Operating Experience with Ostara Struvite Harvesting Process

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The Madison Metropolitan Sewerage District (the District) operates a 158 ML/d (42 MGD) advanced secondary wastewater treatment plant with biological phosphorus and ammonia nitrogen removal, named the Nine Springs Wastewater Treatment Facility. Our most recent major plant upgrade project (called the "11th Addition") to the wastewater treatment plant included upgrades to the solids handling and anaerobic digestion facilities including: 1) Change from DAF thickening to GBT thickening of waste activated sludge (WAS). 2) Addition of acid phase digestion prior to methane phase. 3) Heating of the thickened WAS with steam injection heating prior to acid phase digestion. 4) Release of phosphorus from the WAS prior to thickening by combining and holding a recirculation stream of acid phase sludge with the WAS. 5) Struvite recovery from the combined filtrate streams generated from digested sludge thickening and WAS thickening. 6) The capability for time/temperature batching of a portion of the digested sludge to produce a Class A Biosolids product. A generalized process diagram is shown in Figure 1. Design loadings and current loadings for the phosphorus harvesting process are shown in Table 1.

Struvite accumulation in the anaerobic digestion process at Madison has been an issue for decades. In the late 1990s, however, when biological phosphorus removal was implemented at the Nine Springs WWTF the struvite problem became more acute. This is because struvite is formed from equal chemical molar ratios of magnesium, ammonium, and phosphate. The source water for Madison is hard groundwater, high in dissolved magnesium, which provides this necessary ingredient. Anaerobic digestion—which Madison has been using since the late 1920's—results in high ammonia levels in the recycle stream from the digester, thus accounting for the second key ingredient. Biological phosphorus removal concentrates phosphorus in the cells that are eventually wasted to anaerobic digestion, and immediate phosphorus release occurs in the digesters. This increases the soluble phosphorus concentration in the digesters, the final key ingredient, resulting in an increase in the overall solubility product of struvite and thus the production of unwanted struvite. To combat the operational and maintenance challenges stemming from this increased struvite formation in the digesters, Madison Metropolitan Sewerage District began researching projects with the University of Wisconsin-Madison on ways to remove the struvite precipitate in a controlled fashion from the digesters. It was quickly realized that this could also potentially result in a beneficial reuse product.

In planning for the 11th Addition project, it came to the attention of the District that commercial entities were already working on similar processes and ideas, and had relationships with customers that would be needed to handle a beneficial reuse product created from such a process. The District piloted a couple of the technologies before electing to take pre-bid packages for the process, with the intent to integrate the successful vendor and their process into the 11th Addition project and bidding documents. Following submittal of three proposals in early 2010, the District elected to enter into partnership with Ostara Nutrient Recovery Technologies for provision of equipment and product marketing relationships. Design and construction of the 11th Addition actually followed the entering into of this agreement, so the result was that over three years elapsed from the time an agreement was entered into and the actual start-up was ready to commence in late 2013.

The Ostara process for struvite harvesting has been operational on site at Madison since November, 2013. The District operates and owns the process, with control software, operational parameters, and constant input and advice provided by Ostara operational personnel. Bagged product is sold to Ostara and picked up about every two to three weeks. The soluble phosphorus in the feed is produced mainly by WAS thickening. Phosphorus is released from the cells back into a dissolved form in a pair of large tanks preceding WAS thickening, which we call the phosphorus release or "P-release" tanks. Madison is using a small quantity of digestate from a nearby acid-phase anaerobic digester to combine with the incoming WAS to trigger release of phosphorus from the cells before thickening. The acid phase digestion process has total volatile fatty acid (VFA) concentrations around 5,000 mg/l as acetic for recycling and releasing P from the WAS. The acid phase digestion process also solubilizes phosphorus and magnesium to concentrations of approximately 600 mg/l and 180 mg/l respectively. These concentrations in the recirculation stream also add to concentrations released from the WAS due to the VFA additions. Shown in Figure 2 is an average mass balance for the process from January, 2013 through April, 2015. This process has proven fairly stable and effective irrespective of time of year.

