NJWEA 101st Annual Conference & Exposition

Alternative Methods on Struvite Control

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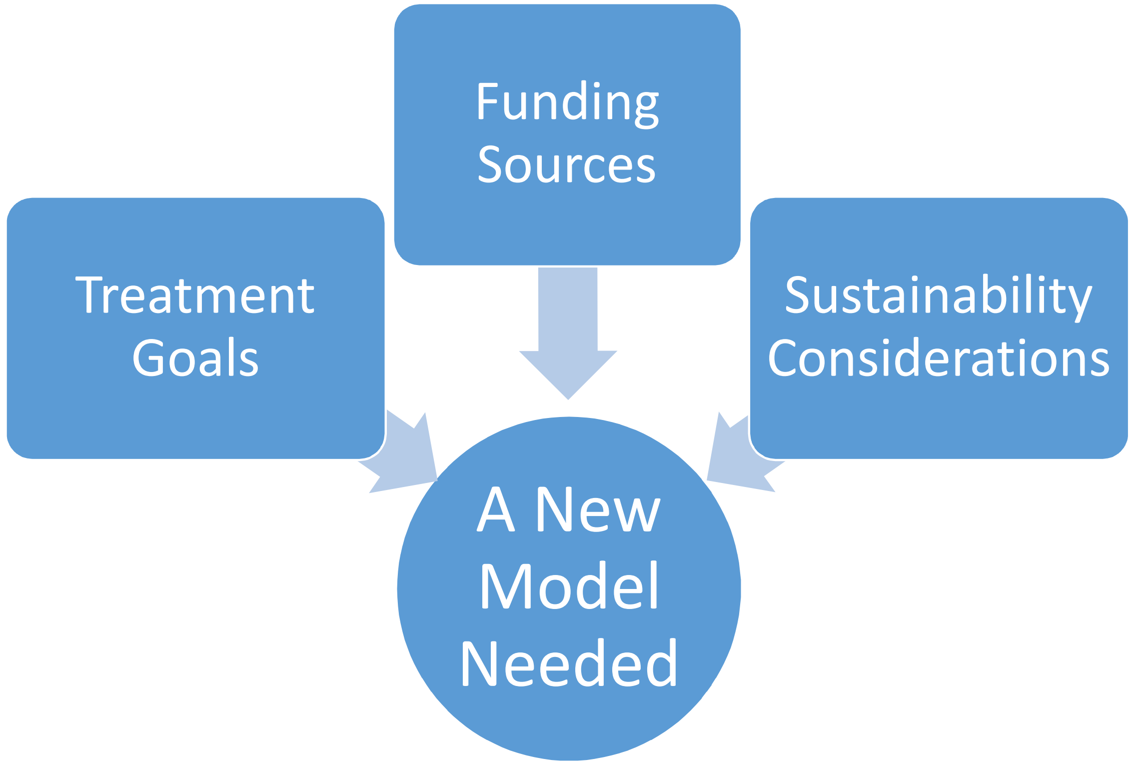
The City College of New York

An Evolving Mandate for Water Agencies

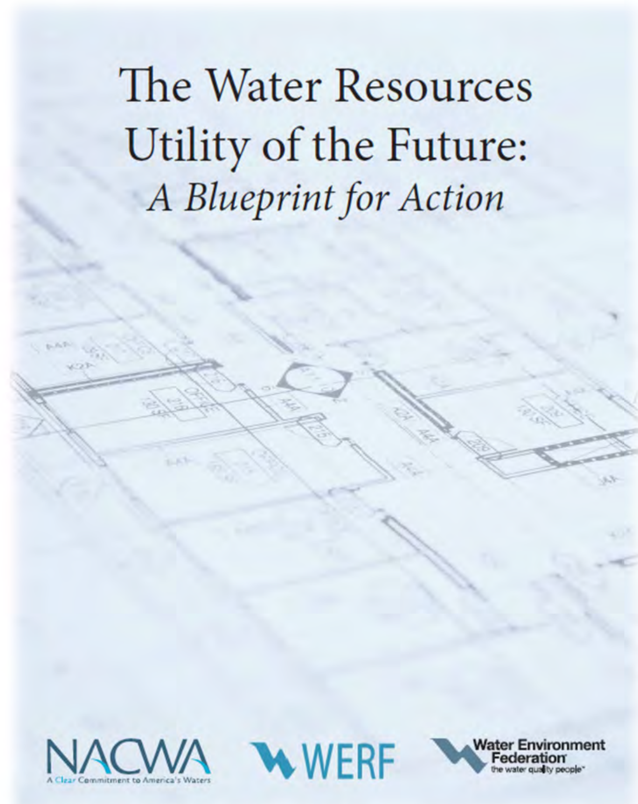


A New Model is Put Forth

- Which Resources Do We Target?

