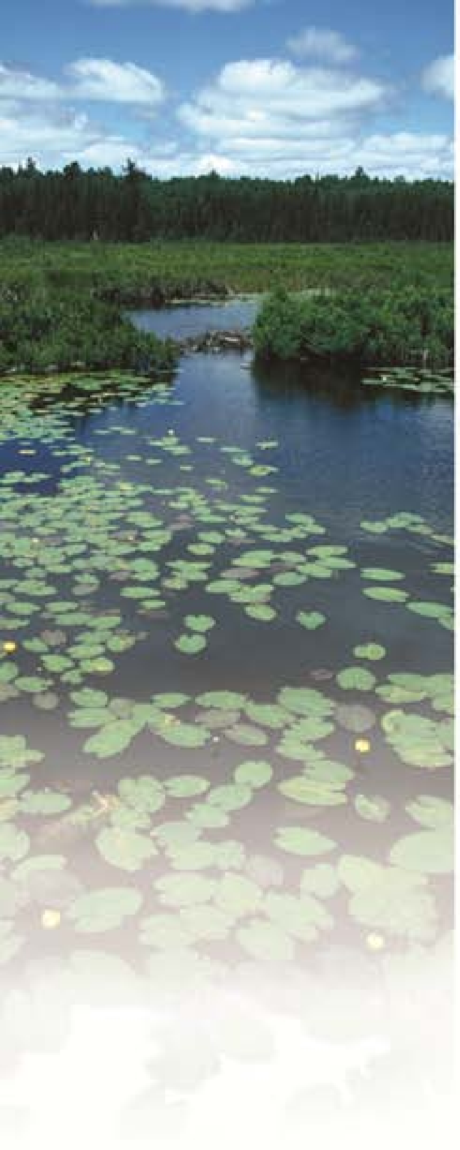

Sustainable Approaches to Meeting Potential Future Nutrient Limits – Part 1

Samuel Jeyanayagam, PhD, PE, BCEE
Vice President/Senior Principal Technologist
CH2M HILL

OWEA Annual Conference
23 June 2011

Presentation Outline

- Why Remove Nutrients?
- Overview of Wastewater Treatment
- Nutrient Removal
