October 11, 2018

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Orthophosphate Monitoring and Phosphorus Removal Control

OWEA 2018 PLANT OPERATIONS AND LAB WORKSHOP

Today's Topics

Process monitoring of phosphorus

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

Chemical and biological removal of phosphorus from wastewater

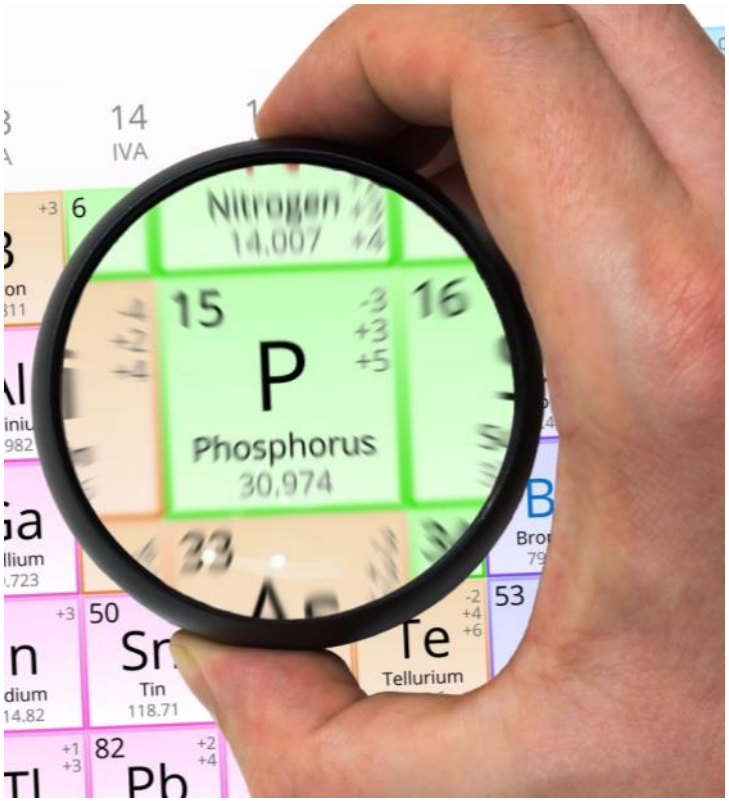
Phosphorus Chemistry

PO_4^{3-} (+5) most common occurrence in environment

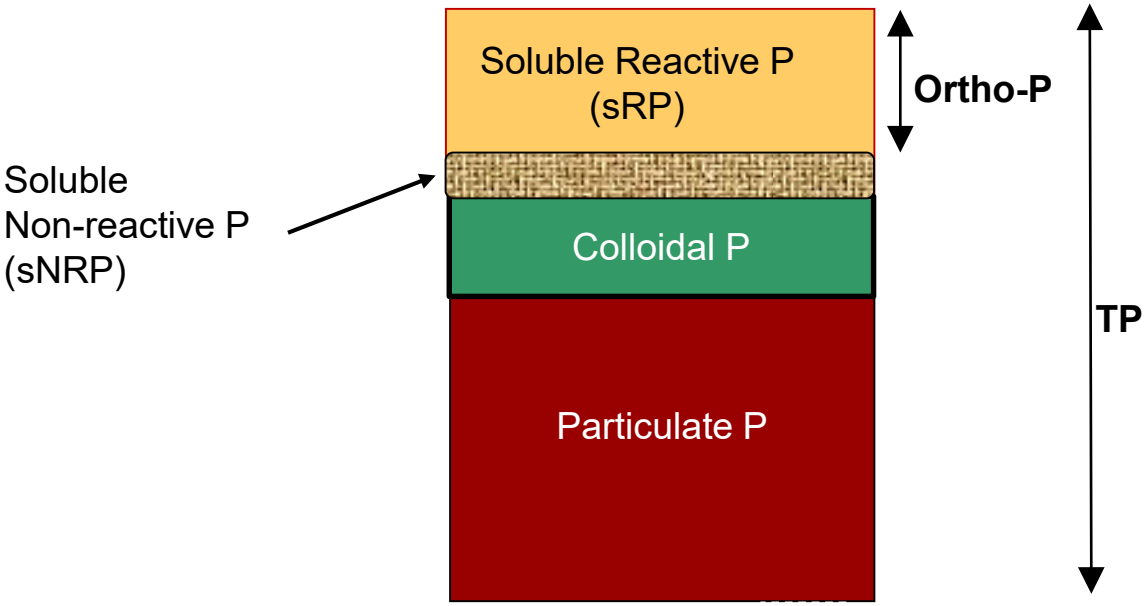
1 of 5 main elements of living organisms (CHONP)

