1

Understanding And Modeling Solids Stream Phosphorus Release, Precipitation, And Solids Handling

Thursday, January 24, 2019
1:00 – 3:00 PM ET

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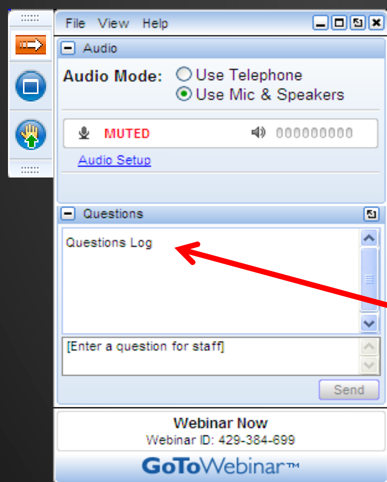
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

John B. Copp Ph.D.
Primodal Inc.
Hamilton, Ontario

Primodal
Earth Essential Technologies

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4

Solids Stream P – Jan. 24, 2019

An MRRDC Short Course

Solids Stream Phosphorus Modeling

- Topics:
  - Basics of Phosphorus Removal
  - Phosphorus Issues in the Solids Stream
  - Digestion Phosphorus Chemistry
  - Dewatering Impacts & Mitigation

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5

Solids Stream P – Jan. 24, 2019

An MRRDC Short Course

Solids Stream Phosphorus Modeling

- Speakers:

Patrick Dunlap
Black & Veatch

Murthy Kasi
Smith & Loveless

Hélène Hauduc
Dynamita

Mario Benisch
HDR

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6

Our Next Speaker

Patrick Dunlap, MS, PE

Process Engineer

Denver CO

BLACK & VEATCH

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7

Liquid Stream P Removal

Background to Impact on Residuals

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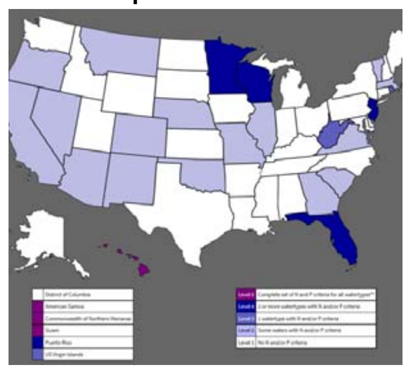
8

Phosphorus Removal

Eutrophication

Phosphorus Limits



EPA, 2017

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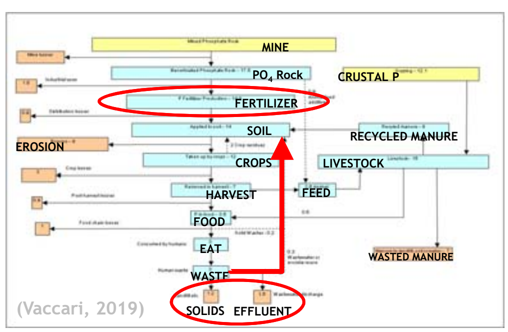
9

Phosphorus Scarcity

- Several hundred years of economically recoverable P reserved at current usage rates
- … but the two largest P fertilizer producers (USA & China) will run out or recoverable reserves at current production rates within decades
- P Recovery potential at WWTPs is an important part of managing this challenge

USGS 2017 Report	2017 Prod (Mt/yr)	Prod % of global	Reserves (Mt)	Reserves % of global	Life (yrs)
Morocco_and_Western_Sahara	27	10%	50,000	71%	1,852
China	140	53%	3,300	5%	24
United_States	28	11%	1,000	1%	36
Rest of the World	68	26%	15,939	22%	234
World_total_(rounded)	**263**	100%	70,000	100%	266



(Vaccari, 2019)

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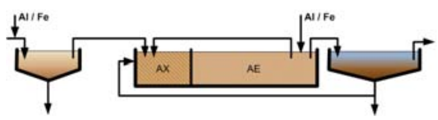
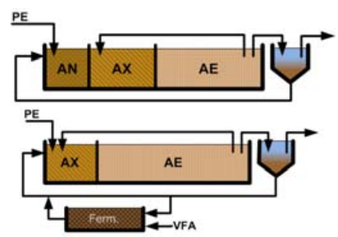
10

Chemical vs Biological P Removal

Chemical P Removal
- Consistent Performance
- Less disruptive/simpler operation
- Additional operational cost for chemical & residuals disposal
- Nuisance precipitates

Biological P Removal
- Lower operational cost
- Creates opportunity for P Recovery
- Requires additional bioreactor vol.
- Dewatering Impacted
- Nuisance precipitates





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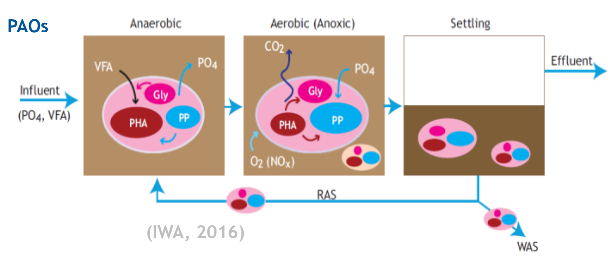
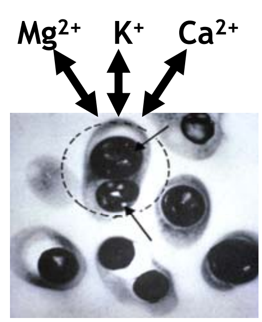
11

Enhanced Biological Phosphorus Removal (EBPR)



(IWA, 2016)



(Fuhs & Chen, 1975)

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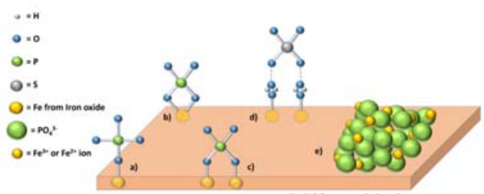
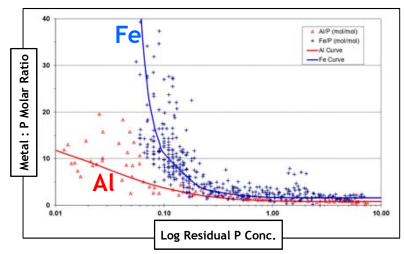
12

Chemical P Removal

- Phosphorus is removed by metal coagulants (Alum/Ferric) through co-precipitation and adsorption
- Metal:P molar ratio for additional removal increases lower PO_4-P concentrations.

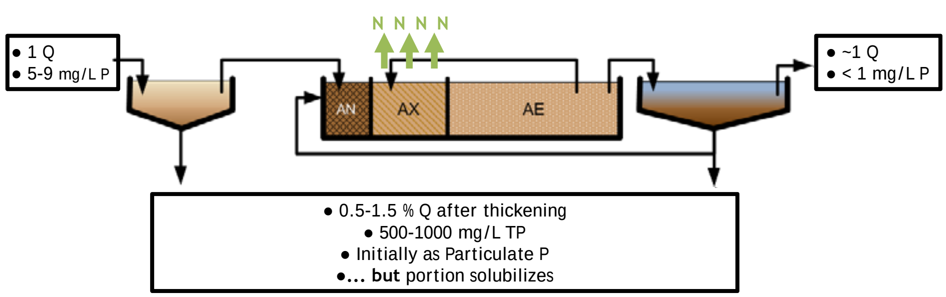


(Wilfert, 2018)



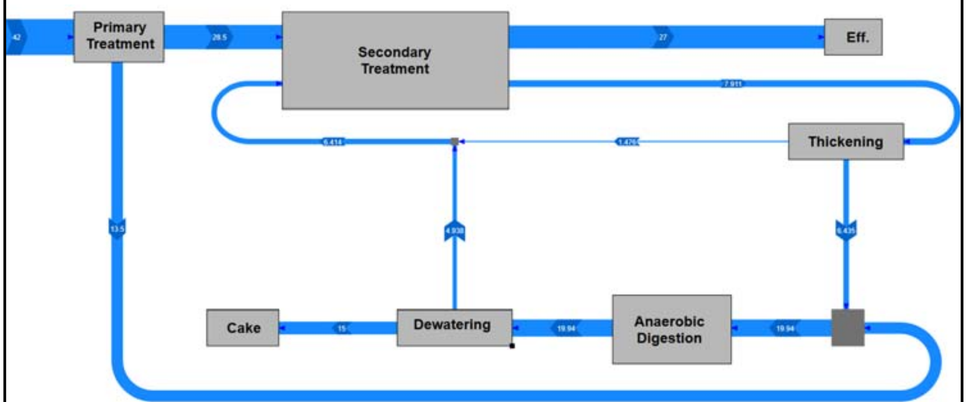
13

Nitrogen vs Phosphorus Removal



14

Phosphorus Mass Balances – Conv.



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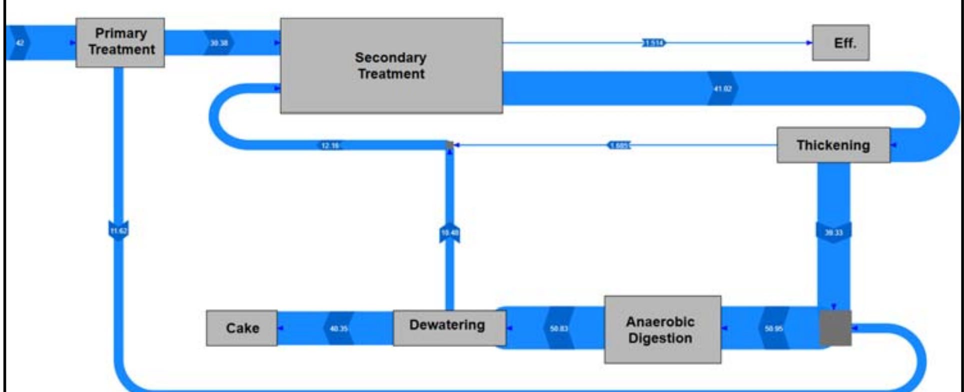
15

Phosphorus Mass Balances - EBPR



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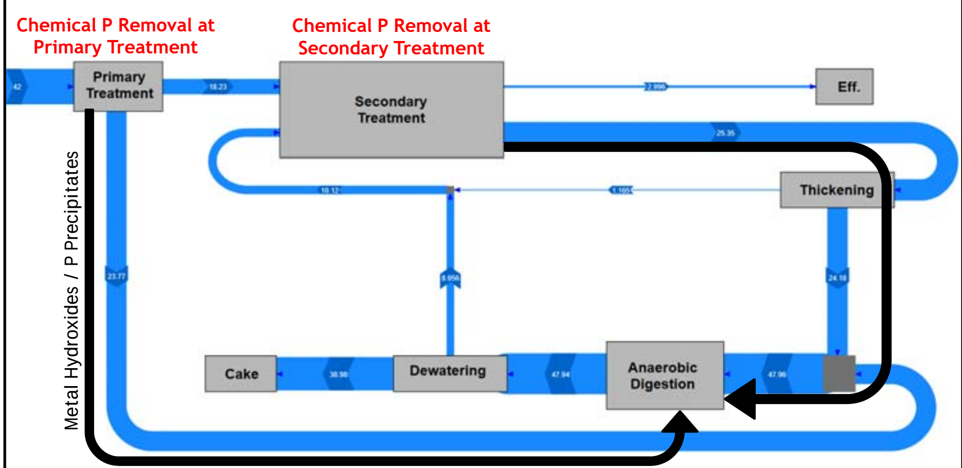
16

Phosphorus Mass Balances – Chem. P



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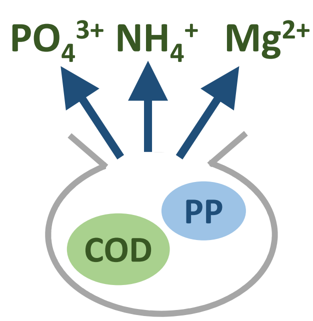
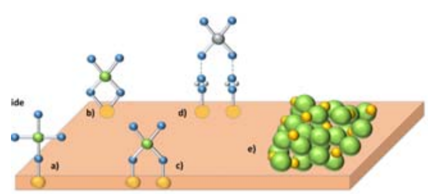
17

P Release in Digester

- Concentrations of Phosphate & other ions increase in ADs due EBPR P release, decay / lysis of cells, and dissolution of metal precipitates
- Phosphorus in recycle streams can be a significant source of P, up to 30% of the load with EBPR (heavily dependent on AD Chemistry).