  - Phosphorus Removal
  - Nitrogen Removal
- Sustainability Perspective
- Design & Operational Considerations
- Take Home Messages

Part 1

Part 2

Presentation Outline

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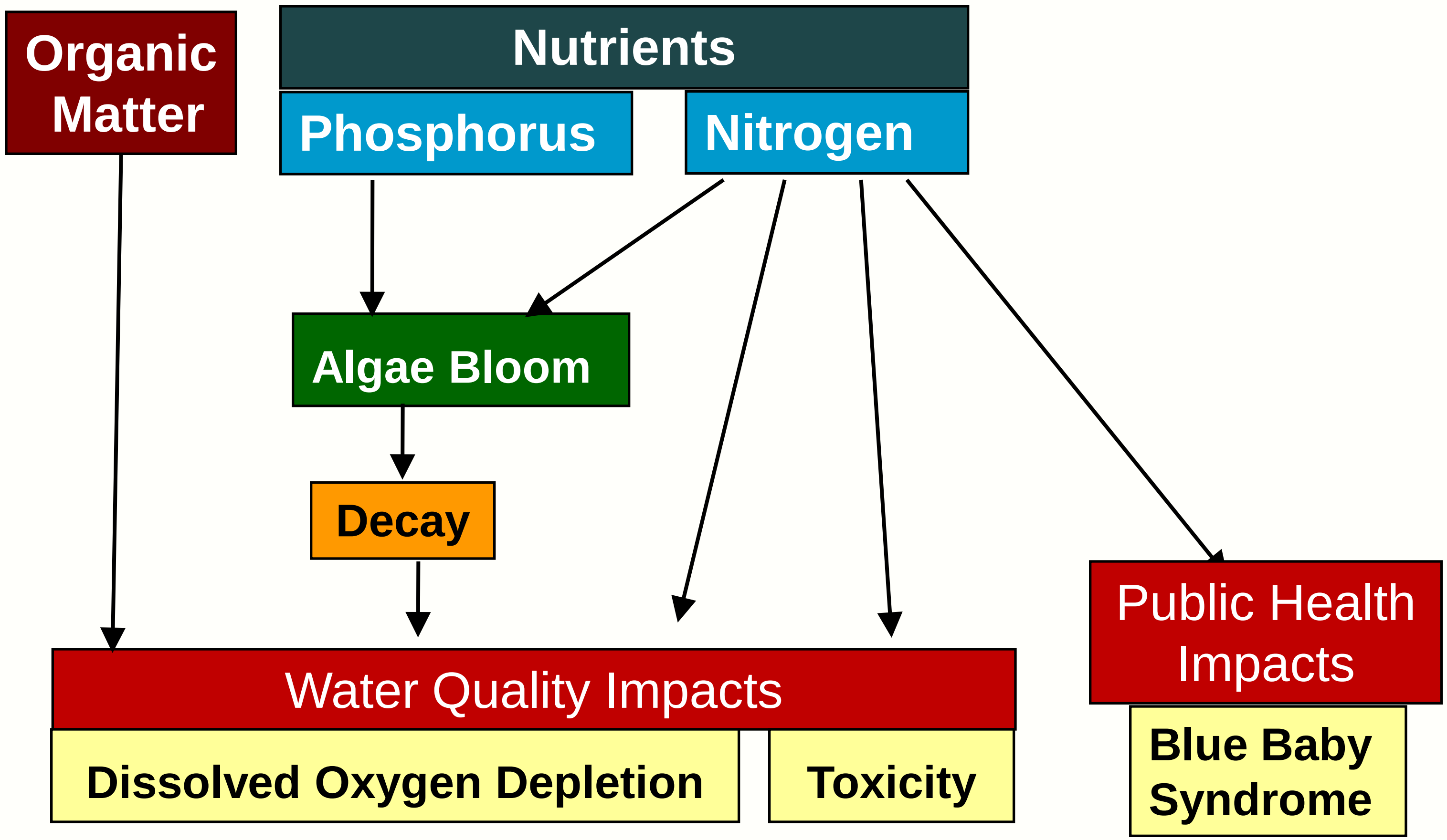
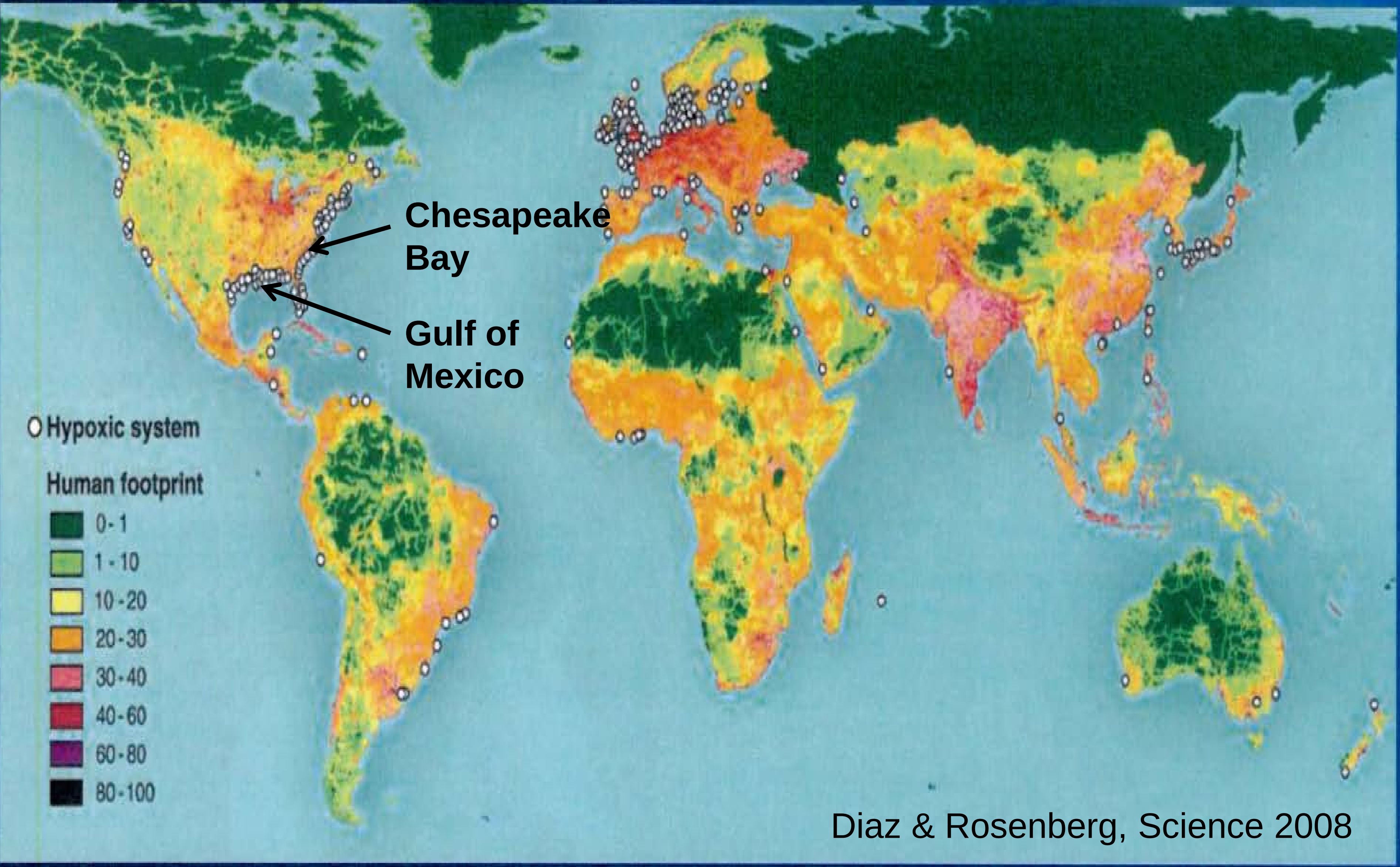
The Problem with Nutrients



