Nutrient Removal and Recovery by the Precipitation of Magnesium Ammonium Phosphate

By

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A Thesis Submitted for the Degree of
Master of Philosophy
DECLARATION

NAME: Guangan JIA                         PROGRAM: Master of Philosophy

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I have to say it has been a long and windy journey to get to the completion of this project. At times, there were huge obstacles that I had to deal with and without help and support from the research group and The School of Chemical Engineering, this thesis would not have been possible. I would like to extend my gratitude to the following people for their contribution throughout this project:

- My supervisors Associate Professor Bo Jin (The School of Chemical Engineering, The University of Adelaide), Associate Professor Joerg Krampe (South Australia Water Corporation), Dr. Hu zhang (The School of Chemical Engineering, The University of Adelaide) and Associate Professor Sheng Dai (The School of Chemical Engineering, The University of Adelaide). Thank you for your patience with and faith in me.

- This project would not have been possible without support from South Australia Water Corporation and United Water in Bolivar, thanks very much for providing centrate and data of wastewater.

- I also want to thank research group members: Lijuan Wei, Ming Dai, Dr Guiseppe Laera, Frank Fan, Xing Xu, and Cuong Tran from The School of Chemical Engineering, The University of Adelaide, thank you for your sincere help and useful suggestions.

- The staff at School of Chemical Engineering who would happily assist with my queries.

- Fellow post-graduate colleagues at School of Chemical Engineering, I appreciated the time spent with these great research students, it was a real pleasure doing research in this university.
• The staff at Adelaide Microscopy, in particular Ken.

• My parents, my wife, and my two sons for their patience and emotional support and constant faith in me, without their support, I would go nowhere.
Phosphate and ammonium are the main nutrient sources in wastewater, contributing to eutrophication of water bodies. Removal of these nutrients from wastewater using conventional technologies is a challenge in water industry. Many processes have been developed to remove these two nutrients. On the other hand, phosphorus from nature is not infinite, which will be running out in about 50 – 100 years. Therefore recycling phosphorus is becoming an issue, as well as a challenge, for researchers all over the world.

This research is to investigate a chemical process technology to recover the nutrients by the precipitation of magnesium ammonium phosphate (MAP), which is valuable product and nutrient fertiliser. This is a new process based on the chemical equilibrium, which is greatly affected by pH of the solution, concentrations of Mg$^{2+}$, NH$_4^+$, PO$_4^{3-}$, and other ions and organic matters included in the wastewater. In order to implement this process, the optimal pH, and the best molar ratio of Mg$^{2+}$, NH$_4^+$ and PO$_4^{3-}$ must be adequately studied.

In this thesis, the optimal pH and optimization of the molar ratio of Mg$^{2+}$:NH$_4^+$:PO$_4^{3-}$, were studied based on synthetic wastewater. It was found that the best pH range was 9-9.5, and the best molar ratio was Mg$^{2+}$:NH$_4^+$:PO$_4^{3-}$ =1.3:1:1.1

Visual MINTEQ 3.0 software was then introduced to predict the possible solids precipitated and additional alkaline required in order to maintain the optimal pH value during experiments. Laboratory scale experiments were carried out under the same conditions of model input. Struvite yielded from laboratory experiments was tested and confirmed by SEM and X-ray diffraction. The results indicated that the experimental results agreed well with that of model prediction within the error deviation. Reagent addition rate and temperature were also tested in terms of removal
efficiency and morphology of the precipitates. These two factors can affect size and morphology of crystals, but have limited impact on the removing efficiency compared to pH and concentration.

The main advantages of this technology are to recover nutrients and to prevent eutrophication. Preliminary results of operational factors of laboratory scale MAP system have been discussed and presented. Conclusions and recommendations were also made in this work.
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STPs: Sewage treatment plants

SDE: Sludge dewatered effluent

WWTP: wastewater treatment plant

MAP: Magnesium ammonium phosphate

SEM: Scanning electron microscopy

XRD: X-ray diffraction

AD: Anaerobic digestion

LCFAs: Long chain fatty acids

EPA: Environmental protection agency

BNR: Biological nutrient removal

PAOs: Polyphosphate accumulating organisms

A^2/O: Anaerobic-aerobic-oxic

ICW: Integrated constructed wetland

SBRs: Sequencing bench reactors

UASB: Upflow anaerobic sludge blanket

RSM: Response surface technology

CCD: Central composite design

TS: Total solids
PS: Solubility product

HAP: Hydroxyapatite

OCP: Octacalcium phosphate

TCP: Tricalcium phosphate

DCP: Monetite

DCPD: Brushite

CBA: Cost-benefit analysis
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