Phosphorus Removal from Wastewater

Capital Avoidance Strategies

In most wastewater treatment facilities, opportunities for significantly improving phosphorus removal without major capital investment exist. Biological phosphorus removal alone can oftentimes provide compliance with effluent limits of 0.5 mg/L total-phosphorus; sometimes lower. In order to consistently meet permit limits of less than 0.5 mg/L, effluent filtration and/or chemical treatment is generally necessary.

To optimize phosphorus removal, it generally makes sense to explore, experiment, and evaluate biological treatment options. That is, seek ways to either (a) establish a pre-anaerobic treatment zone, or (b) import an anaerobic sidestream back into the mainstream.

Bacteria release phosphorus in anaerobic conditions and then take up much more than was released during subsequent aerobic conditions. Exactly why this happens is complicated and subject to some scientific debate. Volatile Fatty Acids (VFAs) play a big part.

The anaerobic-aerobic cycle can either occur in the mainstream flow, or a sidestream waste can be subjected to anaerobic conditions and reintroduced to the mainstream flow. For sidestream wastes, it is best to keep the anaerobic treatment in a "fermentation" stage. This is done by periodically (say, daily for an hour) aerating the anaerobic tank to kill of the methane producing bacteria.

Biological Phosphorus Removal: pre-Anaerobic Zone

Facilities equipped with pre-anoxic treatment tanks are the easiest to convert to pre-anaerobic. To make the anaerobic, the dissolved oxygen (DO) needs to be reduced to zero. This can usually be done by: (a) reducing internal recycle pumping, (b) lowering aeration tank DO levels, and/or (c) eliminating all extraneous sources of oxygen. A dissolved oxygen meter can be used to confirm that a pre-anoxic tank is anaerobic. Even better is to use an ORP meter. An ORP reading of -250 at the pre-anaerobic tank outlet is typically sufficient.

Internal Recycle. Our experience with facilities that internally recycling three to four times the influent rate has not been good. We've found that better denitrification results from internally recycling one times the influent flow or less. A very effective way of reducing oxygen input is to reduce the internal recycle rate and, to the extent practical, RAS rates too. Minimizing these oxygen inputs is usually the quickest, easiest way to transform a pre-anoxic tank to pre-anaerobic.

Aeration DO. Aeration tanks require enough oxygen to provide complete BOD and ammonia removal. Once these objectives have been met, there is no need for further oxygen. Careful control of aeration tank DO not only saves money in reduced electrical expenditures, it improves pre-anoxic / pre-anaerobic treatment. Surplus oxygen, in fact, is recycled back to the pre-anoxic tank where it is toxic to the denitrification process.

Eliminate oxygen inputs. Oxygen enters the pre-anoxic tank in three ways: (1) with the influent, RAS, and/or internal recycle; (2) by mixing – air lift mixers, surface aeration, floor mount aeration; and (3) splashing of influent flows that introduce air. DO inputs need to be minimized to keep conditions anaerobic.

Finally, regarding pre-anaerobic treatment, the longer the retention time, the easier it is to maintain truly anaerobic conditions. The easiest ways to increase hydraulic retention time are to minimize internal recycling and/or add tanks. Minimizing RAS pumping may be something worth considering.

Biological Phosphorus Removal: Introducing Anaerobically treated waste

In situations where it is not practical to create an anaerobic treatment zone ahead of aeration, it is oftentimes possible to import or create an anaerobic waste that will provide the same quality of phosphorus removal. The following options exist: (a) trucking in septic pump-out waste (septage), and/or (b) returning a portion of anaerobically treated sludge, be it primary sludge, gravity thickener waste, RAS or WAS.

Septage. The processing of trucked-in septic tank waste can, for some facilities, provide sufficient anaerobically treated waste to allow for effective biological phosphorus removal. If the volume of septage is large relative to plant flow, the anaerobic waste may provide enough volatile fatty acids (VFAs) for the aeration tank bacteria to take up phosphorus to meet effluent phosphorus limits. Making it work may (or may not) involve some creative pretreatment, storage, pumping and piping to convey the waste to the aeration tank.

Return anaerobically treated sludge. Any form of anaerobically held sludge can be used as a source of VFAs: primary, secondary, mixed. As long as the sludge has been held long enough to become anaerobic, VFAs are formed. Fully anaerobically digested sludge, however, contains few VFAs; the acids are broken down and are not available for phosphorus removal. The ideal sludge treatment is to "ferment" the sludge long enough to create VFAs, but not so long as to break down the volatile fatty acids. This can be done by aerating the sludge holding tank for an hour per day.

If a portion of the waste activated sludge is returned, it will be necessary to increase the wasting rate. Otherwise the mixed liquor concentration will increase.

Chemical Phosphorus Removal

Various chemicals can be used to effectively remove phosphorus: iron solutions, aluminum solutions, or lime.

Each compound has its advantages and disadvantages as discussed below. To meet stringent phosphorus limits it is generally most cost effective to add chemicals to more than one location. In order to determine the best chemical(s) the typical practice is to perform jar testing with various chemicals prior to full-scale, in-plant trials. Most chemical supply companies will perform an such an evaluation for free.

When evaluating options, one thing to consider is the fact that chemical treatment only works on the soluble fraction. Particulate phosphorus – the phosphorus that is attached to effluent TSS particles – will not be removed by chemicals. If the effluent TSS is over 10 mg/L or if effluent total-phosphorus concentrations of less than 0.5 mg/l are required, an understanding of soluble vs. insoluble effluent total-P is important.

An important consideration in selecting chemicals is sludge disposal. The use of aluminum products creates a sludge with increased aluminum. Sludge incineration facilities can be adversely impacted by aluminum; it causes struvite to form as "clinkers." Some incinerators won't take aluminum laded sludge.

Some of the more common chemical addition points are: (a) influent (precipitant is removed in primary clarifiers), (b) aeration tanks – beginning, middle, end (precipitant is removed in secondary clarifiers), and (c) prior to filtration (precipitant is removed during filtration).

The advantages of using iron salts are: better dewatering, sulfate removal (odor control as a bonus), material can be stored out-of-doors, and BOD removal. The disadvantages of using iron salts are: safety (the material is highly corrosive), consumes alkalinity, and stains UV bulbs and reduces UV efficiency.

The advantages of using aluminum salts are: lower overall cost, less alkalinity is consumed, can be used as direct filtration aide, and is more tolerant to overfeeding. The disadvantages to using aluminum salts are: it must be stored inside and some incinerators will not accept aluminum treated sludge.

Lime is delivered as a powder in bulk. It is alkaline and difficult to work with. Because it needs to be slaked prior to use, it is not practical for facilities with flows of less than 5 MGD.