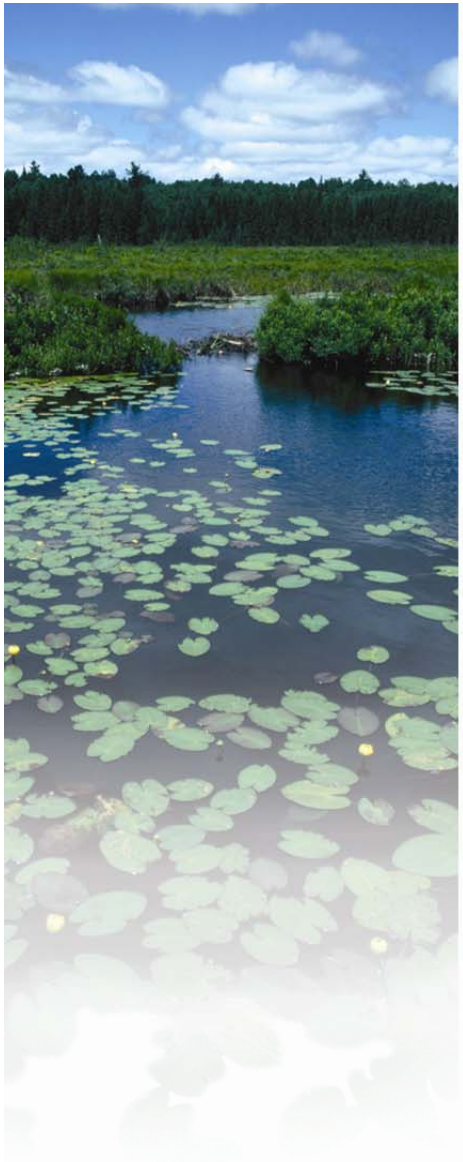

Chemical Phosphorus Removal 101

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Outline

- What is chemical phosphorus removal?
- Mechanisms of phosphorus precipitation
- Other Impacts
- Methods of metal salt addition
- Locations of Metal Salt addition: Details and impacts at each point

What is Chemical Phosphorus Removal?

- There are two steps to chemical phosphorus removal:
  - The adsorption of soluble (PO_4^{-3}) phosphate into metal hydroxide floc.
  - The subsequent separation of the metal hydroxide/phosphate floc from the liquid phase
    - by settling/clarification
    - by filtration
- It is NOT precipitation!
  - $FePO_4$ and $AlPO_4$ only exists at very low pH, less than 5.

What is Chemical Phosphorus Removal?

- The most commonly used metal salts are
  - Iron: Ferric (+3) and Ferrous (+2) chloride and sulfate ($FeCl_3$, $FeCl_2$, $Fe_2(SO_4)_3$, $FeSO_4$)
  - Aluminum: Alum or Poly-Aluminum Chloride
- Calcium was once the preferred precipitant, but is only effective at high pHs, i.e. >10.
- The precipitation of Struvite ($MgNH_3PO_4$) also occurs in wastewater treatment plants:
  - Unintentionally in anaerobic digesters and the downstream equipment/piping
  - Intentionally in struvite recovery systems.

What is Chemical Phosphorus Removal?

- This presentation is focused on the use of metal salts (iron and aluminum) to reduce plant effluent phosphate levels.
- Contrary to previous beliefs, ferric iron and aluminum have similar abilities to remove phosphorus.

Mechanisms of Phosphorus Removal

- Adsorption
  - Metal Hydroxide Flocs form by the bonds between the metal and oxygen.
  - Phosphate can replace that bond and be adsorbed into the floc
  - As floc size increases, the ability of the iron to bond with the phosphate is reduced
    - Fewer iron atoms are near the surface of the floc and available to bond with soluble phosphate
  - Adsorption will continue after the initial dosage point!

