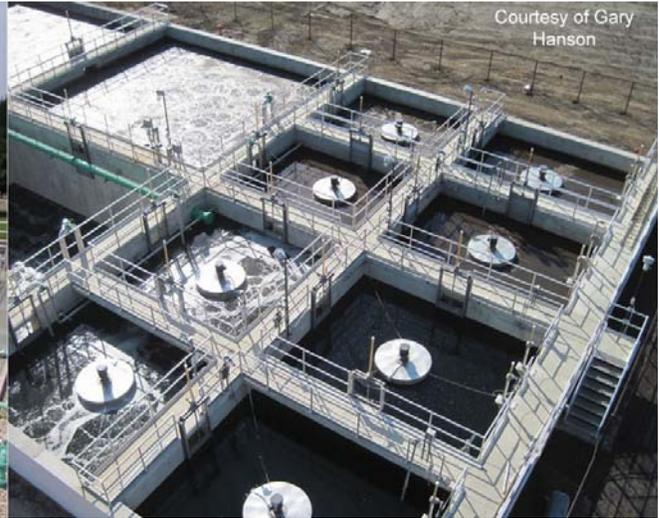




# Wisconsin Department of Natural Resources Wastewater Operator Certification

## Advanced Phosphorus Removal Study Guide

January 2009 Edition



### Subclass I

Wisconsin Department of Natural Resources  
Bureau of Science Services  
Operator Certification Program  
P.O. Box 7921, Madison, WI 53707

<http://dnr.wi.gov>

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## Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and wastewater businesses, jointly prepared the objectives and exam questions for this subclass.

How to use this study guide with references

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.
2. Use the resources listed at the end of the study guide for additional information.
3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the internet at <http://dnr.wi.gov>, keyword search "operator certification". It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

## Acknowledgements

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## **Part 1 - Advanced - Biological Removal**

### **Chapter 1 - Theory and Principles of Biological Removal**

#### **Section 1.1 - Definitions**

1.1.1 Define Glycogen.

Glycogen is a polysaccharide of glucose which is another energy storage inside a cell. It is present in all cells, but microorganisms which accumulate glycogen in cells during the anaerobic stage of a bio-P process are not able to perform biological phosphorus removal.

1.1.2 Define Polyhydroxyalkanoates (PHA).

Polyhydroxyalkanoates (PHAs) are energy-rich carbon polymers inside a bacterial cell, which are converted from readily available organic molecules such as volatile fatty acids (VFAs) in the wastewater. PHAs are the intracellular energy storage of the phosphorus accumulating organisms (PAOs). The PAOs utilize PHA as an energy source to uptake phosphorus from the wastewater in the aerobic zone of the biological phosphorus removal process.

#### **Section 1.2 - Wastewater Characteristics**

1.2.1 List major industrial sources of phosphorus.

- A. Dairies
- B. Food Processors
- C. Metal Finishers
- D. Hospitals
- E. Schools
- F. Car Washes

1.2.2 Discuss the importance of the wastewater volatile fatty acid (VFA) content in enhanced biological phosphorus removal.

The organic material entering an anaerobic selector must be soluble and readily available to phosphorus accumulating organisms (PAOs). The smallest molecules that organic material can be broken into are volatile fatty acids (VFAs) that are then utilized by PAOs to form and store PHA's for later use. It is this VFA use and PHA storage that is the primary mechanism that gives PAOs a selective advantage.

Municipal wastewater that ferments in its travel through a collection system can be a good source of VFAs for EBPR operations. The VFA most easily utilized by PAOs is acetic acid (CH<sub>3</sub>-COOH).

#### **Section 1.3 - Biological Principles**

1.3.1 Describe the basic theory of Enhanced Biological Phosphorus Removal (EBPR).

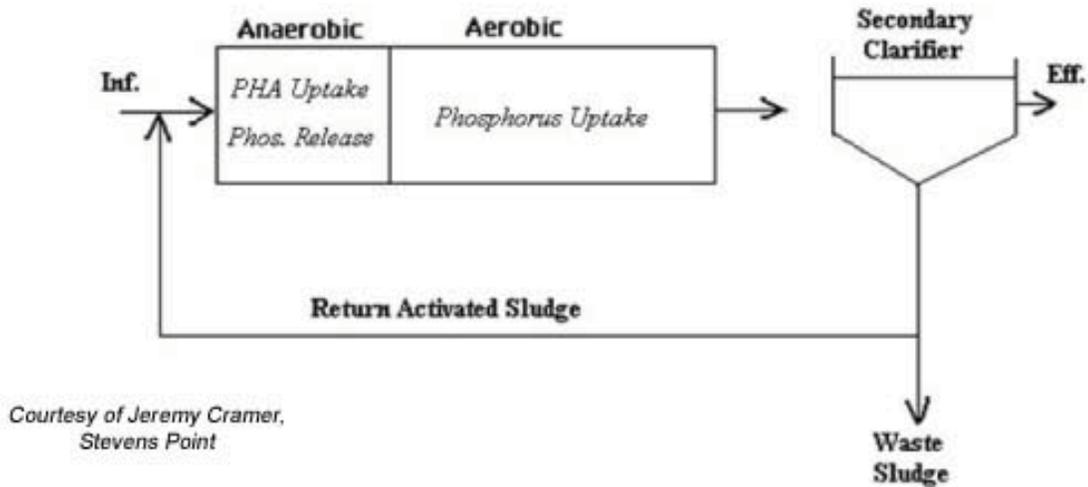
EBPR relies on the selection and proliferation of a microbial population capable of uptaking orthophosphate in greater amounts than their normal biological growth requirements.

