COMPACT AND ROBUST MEMBRANE BIOREACTOR FOR SOURCE-SEPARATED URINE RESOURCE RECOVERY FOR A CIRCULAR ECONOMY

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Doctor of Philosophy

under the supervision of Prof Hokyong Shon and
Dr Sherub Phuntsho

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Certificate of Original Authorship

I, Jiaxi Jiang declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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2. **J. Jiang**, S. Phuntsho, N. Pathak, Q. Wang, J. Cho, H.K. Shon, Critical flux on a submerged membrane bioreactor for nitrification of source separated urine, Process Safety and Environmental Protection, 153 (2021) 518-526.

3. J. Ren, D. Hao, **J. Jiang**, S. Phuntsho, S. Freguia, B.-J. Ni, P. Dai, J. Guan, H.K. Shon, Fertiliser recovery from source-separated urine via membrane bioreactor and heat localized solar evaporation, Water Research, 207 (2021) 117810.

4. F. Volpin, U. Badeti, C. Wang, **J. Jiang**, J. Vogel, S. Freguia, D. Fam, J. Cho, S. Phuntsho, H.K. Shon, Urine treatment on the international space station: current practice and novel approaches, Membranes, 10 (2020) 327.

5. F. Volpin, **J. Jiang**, I. El Saliby, M. Preire, S. Lim, M.A. Hasan Johir, J. Cho, D.S. Han, S. Phuntsho, H.K. Shon, Sanitation and dewatering of human urine via membrane bioreactor and membrane distillation and its reuse for fertigation, Journal of Cleaner Production, 270 (2020) 122390.

Journal Articles Under Review

1. W. Shon, **J. Jiang**, S. Phuntsho, H.K. Shon. (Under review). Nutrient in a Circular Economy: Role of urine separation and treatment.

2. **J. Jiang**, A. Almuntashiri, W. Shon, S. Phuntsho, Q. Wang, S. Freguia, I, El-Saliby, H.K. Shon. (Under review). Feasibility study of powdered activated carbon membrane bioreactor (PAC-MBR) for source-separated urine treatment: a comparison with MBR.

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3. The International Workshop on Membrane in Kobe (IWMK 2021), 18-19 November 2021 online. Poster presentation

4. 2021 Rich Earth Virtual Summit, 3-5 November 2021 online. Attended

5. North American Membrane Society (NAMS 2020), 18-21 May 2020 online. Attended

6. The 2021 International Conference on the "Challenges in Environmental Science and Engineering" (CESE-2021), 6-7 November 2021 online. Oral presentation

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Abstract

Human urine contains essential nutrient – nitrogen (N), phosphorus (P) and potassium (K) - for crop cultivation. However, using raw human urine as a direct agricultural fertilizer source is limited, due to its distinct odour, high pH condition, pathogen risk associated with faecal cross-contamination, and the possible presence of high concentrations of pharmaceuticals. Biological nitrification, a two-step biological oxidation process, is therefore a promising technology to covert volatile and odorous ammonia into stable odour-free nitrate, while still preserving all the nutrients. Although biological nitrification is a well-understood process, only a few research groups have studied the application of this process with undiluted human urine, and the experiences to optimize the nitrification of source-separated urine without addition of alkalinity are even less.

In addition, micropollutants such as pharmaceuticals and personal care products are a group of emerging environmental contaminants, which are structurally complex and can cause adverse physiological effects on human health even at low concentration when exposed for long-term. However, the current wastewater treatment technologies are not designed to remove these compounds, and hence most of these residual pharmaceuticals and hormones remain in the treated effluent. Therefore, it is very important that we remove the residual micropollutants by a natural biological process.

The combined processes of powdered activated carbon - microfiltration membrane bioreactor (PAC-MF-MBR) is thereby proposed in this work to optimize the efficiency of biological nitrification, control membrane fouling, improve organic removal efficiency from 88% to 96%, achieve greater than 99% removal efficiency among all targeted micropollutants (metronidazole, acetaminophen, naproxen, ibuprofen carbamazepine and estriol), promote more rapid biomass growth, increase sludge floc size growth by 17% and achieve complete nutrient recovery from source-separated urine. This study demonstrates the potential application of full-scale PAC-MF-MBR plant in treating source-separated urine at building level for complete nutrient recovery.

Keywords: membrane bioreactor (MBR); powdered activated carbon (PAC); source-separated urine; circular economy; resource recovery; nitrification; micropollutant; fouling