Resource Neutrality Represents Just One Element of the Roadmap

Resource Intensity Reduction	
Community Quality of Life	
Diversified Revenue Base	



http://www.nacwa.org/index.php?option=com_content&view=article&id=1604&Itemid=250

Transitioning to Resource Recovery

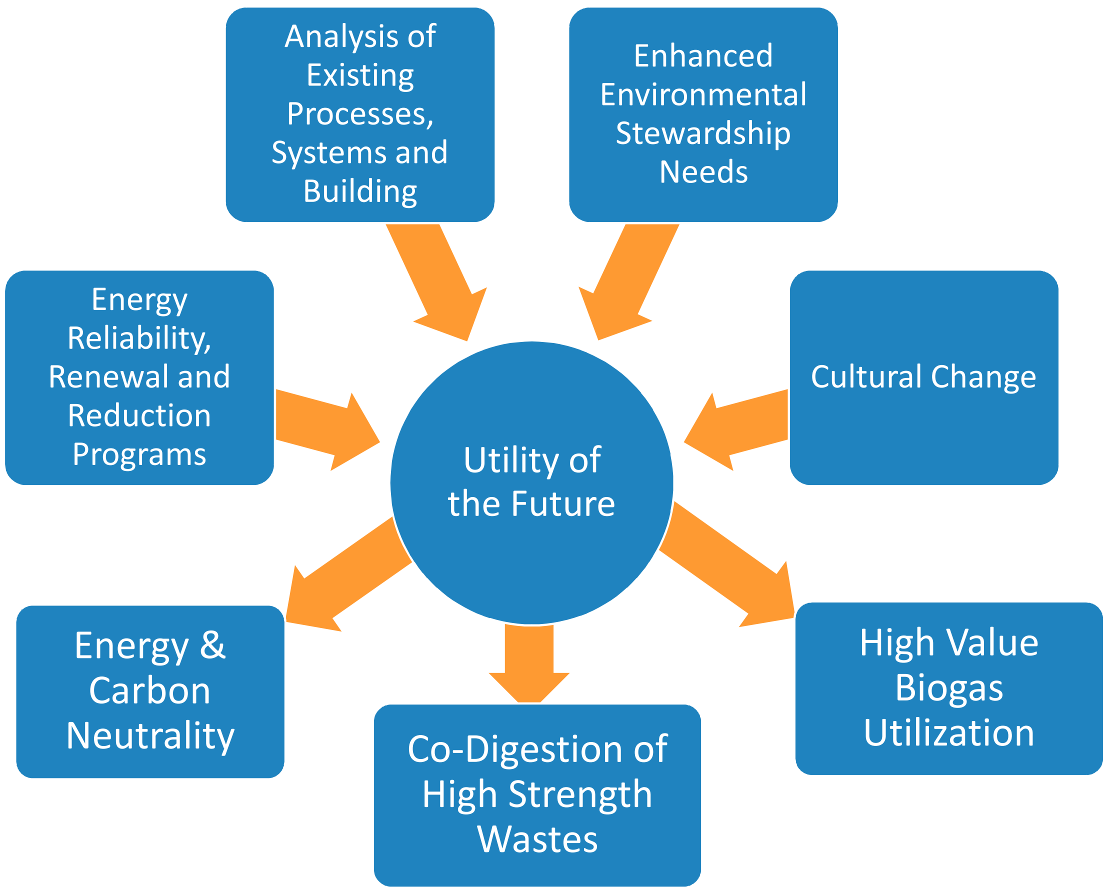
Waste Water Treatment Plant → *Water Resource Recovery Facility*

- Innovative Approaches to Treatment Critical to Success of the Transformation

Resource Intensity Reduction	✓
Community Quality of Life	✓
Diversified Revenue Base	✓

(NACWA, 2013)

The Road to the Utility of the Future Is Highly Organization/Locality Specific



As a Water Resource Recovery Facility :

Water-energy-nutrients nexus

Struvite as a nuisance?
Contrasted to
Struvite as nutrient recovered?