Enhanced biological phosphorus removal is a process that uses alternating anaerobic and

aerobic zones to provide an environment that encourages the growth of Phosphorus Accumulating Organisms (PAO). PAOs store excess polyphosphate in their cell mass and phosphorus is removed with the waste sludge.

Figure 1.3.1.1

A typical EBPR reactor configuration.



## Section 1.4 - Performance Limiting Factors

- 1.4.1 Discuss supplemental food (carbon source) that can be purchased for biological phosphorus removal when VFA's are limiting.

A readily biodegradable food source such as volatile fatty acids (VFAs) is needed for successful biological phosphorus removal. If the level of soluble BOD in an anaerobic selector is too low there may not be enough VFAs available to promote the growth of phosphorus accumulating organisms (PAOs). Supplemental chemical sources of highly soluble food can be commercially purchased, such as methanol, acetic acid, sugar solutions and glycerol. Other supplemental sources can be used as well. Because acetic acid is the most easily used VFA by PAOs, it is the VFA of choice to add as a supplemental food (carbon source) for anaerobic and anoxic selectors.

## Chapter 2 - Operation and Maintenance

### Section 2.1 - Definitions

- 2.1.1 Define struvite.

Struvite is magnesium ammonium phosphate ( $MgNH_4PO_4 \cdot 6H_2O$ ). It forms hard, very insoluble, white, yellowish-white or brownish-white crystals.

### Section 2.2 - Reactors

- 2.2.1 Discuss the use of a fermenter for biological phosphorus removal.

When influent VFA's are insufficient, sludge fermentation, usually primary sludge, can be a way for large plants to augment the supply of VFAs (especially acetic and propionic acids)

needed for biological phosphorus removal. On-site fermenters can be designed and incorporated into the biological phosphorus removal system if needed. The reader is referred to MOP-29, Chapter 9 for sludge fermentation information.

### **Section 2.3 - Biosolids Issues**

#### **2.3.1** Discuss operational problems caused by the formation of struvite.

Struvite deposits can clog pipes and valves, interfere with instrumentation and reduce the operating life of equipment such as belt filter presses. Struvite commonly forms in anaerobic digesters where ammonia, magnesium and phosphate are present and pH increases. EBPR plants with anaerobic digesters have a higher potential for struvite formation than conventional activated sludge plants. PAOs will uptake positively charged magnesium ions to balance the negative charge associated with phosphate accumulation. This results in a higher magnesium loading to the digesters.

Struvite formation is very sensitive to pH. Digested sludge in an anaerobic digester is near neutral and supersaturated with carbon dioxide. When the sludge is removed from the digester, carbon dioxide escaping from the sludge will increase the pH. Carbon dioxide loss is likely wherever turbulence occurs. Therefore struvite formation is common at pipe elbows, mixer blades, valves, pump impellers and dewatering equipment.

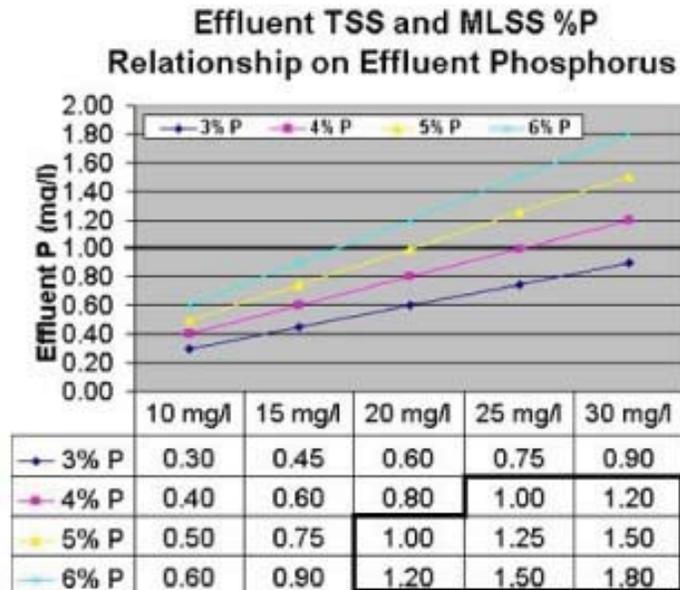
## **Chapter 3 - Monitoring, Process Control, and Troubleshooting**

### **Section 3.1 - Data Understanding & Interpretation**

#### **3.1.1** Describe the significance of phosphorus content in the sludge as related to biological phosphorus efficiency and effluent phosphorus.

Sludge phosphorus content is defined as the percentage of phosphorus in cell mass and is expressed as P/VSS (%). In a conventional activated sludge treatment process, the sludge phosphorus content is approximately 1.5 - 2.5%. In an enhanced biological phosphorus removal (EBPR) system, the sludge phosphorus content is 3.0 - 6.0 % or higher. The more efficient the biological phosphorus removal system is, the higher the sludge phosphorus content will be. Phosphorus is removed from the treatment system by wasting sludge! Because the activated sludge phosphorus content is high in an EBPR plant, effluent total suspended solids (TSS) should be kept low. A small amount of TSS with high phosphorus content could contribute to a high total phosphorus (TP) concentration in the effluent.

