OUTLINE

• Struvite formation basics
• Locations for struvite formation
• Potential impacts and maintenance requirements
• Monitoring for struvite
• Design techniques to minimize struvite impacts
WHAT IS STRUVITE?

- Crystalline substance
- MgNH$_4$PO$_4$·6H$_2$O
- Magnesium ammonium phosphate hexahydrate
WHERE DOES STRUVITE FORM?

• Anaerobic digesters
• Digested sludge piping, valves, pumps, and mixers
• Dewatering equipment
• Filtrate and centrate piping, valves and pumps
• Rough surfaces preferred
CONDITIONS THAT PROMOTE STRUVITE FORMATION

- Alkaline and higher pH conditions
- Minimum solubility is approximately pH = 10.3
- Elevated temperatures
- Availability of constituents (magnesium, ammonia, and phosphorus)

![Struvite Solubility Product with pH](image)

**Solubility decreases with increasing pH**
WHAT IS VIVIANTE?

- Crystalline substance
- $\text{Fe}_3(\text{PO}_4)_{2.8}(\text{H}_2\text{O})$
- Ferric phosphate
- Color is typically blue, green, or gray-black.
CONDITIONS THAT LEAD TO VIVIANITE FORMATION?

- Excess iron concentrations
- Acidic conditions (lower pH)
- Elevated temperatures
WHERE DOES VIVIANTE FORM?

- Heat exchanger sludge piping
- Sludge conveyance systems with excess iron concentrations and lower pH
IMPACTS OF STRUVITE (OR VIVIANITE) FORMATION

- Increased O&M costs.
- Increased energy costs.
- Equipment downtime.
- Need for redundant equipment and piping.
- Impacts to process control.
STRUVITE CLEANING

- Chemical cleaning (acid or dispersant)
- High pressure flushing
- Pigging
- Removal and replacement of conveyance system components
MONITORING FOR STRUVITE WITH THERMAL IMAGING

- Rapid and nondestructive approach to assess the extent of scaling in piping systems
- Struvite decreases heat transfer and temperature variations can be detected on the surface of piping systems
- Thermal imagery used to map the temperature profile for the piping systems – colder locations indicate struvite formation
- Avoids the need to remove and inspect extensive conveyance systems
- May allow preemptive maintenance before process problems occur
- Dallas Water Utilities and Carollo have proven the utility of this method at their Southside WWTP
METHOD FOR MONITORING VIVIANITE & STRUVITE FORMATION AT HEAT EXCHANGERS

• Struvite and vivianite reduce heat transfer.

• Portable Infra-red probe for monitoring surface temperatures of HX and associated piping.

• On-line heat transfer coefficient measurement and trending using temperatures and flow of hot stream and cold streams with alarms.

• Algorithm initiates acid cleaning alarm.

• Proven beneficial at the Truckee Meadows WWTP.

Heat Transfer Q = U x Area x LMTD
U = Heat transfer Coefficient (varies with scaling)
Area = Surface Area of HX
LMTD = Log Mean Temperature Difference
LMTD = \{(TE1 – TE4) – (TE2 – TE3)\}/LN\{(TE1 – TE4) – (TE2 – TE3)\}
CALCULATING POTENTIAL FOR STRUVITE

- Sacramento State – Office of Water Programs
- Software tool for calculating struvite precipitation potential
- Conduct sampling and laboratory testing, then input water quality parameters into software
- Input parameters can be changed to capture various operating conditions
- CD-ROM can be ordered for $75
CONVEYANCE DESIGN TO MINIMIZE STRUVITE

- Pipe materials – glass-lined DIP, PVDF, or other smooth lined pipe
- Pipe sizing for optimal velocity
- Valve selection to minimize turbulence
- Short piping runs
- Dual piping system to allow for one system to be taken out of service
- Access to piping for inspection and cleaning
PROCESS & MECHANICAL DESIGN TO MINIMIZE STRUVITE

- Potential for dilution to reduce formation conditions (example – combine thickening centrate and dewatering centrate)
- Chemical addition
  - Ferric or aluminum salt addition (precipitation and pH reduction)
  - Dispersing agents
  - pH adjustment (carbon dioxide)
- Heat exchangers
  - Lower the temperature delta and oversize the heat exchanger
  - Add ability to acid clean sludge lines – requires redundant unit
- Phosphorus recovery (OSTARA)
CHEMICAL PHOSPHORUS PRECIPITATION TO PREVENT STRUVITE FORMATION