Major component of fertilizers

Limiting nutrient in fresh water

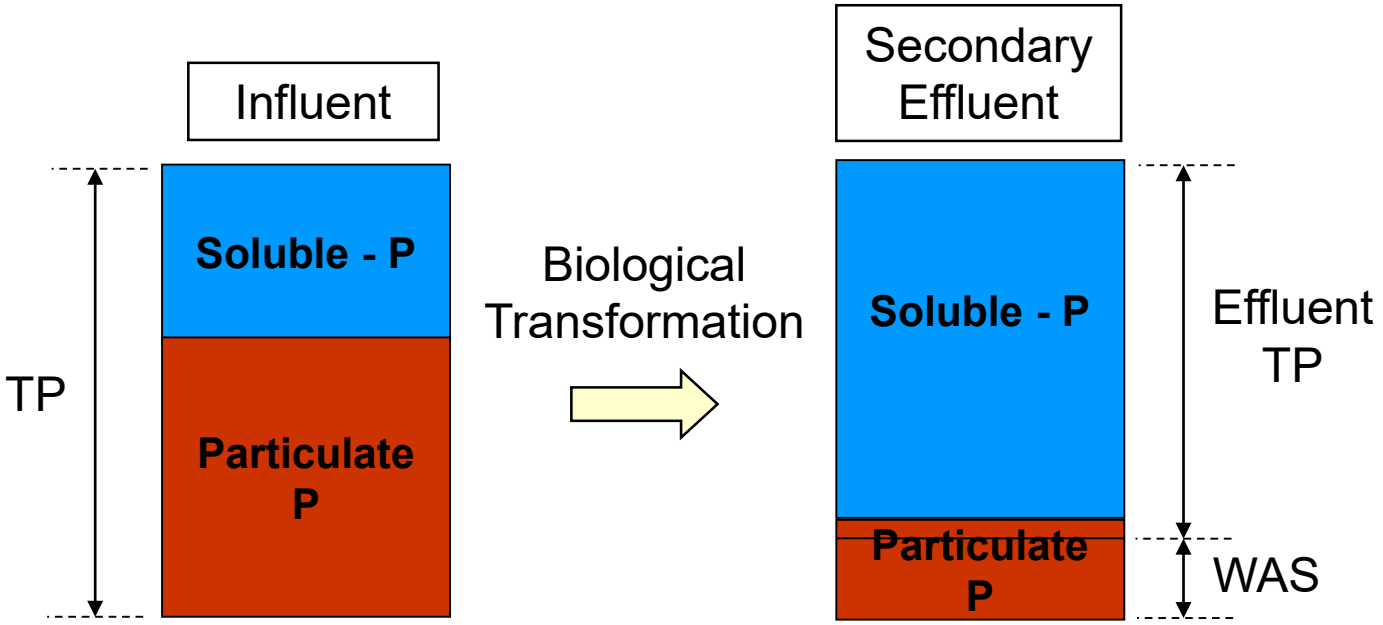


Phosphorus Forms in WW*



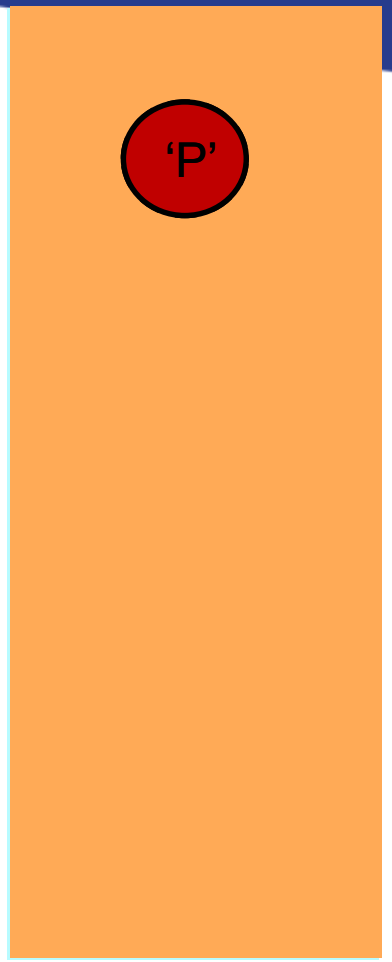
*All are PO_4^{3-}

Most WRRFs Are Not Designed to Remove ‘P’



How is ‘P’ Removed?

1. Biological
2. Chemical

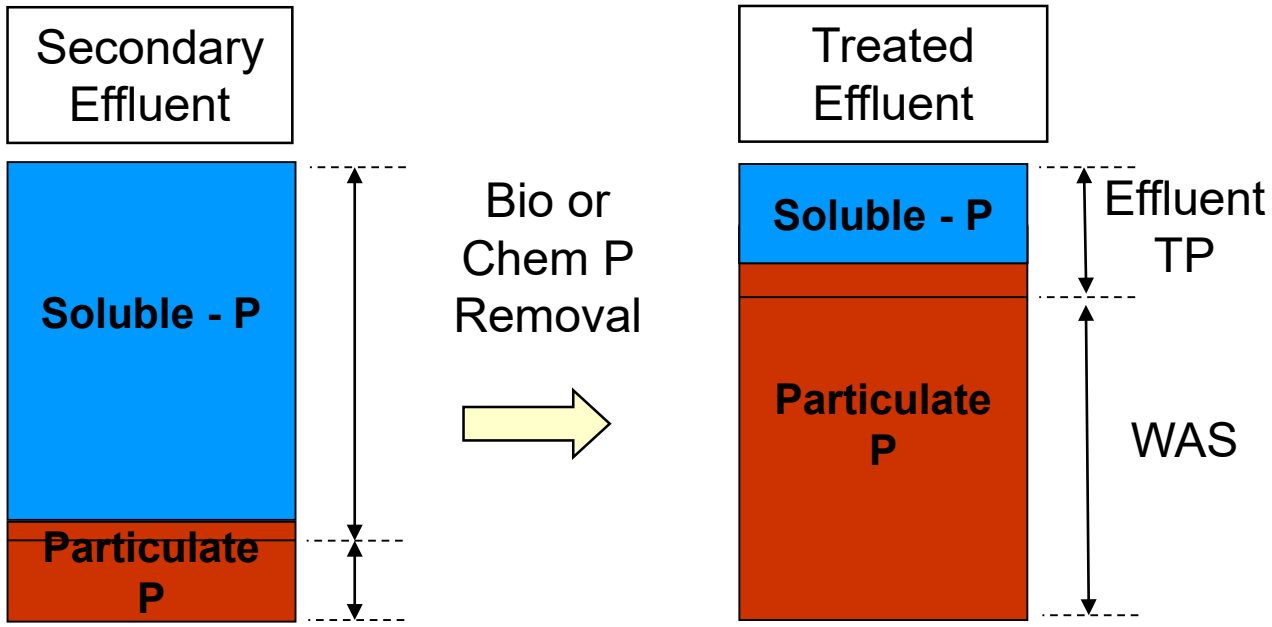


Basic concept:

‘P’ dissolved ⟶ ‘P’ Particulate

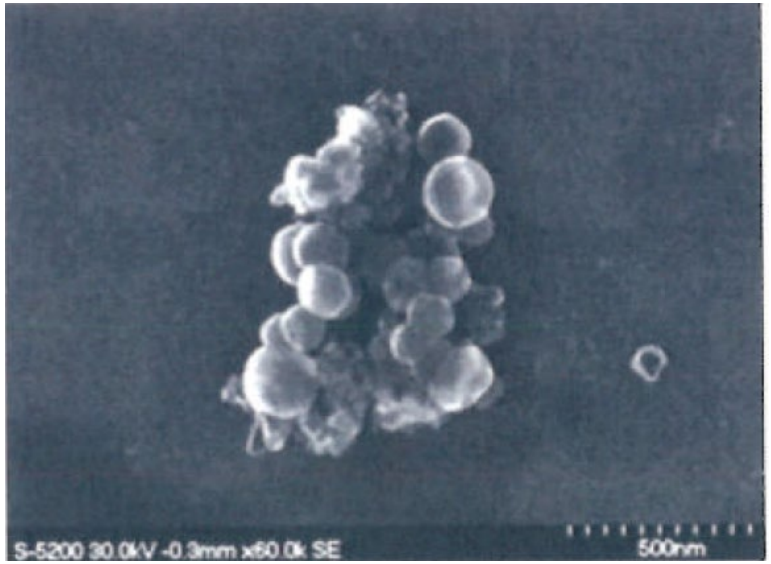
Most WRRFs Are Not Designed to Remove ‘P’

Some ‘P’ removal occurs normally



Particulate Forms of P in Treated WW

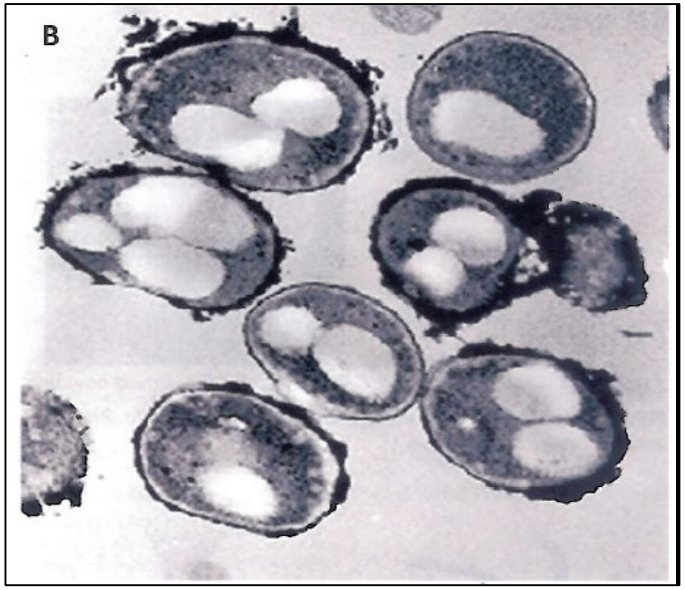
Surface Complexation



SEM image of 1-minute old ($FeOH_3$) floc, Dr. Vladimir Kitaev, Wilfred Laurier University

