Orthophosphate Monitoring and Phosphorus Removal Control
Today’s Topics

Process monitoring of phosphorus

• Chemistry
• Removal mechanism
• Analyzers
• Treatment
• Case studies

Chemical and biological removal of phosphorus from wastewater
Phosphorus Chemistry

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

1 of 5 main elements of living organisms (CHONP)

Major component of fertilizers

Limiting nutrient in fresh water

What goes in, must come out
Phosphorus Forms in WW*

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

*All are PO$_4^{3-}$
How is ‘P’ Removed?

1. Biological
2. Chemical

Basic concept:
‘P’ dissolved → ‘P’ Particulate
Particulate Forms of P in Treated WW

Surface Complexation

HMO floc w/ adsorbed P

Enhanced Biological P Removal (EBPR)

Polyphosphate granules in bacteria

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

- **TP**: Total Phosphorus
- **OP**: Orthophosphate

**Load detection**

**Feedback control**

**Compliance**

**Primary Settling**

**Activated Sludge**

- Aeration
- Final Settling Tank

**Effluent**

- Sand filter
- Disinfection

Total Phosphorus

Orthophosphate
Phosphorus Analyzers
Colorimetric Measurement of P

- Measures ortho-P
- Sample processing required for sNRP or TP (additional step)
  - Yellow method
    - Detection limit = 0.05 mg P/L
    - Used in most online analyzers
  - Blue method used in lab for compliance monitoring
Orthophosphate Cabinet Analyzers

Wet chemistry

4 main components

- Electronics
- Photometer & tubing
- Sample transport
- Reagent & solutions
Analyzer Mounting
Sampling System

![Sampling System Image 1](image1)

![Sampling System Image 2](image2)
P Removal Treatment
## Effect of P Removal on WRRF Operations

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<th>EBPR</th>
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<tr>
<td>Operating Complexity</td>
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- 📉 - Strong positive impact
- 📈 - Positive
- 📉 - Negative
- 📉 - Strong negative impact

Adapted from Dube, P. (2018), Understanding the Effects of Nutrient Removal on Dewatering, wefhq update appearing in The Conduit magazine
Chemical Removal - Simultaneous Precipitation

- Fe
- P700
- ‘P’
Floating Point Control

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

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

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

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

**FCL Pump Step Control Setpoints**
- Phos Control Setpoint: 0.65 mg/L
- Pump Large Adj Setpoint: 2.00%
- Pump Small Adj Setpoint: 0.50%
- Pump Large To Small Adj Dwn: 0.10 mg/L
- Pump Large To Small Adj Up: 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

![Graph showing historical trending of phosphorus levels](image-url)

- **Phosphorus (mg/L)**
- **Time (24/2015)**
- **February 2015 Calendar**

The graph illustrates the phosphorus levels over time, starting from 9:22:46 AM and ending at 11:10:35 AM, with a peak around 5:53 PM. The data is highlighted from 2/13/2015.
Analog Signal Directly to Feed Pump

Controller Settings:
- Current output: 150
- Recorder type: 4.20 mA
- Measured variable: Main variable
- Start value: 0.6 mg/L
- End value: 3.0 mg/L
- Attenuation: 20.0 mA/s
- Error
  - Behavior at error: Fixed current value
  - Current with error: 4.0 mA

Certified metering pump:
- Model: EHE 661, LC
- Serial number: 09011205552
- NSF/IANS 61 certification
- Capabilities:
  - Capacity: 20.5 SPH
  - Max Pressure: 30 PSI
  - Stroke Rate: 1-340 SPH
  - Voltage: 115V, Voltage: 1.5A
  - Thermally protected: Freq 80000
Wisconsin WRRF Chemical Usage

Chemical usage easy to track
Simple payback is 1 year or less
Other benefits like less sludge production not quantified
Enhanced Biological Phosphorus Removal

**Anaerobic Zone**
- **BOD**
- **Energy** ($E_i$)
- **PHB**
- **Polyphosphate**
- **P Release**
- **DO, NO$_3$**

**Aerobic Zone**
- **DO**
- **Energy** ($E_d$)
- **CO$_2$ + H$_2$O**
- **Excess P Uptake**
- **Polyphosphate**
- **More bacteria**
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”
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
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 WRRF 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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