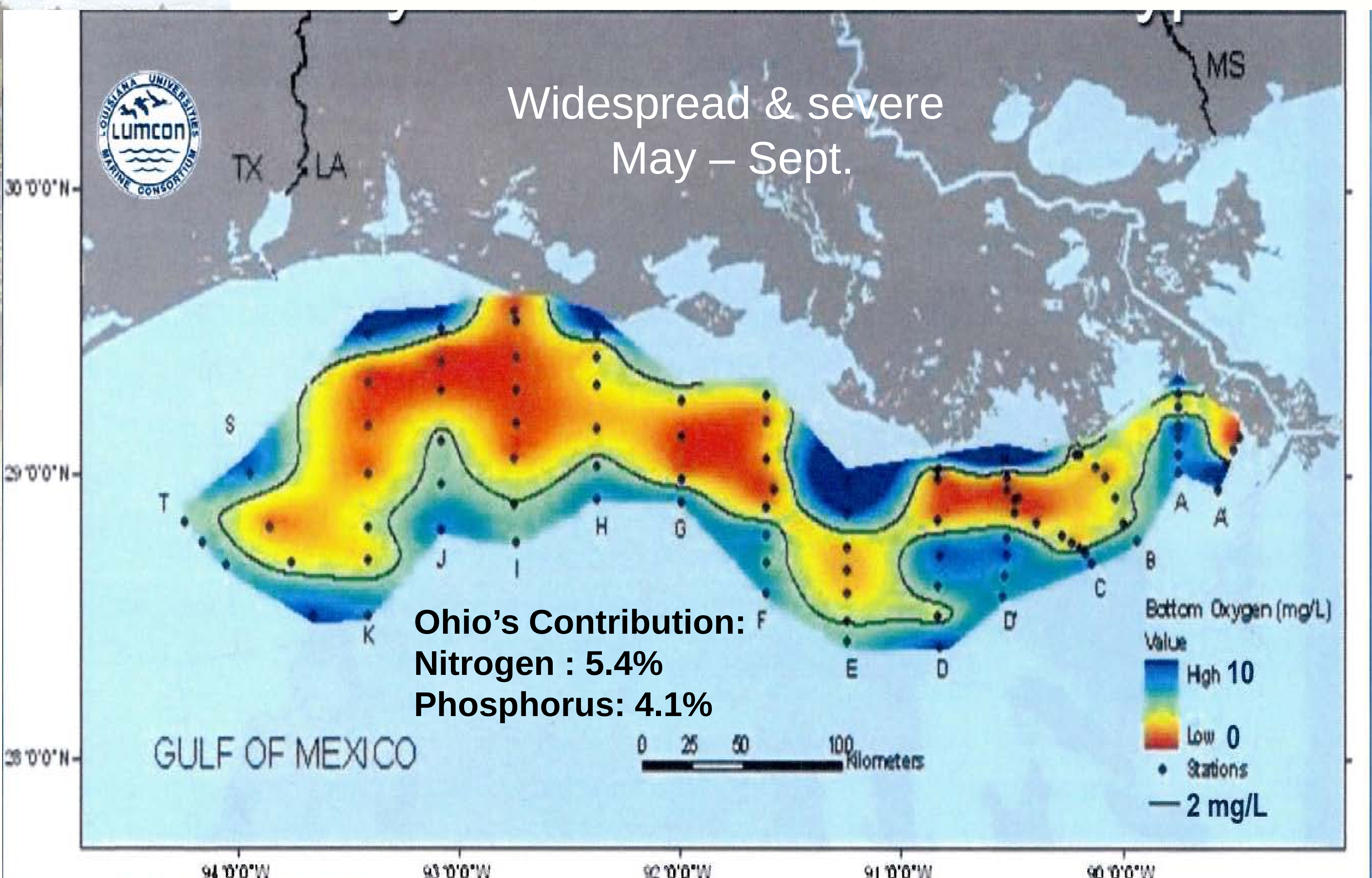
Human Footprint vs. Hypoxia



Diaz & Rosenberg, Science 2008

Bottom-Water Hypoxia
(21-27 July, 2007)

Widespread & severe
May – Sept.



Ohio's Contribution:
Nitrogen : 5.4%
Phosphorus: 4.1%

Source: N. Rabalais, LUMCON

The Current Ohio Scene

- Total 4100 NPDES permits
- 188 WWTPs have TP limits
  - Mostly 1.0 mg/L
  - Some 0.5 mg/L
- 353 WWTPs required to monitor TP
  - Many will see a TP limit in the future
- TN limit – Not anticipated in the near future

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The Three Most Important Considerations in Biological Treatment

Bugs, Bugs, Bugs…..

Organism	Energy Source	Carbon Source	Oxygen Source	Process
Heterotrophs	Organic (BOD)	Organic	Dissolved Oxygen	• BOD removal • Biol. P Removal
			NO_3	• Denitrification
Autotrophs	Inorganic (NH_4)	Inorganic (CO_2)	Dissolved Oxygen	• Nitrification

Municipal wastewater contains what the bugs need!

If We Provide they Will Come…

“*Everything is Everywhere, Environment Selects*.”

We select the bugs we need by providing the right environment for them to grow.

However, this could also favor the growth of nuisance organisms

Let's Make a Cake!

"Wastewater treatment is like making a cake!"

- Right ingredients; right amounts
  - Air, food, bugs, environment etc.
  - ***Stoichiometry***

- Right baking time & temp.
  - Solids Retention Time (SRT) HRT is incidental!
  - ***Kinetics***

<ins>Both</ins> are equally important

Presentation Outline

- Why Remove Nutrients?
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- **Nutrient Removal**
  - ➢ **Phosphorus Removal**
  - ➢ Nitrogen Removal
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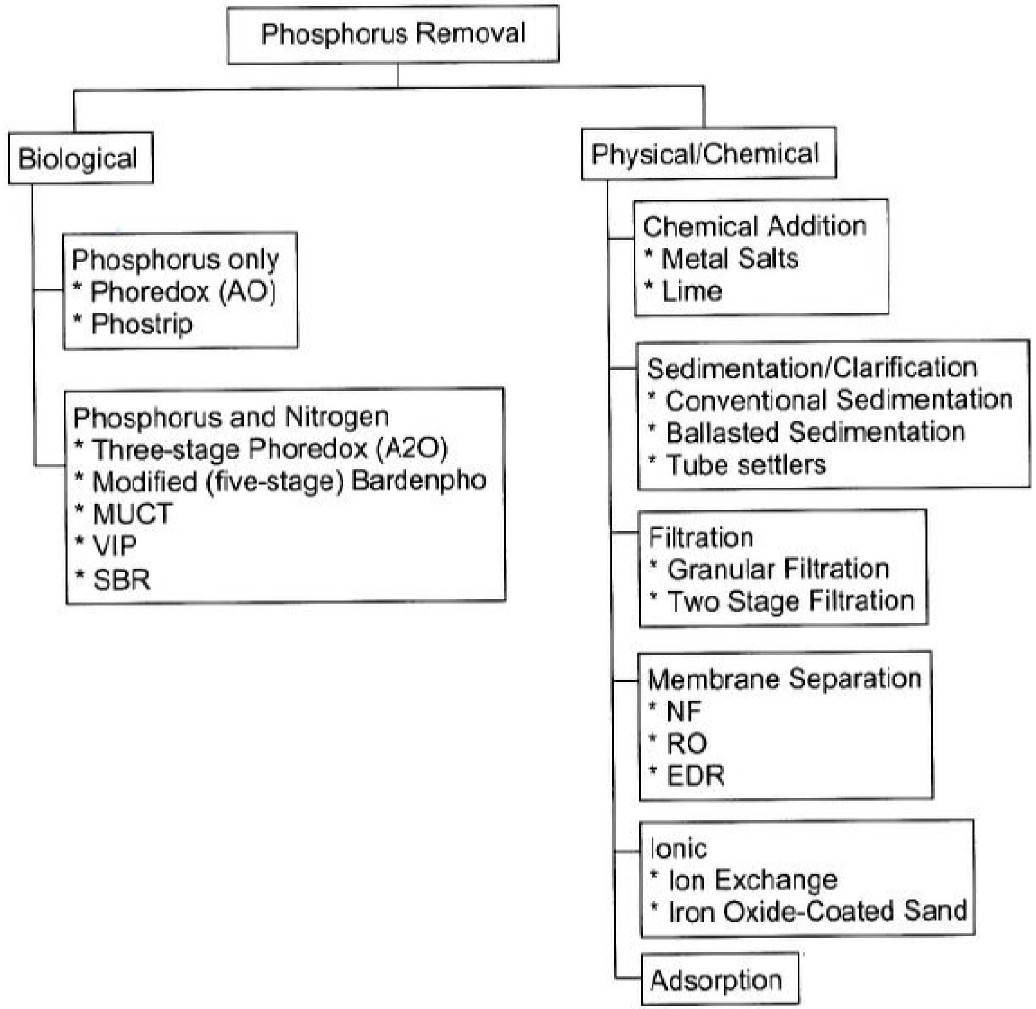
Phosphorus Removal Alternatives



