BUILDING A WORLD OF DIFFERENCE

No P in My Sludge? Nutrient Recovery Benefits for Biosolids

2018 OWEA Biosolids Workshop

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BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH

Agenda

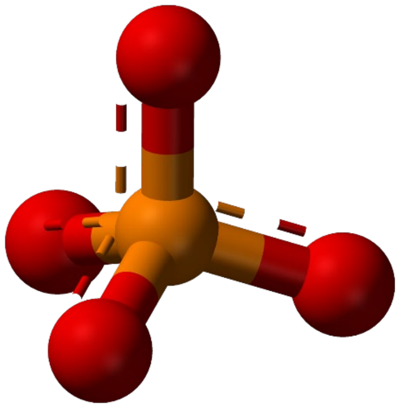
1. Phosphorous and why we care
2. Enhanced biological phosphorous removal (EBPR) and its unintended consequences
3. The technologies and how they prevent these consequences
4. Case study – 16-mgd Liverpool WWTP in Medina County, Ohio
5. The big picture

Phosphorous

…and why we care

Increasing Population Requires Better Phosphorus Management

- Phosphorus-bearing materials cannot be converted to a gas and released to the atmosphere
- Liquid-stream phosphorus removal
- Conversion of soluble phosphorus to a solid
- Chemical and/or biochemical
- Solid/liquid separation
- Settling, filtration, or flotation methods



" We may be able to substitute nuclear power for coal power, and plastics for wood, and yeast for meat, and friendliness for isolation, but for phosphorous there is neither substitute nor replacement." – Isaac Asimov

Ohio Regulatory Strategies

- Similar to Others in Great Lakes and Upper Ohio River Watersheds
- Increased monitoring, research, and planning
- More stringent limits
- Regulatory developments and technology advances have spurred interest in enhanced biological phosphorus removal (EBPR) alternatives