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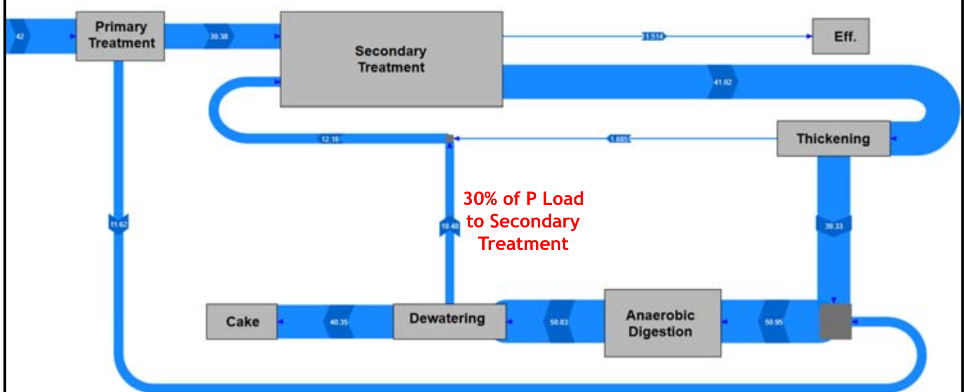
18

Phosphorus Mass Balances - Recycles



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19

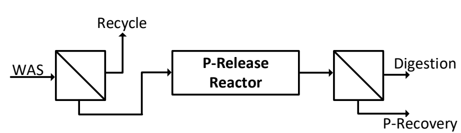
Recycle Phosphorus Management

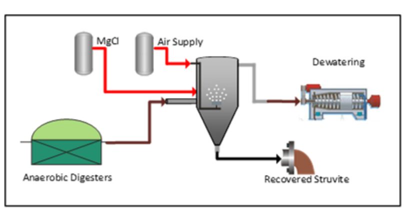
Options for recycle stream P reduction

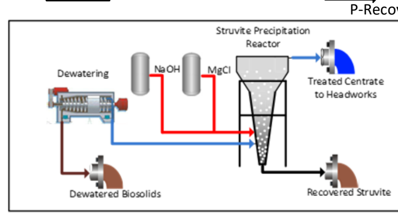
- Addition of coagulants to digesters
- Addition of coagulants to dewatering

Options for recycle stream P reduction/recovery

- Phosphorus recovery (struvite/brushite precip.)
- Pre-digester P release w/ recovery







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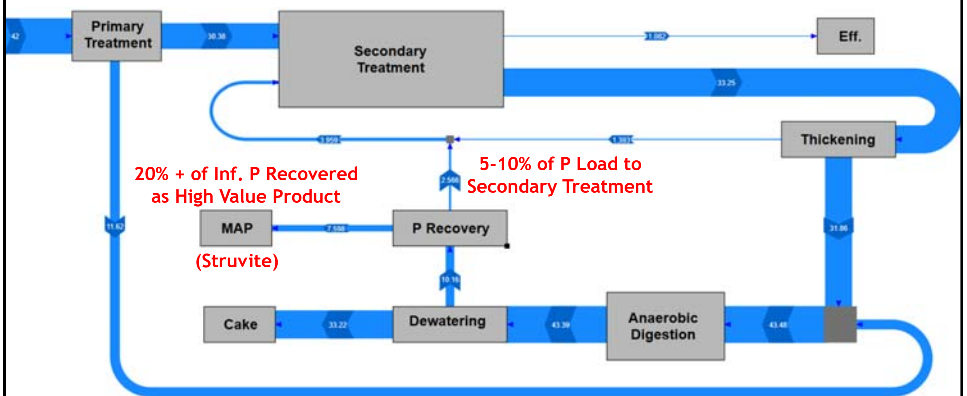
20

Impact of P Recovery



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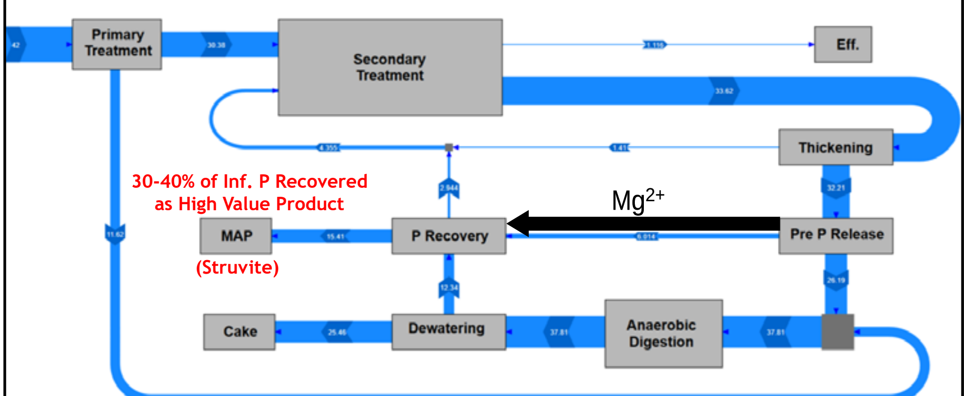
21

Impact of P Pre-Release / Recovery



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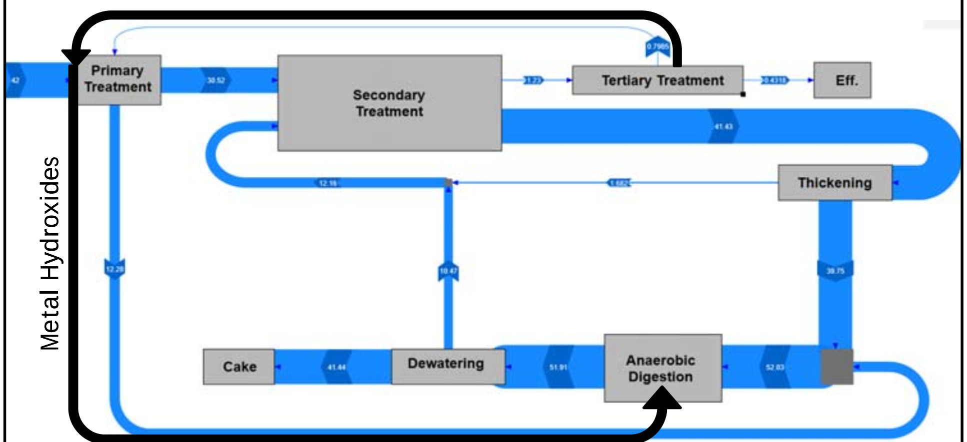
22

Phosphorus Mass Balances - Tertiary



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23

Conclusions

- When P is removed from the mainstream it is sent to residuals in concentrated forms
- How P is removed in the mainstream will impact the form of P sent to residuals and other ions (Fe, Al, Mg, K Ca) which go along
- This can cause problems with nuisance precipitates and dewatering performance
- Heavily dependent on digester chemistry

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Our Next Speaker

Murthy Kasi, PhD, PE

Process Engineering Manager

Lenexa, KS

Smith & Loveless Inc.

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Phosphorus Precipitates: Nuisance and Mitigation

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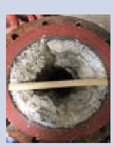
26

Outline

- Phosphorus Precipitates & Formation
- Operational Impacts
- Mitigation Strategies

27

Common Phosphorus Precipitates

Magnesium-based	Iron-based	Calcium-based
Struvite ($MgNH_4PO_4{\cdot}6H_2O$) *Magnesium Ammonium Phosphate*  	Vivianite ($Fe_3(PO4)_2{\cdot}8H_2O$ *Ferrous (Fe^{2+}) based*  	Hydroxylapatite $Ca_5H(PO_4)_3OH$ 
	Strengite ($FePO4{\cdot}2H_2O$ *Ferric (Fe^{3+}) based*	Octacalcium Phosphate $Ca_4H(PO_4)_3$
		Brushite $CaHPO_4{\cdot}2H_2O$

28

Where in Wastewater Treatment do these form?

Unintentional Precipitation is a **Nuisance**

Struvite is the most common nuisance

- Anaerobic digesters
- Digested sludge piping, valves, pumps, and mixers
- Dewatering equipment
- Filtrate and centrate piping, valves and pumps
- Rough surfaces preferred

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What Promotes Phosphorus Precipitation?

- Concentrations of chemical species (e.g. Mg^{+2}, PO_4^{-3}, NH_4^{+}, etc.)
- pH
- Temperature

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Chemical Species for Phosphorus Precipitates

Struvite ($MgNH_4PO_4{\cdot}6H_2O$)	Vivianite ($Fe_3(PO4)_2{\cdot}8H_2O$) Strengite ($FePO4{\cdot}2H_2O$)	Hydroxyapatite ($Ca_5H(PO_4)_3OH$) Octacalcium Phosphate $Ca_4H(PO_4)_3$ Brushite $CaHPO_4{\cdot}2H_2O$
Mg	Fe^{+2} or Fe^{+3}	Ca^{2+}
NH_4^+	PO_4^{-3}	PO_4^{-3} or HPO_4^{-2}
PO_4^{-3}		

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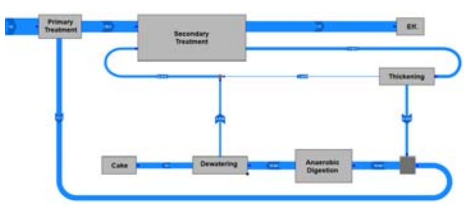
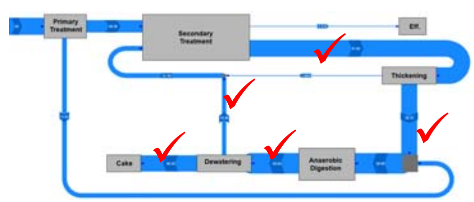
31

Chemical Species Generation in Wastewater Treatment Processes

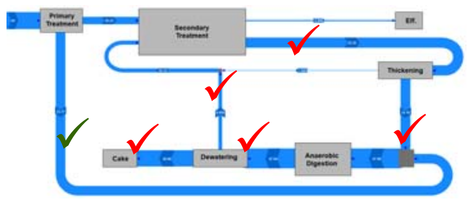


Conventional



EBPR

Chemical-P



- Higher conc. in **EBPR** and **chem-P** plants compared to **Conventional**
- Locations with higher conc.
  - EBPR: all secondary solids lines and solids process units
  - Chem-P: plus primary solids line

