VIABILITY OF PHOSPHORUS RECOVERY FROM WASTEWATER AT BURWOOD BEACH WASTEWATER TREATMENT WORKS

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ABSTRACT

Phosphorus is an essential nutrient for all life. Phosphorus is a non-renewable resource and is estimated to reach a peak in production around 2030. Wastewater is a source of phosphorus and there are numerous technologies are available for its recovery. Phosphorus recovery is technically possible; however the viability will ultimately depend on commercial factors.

This research focussed on the concept of peak phosphorus and the available technologies for the recovery of phosphorus from wastewater. The BioWin activated sludge modelling program was used to investigate phosphorus recovery options at Burwood Beach Wastewater Treatment Works (WWTW), a high rate activated sludge treatment process located in the lower Hunter region of NSW, Australia. This modelling determined the quantity of phosphorus that could be recovered from a range of treatment processes options.

There are two main forms in which phosphorus can be recovered from wastewater, either combined in the sludge (or 'biosolids') or chemically precipitated and crystallised as Struvite (Magnesium Ammonium Phosphate), or a combination of the two. Applications for reuse of biosolids are dependent on the class of the product produced and also on its marketability. Struvite, on the other hand, is a readily marketable commodity. A preliminary cost assessment has been conducted on phosphorus recovery in the form of Struvite at Burwood Beach WWTW. A net present value assessment determined that an increase of between 260-410% in the market value of Struvite would be required in order to achieve commercial viability for this application.

KEYWORDS

Phosphorus recovery, wastewater, struvite

1.0 INTRODUCTION

Phosphorus is an essential element for all living matter. Humans, plants and animals all need phosphorus to grow. Phosphorus is a major component of bones and teeth, helps to maintain a normal pH in our body, and is a key element in generating and utilising energy (Westheimer, 1992). Inorganic phosphorus in the form of phosphate (PO_4^{3-}) is an essential component of biological molecules including DNA and RNA, where it forms part of the structural framework (Westheimer, 1992). Additionally, living cells use phosphate to transport cellular energy in the form of adenosine triphosphate (ATP). Almost every cellular process uses energy obtained from ATP. For living organisms, phosphorus is obtained from food consumed. A human adult requires between 700-1250 mg per day in order to sustain a healthy level in the body (Cordell, 2009).

Similar to fossil fuels, naturally occurring phosphorus reserves are limited and will therefore eventually run out. However, unlike fossil fuels where there are a number of alternatives for energy production, there is no alternative for phosphorus.

Phosphorus is applied to crops as a fertilizer, and in many soils is the limiting nutrient to crop yields (Cordell, 2008). Currently 90% of the phosphorus used in the manufacture of fertilisers is obtained from phosphate rock (Rosmarin, 2004), with the remainder used primarily in detergents. Unlike nitrogen, which can be replenished from the atmosphere, the only naturally occurring, concentrated source of phosphorus is from phosphorus containing rocks and guano (Van Wazer, 1961).

Once phosphorus is applied to soil in the form of fertilizers and following plant uptake a portion of the phosphorus is left in the soil, and another portion will end up in rivers and lakes due to surface water runoff and ground water flow. A portion of the phosphorus taken up by plants will end up in human excreta and finally at the wastewater treatment plant. The wastewater treatment industry currently uses significant amounts of chemicals to precipitate and remove phosphorus prior to effluent discharge to avoid the eutrophication of waters and also to meet regulatory concentration limits. Removal of phosphorus is costly in terms of chemical use, sludge management and energy used.

The BioWin modelling program was used for a case study of phosphorus recovery at Burwood Beach Wastewater Treatment Plant (WWTP) to determine the possible phosphorus recovery along with other important operational factors such as biosolids production. Consideration was also given on the current situation and the drivers, both technical and commercial, for future changes to the process configuration to incorporate phosphorus recovery technology. A framework for the commercial assessment of technologies has been developed, and a net present value assessment for the recovery of Struvite was undertaken.

2.0 ABOUT BURWOOD BEACH WWTW

Burwood Beach is Hunter Water Corporation's largest WWTW and is designed to treat domestic, commercial and industrial sewage from a population of approximately 220,000 people, or 48 megalitres per day (ML/d), from the Newcastle area in New South Wales Australia. A process flow diagram is given in Figure 1 below.

