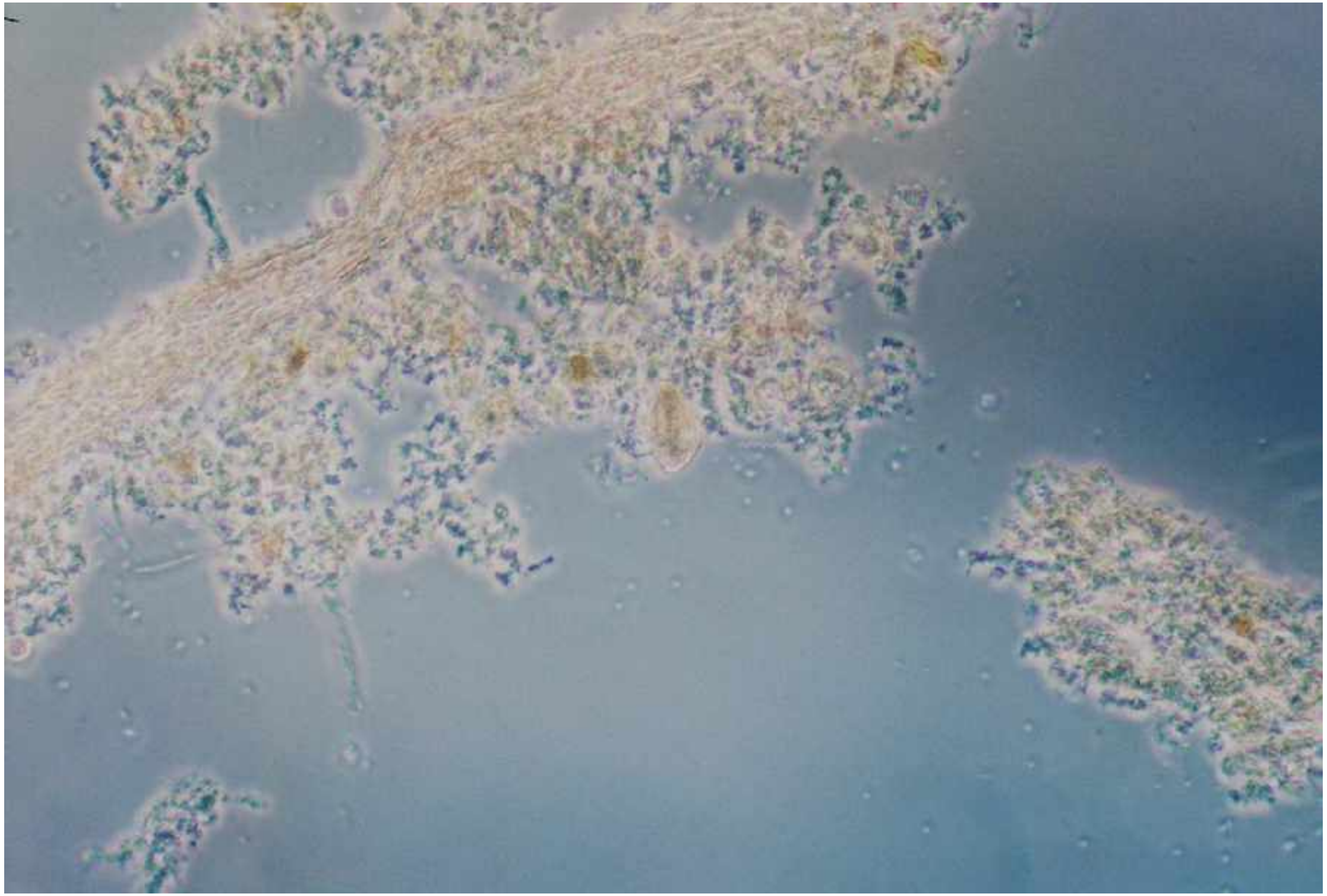
No Evidence of Filamentous Bulking



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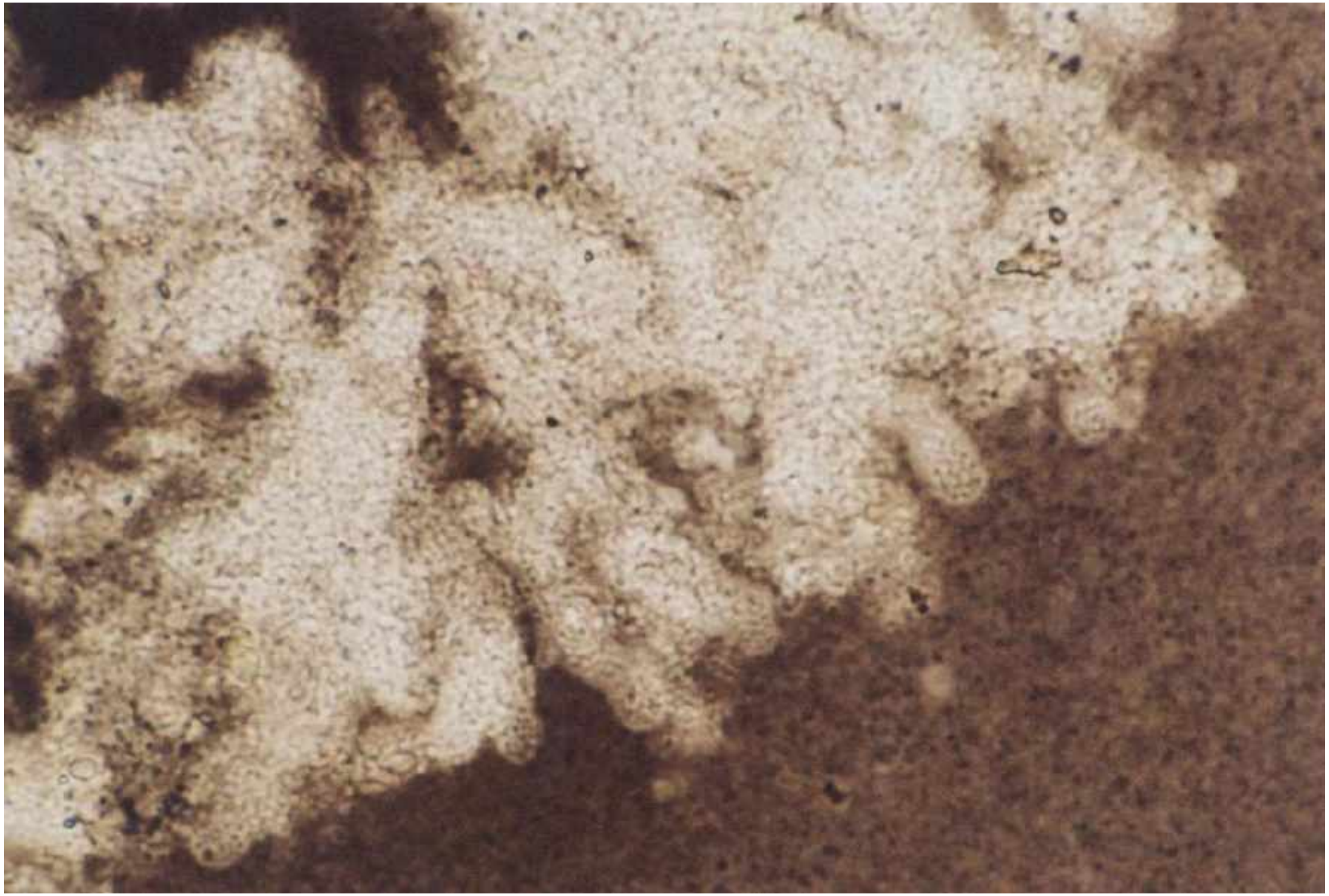
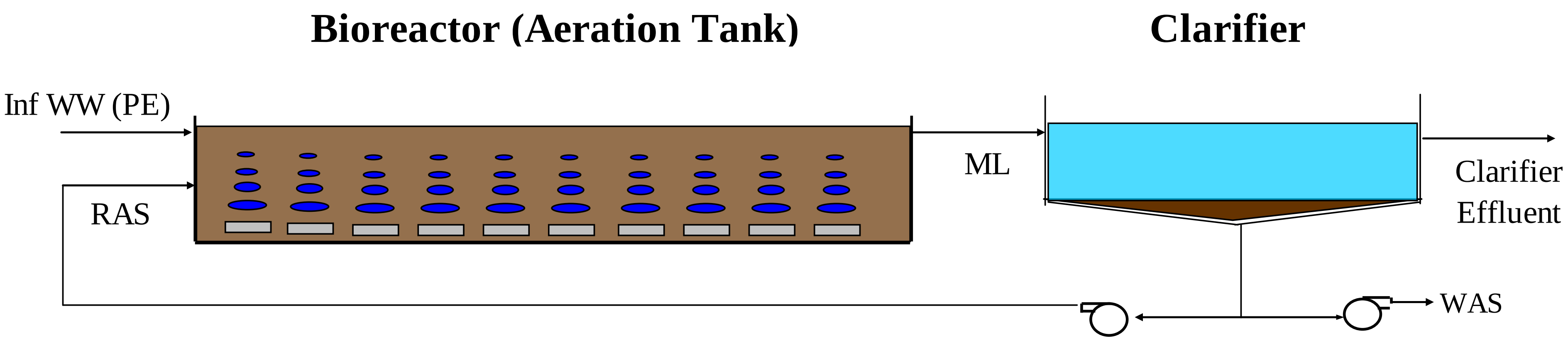
India Ink Stain Reveals Significant Exocellular Polymer (slime)



Third Key to Success: Controlling Population Dynamics

Goal: Maintain Proper Concentration & Type of Biomass to Meet Treatment Objectives

Accomplished Through Sludge Wasting



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Control of Population Dynamics (Through Sludge Wasting) Affects:

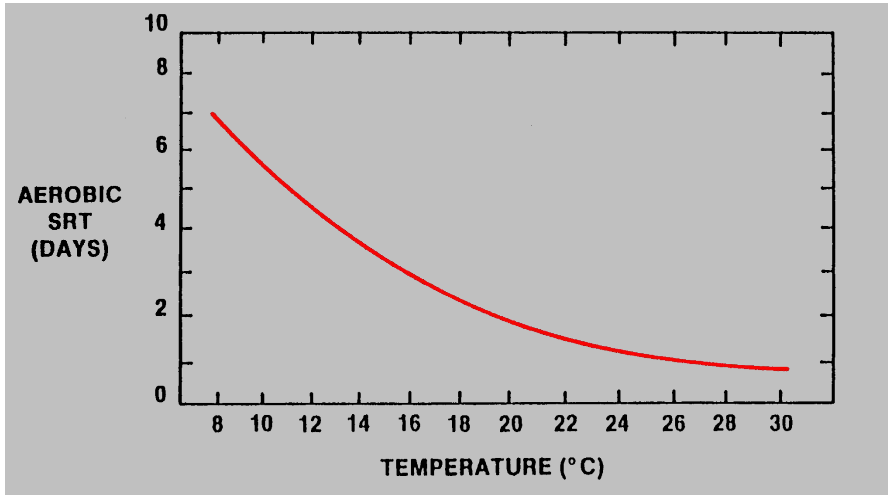
- Solids Retention Time (SRT)
- MLSS Concentration
- Nitrification Performance
- Loading Rates
  - Organic Loading on Bioreactors
  - Solids Loading on Clarifiers
- Presence/Avoidance of Some Problem Causing Organisms
  - Filaments (Bulking/Foam)

Key Definition

- Solids Retention Time (SRT)
  - SRT is average time a cell or solid particle stays in system
  - SRT = Mass in System/Mass Wasted From System
  - SRT is probably the most important process control measure in activated sludge systems
  - SRT is often called sludge age and sometimes Mean Cell Residence Time (MCRT)
  - SRT can refer to various bioreactor zones (aerobic, anoxic, total)

Sludge Wasting Strategies

- Target MLSS Concentration
- Target F:M Ratio
- Target SRT-Sludge Age-MCRT
  - Best Method, Particularly for Nitrifying Systems
  - Vary Target SRT Based on Seasonal Conditions
    - Mainly Temperature
    - Safety Factor Often Applied
  - SRT, Sludge Age & MCRT Are Often Used Interchangeably
    - Know Site-Specific Definition
    - Know Whether “Aerobic” or “Bioreactor”



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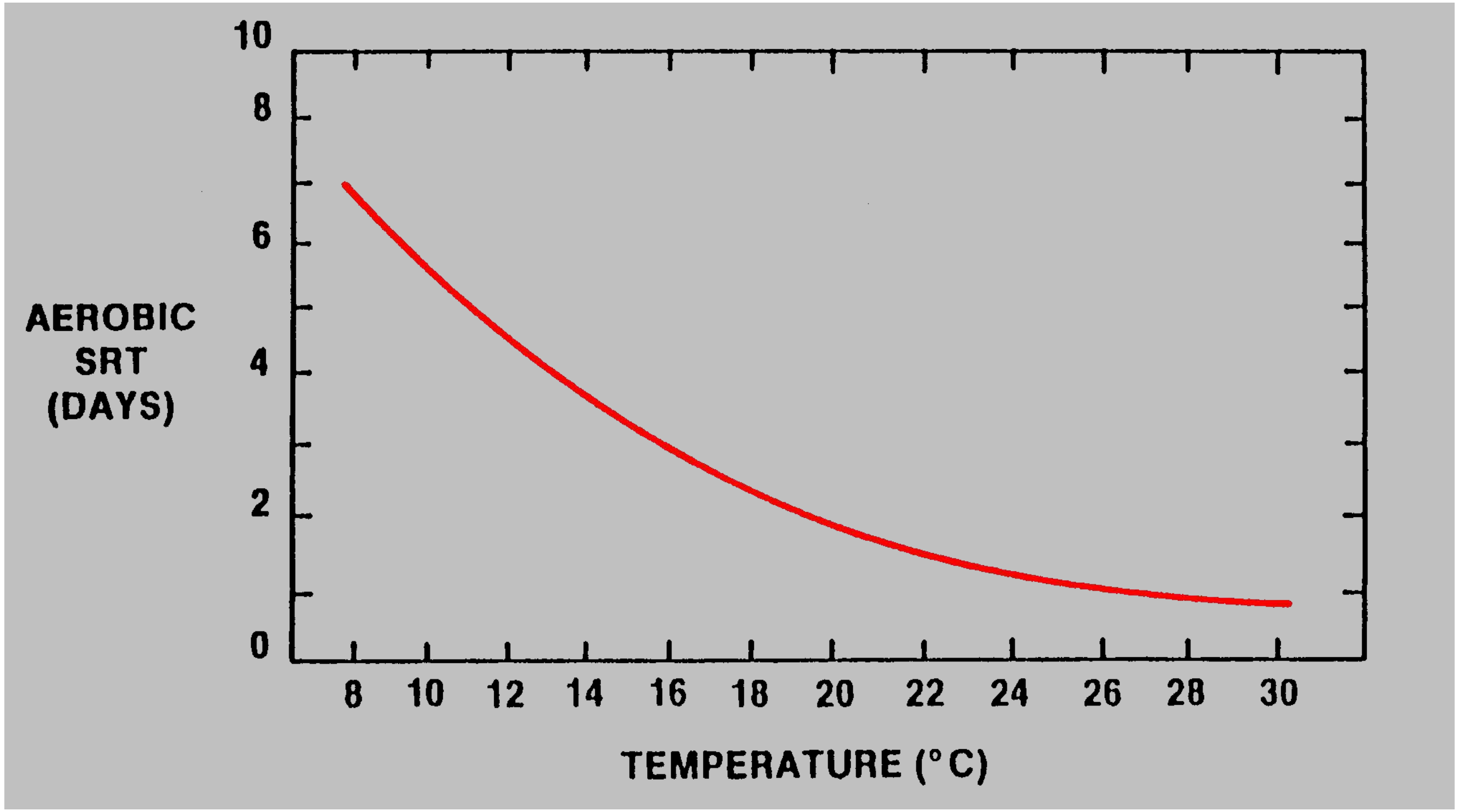
Target SRT Control

Daily Waste Volume = M_{MLSS}/(Target SRT*X_{WAS}*8.34)



This computation can seem tedious, intimidating…

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Target SRT Control

Daily Waste Volume = $M_{MLSS}/(SRT*X_{WAS}*8.34)$

This computation can seem tedious, intimidating…but simple spreadsheets can be great process control aids and provide historical records.