Figure 3.1.1.1



3.1.2 Discuss how much phosphorus is released in the anaerobic selector of an optimized municipal EBPR plant.

The amount of phosphorus released in the anaerobic selector varies from plant to plant. Generally phosphorus released is 4 times the total phosphorus in the influent. EBPR plants have been successful at a release of 2.5 times the influent concentration (Bernard, J.L and M.T Steichen, WEF, 2007). Monitoring the influent phosphorus and the phosphorus level in the effluent of the anaerobic selector is a good process control practice for assessing the phosphorus release in this reactor.

### Section 3.2 - Side Streams

3.2.1 Discuss sidestream treatment of phosphorus when using biological phosphorus removal.

The idea of biological phosphorus removal is to create conditions in secondary treatment that result in the microorganisms absorbing excess phosphorus. This phosphorus is removed from the flow when the activated sludge is wasted. If a sidestream is high in phosphorus, the sidestream can be treated. Metal salts can be added to these sidestreams to precipitate the phosphorus to avoid overloading the plant. If only the sidestream is treated chemically, biological phosphorus effluent limits still apply.

### Section 3.3 - Corrective Actions

3.3.1 Discuss corrective actions that can be taken when problems removing phosphorus biologically occur.

OBSERVATION: BOD/TP RATIO HAS CHANGED

Possible Cause: High P in side stream recycles from sludge handling

Monitor or Check: BOD, soluble BOD, TP and orthophosphate in influent to anaerobic zone

Possible Solution: Control volume of side stream P recycles or provide side stream P

removal

Possible Cause: Increased in P in raw influent from industrial or commercial discharges

Monitor or Check: High TP in raw influent

Possible Solution: Control industrial or commercial P discharge to sanitary sewer system

=====

OBSERVATION: P release is poor or not occurring in anaerobic zone

Possible Cause: Insufficient VFAs

Monitor or Check: VFAs/soluble BOD entering anaerobic zone and orthophosphate at end of anaerobic zone.

Possible Solution: a) Supplement VFA by chemical addition b) Increase HRT of anaerobic zone if possible to ferment BOD

=====

OBSERVATION: ANAEROBIC ZONE NOT TRULY ANAEROBIC

Possible Cause: Excess DO from recycle flows

Monitor or Check: ORP above -100 mv in anaerobic zone - DO in recycle

Possible Solution: a) Reduce DO in aeration basin b) Reduce RAS or internal mixed liquor recycle to anaerobic zone

Possible Cause: Excess NO<sub>3</sub> from recycle flows

Monitor or Check: ORP above -100 mv in anaerobic zone - Nitrate in recycles

Possible Solution: a) Reduced RAS or internal mixed liquor recycle to anaerobic zone b) Increase anoxic zone HRT if possible to promote denitrification

Possible Cause: Air entrainment from excessive turbulence in anaerobic zone or upstream processes, such as aerated grit tanks.

Monitor or Check: ORP above -100 mv in anaerobic zone but no nitrates or DO in recycles

Possible Solution: Reduce turbulence if possible

=====

OBSERVATION: INSUFFICIENT VFA IN ANAEROBIC ZONE

Possible Cause: Changes in influent waste strength

Monitor or Check: BOD, soluble BOD, TP and orthophosphate in influent to anaerobic zone

Possible Solution: a) Supplement VFA with chemical addition b) Add fermented primary sludge

=====

OBSERVATION: RAPID P UPTAKE IN AERATION BASIN BUT EFFLUENT P IS HIGHER

Possible Cause: Secondary release occurring in aeration basin

Monitor or Check: TP profile of aeration basin

Possible Solution: Reduce SRT by wasting more sludge

Possible Cause: Secondary release occurring in sludge blanket in final clarifier

Monitor or Check: Check P in RAS - Sludge blanket in final clarifier

Possible Solution: Reduce sludge blanket depth

Possible Cause: If P increases at end of anoxic zone secondary release occurring in anoxic zone with excessive HRT

Monitor or Check: P profile through anoxic zone

Possible Solution: Reduce anoxic zone HRT if possible

=====

OBSERVATION: GOOD P RELEASE IN ANAEROBIC ZONE BUT POOR P REMOVAL

Possible Cause: If anaerobic HRT is too long secondary release could occur after VFA are used up

Monitor or Check: TP profile through selector basins

Possible Solution: Increase RAS to reduce anaerobic HRT

## Chapter 4 - Calculations

### Section 4.1 - Calculations

4.1.1 Determine the hydraulic retention time in an anaerobic selector.

GIVEN:

Influent Flow = 1.15 MGD

Return Activated Sludge Flow = 0.600 MGD

Selector Volume = 150,000 gallons

FORMULA & SOLUTION:

Detention Time (Hrs) =

$$\begin{aligned} \text{Tank Volume (MG)} \div [\text{Influent Flow (MGD)} + \text{RAS Flow (MGD)}] \times 24\text{hrs/day} \\ = 0.150 \text{ MG} \div [1.15 \text{ MGD} + 0.600 \text{ MGD}] \times 24 \text{ hrs/day} \\ = 2.1 \text{ hrs} \end{aligned}$$

