How Sidestream Phosphate Removal can Benefit Biosolids Management Programs in Florida's Nutrient-Sensitive Watersheds

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Florida is the nation's leading producer of phosphorus, but unlike nitrogen, phosphorus is a limited nutrient. The global limitation on raw phosphorous, as well as an increased understanding of nutrient sensitive ecosystems, have sparked the development of systems to recover phosphorous from wastewater treatment plants. An increasingly implemented phosphorus recovery strategy is the precipitation of struvite (also known as magnesium ammonium phosphate, or $MgNH_4PO_4$) from high strength wastewater streams.

Struvite is a relatively soft mineral; nonetheless, nuisance struvite precipitation on equipment and pipe surfaces is a significant maintenance concern for some treatment plants with anaerobic digestion. Numerous benefits of nutrient recovery by controlled struvite precipitation have been widely discussed at a national level, including reduced precipitation of nuisance struvite, decreased chemical requirements for phosphorus removal, and a beneficial payback from sale of the struvite pellets.

An example of nuisance struvite precipitation is in Figure 1, which shows a decant pump impeller that is used to decant and return supernatant to a treatment plant from a biosolids storage lagoon. The wastewater utility operating this lagoon anaerobically digests its waste solids and is not required to control effluent phosphorus with chemical or enhanced biological means. This is a textbook location for nuisance struvite precipitation as it is downstream of digestion where the constituents of struvite, dissolved magnesium, ammonium, and phosphate are plentiful and agitation of the supernatant may tend to strip carbon dioxide, resulting in locally high pH. Struvite has a minimum solubility (and highest precipitation potential) at an approximate pH of 10, but any increase of pH above neutral conditions may exacerbate nuisance struvite precipitation.

Considering biosolids management in Florida, however, an additional benefit to struvite recovery is clear: reduction of biosolids phosphorus content. As of Dec. 31, 2012, land application of biosolids in the Lake Okeechobee, Caloosahatchee River, and St. Lucie River watersheds is prohibited, except for those Class AA biosolids that are marketed and distributed as fertilizers, per Rule 62-640.850 F.A.C., unless the applicant demonstrates that the nutrients nitrogen and/or phosphorus in the biosolids will not add to the nutrient loadings in the watersheds. During the permitting process, the applicant is required to include a site-specific nutrient management plan and perform a site demonstration of a net balance between the nutrient imports and exports.

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Figure 1. Struvite accumulation on the impeller of a post-digestion biosolids decant pump. Implementing struvite recovery minimizes the risk of nuisance struvite deposition such as this and directs nutrients toward beneficial reuse.

Phosphorus recovery strategies, such as struvite recovery, are important to Florida utilities that manage biosolids programs in nutrient sensitive watersheds because they create an alternate fate for phosphorus apart from land (as biosolids) and water (as effluent). Unlike nitrogen, phosphorus is a conservative element within a treatment plant. This means that the total mass balance of phosphorus in the plant influent must equal that in the biosolids and plant effluent.

Historically, nutrient permitting has focused on treatment plant effluents discharged to surface waters. Meeting effluent discharge permits typically means maximizing the phosphorus content of the biosolids. Implementing in-plant phosphorus recovery is akin to adding an additional "phosphorous spigot," allowing the plant to maintain low levels of effluent phosphorus discharge while also reducing phosphorous discharge to land via biosolids.

The schematics in Figures 2A and 2B show example layouts, phosphorus transport, and phosphorus balance in facilities performing chemical phosphorus removal and enhanced biological phosphorus removal, respectively. In Figure 2B, the notable advantages are the elimination of metal salt addition for phosphorus removal and a significant reduction in the mass of phosphorus that has its fate in the biosolids.

Treatment process modeling tools can be made sensitive to phosphorus balance issues, including struvite precipitation and biosolids phosphorus content. The challenge with using stock treatment process models is that they do not do a particularly good job of describing nuance phenomena that may greatly impact struvite precipitation, such as struvite precipitation