Background Information on Struvite

- Magnesium, Ammonium and Phosphate (MAP)

  $$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \longrightarrow MgNH_4PO_4.6H_2O$$

- White, yellowish white, or brownish white in color

26 Ward WWTP ANAMMOX MBBR Pilot

Struvite Precipitation at the Municipal WWTPs

- Struvite Formation can be seen at Municipal Wastewater Treatment Plants

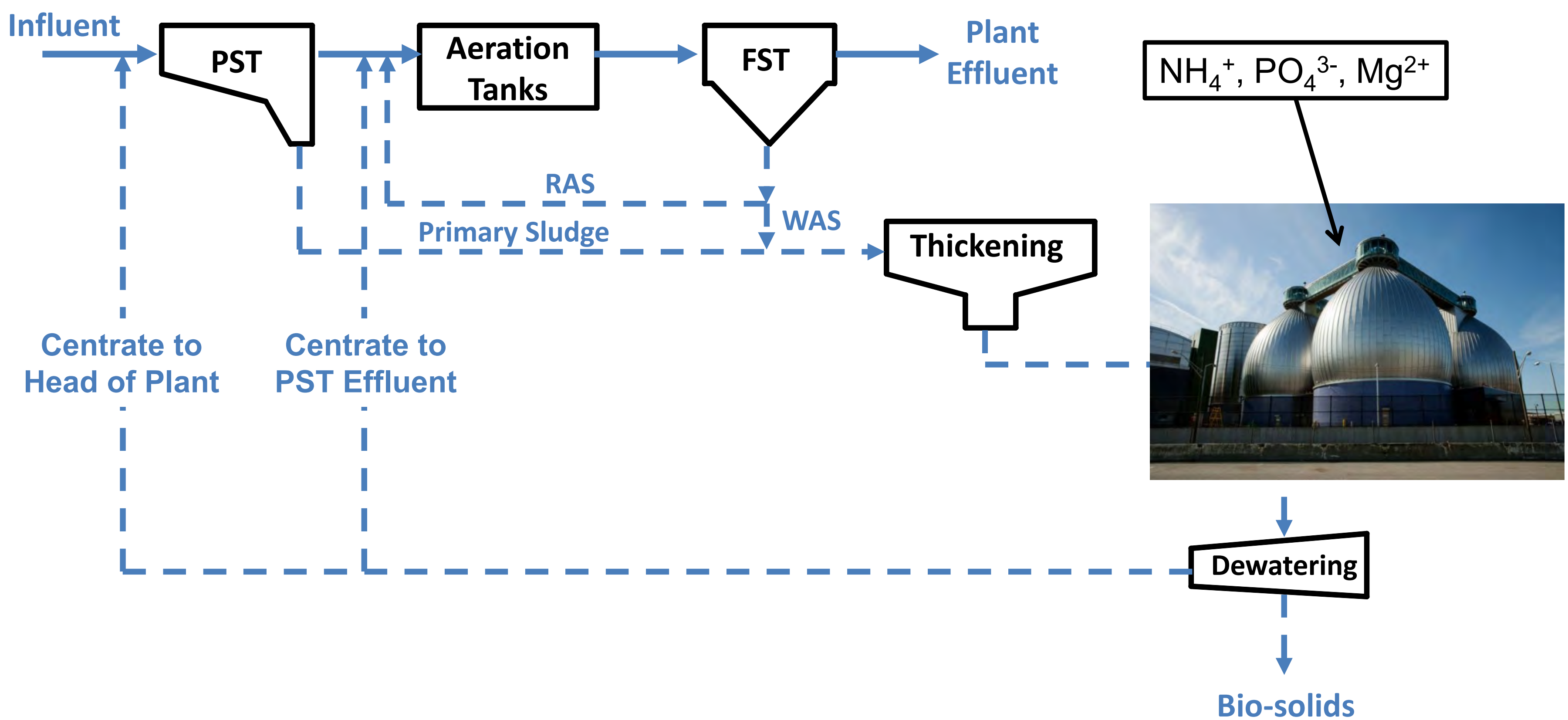
Centrate Return Line

Centrifuges

Separate Centrate
Treatment Aeration Tanks

Source of Struvite at the Municipal WWTPs

- The potential for struvite precipitation originates in the anaerobic digesters.



The two methods compared in this study

- ❑: **Struvite Control by using Ferric Chloride Addition**
- ❑: **Preferential Precipitation of Struvite through Aeration**

Struvite Formation Control Methods

- Struvite formation control by adding Ferric Chloride
  - Precipitate **PO_4^{3-}** ⬇
  - **Decrease** the pH of the sludge ⬇
  - **Increase** the struvite solubility ⬆

Mg^{2+} , NH_4^+ , PO_4^{3-}

- Alternative Struvite control method:
  Preferential precipitation of struvite from anaerobically digested sludge by air stripping the CO_2.
  - **Raise** the pH ⬆
  - **Decrease** the struvite solubility ⬇
  - Precipitate **Struvite** ⬇