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Concentrations in Solids Streams

- Several factors impact concentrations of chemical species in solids streams
  - Efficiency Thickening prior to digestion — % solids – 4, 5, 6, etc.
  - Thermal hydrolysis process included? — increased digestion and higher orthophosphate
  - WASSTRIP — Orthophosphate extracted from WAS before sent to digesters
  - Chemical type and addition points for phosphorus removal — Iron, aluminum, cerium; Primary clarifier, aeration basins, secondary clarifiers

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33

Concentrations in Anaerobic Digester

Concentrations for a specific scenario are presented here

Assumptions for the following Table:

- 4% Total Solids in Digester Feed for all 3 treatments
- No WASSTRIP
- Chemically Enhanced Primary Treatment with Fe-based salts

Treatment → / Chemical Species ↓	Conventional	EBPR	Chemical P (CEPT)*
Mg^{+2} (mg/L)	40 →	140	40
Fe^{+2} or Fe^{+3} (mg/L)	300	300	4000
Ca^{2+} (mg/L)	150 →	200	150
NH_4^+ (mg N/L)	1,100	1,100	1,100
PO_4^{-3} (mg P/L)	300 →	750	750

*No Bio-P

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34

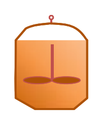
pH & Temperature

Location in Wastewater Treatment Plant	pH	Temperature
Liquid Processes (raw influent, primary clarifiers, aeration basins, etc.)	6.7 to 8	10 to 25°C
Solids Processes (thickening, digestion, dewatering, phosphorus release, etc.)	6.5 to 7.5	35 to 55°C

35

Struvite Formation - Example Scenario

Consider the following concentrations in an anaerobic digester:



Mg^{+2} = 40 mg/L

NH_4^{+} = 1,100 mg/L

PO_4^{-3} = 300 mg/L

C in mol/L

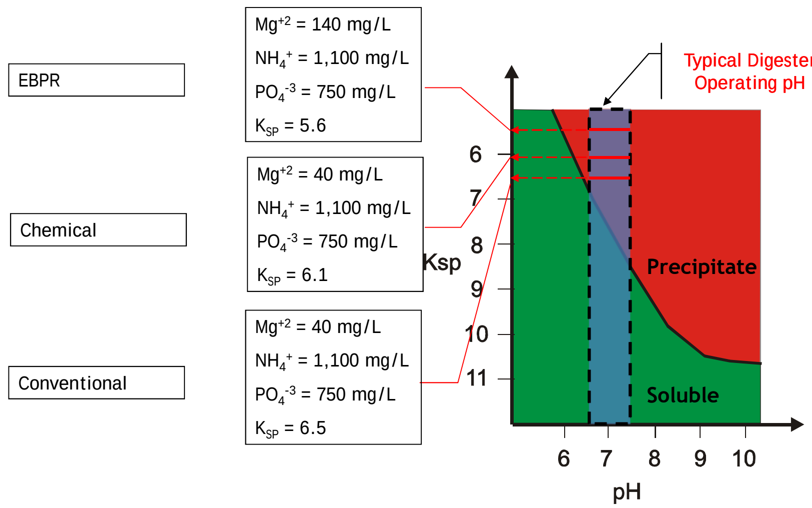
$$K_{sp} = -\log\left([C_{Mg^{2+}}]\cdot[C_{NH4^{+}}]\cdot[C_{PO_4{}^{3-}}]\right)$$

$$K_{sp} = -\log\left(\frac{40\,\frac{mg}{L}}{24\,\frac{g}{mol}\cdot 1000\,\frac{mg}{g}}\cdot\frac{1100\,\frac{mg}{L}}{18\,\frac{g}{mol}\cdot 1000\,\frac{mg}{g}}\cdot\frac{300\,\frac{mg}{L}}{96\,\frac{g}{mol}\cdot 1000\,\frac{mg}{g}}\right)$$

$$K_{sp} = 6.5$$

36

Struvite Formation - Digester Scenario

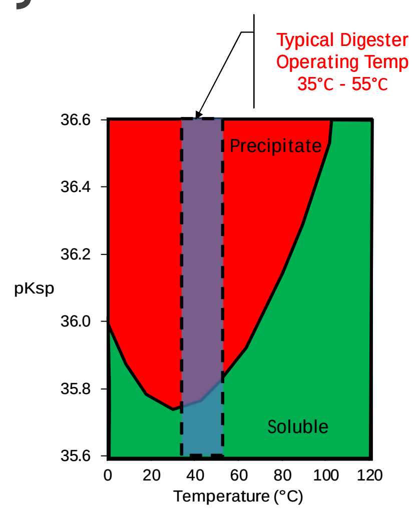


37

Vivianite Solubility

$$K_{sp} = -\log\left([C_{Fe^{2+}}]^3 \cdot [C_{PO_4^{3-}}]^2\right)$$

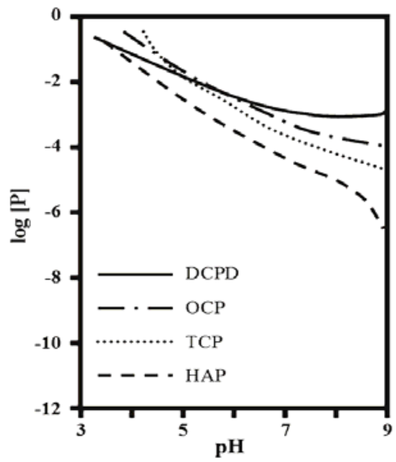
- Typical digester operations favor vivianite precipitation
  - Acidic conditions (lower pH)
  - Elevated temperatures
  - Low Oxidation-Reduction Potential (reduced environment)
  - Excess iron concentrations due to chemical addition
- Often preferred over struvite formation
  - Softer material than struvite



38

Calcium Phosphates Solubility

- Can be problematic in hard waters with high Ca^{+2} concentrations
- Struvite and vivianite have greater phosphorus precipitation potential than calcium phosphates, especially in low pH conditions



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Nuisance or Resource??

Unintentional precipitation
can be a nuisance

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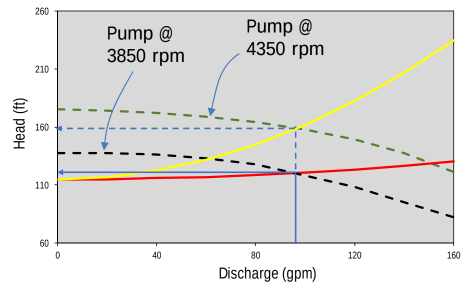
40

Impact on Plant Operation - Pipes & Pumps

Deposits in pipes

Meridian, ID
Wastewater Resource Recovery Facility



Reduction of pipe diameter changes system curve

- Higher energy cost
- Reduced equipment life
- Reduced capacity

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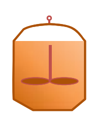
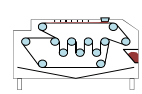
Impact on Plant Operations - various processes/equipment

- **Digesters**
  - Decrease of mixer speeds due to struvite deposits on blades and impellers
  - Decrease in digester capacity and increased heating requirements



- **Dewatering**
  - Decrease in filter press efficiency due to filter blinding; increased filter press operational time



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42

Impact on Plant Operation

Deposits on digester wall

Deposits on mixer blade in dewatering centrate storage tanks

Deposits on belt filter press rollers

43

Conditions Leading to Phosphorus Precipitation

Struvite

- Excess concentrations of Mg^{+2}, NH_4^+, and PO_4^{-3}
- Increased pH of solution
- Turbulence
- Stripping of CO_2
- Rough surfaces

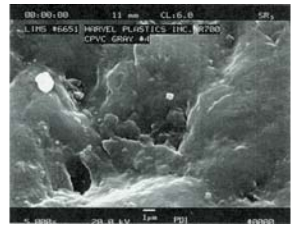
Fe-phosphates

- Excess iron and PO_4^{-3} concentrations
- Lower pH conditions
- Elevated temperatures

44

Struvite Control

- Minimize CO2 stripping
- Short straight pipes
- Cleaning loops
- Removable pipe lining
- Pinch valves
- Selecting right pipe material
- Magnesium dosing (1.3 Mg:1P)
- Iron salts addition (1.5 Fe:1P)
- pH adjustment (reduce pH to <7.5)



CPVC (5000 x)

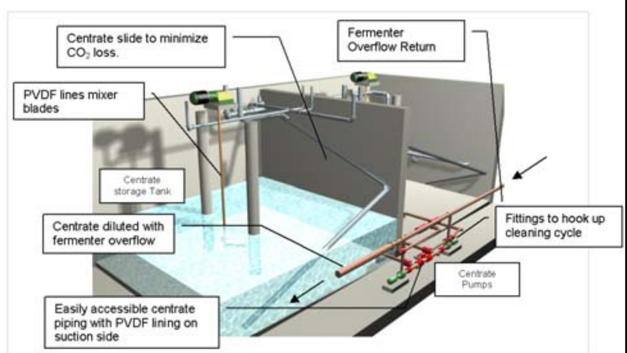
Spears LXT (5000 x)

(C) Photos by SPEARS Inc

45

Facility Design Example

- Benefits:
  - Optimized Bio-P
  - Alum use was reduced from 150 to 20 ppm
  - FeCl3 costs reduced by $15,000/yr



Centrate storage and conveyance system at Durham AWWTP and its struvite control features

Source: Baur, R., Benisch, M., Clark, D., Sprick, R.G., Struvite Control- Dealing With A Common and Nuisance, WEFTEC 2002

46

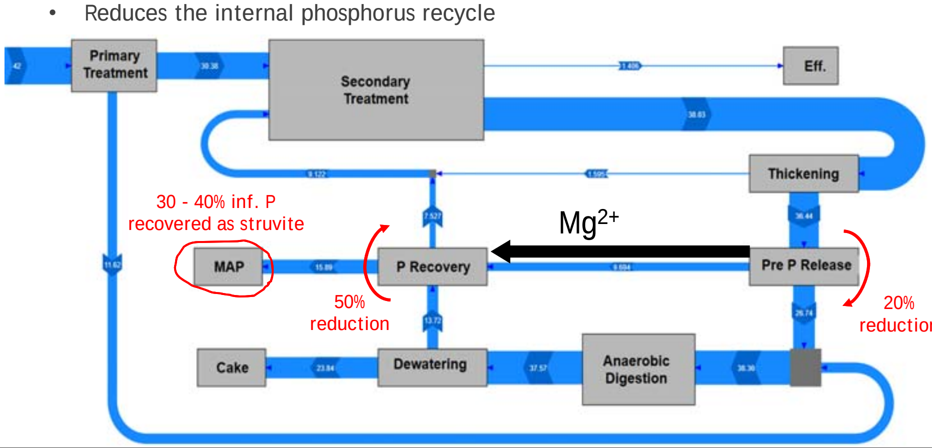
Other options?

Intentional Phosphorus Precipitation?

