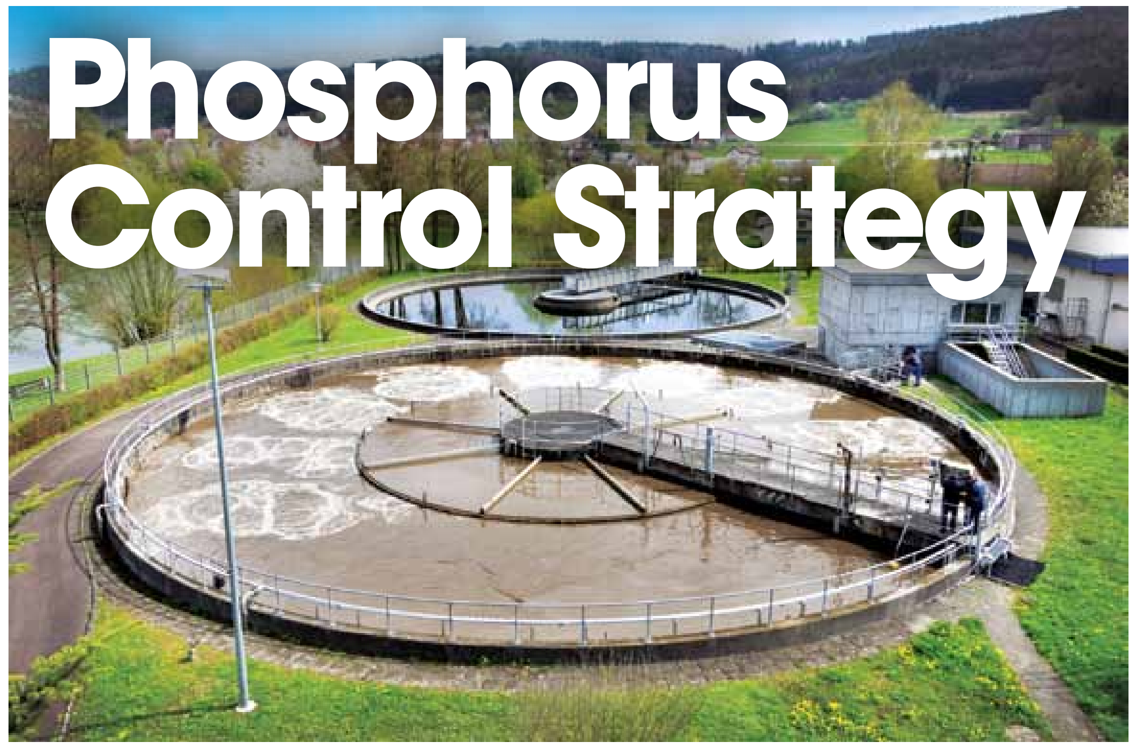
Phosphorus Control Strategy



By Tracy Doane-Weideman

Improving phosphorus reduction at water resource recovery facilities

New water quality standards require reduction in the amount of nitrogen and phosphorus released from water resource recovery (WRR) plants because these nutrients cause pollution in streams, lakes and rivers. While it is possible with modern treatment processes to achieve these reductions, the result can be much higher costs in terms of the chemicals and electrical power needed. This article will show how compliance can be attained at more reasonable costs by adding points of measurement at key points to help optimize water treatment processes.

Excessive nitrogen and phosphorus migrating into water bodies often is the direct result of human activities such as agricultural and storm water runoff, wastewater discharge, commercial cleaning operations, and household and yard maintenance.

To address these water quality problems, state environmental agencies in the U.S. and the U.S. Environmental Protection Agency (EPA) are requiring dischargers to reduce the amount of phosphorus in their effluent. For example, on Dec. 5, 2013, EPA announced a new collaborative framework for implementing the Clean Water Act Section 303(d) Program with states. Other regulatory agencies worldwide also are examining these issues and responding with laws of their own.

Phosphorus in Wastewater

Implementing water quality improvement plans, often referred to as total maximum daily loads, is challenged by the availability and cost of treatment technologies capable of achieving low phosphorus targets. However, significant improvements can be made through operational changes to existing systems though process optimization.

NPDES permits in the U.S. contain ever-decreasing limits in terms of total phosphorus. Raw municipal wastewater contains between 5 and 20 mg/L total phosphorus which is reduced to 3 or 4 mg/L after conventional secondary treatment. WRR facilities incorporating enhanced biological nutrient removal often can reduce total phosphorus concentrations to 0.3 mg/L or less.