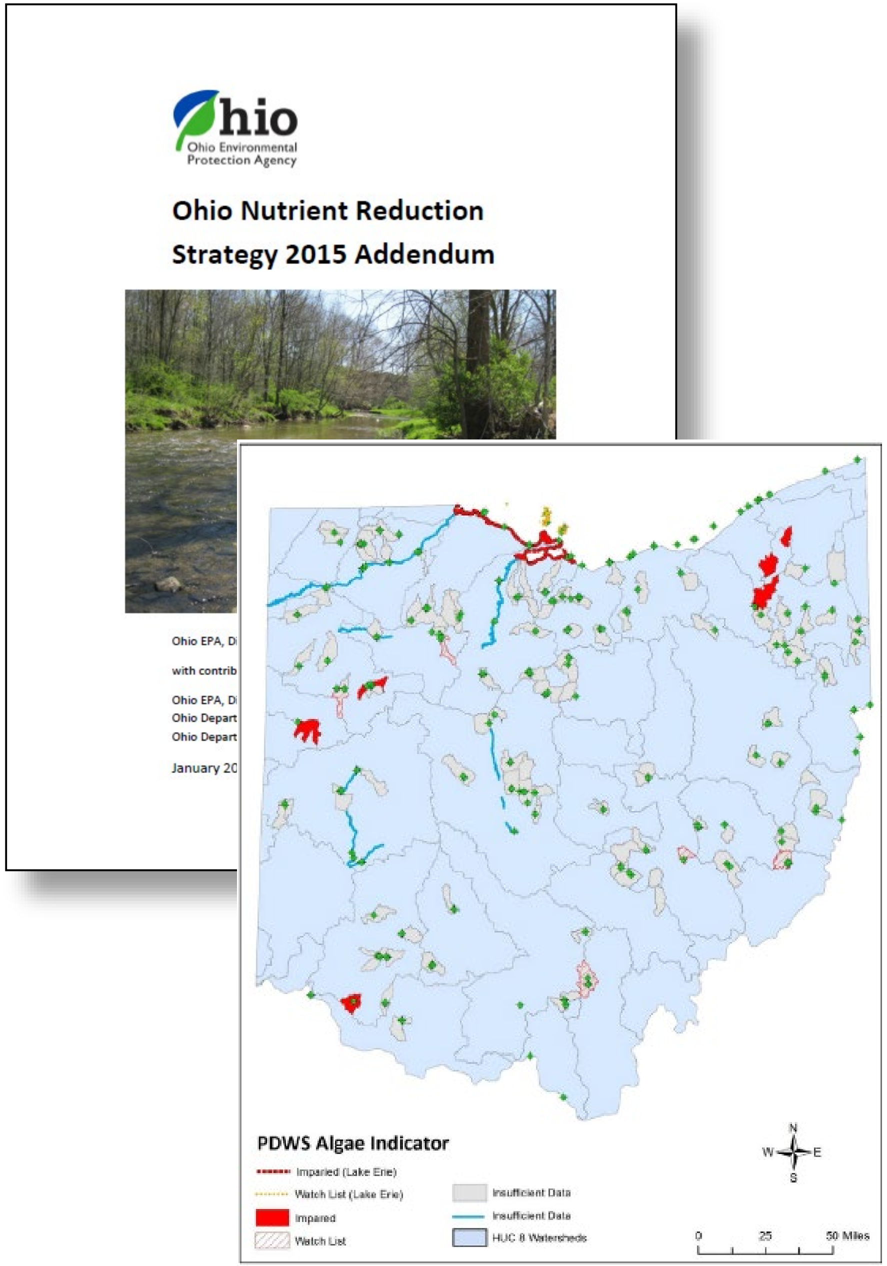


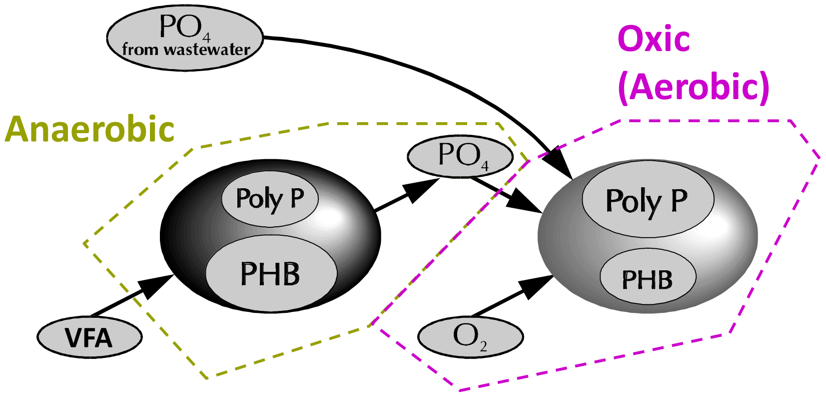
Figure 2. Assessment units with algae indicator results.

Enhanced Biological Phosphorous Removal (EBPR)

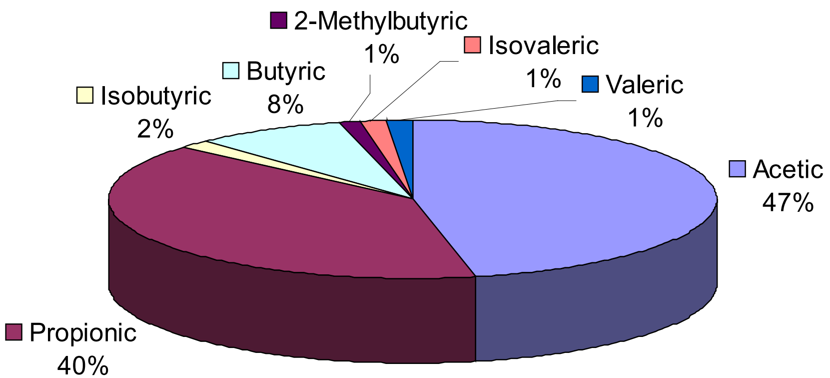
… and its unintended consequences

Mainstream Thinking for EBPR

- Volatile fatty acids (VFAs) drive EBPR mechanism of phosphate accumulating organisms (PAO)
- Anaerobic zone required
- Mixture of VFAs required for PAO to outcompete glycogen accumulating organisms (GAO)



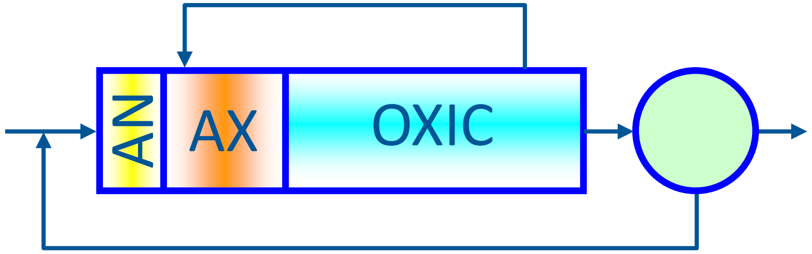
PAO Luxury Uptake Mechanism (Fuhs & Chen, 1975)



Fermentate Analysis
Wakarusa WRF (Lawrence, KS 2007)

First Fermenter Kelowna BC, 1979

S2EBPR is New Reality for EBPR



Traditional EBPR

- Mainstream anaerobic zone
- *Accumulibacter* needs volatile fatty acids (VFA) to trigger P removal
- Poor performance in cold, wet conditions due to lack of VFA

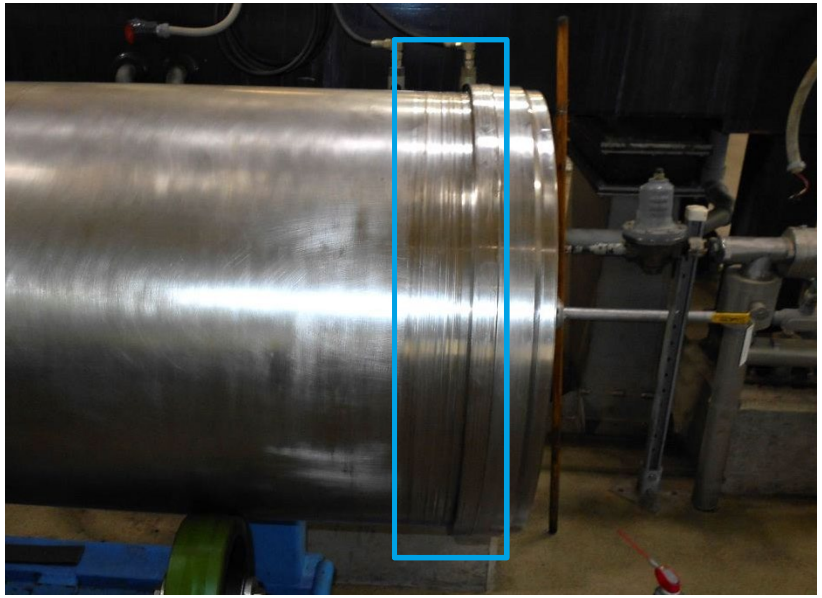
Side-stream EBPR (S2EBPR)

