

Wastewater Treatment and Reuse Using A²O Process

Coupled with Microfiltration

by

LU, Qihong (Nick)

**A thesis submitted for partial fulfillment of the requirements for the
degree of**

Master of Science in Civil Engineering

2012



**Faculty of Science and Technology
University of Macau**

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Approved by _____ Prof. Hojae Shim
Supervisor

Date _____

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VITA

LU, Qihong (Nick) was born in the city of Jingzhou in Hubei province on June 20, 1986. He graduated from Middle School of Shashi and received the bachelor degree in Chemical Engineering from South China University of Technology in China in 2009. He continued his MS study at the University of Macau under the supervision of Professor Shim, Hojae.

Conference presentation:

1. Guo, L., **Lu Q.H.**, Xie, W.B., and Shim, H., (2011). Comparison of A²O and SBR processes for the advanced biological wastewater treatment. 5th International Congress of Chemistry and Environment. Negeri Sembilan, Malaysia, May 27-29.(as coauthor)
2. **Lu, Q.H.**, Xie, W.B., Sun, J., and Shim H., (2011). Wastewater Treatment and Reuse Using A²O Process Coupled with Microfiltration, Bioinformatics and Biomedical Engineering (iCBBE) 2011 5th International Conference. Wuhan, China, May 10-13. (as presenter)
3. **Lu, Q.H.**, Xie, W.B., Guo, L., and Shim, H. (2010). Coupling A²O/SBR process with membrane filtration: Comparison of biological nutrient removal performance and effluent reuse potential. 17th International Petroleum & BioFuels Environmental Conference. San Antonio, U.S.A. August 31-September 2. (as presenter)

Journal paper:

1. Guo, L., **Lu, Q.H.**, Xie, W.B., and Shim, H., (2011), Comparison of A²O and SBR Processes for the Advanced Biological Wastewater Treatment, Research Journal of Chemistry and Environment, 15, (2), 629-632.
2. **Lu, Q.H.**, Guo, L., Sio, H.M., and Shim H., (2012). Comparison of Biological Nutrients Removal Performance and Effluent Reuse Potential after Wastewater

Treatment by A²O/SBR Process Coupled with Microfiltration, Water and Environment Journal. (under review)

3. Guo, L., **Lu, Q.H.** Chung, J., and Shim, H. (2012), Comparative study on the effect of hydraulic retention time on SBR and A²O processes for advanced wastewater treatment, Water Environment Research.(under review)
4. Li, J., **Lu, Q.H.**, Guo, L., Chung, J., Nip, S., and Shim, H. (2012). Assessment and characterization of wastewater quality in Macau. Environmental Monitoring and Assessment. (In preparation).



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ABSTRACT

Wastewater Treatment and Reuse Using A²O Process Coupled with Microfiltration

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Thesis Supervisor: Prof. Hojae Shim

Master of Science in Civil Engineering

A laboratory-scale anaerobic/anoxic/oxic (A²O) reactor followed by the microfiltration (MF) system was operated to evaluate the performance on the organics and nutrients removal from synthetic and real wastewater and find the effluent reuse potential. In synthetic wastewater test, the effects of hydraulic retention time (HRT) and internal recycle ratio, as the operating parameters, as well as the characteristics of influent wastewater, such as influent C/P ratios were investigated for the A²O process. The optimum performance of the A²O reactor was realized at 13.8-h HRT with the internal recycle ratio of 200% of the influent flux. When the influent C/N ratio was at 10 or above and the C/P ratio was at around 200, the effluent quality for the reactor was excellent, with the removal efficiency for chemical oxygen demand (COD), ammonia nitrogen (NH₃-N), total nitrogen (TN), and total phosphorus (TP) at 97%, 98%, 89%, and 80%, respectively. Among operational parameters for the microfiltration (MF), the trans-membrane pressure (TMP) was not much related to the permeate quality which was affected by the quality of effluent from the pretreatment

A²O process. The A²O reactor coupled with the microfiltration membrane filter showed an excellent performance on the further removal of suspended solids (SS) (to <1 mg/L) and turbidity (to <0.1 NTU). In addition, the final effluent/permeate showed a stable and excellent quality in terms of color, COD, and NH₃-N contents (3 PtCo, 10 mg/L, and 0.01 mg/L, respectively), good enough to meet the quality goals for many regional reuse purposes. In the real wastewater test, the percentages of COD, BOD₅, NH₃-N, TN, and TP removals were averaged at 86.0, 97.5, 88.9, 84.7 and 67.5, respectively, for the A²O process. The hybrid process showed a good performance then fed with real wastewater as well. There is a great potential to upgrade retrofit the traditional activated sludge processes to A²O coupled with MF system for the advanced wastewater treatment in Macau WWTP.