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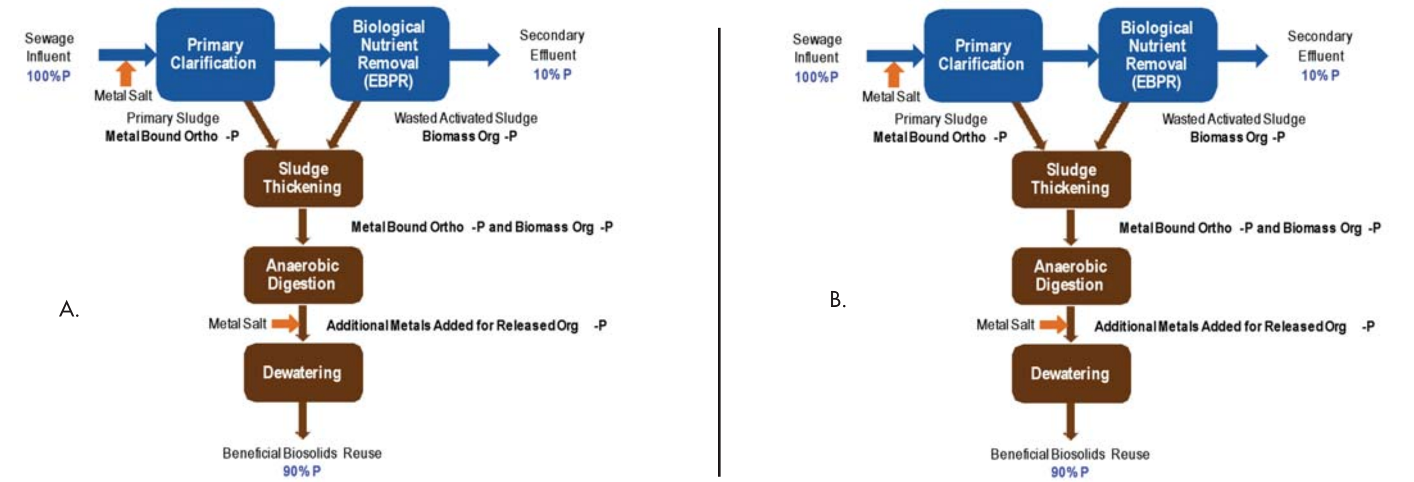

Figure 2. Phosphorous transport in a treatment plant using (A) metal salt addition and (B) enhanced biological phosphorus removal for effluent phosphorus control and the opportunity for sidestream phosphorus recovery. The numbers highlighted in blue denote the percent of influent phosphorus mass residing in a particular process stream.

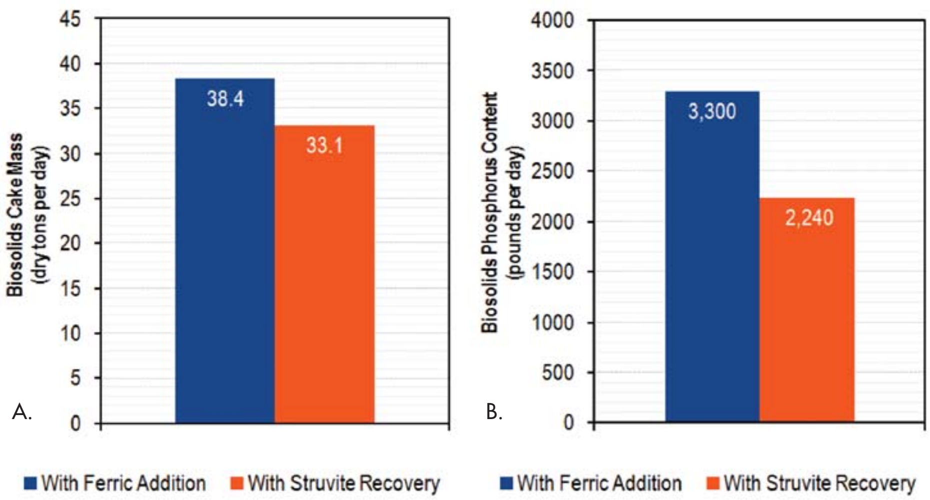

Figure 3: Modeled effect of two centrate phosphorous control strategies on biosolids hauling requirements and biosolids phosphorus content at a representative enhance biological phosphorous removal (EBPR) treatment plant. In both respects, struvite recovery produces a less costly-to-manage residual biosolids stream.

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within an anaerobic digester (which is a nonbeneficial sink if the goal is beneficial phosphorus recovery) and carbon dioxide stripping, resulting in sludge pH changes downstream of digestion. After correcting for these shortcomings in the stock model, for example, by adding supplemental magnesium salts to the modeled anaerobic digester, an accurate estimate of the plant-wide impacts on struvite recovery can be obtained.