- Side-stream anaerobic fermenter
- *Tetrasphaera* produces VFA and uptakes P in anoxic/oxic and denitrifies in anoxic zone
- Not dependent on influent VFA
- Works together with *Accumulibacter*
- Deep anaerobic conditions fatal for GAOs

- **Good news for cold, weak influents and wet weather!**
  - More efficient use of influent carbon for TP and TN removal
  - Less need for chemicals (ferric, alum, methanol, etc.)
  - Negligible impact from cold or wet-weather flows
  - PAOs outcompete GAOs in cold temperatures

Unintended Consequences of EBPR

- Anaerobic digestion
  - Recycled loads of phosphorus and ammonia in return liquors to the liquid-stream process
  - Decreased dewaterability of digested biosolids
    - Lower than desired %TS
    - Higher than desired polymer usage
- Increased maintenance due to nuisance struvite or vivianite scaling
- Rate and frequency of farm fields biosolid application



Grooves on liquid end of centrifuge bowl from struvite scoring at Jackson Pike WWTP (Columbus, OH 2017)

The Technologies

… and how they prevent these consequences

Preventing These Consequences

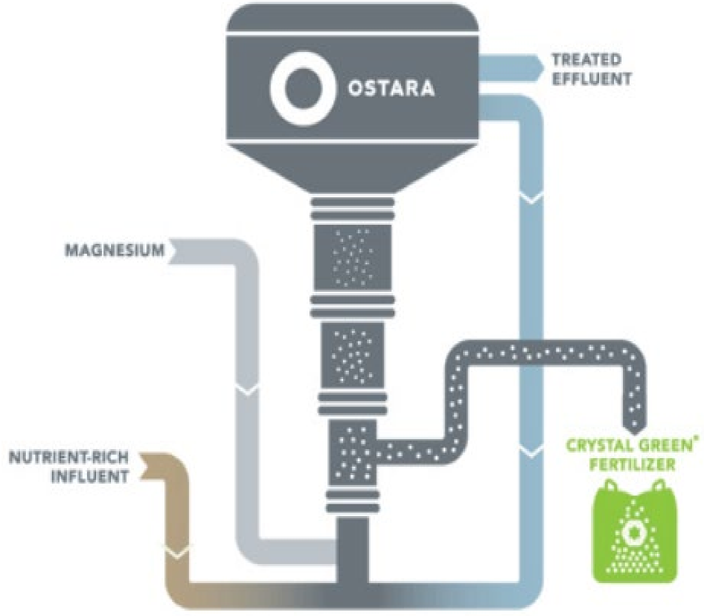
- Struvite recovery from dewatering liquors, with or without pre-digestion anaerobic release
- Struvite sequestration in digested sludge
- Struvite recovery from digested sludge
- Pre-digestion brushite recovery
- Ferric addition to digested sludge
- Degasification of digested sludge

Struvite Recovery from Dewatering Liquors, with or without Pre-digestion Anaerobic Release