HMO floc w/ adsorbed P

Enhanced Biological P Removal (EBPR)



Polyphosphate granules in bacteria

Phosphorus Monitoring Applications

TP

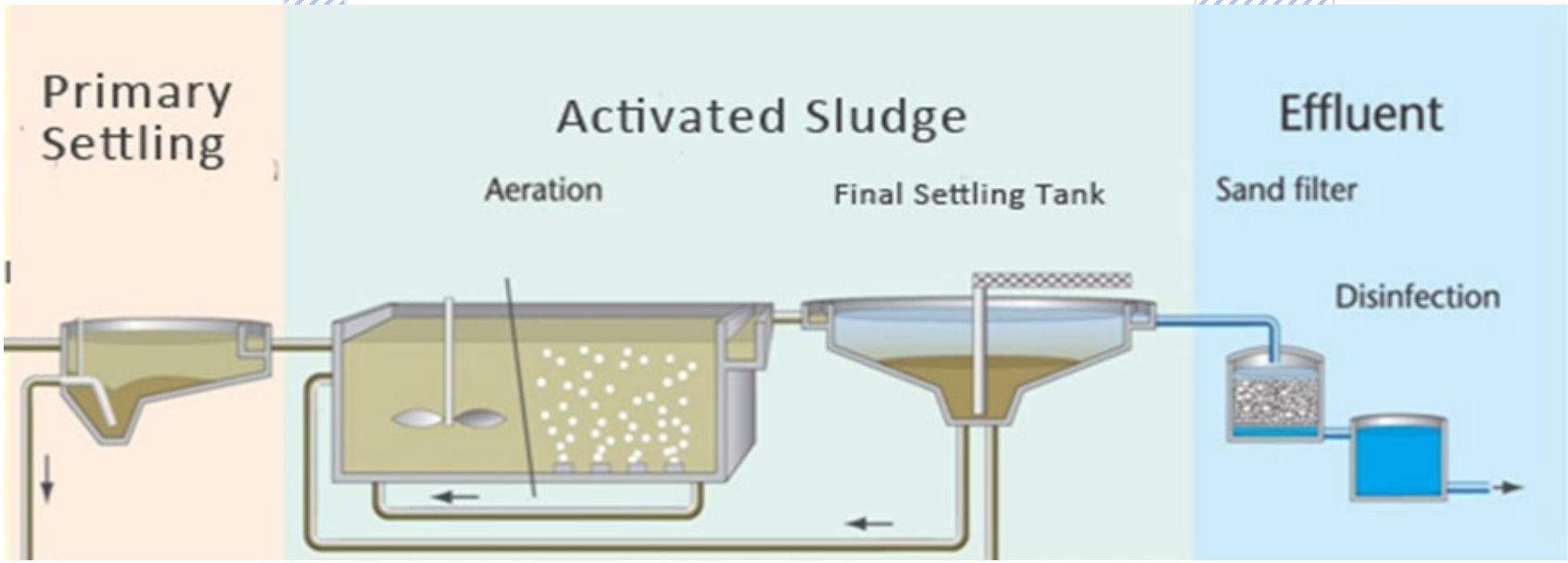
Early warning,
Feed forward
control

OP

Feedback control,
Upset detection

TP

Compliance

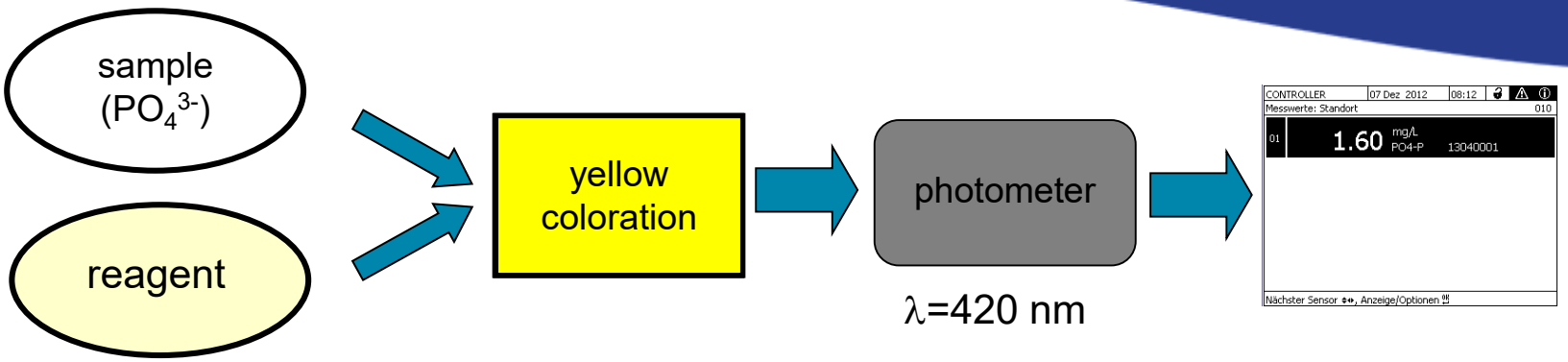


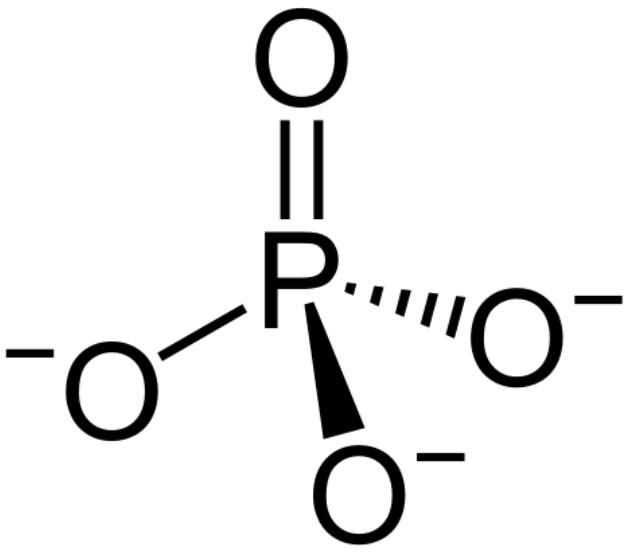
TP Total Phosphorus

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

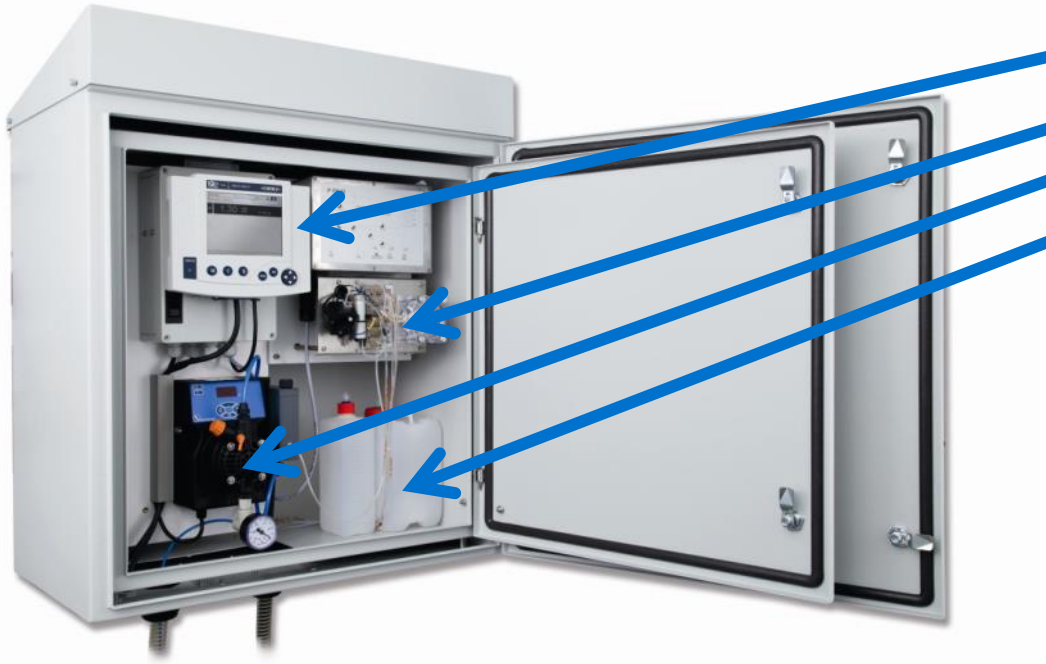
Transparency

Low, low, low reagent consumption

Orthophosphate Cabinet Analyzers

Wet chemistry

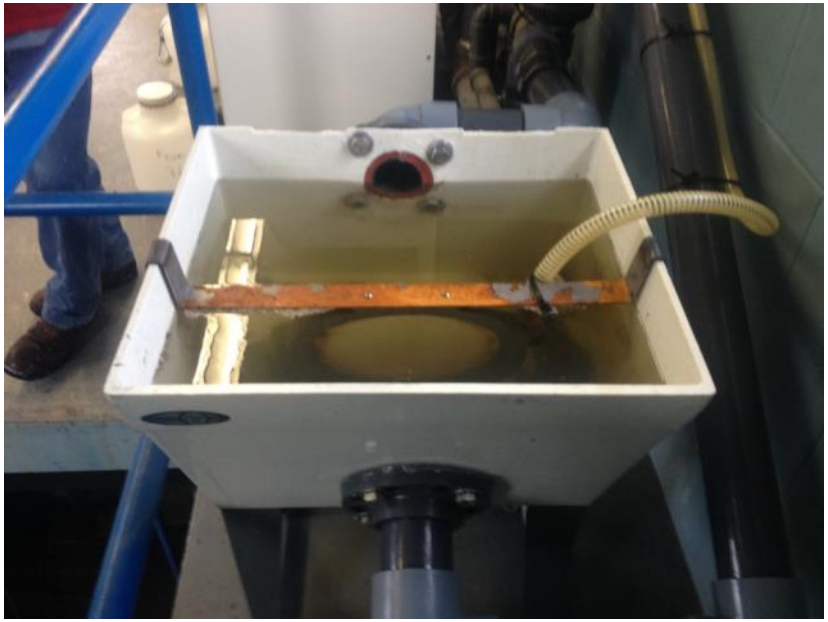
4 main components



- Electronics
- Photometer & tubing
- Sample transport
- Reagent & solutions
- Filter (not shown)