Phosphorous Removal

Phosphorus removal occurs in all WWTPs due to metabolic requirements

- Secondary sludge contains about 2% P by weight
- Not sufficient for environmental protection

Two methods available for additional P removal:

- Chemical Phosphorous Removal
- Biological Phosphorous Removal

Basic concept:

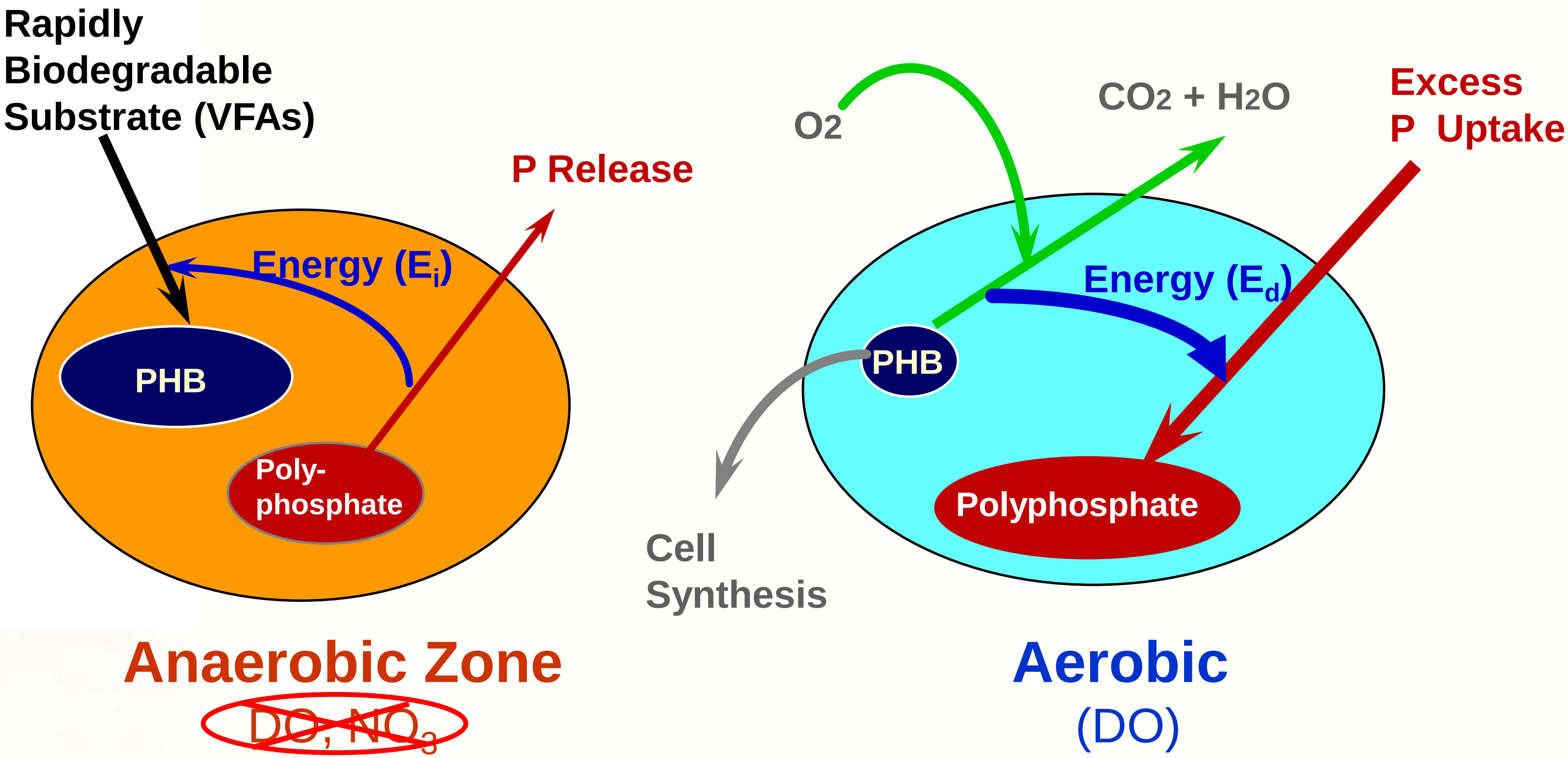
Reactive P (mostly ortho-P) → **Particulate P**↓

Phosphorus removal occurs when sludge is wasted

Biological Phosphorus Removal

- Removal exceeding metabolic requirements
  - Enhanced Biological P removal (EBPR)
  - Luxury P removal
  - Excess P removal
  - Bio-P
- Mediated by specialized heterotrophs, Phosphorous Accumulating Organisms (PAOs)