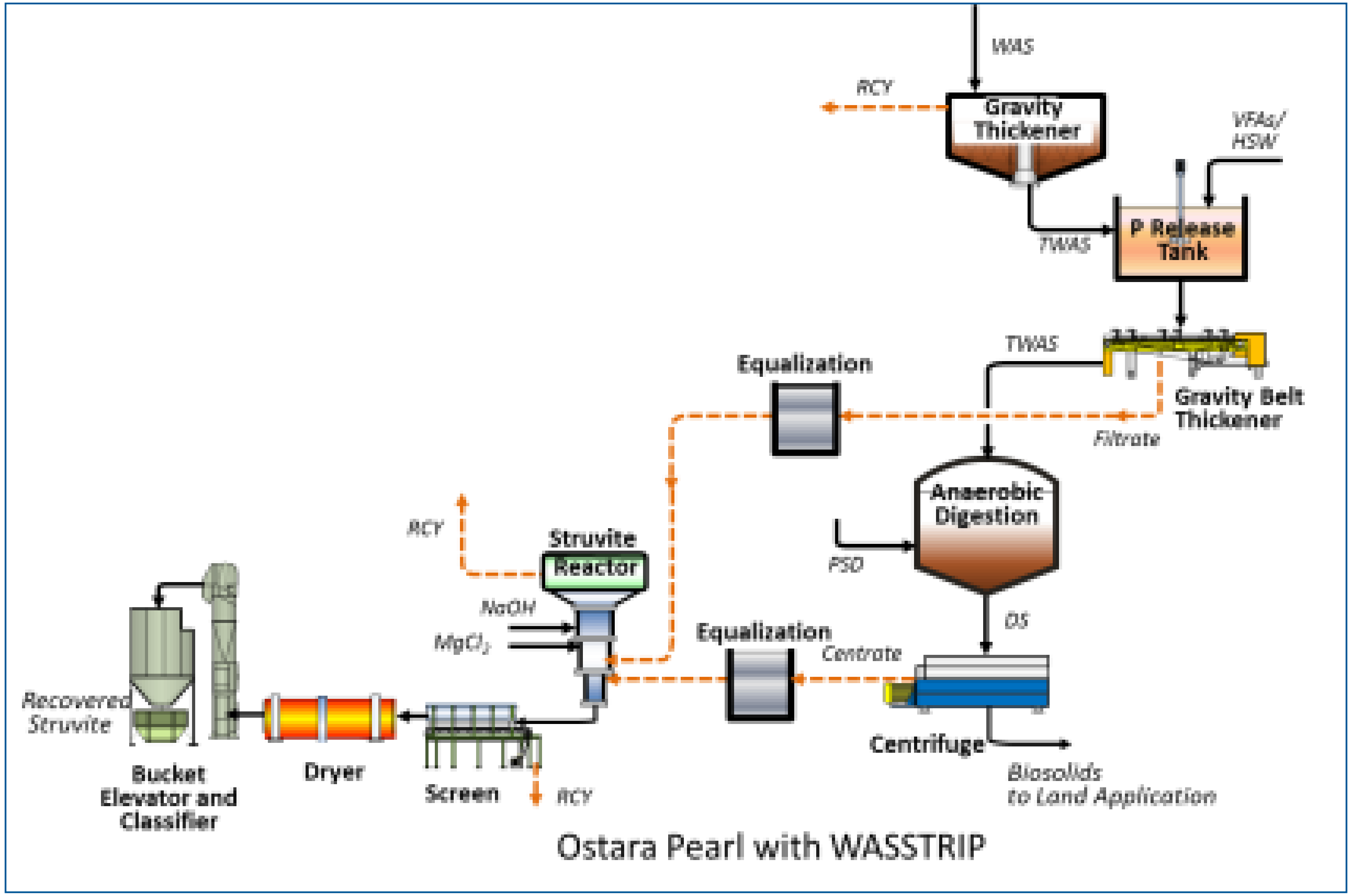
Struvite Recovery from Dewatering Liquors, with or without Pre-digestion Anaerobic Release

- Extracts magnesium and phosphate from WAS thickening centrate and ammonia from digestate dewatering centrate
  - Mixed with magnesium chloride and, if necessary, sodium hydroxide
  - Lowers the potential for nuisance struvite scaling
  - Extracted nutrients are recovered as a commercial-grade struvite fertilizer product
    - Ostara's WASSTRIP and Pearl processes

Ostara Crystal Green®



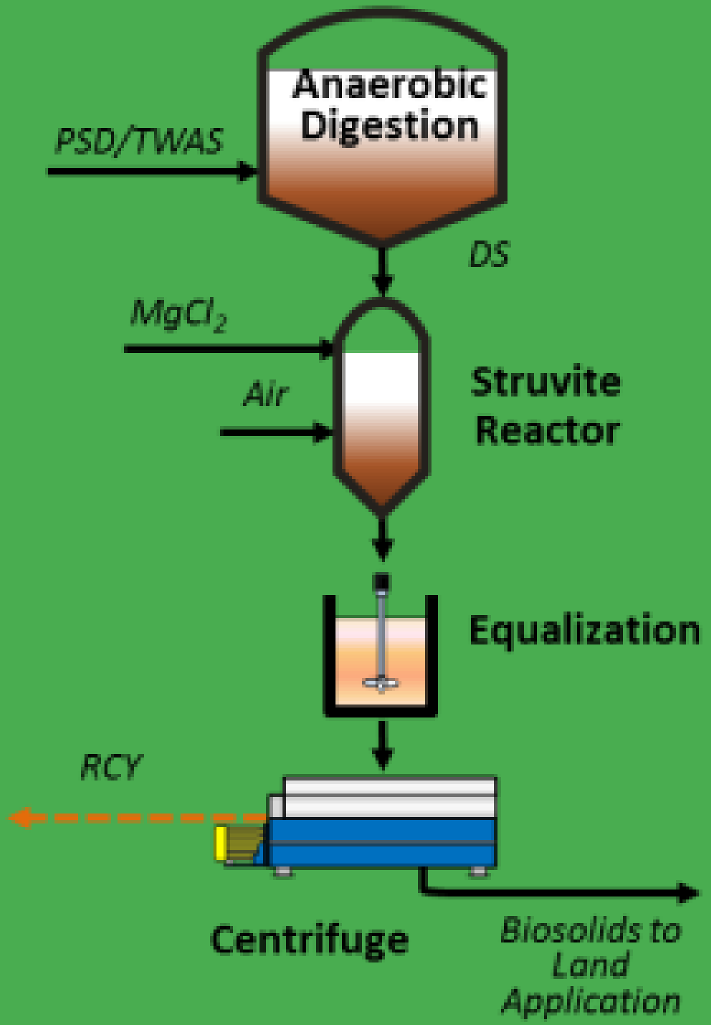
- Pearl: Controlled chemical precipitation in a fluidized bed reactor that recovers struvite in the form of highly pure crystalline pellets
  - Up to 90% P and 40% NH3 load is removed
- WASSTRIP: Additional step to maximize phosphorus recovery with anaerobic digesters
  - Pre-digestion tank upstream of WAS thickening to promote the release of ortho-phosphate and magnesium prior to digestion and dewatering