Mechanisms of Phosphorus Removal

- Solid - Liquid Separation
  - Adsorption of phosphate into metal hydroxide flocs does not “remove” phosphorus.
  - The flocs must be removed. They contain the phosphorus and will increase effluent total phosphorus levels if not separated
  - Solids “Dilution”
    - Higher dosages reduce the phosphorus content of TSS

Mechanisms of Phosphorus Removal

- Solid - Liquid Separation
  - Clarification and Settling
    - Handles high metal salt dosages, which allows more removal in that unit process
    - Lower effluent quality
  - Filtration
    - Conventional: Higher Effluent Quality, Low Solids handling
    - Membrane: Highest Effluent Quality, High Solids Handling

Other Impacts of Metal Salt Addition

- The addition of metal salts affects many other aspects of wastewater treatment
  - pH: Metal salts are acids and reduces both pH and alkalinity
  - Total Suspended Solids:
    - 1 mg/L Iron Dosage = 1.9 mg/L TSS
    - 1 mg/L Aluminum Dosage = 2.9 mg/L TSS
  - Volatile Suspended Solids:
    - 1 mg/L Iron Hydroxide = 0.25 mg/L TSS
    - 1 mg/L Aluminum Hydroxide = 0.35 mg/L TSS
    - Affects Digester VSS Destruction

Other Impacts of Metal Salt Addition

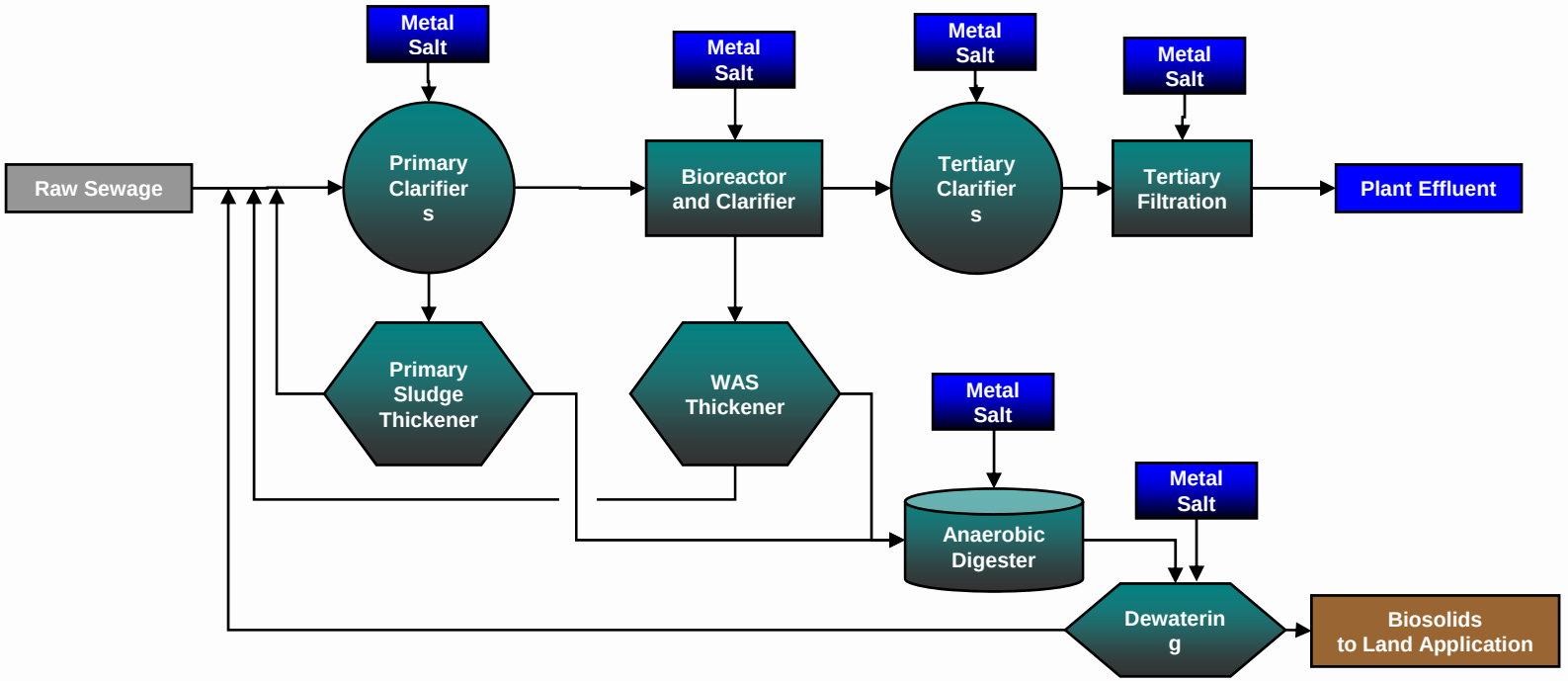
- Residuals and Biosolids
  - Iron generally improves dewaterability
  - Aluminum generally decreases dewaterability
  - Both metal salts reduce mobility of phosphorus in land applied solids
- Reduces Struvite formation
- Iron reduces H_2S in liquids and in digester biogas
- Operational challenges of Chemical Handling