47

Phosphorus Recovery Benefits

- Reduces phosphorus concentrations in solids streams to anaerobic digester and dewatering processes
- Reduces the internal phosphorus recycle



48

Recovery Options

- Can be recovered in all three forms
  - Struvite (magnesium-based)
  - Brushite or hydroxyapatite (calcium-based)
  - Vivianite (iron-based)
- Recovery as struvite is the most common
  - Commercial recovery methods available for Ca-P
  - Recovery as Fe-P is still in research stage

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49

P-recovery Methods

As struvite

- Ostara®
- Multiform harvest™
- Struvia™
- AirPrex™
- NuReSys™
- DHV Crystalactor

As calcium phosphates

- P-Roc®
- CalPrex™
- Quick Wash®
- ExtraPhos®

As sludge ashes

- EcoPhos®
  - Extracts as H_3PO_4 or Calcium phosphate
- P-Bac (Incore)®
  - Extracts as Struvite or Calcium phosphate

For additional information:
Law and Pagilla (2018) Phosphorus Recovery by Methods
Beyond Struvite Precipitation, Water Environment Research, 2018, 90(9): 840-850

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50

P-recovery Economics

	Struvite	Calcium phosphates
Recovery	80 to 90%	50 to 100%
Capital costs	$28 to $280 per ton per day	$3.5 to $4.5 per ton per day
Market value	$50 to $1,800 per ton	n/a

1 ton = 2,000 lb

Source: Vaneeckhaute, C., Lebuf, V., Michels, E., Belia, E., Vanrolleghem, P. A., Tack, F. M., & Meers, E. (2017). Nutrient recovery from digestate: systematic technology review and product classification. Waste and Biomass Valorization, 8(1), 21-40.

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51

Conclusions

- EBPR or chemical-P removal:
  - Increase in concentrations of phosphorus precipitating species in solids streams
  - Struvite (magnesium-based phosphate) formation is the major nuisance
- Control options should be carefully evaluated before selection
  - Addition of iron salts – secondary nuisance due to vivianite formation; increased sludge production; high chemical costs; decreased P recovery
  - pH control by acid addition – agitation due to pumping and mixing still causes increase in pH
  - Proper pipe material – scratches/roughness over time favors struvite formation

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52

Conclusions

- P-recovery can minimize impacts on downstream unit processes, e.g. digester, dewatering equipment
  - May still require chemical addition to control struvite in digesters
- Several commercial P-recovery options are available

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53

Our Next Speaker

Hélène Hauduc, PhD

Senior Process Engineer

Toulouse, France

sumo dynamita PROCESS MODELING

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Chemical Processes in Anaerobic Digesters

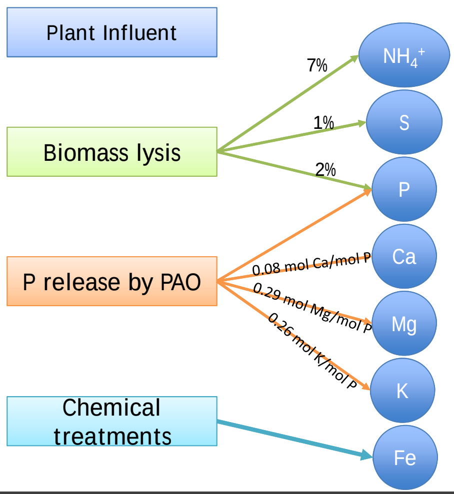
55

Outline

- P from EBPR and ChemP in AD
- Interactions between P, S and Fe cycles
- Mitigation Strategies
- Comprehensive model of relevant AD reactions

56

Chemical species in AD



	Conventional [mg/L]	EBPR [mg/L]	ChemP [mg/L]
NH_4^+	1100	1100	1100
S	150	150	150
P	**300**	**750**	**750**
Ca	**150**	**200**	**150**
Mg	**40**	**140**	**40**
K	20	190	20
Fe	**300**	**300**	**4000**

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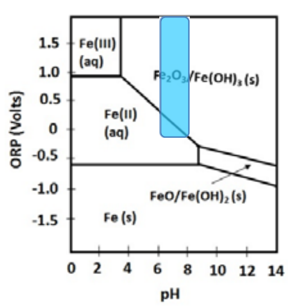
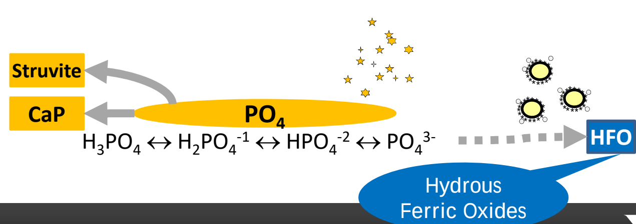
Phosphate reactions



Pourbaix diagram from Wilfert et al (2015)

ChemP: Iron addition



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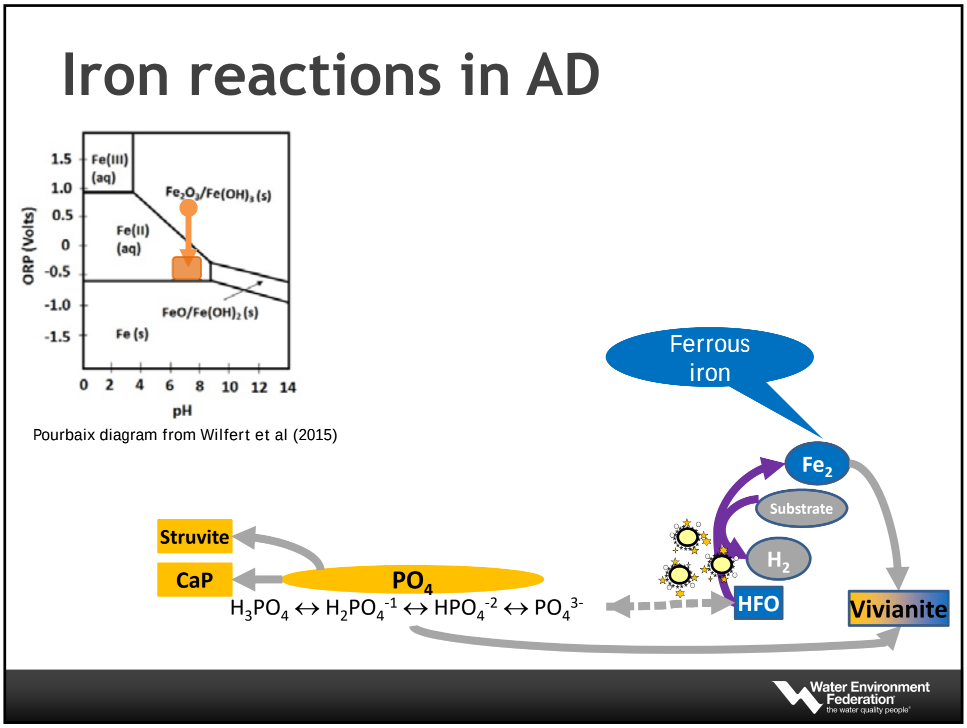
Iron reactions in AD
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
ORP (Volts)
Fe(III) (aq)
Fe2O3/Fe(OH)3 (s)
Fe(II) (aq)
FeO/Fe(OH)2 (s)
Fe (s)
0 2 4 6 8 10 12 14
pH
Pourbaix diagram from Wilfert et al (2015)
Ferrous iron
Fe2
Substrate
H2
HFO
Vivianite
Struvite
CaP
PO4
H3PO4 ↔ H2PO4-1 ↔ HPO4-2 ↔ PO43-
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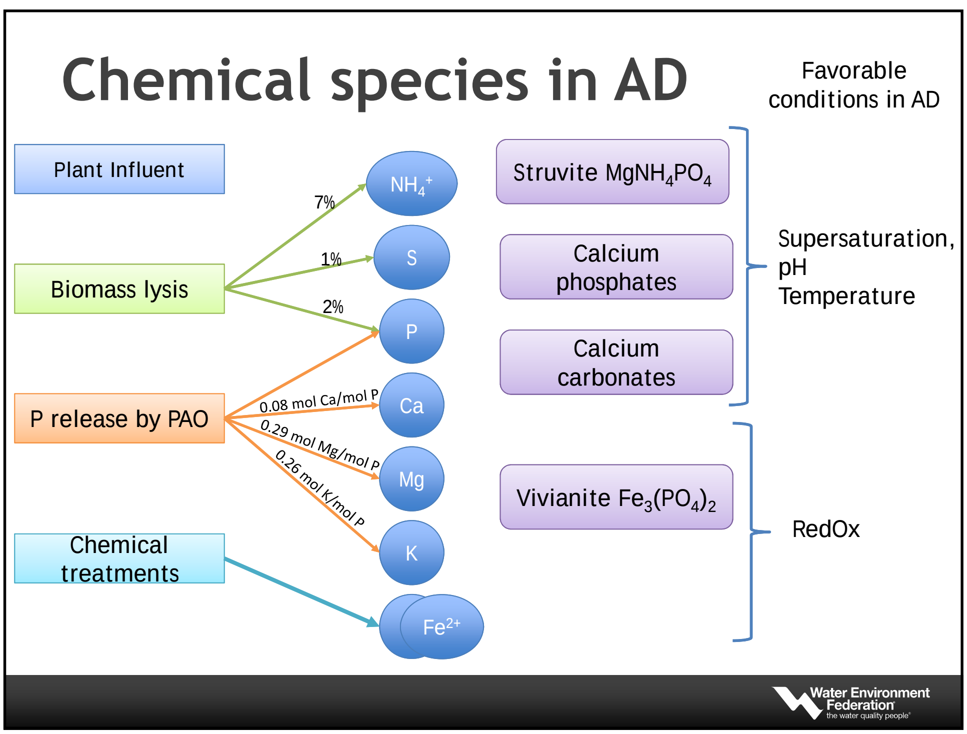
Chemical species in AD
Favorable conditions in AD
Plant Influent
Biomass lysis
P release by PAO
Chemical treatments
7%
1%
2%
0.08 mol Ca/mol P
0.29 mol Mg/mol P
0.26 mol K/mol P
NH4+
S
P
Ca
Mg
K
Fe2+
Struvite MgNH4PO4
Calcium phosphates
Calcium carbonates
Vivianite Fe3(PO4)2
Supersaturation, pH Temperature
RedOx
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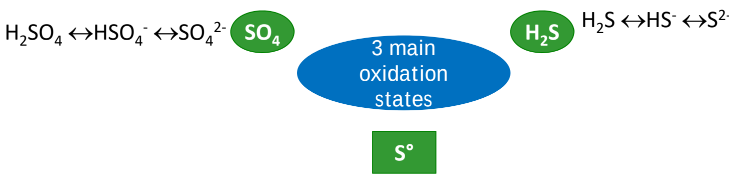
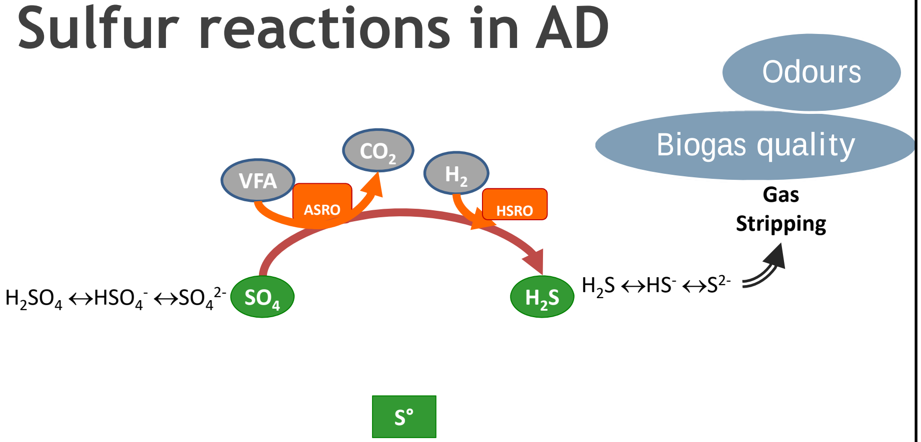
Sulfur reactions in AD