Advantages	Disadvantages
Struvite control upstream of the digestion process	High capital cost
Reduces P and NH3 load returned to the main plant	Large footprint
Less sludge compared to chemical phosphorus treatment alternatives	Adds process complexity
Potential to recover fertilizer product, generating revenues	Proprietary technology
Reduces P content of biosolids, potentially increasing availability of sites for land application	Requires additional pumping of centrate
Increases environmental sustainability	

Struvite Sequestration in Digested Sludge

Struvite Sequestration in Digested Sludge



AirPrex P Sequestration

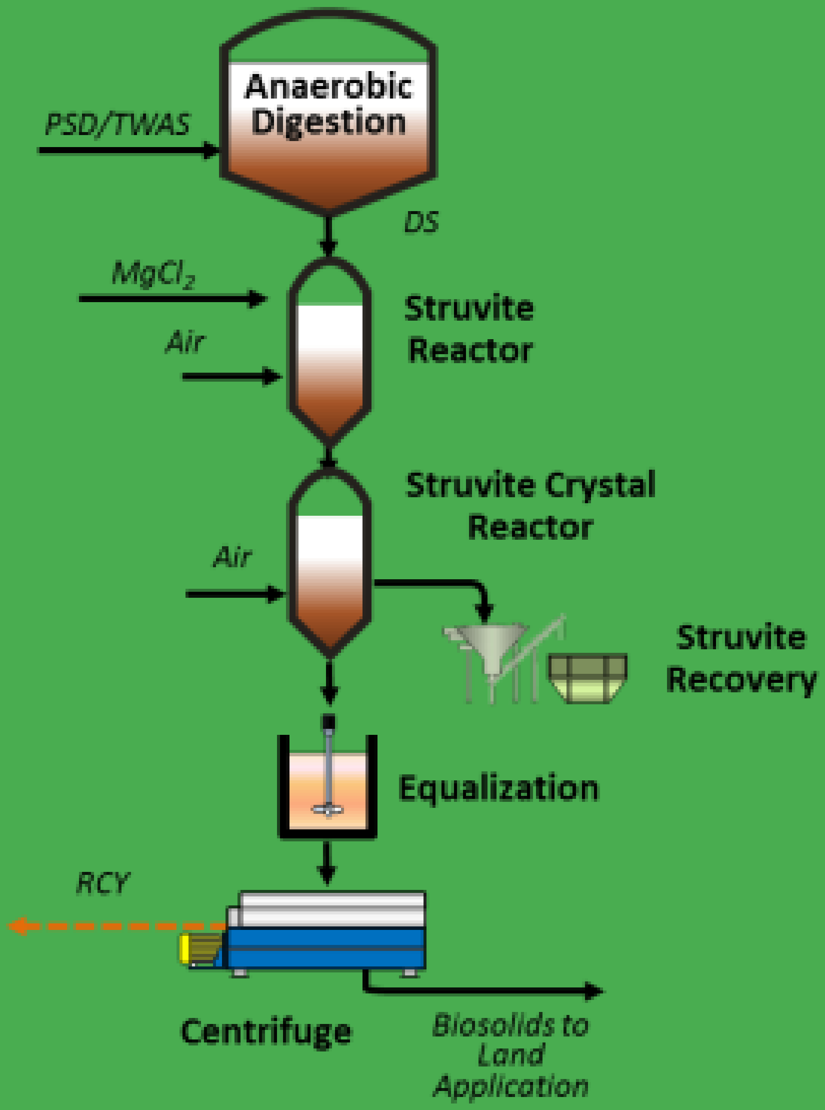
- Digestate flows into reactor tank(s) where air stripping raises the pH and magnesium chloride is added to drive struvite crystalization
  - AirPrex by CNP
    - Stripping converts aqueous carbonic acid and releases it to the atmosphere as CO2
      - Raising the digestate pH
    - Magnesium chloride and air are added
    - Reactor contents are held and mixed until struvite is formed
    - Struvite particles remain small and are removed from the system with dewatered cake

Struvite Sequestration from Digested Sludge

Advantages	Disadvantages
Struvite control at dewatering	Limited operating history in the U.S.
Lower capital cost	Not as effective as Ostara for preventing struvite scaling
Eliminates need to handle and store fertilizer product	Digestate pumping to reactor
Reduces P and NH3 load returned to the main plant	Will not prevent scaling prior to unit
Less sludge compared to chemical phosphorus treatment alternatives	Adds process complexity
	Proprietary technology

Struvite Recovery from Digested Sludge

Struvite Recovery from Digested Sludge



AirPrex with Recovery

- Same process as AirPrex with Sequestration, with an added step for harvesting
  - Reactor volume is increased
  - The detention time in the reactor is increased to increase struvite crystal size
  - Struvite removal and handling equipment are provided
  - Increases system construction cost