Whitewater WWTP Activated Sludge Wasting Calculator

SEE INSTRUCTIONS ABOVE

Daily Inputs Date:	06/03/20	
MLSS Concentration:	1,480	mg/L
RAS/WAS Concentration:	4,100	mg/L
Ave Final Clarifier Blanket Depth:	0.5	ft
Mixed Liquor Temperature:	58.8	deg F
30 Minute Settling Volume:	160	mL
Yesterday's WAS Flow:	55,500	gal/day
Yesterday's Plant Flow:	1.743	MGD
Yesterday's Composite Eff. TSS:	1.0	mg/L

Calculate WAS Target Volume

Process Inputs	Today	Yesterday	Range of Typical Values	
Target Aerobic SRT:	8.5	8.5	6-14 days	
Days Per Week to Waste:	5	5	5-7	
Waste From RAS or Aeration Basin?	1	1	1 = RAS/0 = Aeration Basin	
Aeration Trains in Service:	2	2	1 or 2	Aeration Trains in Service
Aeration Basin A5 in Service?	1	1	1 = Yes/0 = No	A5 in Service?
Final Clarifiers in Service:	2	2	1 or 2	

Today's Wasting Target:	63,795	gal/day

System Monitoring	Daily	7 Day R.A.		
Aerobic SRT:	4.5	8.2	days	120.3
Total Bioreactor SRT:	5.9	10.8	days	
Total System SRT:	6.4	11.5	days	
Actual MLSS Conc:	1,480	1,800	mg/L	
SVI:	108	93	mL/g	

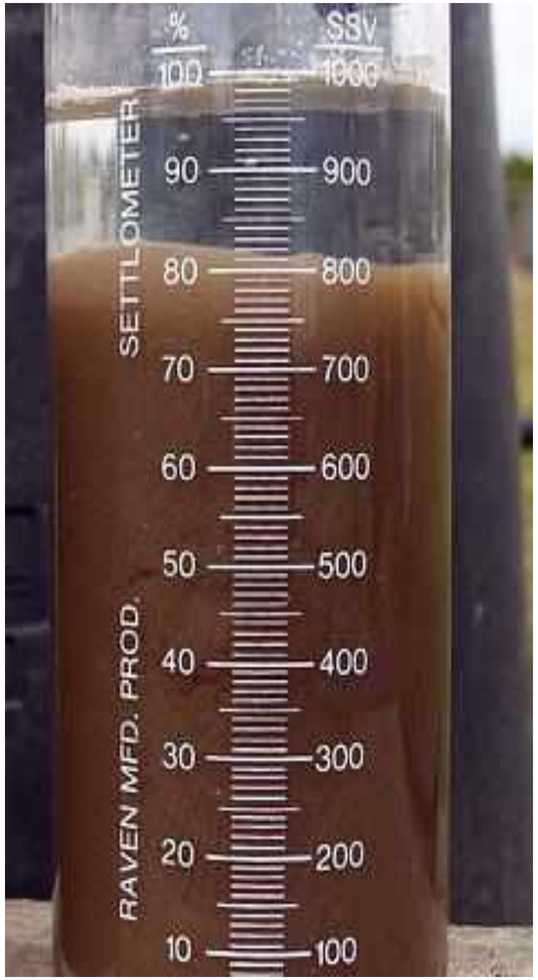
Wasting Calculation Data Summary →

Date	Today's Values MLSS mg/L	Today's Values RAS/WAS mg/L	Ave Final Clar Blanket ft	Mixed Liquor Temperature F	Target Aerobic SRT days	30 Minute Settling Volume mL	Yesterday's Plant Flow MGD	Yesterday's Effluent TSS (mg/L)	Yesterday's WAS Flow gal/day	Today's SVI mL/g	MLSS mg/L	RA
06/03/20	1,480	4,100	0.5	58.8	8.5	160	1.74	1.0	55,500	108	1,800	
06/02/20	1,900	4,420	1	58.5	8.5	180	1.95	1.4	53,700	95	1,916	
06/01/20	1,920	4,060	0.5	56.7	9.0	170	1.61	2.8	0	89	1,931	
05/31/20	1,830	3,900	0.5	57.0	9.0	170	1.66	1.8	0	93	1,931	

Calculator Inputs & Results | Recent ML Temp vs SRT | Recent SVI Analysis | Aer SRT ML Temp SVI Allc ...

Control the Process – Don’t Let It Control You

- Ensure Proper Environmental Conditions
  - DO, Nutrients, Alkalinity
- Control Population Dynamics Based on Solids Retention Time
- Monitor the System!



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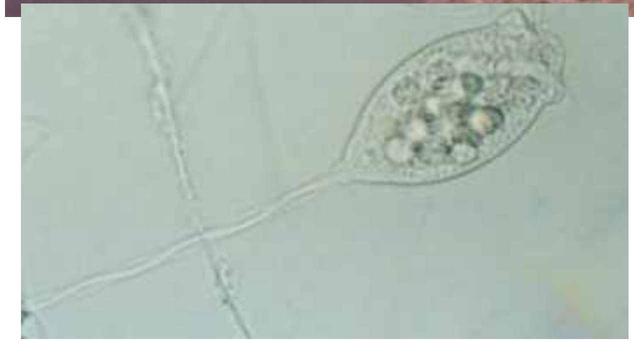
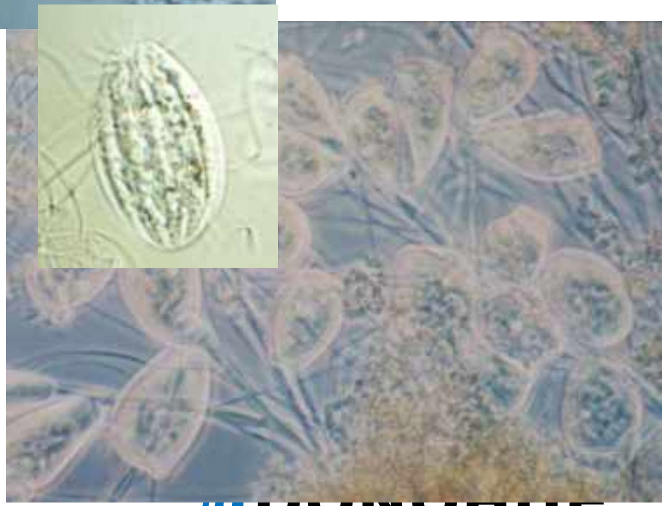
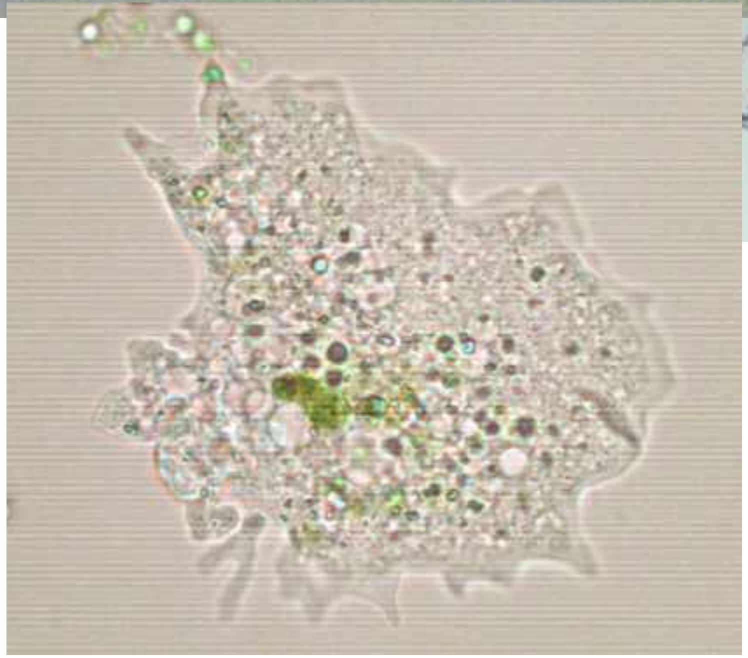
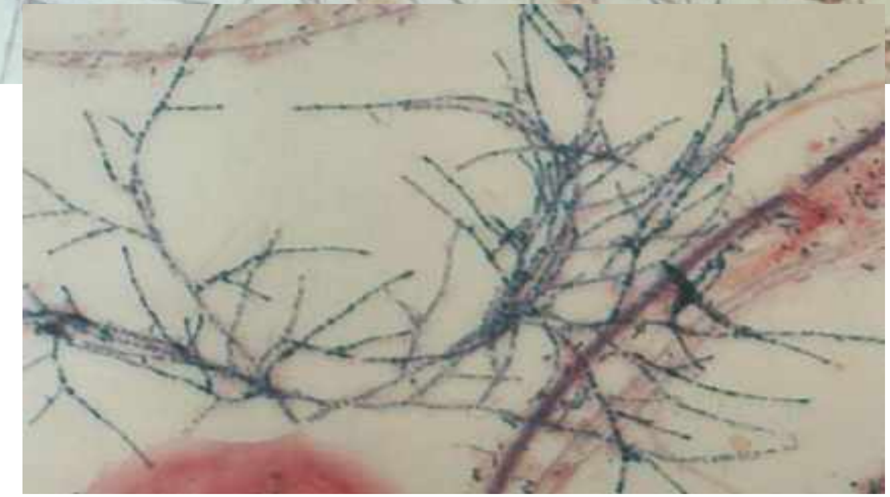
Let’s Look at The Critters – Higher Life Forms (Good Ones)





More Critters – Not So Good Indications





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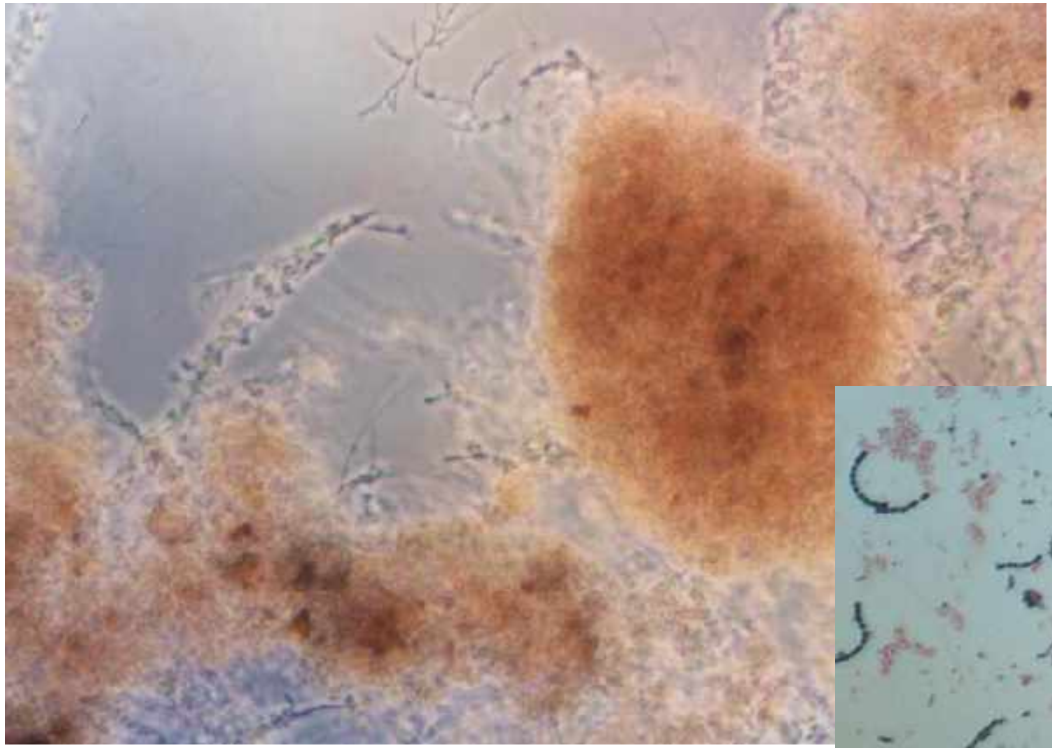
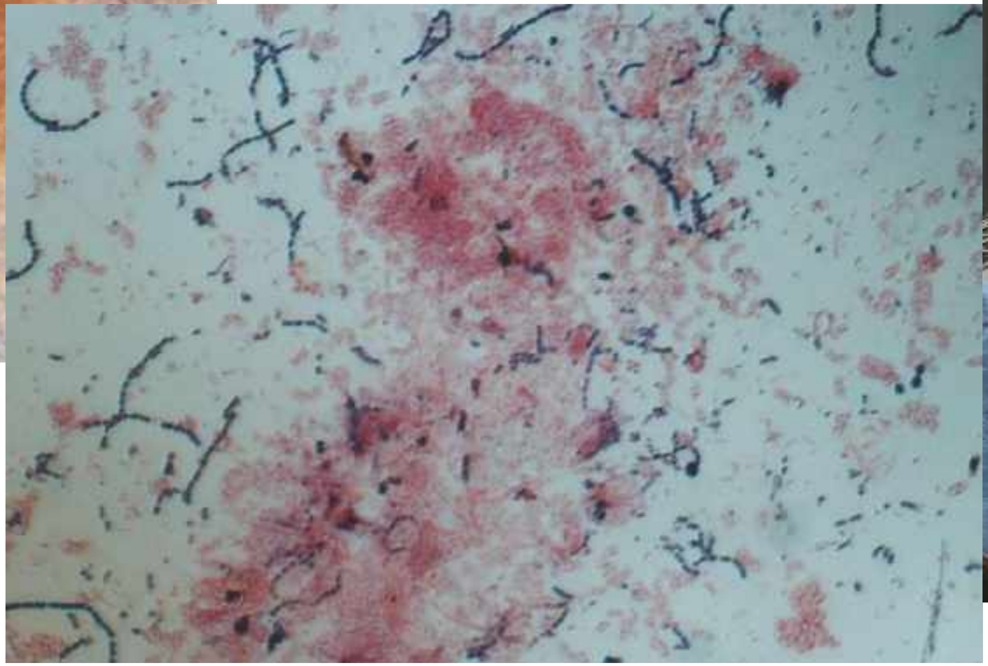
View of the Bulk Solution – Good and Bad