As mentioned earlier in the article, ammonia is also needed for the chemical precipitation of struvite. Anaerobic digestion is the source of this ammonia, obtained from the filtrate (and/or centrate, if we are dewatering digested sludge for Class A biosolids production) coming off the post-digestion thickening process. At Madison this post-digestion filtrate stream is combined with the pre-digestion WAS filtrate to create a combined filtrate mixture which is now high in all three ingredients (phosphorus, magnesium, and ammonia, all in dissolved form)—only the pH level (which keeps the mixture below saturation) at this point prevents the formation of struvite in the process. From here the combined filtrate is pumped and fed to the reactors in measured and controlled amounts.

Within the reactors, magnesium chloride is added to the feed stream to further increase the solubility product, and sodium hydroxide is added to increase the pH. Spherical particles of struvite are precipitated and removed from the reactor. The spherical sizes of the struvite "prills" are such that it can be used in similar applications as chemical fertilizer, or combined with other chemical fertilizer constituents.

Anticipated benefits of struvite harvesting have been met in some areas, but operational experience with the system and other process needs are requiring modifications and research for improving process performance. The following are some process details and notes on changes either implemented or being investigated:

1) The soluble P removal in struvite harvesting has met the projected 80 to 85% removal projections.
2) Concentrations in the combined feed to the Pearl reactors are approximately 160 mg/l orthophosphate, 80 mg/l magnesium, and 220 mg/l ammonia. These concentrations were increased from design concentrations by pre-thickening approximately 30% of the WAS in the retired DAF thickening process.
3) Soluble P concentrations in the digesters have decreased from ~200 mg/l to ~100 mg/l. Evidence supports that this is resulting in significantly less struvite precipitation in the digesters and in digested sludge piping, translating to decreased O&M costs in these areas.
4) A comparable decrease in the water extractable phosphorus in the Biosolids has positively impacted land re-application limitations for phosphorus.
5) The total phosphorus removal by the struvite harvesting process has been lower than expected due to loss of struvite fines in the reactor effluent and back to the plant. This recycle is increasing the phosphorus loading to the secondary process and may negatively impact biological phosphorus removal if unchecked.

6) Elimination of the ferric chloride addition was planned with inclusion of struvite harvesting facilities. Management of H2S levels in the plant's permit for air emissions from engines is necessitating a low dose of ferric chloride to the digester feed.
7) A low ferric chloride dose is also added to the sludge feed to thickening and dewatering processes. The pH elevates in the filtrate and centrate during digested sludge thickening and dewatering. This results in the formation of struvite in the filtrate and centrate in spite of much lower soluble P concentrations in the methane phase digesters. A low ferric chloride dose into the digested sludge feed suppresses the nuisance struvite formation as well as improved thickening and dewatering.

Relative to maintenance, estimates of labor requirements before start-up of the system were made for the process based on experience at other facilities. Because of the tendency for prills at Madison to grow beyond optimum size the harvesting down and re-seeding of the reactors has proven to be needed more frequently than anticipated. The struvite product dryers also had a tendency to plug with time as was anticipated, but the cleaning procedure was not labor friendly for the dryers as originally installed. Modifications were made to the dryers in the meantime to facilitate easier access and maintenance, which greatly reduced dryer cleaning time. These modifications have been built into subsequent installations of the process.

Integral in these process investigations is the new paradigm that various unit operations in the treatment plant, such as return sludge, waste sludge, and thickening/dewatering processes, are now quite intertwined with successful operation of struvite harvesting. With those facts considered, an efficiently operating struvite harvesting process with minimal downtime is absolutely necessary to protect the plant biological phosphorus removal process from overloading and upsets. Extensive laboratory work and process monitoring are on-going in ajoint effort between Madison Metropolitan and Ostara to find keys to achieving improved performance from the 11th Addition struvite harvesting modifications. While the initial startup and basic operation of the equipment and process went smoothly, the system in Madison has encountered several process challenges not experienced elsewhere to date. The District and Ostara are continuing to work together to optimize the process performance. Several process modifications have been made and others are currently being investigated.