4.1.2 Given influent and waste sludge phosphorus content, what will the effluent phosphorus be?

Influent Flow = 0.300 MGD

Influent P = 7 mg/L

WAS Flow = 0.030 MGD

WAS P = 54 mg/L

FORMULA & SOLUTION:

$$\begin{aligned}\text{Effluent P (lbs)} &= \text{Influent P (lbs)} - \text{WAS P (lbs)} \\ &= (0.300 \text{ MGD} \times 7 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L}) - (0.030 \text{ MGD} \times 54 \text{ mg/L} \times 8.34 \\ &\text{ lbs/MG/mg/L}) \\ &= 17.5 \text{ lbs} - 13.5 \text{ lbs} \\ &= 4 \text{ lbs}\end{aligned}$$

$$\begin{aligned}\text{Effluent P (mg/L)} &= \text{Effluent P (lbs)} \div [\text{Effluent Flow (MGD)} \times 8.34 \text{ lbs/MG/mg/L}] \\ &= 4 \text{ lbs} / (0.300 \text{ MGD} \times 8.34 \text{ lbs/MG/mg/L}) \\ &= 4 \text{ lbs} / 2.5 \text{ lbs/mg/L} \\ &= 1.6 \text{ mg/L}\end{aligned}$$

4.1.3 Determine the sludge age in a biological phosphorus removal plant.

GIVEN:

Volume of anaerobic selector = 45,000 gallons  
Volume of anoxic selector = 55,000 gallons  
Volume of aeration basins = 500,000 gallons  
Mixed liquor suspended solids (MLSS) = 3400 mg/L  
Wasting Rate = 20,000 gal/day  
WAS concentration = 5,000 mg/L

FORMULA:

Sludge Age (Days) = Mass of Solids in Biological Reactors (lbs) ÷ Solids Removed Daily (lbs)

$[\text{Tank Volumes (MG)} \times \text{MLSS (mg/L)} \times 8.34 \text{ lbs/MG/mg/L}] \div [\text{WAS Rate (MGD)} \times \text{WAS Conc (mg/L)} \times 8.34 \text{ lbs/MG/mg/L}]$

$[(0.045 \text{ MG} + 0.055 \text{ MG} + 0.500 \text{ MG}) \times 3400 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L}] \div (0.020 \text{ MGD} \times 5,000 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L})$

= [17014 lbs ÷ 834 lbs]

= 20 days

4.1.4 What is the concentration of total phosphorus in plant effluent if the soluble phosphorus is 0.2 mg/L and effluent TSS is 30 mg/L. The phosphorus content of the mixed liquor is 5%.

GIVEN: Effluent Soluble P = 0.2 mg/L  
Effluent TSS = 30 mg/L  
MLSS P = 5%

FORMULA/SOLUTION:

$$\begin{aligned}\text{Total Phosphorus} &= \text{Soluble Phosphorus (mg/L)} + \text{Particulate Phosphorus (mg/L)} \\ &= \text{Soluble Phosphorus (mg/L)} + [\text{Effluent TSS (mg/L)} \times \% \text{ P}] \\ &= 0.2 \text{ mg/L} + (30 \text{ mg/L} \times 0.05) \\ &= 0.2 \text{ mg/L} + 1.5 \text{ mg/L} \\ &= 1.7 \text{ mg/L}\end{aligned}$$

4.1.5 Given data, determine the total phosphorus loading into a treatment plant.

GIVEN:

Influent Flow = 0.240 MGD

Influent P = 6 mg/L

Sludge Storage Tank Decant Flow = 10,000 gpd

Sludge Storage Tank Decant Phosphorus = 48 mg/L

Belt Press Filtrate Flow = 12,000 gpd

Belt Press Filtrate Phosphorus = 20 mg/L

FORMULA & SOLUTION:

Total Phosphorus Loading (lbs) =

[Influent Flow (MGD) × Influent P (mg/L) × 8.34 lbs/MG/mg/L] + Phosphorus from Sidestreams (lbs)

= [Influent Flow (MGD) × Influent P (mg/L) × 8.34 lbs/MG/mg/L] + [Storage Tank Decant Flow (MGD) × Storage Tank P (mg/L) × 8.34 lbs/MG/mg/L] + [Filtrate Flow (MGD) × Filtrate P (mg/L) × 8.34 lbs/MG/mg/L]

= [0.240 MGD × 6 mg/L × 8.34 lbs/MG/mg/L] + [0.010 MGD × 48 mg/L × 8.34 lbs/MG/mg/L]  
+ [0.012 MGD × 20 mg/L × 8.34 lbs/MG/mg/L]  
= 12 lbs + 4 lbs + 2 lbs  
= 18 lbs per day

## Part 2 - Advanced - Chemical Removal

### Chapter 5 - Theory and Principles of Chemical Removal

#### Section 5.1 - Definitions

##### 5.1.1 Define Alkalinity.

Alkalinity is the ability of wastewater to neutralize acids caused by water's carbonate, bicarbonate and hydroxide content. It is a measure of how much acid must be added to lower the pH to 4.5. Wastewater that has low alkalinity will see the pH drop more easily than a high alkaline wastewater when acidic metal salts are added for phosphorus removal. Alkalinity is expressed in milligrams per liter (mg/L) of equivalent calcium carbonate.

##### 5.1.2 Define Mole.

The molecular weight of a substance, usually expressed in grams.

#### Section 5.2 - Chemicals & Chemical Reactions

##### 5.2.1 Describe the chemical reaction of metal salts with phosphorus (on a mole basis).

A positively charged iron ion (+3) combines with a negatively charged phosphate ion (-3) to form the precipitate, iron phosphate.



This equation shows that 1 mole of Fe will react with one mole of P. The mole ratio is therefore 1:1. Mole ratios sound intimidating, but what they are really about is the ratio of the metal atom (either Fe or Al) to the influent phosphorus atom (P). The mole ratio describes how many atoms of Fe or Al are needed to treat 1 atom of influent P.