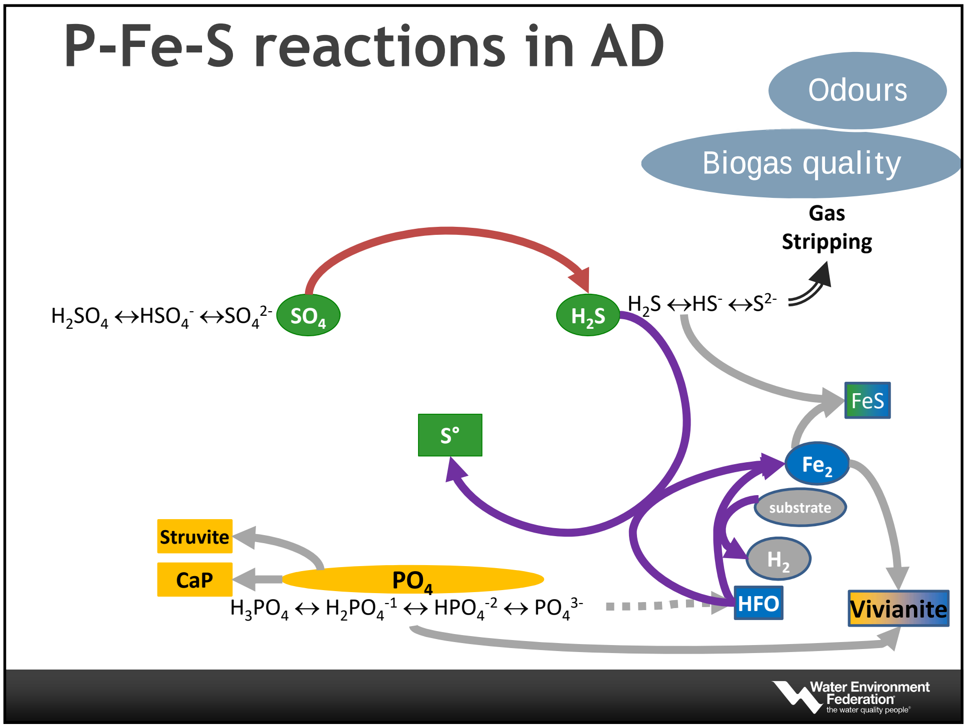


61

Sulfur reactions in AD



62


P-Fe-S reactions in AD
Odours
Biogas quality
Gas Stripping
H2SO4 ↔HSO4- ↔SO42-
SO4
H2S
H2S ↔HS- ↔S2-
FeS
S°
Fe2
substrate
H2
HFO
Struvite
CaP
PO4
H3PO4 ↔ H2PO4-1 ↔ HPO4-2 ↔ PO43-
Vivianite
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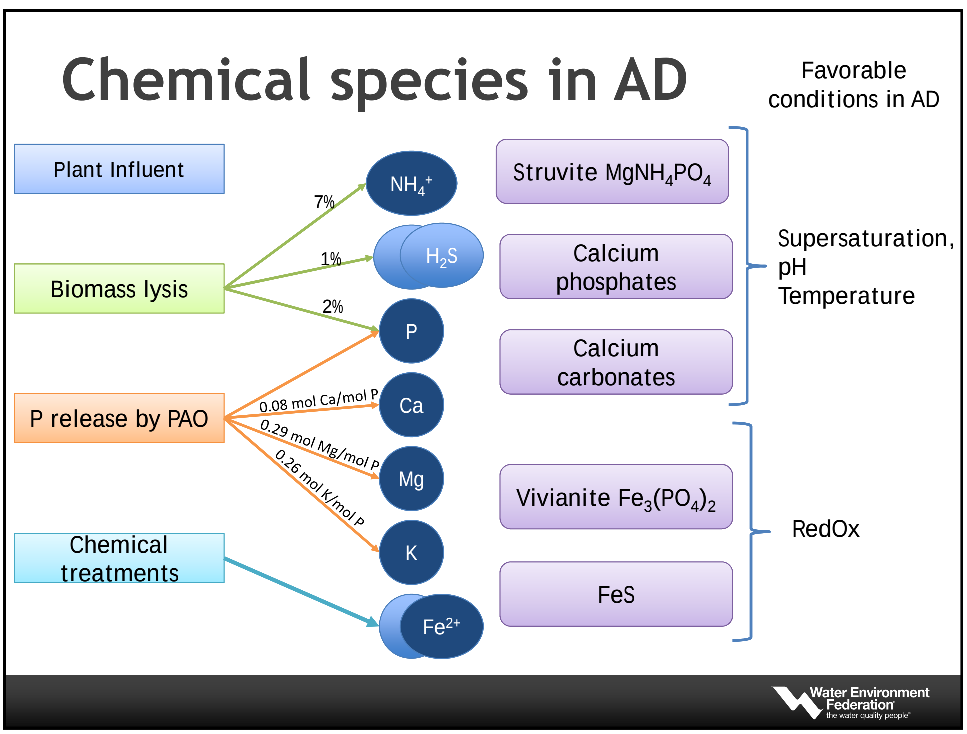
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H2S
P
Ca
Mg
K
Fe2+
Struvite MgNH4PO4
Calcium phosphates
Calcium carbonates
Vivianite Fe3(PO4)2
FeS
Supersaturation, pH Temperature
RedOx
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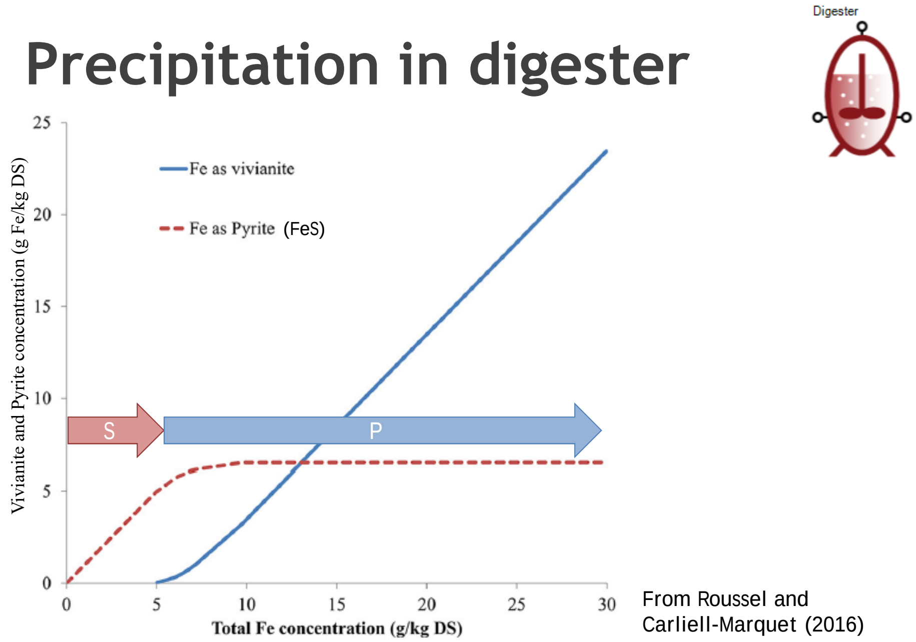
Precipitation in digester



From Roussel and Carliell-Marquet (2016)

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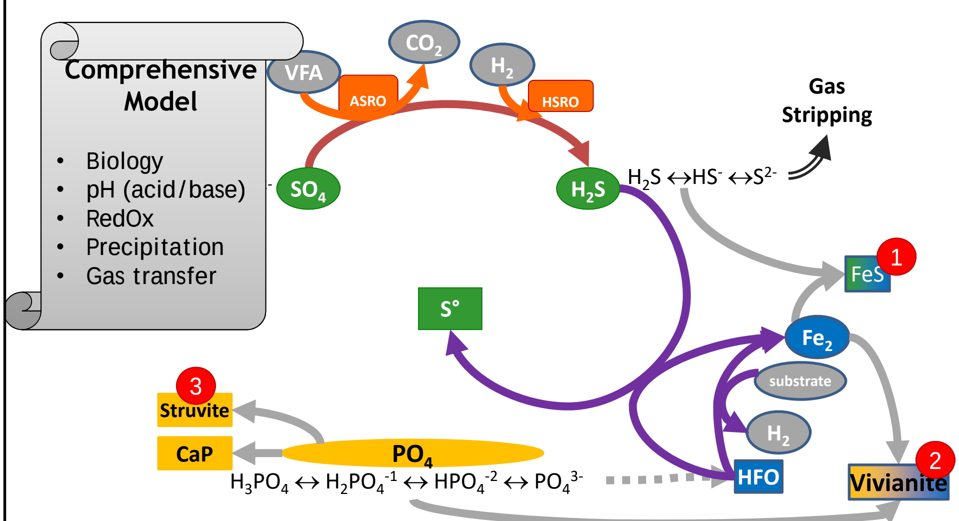
Comprehensive model



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Lander Street primary digester Simulation of mitigation strategies

Parameter	Unit	Data	Model	Fe for H_2S control 25 g $FeCl_3$/kg VSS	Fe for struvite control 100 g $FeCl_3$/kg VSS
Digester Total Solids	%	1.70%	2.10%	2.15%	2.24%
Digester VSS	% of TS	67%	66%	65%	62%
Digester pH	-	7.15	7.16	7.07	6.80
Alkalinity as $CaCO_3$	mg/L	4100	3544	2939	1762
Gas production	Nm³/hr	176	172	174	178
Digester gas H_2S	ppm	2125	1926	141	4
Digester ammonia	mg N/L	1169	979	978	1018
Digester phosphate	mg P/L	156	166	113	2
Struvite	mg TSS/L	?	842	827	37
Vivianite	mg TSS/L		0	578	2488
Iron sulfide	mg TSS/L		0	146	163

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Conclusions on Chemical Processes in Anaerobic Digesters

- AD processes results in nuisances:
  - Struvite precipitation
  - H_2S in biogas
- Fe addition in water line and sludge line as mitigation strategy for P and S control
- Complex interactions of P-S-Fe cycles

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Conclusions on a comprehensive model

- Optimisation of mitigation strategies
- Impact of mitigation strategies
  - On return streams and mainstream processes
  - On digestate chemical composition

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Our Next Speaker

Mario Benisch PE
Senior Process Engineer
Portland, OR

HDR

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IMPACT OF EBPR ON DEWATERABILITY

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01 What do we know?