Mg^{2+} , NH_4^+ , PO_4^{3-}

Effect of pH on Struvite Formation

- Struvite formation occurs when the molar concentration product of Mg^{+2}, PO_4^{-3}, and NH_4^+ exceeds the conditional solubility product (pK_{so})

$$pK_{so} = -\log([PO_4]\ [Mg]\ [NH_3])$$

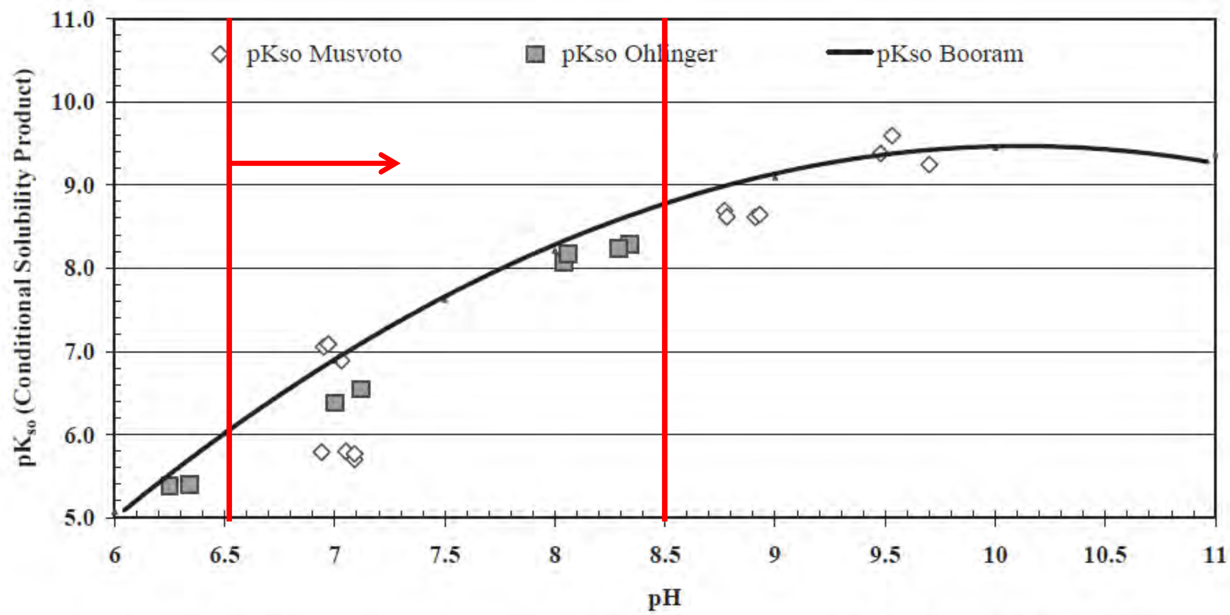


Fig. 2. A comparison of pK_{so} data for struvite over a range of pH values (calculated from data published by Musvoto et al. [37,38], Booram et al. [39], Ohlinger et al. [66]).

James D Doyle *et al,* Struvite Formation Control and Recovery, Water Research, Volume 36, page 3925-3940, March 2002.

Method 1:
Struvite Control by using Ferric Chloride

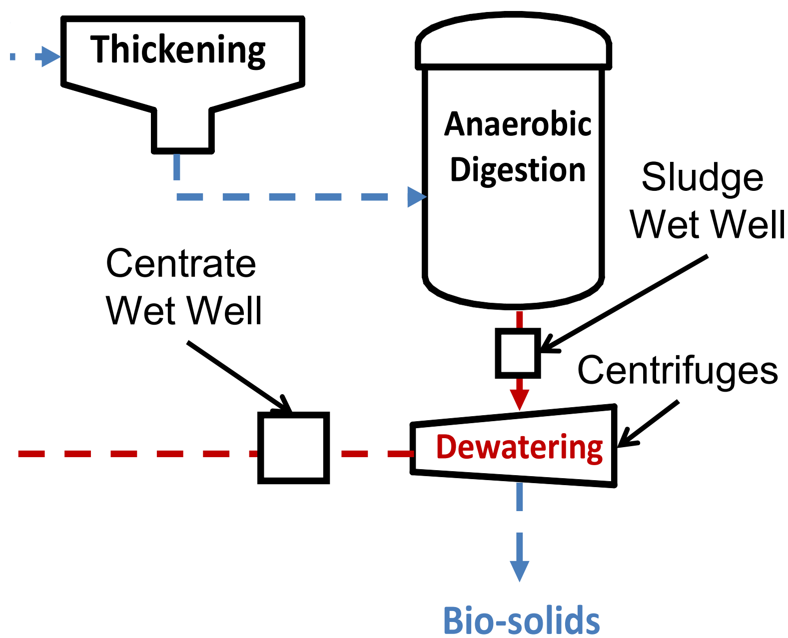
$FeCl_3$ Precipitation Reaction

- Chemical Precipitation Reaction of Iron

1. $Fe^{3+} + PO_4^{3-} \rightarrow FePO_4 \downarrow$

2. $2Fe^{+3} + 6HCO_3^- \rightarrow 2Fe(OH)_3 \downarrow + 6CO_2$

- $FeCl_3$ dosing at the NYC WRRFs
  - Centrifuges
  - Sludge Wet Well
  - Centrate Wet Well