One Last Look – Perspectives on Foaming

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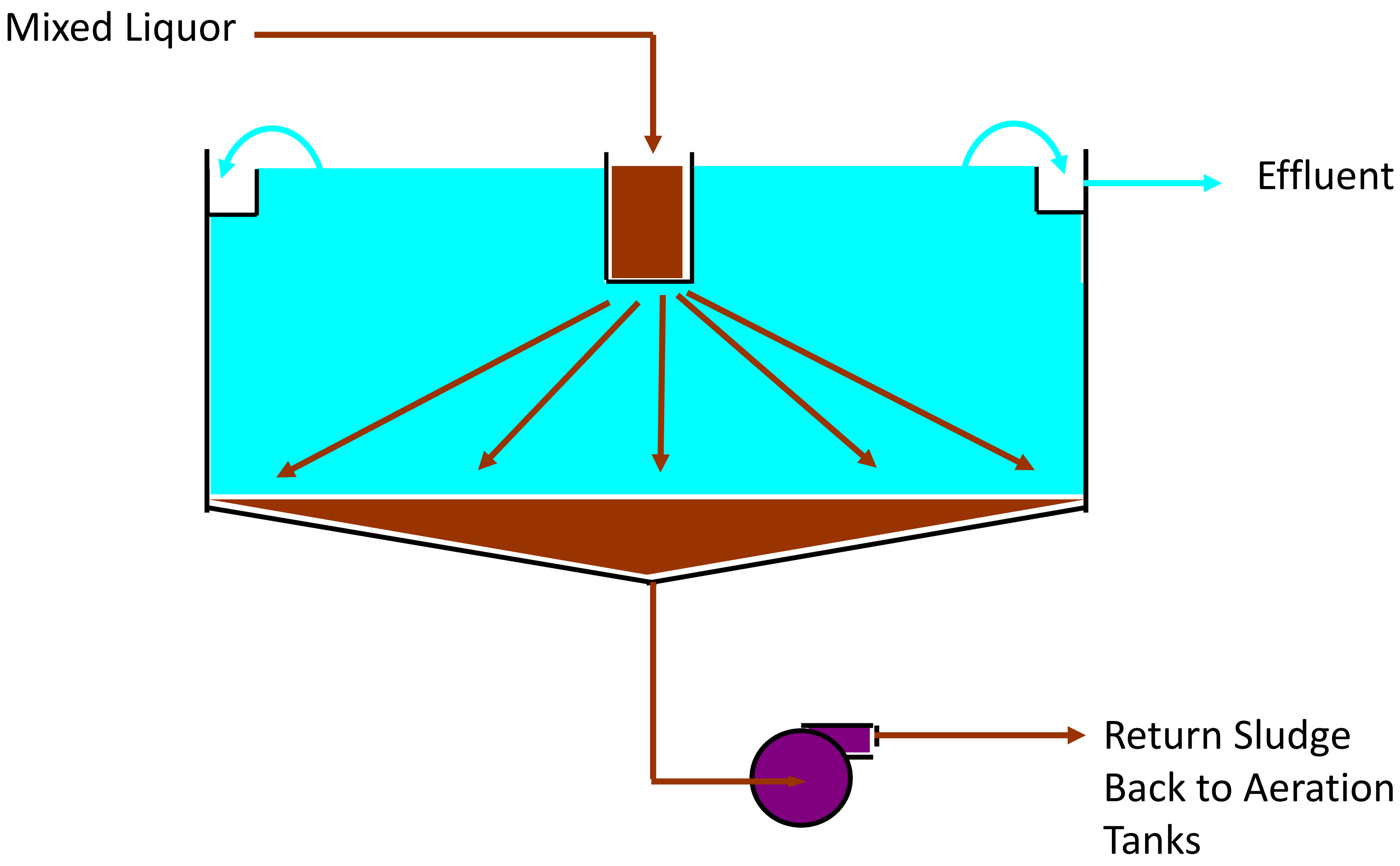
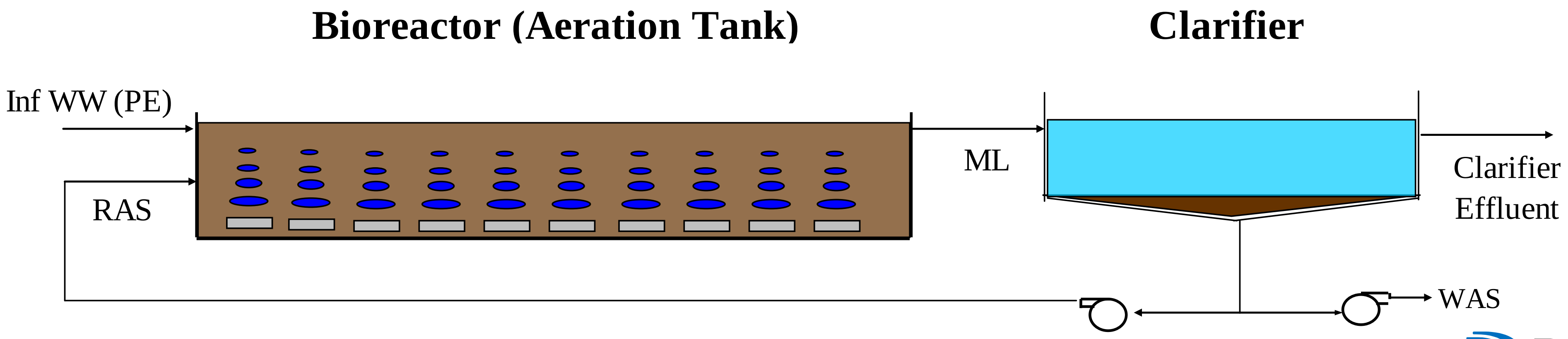
What About Clarifiers?

What Happens in a Clarifier?



Goals/Objectives of Secondary Clarification:

- Flocculate Solids to Enhance Settleability and Compactibility
- **Separate and Remove Settleable and Floatable Solids to Produce a Clear, High Quality Effluent**
- Concentrate the Solids and **Either Return Them to the Bioreactor (RAS) or Remove Them From the System (WAS)**



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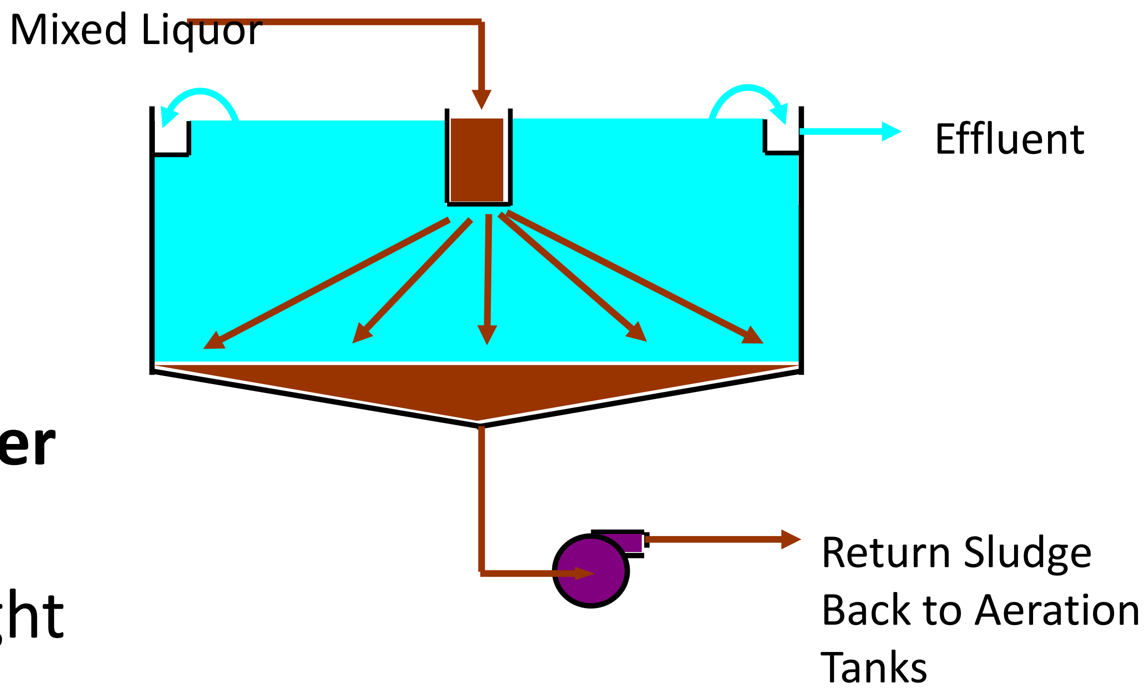
Effective Secondary Clarification

Depends On:

- Appropriately Designed Units
  - Number Available, Surface Area, Depth
- Good Inlet/Hydraulic Characteristics
- **Number in Service**
  - **Appropriate Loading Rates**
  - **"More is Better"???**
- **Getting Settled Solids Out of the Clarifier**
  - **As Quickly as Possible**
- Minimizing Annoyance Factors That Might Affect Performance
  - Algae on Weirs



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Getting Settled Solids Out: RAS Pumping

Goals Are To:

- Remove Settled Biomass From Clarifier and Return it to the Biological Reactor
  - (Allow Biomass to Thicken Before Reintroduction into the Biological Reactor)
- RAS Pumping is Our Main Clarifier Control Tool
  - Two Main Strategies: Constant Speed vs Flow Pacing

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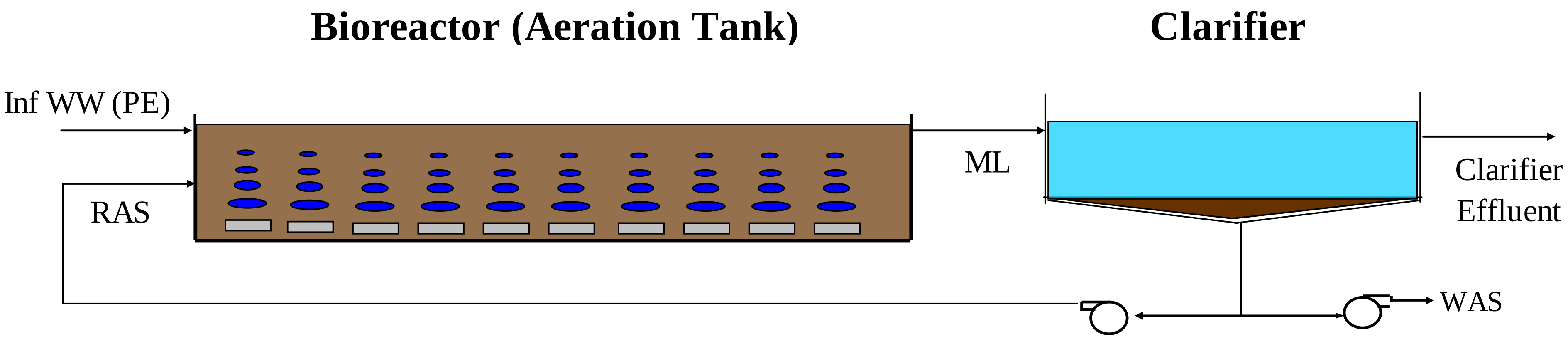
RAS Pumping Control Options

- Constant Return Rate
  - Simple
  - Low Level of Instrumentation/Automation
  - Results in Shifting Storage of Solids Between Aeration Tanks and Clarifier Blankets
  - Extensive Diurnal F:M Loadings



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RAS Pumping Control Options (cont'd.)

- Flow Proportional Control
  - RAS Pumping Rate Varies as Direct Proportion of Plant Flowrate
  - Requires Flow Metering and Variable Pumping Rate Capability
  - More Consistent Blanket Control
  - More Consistent Diurnal F:M Loadings
  - Can Result in Peak Solids Loading Rates on Clarifiers

When Upsets Occur

- Review Past Records For Similar Occurrences
- Look at All Monitoring Data For Clues
- Make Use of Resources Available
  - Published Materials
  - Regulatory Resources
  - Peers
  - University/Consulting Resources

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Example: Filament Outbreaks

Figure Out What You're Dealing With and Take Action

- Published Resources
- Past Experiences
- Filament Identification Resources
- Tools to Combat the Cause
  - RAS Chlorination
  - Fix "Nutrient" Deficiency
  - Adjust the SRT/Sludge Age

	A	B	C	D	E	F
1	**Speedway WWTP RAS Chlorination Calculator - North Plant - Fresh Sodium Hypochlorite**					
2	Today's Date:	03/03/20			XXX	Red Bold Text in Yellow
4	Total Bioreactor Volume in Service (MG):	0.2317				
5	MLSS Concentration (mg/L):	4,700				
7	Clarifier 3 in Service?	1	0 = No/1 = Yes			
8	Clarifier 3 Volume in Service:	0.248				
9	Clarifier 4 in Service?	1	0 = No/1 = Yes			
10	Clarifier 4 Volume in Service:	0.298				
12	Clarifier Sludge Blanket Depth (ft):	2.0	Average blanket depth of all clarifiers in service.			
13	Average Sludge Judge Concentration (mg/L):	0	If blankets < 3' enter 0. If blankets > 3' then pour sludge judge contents into bucke			
15	Activated Sludge MLSS Inventory (lbs):	9,082				
17	Sodium Hypochlorite Solution Strength (%):	12.5%	(lbs NaOCl per lb Solution)			
18	Sodium Hypochlorite Solution Density (lb/gal):	9.8				
19	Hypochlorite Pump Maximum Feed Rate (gal/day):	100				
21	Target Dosage Comments:			Maintenance (1-2)	Moderate (3-6)	Aggressive (7-10) (Se
22	Target RAS Chlorination Dosage (lb Cl2/1,000 lbs MLSS/day):			1.5	4.5	8.0
23	Hours per 24 Hour Period at this Feed Rate:			18.0	0.0	6.0
24	**Sodium Hypochlorite Solution Feed Rate at Dosage (gal/hour):**			0.49	1.46	2.59
25	**Sodium Hypochlorite Solution Feed Rate at Dosage (gal/day):**			11.7	35	62
26	**Sodium Hypochlorite Solution Feed Rate at Dosage (mL/min):**			31	92	164
28	**Estimated Total Daily Hypochlorite Usage (gal/day):**			56.8		
29						
30	***Precautionary Warning: When RAS chlorinating it is extremely important that you monitor the mixed liquor through daily microscopic examination for signs of excess toxicity to the entire microbial population, as evidenced by high amounts of dispersed bacteria outside of flocs, increase in presence of amoebas and flagellate protozoans, loss of stalked ciliates, free swimming ciliates, rotifers. Other signs of excess toxicity include loss of nitrification, turbid supernatant in settleometer test, increase in effluent TSS/BOD. If signs of excess toxicity appear you should immediately stop RAS chlorinating, then as conditions improve you can begin again at maintenance dosages, if necessary.***					
31						

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Tertiary Treatment (Low Level P)

Tertiary Treatment

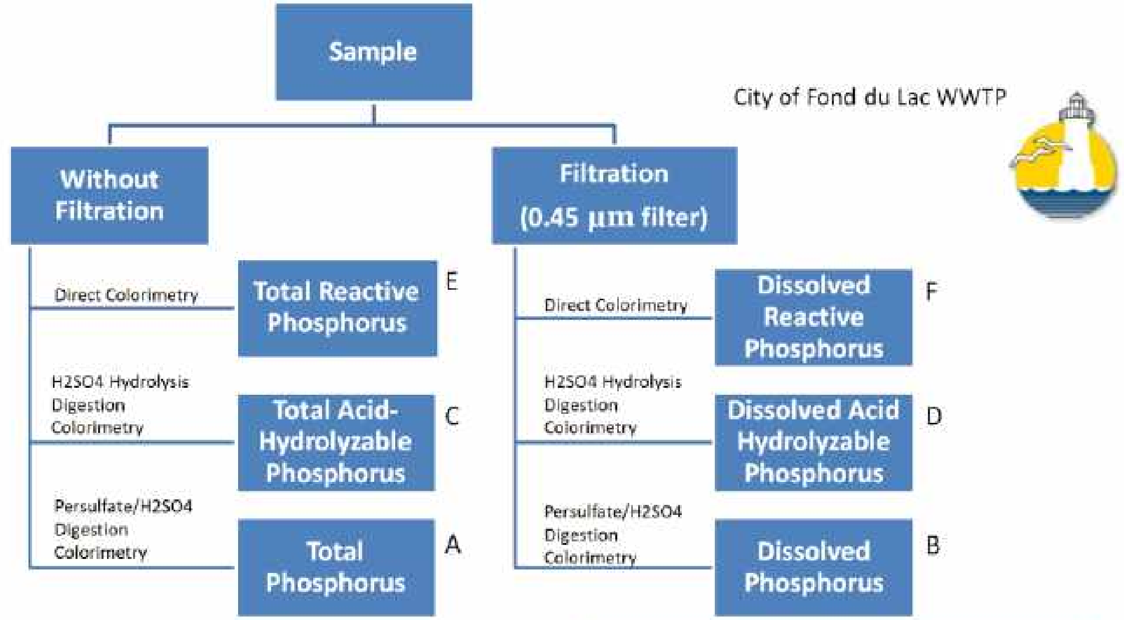
- Traditional Filters
  - BOD/TSS
  - Hydraulically limited

vs.