The full paper can be accessed on the CSWEA website, www.cswea.org.

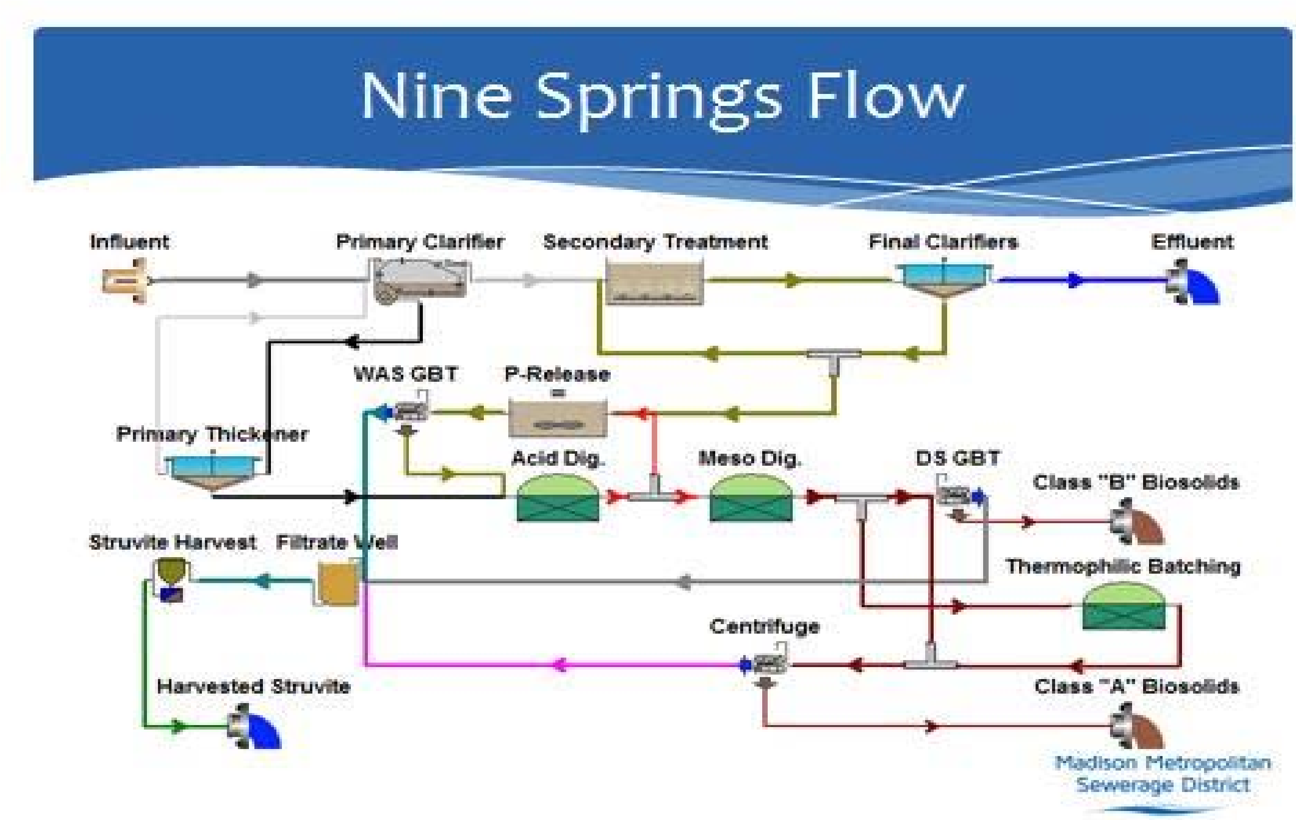

Figure 1. Overall Nine Springs WWTP Plant Schematic

Table 1. Process design loadings and current operating conditions

Process Design Loadings for the Struvite-Harvesting System			Current Operating Conditions
Parameter	**Design Loadings (2010)**	**Future Loadings (2030)**	**Current (2015)**
Combined Filtrate Feed Flow Rate, liters/day	4,432,000	4,735,000	2,560,000
Feed Ammonia Concentration, mg-N/L	175	224	215
Feed Ortho-Phosphate Concentration, mg-P/L	126	163	135
Feed Magnesium, mg-Mg/L	42	44	65