Criteria for Comparison

- pH
- Residual PO_4^{3-} concentration
- Saturation Index

$$\text{Saturation Index} = \log(\text{IAP}) - \log(K_s)$$

Positive ⟶ Over Saturation
Zero (0) ⟶ Saturation
Negative ⟶ Under Saturation

Summary

$FeCl_3$ Dosing Experiments

- Saturation Index [(1)] was calculated by Visual MINTEQ.
  - Visual MINTEQ is a chemical equilibrium speciation model.

$$\text{Saturation Index} = \log(IAP) - \log(K_s)$$

	Untreated Sludge	Average $FeCl_3$ Dosage -σ	Average*$FeCl_3$ Dosage	Average $FeCl_3$ Dosage +σ
pH	7.19	7.00	6.86	6.75
Residual PO_4^{3-}-P (mg/l)	146	60	41	27
pK_s	13.26			
Saturation Index [(1)]	0.564	0.019	-0.127	-0.293

* **Average operating $FeCl_3$ dose at Wards Island WRRF: 1.33 ±0.31 Lit. /1000 liters of biosolids (1.33 gal./1000 gal.)**

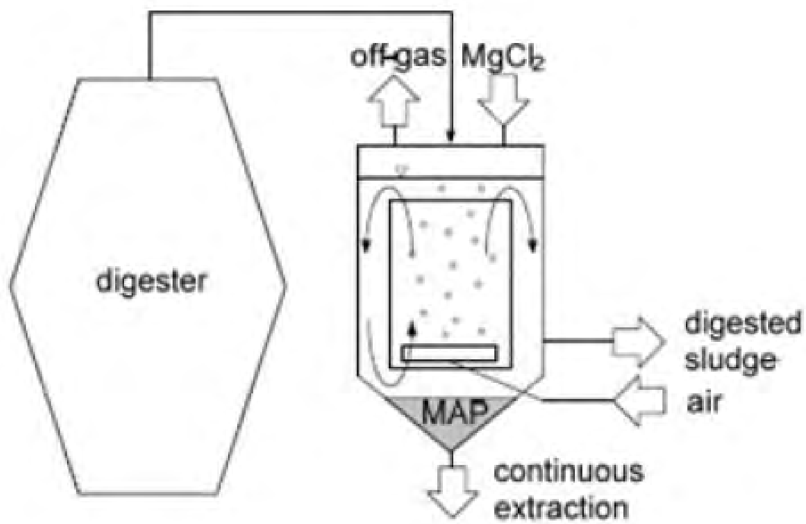
(1) Saturation Index:
Positive → Over saturated
Negative→ Under saturated

Method 2:

Preferential precipitation of struvite by aeration

Struvite Control by Aeration: Full Scale Application

- Preferential precipitation of struvite from anaerobically digested sludge by air stripping (CO_2 removal method) is currently applied at full scale in Germany (Berlin) patented with the name of "AirPrex®"



Struvite Precipitation by Aeration Procedure

Anaerobically digested sludge
(High NH_4^+, PO_4^{3-}, Mg^{2+})

↓

Aeration (CO_2 stripping)