Enhanced Biological P Removal (EBPR) Mechanism



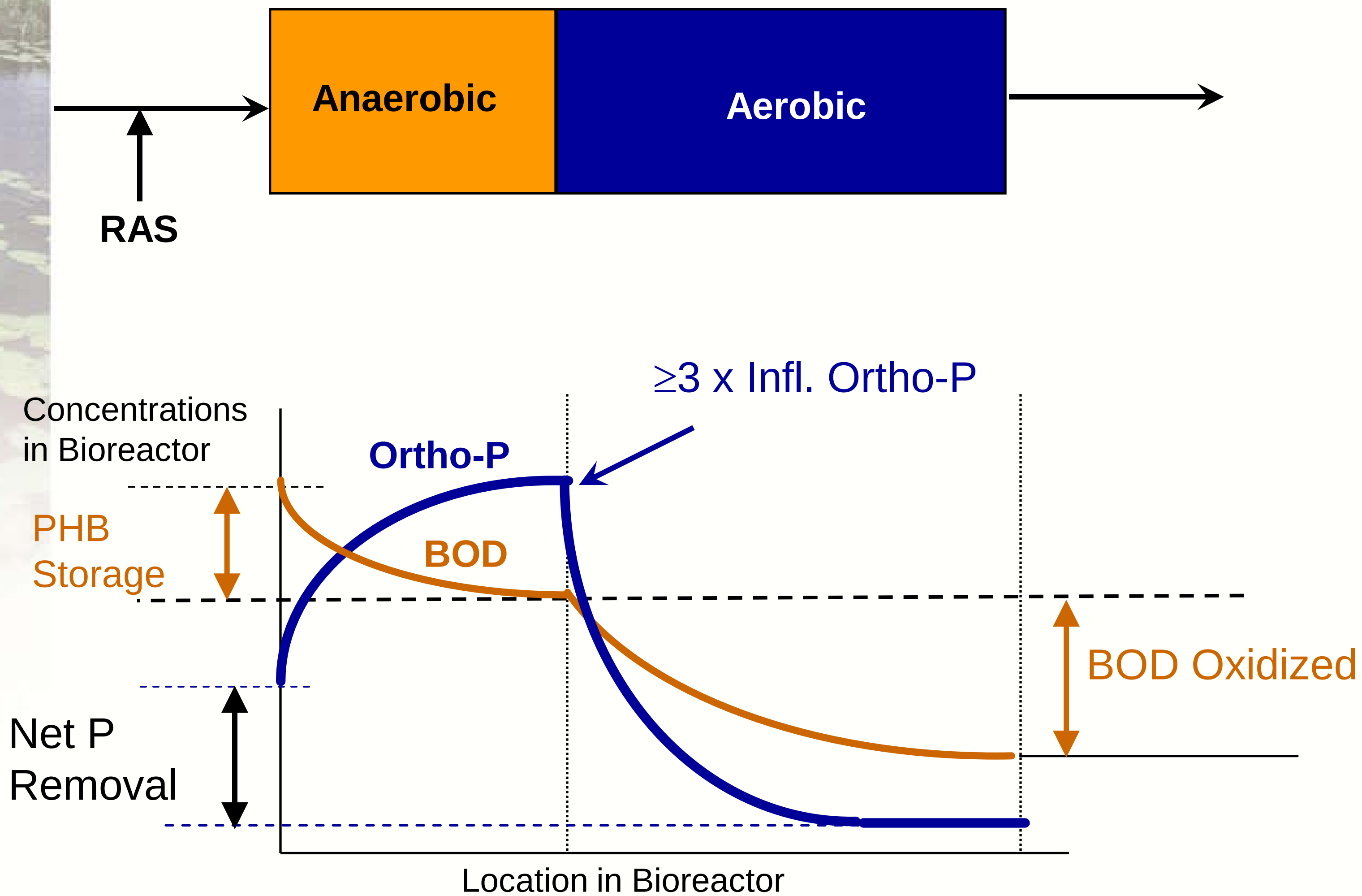
Why does *EBPR* work ?

Energy Investment = E_i

Energy Dividend (E_d)= 24 – 36 x E_i

PHB: Poly-β-hydroxybutyrate

Anaerobic/Oxic (A/O) Process Configuration



Five Prerequisites for Reliable EBPR

1. Its not the process…
2. Integrity of the anaerobic zone
3. Maximize solids capture
4. Minimize recycle loads
5. A fat PAO is a happy bug

1. It is not the Process…

EBPR needs consistent & adequate supply of VFAs (Food)

- Causes of inadequate VFAs:
  - Excessive BOD removal in the primary clarifier
  - Wet weather flows & snow melts
  - High recycle P loads

Readily Biodegradable Organic Matter is Crucial for EBPR

- VFA requirement
  - Acetic and Propionic Acid: **7 to 10 mg VFA/mg P removed**
- Measure of adequate VFAs
  - cBOD:TP 25:1
  - COD:TP 45:1
  - VFA:TP 10:1
  - rbCOD:TP 15:1

  - Influent to biological system
  - Must consider recycle loads
- Sources
  - Influent (most common)
  - Fermentation in anaerobic zone
  - Primary sludge fermentation
  - Purchased acetic acid

2. Integrity of the Anaerobic Zone

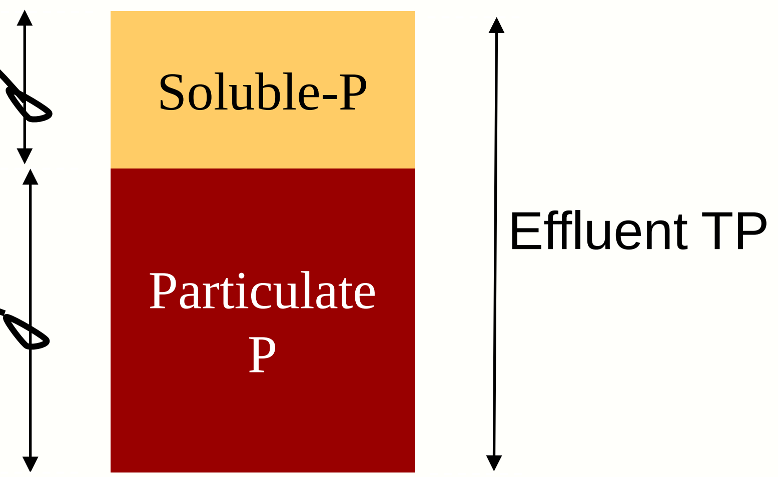
- Anaerobic zone is crucial for PAO selection
- Need to ensure <0.2 mg/L DO

Source	Dissolved Oxygen	Nitrate
Influent (pre-aeration)	√	
RAS	√	√
Back mixing	√	√
Vigorous mixing	√	

3. Maximize Solids Capture

Determined by EBPR or Chem-P removal efficiency

Determined by solids capture efficiency (clarifier & filter)