Analyzer Mounting

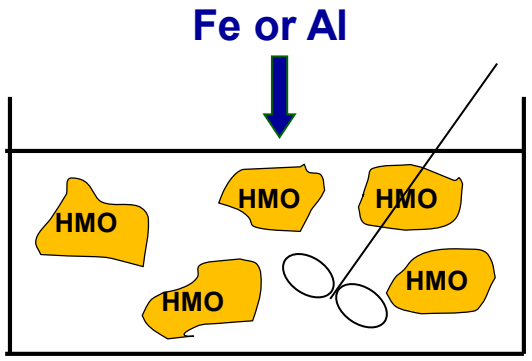
Sampling Filtering & Transport



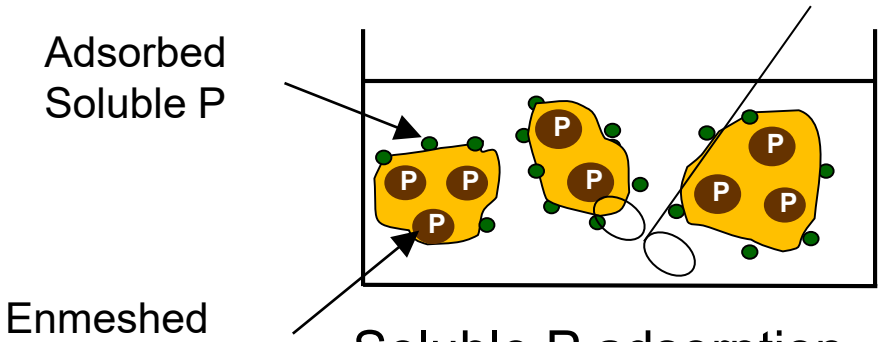
P Removal Treatment

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



HMO Formation



Soluble P adsorption
Particulate P enmeshment

SCM vs. Equilibrium