↓

Increase in pH ⬆

↓

pK_{so} ⬇

↓

$[Mg^{2+}][NH_4^+][PO_4^{3-}]$ exceeds pK_{so}

↓

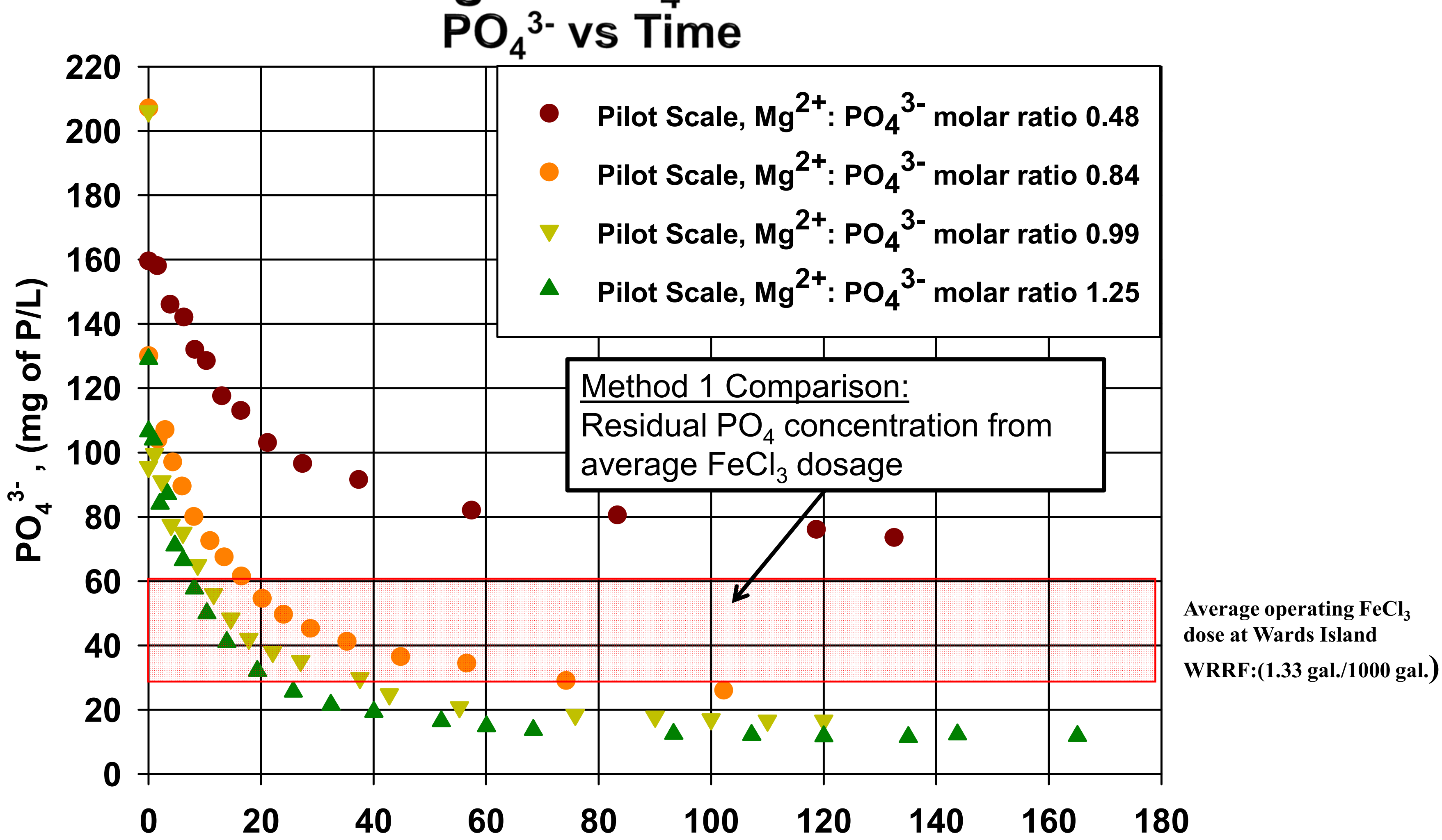
Struvite solubility decrease ⬇

↓

Struvite precipitates

Method 2:
Aeration Experiments

Effect of Mg^{+2} : PO_4^{3-} molar ratio



Note: External addition of $MgCl_2$

Air Flow Rate : 30 cfh

Summary

Pilot Scale Experiments: No Mg Addition

- Aeration Experiment:
  - Air Flow Rate: 30 cfh
  - No external Mg^{+2} addition ($Mg:PO_4 = 0.48$)

*Method 1 Baseline Residual PO_4-P concentration: 27 ~ 60 mg/L

	Untreated Sludge	Aerated Sludge* (120 Minutes)
Residual PO_4^{3-}-P (mg/l)	159	73.5
pH	7.05	8.42
pK_s	13.26	
Saturation Index [(1)]	0.565	1.055

(1) Saturation Index Calculated by Visual MINTEQ:
Positive → Over saturated
Negative→ Under saturated

Summary

Pilot Scale Experiments: Mg Addition

- Aeration Experiment:
  - Air Flow Rate: 30 cfh
  - External Mg^{+2} addition **Mg/PO_4 : 0.99**