02 Water Distribution

03 Impact of EBPR

04 PO4-P or MV/DV

05 Implications

06 Mitigation

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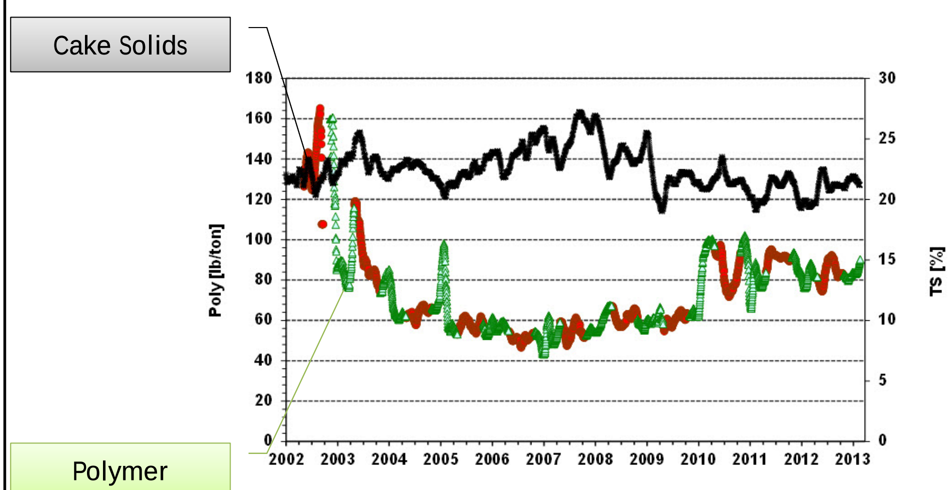
Key Takeaways

- EBPR decreases dewaterability
- Often occurs under the radar
- Struvite = indicator for EBPR
- There are mitigation options

73

What do we know



74

What do we know

- Dewatering performance varies in general
- Increase digester PO_4-P correlates with decline in dewaterability
- Removal of PO_4-P increases dewaterability
- Increase MV/DV ratio correlates with decline in dewaterability
- Ferric (usually) Increases Dewatering Performance

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What do we know

- Alum sometimes increases dewatering performance
- Trivalent metal ions can coagulate biopolymers
- EPS holds water and aids flocculation
- Monovalent metal ions block bridging

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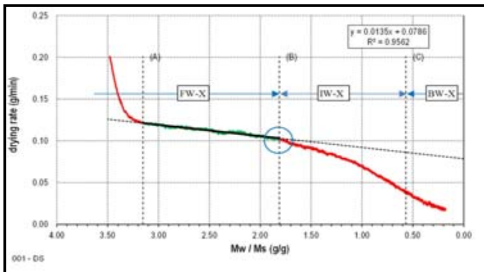

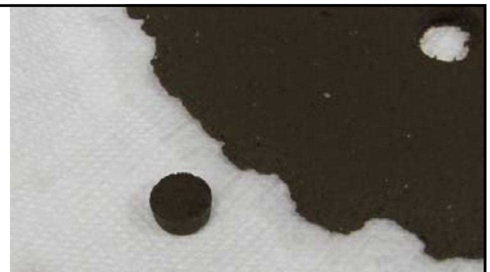

02 Water Distribution

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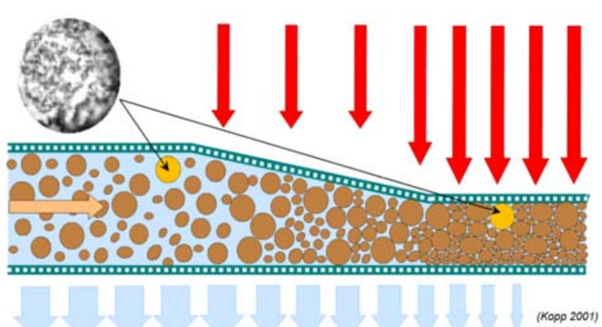
Water distribution



Only free water can be removed with mechanical dewatering

WHY DOES DEWATERING PERFORMANCE VARY?

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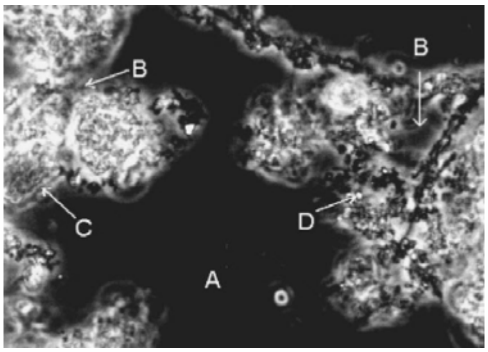
Water distribution



A: Free
B: Interstitial
C: Surface
D: Intracellular

79

Water distribution

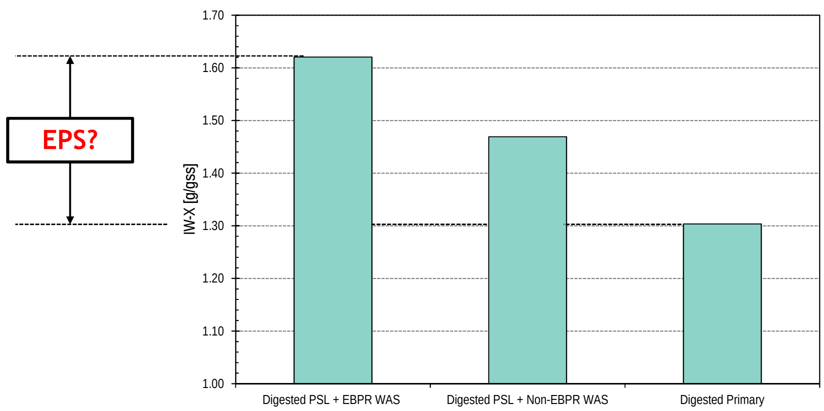
Water distribution in sludge is a function of

- process design
  (liquid treatment, solids treatment, etc)
- influent composition
  (plant influent, external loads)
- chemical addition
  (alkalinity, polymer, coagulants)

80

Water distribution

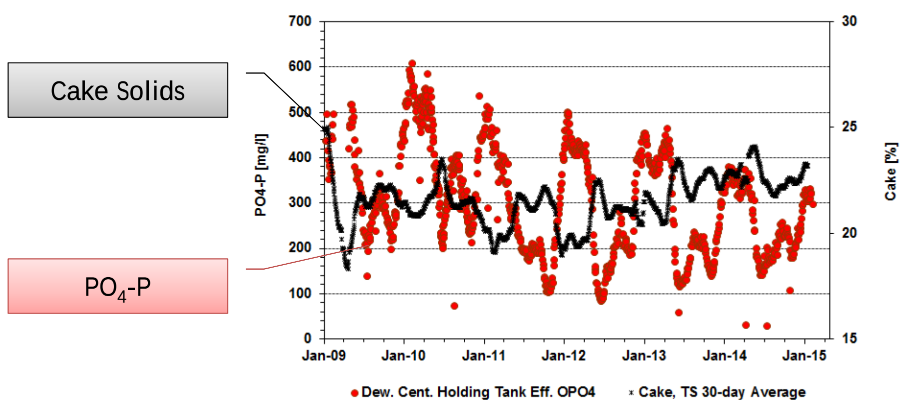
- Thermo-Gravimetric Analysis of Water Fractions



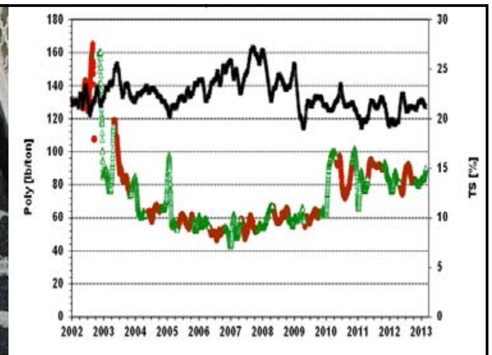
81

Phosphate Concentration

- Dewaterability declines with increasing PO4-P



82



03 Impact of EBPR on Dewatering

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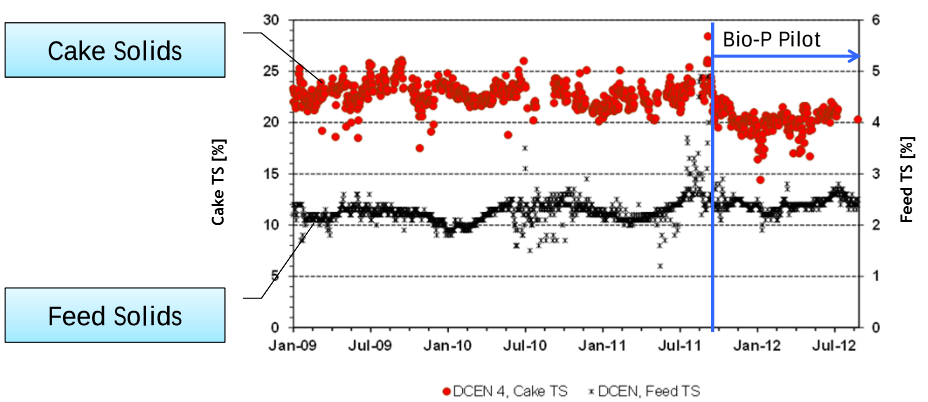
EBPR and Dewatering

- Denver Hite EBPR Pilot



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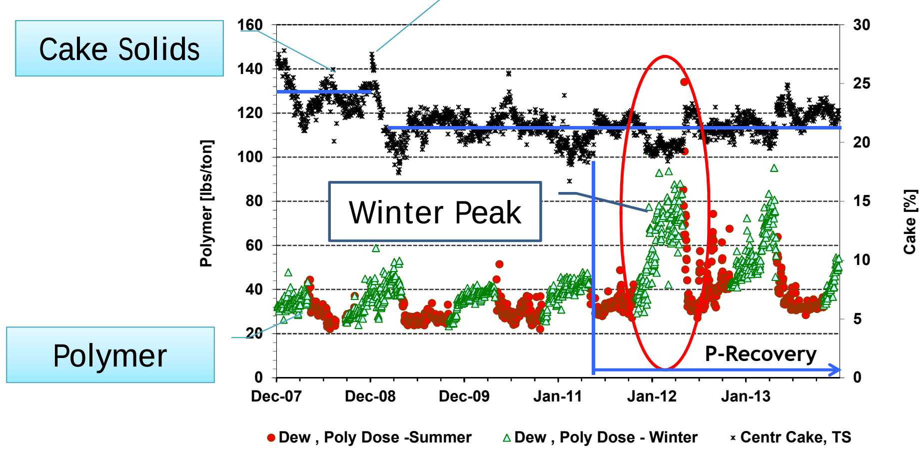
EBPR and Dewatering

