BUSITEMA UNIVERSITY, NAMASAGALI CAMPUS

FACULTY OF NATURAL RESURCES AND ENVIRONMENTAL SCIENCES

An evaluation of physico-chemical water quality from a pilot scale high rate algal pond system utilizing water from River Nile at Namasagali campus, Busitema University: implications for water reuse in aquaculture.

BY

YESHO SILAS

BU/UG/2019/0092

RESEARCH REPORT SUBMITTED TO THE

FACULTY OF NATURAL RESOURCES AND ENVIRONMENTAL SCIENCES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN FISHERIES AND WATER RESOURCE MANAGEMENT OF

BUSITEMA UNIVERSITY

APRIL 2023

DECLARATION

I ……………………….. Hereby declare that unless otherwise references quoted, the work embodied in this research dissertation is entirely a result of my own effort and has never been submitted to any other institution of higher learning for the award of Bachelor's degree

SIGNATURE............................ DATE.......................................

APPROVAL

This is to certify that this research has been submitted with my approval as supervisor.

Signature................................. Date...................................

Dr. Tebitendwa Sylvie Muwanga

(Supervisor)

DEDICATION

I dedicate this thesis to God Almighty for His unlimited grace, consistent love, immeasurable faithfulness, and sparing my life throughout the period of my research. In addition, I dedicate this work to my parents Mr. Yesho Stephen and Mrs. Olive Nadunga, my sisters Ms. Irene Achebeberom, Stella Nasiyo, Winnie Namataka, and my beloved friends Lule Moses, and Sentongo Oscar.

ACKNOWLEDGEMENTS

I am thankful for the laboratory assistance gained from the staff members of Maritime institute, Busitema University, Kamuli Uganda. I am mainly appreciative for the efforts from Mr. Sentongo Oscar who helped me during laboratory analysis and sample collection on time.

Special thanks go to Dr. Tebitendwa Sylvie Muwanga, Lecturer Busitema University who has been with me from the time of the proposal development to this time when the thesis is accomplished. I am really thankful for your guidance, encouragement and more especially, editing my work and providing me with the relevant literature.

Lastly but not least, I am honoured to appreciate my family, more especially my parents, Mr. Yesho Stephen and Mrs. Nadunga Olive, sisters: Acheberom Irene and Stella Nasiyo whose encouragement was a great driver in the completion of this thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYNS

APHA: American public health association

BOD: Biological oxygen demand

COD: Chemical oxygen demand

CW: Constructed wetland

HRAP: High rate algal pond

HRT: Hydraulic retention time

L: Litre

N: Nitrogen

P: Phosphorus

SD: Standard deviation

THRT: Theoretical hydraulic retention time

TSS: Total suspended solids

WSP(s): Waste stabilization pond(s)

cm/s: centimeter per second

gm^{-3} gram per cubic meter

HCO_3^-: hydrogen carbonate ion

mg/L: milligram per litre

µS/cm: microsiemes per centimeter

Wm^{-3}: Watt per cubic meter

ABSTRACT

Pollution of surface water resources especially rivers from point and non-point sources is a major environmental concern. While rivers are a major source of water for reuse in aquaculture, the occurrence of pollutants in river water including nutrients, organic matter total suspended solids (TSS) etc. Therefore, to remediate, this study aimed to investigate the use of high rate algal pond (HRAP) system to treat polluted river water to standards for reuse in aquaculture.

The study employed two pilot scale HRAP designed with and without a paddle wheel, constructed and operated at the Faculty of Natural Resources and Environmental Sciences, Namasagali campus, Busitema University. Physico-chemical water quality parameters and nutrients including: Temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), nutrients (i.e. N & P species) and TSS were monitored for six weeks from 25/01/2023 to 02/03/2023 insitu and in the laboratory following standard methods of water and wastewater treatment by APHA (1998).