Total phosphorus is the sum of organically bound phosphates (nucleotides, phospholipids, etc.), condensed phosphates (polyphosphates and metaphosphates) and inorganic orthophosphate (PO_4^{3-})—with the latter commonly known as reactive phosphate. The majority of phosphorus present in wastewater is in the form of inorganic orthophosphate, and this is what must be measured for the development of removal strategies and subsequent permit compliance.

How to Measure Phosphorus

Many WRR facilities rely on grab samples that are analyzed in a laboratory to determine phosphorus concentration for reporting purposes using EPA and standard methods protocols. To evaluate coagulant chemistries and dosage, periodic jar tests often are used. These methods are widely accepted practices but are not optimal.

There are multiple challenges with manual periodic testing due to instability of incoming phosphorus levels. This is especially important in plants where there is influent from industrial facilities and/or the pH has significant fluctuations. Even in applications where the majority of waste is from municipal sources, phosphorus concentrations can change significantly in short periods of time, and therefore may not be accurately determined by periodic grab sample testing

To obtain more accurate and up-to-date process information, online analyzers are an ideal solution.

Several total phosphorus analyzers are on the market, including the Spectron CA72TP analyzer from Endress+Hauser. The Spectron TP is a colorimetric analyzer that follows EPA and other standard methods for the determination of total phosphorus in water and wastewater in concentrations ranging from 0.05 to 25 mg/L.

Phosphorus removal through chemical and physical methods takes place only when the phosphorus is in the orthophosphate form, and the majority of phosphorus in wastewater is in this form. Orthophosphate analyzers such as the Endress+Hauser Liquiline System CA80PH are widely accepted for process control applications.

The analyzer employs the colorimetric principals of relative color intensity to determine orthophosphate concentration following EPA and standard methods. For low measurements ranging from 0.05 to 10 mg/L PO_4-P, the molybdenum (blue) method is used; for ranges from 0.5 to 50 mg/L PO_4-P the vanado-molybdate (yellow) method is used.

Many NPDES permits require the reporting of a total phosphorus value of the final effluent delivered to surface waters. Knowing the quantity of incoming phosphorus at the inlet of the WRR facility aids load balancing and sludge management strategies. To achieve process optimization, phosphorus typically is continuously monitored using on-line analyzers in the following locations:

- At the influent of the facility, for feed-forward control of chemical precipitants;
- After the primary clarifier, for feed-forward control of chemical precipitants;
- In the bioreactor, to trend biological phosphorus removal;
- Before secondary clarifiers, for feed-forward control of chemical precipitants;
- After the secondary clarifier, for feedback control of chemical prepetition;
- In the effluent, for compliance assurance; and
- In sidestream processes that precipitate struvite under controlled conditions.

WRR facilities use two methods of phosphorus elimination. One method is biological elimination by the uptake of phosphate into the microbial biomass, and the second is chemical precipitation of orthophosphates using metallic salts such as Fe^{3+} or Al^{3+}.

Biological elimination. Phosphorus makes up approximately 2% of the cell mass by dry weight of microbes in wastewater in treatment facilities that are not designed for enhanced biological phosphorus removal (EBPR). The biological uptake that occurs during the cell growth cycle can be reduced by approximately 2 mg/L, which is not sufficient for water quality compliance. EBPR uses specialized polyphosphate-accumulating bacteria in the activated sludge mixed liquors.

Chemical precipitation. There are several dosing points for chemical precipitants based on the plant design and control strategy for the elimination of phosphorus. In one strategy, coagulants are added to the raw wastewater with sedimentation in the primary clarifier as it enters the facility. With this strategy, the need for phosphorus in the biological treatment must be considered to ensure that effectiveness is not reduced in the next stages of treatment.

Getting a Fast ROI

In addition to ensuring that a WRR facility maintains compliance with its NPDES permit, an optimized phosphorus strategy can provide a relatively quick return on investment for online measurement and control.

For example, one facility was using ferric chloride dosing and simple flow pacing at an annual cost of $100,000 per year. The average concentration of orthophosphate was 1 mg/L, but the regulatory limit was 2 mg/L. By installing a dual-channel orthophosphate analyzer and implementing an advanced control strategy to operate closer to the acceptable limit, the facility was able to reduce its annual chemical and sludge management costs by $40,000 per year. This is an example of over-treating and the plant may not have been able to save the money had it not installed the analyzer.

Conclusion

Regulatory limits for phosphorus release to surface waters are in the process of being implemented for the first time in some locales, while evaluation of lowering the limits is occurring in others. In either situation, understanding the type of phosphate measurement required to manage an effective control strategy will allow WRR facilities to achieve compliance with reasonable implementation and operational costs. w&wd

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