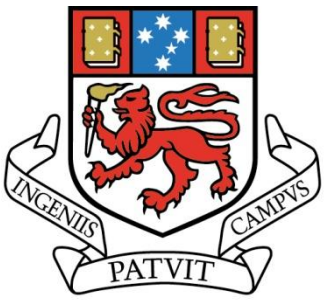
Optimisation of the Norske Skog activated sludge wastewater treatment plant at Boyer: The role of trace metals and vitamins



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Declaration

I declare this thesis contains no material which has been accepted for a degree or diploma in any other tertiary institution, except by way of back ground information and duly referenced in the thesis. To the best of the candidate's knowledge and belief, no material previously published or written by another person is included in the text of the thesis except where due reference is made in the text of the thesis.

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30th June 2013

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Abstract

In January 2008 Norske Skog, Boyer (NSB) , Tasmania, commissioned an activated sludge (AS) wastewater treatment plant to lower the chemical oxygen demand (COD) and suspended solids (SS) in the treated effluent discharged from the mill. In October 2009 the company also changed the feed stock of the mill from a mixed *Pinus radiata* and *Eucalypt* to solely *P. radiata*, altering the pulping process. The cold caustic soda (CCS) plant was decommissioned and replaced with an additional thermo-mechanical pulping (TMP) plant. Trace metals in the mill wastewater samples were analysed before and after this transition to detect any differences due to the changed feedstock and operating conditions, and to determine if metal levels were sufficient for optimum operation of the AS wastewater treatment plant. These analyses indicated deficiencies of cobalt, copper, iron and molybdenum required for optimal theoretical biological growth.

In this thesis the effects of micro-nutrient additions on a number of important parameters were considered by employing porous pots with a capacity of 4.5 L to mimic the operation of the Boyer AS plant. The selected parameters included COD removal, SS level and residual humic fractions. Also determined were the concentrations and potential effects of the trace metals in the effluent and sludge on the abundance of protozoa and filamentous bacteria. This detailed research on the outcomes of additions of trace metals and water-soluble vitamins to wastewater treatment plants had not previously been reported.

Addition of trace metals including calcium, cobalt, copper, iron and magnesium, to wastewater treatment plants were found to significantly increase COD removal by 4 to 5%. At NSB the incorporation of magnesium oxide to the wastewater treatment process significantly increased the COD removal by 6%, this result indicated that the porous pot results were transferable to an industrial plant. The addition of the water-soluble B group vitamins did not have such a significant effect on the COD removal as the trace metals, with the addition of 1.0 mg/L niacin having a detrimental effect on the AS.

The dissolved residual humic substances in the effluent were fractionated to determine the characteristics of the recalcitrant compounds contributing to the COD. They were separated into three distinct acid fractions (hydrophobic (HPhoA), transphilic (TPhiA) and hydrophilic (HPhiA)) through the use of two non-ionic resins, DAX 8 and XAD 4. The term oxygen demanding matter (ODM) was proposed to describe the residual mass of COD in each of the separate humic fractions. The total ODM (mg) in the influent samples comprised of 20 – 30%, 15% and 25 – 35% of the HPhoA, TPhiA and HPhiA fractions, respectively, comparable to previous research. The HPhoA fraction was

the most significant single contributor to the residual ODM in the Boyer effluent. This fraction is most likely composed of hydrophobic lignin derived compounds. Minimal residual COD was detected in the TPhiA and HPhiA fractions separated from the porous pot effluent.

Due to the potential effects of the trace metal additions on the environment through discharge to the Derwent River it was necessary to determine the ultimate fate of the metal additions. It was found that only the addition of 1.0 mg/L copper potentially exceeded the Australian and New Zealand guidelines for discharge to fresh and marine water. In terms of metals in sludge, the main metals of interest were copper and cobalt and both of these were found to be well below the guidelines for sludge application with the additions investigated.

A complete mass balance of the added metals calcium, cobalt, copper, iron and magnesium found that the highest metal recovery was for the addition of copper and cobalt individually (98 – 147%). The recovery of copper decreased to 62 – 108% when calcium, iron or magnesium was added simultaneously. The majority of each metal added to the porous pots was found in the effluent, where divalent cations form cation bridges with biopolymers, giving a possible mechanism for the increased COD removal. Simultaneous metal additions were also found to inhibit the uptake of copper in the sludge.

The addition of 1.0 mg/L copper, 0.5 mg/L zinc, 0.1 mg/L cobalt or 0.05 mg/L molybdenum to the porous pots did not significantly change the abundance of ciliates and rotifers compared to the control pots. The addition of 0.1 to 1.0 mg/L copper was found to affect the abundance of filamentous bacteria but it did not have a detrimental effect on the COD removal or the SS concentration in the effluent. The inhibition of filamentous bacteria through the addition of copper appeared to be neutralized in the presence of excess calcium and magnesium.

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Publications

1. Including results and discussion from Chapters 2, 3 & 4.
   Barnett, J. Richardson, D. Stack, K. and Lewis, T. *Addition of trace metals and vitamins for the optimization of pulp and paper mill activated sludge wastewater treatment plant*, APPITA Journal, 65(3), p. 237-243, 2012.

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