AirPrex® system in Medina, OH

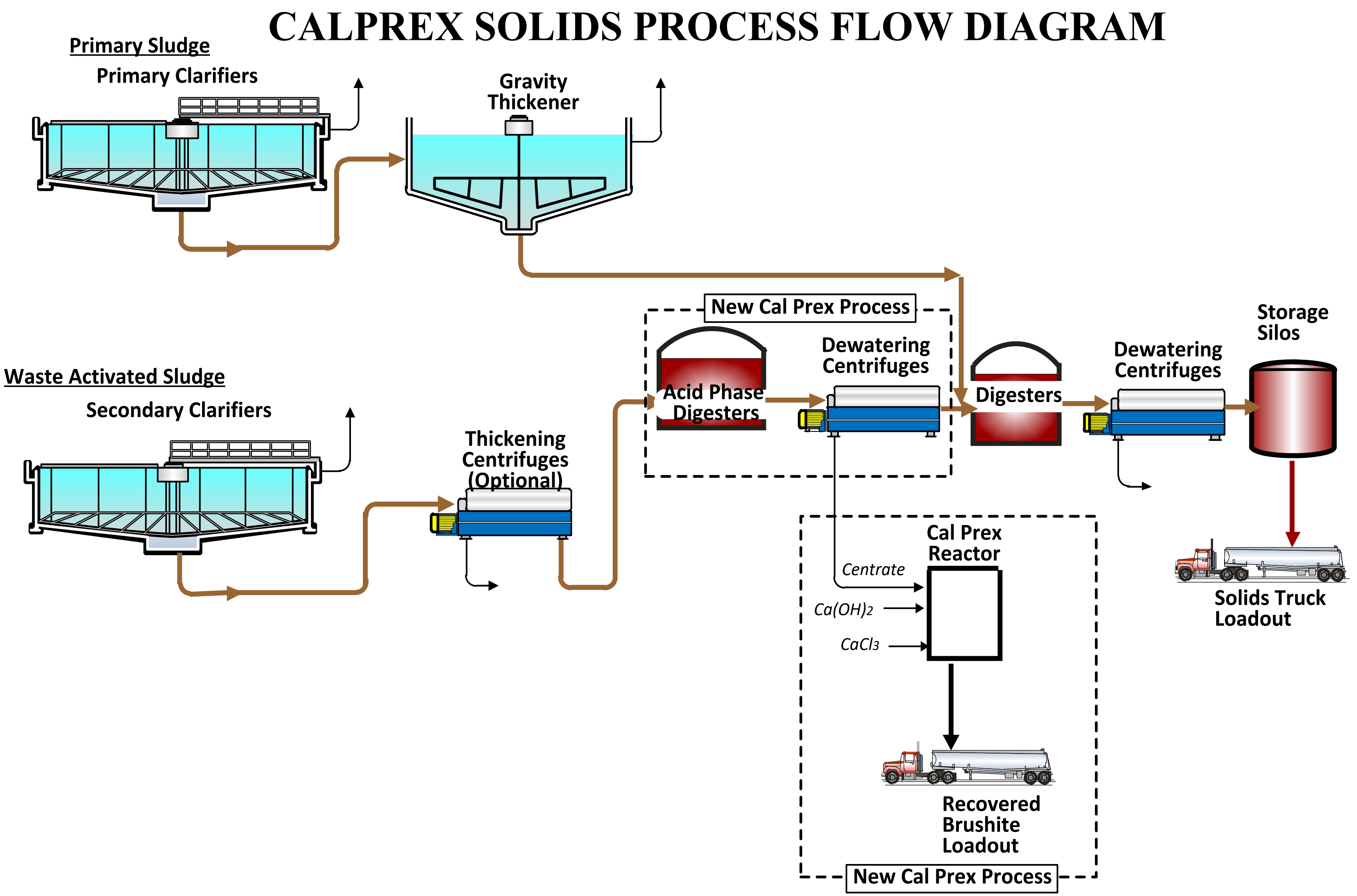
Advantages	Disadvantages
Struvite control at dewatering	Limited operating history in the U.S.
Lower capital cost	Not as effective as Ostara for preventing struvite scaling
Improves biosolids fertilizer value	Harvested product has a lower market value compared to Crystal Green
Reduces P and NH3 load returned to the main plant	Digestate pumping to reactor
Less sludge compared to chemical phosphorus treatment alternatives	Will not prevent scaling prior to unit
Potential to recover fertilizer product, generating revenues	Adds process complexity
Increases environmental sustainability	Proprietary technology

Pre-digestion Brushite Recovery

Pre-digestion Brushite Recovery

- Releases organically bound phosphorus from WAS into the bulk liquid as soluble orthophosphate in an acid phase digester
  - Occurs pre-digestion
    - Reduces digester struvite build-up
  - Recovers brushite
    - Higher market value than struvite
  - Often used in conjunction with AirPrex (post digestion) to capture the most P recovery
- CalPrex

- WAS held in acid-phase digester
  - Low oxygen and low pH environment facilitates P removal
- Sludge is dewatered prior to digestion
  - Centrate is used for brushite recovery in reactor
    - Calcium hydroxide and calcium chloride are added to form brushite crystals
  - Dewatered solids are diluted with water and sent to the existing digestion process



Advantages	Disadvantages
High P removal and recovery efficiency	Highest capital cost
Struvite control upstream of the digestion process	No full scale operating facilities
Compatible with THP addition	Adds process complexity
Low chemical cost	Proprietary technology
Low chloride addition	Requires additional pumping of centrate
Reduces P load returned to the main plant	
Less sludge compared to chemical phosphorus treatment alternatives	
Increases environmental sustainability	
Potential to recover fertilizer product, generating revenues	