Results revealed that the paddle when driven HRAP 1 performed better than the HRAP 2 that had no paddle wheel both in terms of effluent quality and pollutant removal efficiency. The effluent quality from HRAP 1 and 2 were: Temperature: 25.9±0.6 ℃ & 26.0±0.7 ℃, pH: 9.31±0.30 & 10.02±0.09, DO: 3.19±0.35 mg/L& 3.29±0.41 mg/L, EC: 136.06±8.76 µS/cm & 141.89±9.58 µS/cm, TDS: 68.9±6.5 mg/L & 71.4±3.9 mg/L, NO_2^--N: 0.198±0.03 mg/L & 0.202±0.02 mg/L, NO_3^--N: 0.31±0.14 mg/L & 0.27±0.14 mg/L, NH_4^--N: 0.16±0.01 mg/L & 0.16±0.03 mg/L, PO_4^{3-}-P: 9.26±1.83 mg/L & 9.68±2.45 mg/L and TSS: 22.22±6.20 mg/L & 10±2.98 mg/L respectively. However, the pollutant removal efficiencies of HRAP 1 and 2 for different nutrients were: NO_2^--N: 3.41 & 2.88%, NO_3^--N: 10.34 & 10.60%, PO_4^{3-}-P: 18.49 & 19.67%, NH_4^--N: 20.00 & 11.11% and TSS: -36.99 & -5.82% respectively. The higher effluent quality produced from HRAP 1 than 2 could mainly be attributed to the presence of a paddle wheel that constantly mixes and exposes algae to sunlight for optimal algal production and consequently better removal of nutrients through uptake and assimilation.

In conclusion, the paddle wheel driven HRAP 1 revealed a better effluent water quality and higher removal efficiency for all parameters than HRAP 2 (i.e. without a paddle wheel), generating an effluent within the general standards suitable for reuse in aquaculture for the commonly cultured fish species: *Oreochromis niloticus* and *Clarias gariepinus*.

CHAPTER ONE

INTRODUCTION

1.1 Background

Pollution of surface freshwater systems with untreated or partially treated wastewater of point and non-point source origin such as municipal sewage, industrial wastewater, storm-water and agricultural wastewater to mention a few, is one of the world's major environmental problems (Naidoo & Olaniran, 2014). Wastewater contains pollutants including pathogenic organisms, organic matter (BOD and COD), plant nutrients especially nitrogen and phosphorous, total suspended solids (TSS), heavy metals, endocrine disruptors, synthetic organic chemicals, radioactive substances to etc. (Davies, 2005; Akpor *et al*., 2014). These contaminants adversely affects water quality with effects on both human and the aquatic ecosystem health (Davies, 2005).

For instance, use of inorganic fertilizers on agricultural land contains pollutants especially nitrogen and phosphorus which causes eutrophication of water bodies (Aloe *et al*., 2014). According to Akpor (2014) and Akpor & Muchie (2011), the impacts of eutrophication are well documented. Excessive nutrient proliferation on water resources could lead to accelerated algae growth (algal blooms) which can lead to increased cost in water purification. Other impacts of eutrophication are: dissolved oxygen depletion, physical changes to receiving water bodies, bioaccumulation and bio magnification of contaminants, toxic substance release and nutrient enrichment effects. Additionally, the presence of pathogenic microorganisms in wastewater is a major cause of diarrheal diseases like Cholera, typhoid, dysentery etc. in downstream communities (Gerardi & Zimmerman, 2004; Ajonina *et al*., 2015).

Meanwhile, (Postel & Carpenter, 1997) points out that freshwater resources especially rivers are important sources of water for various uses such as supply for domestic use, irrigation purpose, hydroelectric power generation and aquaculture use to mention but a few. Nevertheless, the presence of the pollutants previously highlighted in river water may limit its uses especially for aquaculture purpose.

Therefore, to control pollution of surface water resources low-cost natural wastewater treatment systems are employed in developing countries and they include mainly waste stabilization ponds (WSP), intermittent soil filtration and constructed wetlands (CW). Nevertheless, among these natural systems, WSPs are commonly employed in developing countries.