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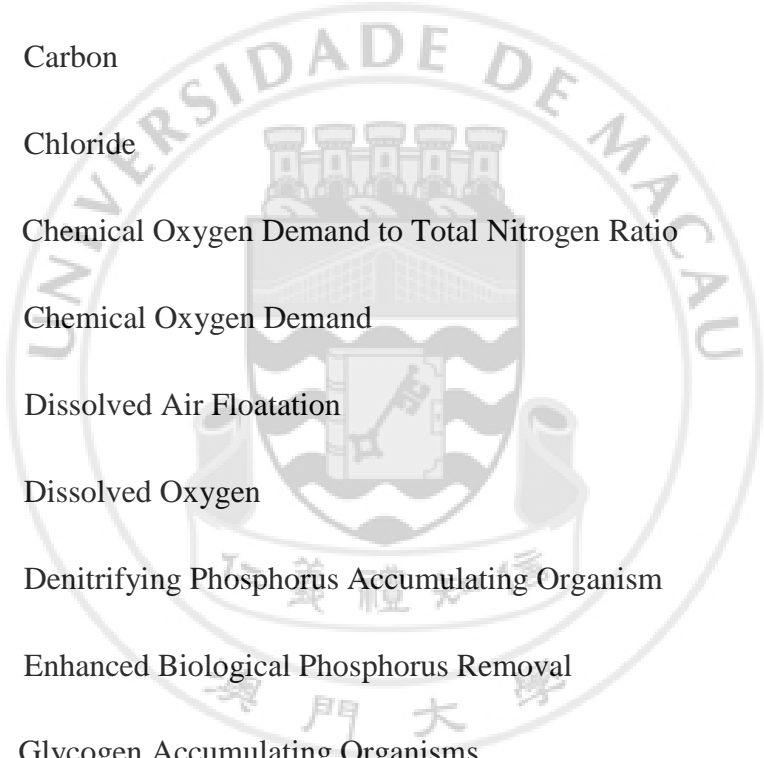
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LIST OF ABBREVIATIONS



A ² O:	Anaerobic / Anoxic / Oxic
AS:	Activated Sludge
BDL:	Below Detection Limit
BNR:	Biological Nutrients Removal
BOD ₅ :	Biological/Biochemical Oxygen Demand (value after 5 days)
C:	Carbon
Cl ⁻ :	Chloride
C/N:	Chemical Oxygen Demand to Total Nitrogen Ratio
COD:	Chemical Oxygen Demand
DAF:	Dissolved Air Floatation
DO:	Dissolved Oxygen
DPAO:	Denitrifying Phosphorus Accumulating Organism
EBPR:	Enhanced Biological Phosphorus Removal
GAOs:	Glycogen Accumulating Organisms
HRT:	Hydraulic Retention Time
IC:	Ion Chromatography
L:	Liter
mg/L:	Milligram per Liter
mg:	Milligram
mL:	Milliliter

ML(V)SS:	Mixed Liquor (Volatile) Suspended Solids
N:	Nitrogen
NAR:	Nitrite Accumulating Rate
N.A.:	Not Applicable
N.M.:	Not Measured
NH ₃ -N:	Ammonia-Nitrogen
NOB:	Nitrite-Oxidizing Bacteria
NO ₂ -N:	Nitrite-Nitrogen
NO ₃ -N:	Nitrate-Nitrogen
NO _x -N:	Nitrogen Oxides-Nitrogen
PAOs:	Phosphorus Accumulating Organisms
PHA:	Polyhydroxy-alkanoate
PHB:	Poly-beta-hydroxybutyrate
PO ₄ ³⁻ -P:	Phosphate-Phosphorus
SAR:	Special Administrative Region
SBR:	Sequencing Batch Reactor
SCOD:	Soluble Chemical Oxygen Demand
SND:	Simultaneous Nitrification–Denitrification
SRT:	Solids Retention Time
SS:	Suspended Solids
TKN:	Total Kjeldahl Nitrogen

TN: Total Nitrogen

TP: Total Phosphorus

VFA: Volatile Fatty Acid

WWTP: Wastewater Treatment Plant



ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor and other people who have spent their effort and patience to contribute me to the success of my master thesis. The followings express the author's gratitude to these people.

In the front, I want to show my great appreciation to my supervisor, Professor Shim, Hojae. His comments and patience are vital factors for completion of my thesis throughout my research experience. His serious editing and hearty words of encouragement are indispensable elements comprising my thesis. The author really appreciates his enthusiasm in pointing out my mistakes to finish my master degree. It is believed that the author becomes more capable of tackling problems in the future. Only the words of thanks may not be sufficient to express my appreciation.

I also would like to give my sincere gratitude to the chairman of my examination committee, Dr. Lok, Man Hoi, and my examiner, Professor Chan, Shek Kiu. Their sincerity to act the members of the examination committee is highly appreciated, and their proficiency in examining this thesis improves the quality of this thesis considerably.

My appreciation also extends to Eric who helped me a lot in course work, lab experiments and thesis/paper writing, to Tim who gave me much valuable advice in thesis/paper writing and daily life, to Edward who helped me do a lot experiments, to Celery, Brian and Mr.Xie who helped me take care of the reactors, to A wei and Miss Wang who helped me taking real wastewater.

There is no doubt that this project is a hard task for me. However, the kind guidance from my supervisor and support from my teachers, classmates and family and friends act as lubricants in smoothing the rocky road of doing this project

The author gratefully appreciates the financial support of the Research Committee of University of Macau for this study.

