TECHNICAL BULLETIN

WASTEWATER TREATMENT PHOSPHATE REMOVAL

Phosphates have many different uses in industry today. Some examples are detergents for cleaning, boiler treatments for preventing scale, and water treatments to soften the water. These applications require different types of phosphates. Phosphates can be categorized into three basic forms:

- Orthophosphate
- Polyphosphate
- Organic Phosphate

Both orthophosphate and polyphosphate are considered inorganic phosphates. A waste treatment plant can see any one or any combination of these types of phosphates in their influent stream.

Chemical and biological treatments are methods used to lower phosphates below plant discharge permits. When tighter controls on waste treatment plant effluent or a change in the influent waste force phosphate levels to raise above the effluent's limit, it becomes necessary to review the system and optimize for phosphate removal. In this document we will be discussing only the chemical approaches for phosphate removal.

To optimize the wastewater treatment system, we first must determine our end goal for the effluent. A portion of the goal of the overall treatment program may be to discharge water below the plant's phosphate permit level. Because there are three forms of phosphate, the discharge charge limit of the effluent stream is usually described in terms of TOTAL phosphate. However, this is not always the case. When obtaining the plant discharge limit, it is important to first verify if there is a phosphate limit and if so, in what way is the phosphate being reported. The most common ways to report phosphate limits are to report the phosphate (or phosphorous) as,

- P
- PO_4
- P_2O_5

In addition to discharge permits using any of these three methods of reporting phosphate, testing laboratories will do the same. So, it is important to make sure that the tests being run to confirm results

match what is needed for the discharge permits. Fortunately, it is easy to convert between the three factors.

- P x 3.07 = PO_4 (Similarly, PO_4 / 3.07 = P)
- P x 2.29 = P_2O_5 (Similarly, P_2O_5 / 2.29 = P)
- PO_4 X 0.746 = P_2O_5 (Similarly, P_2O_5 / 0.746 = PO_4)

So, if you have a plant discharge that needs results reported as P, but the testing lab reports results as PO_4, you simply divide the lab results by 3.07 to convert to P.

Now that the treatment goal has been determined, an analysis of the various treatment options can be conducted to determine the best approach. Orthophosphate is the form that is easiest removed. The other forms eventually convert to ortho given time (longer mix times), temperature (higher temperatures) and pH (lower pH).

Aluminum Treatment

The first treatment method to be discussed uses aluminum to precipitate phosphate. Aluminum reacts with phosphate to give aluminum phosphate in the weight ratio of 0.28 lbs Al for each pound of PO_4:

$$Al^{3+} + PO_4^{3-} \rightarrow AlPO_4$$

Aluminum phosphate's solubility is pH dependent. The minimum solubility for aluminum phosphate is at a pH of 6.0. Once the phosphate is reacted with aluminum, bringing the pH to 6.0 will result in maximum aluminum phosphate precipitation.

The most common forms of aluminum used to precipitate phosphate are 50% Liquid Alum (Aluminum Sulfate) and Aluminum Chloride solutions. Because other reactions occur with aluminum at a 6.0 pH, an excess amount of aluminum is required. Some rough guidelines for reduction of phosphorus by aluminum is as follows:

Ratio of ppm of Alum/Aluminum Chloride Solution to ppm of Phosphorous as P	Typical Reduction in Total Phosphate
26:1	75%
32:1	85%
44:1	95%

With any treatment system, please verify results through jar testing. Aluminum enters into many other reactions besides phosphate, so results may vary from the chart above depending on other contaminants in the wastewater stream.

Iron Treatment

The second method of treatment is with Iron. Ferric reacts with phosphate in a similar manner as aluminum. Again, the precipitate is pH sensitive, with a minimum solubility range of 4.5 to 5.0. The weight ratio of ferric to phosphate is 1.8 to 1. And just like with aluminum, competing reactions drive

up this ratio. Ferrous iron also works to precipitate phosphate with a minimum solubility range of 7 to 8 and similar dosages as ferric.

Lime Treatment

Treatment with lime is the third method for phosphorous precipitation. The precipitation reaction is as follows:

$$3HPO_4^{2-} + 5Ca^{2+} + 4OH^- \rightarrow Ca_5(OH)(PO_4)_3 + 3H_2O$$

This reaction is pH dependent, but at a pH of 9.0 most of the phosphate is precipitated. At a pH of 10.0 this method can achieve a total phosphate as low as 1ppm. Note that many other reactions occur with lime so a quantitative amount of lime per part of phosphorus is not available. This method also produces the most sludge of the three methods.

The three methods discussed(aluminum, ferric, and lime) are the most common chemical treatments used for phosphorous removal. Other more specialized treatment methods are available if lower concentrations are required. These methods include multiple chemistry approaches, chlorination, biological treatment, and other non-chemical methods. Again, if the goals of the treatment program are known, an appropriate treatment program can be developed and implemented to meet the needs of the waste treatment system.