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Staying Ahead of Struvite Problems in Wastewater Treatment Plants

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Abstract **-** The formation of phosphate-based precipitates in wastewater treatment plants is a nuisance not only from an operation point of view because it clogs piping and damages pumps and valves but also from an economic stance when significant costs are incurred to clean or replace the clogged pipes. Among the phosphate precipitates struvite is the most prevalent. In most instances the formation and build-up of struvite within the treatment stream goes unnoticed until a critical stage is reached where the only option is replacement of the clogged pipes. One way to stay ahead of this problem is the regular monitoring of the parameters that influence struvite build-up and to take action before it is too late. Since phosphorus is usually the limiting parameter for struvite precipitation, observing the changes in its concentration can provide valuable information on potential struvite formation. This paper presents a case study where detailed investigations were carried out to determine struvite formation potential in a secondary wastewater treatment plant in Canada.

Keywords**:** Phosphorus, Struvite, Supersaturation ratio, Wastewater.

1. Introduction

It is well known that a number of wastewater treatment plants employing anaerobic digestion of its sludge encounter nutrient-related problems, especially with respect to the formation of struvite (magnesium ammonium phosphate hexahydrate, MAP) (Fattah, 2012). These formations foul and encrust the sludge return lines, pumps and valves. Presence of struvite is high in post-digestion areas, especially in treatment plants employing anaerobic digestion. The formation and growth of 'uncontrolled' struvite increases operational (for example pumping) and maintenance costs, as well as reduces the plant's hydraulic capacity. On the other hand, controlled production of struvite has the potential to be economically beneficial to treatment plants since the maintenance costs decreases and extra revenue can be generated from the commercial trade of the struvite crystals which can be used as fertilizers.

Another important aspect of the presence of phosphorus and nitrogen in the treatment stream is the 'nutrient looping'. In case of no phosphorus removal step in the treatment stream, both struvite formation and nutrient looping may occur. Nutrient looping is the trapping of untreated nitrogen and phosphorus within the treatment plant. Nutrient looping occurs when the centrate or digested supernatant, which typically have high phosphorus and nitrogen concentration, is returned back to the headworks area for further treatment. Nutrient trapping hampers biological treatment processes and hence process efficiency is decreased (Sagberg et al. 2006).

1.1. Factors Affective Struvite Formation

Supersaturation ratio (SSR) is often used in the wastewater treatment industry as an indication of struvite formation potential (Fattah et al. 2012). Some of the major factors influencing SSR are (a) concentrations of the constituent ions (ortho-phosphate (P), ammonium-nitrogen (N) and magnesium (Mg)), (b) the pH, (c) temperature and (d) the conductivity of the wastewater. A supersaturation value of greater than unity indicates that struvite formation is most likely to occur.

This study was conducted to investigate the status of the struvite formation potential at a secondary wastewater treatment plant in Canada. The wastewater treatment plant has reported recurrent issues of uncontrolled struvite formation in the piping system downstream of the digester and the centrifuge. Data from the current study was compared with a similar study carried out two years back to investigate possible trends in the parameters monitored.

2. Objectives of the Study

The specific objectives of this study were the following:

1. Compare current struvite formation potential in terms of phosphate concentrations with those from previous study: The purpose of this exercise was to evaluate potential changes in the phosphate concentration that may indicate likely problems related to formation of struvite. Results from two study periods that were two-years apart were evaluated.
2. Determine the changes in the phosphate concentrations and struvite formation potential in terms of SSR at the sampling points.

3. Materials and Methods

Supersaturation ratio was used as an indication of the possibility of struvite formation at any particular location in the treatment stream over two study periods. Wastewater samples were tested in the laboratory and the resulting data was used to evaluate the struvite formation potential by running a struvite formation program coded in Matlab. The sampling periods have been designated as Study A and Study B, with B being the more recent. The parameters that are used to calculate SSR (mentioned in Section 1.1) were measured every week over a period of two months regularly to investigate the difference in the readings at two different locations of the treatment stream namely (a) the centrate formed after centrifuging of the sludge and (b) the centrate sump, which is a holding tank for the centrate. It is from this sump that the centrate is returned and mixed with the primary clarifier effluent (looping in the treatment plant). The reason for sampling at the sump was to investigate the possible phosphorus precipitation at this location due to prevalent lower temperatures. The samples were centrifuged for 10 minutes at 4000 RPM due to high solids content. The resulting supernatant was filtered using 0.45 micron filter paper prior to analytical measurements. All parameters and conditions were measured according to APHA et al. (2005).