- Low Level Phosphorus Systems – focus of this segment
  - TP in addition to BOD/TSS
  - Hydraulic and Solids limited

Tertiary Treatment

- Sampling:
  - Importance of phosphorus speciation



A	Total Phosphorus
B	Total Soluble Phosphorus
C	Total Acid Hydrolyzable Phosphorus
D	Total Soluble Acid Hydrolyzable Phosphorus
E	Total Reactive Phosphorus (Ortho)
F	Total Soluble Reactive Phosphorus (Ortho)

A-B	Total Insoluble
C-E	Total Polymerized
D-F	Soluble Polymerized (Soluble Poly P)
A-C	Total Organically Bound
B-D	Soluble Organically Bound
A-E	Total Non-Reactive
B-F	Soluble Non-Reactive (SNRP)

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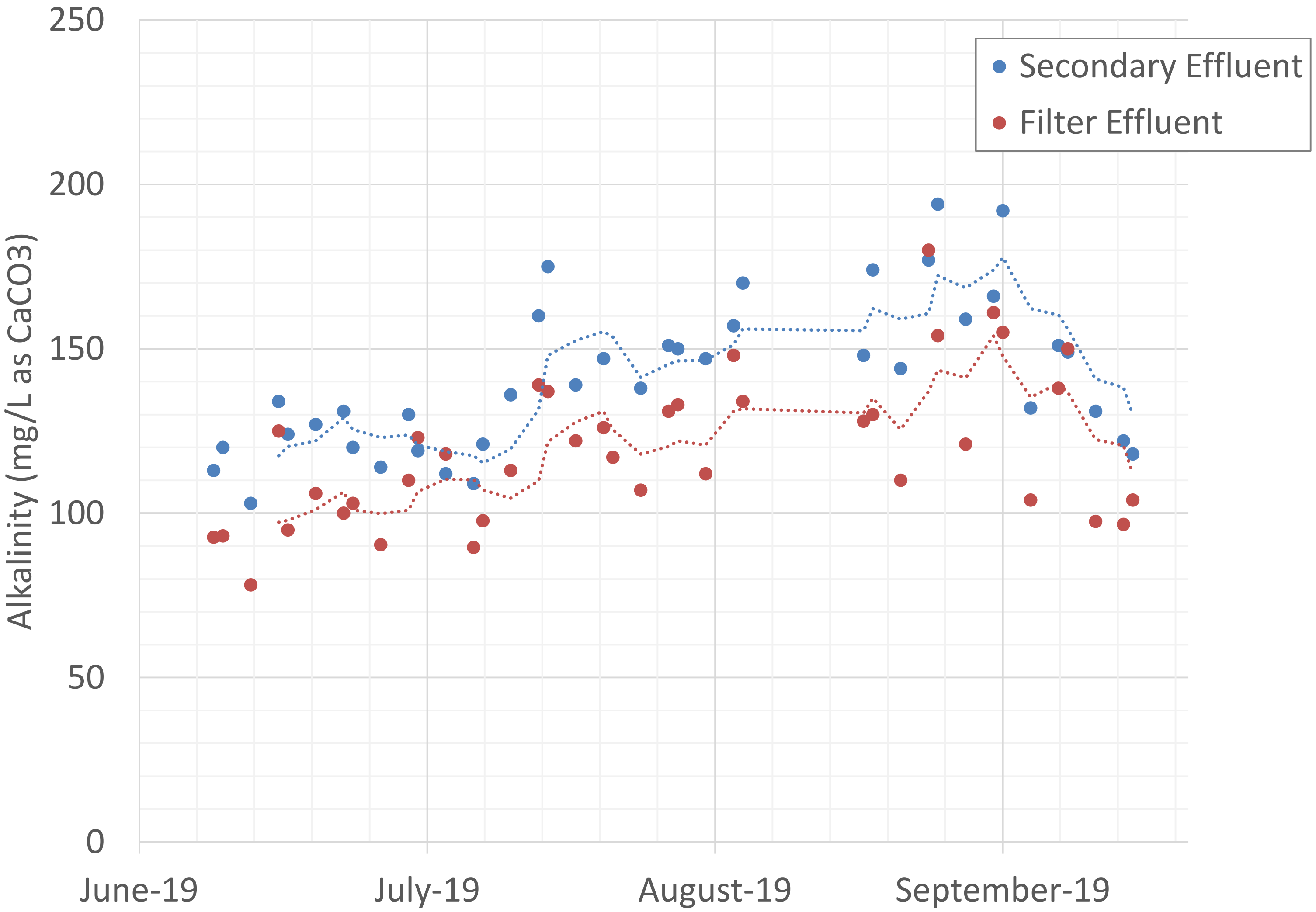
Tertiary Treatment

- Sampling:
  - Alkalinity
    - Observed decrease of (20-30) mg/L



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Tertiary Treatment

- Sampling:
  - Grab samples
  - Online analyzers (low range)
  - Online turbidity
  - Composite effluent sampler

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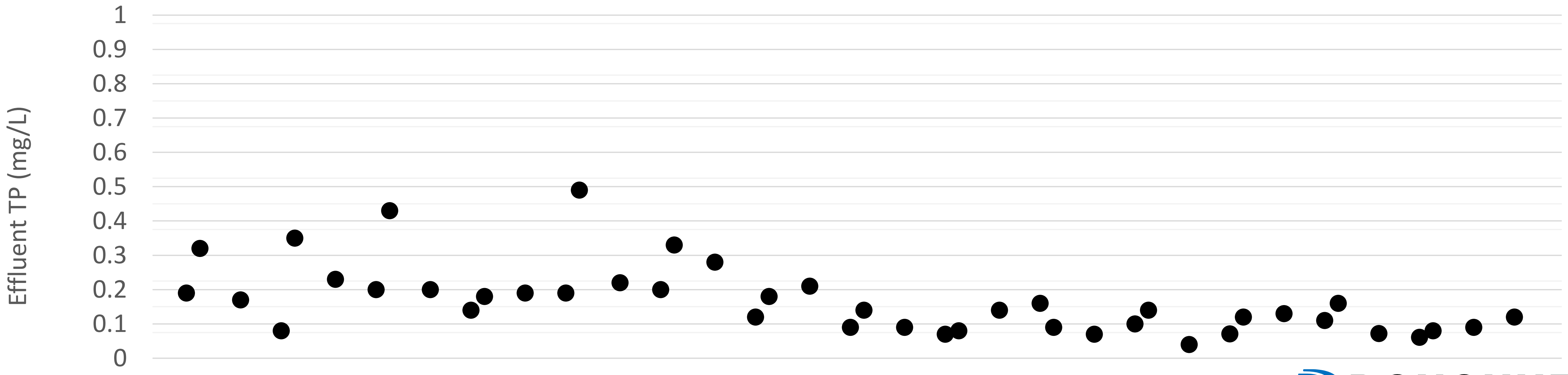
Tertiary Treatment

- Monitoring
  - Historical data – record of optimization and upgrade

Words to live by:

"You can't control what you don't measure."



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Tertiary Treatment

- Monitoring
  - Dose validation
    - Tank Level (visual/sensor)
    - Feed Pump Setting (calibrated)

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Tertiary Treatment

- Monitoring
  - Floc development
  - Spot light / illuminate

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Tertiary Treatment

- Monitoring
  - Backwash frequency – measure of capacity

- Before

- After

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Tertiary Treatment

- Control
  - Dose – Chemical Type
  - Consider alkalinity, UV bulbs...

Bulk dose setup for ferric chloride

Tote Connection for
- Alum
- PAC
- RE300
- Etc

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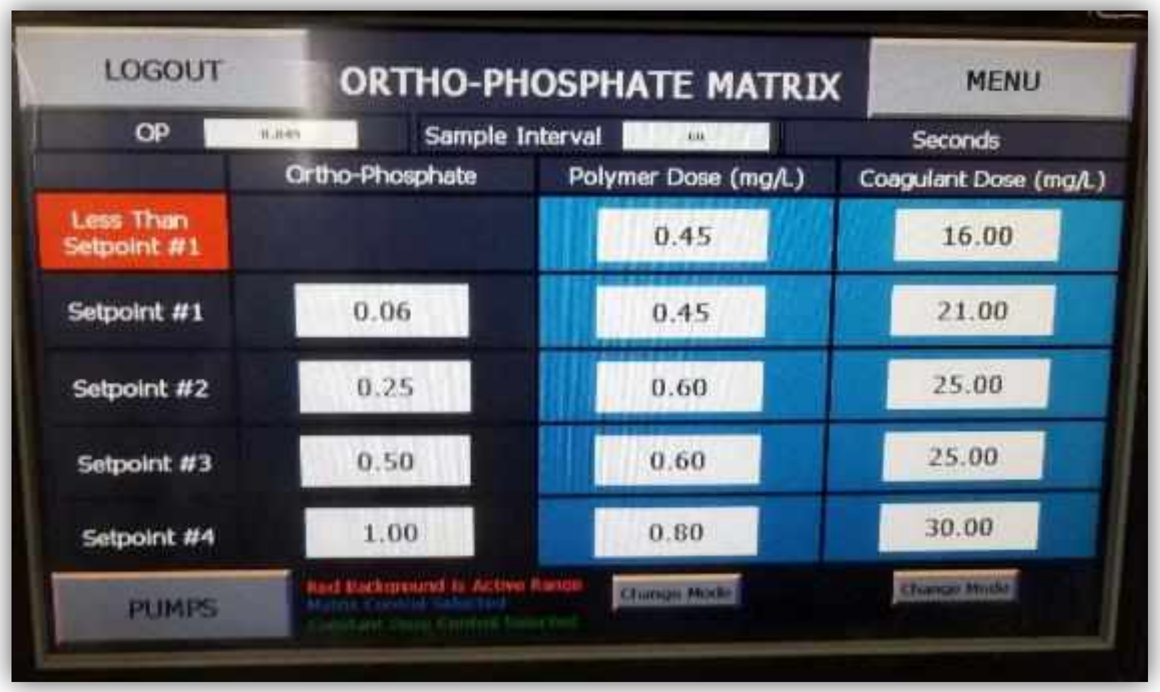
Tertiary Treatment

- Control
  - Dose Rate (molar, auto mode)



- Initial dose 20 mg/L Ferric, start high then back off checking residual orthoP
- Stable polymer dose (0.5 mg/L)
- Monitor floc development in Floc Tank / Filter Influent Well
- Polymer and Ferric need to be balanced or it will blind/backwash

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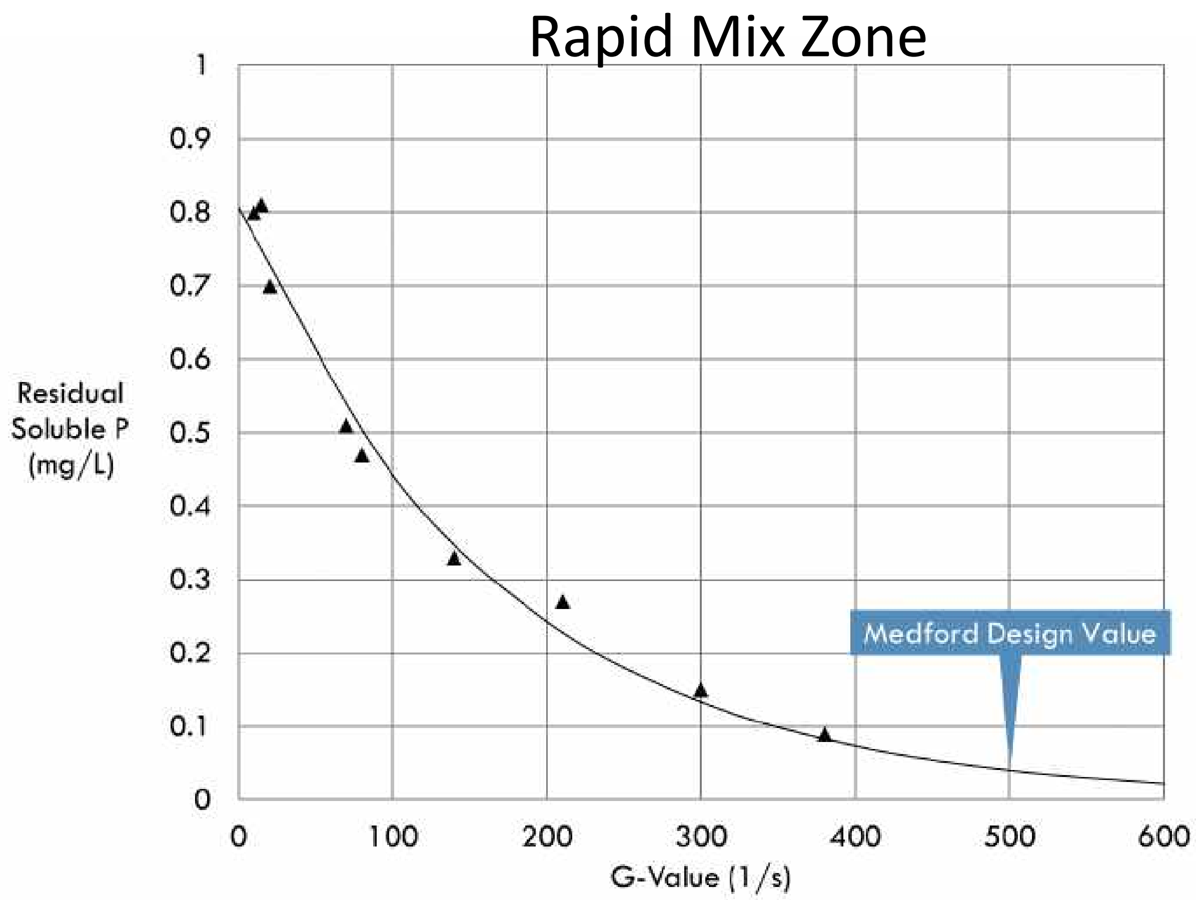
Tertiary Treatment

- Control
  - Mixers - VFDs
  - Mixing Intensity
    - Rapid Mix Zone
      (high G-value; >500)
    - Floc Development
      (low G-value; 5-100)



Takacs, et. al

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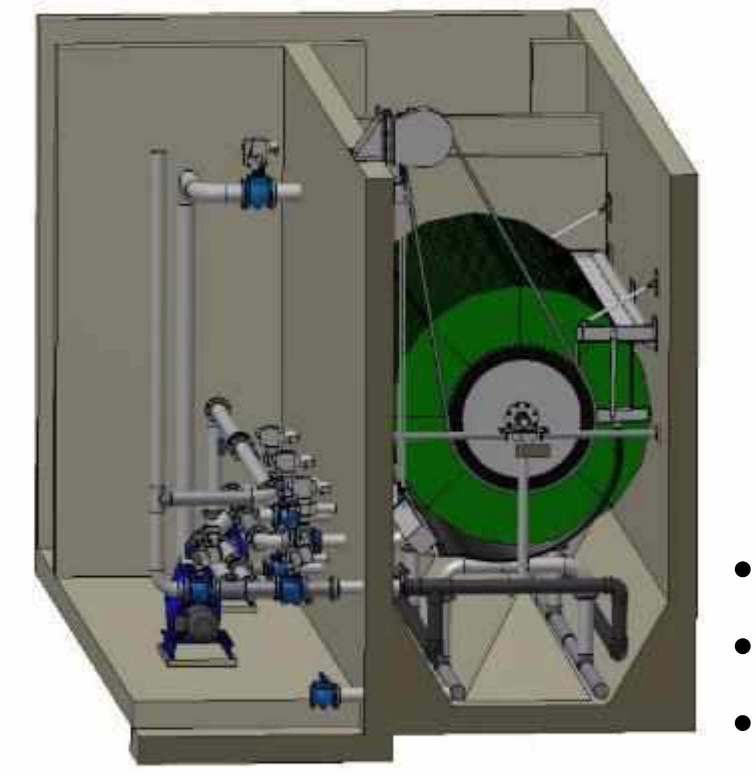
Tertiary Treatment

- Filtration Rate (limited by backwash) – units in service decisions



- Outside In
- Vacuum backwash
- Can be tolerable to high solids loading rate

- Inside Out
- Spray backwash
- Compact design

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Tertiary Treatment

- How to Handle Excess Flows

  If capacity limited (right-sized), overflow location has an impact

  - Secondary Effluent (soluble phosphorus)

  vs

  - Filter Influent (chemical solids)

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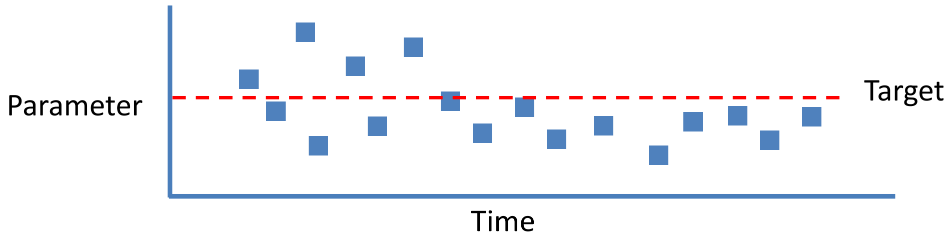
Disinfection

