Luxury Uptake of Phosphorus by Microalgae in New Zealand Waste Stabilisation Ponds

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Thesis Abstract

The discharge of phosphorus to waterways within wastewater effluent causes significant environmental damage through microalgal blooms and eutrophication. This is a particular problem for wastewater treatment plants that rely on waste stabilisation ponds (WSPs) for the bulk of their treatment. While having simple designs and low running costs, WSPs are mostly ineffective at phosphorus removal, with only 15 – 50% removal achieved on average according to some studies.

The luxury uptake phenomenon within microalgae has been identified as one mechanism that could improve WSP phosphorus removal. This occurs when microalgae store phosphorus beyond what is required for their metabolism as polyphosphate, leading to phosphorus contents above the standard 1 %P/g VSS for microalgae. However, studies on this subject in full scale WSPs to date have been limited to just two different ponds. To improve knowledge on this mechanism, this study aimed to assess the impact of environmental conditions, climatic region and pond type on microalgal luxury uptake, as well as determine which specific microalgal and cyanobacterial genera were best able to perform this mechanism. To achieve these objectives, a yearlong study was conducted on 13 different WSPs from 7 sites within various climatological regions within New Zealand, as well as two pilot scale High Rate Algal Ponds (HRAPs).

From this study, it was found that luxury uptake was found to occur in 56% of the WSP, with a peak phosphorus content of 3.8 %P/g VSS. Conversely, only one sample taken from the HRAPs was found to exhibit luxury uptake. Total dissolved phosphorus (TDP) concentration and rainfall were found to have a significant effect on biomass phosphorus content at a 95% confidence level, while the WSP climate was found not have an influence. There were no significant differences between the biomass phosphorus contents in primary and secondary ponds, with averages of 1.31 %P/g VSS and 1.21 %P/g VSS respectively, while HRAPs (0.71 %P/g VSS) were significantly lower due to the low TDP concentrations experienced by these ponds.

22 of the 23 identified microalgal and cyanobacterial genera were found to perform luxury uptake, at varying frequencies. The cyanobacterium *Planktothrix* was most effective, storing polyphosphate as granules in 84% of the samples it was identified in. *Scenedesmus*, *Pediastrum*, and *Schroederia* were also effective, at frequencies of 73%, 82% and 79% respectively. There was some correlation between storage of phosphorus as polyphosphate and enhanced phosphorus contents in the biomass, with nearly all samples containing no visually identifiable polyphosphate granules exhibiting phosphorus contents below 1 %P/g VSS. However, there were only limited correlations between the amount of polyphosphate and the levels of the significant variables identified previously.

This research provides valuable insight into the phosphorus uptake behaviour of microalgae and cyanobacteria, and shows that there is some potential for development of a new engineered process targeting improved phosphorus removal. If the phosphorus content of

biomass in this new process could consistently attain a level of 3 %P/g VSS, phosphorus removal from wastewater for an average community of 500 people could be increased from 31% to 93%, thus greatly reducing the impact of wastewater discharge on the receiving environment.

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This thesis is dedicated to my Grandmother

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