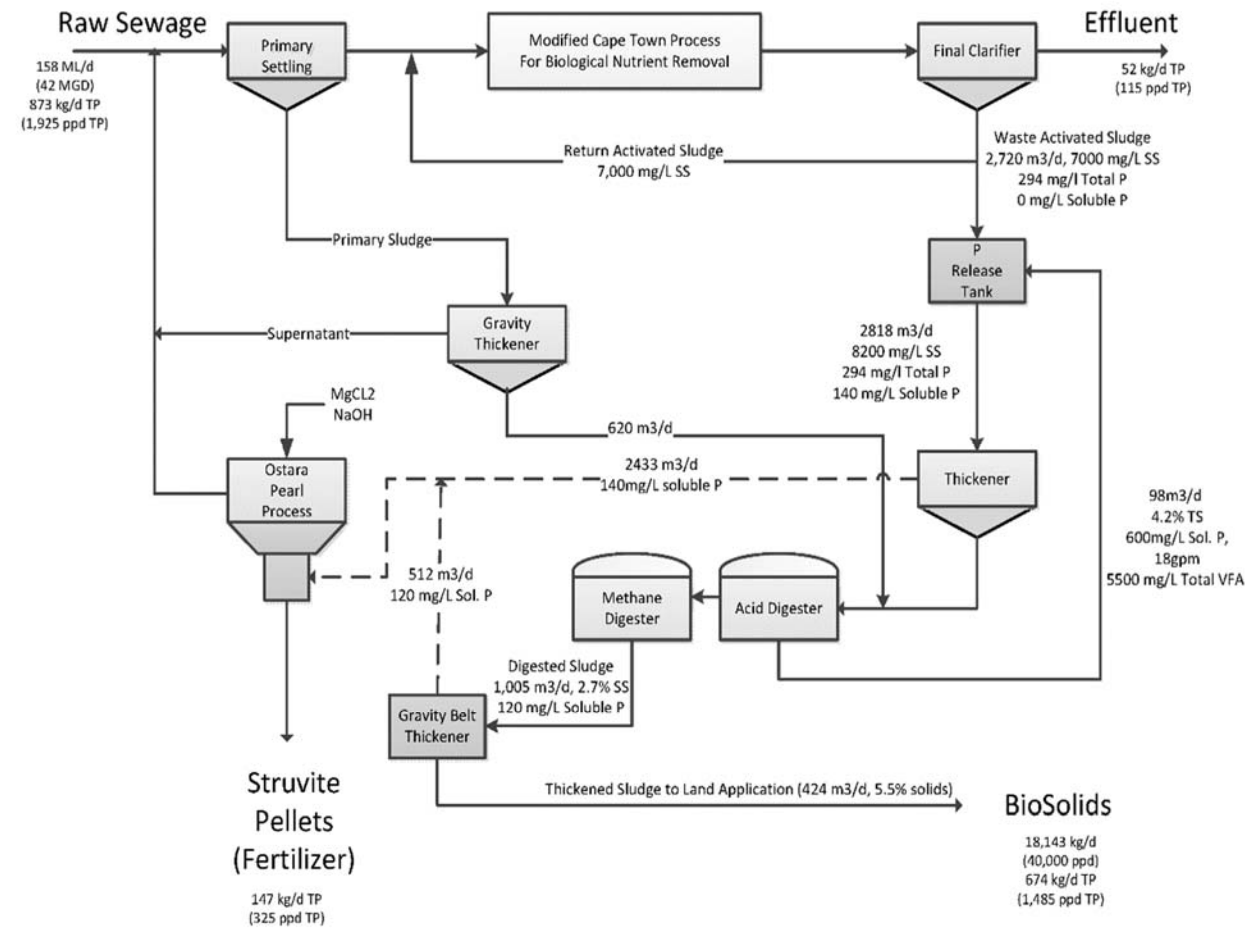

Figure 2: Schematic with mass balance