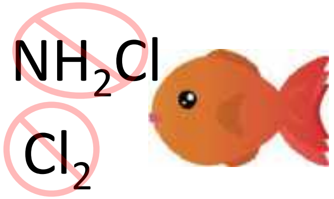
Chemical Disinfection

- Goals for Monitoring and Control:
  1. Optimize chemical use and cost

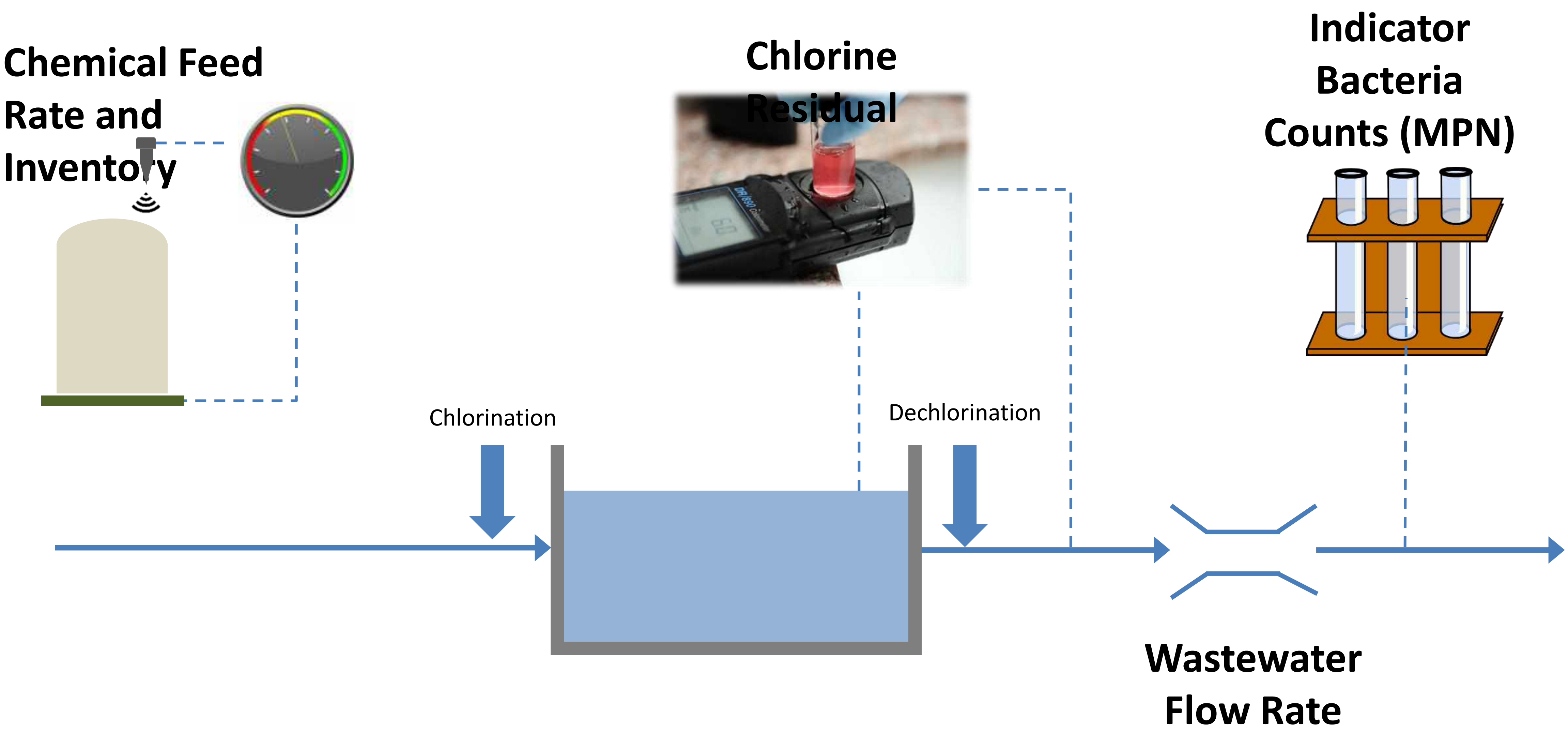
  2. Maintain consistent performance



  3. Avoid water quality issues



Disinfection Monitoring



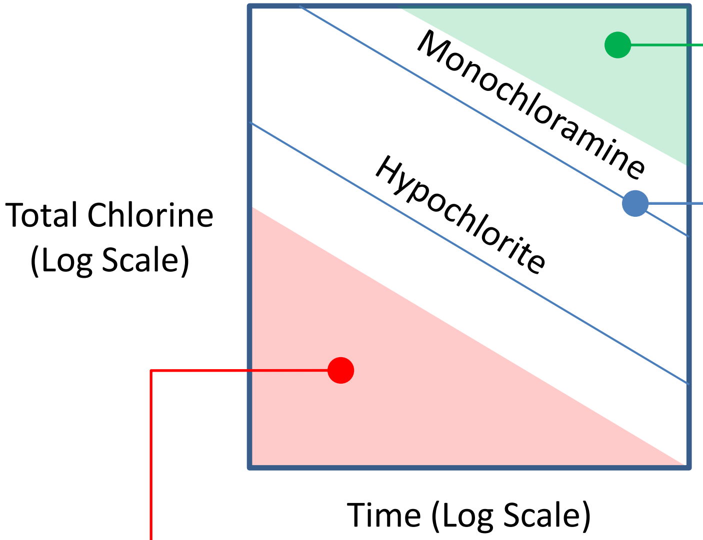
Optimizing Disinfection Efficacy

- CT Value:
  - C = Disinfectant (Residual) Concentration
  - T = Detention or Contact Time

Log Reduction is proportional to **<u>C x T</u>**
(Product of ***Both*** Factors)

2-log reduction = 99% kill
3-log reduction = 99.9% kill
4-log reduction = 99.99% kill

Time vs Residual Concentration for E. coli Kill



Adequate Time and/or High Residual = Good Disinfection

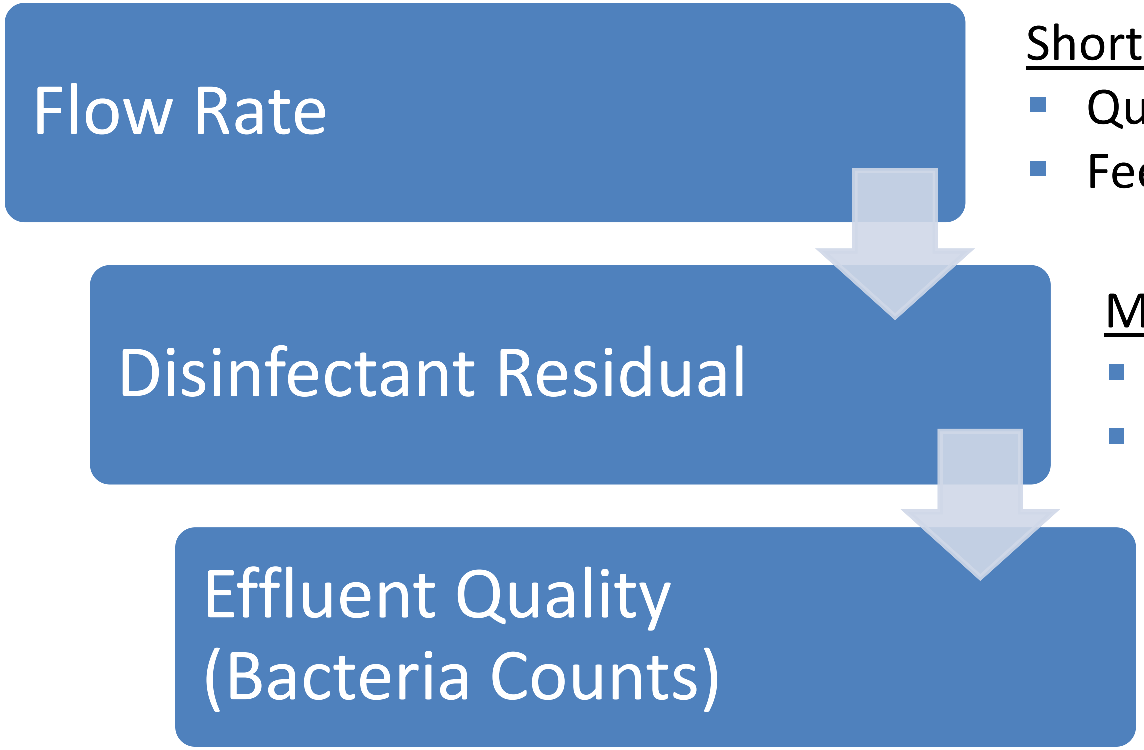
Monochloramine is a weaker disinfectant – for nitrifying plants, consider increasing residual during high ammonia upsets

General note: consider increasing dose to maintain adequate residual during high TSS events or other upsets that increase chlorine demand

Short Detention Time and/or Low Residual = Poor Disinfection

Control Timescales

- Adjust chemical feed based on:

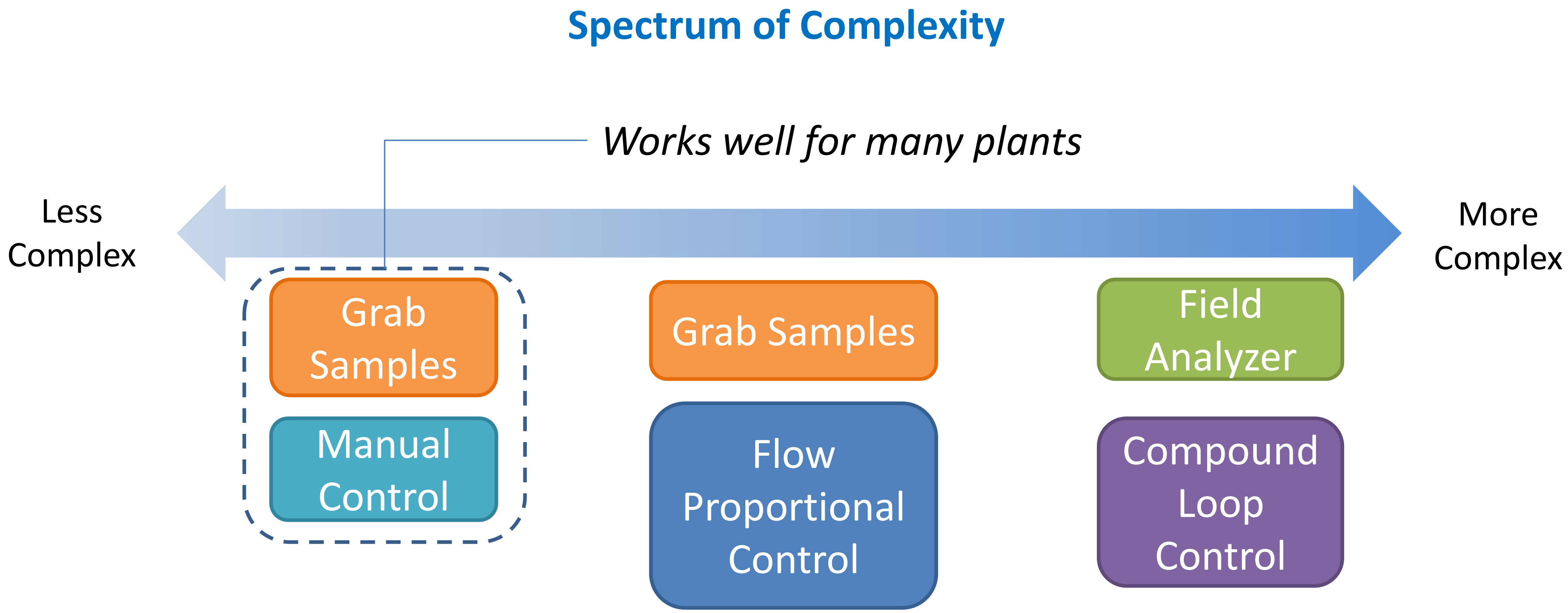


<u>Short Time Scale</u>
- Quick control response
- Feed must be proportional to flow to maintain same dose

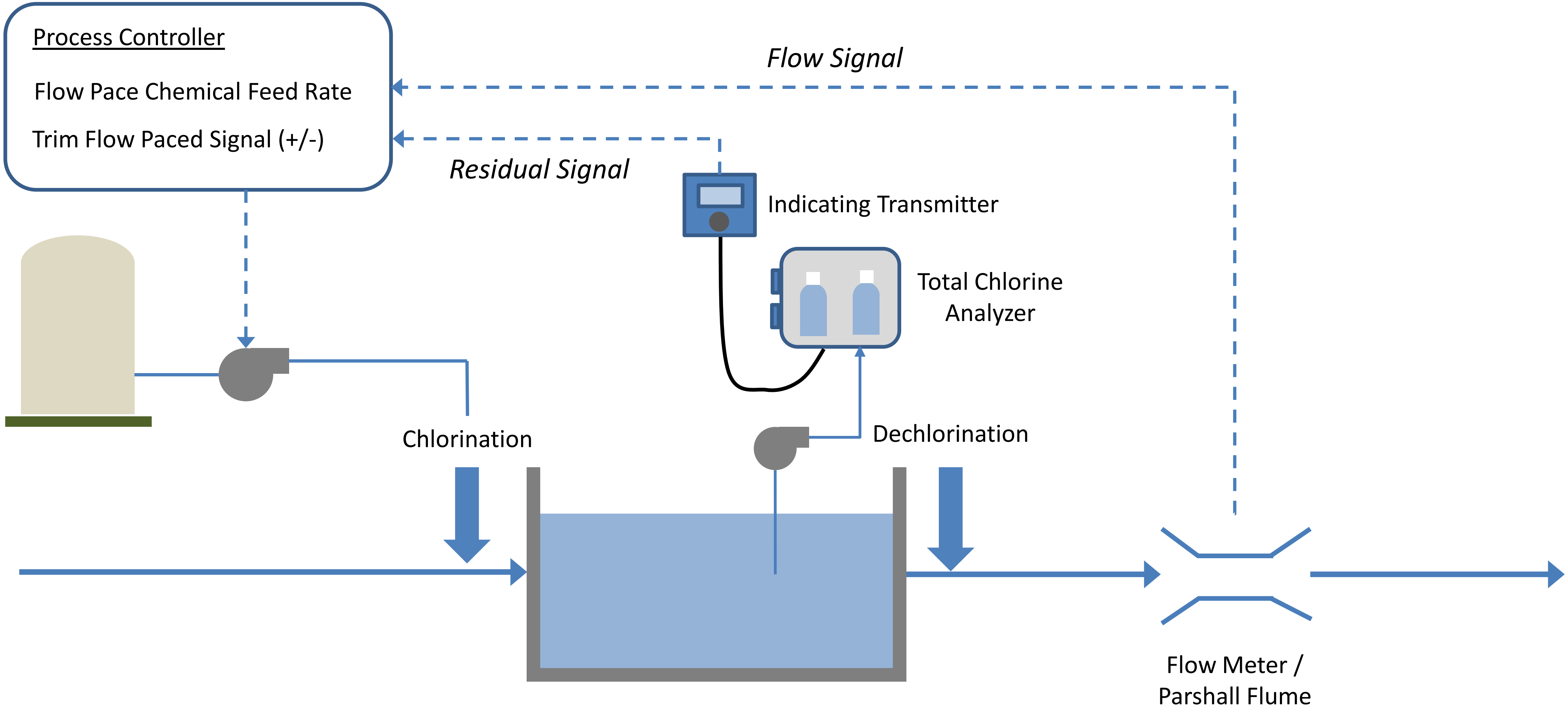
<u>Medium Time Scale</u>
- Tempered control response
- Consider lag time in system

<u>Long Time Scale</u>
- Manual performance evaluation
- Adjust dose or residual based on historical performance