Ferric Addition to Digested Sludge

Ferric Addition to Digested Sludge

- Add metal salts such as ferric chloride prior to dewatering
- Iron phosphate complex forms and precipitates
- Removed with the dewatered cake

Advantages	Disadvantages
Simple process	Additional chemical onsite
Prevents struvite scale formation after metal salt addition	Increases the volume of sludge requiring treatment and disposal
Reduces soluble phosphorus returned to the main plant	Increases the iron content of final biosolids for land application
Controls odor and H2S	Does not reduce struvite potential upstream of metal salt addition
	May promote the formation of vivianite

Degasification of Digested Sludge

Degasification of Digested Sludge

- Diffusers provide air-stripping of digested biosolids to remove excess CO2
  - Increases the pH and encourages the formation of struvite
    - Magnesium is limiting
  - Struvite formation inside the degassing tank is likely to scale out on the tank surfaces and internal air piping and diffusers
- Degasification process often does not drive the pH high enough for complete struvite crystallization, requiring ferric chloride addition for further P control
  - Requires less ferric chloride than only ferric addition

Advantages	Disadvantages
Simple process	Scaling on degassing tank requires significant maintenance effort
Low capital cost	Additional chemical onsite
Prevents struvite scale formation at dewatering	Increases the volume of sludge requiring treatment and disposal
Controls odor and H2S	Does not significantly increase dewatering efficiency and final cake concentration
Reduces soluble phosphorus returned to the main plant	Does not reduce struvite potential upstream of metal salt addition
	May promote the formation of vivianite

AirPrex® system in Medina, OH

Liverpool WWTP

- 16-mgd WWTP in Medina County, Ohio
- Upgrades include
  - Side-stream enhanced biological phosphorus removal (S2EBPR) for liquid-stream phosphorus removal
  - Biosolids improvements
    - Anaerobic digestion with thermal hydrolysis
    - Struvite sequestration

Improvements include struvite sequestration + S2EBPR as part of energy savings performance contract

Basis of Design

Criterion	Pearl + WASSTRIP	AirPrex w/ Harvesting	AirPrex	Degas + Ferric	Ferric
1. WWTP Performance					
Reduce nuisance precipitate formation	High	Medium	Medium	Medium	Low
Improve phosphorus removal capacity	High	Medium	Medium	High	Medium
Improve reliability to meet TP limits	High	Medium	Medium	Medium	Medium
Offers improvements to the dewatering process	High	High	High	Medium	High
2. Environmental / Health / Social / Economic					
Perform nutrient recovery	High	Medium	Low	Low	Low
Reduce chemical sludge quantity produced/disposed	High	High	Medium	Low	Low
3. Financial					
Net Present Value of alternative	High	Medium	Low	Medium	Medium
Capital costs of alternative	High	Medium	Low	Medium	Medium
4. Risk Assessment					
Technological track record	Medium	Low	Low	High	High
Manpower hours and skill required	Medium	Medium	Medium	Low	Low

Liverpool WWTP

- First U.S. application of the AirPrex technology, which has operating installations in Germany.
- County is moving forward with these upgrades as part of an Energy Savings Performance Contract with Black & Veatch.

AirPrex® system in Medina, OH

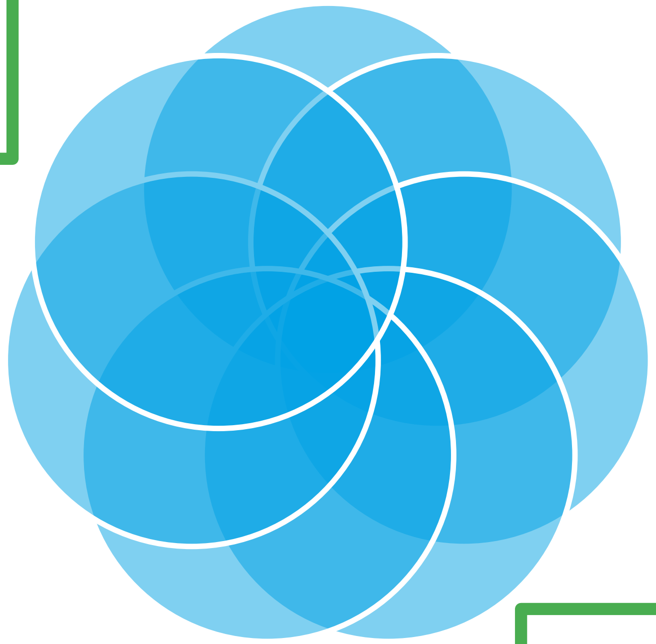
The Big Picture

Multiple Benefits of Nutrient Recovery and Removal

Reduced nutrient loads in plant recycles – reduced treatment cost

Improved environmental stewardship and overall sustainability

Less sludge compared to chemical phosphorus treatment alternatives



Reduced potential for struvite formation in dewatering piping

Potentially improved sludge dewaterability

Production of a fertilizer product with enhanced value

Reduced P-content in biosolids, closer to balanced agronomic ratios

Why Do I Want Less P in My Sludge?