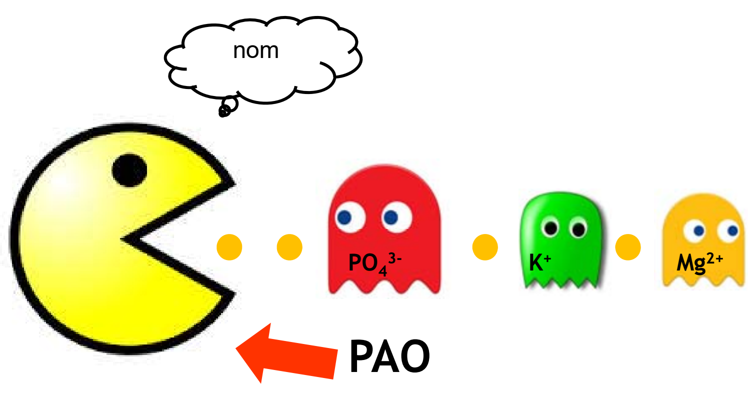
- Rock Creek AWWTP



85

EBPR and Dewatering

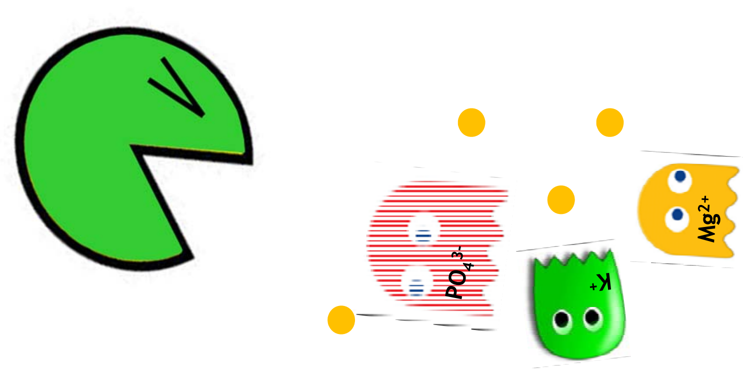
- P-Uptake



86

EBPR and Dewatering

- ANR P-Release



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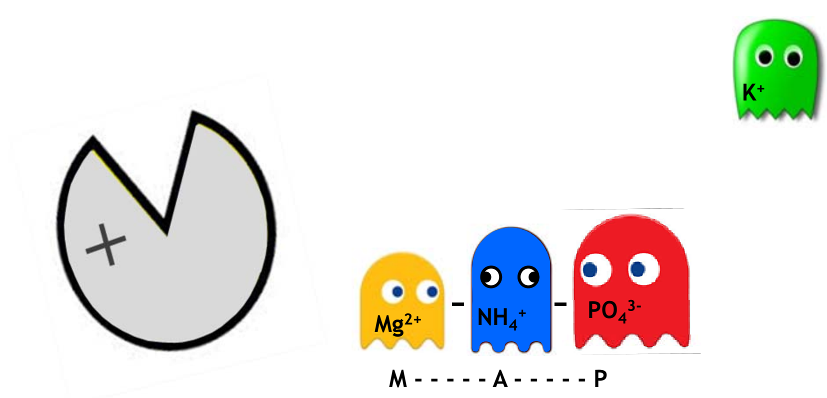
EBPR and Dewatering

- Digestion and Struvite Formation



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EBPR and Dewatering

- Bio-P Transfer P to digester and Mg and K
- Mg^{2+} Precipitates out as $MgNH_4PO_4$ $6H_2O$



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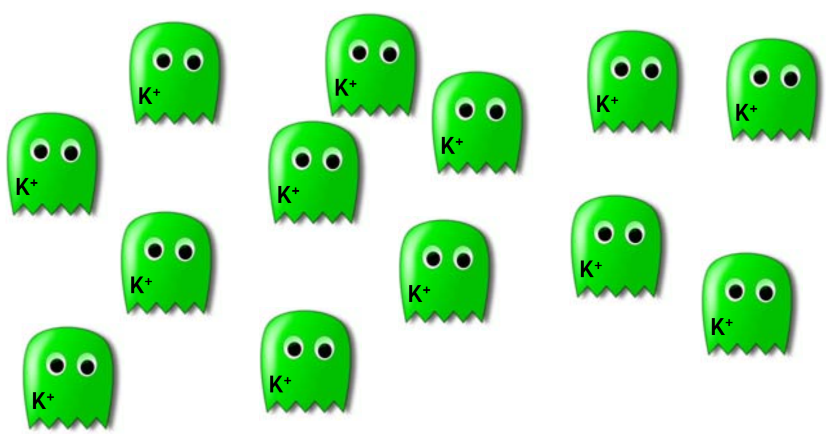
EBPR and Dewatering

- K^+ Remains



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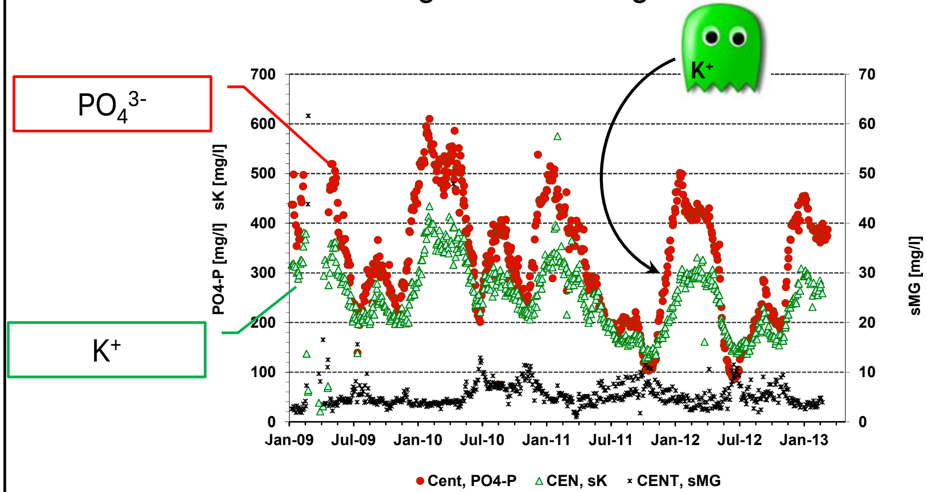
EBPR and Dewatering

- Bio-P Transfer P to digester and Mg and K



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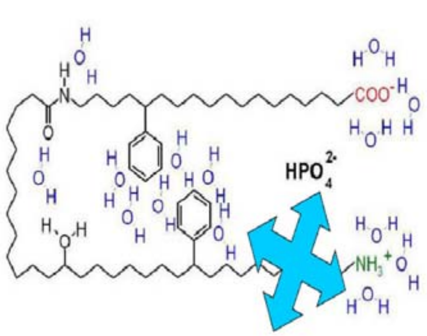

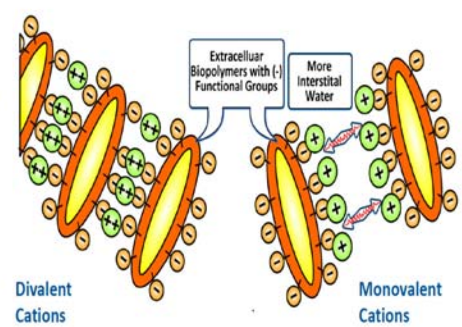

04 PO4-P vs. MV/DV

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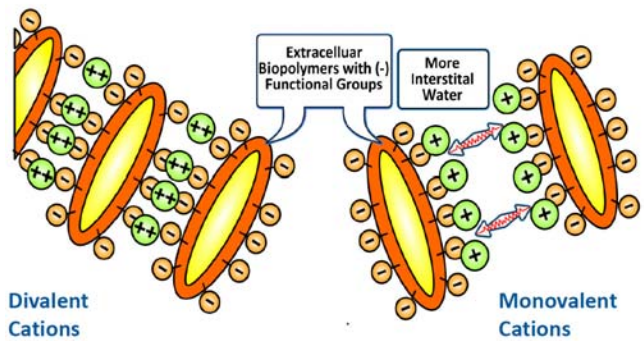
Monovalent/Divalent Cation Ratio (M/D)

- Divalent Cation Bridging



(Source: Nova, Higgins)

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Monovalent/Divalent Cation Ratio (M/D)

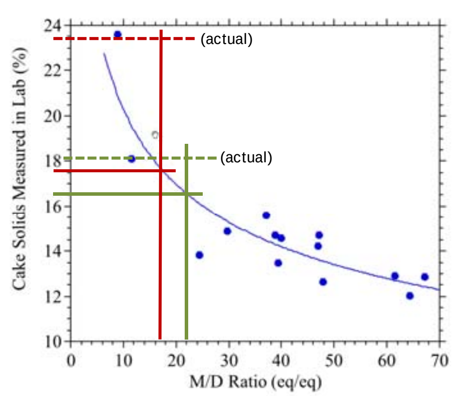

Figure 3. Relationship between cake solids and the M/D ratio for the different samples.

(Source: Higgins)

Summary from Kopp report			
		Lakota	Redondo
NH4-N	mg/L	1130	1240
PO4-P	mg/L	130	68
Na	mg/L	52	454
K	mg/L	260	304
Mg	mg/L	16	31
Ca	mg/L	52	83
M/D	-	22.8	17.1
pH	-	7.4	7.7
cond	mS/cm	8.8	14.6
Poly	lb/dry ton	48.1	75.0
DS(A)kbkopp	%	18.0	23.4

(Source: City of Lakehaven)

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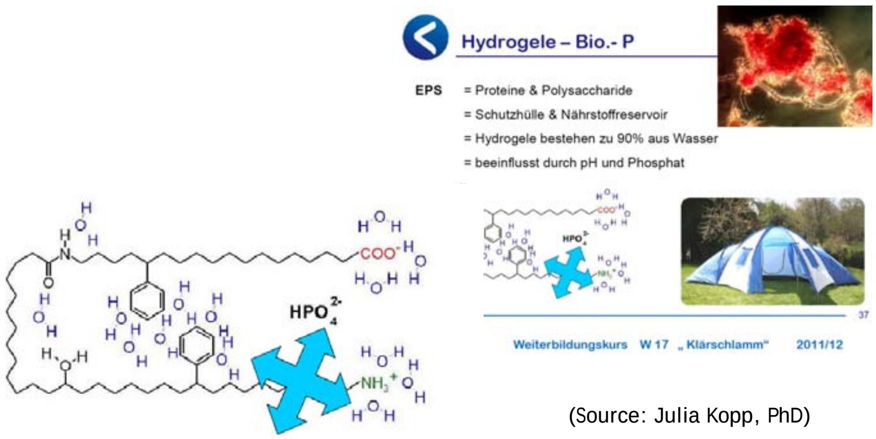
EBPR and Dewatering

- PO4-P Increase EPS stored Water



(Source: Julia Kopp, PhD)

95

PO4-P vs. Dewaterability

- Phosphate (anions) in Food Processing
  - Can dissolve proteins
  - Act stabilizing on dispersions, suspensions, and emulsions
  - When phosphate anions enter protein molecules they unfold the protein through electrostatic repulsion and bridge forming which impact its water binding ability
  - Diphosphate have very specific impact on the water storage in muscle protein (casein and actomyosin)

(Source: Yvonne Matthei pp, PhD)

96

PO4-P vs. Dewaterability

- Use of Phosphate (anions) in Food Processing
  - To reduce growth of gram positive microorganism (extend shelf live of cream cheese with poly-phosphates)
  - pyrophosphate used to restore water content in meat and to slow down auto-oxidation reactions by binding multivalent cations
  - Phosphate is added to milk products to stabilize milk proteins, stabilize the pH, binding of multivalent cations, and to increase viscosity (i.e. for cream)
  - To enrich food products with Ca, Mg, Fe, etc

(Source: Yvonne Matthei pp, PhD)

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05 Implications

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Implications

- Polymer → 100% to 200% more
- Cake TS → 3% - 5% less
- Operating cost → Polymer, Hauling
- Resiliency → Struvite
- Recovery option
- Procurement

(Source: Yvonne Matthei pp, PhD)

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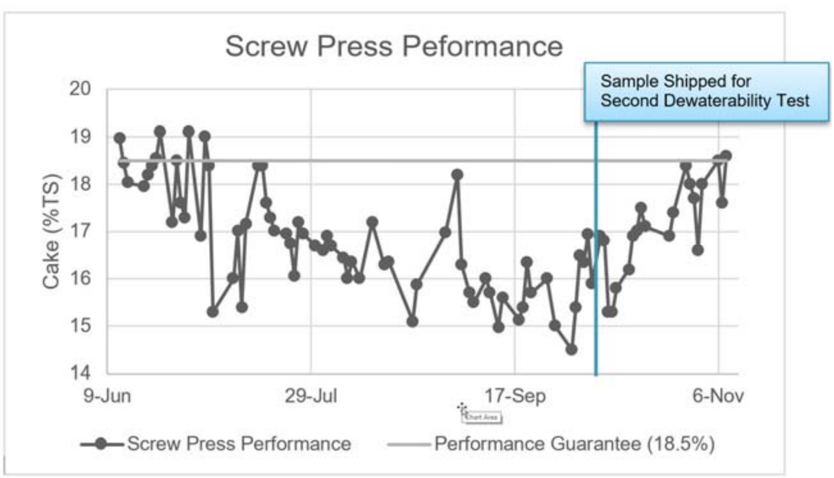
99

