Bio-P, Digestion and Dewatering: Unexpected Consequences?

Iowa WEA 2016 Annual Conference
June 9, 2016

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Presentation Outline

- History/Background Information
  - Central States Region Survey
- Supporting Evidence
- Suspected Causative Factors
- Future Plans
- déjà vu?
History/Background Information
### Sun Prairie WPCF

- **Major Plant Upgrade 2006**
  - RBC to Bio-P Nitrifying Activated Sludge
  - Anaerobic Digestion Improvements
  - Belt Filter Press Dewatering
    - Pilot Testing During Design => Dewatered Cake ~ 22% TS

- **Startup Last Quarter 2006/Early 2007**
  - Initial Dewatered Cake ~ 17-18% TS
  - Cake Solids Decreased Over Several Month Period
    - Currently Achieving 12-14% TS
Sun Prairie WPCF
Beloit WPCF

- Bio-P & Anaerobic Digestion Since 1992
- Added BFP in 2012
- Dewatered Cake Characteristics
  - Good Release From Belt
  - No Free Water (Appears Typical of 18% TS +/-)
  - 10-12% TS Typical
- Plant Staff Worked to Optimize Performance
Beloit WPCF

- **Dewatering Optimization Efforts**
  - Moved Polymer Injection & Mixing Valve Location
  - Added Belt Spray Bars in Washboxes
  - Increased Belt Hydraulic Pressure
  - Added PRV to Eliminate Gas Binding in Feed Line
  - Put Second Digester Online to Increase VS Destruction

- **Results: Currently Achieving ~ 15% TS**
  - At Similar Polymer Dosage & Sludge Feed Rate
Marquette (MI) WWTF

- **Major Plant Upgrade 2009**
  - RBC to Bio-P Nitrifying Activated Sludge
  - Anaerobic Digestion Improvements
  - Belt Filter Press Dewatering

- **Startup**
  - Initial Dewatered Cake ~ 12-14% TS
  - Changed Polymer Spring 2011
    > Currently Achieving 14-16% TS
Kiel WWTP

- Activated Sludge, Anaerobic Digestion, BFP Dewatering & RDP EnVessel Pasteurization
  - Dewatered Cake 15-19% TS

- Converted to Bio-P ~ April 2012
  - Discontinued Need for Ferric Addition
  - Dewatered Cake 15-16% TS

- What’s Different Than Sun Prairie, Beloit, Marquette???
  => Only Primary Sludge Goes to Anaerobic Digestion
However, there have been consequences...

Significant Reduction in Stack Height
Ok, Is This Real or Not???

Others Are Also Seeing This, Including:

- Other Wisconsin Plants (ongoing survey)
- Hampton Roads Sanitary District Atlantic & Nansemond Plants
- Met Council Environmental Services Empire & Blue Lake Plants
- Metro Denver, CO

A number of plants in Europe as well...
HRSD Plants

- **Nansemond**
  - Anaerobic Digestion & High Solids Centrifuges
  - Originally VIP/MUCT With Supplemental Ferric
    > Dewatered Cake 22-24% TS Consistently
  - Conversion to 5 Stage Bardenpho, Ostara & No Ferric
    > Dewatered Cake 18-18.5% Solids
  - Was Ferric Addition Making a Difference, or Did Ostara Have an Impact?
HRSD Plants

- **Atlantic**
  - Originally HPO With CEPT (using Ferric & Polymer), Anaerobic Digestion, Centrifuge Dewatering
    > Poor Settleability Mixed Liquor
    > Dewatered Cake ~ 19% TS
  - Converted HPO to A/O, Eliminated CEPT, Acid/Methane Digestion
    > Bio-P & Struvite Formation
    > Excellent Settleability Mixed Liquor
    > Dewatered Cake 15-17% TS
  - Was Deterioration Related to Elimination of Ferric, Formation of Struvite, or Combination?
MCES Empire Plant

Conversion from 2 Sludge to 1 Sludge System

Anaerobic Basins On-Line

Cake Solids (%)

Effluent Total P (mg/l)

Belt Press Cake Total Solids  Plant Effluent Total Phosphorus

Courtesy of Sprouse, 2013
MCES Thoughts to Date

Empire

- **Was Deterioration in Dewatering Due to:**
  - Going from two-stage to single stage activated sludge?
  - Bio-P?
  - New soluble waste streams increasing WAS/PSD ratio to digestion?
  - Combination?