Approaches to Monitoring/Control



Compound Loop Control

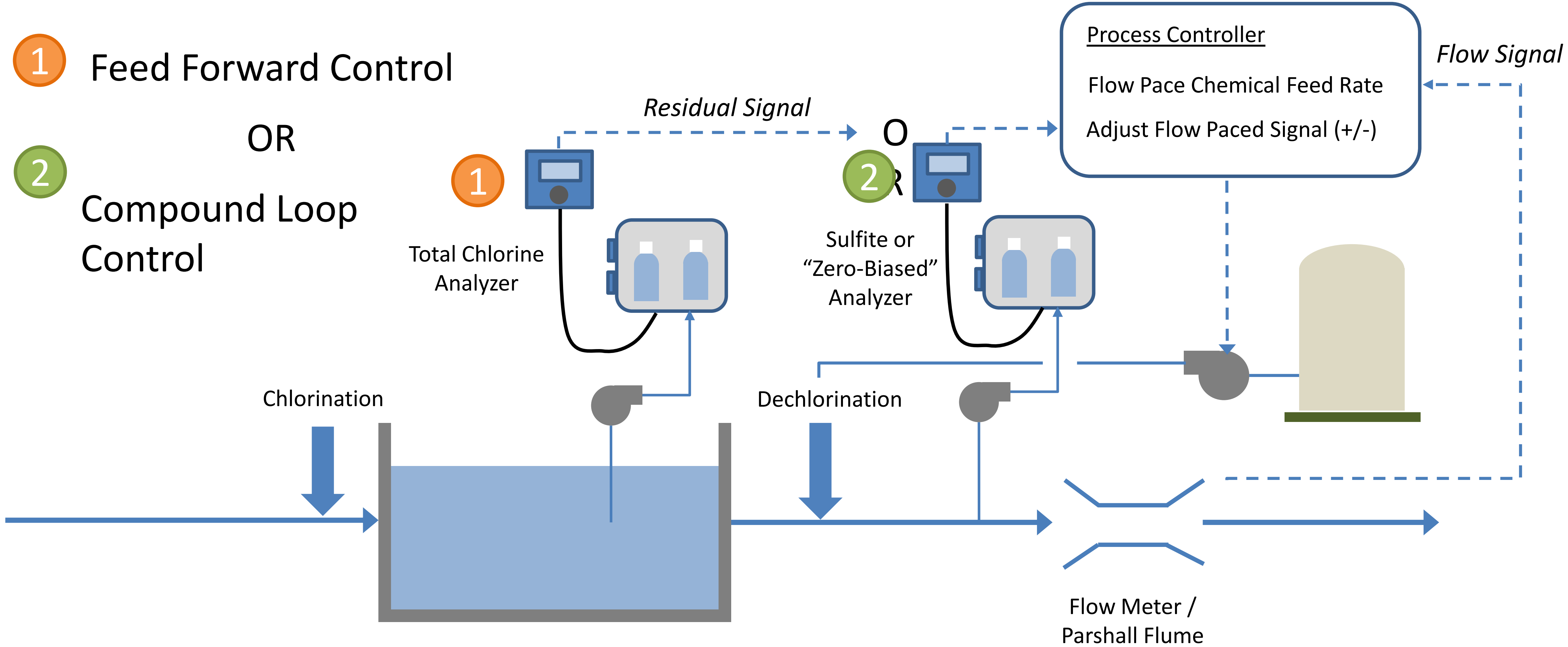


Dechlorination Control

1 Feed Forward Control

OR

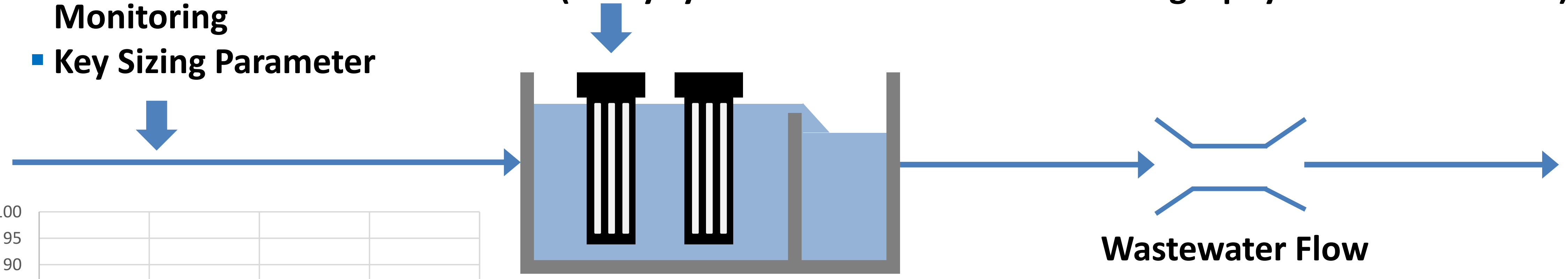
2 Compound Loop Control

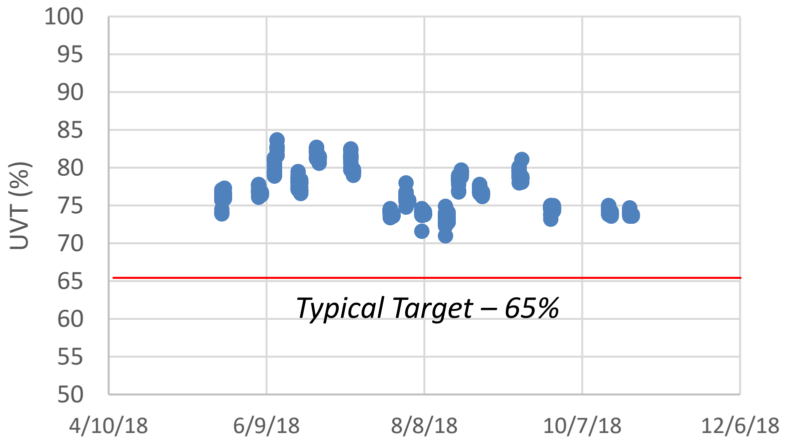


UV Disinfection Monitoring & Control

UV Transmittance
- **Initial Effluent Monitoring**
- **Key Sizing Parameter**

Bulb Maintenance Monitoring:
- **Fouling Rate**
- **Cleaning & Replacement Interval**
  (Many systems have automated cleaning – physical and chemical)





Fixed or Variable Weir - Maintain Adequate Bulb Submergence

Wastewater Flow Rate

Process Control to Save Energy & Bulb Life:
- **Dim Lamps**
- **Turn Modules On/Off**
- **>50% Turndown (Most Systems)**

Chat

Answer the following:

Are you more concerned about peak flow events or E. Coli limits?

5 Minute Break

Process Control & Monitoring: What's Really Important
Virtual Operator Training ~ June 18, 2020

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Anaerobic Digestion

Why Anaerobic Digestion?

- Stabilizes Sludge Generated at the WWTF
  - To Minimize Impacts on Other Treatment Processes (Sidestreams)
  - So It Can Be Disposed Of Cost-Effectively Through Beneficial Reuse
  - To Reduce Its Odor Potential
- Reduces the Mass of Biosolids for Disposal
- Produces Methane Gas
  - Which Can Be Beneficially Used for Heating or Power Production

What Happens During Anaerobic Digestion?

Essentially Four Phases of Biotransformations

Hydrolysis	Acidogenesis	Acetogenesis	Methanogenesis
Carbohydrates	Sugars	Carbonic Acids	Hydrogen Acetic Acid CO_2
Fats	Fatty Acids	Hydrogen CO_2 NH_4	Methane CO_2
Proteins	Amino Acids		

First 3 phases take 1 – 2 days (biological solids like WAS can take a little longer).
Methanogenesis takes 10 – 20 days, methanogens are very sensitive to their environment.

- 1st Phase (Hydrolysis) – Complex organics are broken down
- 2nd Phase (Acidogenesis) – Acid forming microorganism convert products of hydrolysis to acids, CO2 and hydrogen
- 3rd Phase (Acetogenesis) – Organic acids are further broken down to acetic acid and ammonia.
- 4th Phase (Methanogenesis) – Methane forming bacteria covert acetic acid, hydrogen and CO2 into methane (digester gas).

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Anaerobic Digestion – Keys to Success

- Maintaining Appropriate Loading Rates
- Practicing Effective Mixing
- Maintaining Proper Temperature Control
- Practicing Effective Feeding
- Performing Essential & Effective Monitoring

It really all comes down to keeping the methanogens healthy & happy.

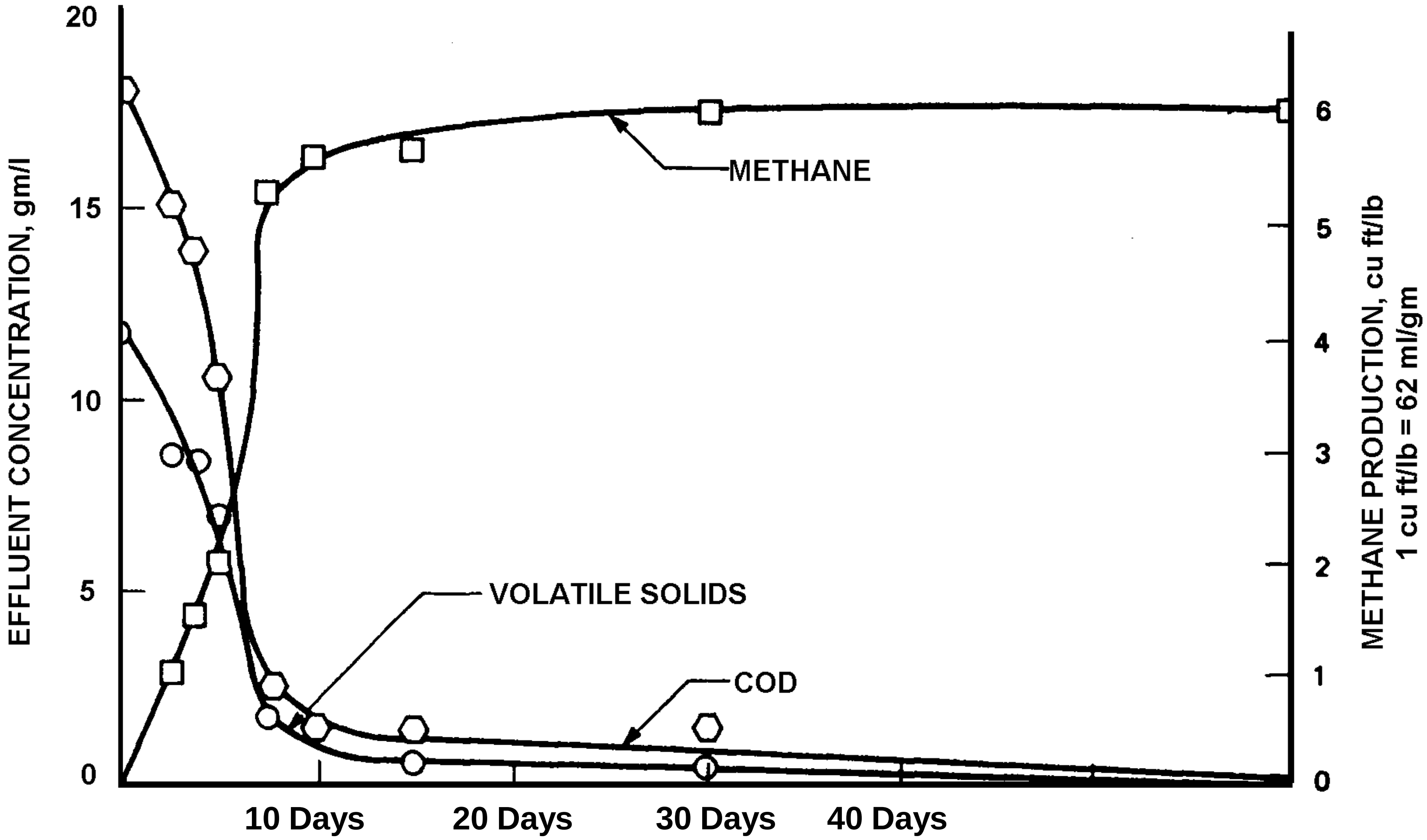
Digestion Loading Rates

Key Loading Rate Issues:

- Limited Control – We're Given a Certain Tankage to Make Use Of
  - Multiple Tanks – Series vs Parallel Operation (Primary vs Secondary)
- Solids (Hydraulic) Retention Time (SRT/HRT)
  - The Single Most Important Loading Rate Parameter
  - Methanogens Are Slow Growing Sensitive Organisms
  - Need to Do What We Can to Maximize SRT
- Volatile Solids/Organic Loading (VS Loading)
  - Units Are lbs VS/cf/day
  - Generally Can Handle Up to 0.2 lbs VS/cf/day Provided You Have Sufficient SRT
  - How Can We Control? Mainly Hauled in Wastes

The Importance of Adequate SRT

- Remember the Four Conversion Phases – At Too Low SRT Methane Formers Can't Keep Up With Acid Formers



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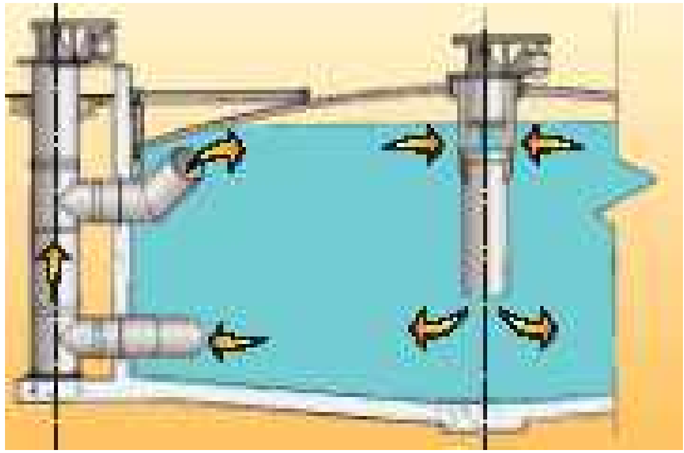
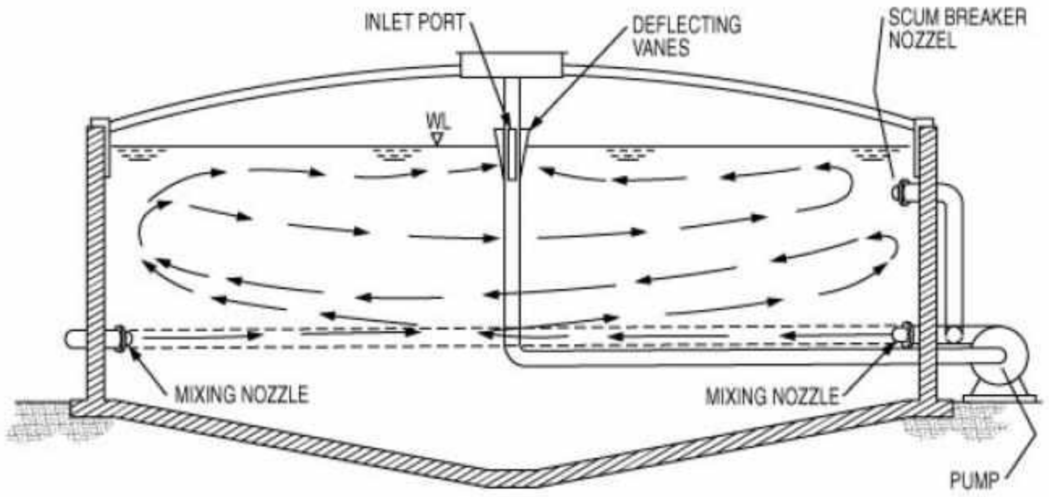
Digester Mixing

- Control May Be Limited by Infrastructure
  - What Kind of Mixing System
  - Flexibility in Mixing System
- Goals:
  - Uniform Mixing
  - Avoid Excessive Turbulence
  - Try to Maximize "Active Volume"
  - Try to Break Up Scum





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Digestion Temperature

- Mesophilic Digestion – 86-102 deg F (Thermophilic ~130-140 deg F)
  - Optimal Range (for Methanogens) 94-98 deg F
- **Temperature Stability As Important As Actual Temperature**
  - Rule of Thumb: Digester Temperature Change < 1 deg F/day
  - Consider that methanogens suffer with fluctuating temperatures much more than "acid formers"
    - Widely varying temperatures lead to "Sour Digesters" with drop in pH and loss of methane formation
    - Also can lead to significant sidestream loadings back to liquid treatment

Digestion Temperature Maintenance

- Typically Through Sludge Recirculation Through Heat Exchangers
  - Avoid Intermittent Operation
  - Monitor Temperatures Regularly
    - Sludge In/Out
    - Hot Water Supply In/Out
    - Watch For Changes – May Be Plugging or Precipitation of Mineral Coatings Impairing Heat Transfer

Digestion Feeding

- Continuous Feed Preferred
  - Helps Maintain Stable Balance Between Acid & Methane Formers
- In Non-Continuous Not Possible, Small Quantities Fed Frequently Provides Reasonable Compromise
  - e.g., 3 Digester System – Feed 20 minutes/hour each then repeat
- Higher SRT Digesters Have Much Greater Ability to Handle Inconsistent Feeding

Regular/Daily Digestion Monitoring

- Flows In & Out of Digesters (All Sources)
  - Calculate SRT/HRT (15-20 days, minimum 12 with good temp control)
- Temperatures
  - Of All Digesters (Sludge Inlet to Heat Exchangers)
  - Flows In/Out of Heat Exchange Equipment
- VS of Feed Sludge(s) In & Digested Sludge Out
  - Calculate Volatile Solids Destruction Via True Mass Balance
    - Typically Expect 45-65%
    - Don’t Use Van Kleeck Approximation
  - Lbs VS/cf/day (Goal < 0.2 with adequate SRT, lower preferred)
- Daily Gas Production (to All End Uses, including Flare)
  - Typically Expect 12-18 cf gas/lb VS destroyed