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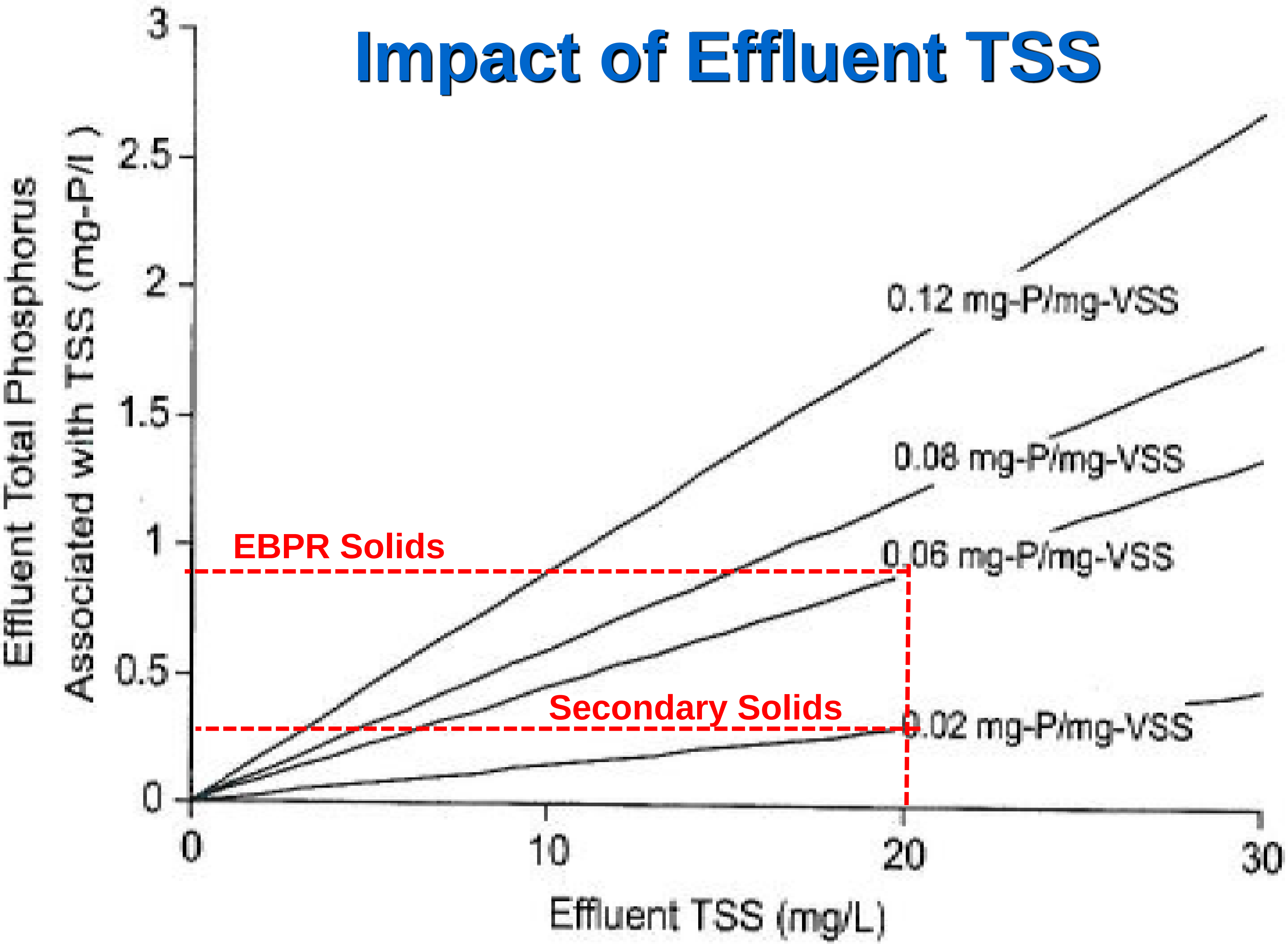
Impact of Effluent TSS



4. Minimize Recycle Loads

- EBPR sludge can release P during anaerobic digestion
- The resulting P-rich recycle from dewatering operation can overload the main process
- Potential TP non-compliance

5. A Fat PAO is a Happy Bug!

Minimize competition from Glycogen Accumulating Organisms (GAOs)

	Anaerobic	Aerobic
PAOs	• VFA uptake & PHB storage • P Release	• Excess P Uptake • PHB metabolized
GAOs	• VFA uptake & PHV storage • Glycogen used	• Glycogen storage • PHV metabolized

Adequate VFAs does not necessarily ensure reliable EBPR

Conditions Thought to Favor GAO Dominance

- Warmer temperatures
- Long SRT
- Anoxic and anaerobic HRTs too long
- Variable supply of VFAs
- Continued use of acetic acid
- pH significantly less than 7

Current Understanding of the Chem - P Removal Mechanism

Fe & Al salts are most commonly used. Involve similar reactions.

1. Hydrous metal oxide (HMO) floc forms (predominant)

$$\text{Alkalinity} \xrightarrow{\text{Chemical (Al, Fe)}} \text{Hydrous Metal Oxide (HMO)} \downarrow$$

2. Soluble P (PO_4) adsorbs to HMO reactive sites

$$\text{HMO} + P_{sol} \longrightarrow \text{HMO - } P_{sol} \text{ Complex} \downarrow$$

Continued chemical addition results in

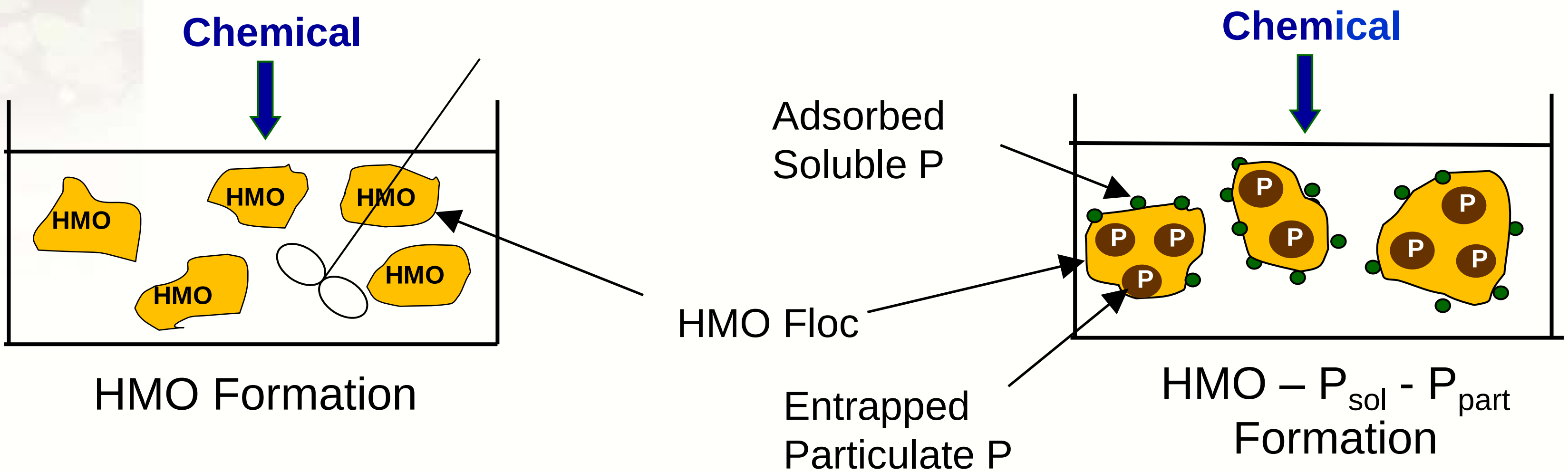
- Larger floc size; fewer adsorption sites
- Less P removal per mg chemical added