4. Results and discussions

4.1 Comparison of Ortho-phosphate concentration

4.1.1 Centrate

The average ortho-P (OP) concentrations over the sampling period were 195 mgP/L and 208 mgP/L, for Study A and Study B, respectively (Fig. 1a). There has been a slight increase (6.6%) in the average concentration of ortho-P in the centrate from 2009 to 2011. However, as illustrated in Fig.2, there were periods of high OP (above 215 mgP/L) than the average of 208 mgP/L. Although the differences are small, the combination of OP increase, in addition to other struvite precipitation factors' increase (Mg, NH_3-N, pH) on a particular day, can bring about rapid struvite formation. Therefore, it is necessary to monitor all the factors simultaneously. Since there is no significant increase in the OP concentration in the influent, this increase indicates that over the last two years phosphate has been accumulating in AIWWTP. In terms of struvite formation, this is a worrisome trend. It is also worthwhile to compare the phosphate concentration in the centrate with that in the centrifuge feed. It is expected that there would be negligible change in OP concentration brought about by centrifuging the digested sludge. However, although there was a 3 mg/L lowering of the phosphate, this relates to approximately 5.6 kg/d loss of phosphate. It is highly likely that some of this precipitate may accumulate within the centrifuge itself, or in the accompanying piping.

4.1.2 Centrate Sump

The average ortho-P (OP) concentrations over the sampling period were 138 mgP/L and 161mgP/L, for Study A and Study B, respectively (Figure 1b). As expected (since the centrate concentrations are higher), there was an increase of 17% in the centrate sump ortho-phosphate concentrations in Study B than in Study A. With no significant increase in influent OP and only 6.6% increase in the centrate OP, it is reasonable to hypothesize that OP is being accumulated in the centrate sump.

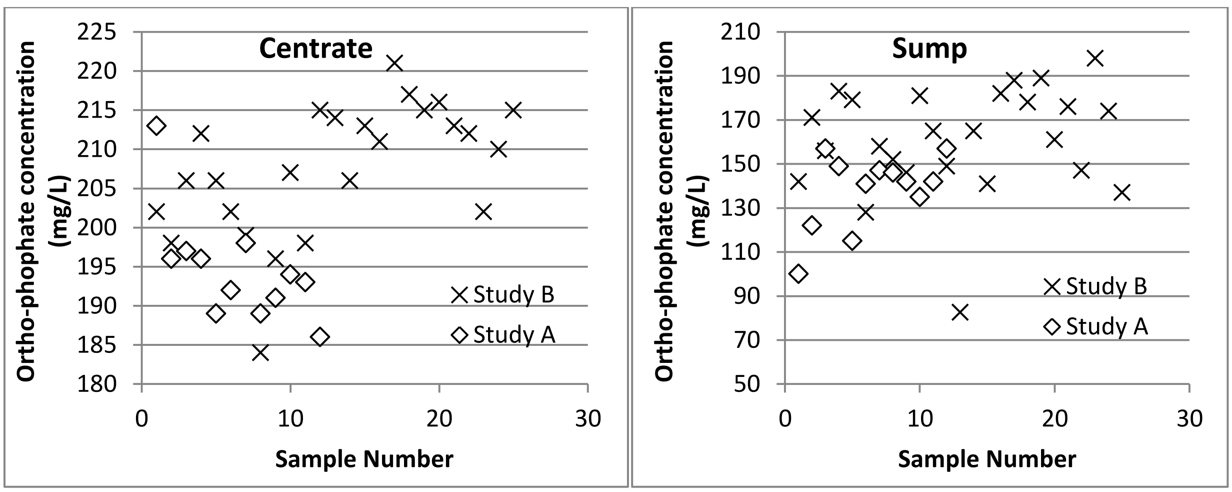

Fig. 1. (a) Centrate and (b) centrate sump orthophosphate concentrations during the two study periods.

4.2 Supersaturation Ratios (SSR) In The Treatment Plant

The SSRs in the three sampling locations during Study B are shown in Figure 2. It is observed that there were days when the SSR was above unity, indicating that formation of phosphate precipitates in the form of struvite is possible. It is also interesting to note the “peaks and valley” nature of the graphs. This shows the importance of continuous monitoring of factors that determine struvite formation potential. By having the ability to determine struvite formation potential in real time, operators can control the factors on which struvite formation depends on (such as pH and temperature).