For a ferric iron (+3), on an atom-to-atom basis, ("mole" can be thought of as short for molecular weight), 1 mole of Fe will react with 1 mole of P so the mole ratio is 1:1. The weight of one mole of iron is 56 grams and the weight of one mole of phosphorus is 31 grams (see figure 5.2.1.1). The weight ratio of Fe+3 to P therefore  $56 \div 31 = 1.8$  to 1.

For ferrous, iron (+2), the mole ratio of Fe to P is 3:2 (see figure 5.2.1.2), assuming iron stays in the +2 form, 3 moles of iron (168 grams) are needed to remove 2 moles (62 grams) of phosphorus. The weight ratio is thus 2.7 to 1.

For aluminum, the mole ratio of Al+3 to P is 1:1 (see figure 5.2.1.3). One mole of aluminum (26.98 grams) is needed to remove one gram of phosphorus (30.97 grams). The weight ratio is thus 0.87 to 1.

Figure 5.2.1.1

Reaction for the precipitation of phosphorus with Ferric Chloride

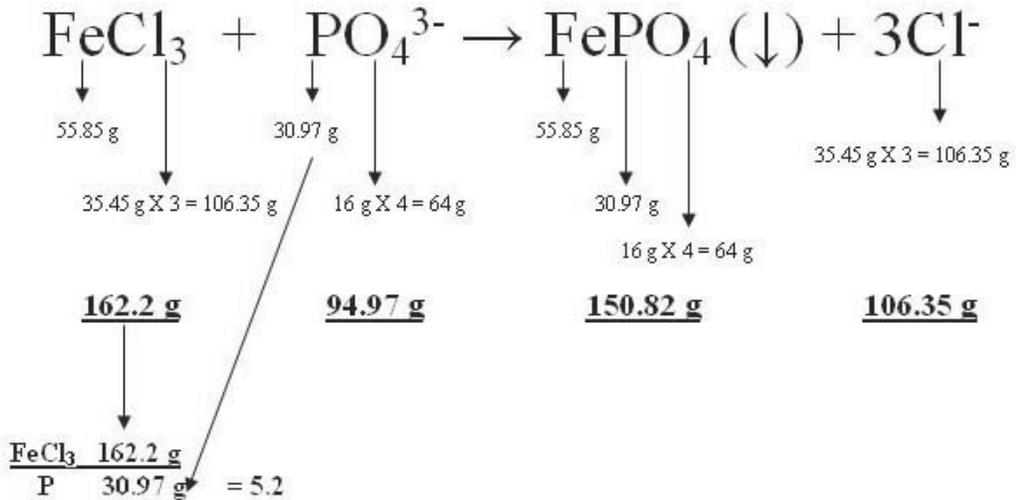


Figure 5.2.1.2

Reaction for the precipitation of phosphorus with Ferrous Chloride

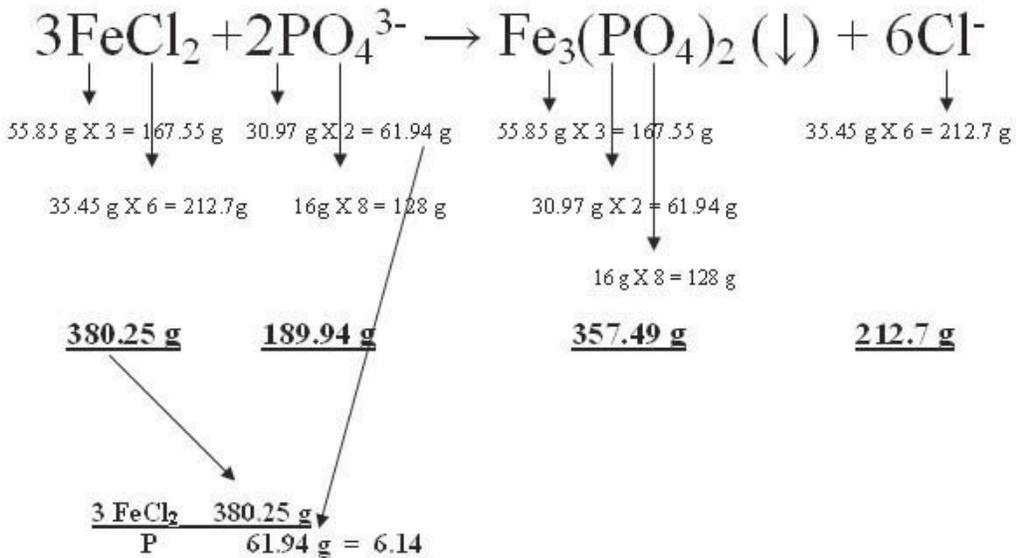
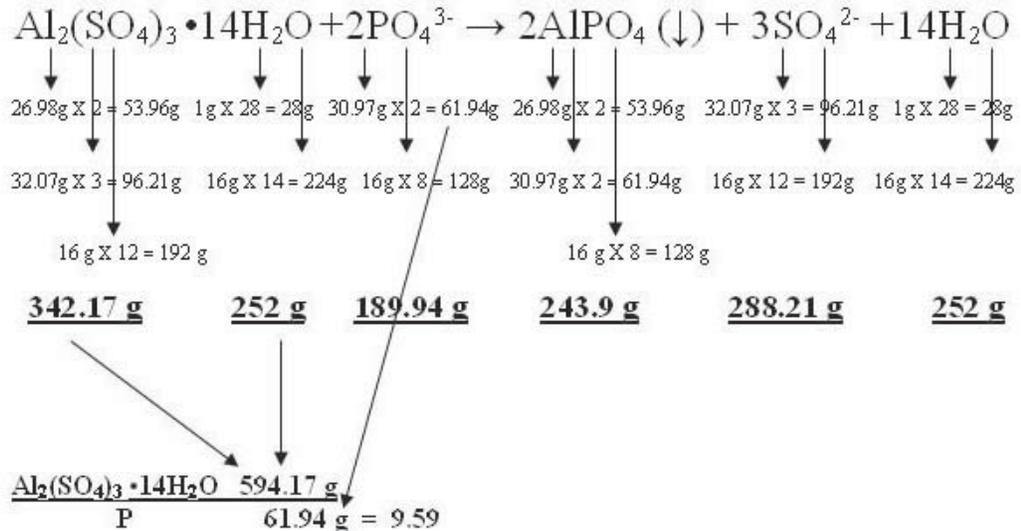