Current Understanding of the Chem - P Removal Mechanism

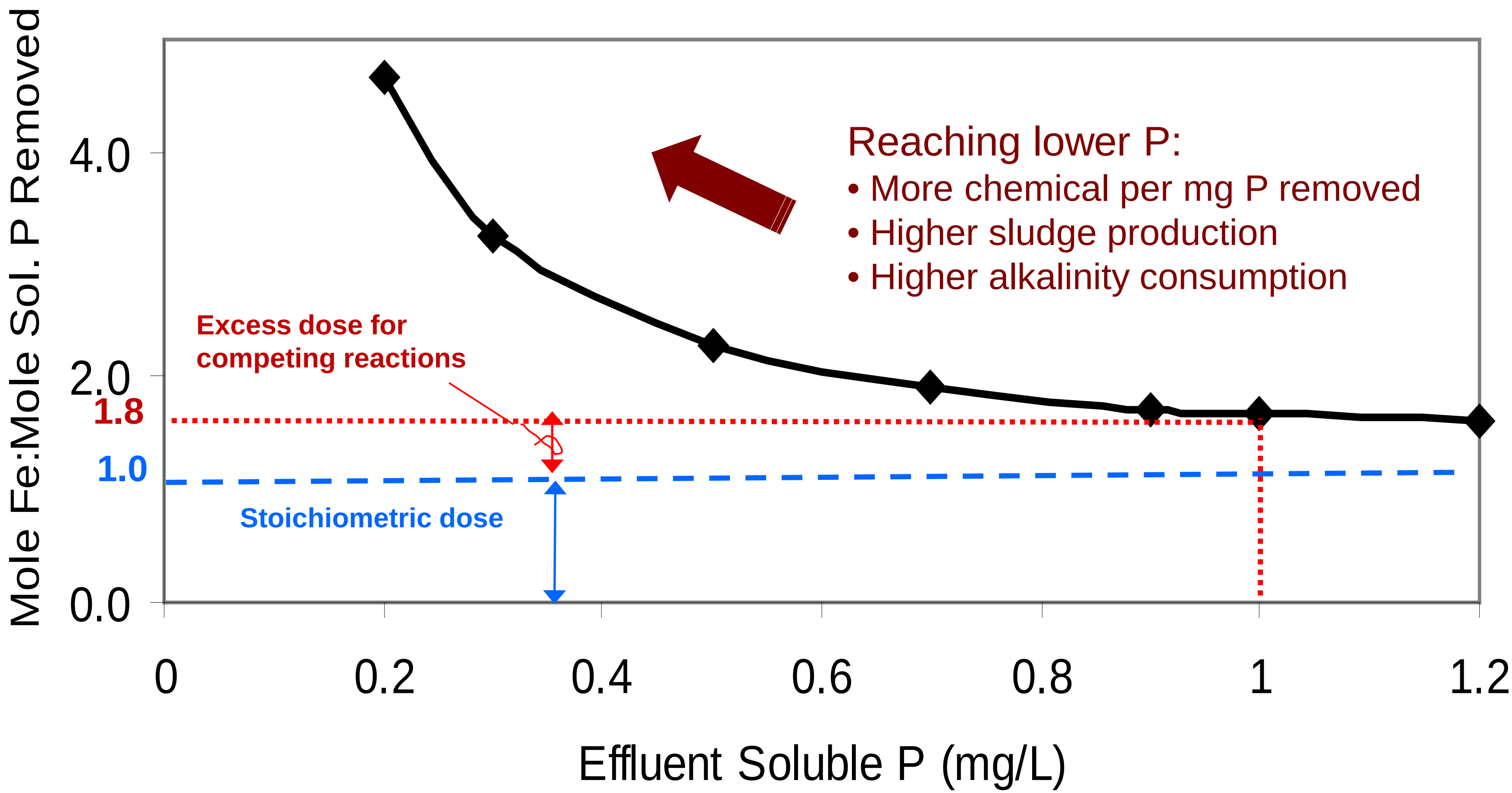
Minor reactions also occur concurrently

- Co-precipitation: HMO enmeshes colloidal P

$$\text{HMO - P}_{sol}\ \text{Complex} + \text{P}_{part} \longrightarrow \text{HMO - P}_{sol}\ \text{-}\ \text{P}_{part} \downarrow$$



What Plant Data is Telling Us…



Best fit curve based on plant data (WEF)

Plant Wide Impacts of Chem-P Removal

- Decreased UV transmittance
- Increased inert fraction in the MLSS
  - Overestimate of VSS
  - Higher MLSS
- Increased sludge production
- Alkalinity consumption
- Continued P removal after chemical feed is terminated