Other Impacts of Metal Salt Addition

- Liquid Stream Addition
  - Primary Clarifier colloidal BOD removal
    - Coagulation
  - Co-precipitation of metals
    - Copper
    - Mercury
    - etc.

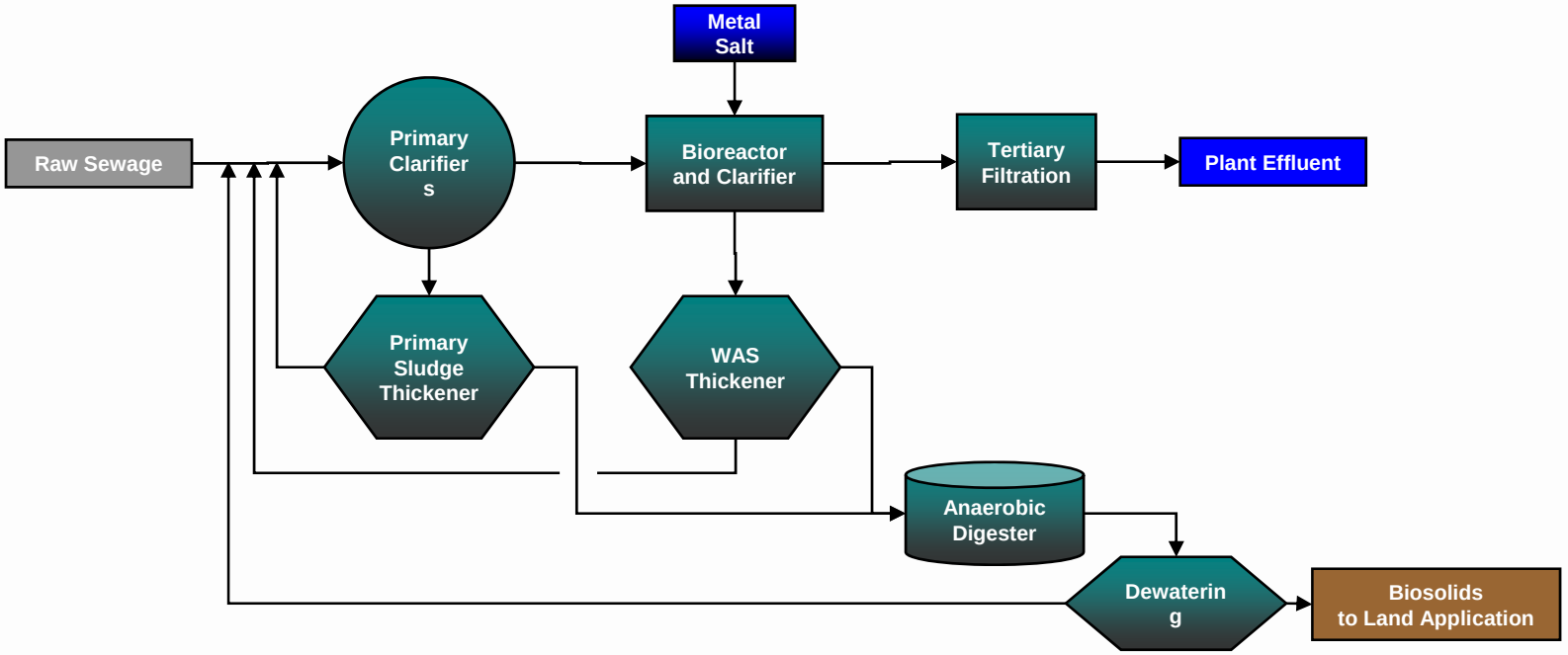
Methods of Metal Salt Addition

- There are many places metal salts can be added



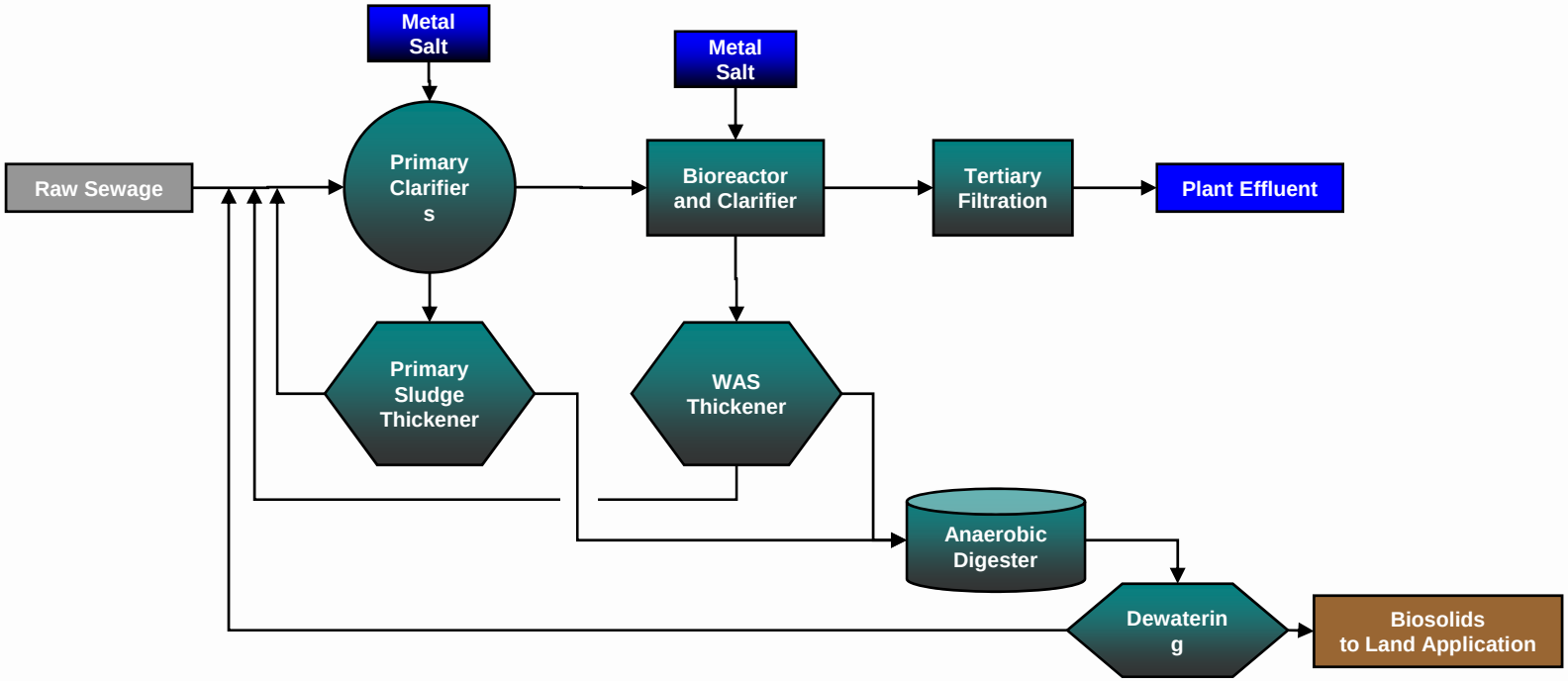
Methods of Metal Salt Addition

- You can add at a single point



Methods of Metal Salt Addition

- You can add to multiple points



Metal Salt Addition Locations

- Raw Sewage
  - Iron controls odor
  - Gives more contact time prior to primary or secondary treatment
  - Usually done for either odor control or prior to chemically enhanced primary treatment

Metal Salt Addition Locations

- Primary Clarifier
  - Chemically Enhanced Primary Treatment
