WWOA

Virtual Operator Training Series

- April 30th  Activated Sludge  9am – Noon
- May 6th  Anaerobic Digestion  9am – Noon
- May 14th  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.

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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
Process Control & Monitoring: What’s Really Important

WWOA Virtual Training Series
Introductions

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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
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

- Screening
- Grit Removal
- Primary Clarification
- Bioreactor
- Secondary Clarification
- Tertiary Filtration
- Disinfection
- Digestion
- Thickener
- Dewatering
- Filtrate
- Thickener
- Backwash

- Permit Required
- Process Sample
Special Sampling (Speciation)

COD
- Unbiodegradable Soluble
- Unbiodegradable Particulate
- Slowly Biodegradable Particulate
- Slowly Biodegradable Colloidal
- Readily Biodegradable

Nitrogen (TKN)
- Organic N
- Ammonia N

Phosphorus
- Soluble Non-Reactive
- Soluble Reactive
- Particulate
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)
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
Influent Pumping

26.6 ft

- 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
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
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
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.
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
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
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
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
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
Primary Clarification
Primary Clarification

Primary treatment: removes stuff that already settles

Activated sludge: converts non-settleable to settleable, then settles it out
1. Remove solids by gravity (low cost).

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

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

- Primary Clarifiers
  - Primary Influent
  - Primary Effluent

- Settles

- Total BOD
  - Particulate
  - Soluble
  - Colloidal

- Passes to Secondary Treatment
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?
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
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
CEPT Doses and Removal Efficiency

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)

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Unit cost (£/ton)</th>
<th>Average dose (g/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td>175–200</td>
<td>15–45</td>
</tr>
<tr>
<td>Polyaluminium chloride (PACl)</td>
<td>250–400</td>
<td>15–40</td>
</tr>
<tr>
<td>Calcium hydroxide (lime)</td>
<td>50–80</td>
<td>100–250</td>
</tr>
<tr>
<td>Ferric chloride</td>
<td>250–350</td>
<td>30–60</td>
</tr>
<tr>
<td>Ferric sulphate</td>
<td>200–290</td>
<td>45–60</td>
</tr>
<tr>
<td>Polymer (Polyelectrolyte)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– cationic</td>
<td>2200–3000</td>
<td>0.1–2.0</td>
</tr>
<tr>
<td>– anionic</td>
<td>2000–2300</td>
<td>0.5–3.0</td>
</tr>
</tbody>
</table>

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.
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 (particularly 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 BOD₅ REMOVAL RATES FOR VARIOUS FILTER TYPES

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>BOD₅ Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Rate</td>
<td>80 - 90</td>
</tr>
<tr>
<td>Intermediate Rate</td>
<td>50 - 70</td>
</tr>
<tr>
<td>High Rate</td>
<td>65 - 85</td>
</tr>
<tr>
<td>Roughing Filter</td>
<td>40 - 65</td>
</tr>
</tbody>
</table>

**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
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:

$$SK = \frac{mg}{d} \times \frac{1,000,000 \text{ gal}}{mg} \times \frac{d}{1,440 \text{ min}} \times \frac{1}{2,462 \text{ sf}} \times \frac{m^3}{0.41 \text{ sf} - \text{min}} \times \frac{m}{1,000 \text{ mm}}$$

$$SK = \frac{4 \text{ arms} \times 0.1 \text{ rounds}}{\text{min}} \times \frac{60 \text{ min}}{\text{hr}}$$

*Note: Auto SK schedule operates on AUTO SK SCHEDULE. Use manual for constant speed mode.*

All lift pumps must be OFF to turn off distributor.
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
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
Chat

Answer the following:

Are you missing baseball this year?
5 Minute Break

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

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CLEARAS
WATER RECOVERY

ENVIRONMENTAL
EQUIPMENT

ENERGY

MULCAHY SHAW WATER

WISCONSIN PUMP WORKS
Fluid Handling Professionals
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.
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)
Selectors/BNR Monitoring Considerations

Example: MUCT’ Process

- Anaerobic: P release & VFA’s used
- Anoxic: NO3 → N2

Influent

Bioreactor

RAS w/ NO3
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.*
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
Achieving Appropriate Loading Rates

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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
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
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
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
Adequate Nutrients Needed

- **Nitrogen & Phosphorus**
  - P Deficiency Most Common
  - Industrial Impacts
  - In-Plant Chem Feed

- **Other Essential “Nutrients”**
  - DO
  - Food
  - Micronutrients
No Evidence of Filamentous Bulking
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

Bioreactor (Aeration Tank) → Clarifier

Inf WW (PE) → RAS → ML → Clarifier Effluent

WAS
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”
Target SRT Control

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

This computation can seem tedious, intimidating...
Target SRT Control

Daily Waste Volume = \( M_{MLSS} \div (SRT \times X_{WAS} \times 8.34) \)

This computation can seem tedious, intimidating...but simple spreadsheets can be great process control aids and provide historical records.
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!
Let’s Look at The Critters – Higher Life Forms (Good Ones)
More Critters – Not So Good Indications
View of the Bulk Solution – Good and Bad
One Last Look – Perspectives on Foaming
What About Clarifiers?

What Happens in a Clarifier?