Low energy mixing limits P removal

Much lower dosages are possible

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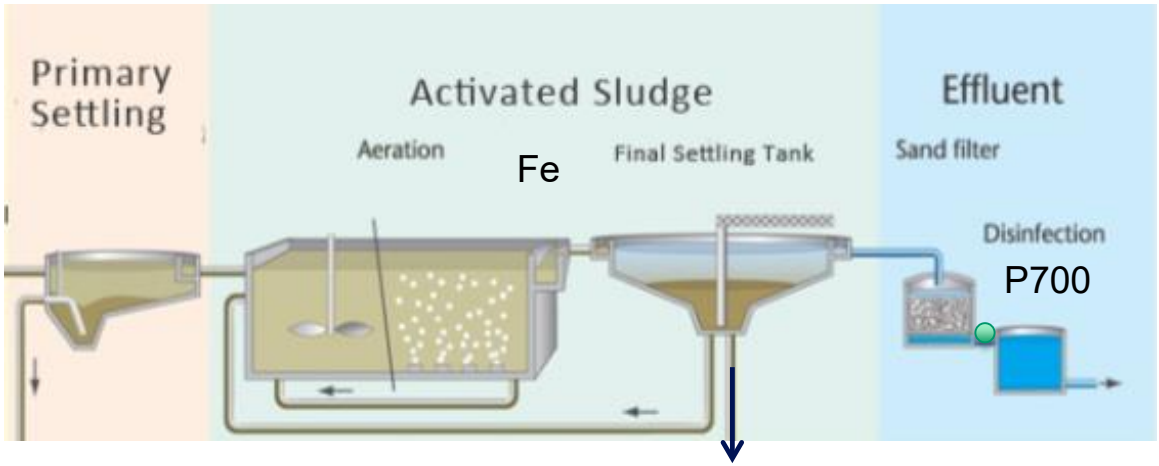
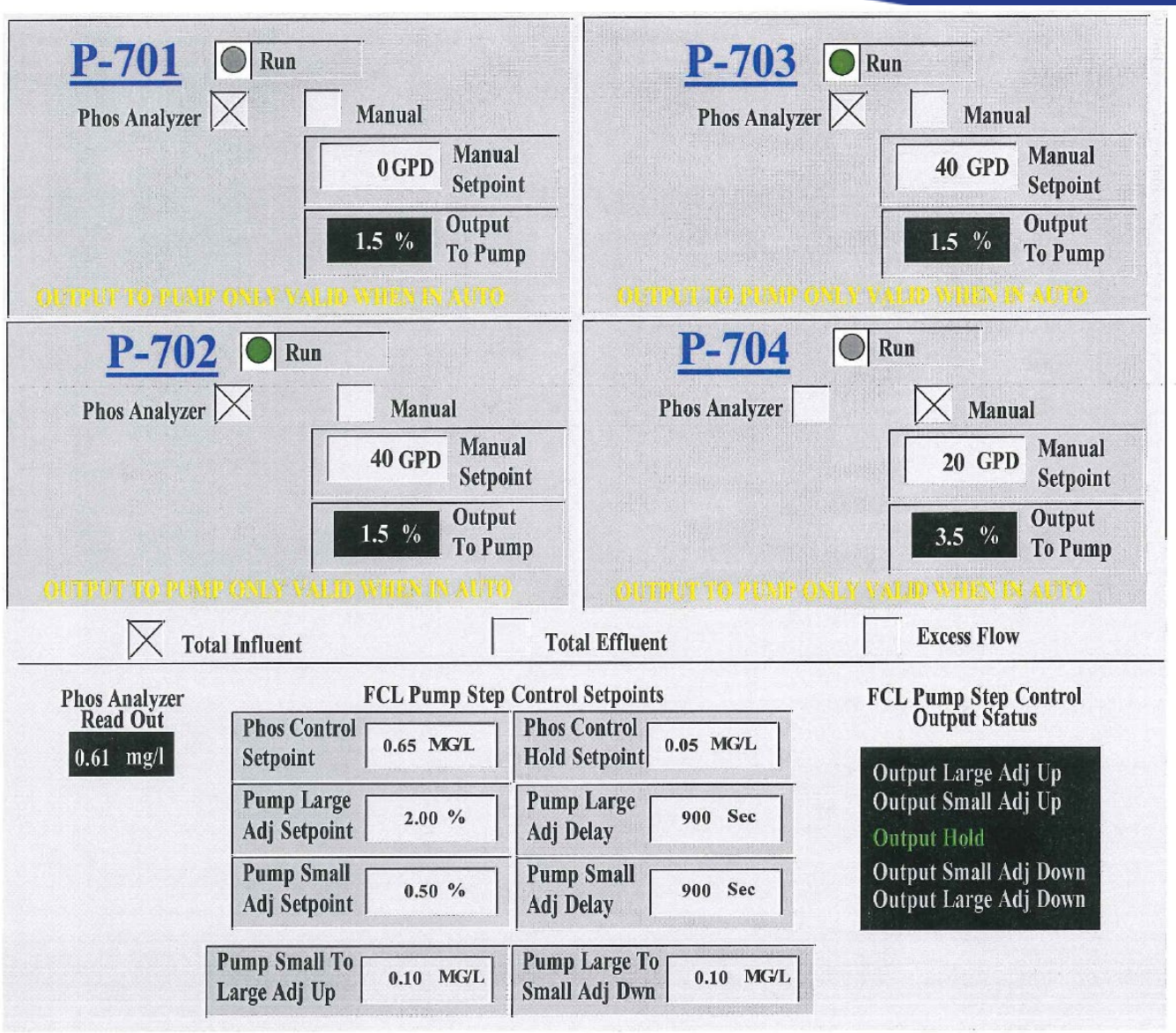
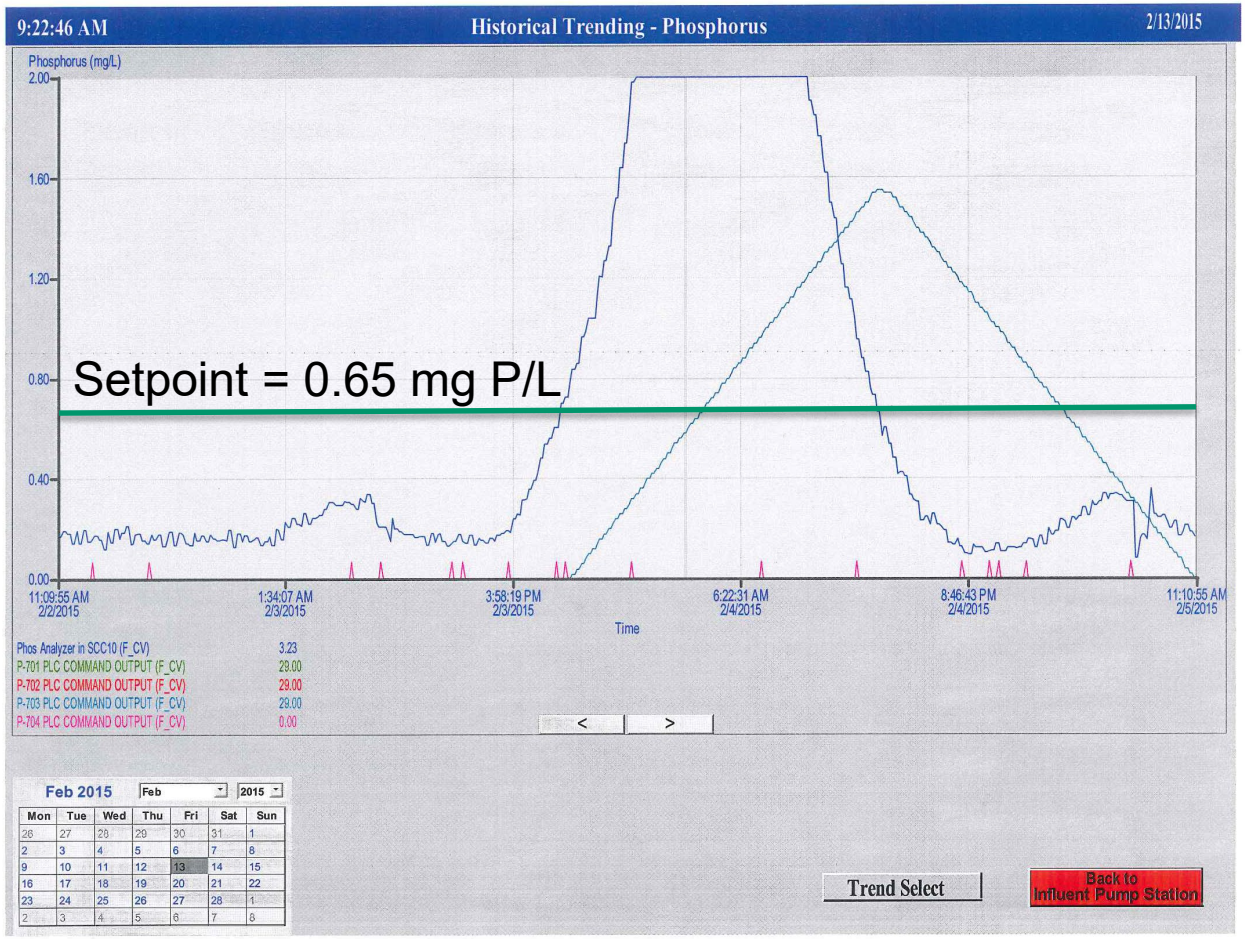
Chemical Removal - Simultaneous Precipitation