- Goal: chemically bind soluble phosphorus for removal as sludge or cake solids
- Ferric chloride is the most common chemical used
- Adding iron forms vivianite, iron hydroxide, and iron sulfate
- Iron preferentially reacts with hydrogen sulfide (H2S); therefore, must add sufficient iron to account for multiple reactions
- Actual iron dosage should be determined by bench-scale or full-scale testing
FERRIC CHLORIDE ADDITION TO PREVENT STRUVITE FORMATION OR ACCUMULATION

- **Typical ferric chloride feed points**
  - Primary clarifiers
  - Upstream of anaerobic digesters
  - Upstream of dewatering equipment

- **Typical dose rates**
  - Prevention of struvite accumulations = 10 – 35 pounds iron per dry tons solids (lb/dt)
  - Prevention of struvite formation = up to 75 lb/dt

- **Cost Impacts**
  - Additional chemical costs
  - Additional solids handling
PH ADJUSTMENT

- Carbon dioxide has been used to lower pH to a level that prevents struvite formation
  - MWRDGC - Stickney WRP (Chicago)
  - Feed CO2 to digested sludge upstream of dewatering centrifuges
  - Target pH
    ✓ Centrifuge feed = 6.5
    ✓ Centrate = 7.2
  - Reported lower operating costs than iron addition
USE OF DISPERSING AGENTS

- Proprietary products have been developed.
- Prevents struvite deposition by interfering with crystal formation.
- Multiple vendors offer products.

<table>
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<tr>
<th>Product Name</th>
<th>Product Dose per L of Sludge Flow</th>
<th>Vendor</th>
<th>Link</th>
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<tbody>
<tr>
<td>Flosperse</td>
<td>20 – 60 mg/L</td>
<td>SNF INC. (previously Polydyne)</td>
<td><a href="http://www.snf-group.com/IMG/pdf/Dispersants-anti_Struvite.pdf">http://www.snf-group.com/IMG/pdf/Dispersants-anti_Struvite.pdf</a></td>
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<tr>
<td>PolyGone Lines</td>
<td>62 mg/L</td>
<td>Schaners Wastewater Products</td>
<td><a href="http://www.struvite.com/products.html#polygone_lines">http://www.struvite.com/products.html#polygone_lines</a></td>
</tr>
</tbody>
</table>
USE OF DISPERSING AGENTS (CONT.)

- Flosperse dose = 0.3 gallons per million gallons of wastewater treated.
- Typical feed points are dewatering feed or centrate/filtrate.
- Can be used alone or in combination with ferric chloride to prevent struvite formation.
- Costs are typically similar to ferric chloride addition ($9 to $14 per ton dry solids)
- Use of chemical can also dissolve or soften existing deposits.
- Can be used effectively in pipelines along with high pressure flushing to clean out deposits.
HEAT EXCHANGER DESIGN

- Limit hot water temperature at heat exchanger to approximately 150 degrees F. This also prevents sludge “baking” onto the piping.

- Delta temperature between water and sludge is then limited to help minimize struvite or vivianite formation.

- Increase the size of the heat exchanger to accommodate the smaller delta temperature.

- Acid phase digester heat exchangers are especially prone to vivianite formation due to low pH and high temperature conditions.

- Consider redundant heat exchanger to allow for regular inspection and cleaning.
PHOSPHORUS RECOVERY ALTERNATIVES FOR STRUVITE CONTROL

• pH control and/or magnesium addition.

• Proprietary fluidized bed processes have been developed in Japan – not available in the USA.

• OSTARA is a patented phosphorus harvesting process for centrate, using magnesium chloride addition and pH adjustment to create struvite in a pellet form (pearls).
OSTARA PROCESS DESCRIPTION

- Equalized centrate laden with Mg, P and NH$_3$-N pumped into reactor
- MgCl$_2$ is added in stoichiometric excess
- pH is adjusted to slightly alkaline
- Struvite crystals grow in crystallizer on previously formed crystal stock
- Crystals are harvested and screened for size. Large product crushed and recycled, small product returned for more growing
- Crystals are dried and bagged.
- Centrate recycled to plant influent
OSTARA PROCESS SCHEMATIC

Pearl® Process Operation

Precipitation chemistry

\[ \text{Mg}^{2+} + \text{NH}_4^+ + \text{PO}_4^{3-} \]

pH

Crystal growth

Simple operation

- Remote automation
- Material handling
- Sampling/analysis/calibration

Courtesy M. Kuzma, Ostara
SUMMARY

• Bad news:
  • Struvite (and vivianite) formation potential exists at many wastewater treatment facilities.
  • This causes increases to capital and O&M costs.
  • Process conditions can be impacted.

• Good news:
  • There has been significant progress in developing monitoring techniques.
  • Chemical feed or phosphorus recovery systems can minimize struvite formation.
  • Proper design of conveyance systems and heat exchanger facilities can lower O&M costs.
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