Figure 5.2.1.3

Reaction for the precipitation of phosphorus with Alum



5.2.2 Describe the characteristics of the chemicals (metal salts) used for phosphorus removal.

1. Ferric Chloride
  2. Ferrous Chloride
  3. Ferrous Sulfate
  4. Aluminum Sulfate (alum)
- 
1. Ferric Chloride (FeCl3).
    - Acidic (may lower pH) and alkalinity.
    - Very corrosive.
    - Fume-producing.
    - Supplied 33-36% solution (11-13% iron).
    - Several grades available.
    - Stains concrete and other materials.
    - Can affect UV disinfection.
    - May affect effluent chloride.
  
  2. Ferrous Chloride (FeCl2)
    - Acidic (may lower pH) and alkalinity.
    - Very corrosive.
    - Fume-producing.
    - Supplied as 18-28% solution (8-13% iron).
    - Stains concrete and other materials.
    - May affect effluent chloride.
    - May affect UV disinfection.
    - Potential impurities.

3. Ferrous Sulfate ( $\text{FeSO}_4$ )

- Acidic (may lower pH) and alkalinity.
- Very corrosive.
- Fume-producing.
- Supplied as 23-25% solution (5-7% iron).
- Stains concrete and other materials.
- Should be stored in indoor heated space.
- May affect UV disinfection.
- Potential impurities.

4. Aluminum Sulfate (alum)  $\text{Al}_2(\text{SO}_4)_3$

- Acidic (may lower pH) and alkalinity.
- Moderately corrosive.
- 49% aluminum sulfate (8-9% aluminum) in liquid form.
- Also available in dry form (powder). Must be mixed with water before use.
- Very temperature sensitive in liquid form (must be kept above freezing).
- Clear, light green or yellow liquid.

5.2.3 Describe the precipitates that form when metal salts are added to wastewater.

When metal ions, iron or aluminum, are added to wastewater, two primary precipitates form: an insoluble metal phosphate and an insoluble metal hydroxide. For a given metal, the formation of these precipitates is governed by the wastewater alkalinity and soluble orthophosphate concentration in the wastewater as well as their equilibrium solubility at a given pH.

5.2.4 Discuss the effect of wastewater pH on phosphorus removal chemical feed requirements.

Each phosphorus removal chemical (metal salt) has an optimum pH range for precipitating out the phosphorus as a metal phosphate. Iron phosphate [ $\text{FePO}_4$ ] and aluminum phosphate [ $\text{AlPO}_4$ ] are least soluble at a pH of 6.8-7.0 and thus precipitate out best at these pHs. Wastewater pH levels outside of this optimum range will require more chemical to achieve the same removal efficiency. While not all wastewaters are at a pH of 6.8-7.0, metal phosphates still precipitate out well in the pH range of most wastewaters of 6.0-8.5.

5.2.5 Discuss the effects of influent wastewater with high sulfides on phosphorus removal using iron salts.

Sulfide will react with iron forming a black precipitate. High sulfide wastewater will require higher dosages of iron salts.

Sources of sulfides include hauled and certain industrial wastes, and collection systems with long detention times.

5.2.6 Describe how the metal salt dose changes to meet very low effluent phosphorus limits.

Reaching very low effluent phosphorus concentrations requires increasing amounts of metal salt because of the competition between phosphate and hydroxide precipitation.



## Chapter 6 - Operation and Maintenance

### Section 6.1 - Definitions

#### 6.1.1 Define vivianite.

Vivianite, a hydrated iron phosphate, ( $\text{Fe}_3(\text{PO}_4)_2 \cdot 8(\text{H}_2\text{O})$ ) is a hard crystal that can form in wastewater treatment plant piping and valving when iron salts are added in excess for chemical phosphorus removal.

### Section 6.2 - Equipment

#### 6.2.1 Discuss the types of chemical feed pumps used in chemical precipitation of phosphorus. Positive displacement and peristaltic feed pumps are commonly used for feeding metal salts. Either type of pump can be adjusted automatically, allowing for the appropriate dosage.

### Section 6.3 - Handling and Storage

#### 6.3.1 List the materials and conditions for the storage and feeding of the following chemicals:

##### A. Iron Salts:

Ferric chloride, ferric sulfate and ferrous sulfate should be stored in tanks made of fiberglass reinforced plastic (frp), polyethylene, or saran-lined steel. The tank must be surrounded with a containment area in case of a leak. Feed pumps should be compatible with the chemicals being used. Schedule 80 PVC piping and valving is commonly used for iron salts. The storage temperature of metal salts is an important factor to remember.

