Today’s Topics

Process monitoring of phosphorus

- Chemistry
- Removal mechanism
- Analyzers
- Treatment
- Case studies

Chemical and biological removal of phosphorus from wastewater
Phosphorus Chemistry

$\text{PO}_4^{3-} \ (+5)$ most common occurrence in environment

1 of 5 main elements of living organisms (CHONP)

Major component of fertilizers

Limiting nutrient in fresh water
Phosphorus Forms in WW*

Soluble Reactive P (sRP)
Soluble Non-reactive P (sNRP)
Colloidal P
Particulate P

Ortho-P
TP

*All are $\text{PO}_4^{3-}$
Most WRRFs Are Not Designed to Remove ‘P’
How is ‘P’ Removed?

1. Biological
2. Chemical

Basic concept:
‘P’ dissolved $\rightarrow$ ‘P’ Particulate
Most WRRFs Are Not Designed to Remove ‘P’

Some ‘P’ removal occurs normally

- **Soluble - P**
- **Particulate P**
- **Bio or Chem P Removal**
- **Treated Effluent**
- **Soluble - P**
- **Particulate P**
- **Effluent TP**
- **WAS**
Particulate Forms of P in Treated WW

Surface Complexation

Enhanced Biological P Removal (EBPR)

SEM image of 1-minute old (FeOH₃) floc, Dr. Vladimir Kitaev, Wilfred Laurier University

HMO floc w/ adsorbed P

Polyphosphate granules in bacteria
Phosphorus Monitoring Applications

TP
Early warning, Feed forward control

OP
Feedback control, Upset detection

TP
Compliance

TP
Total Phosphorus

OP
Orthophosphate
Phosphorus Analyzers
Colorimetric Measurement of P

- Measures ortho-P
- Sample processing required for sNRP or TP
  - **Yellow** method
    - Detection limit = 0.05 mg P/L
    - Used in most online analyzers
  - **Blue** method used in lab for compliance monitoring
Desirable Features of Online Analyzer

Easy to use

Minimal maintenance

Transparency

Low, low, low reagent consumption
Orthophosphate Cabinet Analyzers

Wet chemistry
4 main components

- Electronics
- Photometer & tubing
- Sample transport
- Reagent & solutions
- Filter (not shown)
Analyzer Mounting
Sampling Filtering & Transport
P Removal Treatment
Chemical P Removal – Surface Complexation Model (SCM)

1. Reaction with alkalinity to form hydrous metal oxide (HMO) floc
2. Soluble P adsorbs to HMO reactive sites
3. Co-precipitation: HMO enmeshes colloidal & Particulate P
SCM vs. Equilibrium

Low energy mixing limits P removal

Much lower dosages are possible
Chemical Removal - Simultaneous Precipitation

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Fe

P700

‘P’
Floating Point Control

P-701
- Phos Analyzer: Run
- Manual: Off
- 0 GPD Manual Setpoint
- 1.5% Output To Pump

P-702
- Phos Analyzer: Run
- Manual: Off
- 40 GPD Manual Setpoint
- 1.5% Output To Pump

P-703
- Phos Analyzer: Run
- Manual: Off
- 40 GPD Manual Setpoint
- 1.5% Output To Pump

P-704
- Phos Analyzer: Run
- Manual: Off
- 20 GPD Manual Setpoint
- 3.5% Output To Pump

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Phos Analyzer Read Out:
- 0.61 mg/l

FCL Pump Step Control Setpoints:
- Phos Control Setpoint: 0.65 mg/l
- Phos Control Hold Setpoint: 0.05 mg/l
- Pump Large Adj Setpoint: 2.00%
- Pump Large Adj Delay: 900 Sec
- Pump Small Adj Setpoint: 0.50%
- Pump Small Adj Delay: 900 Sec
- Pump Small To Large Adj Up: 0.10 mg/l
- Pump Large To Small Adj Dwn: 0.10 mg/l

FCL Pump Step Control Output Status:
- Output Large Adj Up
- Output Small Adj Up
- Output Hold
- Output Small Adj Down
- Output Large Adj Down
Chemical Dosing System Operation

Setpoint = 0.65 mg P/L
Analog Signal Directly to Feed Pump
Wisconsin WRFF Chemical Usage

- Chemical usage easy to track
- Simple payback is 1 year or less
- Other benefits like less sludge production not quantified

% Reduction in Chemical Usage

- Plant A: 25%
- Plant B: 9%
- Plant C: 92%
Enhanced Biological Phosphorus Removal

Anaerobic Zone

- BOD
- Energy ($E_i$)
- Polyphosphate
- PHB
- P Release
- $\text{DO, NO}_3^-$

Aerobic Zone

- CO$_2$ + H$_2$O
- Energy ($E_d$)
- Polyphosphate
- PHB
- Excess P Uptake
- DO

More bacteria
EBPR Monitoring Opportunities

COD / BOD
DO
Nitrate
ORP
TSS
Sludge blanket depth
P Removal with Effluent TSS

Effluent TP = Dissolved P + Particulate P

Efluent Particulate P, mg/L

Effluent TSS, mg/L

10% P
8% P
6% P
4% P
2% P
ORP Control of EBPR

- ORP high / air “off”: ~250 mV
  - Anaerobic to Oxic
  - DO SP: 1.7 to 1.9 mg/L
  - Nitrification
  - P uptake
- ORP low / timer start: ~50 mV
  - Oxic to Anoxic
  - Denitrification
  - Timer start

Anaerobic Timer: 40 min.
- Anaerobic
- P release
- Air “on”
2009 – 1 mg/L TP Limit with EBPR

Smith, R.C., Goble, L, “To Everything There is a Season: Lessons from Four Seasons of Phosphorus Removal at Greene County Sugarcreek WRRF”, WEFTEC 2010
### Effect of P Removal on WRRF Operations

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<tr>
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<th>Chemical Removal</th>
<th>EBPR</th>
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<tr>
<td>Operating Complexity</td>
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- ![Up Arrow] - Strong positive impact
- ![Down Arrow] - Positive
- ![Down Arrow] - Negative
- ![Down Arrow] - Strong negative impact

Adapted from Dube, P. (2018), Understanding the Effects of Nutrient Removal on Dewatering, wefhq update appearing in The Conduit magazine
Phosphorus in wastewater occurs as $\text{PO}_4^{3-}$ and is either dissolved or particulate.

Chemical and biological P processes convert soluble P to particulate P which can be removed from wastewater by sedimentation.

It is important to consider the impact of P removal on wastewater treatment plant (WWRF) operations when selecting between chemical and biological P removal.

Monitoring of dissolved P, which is mostly orthophosphate, is useful for process control of P removal processes:
- Minimizing chemical usage
- Status of release/uptake (EBPR)

Oxidation-Reduction Potential (ORP) can be used to optimize the conditions for EBPR.
Questions? Comments? Clarifications?

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