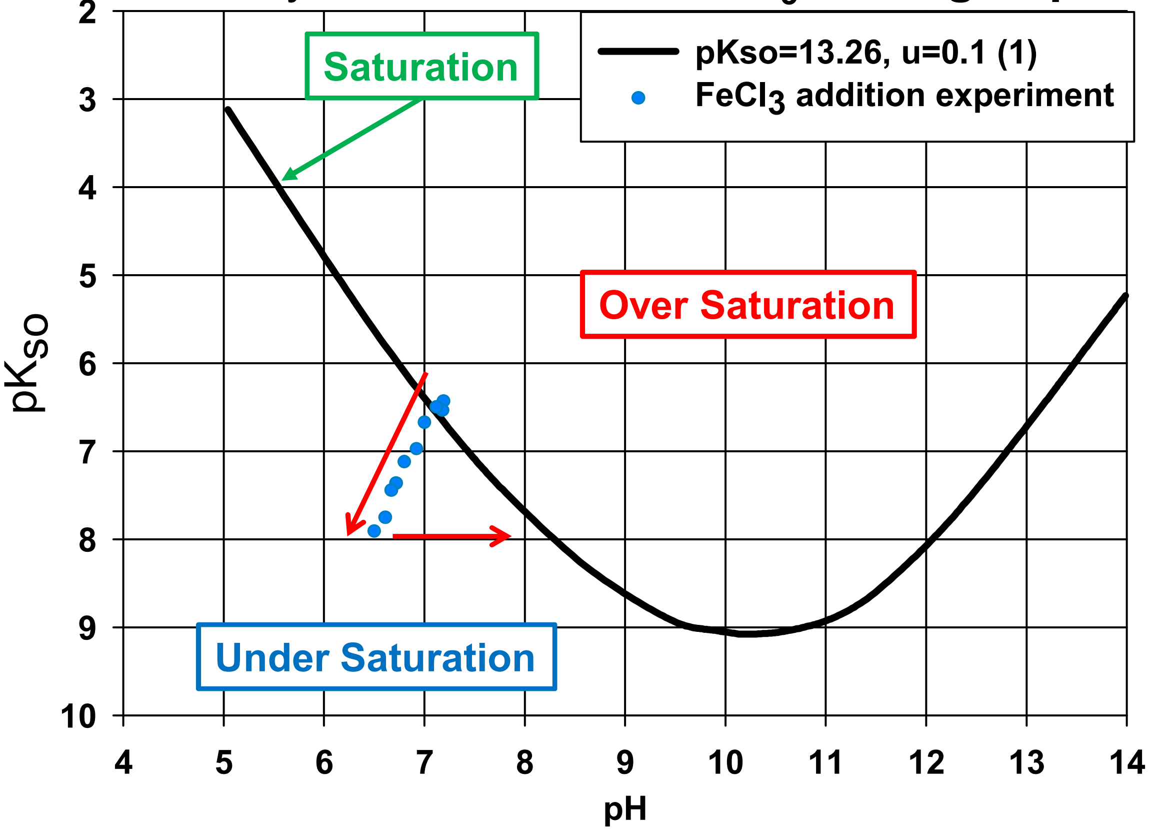
*Method 1 Baseline Residual PO_4-P concentration: 27 ~ 60 mg/L

	Untreated Sludge	Aerated Sludge ~ 10 minutes	Aerated Sludge ~ 20 minutes	Aerated Sludge ~ 40 minutes
Residual PO_4^{3-}-P (mg/l)	**206**	**60**	**41**	**27**
pH	**6.87**	**7.4**	**7.65**	**8**
pK_s	**13.26**			
Saturation Index(1)	**0.590**	**0.826**	**0.898**	**0.982**

(1) Saturation Index Calculated by Visual MINTEQ:
Positive → Over saturated
Negative→ Under saturated