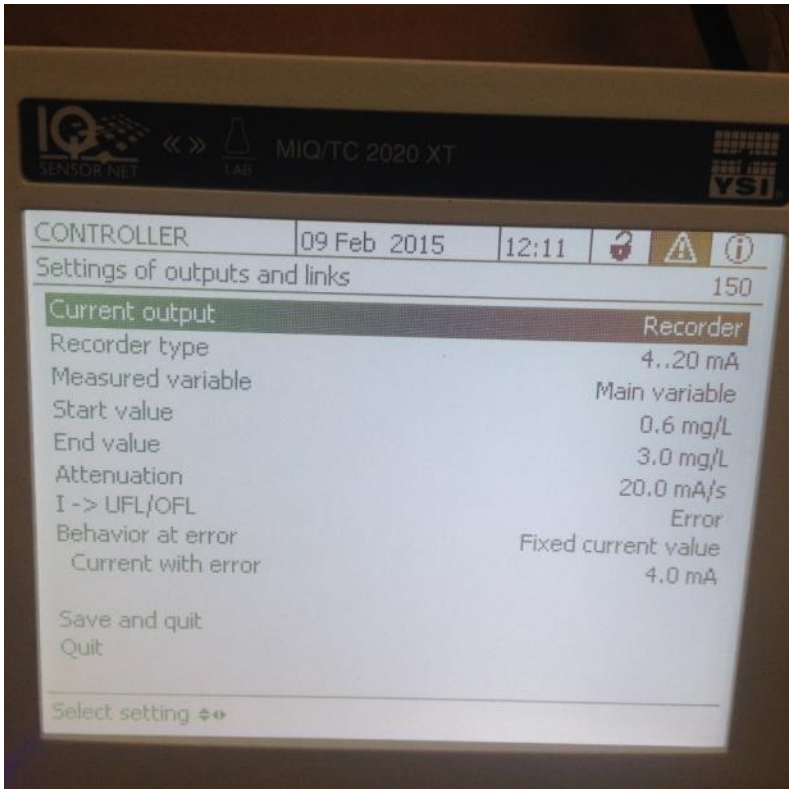
Floating Point Control

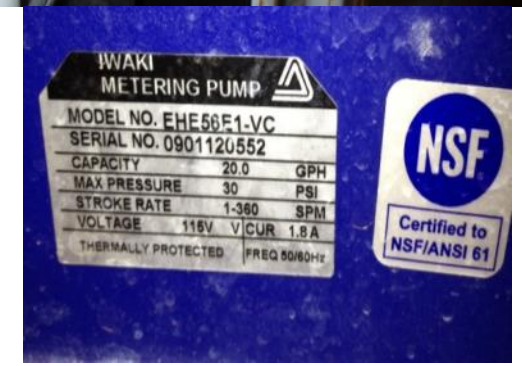


Chemical Dosing System Operation

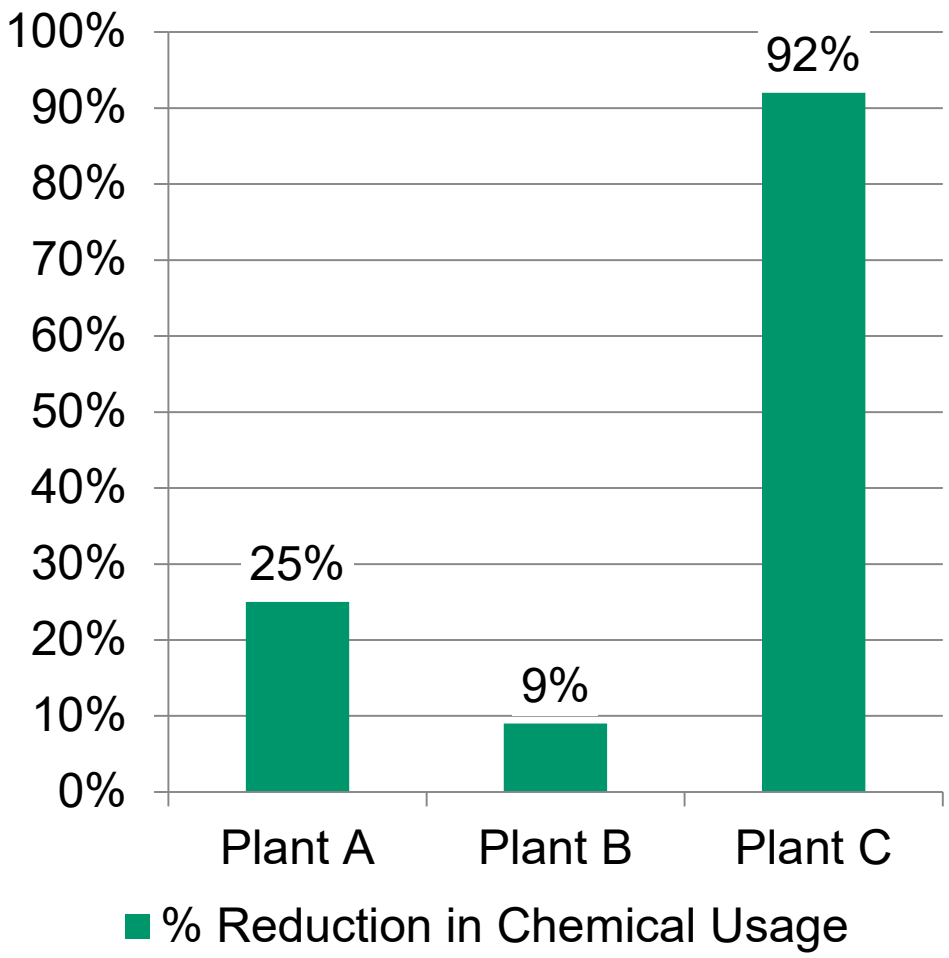


Analog Signal Directly to Feed Pump





Wisconsin WRRF Chemical Usage

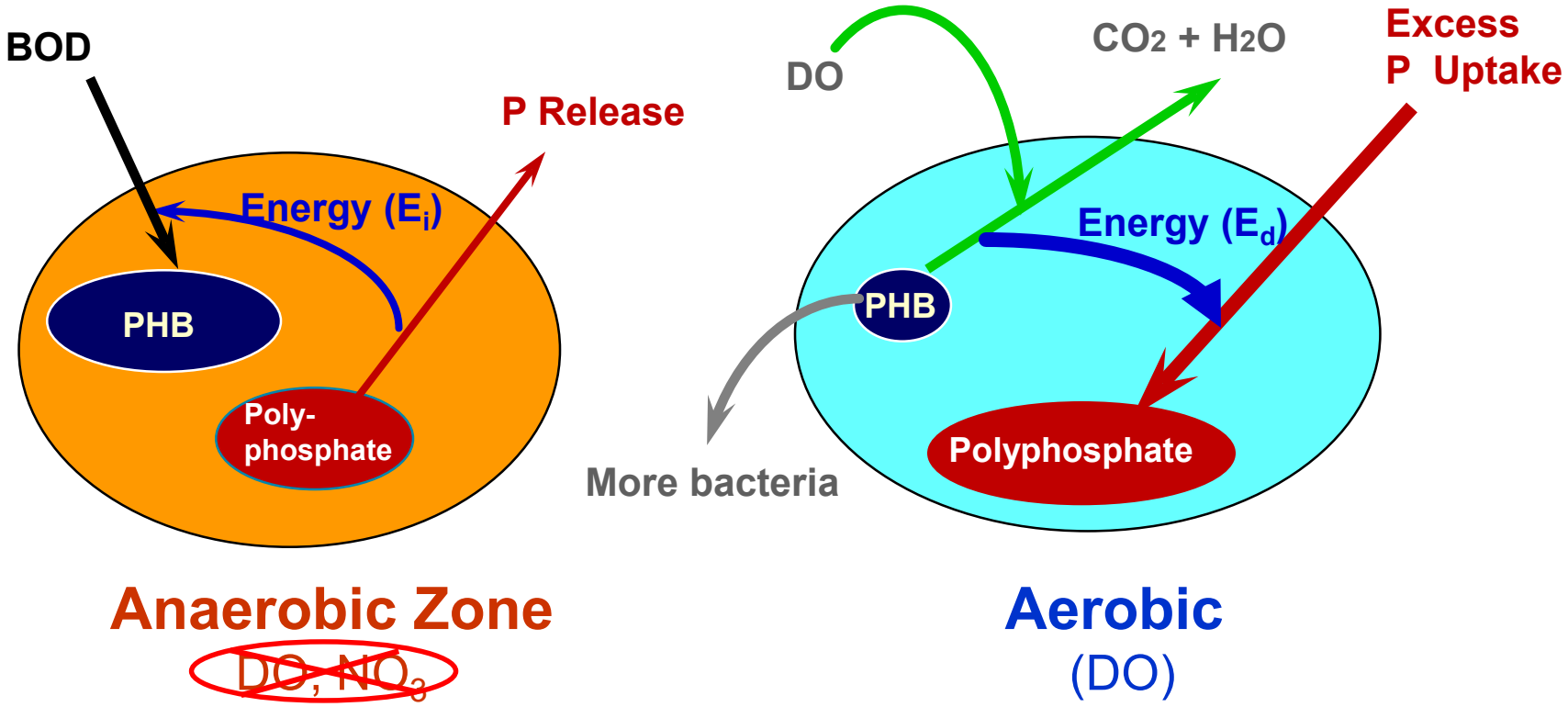


Chemical usage easy to track

Simple payback is 1 year or less

Other benefits like less sludge production not quantified

Enhanced Biological Phosphorus Removal