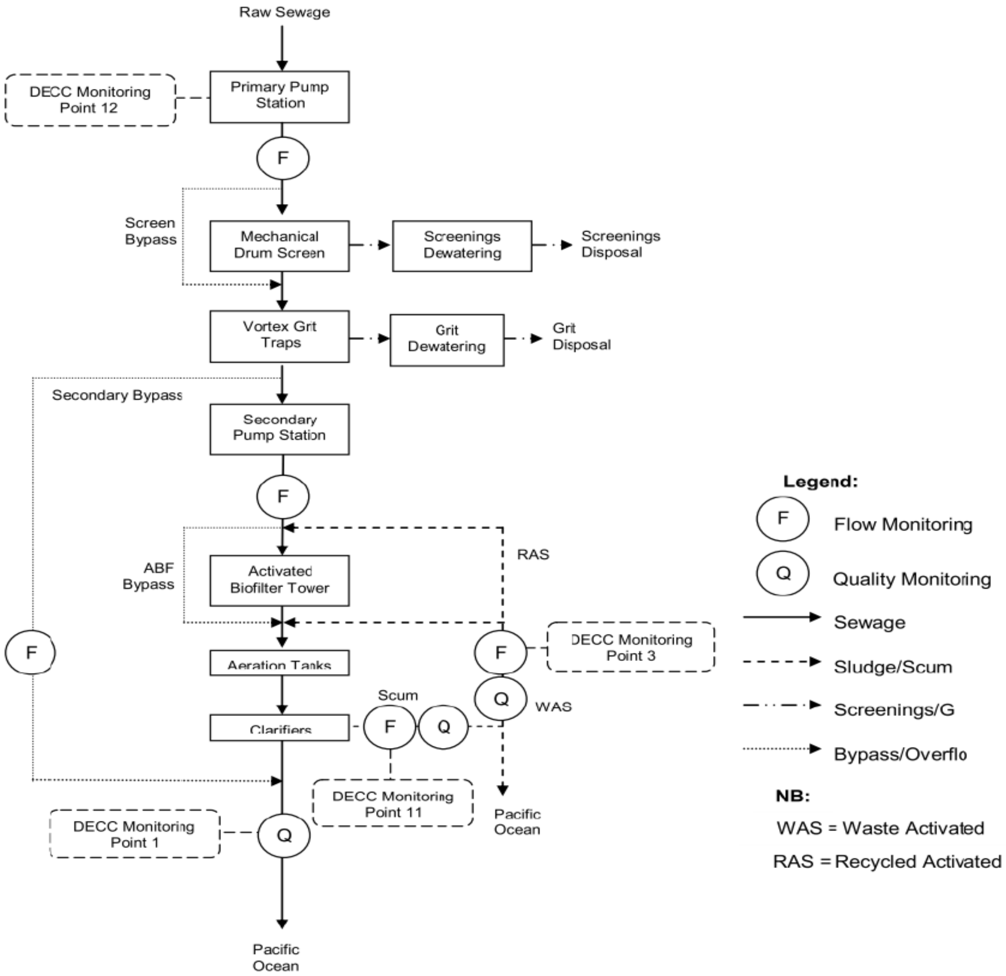

Figure 1: ***Burwood Beach WWTW process flow diagram***

Hunter Water is currently undertaking further investigations in order to determine the most sustainable long-term biosolids management strategy and effluent discharge conditions for the plant. The study involves development of a range of upgrade options along with further water quality and marine ecological assessment which is being undertaken in consultation with key stakeholders. Waste sludge is currently discharged to the oceanThe ultimate decision on future requirements for sludge treatment and management will depend on a number of factors including the results of ongoing environmental monitoring and a Community Reference Group (CRG) established for the upgrade.

The Department of Environment and Climate Change and Water (DECCW) also sets contaminant concentration and load limits for effluent discharge. Currently there are no concentration or load limits for phosphorus discharge from the Burwood Beach plant; however it is possible that this will not continue into the future. Whilst there are currently no licence conditions relating to phosphorus discharge from the plant, the potential for phosphorus recovery from the plant is a key consideration for the upgrade project.

3.0 DISCUSSION

BIOWIN modelling was undertaken to model a number of process options for the recovery of phosphorus at Burwood Beach WWTW. The scenarios shown in Table 1 below were modelled and evaluated in terms of the phosphorus recovery viability.

Table 1: ***Phosphorus modelling scenarios for Burwood Beach WWTW***

Process	Sludge Treatment /Biosolids	Phosphorus Recovery Method
Activated biofilter / high-rate activated sludge process (ABF/AS)	Discharge to ocean	Not Recovered
	Anaerobic Digestion	Crystallisation
Biological Phosphorus Removal	Pasteurisation	Biological (Biosolids)
Modified Ludzack-Ettinger + Primary Sedimentation (PST + MLE)	Anaerobic Digestion	Crystallisation

4.0 RESULTS

Figure 2 below summarises the results of the BioWin modelling in terms of phosphorus recovery possible in the sludge and effluent streams for each scenario. The two processes which allow the highest phosphorus recovery are (i) biological phosphorus removal (BNR) and (ii) PST + MLE + anaerobic digestion.