  - Improves removal of
    - Phosphorus
    - TSS
    - BOD (Colloidal removal)
  - Need to avoid removing too much phosphorus. Nutrient limitations in bioreactor is possible

Metal Salt Addition Locations

- Bioreactor
  - Normally added prior to clarification
  - Gives very long contact time since the metal hydroxides build up in the bioreactor
  - Can be difficult to work with biological phosphorus removal
  - Not subject to nutrient limitations since the metal phosphate is bio-available

Metal Salt Addition Locations

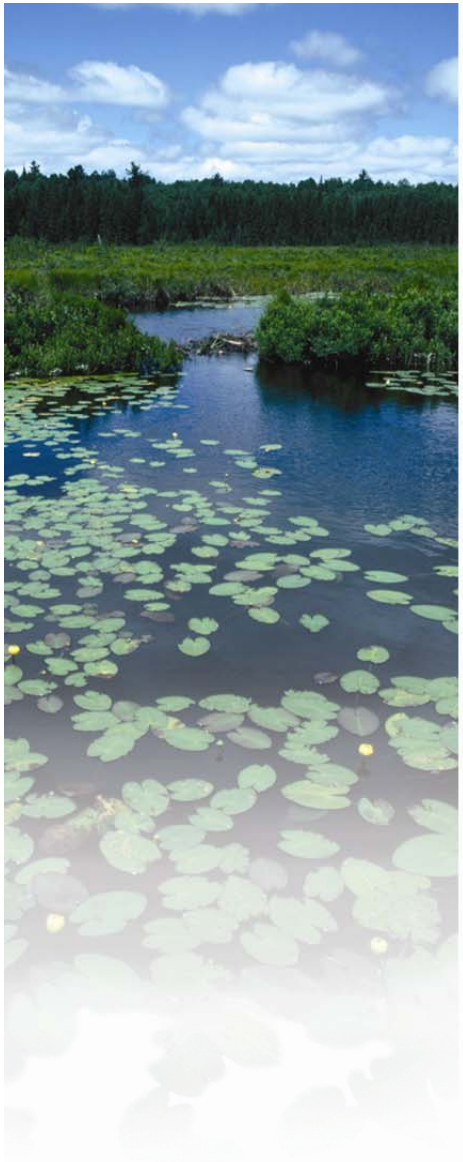
- Tertiary Clarification
  - Many different types
  - Needed to remove high phosphorus levels in secondary effluent
  - Provides a considerable level of flexibility
- Tertiary Filtration
  - Conventional and Membrane
  - Conventional filters have limits on influent TSS loads
  - Membranes can handle higher TSS levels
  - Highest level of TSS removal.

Metal Salt Addition Locations

- Prior to digestion
  - Normally done only with iron
  - Reduces digester gas H_2S levels (<200 ppmv possible)
  - Binds phosphorus once sulfide is removed
    - reduces struvite formation
    - reduces recycle of phosphorus in the recycle stream

Metal Salt Addition Locations

- Prior to dewatering
  - Controls phosphorus
  - Reduces dewatering centrate struvite by both binding phosphorus and by reducing pH
  - Iron can improve dewaterabily, alum normally reduces dewaterability
  - Phosphorus is removed in the dewatering system



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QUESTIONS?

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