EBPR Monitoring Opportunities

COD / BOD

DO

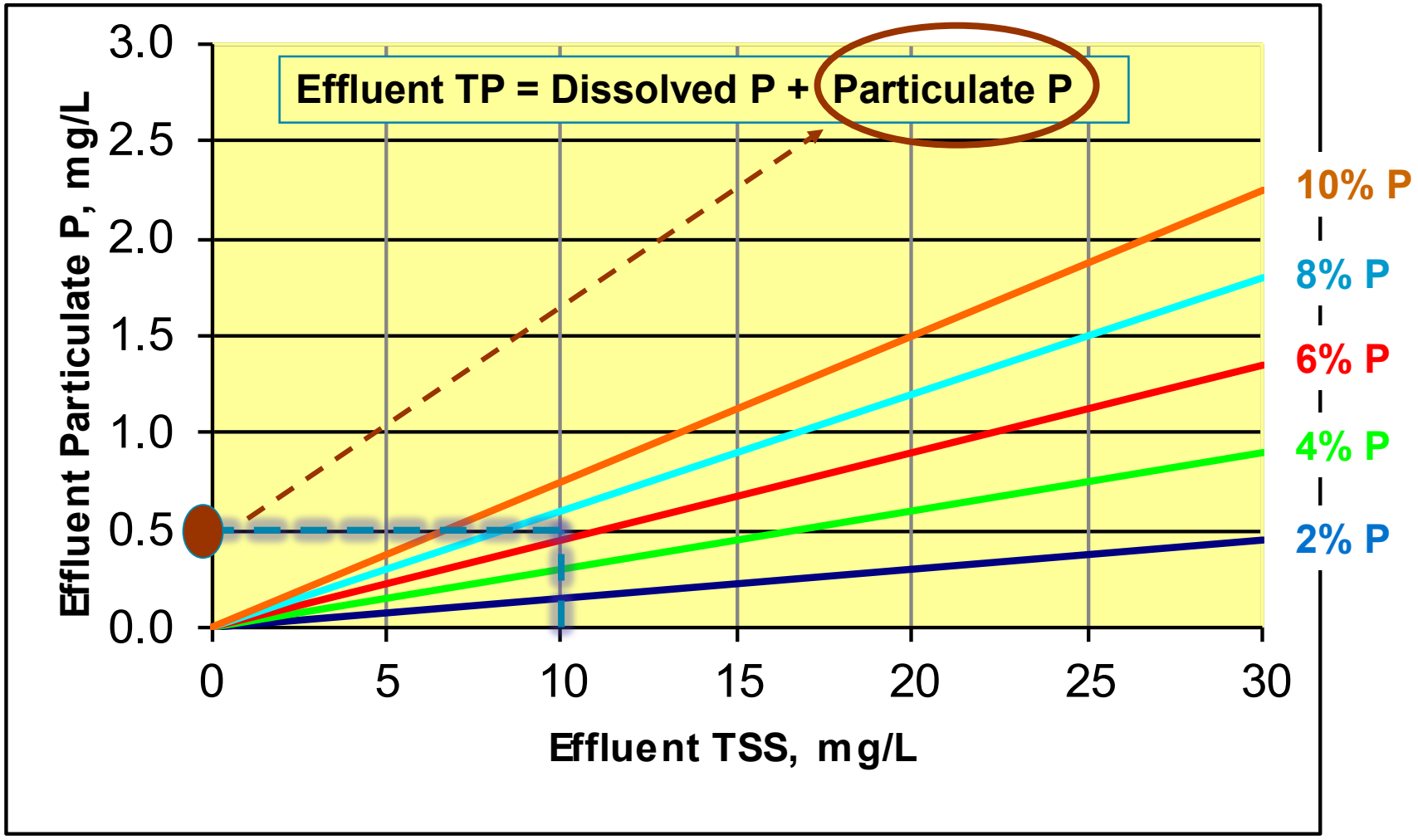
Nitrate

ORP

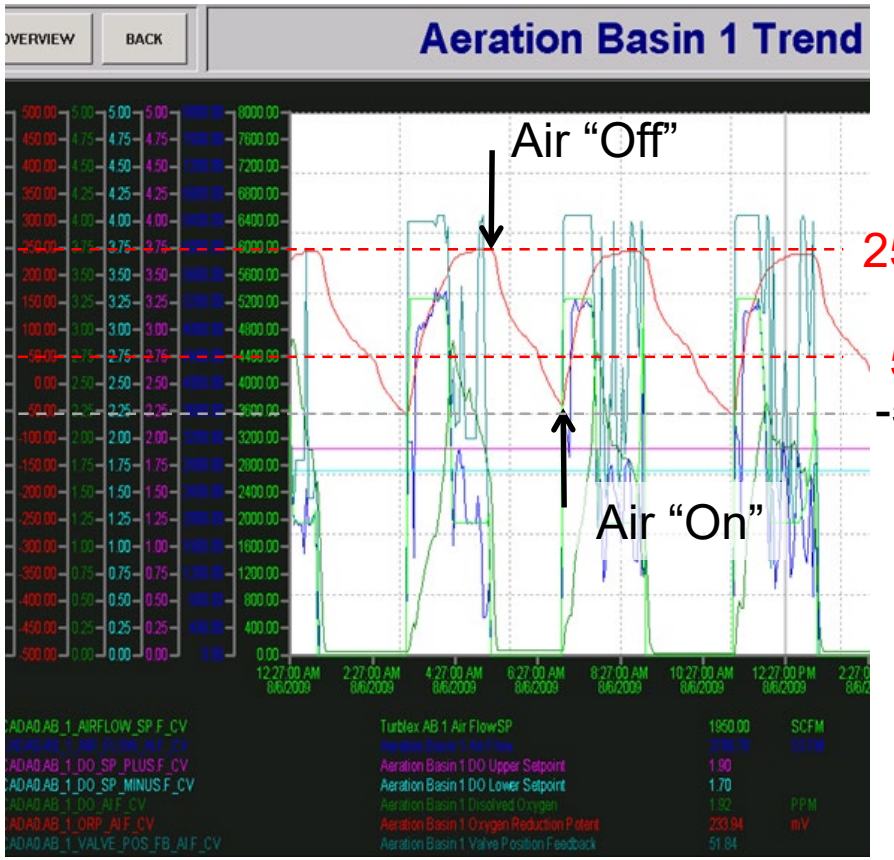
TSS

Sludge blanket depth

P Removal with Effluent TSS



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

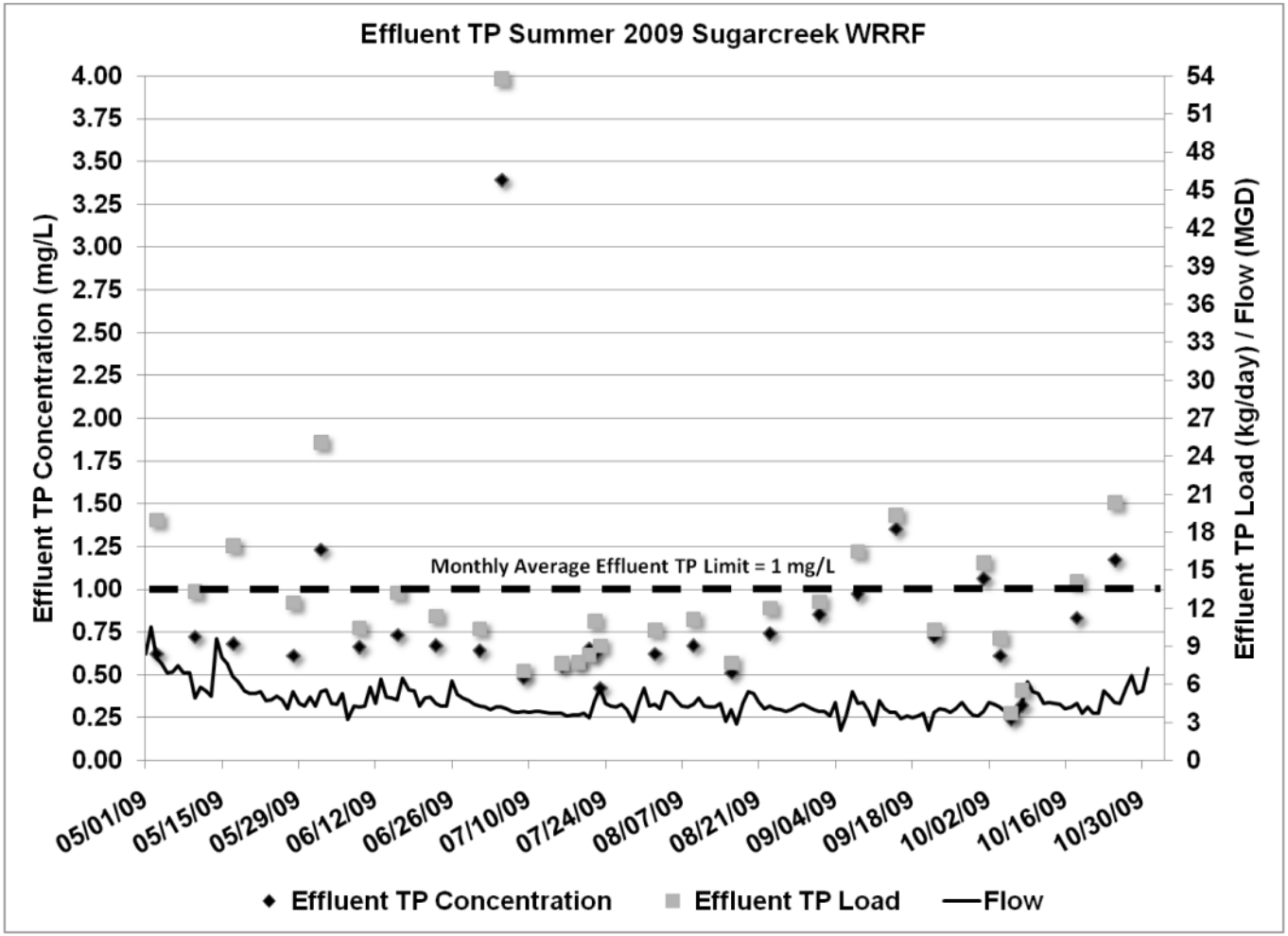
ORP low / timer start: ~50 mV

- 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

	Chemical Removal	EBPR
Nitrogen removal	⇩	⇩
Energy usage		⇧
Supplemental carbon requirements		⇩
Dewatering	⇧	●
Biogas production	⇧	⇩
Sludge production	⇩	
Operating cost	●	⇧
Operating Complexity		⇩

● - 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

Side-stream Enhanced Biological Phosphorus Removal

Summary

Phosphorus in wastewater occurs as 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 ww 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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