Less Often Digestion Monitoring

Regularly (Several Times/Week) Measure/Monitor:

- Volatile Acids/Total Alkalinity Ratio
  - Preferred Range < 0.2
  - Maximum <0.4
- pH
  - Desired Range 6.8-7.2

Less Frequently Check Digester Gas Quality

- Methane Content (65-75%)
- Btu Value (550-700 Btu/cf)

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Despite Best Efforts, Digesters Can Get Upset

- Rise in VA/Alkalinity – Dropping pH
  - Digester Going "Sour"
  - Add Supplemental Alkalinity
  - Lower/Stop Feeding
    - Increase Feed to Other Digesters
    - Cut Off Hauled in Waste
- Digester Foaming
  - Determine Cause/Source & Correct (if possible)
  - Decrease Feed/Isolate
  - Protect Gas Piping Systems/Gas Utilization Equipment

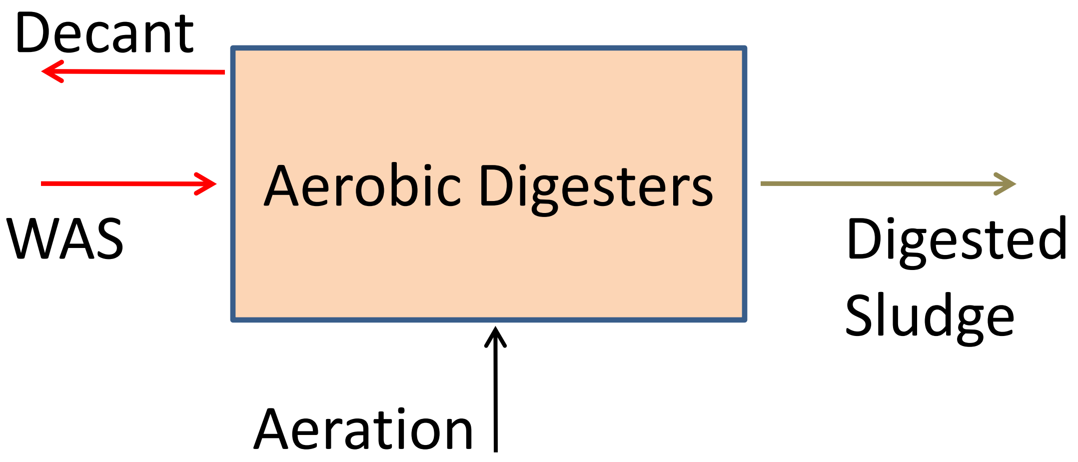
Last Thoughts - Digester Maintenance

- Every Few Years Probably Need to Take Digester Out of Service for Cleaning & Inspection
- Restarting a Digester Can Be Tricky
  - Fill to 1/4 – 1/3 Level With Water & Preheat Concrete Foundation
  - Provide Seed From Well Operating Digester
  - Slowly Restart Feeding
    - Only Primary Sludge to Start, If Possible
    - Closely Monitor Temperature, VA/Alkalinity, pH
    - Vent to Atmosphere and Closely Monitor Gas Quality – Don't "Button Up" Too Soon

Aerobic Digestion

Aerobic Digestion

- Simple process for stabilization
  - using tankage and equipment similar to activated sludge
- Control:
  - WAS Feed
  - Aeration
  - Decant
  - Digested Sludge Pumping



Endogenous Respiration

- Food (BOD) is depleted
- Microorganisms consume their own protoplasm
- Cell tissue is oxidized to:
  - Carbon dioxide
  - Water
  - Ammonia (which is nitrified to nitrate)
  - Ortho-phosphorus
- Exothermic reaction – heat is generated

Control Solids Retention Time

- The concept of degree-days
  - Time-temperature relationship of performance
  - At 20^{o}C, need 25 days
  - At 10^{o}C, need 50 days
- Tankage volume is fixed
- Control WAS concentration
- Control decanting

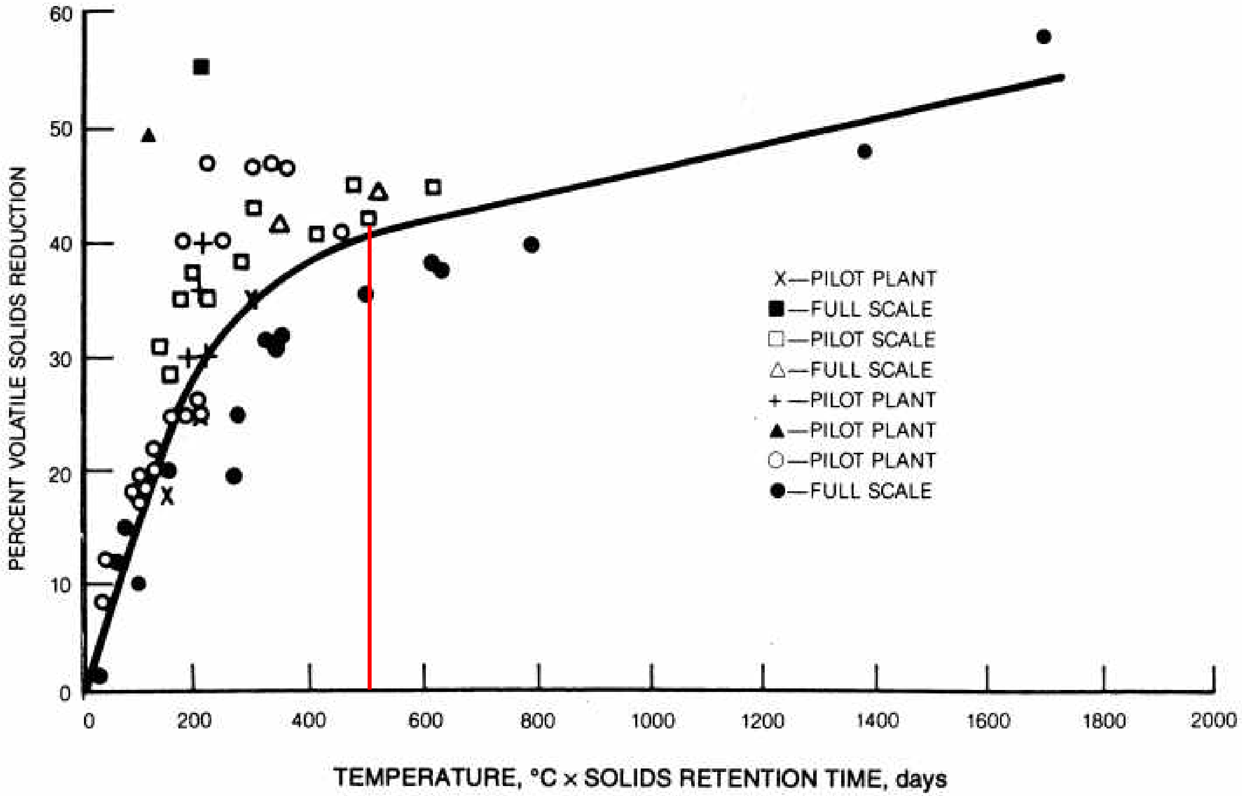


Figure 31.8 **Volatile solids reduction as a function of digester liquid temperature and digester solids retention time**

Nitrification Adds Complexity

- Digestion leads to release of ammonia followed by nitrification
- Nitrification
  - 7 lbs of alkalinity is consumed per 1 lb of ammonia oxidized to nitrate
  - Minimal water is available (reduced water mass) in the digesters for additional alkalinity
  - pH decreases, which reduces digestion performance

Anoxic Cycling to Recover Alkalinity

- Turning the aeration on and off in the digesters creates anoxic cycling and alkalinity recovery
- Anoxic cycling was published in the 1980's, but not established until mid-1990's

Aeration ON

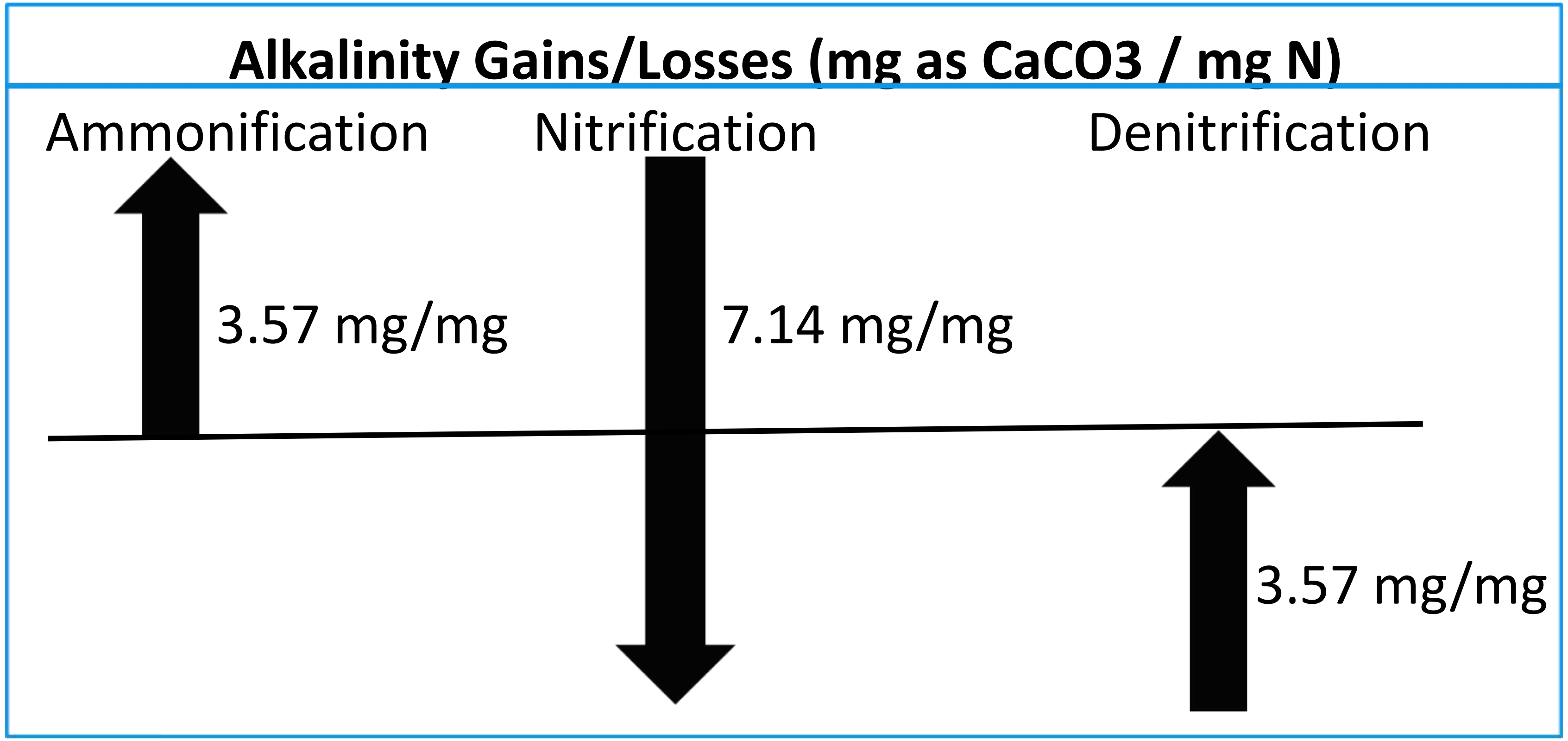
- Digestion occurring
- Ammonia is nitrified to nitrate
- Alkalinity is consumed
- pH decreases

Aeration OFF

- Digestion occurring
- Nitrate is denitrified to nitrogen gas
- Alkalinity is recovered
- pH increases

Anoxic Cycling to Recover Alkalinity

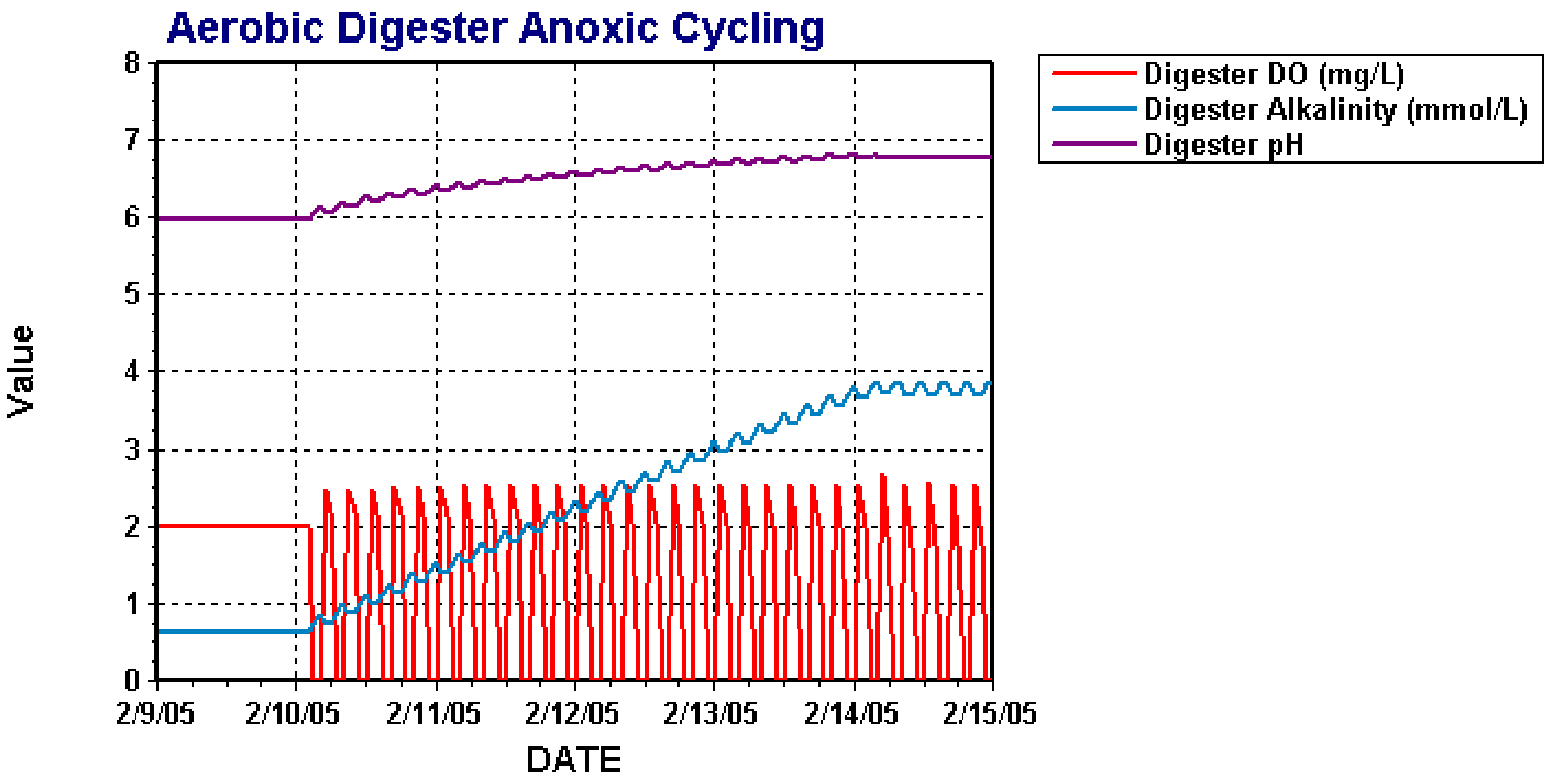
- Alkalinity is produced during digestion
- Alkalinity is consumed during nitrification
- Alkalinity is recovered during denitrification



Anoxic Cycling to Recover Alkalinity

- Alkalinity and pH can be increased by on/off operation of aeration to create anoxic/aerobic cycling in the digester.
- 50/50 aerobic to anoxic cycles ideal

  (see Water Resources Vol. 20, No. 8, 1986: *Anoxic-Aerobic Digestion of Waste Activated Sludge*)