Mixed Liquor

Effluent

Return Sludge Back to Aeration Tanks
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)
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

![Diagram of a clarifier process](Image)
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
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
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
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
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
Tertiary Treatment

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

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

- Monitoring
  - Historical data – record of optimization and upgrade

Words to live by:
“You can’t control what you don’t measure.”
Tertiary Treatment

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

- Monitoring
  - Floc development
  - Spot light / illuminate
Tertiary Treatment

- Monitoring
  - Backwash frequency – measure of capacity
    - Before
    - After
Tertiary Treatment

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

Bulk dose setup for ferric chloride

Tote Connection for
- Alum
- PAC
- RE300
- Etc
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
Tertiary Treatment

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

Takacs, et. al
Tertiary Treatment

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

- Inside Out
- Spray backwash
- Compact design

- Outside In
- Vacuum backwash
- Can be tolerable to high solids loading rate
How to Handle Excess Flows

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

- Secondary Effluent (soluble phosphorus)
- Filter Influent (chemical solids)
Disinfection
Goals for Monitoring and Control:

1. Optimize chemical use and cost

2. Maintain consistent performance

3. Avoid water quality issues
Disinfection Monitoring

Chemical Feed Rate and Inventory

Chlorination

Chlorine Residual

Dechlorination

Wastewater Flow Rate

Indicator Bacteria Counts (MPN)
Optimizing Disinfection Efficacy

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

Log Reduction is proportional to \( C \times T \)
(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**
- **Short Detention Time and/or Low Residual = Poor 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
Control Timescales

- Adjust chemical feed based on:

  **Flow Rate**
  - Short Time Scale
    - Quick control response
    - Feed must be proportional to flow to maintain same dose

  **Disinfectant Residual**
  - Medium Time Scale
    - Tempered control response
    - Consider lag time in system

  **Effluent Quality (Bacteria Counts)**
  - Long Time Scale
    - Manual performance evaluation
    - Adjust dose or residual based on historical performance
Approaches to Monitoring/Control

**Spectrum of Complexity**

- **Less Complex**
  - Grab Samples
  - Manual Control

- **More Complex**
  - Grab Samples
  - Flow Proportional Control
  - Field Analyzer
  - Compound Loop Control

*Works well for many plants*
Compound Loop Control

Process Controller
- Flow Pace Chemical Feed Rate
- Trim Flow Paced Signal (+/−)

Flow Meter / Parshall Flume

Flow Signal

Residual Signal

Indicating Transmitter
- Total Chlorine Analyzer

Chlorination

Dechlorination

Flow Pace Chemical Feed Rate
Trim Flow Paced Signal (+/−)
Dechlorination Control

1. Feed Forward Control
   OR
2. Compound Loop Control

- Total Chlorine Analyzer
- Sulfite or “Zero-Biased” Analyzer
- Process Controller
  - Flow Pace Chemical Feed Rate
  - Adjust Flow Paced Signal (+/-)

- Flow Meter / Parshall Flume
- Chlorination
- Dechlorination
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)

**Wastewater Flow Rate**

**Fixed or Variable Weir - Maintain Adequate Bulb Submergence**

**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

- **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).

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.
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
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
• 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)
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°C, need 25 days
    - At 10°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

**Alkalinity Gains/Losses (mg as CaCO3 / mg N)**

<table>
<thead>
<tr>
<th>Process</th>
<th>Gains/Losses (mg as CaCO3 / mg N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonification</td>
<td>3.57 mg/mg</td>
</tr>
<tr>
<td>Nitrification</td>
<td>7.14 mg/mg</td>
</tr>
<tr>
<td>Denitrification</td>
<td>3.57 mg/mg</td>
</tr>
</tbody>
</table>
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)
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.
Thickening & Dewatering
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
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
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)
Thickening

- Remote 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)
  - Automatic (camera algorithm adjusts polymer)
Thickening

- Automatic

![Diagram of thickening process](image-url)
Thickening & Dewatering

- Operational Decisions
  - Schedule of Operations (date/time, sidestreams return)
  - Sampling (grab vs. composite)
  - %TS (inline, insertion, bench, vs. lab)
Process Control Guidelines – Fort Wayne Example

1. Know your system’s abilities (max, turndown, points of plugging)

<table>
<thead>
<tr>
<th>System</th>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickener Feed Pumps</td>
<td>Number of Pumps</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Capacity of Each Pump</td>
<td>400 gpm @ 26 feet</td>
</tr>
<tr>
<td></td>
<td>Pump Type</td>
<td>Screw Centrifugal</td>
</tr>
<tr>
<td>Thickened WAS Pumps</td>
<td>Number of Pumps</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Capacity of Each Pump</td>
<td>100 gpm</td>
</tr>
<tr>
<td></td>
<td>Pump Type</td>
<td>Progressive Cavity</td>
</tr>
<tr>
<td>Polymer Solution Pumps</td>
<td>Number of Pumps</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Capacity of Each Pump</td>
<td>30 gpm</td>
</tr>
<tr>
<td></td>
<td>Pump Type</td>
<td>Progressive Cavity</td>
</tr>
<tr>
<td>Polymer Makeup Units</td>
<td>Number</td>
<td>2</td>
</tr>
</tbody>
</table>
WAS Thickening

- Process Control Guidelines - Fort Wayne Example

  2. Understand the Design Criteria

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

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
Control Functions

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

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

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

- Pressure: Centrifuge (torque)
Dewatering

- Control Functions
  - Discharge Conveyance
    - Automatic Leveling Devices
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
Questions?
The End – Thank you!

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