Blue Lake

- **Bio-P, Dewatering, Added Anaerobic Digestion**
- **Dewatering Has Deteriorated Since Digestion Added**
Metro Denver, CO Robert Hite WWTF

Full Scale EBPR Pilot

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Suspcted Causative Factors

- Differences in Extra-Cellular Polymeric Substances (EPS)/Soluble P Concentration of Digested Sludge
  - Evidence that soluble Ortho-P binds water to solids
    > Possibly due to increased presence of EPS/EPS binds water
    > Lower digested sludge soluble Ortho-P => higher cake TS

- Divalent Cation Bridging
Divalent Cation Bridging Theory

Courtesy of Sprouse, 2013
Divalent Cation Bridging Theory

- Prominent Divalent Cations Are $\text{Mg}^{2+}$, $\text{Ca}^{2+}$, and $\text{Fe}^{2+}$
- Prominent Monovalent Cations are $\text{Na}^+$ and $\text{K}^+$

To Help Understand This, Let’s Take a Step Back
With Bio-P, P Release Occurs under Anaerobic Conditions...

Carbon Storage (Energy)

Polyphosphate

Readily Biodegradable Organic Matter (VFA’s)

PO$_4$ Released Into Solution Due to Cleavage of Polyphosphate Bonds
...and P Uptake Occurs Under Aerobic Conditions

Carbon Storage

Energy

Polyphosphate

O₂

CO₂ and H₂O and More Cells (Cell Synthesis)

Soluble PO₄ is Taken Up and Stored in Cell As Polyphosphate Molecules
But That’s Not All...

- Anaerobic Conditions Also Result in the Release of Mg$^{2+}$ and K$^+$

- What’s More, Our Bio-P Bugs Don’t Know the Difference Between an Anaerobic Selector Zone and an Anaerobic Digester
  - Bio-P Bugs $\Rightarrow$ Anaerobic Digester $\Rightarrow$ Release of PO$_4^{3-}$, Mg$^{2+}$ and K$^+$
  - Anaerobic Digestion Also Destroys Cells, Leading to Additional PO$_4^{3-}$ and NH$_4^+$ Release
  - Resulting High Concentrations of Mg$^{2+}$, PO$_4^{3-}$ and NH$_4^+$ Create Ideal Conditions for Struvite
Potential End Result…

Magnesium is Decreasing

And What About That Potassium???
Divalent Cation Bridging Theory
An interesting development is struvite harvesting and claims it can help solve this problem. Several slightly different approaches are at the forefront.

- Ostara Pearl & Multiform Harvest
- CNP Airprex
- *Paques Phosphaq*

*Let’s explore this a bit…*
Ostara

- **Struvite Harvesting on Filtrate or Centrate**
  - After Digested Sludge Thickening or Dewatering
Ostara w/WASSTRIP

- PRIMARY
- ANAEROBIC/AEROBIC
- CLARIFIERS

- WASSTRIP
  - High PO₄ and Mg, low NH₃
  - THICKENING

- BIOSOLIDS
- ANAEROBIC DIGESTER
Airprex

- Forms/Removes Struvite Before Thickening or Dewatering
Both Have Shown Promise – Dewatering Improvements of 4-6% TS

- Stevens Point, WI Pilot Test May 2016
Both Have Shown Promise – Dewatering Improvements of 4-6% TS

But so has just adding ferric to the sludge...
Unfortunately, we’re still in a bit of a quandary…

- Is it Divalent/Monovalent Cation Ratio?
Unfortunately, we’re still in a bit of a quandary...

- Or is it Soluble PO$_4$/ESP & Bound Water?
What’s The Future Look Like? Focused Research Efforts Currently Underway…

- Piloting By Utilities/Struvite Harvesting Vendors
  - Some Full Scale Installations (Primarily Ostara)

- WERF Research Project/Bucknell University
  - HRSD
  - DC Water
  - Metro Denver
  - Others

*We’re on a learning curve, similar to struvite a couple decades ago.*
A Final Thought...

As with many issues in our industry – are we simply re-learning the past?
Acknowledgements

- Hampton Roads Sanitary District, Virginia Beach, VA
  - Charles Bott

- Metropolitan Council Environmental Services, St. Paul, MN
  - George Sprouse

- Metro Wastewater Reclamation District, Denver, CO
  - JB Neethling, Mario Benisch

- Ostara

- CNP Airprex & Centrisys
Acknowledgements

- **Sun Prairie WPCF**
  - John Krug, Lee Graves

- **Beloit WPCF**
  - Harry Mathos, Nate Tillis

- **Marquette WWTF**
  - Curt Goodman, Tom Asmus

- **Kiel WWTP**
  - Kris August

- **Stevens Point WWTF**
  - Chris Levebvre
Thanks for your attention!

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