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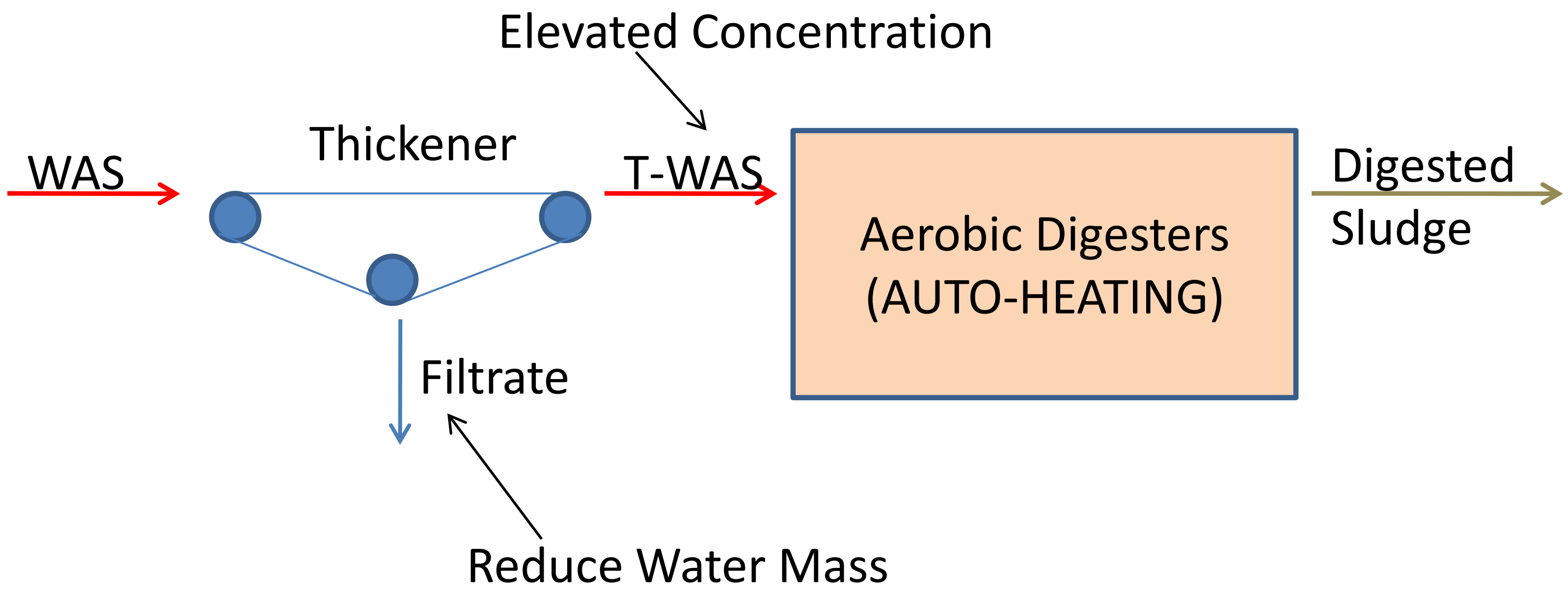
Auto-Heated Aerobic Digestion

- Because endogenous respiration is an exothermic reaction, we can use the heat generated to our benefit….
- Adequate degree-days is much easier to reach if minimum temperature is increased



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Thickening & Dewatering

Thickening

- Common Types of Mechanical Thickening Equipment
  - Dissolved Air Floatation (DAF)
  - Gravity Belt Thickener (GBT)
  - Rotary Drum Thickener (RDT)

- Monitoring – focus is on keeping it operating
- Control – focus is on keeping it at optimal/steady state

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Thickening

- Control Functions
  - Feed Rate
    - Based on sludge pumping rate from the process
  - Polymer
    - Manual (visual – cake and filtrate quality, adjust on rounds)

Thickening

- Manual

Thickening

- Control Functions
  - Feed Rate
    - Based on WAS rate from the process
  - Polymer
    - Manual (visual – cake and filtrate quality, adjust on rounds)
    - Remote Manual (camera displaces being there)

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Thickening

- Remote Manual

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Thickening

- Control Functions
  - Feed Rate
    - Based on WAS rate from the process
  - Polymer
    - Manual (visual – cake and filtrate quality, adjust on rounds)
    - Remote Manual (camera displaces being there)
    - Automatic (camera algorithm adjusts polymer)

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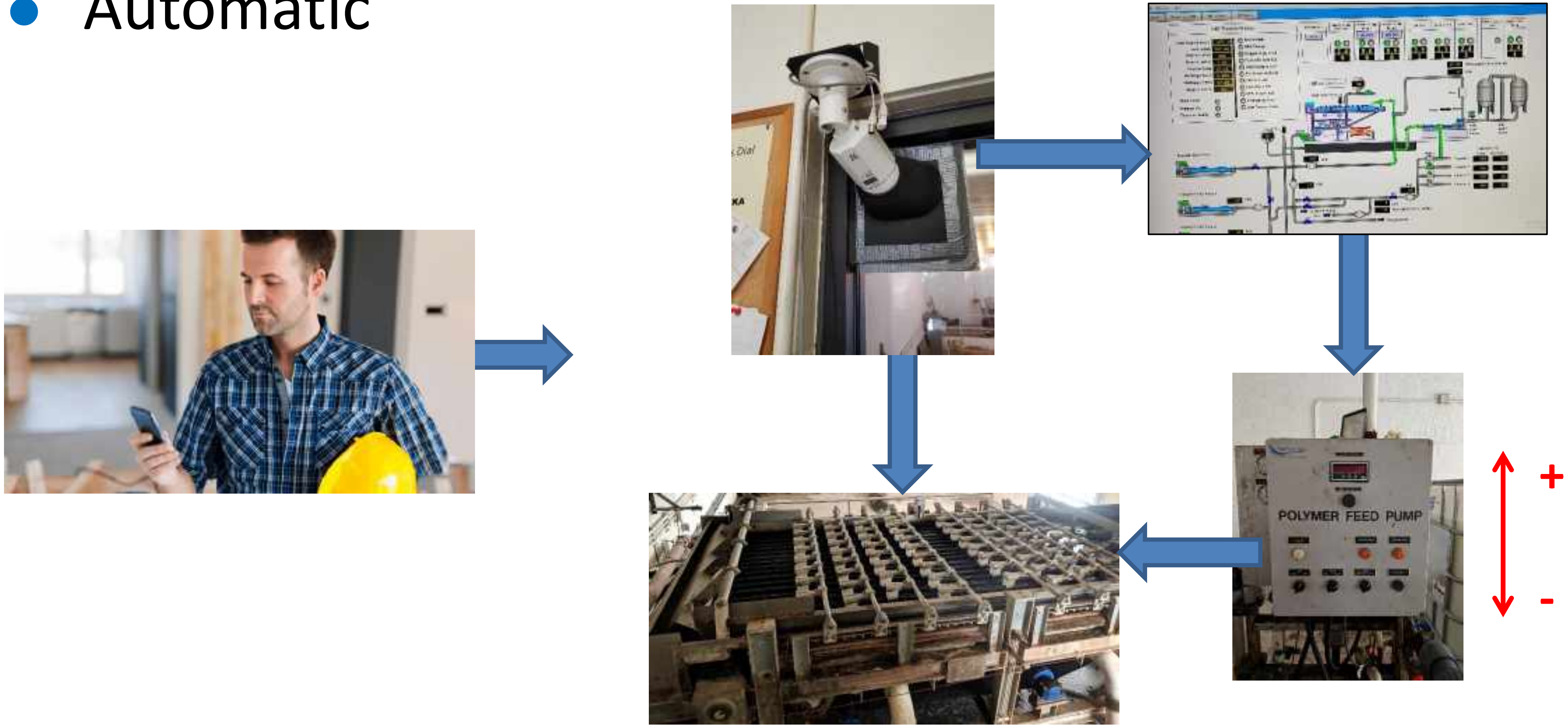
Thickening

- Automatic



Thickening & Dewatering

- Operational Decisions
  - Schedule of Operations (date/time, sidestreams return)
  - Sampling (grab vs. composite)
  - %TS (inline, insertion, bench, vs. lab)




WAS Thickening

- Process Control Guidelines – Fort Wayne Example
  1. Know your system's abilities (max, turndown, points of plugging)

System	Component	Description
Thickener Feed Pumps	Number of Pumps	2
	Capacity of Each Pump	400 gpm @ 26 feet
	Pump Type	Screw Centrifugal
Thickened WAS Pumps	Number of Pumps	2
	Capacity of Each Pump	100 gpm
	Pump Type	Progressive Cavity
Polymer Solution Pumps	Number of Pumps	2
	Capacity of Each Pump	30 gpm
	Pump Type	Progressive Cavity
Polymer Makeup Units	Number	2

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WAS Thickening

- Process Control Guidelines - Fort Wayne Example
  2. Understand the Design Criteria

Parameter	Criteria
Solids Stream	Waste Activated
Inlet Solids Concentration	0.9 – 1.1% Total Solids
Design Flow Rate	90 – 400 gpm
Throughput	2000 lb/hr/dry ton
Machine Type	16x4 Rotary Drum Thickener
Thickened Solids Concentration	Target 5 % Total Solids
Capture Rate	95 %
Polymer Dosage	6 – 10 lb active/dry ton solids

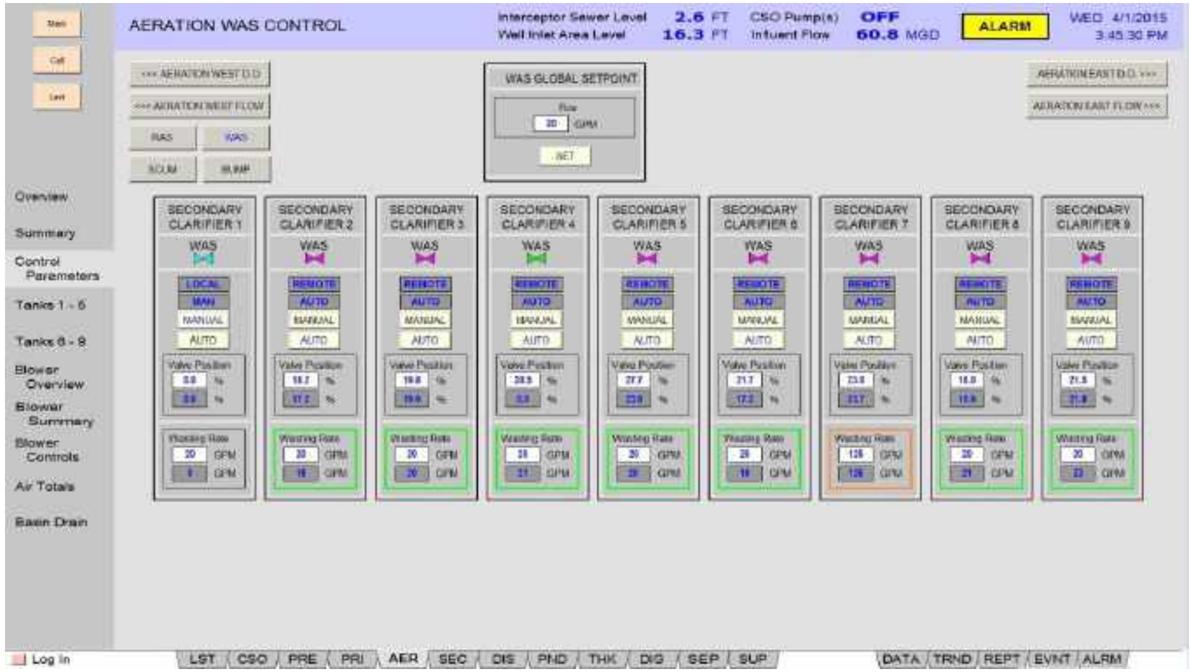
Two Systems – One Duty and One Standby

WAS Thickening

- Process Control Guidelines - Fort Wayne Example

  3. Don’t Let Wasting Control You

     - Current
       - Mixed Liquor Solids Control
       - WAS Flow Setpoint
     - Future
       - On-line Instrumentation (ML and RAS TSS) Meters
       - MCRT Calculation
       - Stabilized WAS to thickening



WAS Thickening

- Process Control Guidelines - Fort Wayne Example

4. Set Goals

Objective

- Thicken all WAS
- Provide effective solids capture to minimize recycled loading to the wastewater process
- Maximize thickening solids concentrations
- Optimize polymer use.

Performance Goals

- Produce a filtrate suspended solids concentration of less than 1,000 mg/l
- Maintain process effective/cost effective polymer dosages (< 10 lb/ton)
- Thicken solids to 3.5 – 4.5%
- Maintain the thickened sludge pipeline pressure less than 60 psig
- Maintain sufficient polymer inventory.

Dewatering

- Common Types of Mechanical Dewatering Equipment
  - Belt Filter Press (BFP)
  - Screw Press
  - Centrifuge

- Monitoring and Control are very similar to thickening

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Dewatering

- Control Functions
  - Feed Rate
  - Polymer
    - Manual / Remote Manual / Auto?
      (few if any run in auto, lack of trust)

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Dewatering

- Control Functions
  - Feed Rate
  - Polymer
    - Manual / Remote Manual / Auto? (few if any run in auto)
  - Pressure
    - Higher pressure → Dryer Cake Solids (until it makes a mess)

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Dewatering

- Control Functions
  - Pressure: BFP (more rollers/belt PLI)

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Dewatering

- Control Functions
  - Pressure: Screw Press (cone back-pressure)

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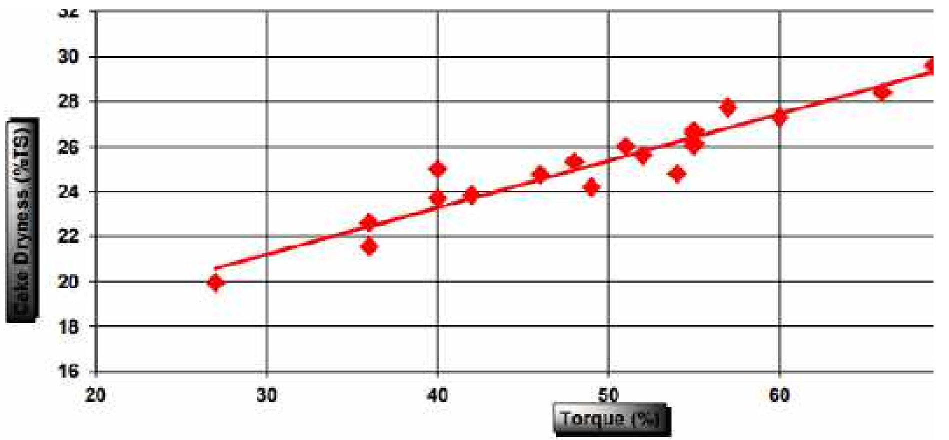
Dewatering

- Control Functions
  - Pressure: Centrifuge (torque)



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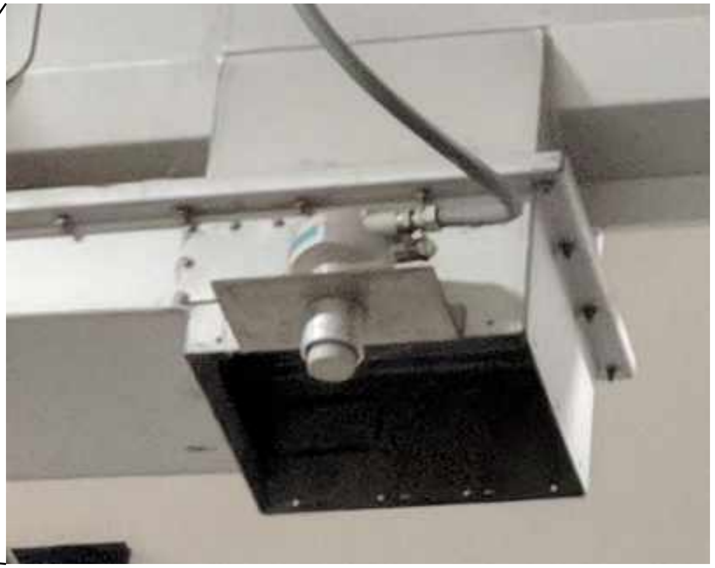
Dewatering

- Control Functions
  - Discharge Conveyance
    - Automatic Leveling Devices



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The ABC'S for Successful Process Control

- **A**dopt Control Strategies That Work Best For You
- **B**e Consistent in All Monitoring and Control
- **C**ollect As Much Information As You Can, and Use It to Evaluate Performance, Develop Trend Charts and Historical Records
- **S**hare What You Learn and Experience With Others

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Questions?

The End – Thank you!

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