What is the Limit Of Technology (LOT) for TP

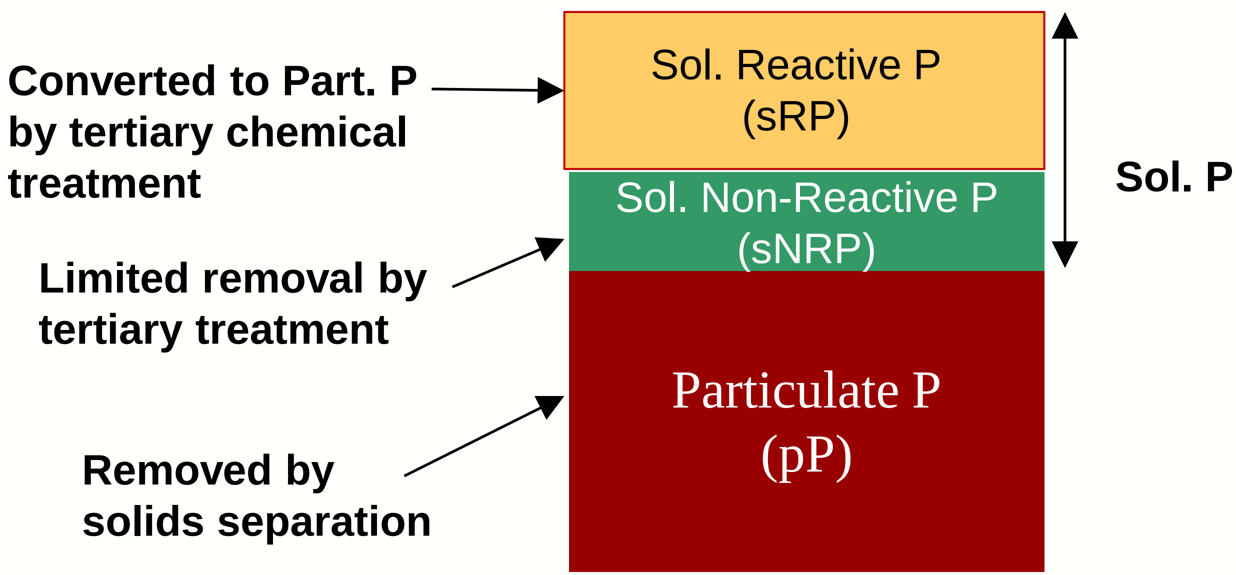
The LOT with EBPR and Chem-P removal:

- W/O Filtration: 0.5 – 1.0 mg/L TP
- W/Filtration: 0.1 – 0.5 mg/L TP

Can we go lower than LOT?

Achieving < 0.1 mg/L TP Requires an Understanding of TP Speciation

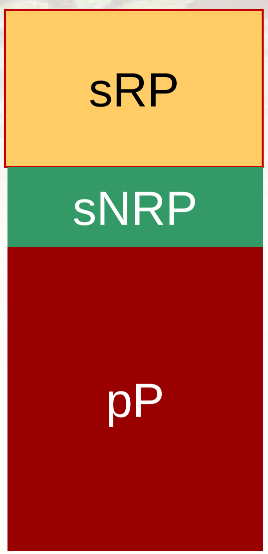
- Achieving <0.1 mg/L TP calls for tertiary treatment
- Removal of sNRP is challenging & determines how low we can go.



Comparison of Tertiary Treatment Technologies (0.01 mg/L Effl. TP)

WERF

Unit Process	sRP	sNRP	pP
Metal salt addition	+++	+	++
Sedimentation & Ballasted sedimentation	-	-	+
Direct filtration	-	-	++
Sedimentation-filtration	-	-	+++
2-stage filtration	-	-	++++
Reactive filtration (Fe oxide coated sand)	+++	?	+++
Membrane filtration	-	-	+++
Reverse osmosis	++++	+++	++++

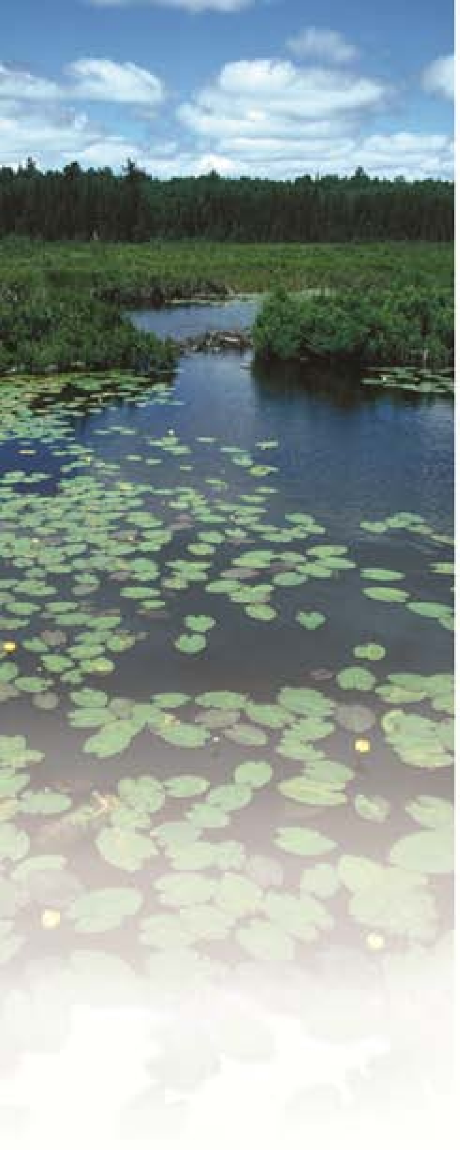


- Need efficient removal of 3 components to achieve low effluent TP
- Difficult to achieve low TN & TP levels simultaneously

Take Home Messages

- Many OH plants will see TP limits (1.0 - 0.5 mg/L TP).
- Most sensitive performance factors:
  - EBPR: VFAs, anaerobic conditions, solids capture, & recycle loads.
  - Chem-P removal: Mixing, alkalinity, & solids capture
- Beware of plant-wide impacts:
  - EBPR: Influent characteristics, secondary release
  - Chem-P removal: Sludge production, alkalinity, UVT
- Technology limits:
  - EBPR or Chem-P. No filtration; 1.0 mg/L TP
  - EBPR or Chem-P + Filtration: 0.5 – 0.1 mg/L TP
  - Tertiary treatment to remove sNRP: <0.1 mg/L TP


Questions?



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Sam Jeyanayagam, PhD, PE, BCEE
Vice President/Senior Principal Technologist
CH2M HILL
Samuel.Jeyanayagam@CH2M.com
Phone: (614) 825-6717

CH2MHILL