##### B. Aluminum Salts:

Aluminum sulfate should be stored in tanks made of fiberglass reinforced plastic (frp), polyethylene, or 316 stainless steel. The tank must be surrounded with a containment area in case of a leak. Feed pumps should be compatible with the chemicals being used. Schedule 80 PVC and stainless steel piping and valving is commonly used for aluminum salts. The storage temperature of metal salts is an important factor to remember.

### Section 6.4 - Preventive Maintenance

#### 6.4.1 Describe maintenance requirements for chemical phosphorus removal systems.

- A. Inspect tanks and piping for cracks, leaks, and metal salt deposits on a regular basis. Repair as soon as possible.
- B. Check equipment for corrosion from chemical fumes. Locate source of fumes and repair or replace corroded parts, if necessary.
- C. Check for developing line blockage by monitoring chemical metering pump discharge pressure. Consult with chemical supplier.
- D. Confirm the heating and ventilation systems are working properly. Repair if necessary.

## Chapter 7 - Monitoring, Process Control, and Troubleshooting

### Section 7.1 - Sampling & Testing

7.1.1 Describe jar testing.

A laboratory procedure used to simulate different chemical feed dosages. This procedure is used to determine the best chemical and dose rate required to achieve a water quality goal. Samples of the wastewater to be treated are placed in jars and varying amounts of the chemical are added to each of the jars and mixed. The lowest dose of the chemical that provides a satisfactory result of the dosage should be used to treat the water.

**Section 7.2 - Process Understanding & Interpretation**

7.2.1 Discuss the effect the addition of acidic metal salts can have on wastewater alkalinity and pH.

Both alum and iron metals salts are acidic and will reduce alkalinity and pH. In low alkalinity wastewaters the addition of metal salts could impair biological treatment, particularly nitrification, by consuming alkalinity. Care should be taken not to overdose metal salts. Adding metal salts before the final clarifiers rather than ahead of the biological reactor may mitigate the impact on the biological treatment.

**Section 7.3 - Side Streams**

7.3.1 Discuss the possible impact of a sidestream high in suspended solids.

Sidestreams or recycle streams usually come from a solids handling, treatment or dewatering processes, such as decanting digesters or sludge storage tanks. These sidestreams could be problematic if the decant or filtrate is high in suspended solids. . The suspended solids could contain large amounts of phosphorus, reintroducing both the solids and phosphorus back into the treatment process. The amount of phosphorus being recycled back through the treatment processes via high suspended solids could be significant. Old sludge solids may also be harder to settle and thus if carried out in the effluent could result in elevated suspended solids, BOD and phosphorus. Solids processing should be operated to minimize the amount of suspended solids in the sidestreams.

7.3.2 List common sidestreams within a treatment plant.

The most common recycle streams are from:

- 1) Thickening/Dewatering Process
  - a) Gravity Belt Thickening Filtrate
  - b) Centrifuge Centrate
  - c) Gravity Thickening Supernatant
  - d) Dissolved Air Filtration Subnatant
  - e) Rotary Drum Thickening Filtrate
  - f) Belt Filter Press Filtrate
  - g) Sludge Drying Bed Underdrain
  - h) Plate and frame filtrate
  - i) Reed Bed Filtrate
- 2) Stabilization/Storage
  - a) Aerobic Digester Decant

- b) Anaerobic Digestion Supernatant
- c) Biosolids Storage Decant
- d) Tertiary Sand Filter Backwash

## **Section 7.4 - Corrective Actions**

7.4.1 Discuss the problems associated with the overfeeding of iron salts to wastewater.

- A. Impedance of UV light transmittance.
- B. Plugging of seal water lines if using effluent reuse.
- C. Plugging of air compressor cooling lines if using effluent reuse.
- D. Formation of vivianite.
- E. Decreased pH and alkalinity.
- F. Chemical cost excess.

7.4.2 State the possible causes and corrections for exceeding effluent phosphorus limits after metal salt addition

POSSIBLE CAUSE: Chemical metering equipment is not working properly.

CORRECTION: Inspect and ensure all chemical metering equipment and piping is operational and performing as required.

POSSIBLE CAUSE: Too low a dose.

CORRECTION: Wastewater characteristics and competing reactions require more chemical than calculated. Add more chemical but no more than needed to meet limit.

POSSIBLE CAUSE: Influent phosphorus loads are higher than normal.

CORRECTION: Sample influent wastewater for phosphorus. Recalculate the dosage rate. Locate sources of high phosphorus and try to reduce.

POSSIBLE CAUSE: Dose point not effective.

CORRECTION: Evaluate if the metal salt should be applied at a different location.

POSSIBLE CAUSE: High effluent suspended solids.

CORRECTION: Review plant operations and determine why effluent solids are elevated (I/I, old sludge, clarifier problems, etc).

POSSIBLE CAUSE: Sidestream phosphorus.

CORRECTION: Sample sidestreams for phosphorus and if high, reduce sidestream flows and phosphorus loadings accordingly. Modify biosolids treatment and dewatering operations if possible.

## **Chapter 8 - Safety**

### **Section 8.1 - Regulations & Procedures**

8.1.1 Discuss how phosphorus effluent limits are established for a wastewater treatment plant. Wisconsin Administrative Code NR 217 - Effluent Standards and Limitations sets forth the requirements for setting effluent phosphorus limits.

NR217 establishes an effluent limitation equal to 1 mg/L total phosphorus as a monthly average for publicly owned treatment works and privately owned domestic sewage works which discharge wastewater containing more than 150 pounds of total phosphorus per month, unless an alternative limitation is provided. The main way for a permittee to request and get an alternative effluent limitation is in the case where biological phosphorus removal technology is utilized as the primary method for phosphorus removal.