Increased Application Rates

Fewer Fields per Year

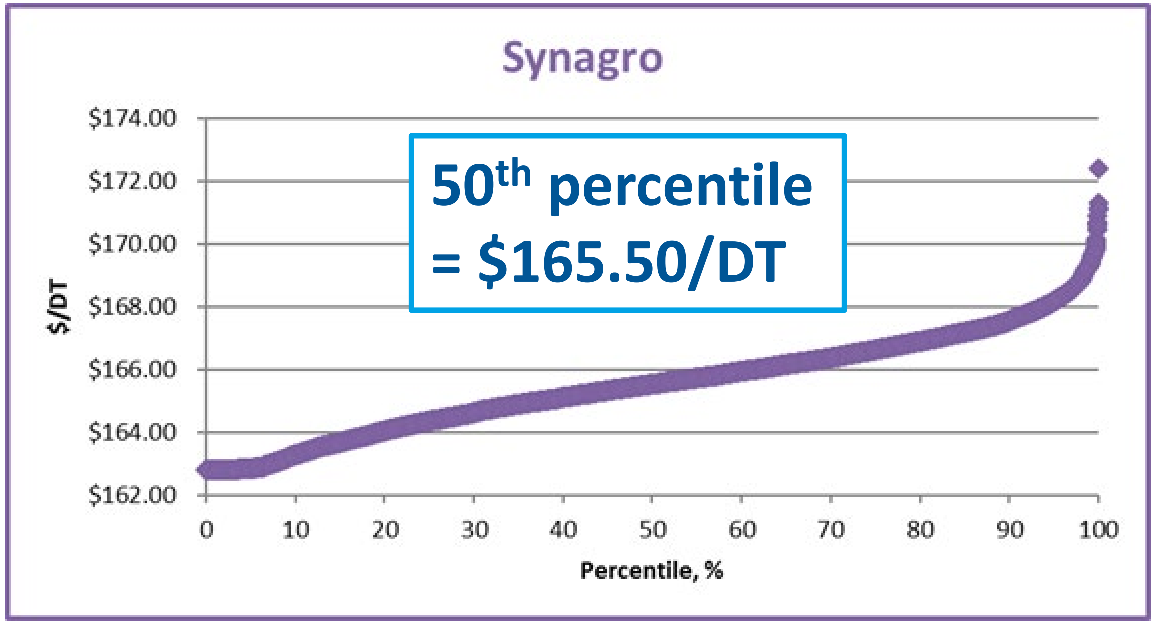
Shorter Travel Time

Trucking Cost

$$$

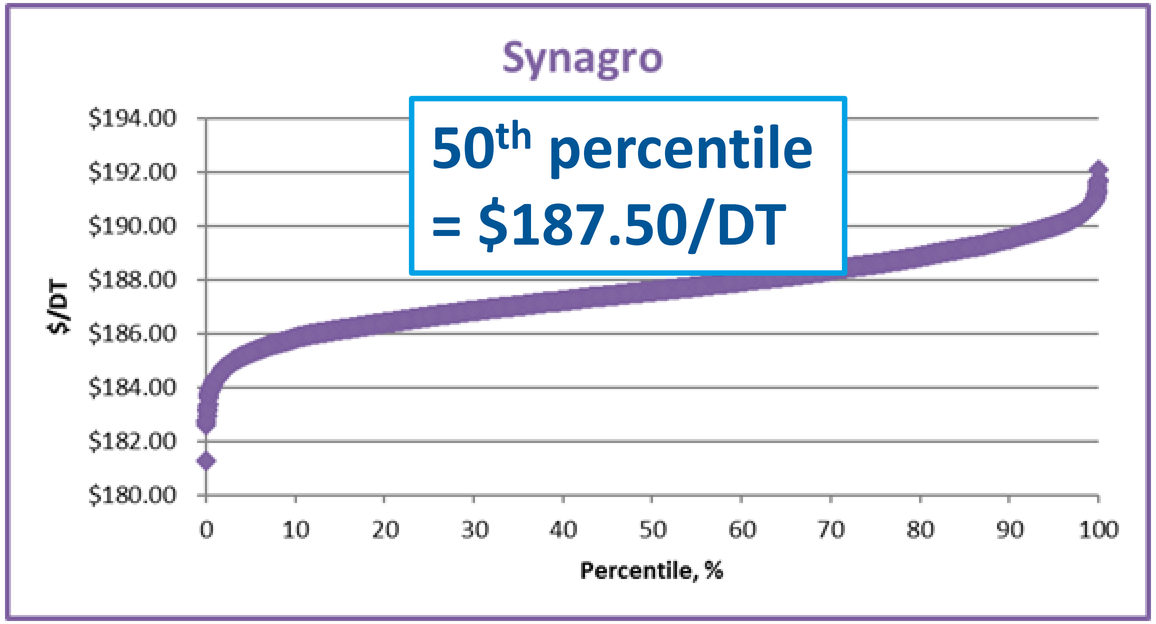
Transportation cost is the MOST expensive disposal cost incurred for land application.

Biosolids land application facility (BLAF) in Columbus, OH



Normal field availability

Difference of 11.73% in cost



50% reduction in availability of land application fields (<1.5 hour round trip) on a yearly basis

*Normalized future projections from 5000 iterations based on historical data from Columbus, OH WWTPs

Questions?