



TECHNICAL BULLETIN: Wastewater

Phosphorus Control in Water and Wastewater

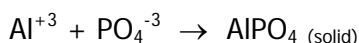
Phosphorus (P) is commonly found in municipal and agricultural waste and wastewater, originating from the digestion of phosphorus-containing food sources. Soluble reactive phosphorus, typically in the form of orthophosphate (PO_4^{-3}), can be a nutrient for aquatic plants, such as algae, which can be either a health risk to aquatic life or an aesthetic nuisance to those living near or using the waterways. In the case of blue-green algae, toxic by-products can be produced, which create health issues if a lake or reservoir would be used as a source of drinking water.

Control of phosphorus can be achieved by forming a precipitant when the soluble phosphorus, in the form of orthophosphate, complexes with a soluble metal, such as aluminum or iron.

Aluminum Sulfate

Alum is commonly used for phosphorus control due to its low metal to phosphorus ratio required for formation of a precipitant. Theoretically, the ratio by weight of aluminum metal to soluble reactive phosphorus expressed as elemental phosphorus (P) is 0.87 ppm Al: ppm P, where "ppm" is "parts per million."

The reaction of soluble aluminum with orthophosphate can be simplified as follows:



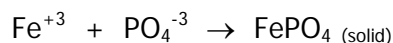
The benefits of using alum in waste or wastewater include the wide pH range where aluminum phosphate remains insoluble, between a pH of 2 and 9. Unless the precipitant is exposed to extremes of either acid or basic conditions, the phosphorus will remain bound to the aluminum. This is important because alum treated waste that is land applied, will have lower levels of phosphorus which are soluble, thus minimizing the carrying of soluble phosphorus into water bodies. Aluminum chloride and polyaluminum chloride can also be used for phosphorus removal in wastewater treatment applications.

Ferric Sulfate

Ferric sulfate is also used for removal of soluble reactive phosphorus from wastewater. The soluble ferric ion (Fe^{+3}) also complexes with orthophosphate to form a precipitant. The theoretical ratio of ferric iron to elemental phosphorus is 1.80 ppm Fe^{+3} : ppm P. The conversion of ppm P to orthophosphate is:

$$\text{ppm P} \times 3.07 = \text{ppm PO}_4^{-3}$$

The reaction of soluble ferric ion with orthophosphate can be simplified as follows:



The benefits of using liquid ferric sulfate in wastewater treatment applications include the ability of the ferric ion to control

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hydrogen sulfide (H_2S) odors through the precipitation of ferric sulfide (Fe_2S_3). Also, a hydrolysis reaction occurs with ferric ion to form a ferric hydroxide floc when added to water. These are competing reactions that will make the actual iron to phosphorus ratio higher than the theoretical, depending on the properties of the wastewater that is being treated.

The ferric iron (Fe^{+3}) is more efficient than ferrous iron (Fe^{+2}) for phosphorus control, due to the higher valence (+3) of the ferric ion vs. the ferrous ion (+2). The theoretical ratio of ferrous iron to elemental phosphorus is 2.7 ppm Fe^{+2} : ppm P.

Application of aluminum or iron based solutions in water or wastewater requires mixing at the point of application if the most efficient removal of soluble phosphorus is to occur. Typically, a rapid mix basin or application in a water line using a quill and corporation fitting just prior to an elbow and basin provide the best method of chemical addition in a plant setting. Always determine the proper materials of compatibility and follow the Material Safety Data Sheet when handling any chemical.

Lake and Reservoir Treatment

Aluminum sulfate is commonly applied to lakes and reservoirs to precipitate out the soluble phosphorus, which will eventually settle to the lake bottom. A second reaction, which occurs when soluble aluminum is added to water, is known as a "hydrolysis reaction". The hydrolysis reaction is a multi-step chemical reaction where the aluminum forms an aluminum hydroxide floc, which also assists in the precipitation of the aluminum phosphate floc as well as other

solids in the water. Due to the hydrolysis reaction, the actual ratio of metal to phosphorus needed to remove soluble reactive phosphorus will be higher than theoretical. Factors that affect the applied ratio will be water alkalinity, temperature, pH, and presence of other substances such as colloidal matter.

Less commonly, ferric salts are injected in the presence of an aeration system to achieve phosphorus control in small lakes. Under anoxic conditions, where oxygen is depleted or unavailable in a region of a lake, the ferric phosphate precipitate can potentially redissolve, thus reversing the intended goal of minimizing the availability of soluble phosphorus in the aquatic environment.

References

1. *CRC Handbook of Chemistry and Physics*, 75ed. 1994, CRC Press, Inc.
2. "Water Engineering & Management", Phosphorus Inactivation in Wastewater Treatment: Biological and Chemical Strategies, Christopher Lind, February 1998.

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