The data in Figures 3A and 3B were obtained from a calibrated whole-plant process model of a treatment facility considering the implementation of struvite recovery on its post-anaerobic digestion recycle stream. These data reveal two significant benefits of the phosphorus recovery. Figure 3A shows the contribution of metal salt addition to overall biosolids mass. In this case, if metal salts were used for phosphorus control, approximately 16 percent of total biosolids production would be from chemically derived (metal phosphate) sludge. As biosolids hauling is typically the single largest expense associated with sludge management by a land-applying utility, a 16 percent increase in biosolids is significant. Figure 3B shows that the total mass of phosphorus in the biosolids is reduced by approximately 33 percent when sidestream struvite removal is applied.

In terms of Florida's requirement of zero net import of phosphorus into sensitive watersheds, the phosphorus contained in the recovered struvite offsets that which would otherwise need to be removed by plant growth and harvest. The practical implication of reduced biosolids phosphorus mass loading is that less crop biomass is required to meet the zero net import requirement for biosolids land application, which translates to less required land application field area.

How important can reduced land application area requirements be for a utility? Consider that reducing land requirements may also have the financial benefit of shorter biosolids hauling distances. Various studies have estimated the cost of biosolids hauling from $0.70-1.00 per wet ton, per mi. Using this value, a wastewater utility generating 10 wet tons of biosolids per day would incur an additional hauling cost of $2,600-3,600 per year for each mi of increased hauling distance. If the average biosolids trip was kept from increasing by 20 mi for this facility, the annual cost benefit would be in the range of $51,000-73,000 per year prior to considering biosolids mass reductions from reduced metal salt dosing. Clearly, consumption of viable lands for biosolids spreading has a tangible and significant impact on the operation costs associated with biosolids management that must be included in any holistic evaluation of in-plant phosphorus recovery.

Table 1 shows a complete life cycle cost analysis (defined in terms of equivalent annual cost over a 20-year period) of implementing struvite recovery at a treatment facility that currently relies on ferric chloride for phosphorus control. The data shown in Table 1 are from an analysis using a calibrated process model and local cost data. Such a cost analysis is specific to a particular facility and particular regulatory, geographic, and public environment. Two scenarios are shown: one where the avoided additional biosolids hauling distance is 5 mi and another where the avoided biosolids hauling distance is 20 mi. Several take-home messages from this analysis include the following:

- Comparing solely the value of recovered struvite to the cost to finance the struvite recovery facility would not suggest that the project is cost-effective.

- Considering solely in-plant impacts of struvite recovery (omitting biosolids hauling related costs), the project would be only marginally cost-effective with a net annual benefit of $66,000.
- Considering both in-plant and biosolids hauling cost benefits, the project is highly favorable in terms of costs, with a payback period of less than five years.
- Reduced hauling distance is a significant factor in the cost analysis; the 20-mi distance reduction results in an annual cost savings larger than the equivalent annual cost of financing the struvite recovery facility.

Much as it is an accepted practice to consider life cycle costing, as opposed to capital cost estimates when selecting process facilities or equipment, it needs to be commonplace to consider the holistic benefits of sidestream phosphorus recovery when considering the feasibility of its implementation in an existing treatment plant. Existing process design tools, with careful manipulation, can provide a great amount of detail about the plantwide impacts of sidestream struvite precipitation and inform the decision process. Specifically in the most sensitive watersheds in Florida, reduced biosolids phosphorus content is a critical and often overlooked aspect of phosphorous recovery. This technology may provide the unique opportunity to couple a process that promotes compliance consisting of stringent nutrient control regulations with one that supports the current resource recovery posture of the wastewater treatment industry.

Table 1. Life cycle cost analysis of implementing struvite recovery at an existing a 25-mgd full-scale wastewater treatment plant at a 5-mi and a 20-mi biosolids hauling distance.

	Item	Cost ($US/year)	Savings at 5 mi Hauling Distance ($US/year)	Savings at 20 mi Hauling Distance ($US/year)
1	Reduced ferric chloride dosage		$330,000	$330,000
2	Reduced supplemental carbon		$184,000	$184,000
3	Sludge production avoided		$470,000	$470,000
4	Reduced aeration requirements		$55,000	$55,000
5	Struvite product value		$164,000	$164,000
6	Recovery process operations	$122,000		
7	Recovery process maintenance	$170,000		
8	Recovery process power	$96,000		
9	Recovery process financing	$282,000		
10	Avoided hauling distance		$128,000	$510,000
	Total Cost or Savings	**$670,000**	**$1,331,000**	**$1,713,000**
	Net Equivalent Annual Savings		**$661,000**	**$1,043,000**