REFERENCES

1. Ajonina, C., Buzie, C., Rubiandini, R. H., & Otterpohl, R. (2015). Microbial pathogens in wastewater treatment plants (WWTP) in Hamburg. Journal of Toxicology and Environmental Health, Part A, 78(6), 381-387.
2. Akpor, O. B., Otohinoyi, D. A., Olaolu, D. T., & Aderiye, B. I. (2014). Pollutants in wastewater effluents: impacts and remediation processes. International Journal of Environmental Research and Earth Science, 3(3), 050-059.
3. Ali, H., Cheema, T. A., & Park, C. W. (2015). Effect of paddle-wheel pulsating velocity on the hydrodynamic performance of high-rate algal ponds. Journal of Energy Engineering, 141(4), 04014039.
4. Aquastat.fao.org/climate-information-tool/2022.
5. Brennan, L., & Owende, P. (2010). Biofuels from microalgae—a review of technologies for production, processing, and extractions of biofuels and co-products. Renewable and sustainable energy reviews, 14(2), 557-577.
6. Bosma, R. H., & Verdegem, M. C. (2011). Sustainable aquaculture in ponds: principles, practices and limits. Livestock science, 139(1-2), 58-68.
7. Buchanan, N., Young, P., Cromar, N. J., & Fallowfield, H. J. (2018). Comparison of the treatment performance of a high rate algal pond and a facultative waste stabilisation pond operating in rural South Australia. Water Science and Technology, wst2018201. doi:10.2166/wst.2018.201
8. Boyd, C. E. (2001). An introduction. Water quality standards, 3, 083-311.
9. Camper, D., Scovazzo, P., Koval, C., & Noble, R. (2004). Gas solubilities in room-temperature ionic liquids. *Industrial & Engineering Chemistry Research*, *43*(12), 3049-3054.
10. Craggs, R., Sutherland, D., & Campbell, H. (2012). Hectare-scale demonstration of high rate algal ponds for enhanced wastewater treatment and biofuel production. Journal of Applied Phycology, 24, 329-337.
11. Davies-Colley, R. J., Craggs, R. J., Park, J., & Nagels, J. W. (2005). Optical characteristics of waste stabilization ponds: recommendations for monitoring. Water Science and Technology, 51(12), 153-161.
12. Delgadillo-Mirquez, L., Lopes, F., Taidi, B., & Pareau, D. (2016). Nitrogen and phosphate removal from wastewater with a mixed microalgae and bacteria culture. Biotechnology reports, 11, 18-26.

13. El-Kamah, H. M., Badr, S. A., & Moghazy, R. M. (2011). Reuse of wastewater treated effluent by lagoon for agriculture and aquaculture purposes. Australian Journal of Basic and Applied Sciences, 5(10), 9-17.
14. El-Shafey, A. A. (1998). Effect of ammonia on respiratory functions of blood of Tilapia zilli. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 121(4), 305-313.
15. Erez, J., Krom, M. D., & Neuwirth, T. (1990). Daily oxygen variations in marine fish ponds, Elat, Israel. Aquaculture, 84(3-4), 289-305.
16. Exum, N., Kosek, M., Davis, M., & Schwab, K. (2017). Surface Sampling Collection and Culture Methods for Escherichia coli in Household Environments with High Fecal Contamination. International Journal of Environmental Research and Public Health, 14(8), 947. doi:10.3390/ijerph14080947.
17. Faleschini, M., Esteves, J. L., & Camargo Valero, M. A. (2012). The effects of hydraulic and organic loadings on the performance of a full-scale facultative pond in a temperate climate region (Argentine Patagonia). Water, Air, & Soil Pollution, 223, 2483-2493.
18. Hadiyanto, H., Elmore, S., Van Gerven, T., & Stankiewicz, A. (2013). Hydrodynamic evaluations in high rate algae pond (HRAP) design. *Chemical Engineering Journal*, *217*, 231-239.
19. https://www.globalseafood.org/advocate/dissolved-oxygen-is-a-major-concern-in-aquaculture-heres-why.
20. Larsdotter, K. (2006). Wastewater treatment with microalgae-a literature review. Vatten, 62(1), 31.
21. Leong, Y. K., Huang, C.-Y., & Chang, J.-S. (2021). Pollution prevention and waste phycoremediation by algal-based wastewater treatment technologies: The applications of high-rate algal ponds (HRAPs) and algal turf scrubber (ATS). Journal of Environmental Management, 296, 113193. doi:10.1016/j.jenvman.2021.113193
22. Mara, D. D., Mills, S. W., Pearson, H. W., & Alabaster, G. P. (1992). Waste stabilization ponds: a viable alternative for small community treatment systems. Water and Environment Journal, 6(1), 72-78.
23. Montemezzani, V., Duggan, I. C., Hogg, I. D., & Craggs, R. J. (2015). A review of potential methods for zooplankton control in wastewater treatment High Rate Algal Ponds and algal production raceways. Algal research, 11, 211-226.