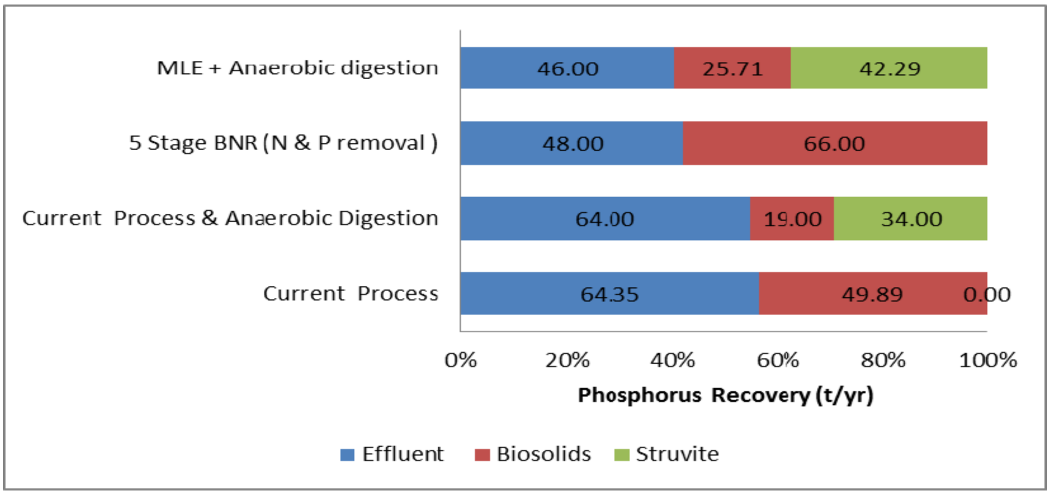

Figure 2: ***Phosphorus stream compositions (From BioWin modelling)***

Table 1 below outlines the potential income that could be derived from the sale of recovered Struvite for two of the modelled treatment configurations. As the market price of Struvite is volatile and influenced by many factors, the income derived was calculated for 'low' and 'high' Struvite price assumptions for each process. Even assuming that the Struvite produced could be sold at the highest price the income derived would still be relatively low compared to the cost for establishing, operating and maintaining the processing facility.

Table 2: ***Potential income from recovered Struvite***

Process Configuration	Benefit (Low) $	Benefit (High) $	Benefit (Boutique Fertiliser) $
Current Process & Anaerobic Digestion	51,158	85,263	948,921
MLE + Anaerobic digestion	110,792	184,654	2,055,082

As there is currently only a small market demand for Struvite, it is difficult to confidently estimate the future value of the product. It has been suggested that Struvite could possibly be sold as a boutique fertiliser to achieve a higher sales price. In Japan, a sales price of up to AU$3800 per tonne has been reported (Taruya *et al.*, 2000). Although the income would be significantly higher if a price of $AU3800 per tonne could be achieved, it would still be dependent on finding a suitable market and the marketing, packaging and distribution costs would likely be much higher compared to the bulk Struvite scenario.

A net present value analysis (NPV) was conducted to determine if the recovery of Struvite would be commercially viable for the Burwood Beach WWTW, compared to the current practice of discharging phosphorus to the ocean. The NPV analysis was based on an operating period of 20 years and used a discount rate of 7%. It is important to note that there remains a relatively high degree of uncertainty regarding the underlying assumptions used for this preliminary financial assessment. Further investigation would be required to determine the capital and operating expenditure with a higher level of confidence.

Assuming values for capital and operating expenditure for phosphorus recovery technology similar to those quoted for Japan (Taruya *et al.*, 2000) the required market value for Struvite for the net present value to break even over a 20 year period was determined. Based on the assumptions used, to achieve zero NPV over 20 years a 260% increase in the current Struvite market price would be required for the MLE + anaerobic digestion process and a 410% increase for the current process + anaerobic digestion.

In addition to income that could be derived from Struvite sales, the future viability of phosphorus recovery at Burwood Beach WWTW will depend on a number of factors. Two of the main factors are (i) whether regulators will continue to allow biosolids to be discharged to the ocean, and (ii) whether concentration and/or load limits on phosphorus will be set for the ocean discharge. Three scenarios have been identified which could significantly alter the commercial viability of phosphorus recovery at Burwood Beach WWTW. These include ‘do nothing’, ‘no biosolids discharge to ocean’ and ‘no biosolids to ocean and phosphorus limits on effluent discharge’.

5.0 CONCLUSIONS

Based on this preliminary assessment it was concluded that phosphorus recovery for the Burwood Beach WWTW is technically possible but would require changes to regulatory or commercial drivers to become financially viable.

The following additional work was also recommended:

- Conduct bench-scale or pilot-scale testing and further BioWin modelling to refine the site specific design parameters and performance predictions for the identified phosphorus recovery methodologies
- Detailed assessment of CAPEX and OPEX for phosphorus recovery technologies
- Determine viability of continued ocean disposal of sludge
- Conduct local market research for Biosolids and Struvite
- Continue to monitor and forecast the technical and commercial viability of phosphorus recovery.

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