4.3 Nutrient Looping

During anaerobic digestion, phosphates that had accumulated in the sludge are released, thereby increasing the soluble fraction of phosphate. When this treated sample is centrifuged, the centrate formed contains high levels of soluble phosphate – one of the key ingredients of struvite formation. At the wastewater treatment plant, this centrate is re-routed back to the primary effluent (PE) channel. The consequence of this routing is that the phosphate present in the raw influent is never fully removed, and the net concentration of phosphate within the treatment cycle increases. This return represented as much as 48% of the plant’s influent phosphate load, as shown in Table 1. The ammonium-nitrogen concentration of the centrate that is returned to the PE channel is 1,075 mg/L; this represents approximately one-fifth of the new TKN mass load arriving through the influent.

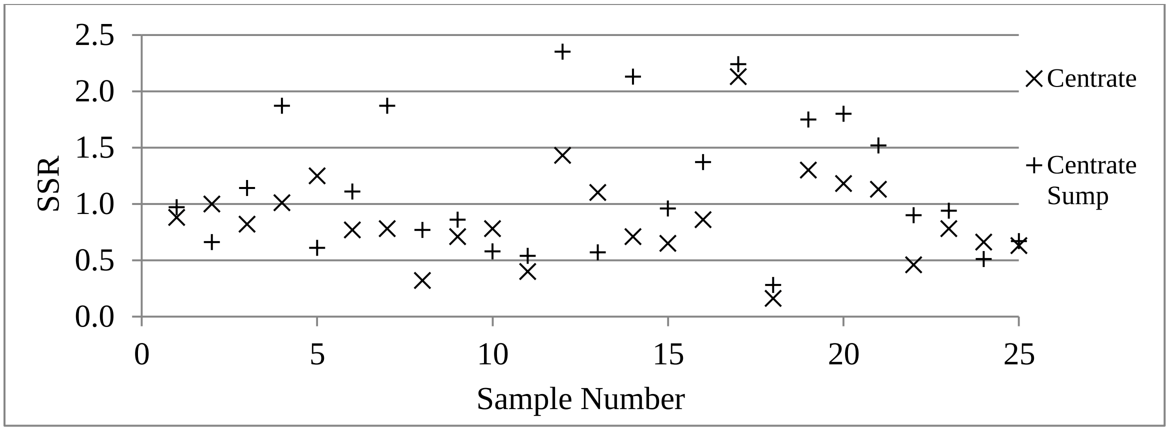

Fig. 2. Supersaturation ratios in the two locations in Study B.

Table1. Nutrient looping in the treatment plant

	Influent	Centrate return
Flow (MLD)	450	1.86
Phosphate conc. (mg/L)	1.4	162
Total load (kg P/day)	630	301
NH_4-N (mg/L)	21.8	1075
NH_4-N load (kg/day)	9,810	2,000

4. Conclusion

Results indicated that the average SSR was lower than 1. But the SSR values were higher than unity on several sampling days. This indicates that struvite formation might have taken place on those particular days when the SSR was high. It was observed that the concentration of Mg/N and P were lower for few days after several days of high SSR.

The phosphate and ammonia-nitrogen concentrations were decreased substantially from the centrifuge to the centrate sump. The loss of phosphate was 45.9 mg/L (84.5 kg/day) while that of ammonia-N was 262 mg/L (482 kg/day); this represents 22% and 19% reduction, respectively. The reduction of phosphate and ammonia-N from the waste stream may have contributed to the uncontrolled struvite formation inside the pipes. The phosphate load from the centrate sump to the primary effluent channel was close to half of the plant's influent phosphate load. For TKN, the return amount was approximately one-fifth.

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References

APHA, AWWA, WPCF (2005). Standard Methods for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, Washington, D.C.

Fattah, K. P. (2012), Assessing Struvite Formation Potential at Wastewater Treatment Plants. International Journal of Environmental Science and Development, 3(6), 548-552.

Fattah, K.P., Mavinic, D.S. and Koch, F.A. (2012), Influence of Process Parameters on the Characteristics of Struvite Pellets. Journal of Environmental Engineering, ASCE. 138(12), 1200-1209.

Sagberg, P., Ryrfors, P. and Berg, K.G. (2006). 10 years of operation of an integrated nutrient removal treatment plant: ups and downs. Background and water treatment. Wat. Sci. Tech., 53(12), 83-90.