Implications



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06 Mitigation through Sludge Conditioning

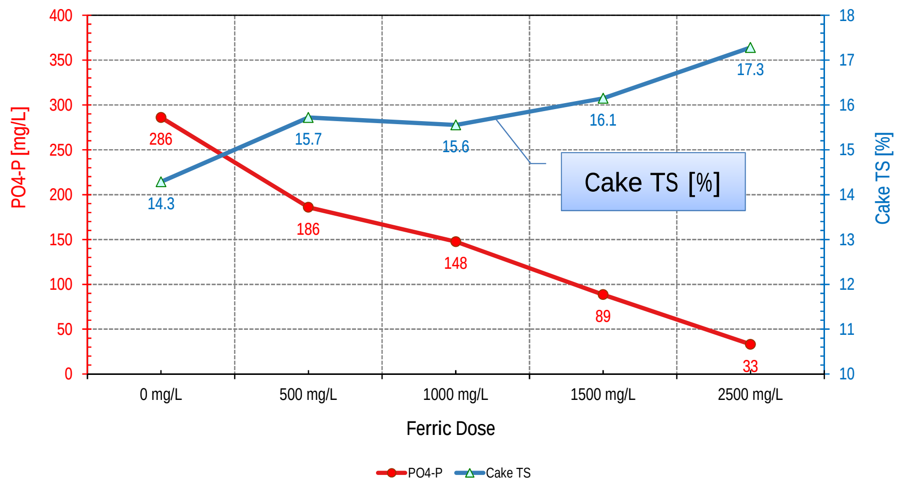
101

Metal Salt Addition

- Simplest Option
- Ferric or Alum
- Recycle P control
- Lower polymer demand
- Dryer cake
- More sludge
- Consumes alkalinity*

102

Metal Salt Addition



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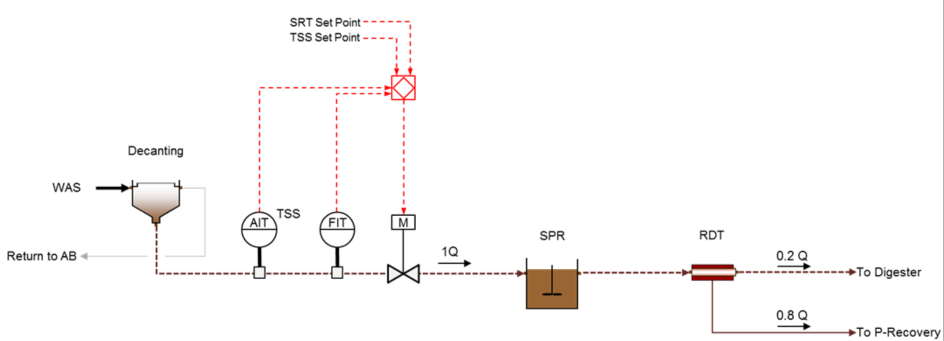
Stored Phosphorus release



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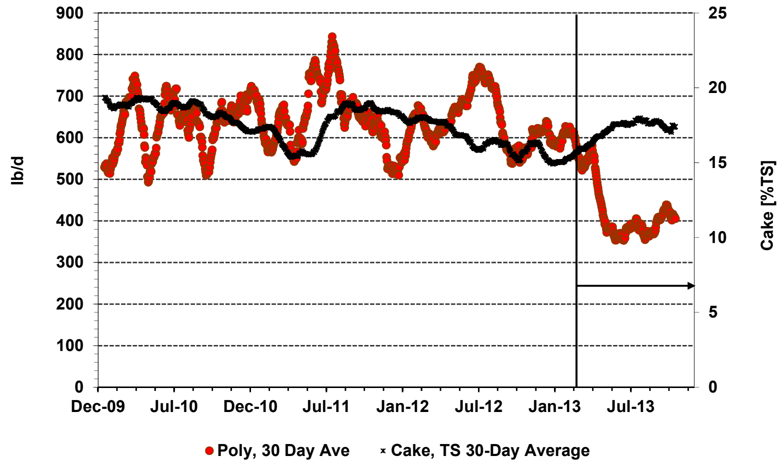
Stored Phosphorus release



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AirPrex

- Post digestion sludge treatment
- Simple process
- Air mixed reactor
- Adding $MgCL_2$ to bind PO_4-P

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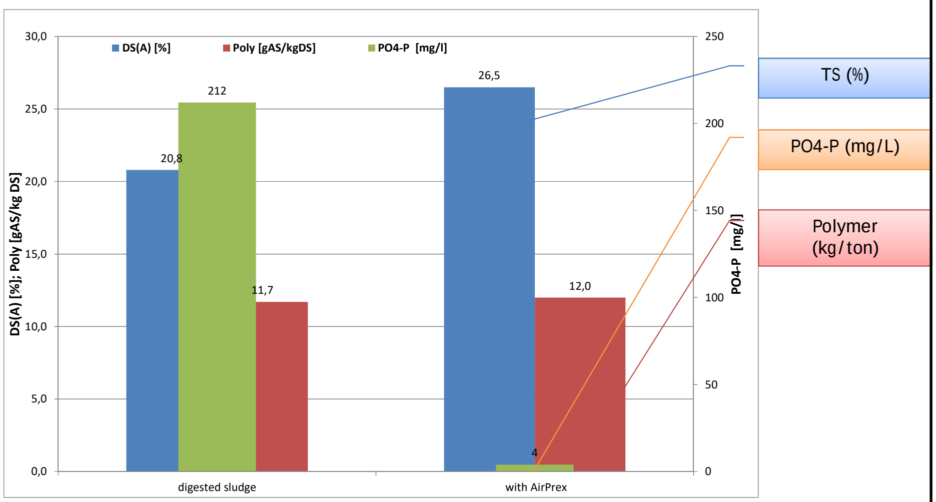
AirPrex

Struvite precipitation by Air-Prex (n=22)	mean
Reduction PO4-P [mg/l]	239
Reduction PO4-P [%]	94
Increase DS(A) [%-Points]	4,7



(Kopp 2013)

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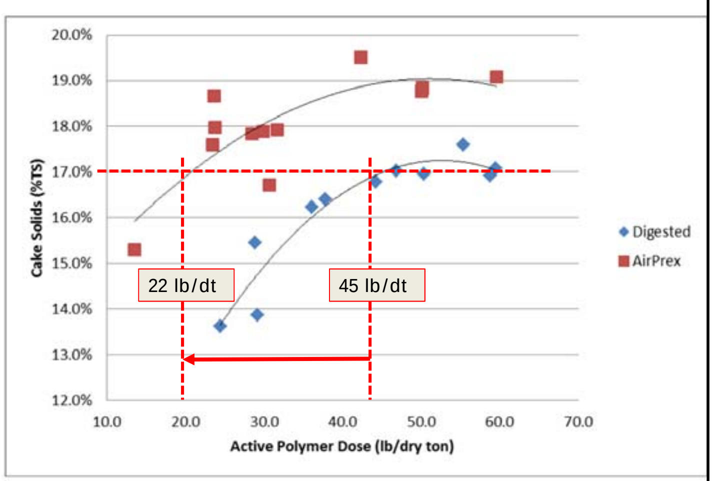
AirPrex Impact on Polymer Demand

- Added value in improved dewaterability



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Thermo Hydrolysis

- Pre Digestion Process
- Cell lysis
- High Temperature and Pressure

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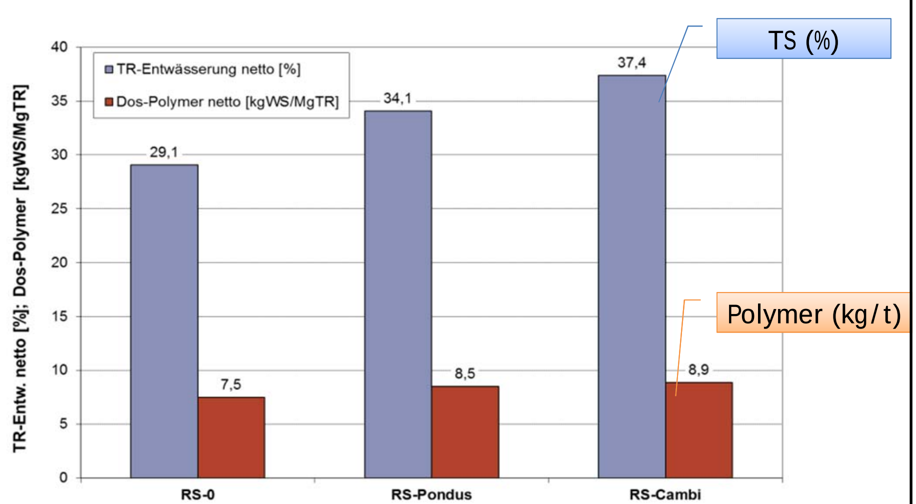
Thermo Hydrolysis



(Kopp 2013)

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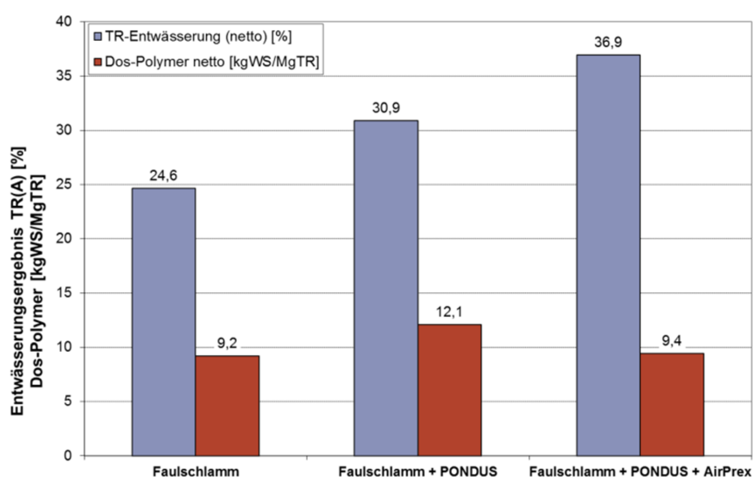
CTHP (PONDUS)

- Chemical/Thermal Hydrolysis
- Simple Process
- 80% – 90% as effective as THP

111

PONDUS



(Kopp 2013)

112

Key Takeaways

- EBPR decreases dewaterability
- Often occurs under the radar
- Struvite = indicator for EBPR
- There are mitigation options

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Closing Slide

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HDR Portland

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mbenisch@hdrinc.com

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Final Q & A

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Solids Stream P – Jan. 24, 2019

An MRRDC Short Course

Solids Stream Phosphorus Modeling

- Final Q & A:

Moderator	→	John Copp	Primodal
Basics	→	Patrick Dunlop	Black & Veatch
Nuisance	→	Murthy Kasi	Smith & Loveless
Chemistry	→	Hélène Hauduc	Dynamita
Dewatering	→	Mario Benisch	HDR

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116