A few other, less common ways for requesting an alternative limit are listed within the code. The alternative effluent limitation established by the Department using the biological phosphorus removal option may not exceed 2 mg/L as a monthly average.

Sometimes sidestreams high in phosphorus have to be chemically treated before being returned back into the treatment plant. If a plant has biological phosphorus removal alternative limit and is chemically treating a sidestream, then the biological limit will remain the same even with sidestream chemical treatment.

## Chapter 9 - Calculations

### Section 9.1 - Calculations

- 9.1.1 Given wastewater treatment plant and sidestream phosphorus loading information, calculate an acceptable sidestream flow rate in gallons per day.

GIVEN:

Design Phosphorus Loading = 15 lbs/day

Sidestream Phosphorus Concentration = 10 mg/L

Recommended Sidestream Phosphorus Loading = No more than 5% of design loading

FORMULA:

Acceptable Sidestream Flowrate = [(Design Phosphorus Load in lbs) × (% Allowable for sidestream)] ÷ [(Sidestream Phosphorus Concentration in mg/L) × 8.34 lbs/MG/mg/L]

$$= (15 \text{ lbs/day} \times 0.05) \div (10 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L})$$

$$= 0.009 \text{ MGD}$$

$$= 9,000 \text{ gallons per day}$$

- 9.1.2 Using metal salt chemical data, theoretically calculate the amount of chemical salt solution to add in gallons per day to remove phosphorus.

GIVEN:

Influent flow = 2.0 MGD

Influent phosphorus = 8 mg/L

Metal salt solution

Specific gravity = 1.40

Percent (%) metal in solution = 12.5%

Metal removal ratio (weight basis) = 1.8:1.0

FORMULAS & SOLUTION:

(1) Determine the amount of influent phosphorus to remove

$$\begin{aligned}\text{lbs phosphorus to remove} &= (\text{influent flow in MGD}) \times (\text{phosphorus concentration in mg/L}) \times \\ & (8.34 \text{ lbs/MG/mg/L}) \\ &= 2.0 \text{ MGD} \times 8 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L} \\ &= 133 \text{ lbs phosphorus}\end{aligned}$$

(2) Determine the pounds of metal salt in a gallon of solution knowing the specific gravity.

$$\begin{aligned}\text{lbs metal salt/gallon} &= \text{specific gravity} \times 8.34 \text{ lbs/gal} \\ &= 1.40 \times 8.34 \text{ lbs/gal} \\ &= 11.68 \text{ lbs metal salt/gal}\end{aligned}$$

(3) Determine the pounds of actual metal in a gallon of metal salt solution with a certain % metal content.

$$\begin{aligned}\text{lbs metal/gallon metal salt solution} &= (\text{lbs of metal salt/gal}) \times (\% \text{ metal}) \\ &= 11.68 \text{ lbs} \times 0.125 \\ &= 1.5 \text{ lbs metal/gal}\end{aligned}$$

(4) Look up removal ratio for the metal salt being used.

(5) Determine the pounds of metal needed to remove the incoming pounds of phosphorus.

$$\begin{aligned}\text{lbs/day of metal to add per lb phosphorus to remove} &= (\text{removal ratio}) \times (\text{Influent lbs of phosphorus}) \\ &= 1.8 \times 133 \text{ lbs phosphorus} \\ &= 239 \text{ lbs/day metal to add}\end{aligned}$$

(6) Determine the gallons per day of metal salt solution with a certain % metal content to add.

$$\begin{aligned}\text{Gallons of metal salt solution to add} &= (\text{lbs of metal to add}) \div (\text{lbs metal/gal}) \\ &= 239 \text{ lbs metal} \div 1.5 \text{ lbs metal/gal} \\ &= 159 \text{ gallon/day of metal salt solution}\end{aligned}$$

9.1.3 Given the costs associated with chemical phosphorus removal, calculate the cost per pound of phosphorus removed.

GIVEN:

Average influent phosphoru = 12 mg/L

Average influent flow = 0.650 MGD

Chemical cost per year = \$4400

Chemical feed O&M cost per year = \$600

Sludge handling cost per year = \$975

FORMULA:

Cost Per Pound of

Phosphorus Removed = (Chemical cost + O&M cost + sludge handling cost) ÷ (Total lbs influent phosphorus removed per year)

$$= (\$4400 + \$600 + \$975) \div (0.650 \text{ MGD} \times 12 \text{ mg/L} \times 8.34 \text{ lbs/MG/mg/L} \times 365 \text{ days/year})$$

$$= \$5975 \div 23744 \text{ lbs phosphorus}$$

$$= \$0.25/\text{lb phosphorus removed}$$

- 9.1.4 Given the specific gravity of a metal salt solution and actual % metal content, determine the pounds of actual metal in a gallon of metal salt solution.

GIVEN:

Ferric chloride solution with a specific gravity of 1.40 and 12.5% iron content.

FORMULAS:

$$\text{lbs metal salt/gallon solution} = (\text{Specific Gravity}) \times 8.34 \text{ lbs/gal}$$

$$= 1.40 \times 8.34 \text{ lbs/gal}$$

$$= 11.7 \text{ lbs/gallon}$$

$$\text{lbs metal/gallon metal salt solution} = (\text{lbs metal salt/gallon}) \times (\% \text{ metal})$$

$$= 11.7 \text{ lbs/gal} \times 0.125$$

$$= 1.46 \text{ lbs/gallon}$$

## References and Resources

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