Struvite Solubility Limit Curve

- Struvite Solubility Limit Curve and **$FeCl_3$ Dosing Experimental Data**

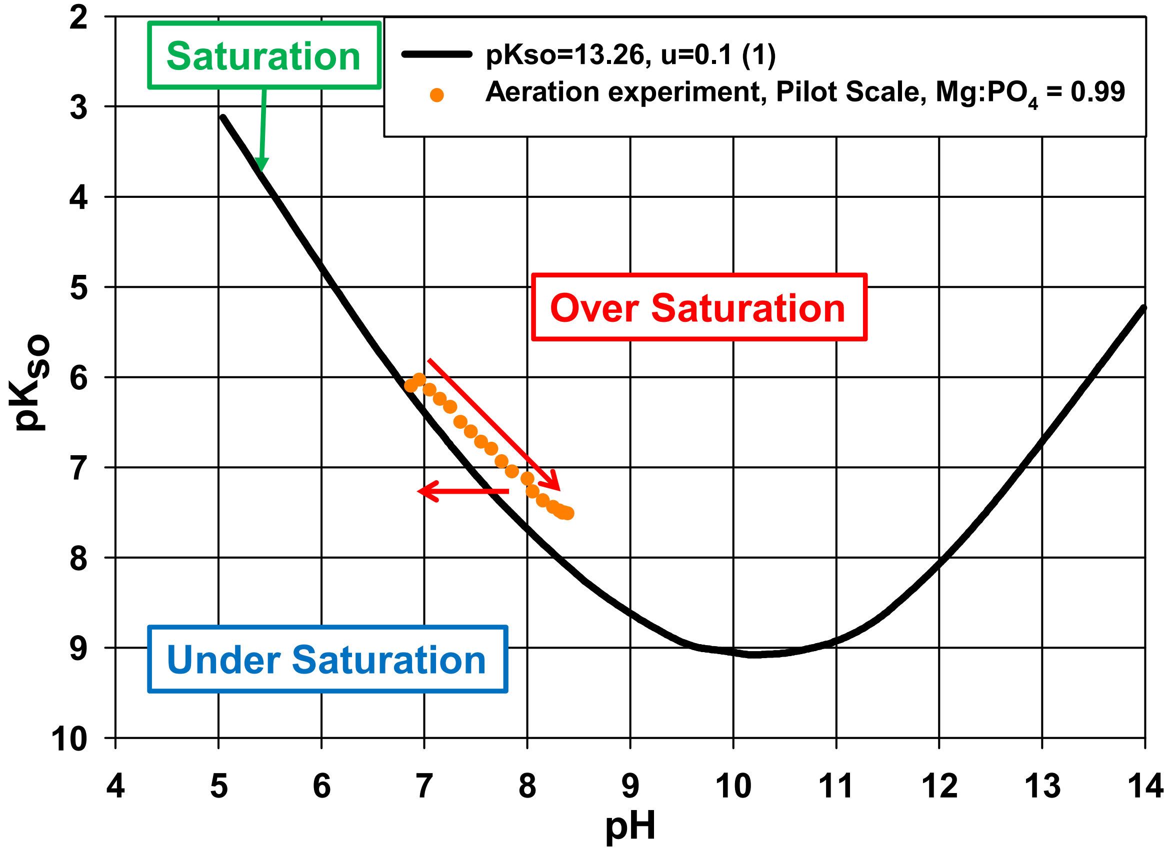


Aeration Experiment (12/13/2012): Tall Column, 30 cfh air flow, initial Mg/PO_4 molar ratio 1.25

(1) K. N. Ohlinger, T. M. Young and E. D. Schroeder (1998) Predicting Struvite Formation in Digestion Wat. Res. Vol. 32, No. 12, 3607-3614

Struvite Solubility Limit Curve

- Struvite Solubility Limit Curve and **Aeration Experimental Data**



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Comparison of Two Struvite Control Methods

	$FeCl_3$ Addition	**Aeration**
Precipitated Form	$FePO_4$ and $Fe(OH)_3$	Struvite
pH	Decrease	Increase
Chemical Addition	$FeCl_3$	If needed $MgCl_2$
Removal of NH_3-N	0 (zero)	45 mg/L NH_3-N removed for 100 mg/L PO_4-P removed

Benefits of the Struvite Precipitation by Aeration

- Recovered struvite can be reused as a slow release fertilizer
- Compared to the $FeCl_3$ addition, less sludge is produced.
- Carbon dioxide stripping technology is well established for optimum design.

Conclusions

- ***Preferential precipitation of struvite through aeration is not only a controlled process but removes both phosphorus and ammonia thus diminishing their loads to downstream BNR treatment processes.***
- ***The struvite produced is incorporated in the cake formed during dewatering increasing its nutrient capacity.***
- ***Less sludge is produced than the commonly used method of ferric chloride addition. Additionally, it may possibly avoid inhibition to BNR processes that have been typically attributed to ferric addition as a potential cause.***

- The technology of carbon dioxide stripping is well established for optimum design while the required equipment is readily available from several vendors.
- There is significant improvement in the dewaterability of the biosolids when supplemental Magnesium is added in the Mg:P ratio above 1 with optimized polymer dosage.

Struvite Harvesting

- At least 36 struvite production facilities worldwide with many in design or construction
- Product has sufficient purity for acceptance into the slow-release fertilizer market
- Nine technology providers, but only five actively marketing their processes in North America
  - **Akwadok**
  - **Centrisys/CNP**
  - **Colsen International**
  - **Multiform Harvest**
  - **Ostara**
  - **Paques**
  - **Remondis Aqua**
  - **RoyalHaskoning/DHV-Procorp Int.**
  - **Unitika Ltd.**

WATER RESOURCE RECOVERY FACILITIES OF THE FUTURE

Questions