Chemically Enhanced Primary Treatment for Carbon Redirection

SWIFt: Track 3 – Process Improvements

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Introductions

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Agenda

1. Intro to CEPT
2. Potential Energy Savings
3. Steps to Evaluate
4. Installing CEPT
5. Lessons Learned
Intro to CEPT

- **Chemically Enhanced Primary Treatment (CEPT)**
  - Using external chemical addition to increase particle capture within primary treatment
  - External chemicals:
    - Coagulant – typically a metal salt like alum or ferric chloride
    - Polymer – “tie it all together”
Intro to CEPT

- Raw Wastewater
- Coagulation
- Flocculation
- Enhanced Sedimentation

Metal Salt
Polymer
Intro to CEPT

Conventional Primary Treatment

55% to 75% of Infl. BOD$_5$ to Secondary Treatment

25% to 45% of Infl. BOD$_5$ to Anaerobic Digestion

Chemically Enhanced Primary Treatment

20% to 60% of Infl. BOD$_5$ to Secondary Treatment

40% to 80% of Infl. BOD$_5$ to Anaerobic Digestion
How does CEPT result in Energy Savings?

• Increasing particulate capture in primary treatment reduces downstream loading to secondary treatment
  – Less loading to bioreactors → Less aeration energy

• Redirects loading to residuals treatment where it could potentially be recovered as biogas using anaerobic digestion
  – “Carbon Redirection”

• Side note: Many facilities install CEPT for increasing wet weather treatment capabilities
Carbon Redirection has been identified as a major player in the “Plant of the Future”

- Water Environment Research Foundation (WERF)
- Look forward 40 years – water quality, energy, values
- 30 attendees at 2009 Workshop – US, Canada, Europe, Singapore
- “Can we achieve carbon and energy-neutral treatment?”
Carbon Redirection –
Minimize plant oxygenation requirements and maximize diversion of carbon to anaerobic treatment for biogas production and energy co-generation

The Urban Water Resource Recovery Center

Sewage

Urban food waste
Spatio
Misc. organics

Primary Clarification or Filtration

Low Energy Membrane for BOD and TDS removal

Nutrient Removal and Recovery

Optimized Anaerobic Digester

Algae Conversion to Biodiesel

Final Filter

Methane

Efficient Electricity Generation

CO2

Primary Revenue
Ultrapure water for industry makeup and aquifer recharge
Peak electricity sales to grid or local use

Other Revenue
Urban waste disposal
Carbon credits
Sewage treatment fees

Secondary Revenue
Brackish water for cooling, irrigation
Fuel savings
Inorganic Fertilizer

Final Effluent

Raw Sewage

Biogas

Liquid line

Solid line

Option 1: ANA

Option 2: A/B PST

Digester

ANAMMOX

SHARON / BIOFILM

Final Effluent

Water Environment Research Foundation, 2010
Typical Impact of Primary Clarification

 Taken from Jeyanayagam, 2016 – *Carbon Redirection and its role in Energy Optimization at Water Resource Recovery Facilities*
Carbon Redirection using Proprietary Technologies

Energy Comparison (30 mgd)

- Conventional Plant
- Plant with Redirection (Captivator)

- Aeration Energy Used
- Energy from Biogas

Credit: Evoqua Water Technologies
VCS Ejby Mølle WWTP – Path to Energy Self Sufficiency

- **Chemically Enhanced Primary Treatment**
- **Partial Effluent Filtration**
- **Lower Bioreactor Sludge Age**
- **No Trickling Filters**
- **Existing Condition (Baseline)**

Comparison of energy produced, additional energy produced, and additional energy saved.
VCS Ejby Mølle WWTP – Implementation of Several EO Os achieved self sufficiency
Evaluate the Potential use of CEPT

• Do you have primary treatment?
• What can I achieve with my wastewater?
  – Wastewater characterization and modeling
  – Jar Testing
  – Stress Testing (optional)
• Sludge handling
  – Sludge Removal
  – Sludge Thickening
  – Anaerobic Digestion/Biogas Recovery
Evaluate Potential

• Wastewater Characterization and Modeling
  – Wastewater can be fractionated into...
    • Soluble (will pass through a PC)
    • Particulate (Can be removed in a PC)
    • Colloidal (Can be removed with a chemical aids)
  – Each can either be biodegradable or non-biodegradable
  – Using sampling across your plant and laboratory analysis, these fractions can be estimated
  – This information can be put into a wastewater process model to estimate the whole plant potential impact
Evaluate Potential

• Jar Testing
  – Determine non-settleable TSS and BOD5
  – Test combinations of coagulants, polymers, and dosages
  – Review secondary impacts:
    – Phosphorus
    – Alkalinity
Evaluate Potential

• Stress Testing (optional)
  – Determines if there are any mechanical limitations to the primary sedimentation system
    • short-circuiting
    • poor sludge removal
  – Review removals for increasing overflow rates
    • TSS, BOD5, COD, etc
Evaluate Potential

• Residuals Handling
  – The use of a whole plant process model can aid in the evaluation to residuals handling
    • Flow/loading impacts to sludge pumping, storage, thickening and dewatering
    • Loadings to Digesters
    • Predict Biogas generation
      – Energy Recovery Potential
    • Impacts to Recycles
What do I need to Install CEPT?