24. Naidoo, S., & Olaniran, A. O. (2014). Treated wastewater effluent as a source of microbial pollution of surface water resources. International journal of environmental research and public health, 11(1), 249-270.
25. Nurdogan, Y., & Oswald, W. J. (1995). Enhanced nutrient removal in high-rate ponds. Water science and technology, 31(12), 33-43.
26. Ouazzani, N., Bouhoum, K., Mandi, L., Bouarab, L., Habbari, K. H., Rafiq, F. & Schwartzbrod, J. (1995). Wastewater treatment by stabilization pond: Marrakesh experiment. Water Science and Technology, 31(12), 75-80.
27. Park, J. B. K., & Craggs, R. J. (2010). Wastewater treatment and algal production in high rate algal ponds with carbon dioxide addition. Water Science and Technology, 61(3), 633–639. doi:10.2166/wst.2010.951.
28. Rahman, A., Ellis, J. T., & Miller, C. D. (2012). Bioremediation of domestic wastewater and production of bio-products from microalgae using waste stabilization ponds. Journal of Bioremediation and Biodegradation, 3(06), 6199.
29. Ranjan, S., Gupta, P. K., & Gupta, S. K. (2019). Comprehensive evaluation of high-rate algal ponds: wastewater treatment and biomass production. In Application of microalgae in wastewater treatment (pp. 531-548). Springer, Cham.
30. Sutherland, D. L., Turnbull, M. H., & Craggs, R. J. (2014). Increased pond depth improves algal productivity and nutrient removal in wastewater treatment high rate algal ponds. Water Research, 53, 271-281.
31. Syed, R., Masood, Z., Hassan, H. U., Khan, W., Mushtaq, S., Ali, A., & Ullah, A. (2022). Growth performance, haematological assessment and chemical composition of Nile tilapia, Oreochromis niloticus (Linnaeus, 1758) fed different levels of Aloe vera extract as feed additives in a closed aquaculture system. *Saudi journal of biological sciences*, *29*(1), 296-303.
32. Tebitendwa S.M, (2011). A Comparison of the Performance and Economics of a Waste Stabilization Pond and Constructed Wetland System in Juja, Kenya. Msc. Thesis, UNESCO-IHE Institute for Water Education, Delft, The Netherlands.
33. Mays S, L.W Water resources handbook 1996.
34. Whitton, R., Ometto, F., Pidou, M., Jarvis, P., Villa, R., & Jefferson, B. (2015). Microalgae for municipal wastewater nutrient remediation: mechanisms, reactors and outlook for tertiary treatment. Environmental Technology Reviews, 4(1), 133-148.
35. WHO, U. (2006). Guidelines for the safe use of wastewater, excreta and greywater. Wastewater use in agriculture, 2, 222.

36. Yaakob, M. A., Mohamed, R. M. S. R., Al-Gheethi, A., Aswathnarayana Gokare, R., & Ambati, R. R. (2021). Influence of nitrogen and phosphorus on microalgal growth, biomass, lipid, and fatty acid production: an overview. *Cells*, *10*(2), 393.