• Coagulant/Polymer Dosing
  – Chemical Storage Facility
  – Chemical Pumping

• Chemical Injection
  – Diffuser
  – Pipe Injection

• Rapid Mix at Coagulant Dosing
  – If insufficient mixing
Misc Pictures – Charlotte (NC) Water McAlpine Creek WWMF

Chemical Building

Ferric Chloride Storage Tanks

Ferric Chloride Dosing Pumps
Lessons Learned

- Wastewater Characteristics
- Jar Testing
- Implications to Secondary Treatment
- Installation Issues
- Residuals Handling Issues
- Aeration System Turndown
Lessons Learned

• Inadequate Wastewater Characteristics
  – Initial evaluation showed incredible promise for CEPT:
    • ~80% TSS removal, ~70% BOD5 removal
  – After a series of sampling, it was found that the soluble BOD5 content was >2x higher than initially estimated
    • ~13% → ~30%
  – Revised CEPT removal estimates:
    • ~80% TSS removal, 50% BOD5 removal
  – Results in higher aeration rates and lower biogas yield than previously estimated
Lessons Learned

• Jar Testing
  • Initial estimates were based on industry averages and performance at another Client Facility
  • Jar Testing showed little to no increase in performance even at high coagulant dosages (>30 mg/L).
  • Further investigation found that coagulation was being inhibited by chelating compounds discharged from a local industry. The chelating compounds were binding with the metal salt coagulant.
  • Example 2: Ferric Chloride dosing estimates were much higher than expected due to (seasonally) high influent sulfides. Iron will preferentially bind with sulfides.
Lessons Learned

• Implications to BNR
  – Alkalinity and Nitrification (Biological ammonia oxidation)
    • Many typical coagulants (Ferric Chloride, Alum) reduce alkalinity when dosed
    • If too much alkalinity is removed, then not enough is available for biological nitrification which can lead to increased risk of inhibition and permit violation
Lessons Learned

• Implications to BNR
  – Phosphorus Removal
    • Coagulants (metal salts) will react with soluble phosphorus.
    • If too much phosphorus is removed, then biological secondary treatment will be inhibited.
  • Rule of thumb:
    – Insure at least 1.5 mg PO4-P/L is available after CEPT
Lessons Learned

• Installation Issues
  – For best performance, need a ‘rapid mix’ (high agitation), when the coagulant is dosed
  – Typical good locations for coagulant dosing
    • Discharge from a force main
    • Drop structure (box)
    • After weir (such as flow splitting structure)
    • Parshall Flume
Lessons Learned

• Installation Issues
  – Ideally need at least 5 minutes of detention time after coagulant addition for flocculation
  – Typical areas for good detention time and flocculation
    • Aerated Grit Chamber
    • Aerated Channels
    • Pre-aeration basin
    • Custom Engineered Flocculation Basin
Lessons Learned

• Installation Issues
  – Once you add polymer, you need minimal shear prior to settling!
  – Any shear will tear the ‘ballasted’ particles apart significantly reducing its effectiveness
  – Most common shear is from flow splitting (weirs). Try to add polymer at this location.
  – Make sure to use a chemical diffuser. If ‘dripped’ in, polymer will tend to float on the surface and not bind to particles!
Lessons Learned

• Residuals Handling
  – CEPT will create a lot of sludge
    • Chemical Sludge + increased TSS capture
  – To be most effective, need to remove the sludge as fast as possible
    • Don’t want this sludge to resuspend
    • Need minimal sludge blanket, no thickening in the clarifier.
    • Sludge concentrations typically are 0.25 – 0.75% TS
  – Low concentrations → High flow rates
    • Do you have adequate pumping capacity?
Lessons Learned

• Residuals Handling
  – (Again) CEPT will create a lot of high volume, low concentration sludge
  – Will need sludge thickening downstream prior to anaerobic digestion which wants ~5% TS sludge
    • Best practice is to use gravity thickeners
      – Inherent storage capacity
      – Capable of handing varying sludge flow rates
    • May need sludge storage if using other mechanical thickening technologies (example: Drum or Gravity Belt Thickening)
Lessons Learned

• Residuals Handling
  – Iron (Ferric) sludge to anaerobic digestion can form vivianite
    • Nuisance precipitant/mineral like struvite
    • Forms a grit that can settle in the digester if mixing is inadequate
    • Can also clog pipes
  – Need to periodically inspect pumps, pipes, etc for evidence and clean as necessary
Lessons Learned

• Aeration System Turndown
  – While CEPT can do a great job at reducing the oxygenation loading to secondary treatment, if the aeration equipment can’t turn down, then energy savings are negated.
    • Need to make sure the aeration system has turndown capability.
    • Or may need to replace blower(s) or mechanical aerator(s) with a smaller unit to take advantage of savings
  – Also need to insure treatment basins don’t become mixing limited (mixing energy > treatment energy)
Chemically Enhanced Primary Treatment (CEPT) for Carbon Redirection

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