FACULTY OF ENGINEERING.

DEPARTMENT OF MINING AND WATER RESOURCES ENGINEERING.

FINAL YEAR PROJECT REPORT

INVESTIGATING THE PERFORMANCE OF DUCKWEED IN MUNICIPAL WASTEWATER TREATMENT.

(Case Study: NWSC-TORORO).

TINDIMWEBWA DOREEN

BU/UP/2014/635

Email: doreentindimwebwa@gmail.com

Contacts: +256789686162 / +256751863491

Main supervisor: Eng. Mohammed Badaza

Co-supervisor: Mr. Oketcho Yoronimo

A final year project proposal submitted to the Department of Mining and Water Resources Engineering as a partial fulfillment of the requirements for the award of a Bachelor of Science degree in Water Resources Engineering.

May 2018

ABSTRACT

This research report suggests the use of duckweed pond systems for the treatment of municipal wastewater. In the current study, an aquatic plant duckweed that is locally available in quiescent waters, ponds and lakes with high nutrient contents were used as an alternative cost effective biological tool for the treatment of municipal wastewater to remove concentrations of organic matter, nutrients and pathogens. Duckweed fronds were introduced into the experimental setup that was carried out at Busitema University premises; where a known mass of duckweed fronds was introduced in the basin. Wastewater quality parameters were tested basing on the varying intervals in the retention period.

The experiments were conducted under outdoor environmental conditions for a retention period of 21 days.

Efficiencies of duckweed for the treatment of municipal wastewater were assessed by measuring some of the physico-chemical parameters and faecal coliforms in the treated wastewater. The observations showed reduction levels of COD (82.60- 83.28%), Nitrate Nitrogen (63.79 – 67.74%), Ammonia Nitrogen (86.22-87.20%), Total Nitrogen (70.11-73.48%), dissolved phosphorus (82.11-85.83%), total phosphorus (73.54-75.88%), faecal coliforms (95.50- 99.70%) for duckweed ponds and COD (82.30- 84.84%), nitrate-nitrogen (65.69-68.28%), ammonia nitrogen (64.24-67.02%), total nitrogen (63.59-69.42%), dissolved phosphorus (43.58-50.12%),total phosphorus (54.09-58.66%), faecal coliforms (99.63- 99.73%) for ponds without duckweed.

Compared with the National standards for discharge of effluents to the environment, all parameters of the duckweed effluents were within the standard limit values except the value for the feacal coliforms which was outside the range. The results showed that duckweed can be successfully used for treatment of municipal wastewater.

An experiment about how the amount of duckweed used affects the nutrient uptake was also conducted. A total of 4 density loads: M1 (25%), M2 (55%), M3 (80%), M4 (100%) of inoculation masses were used. Changes in wastewater and duckweed mass characteristics were recorded for a period of 21 days. The nutrient load in the wastewater reduced significantly in all the three replications of the 4 experimental setups where the experiment of the 25% duckweed mass showed the maximum nutrient removal from the wastewater.

DECLARATION

I, Tindimwebwa Doreen registration number BU/UP/2014/635 declare that the entirety of work contained in this project proposal is my original work except where explicit citations have been made.

Therefore, it has never been submitted to any institution of higher learning for any academic award.

Sign: ……………………….

Date: ……………………….

APPROVAL

I affirm that Tindimwebwa Doreen, registration number: BU/UP/2014/635 compiled this final year project under my supervision, and it can be submitted to the University management for an academic award.

Eng. Mohammed Badaza

Main Supervisor

Sign………………...............

Date………………..............

Mr. Oketcho Yoronimo

Co-supervisor

Sign…………………………..

Date………………………......

DEDICATION

This report is dedicated to my parents Mr. Tindimwebwa K. Pastor and Mrs. Asiimwe Joyce and to my siblings: Starlin, Brolin, Darlin, Crolin and Collins to whom I greatly gained advice and instilled a heart in me to offer this engineering program.

ACKNOWLEDGEMENT

Most importantly, I thank God for the gift of life and inventiveness He has offered to me to accomplish this final year project and report and gather all the necessary knowledge to compile this report.

My sincere appreciation goes to my supervisors **Eng. Mohammed Badaza** and **Mr. Oketcho Yoronimo** for all the guidance and directions that helped me accomplish all that is required for this research project. Special appreciation also go to my friends and mentors particularly **Eng. Kwemara Joseph** and **Eng. Mabala Michael** from Ambitious Construction Company and **Eng. Kenedy Opiyo** from Greenstone Resources Uganda, **Eng. Adolph Karubanga** from ministry of energy and mineral development, **Mr. Massa Tom Keziron** from ministry of water and environment; WSDF-E and **Lt. Josephat Rutinampora** from the UPDF-Engineering Brigade for the great help, advice and guidance in the course of this report compilation: all your efforts are highly appreciated.

I am greatly indebted to my parents; Mr. Tindimwebwa. K. Pastor and Mrs. Asiimwe Joyce for all the support and advice given to me to take heart in doing this research project report. They have been there for me amidst all challenges. In scarcity of resources, they have sacrificed their time, spared their advice and the very last of their property for me. Surely, there is nothing I can give to pay them other than praying for God's providence and blessings upon them.

I also owe gratitude to my fellow students and friends; Owori Douglas Timothy, Mandawun Mildred, Kalule Jessy, Atim Christine Rose, Akisa Doreen, Odongo Isaac Akimfa, Komugisa Sunny and Tibasiima Modesta for their unique character of team work and assistance and the necessary guidance they equipped me with during the compilation of this final year project report.

LIST OF ACRONYMS

COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
ANOVA	Analysis of Variance
NEMA	National Environmental Management Authority
HRT	Hydraulic Retention Time
NWSC	National Water and Sewerage Corporation
FC	Faecal Coliforms
TKN	Total Kjedhal Nitrogen
TP	Total Phosphorus
WSP	Waste Stabilization Ponds
WHP	Water Hyacinth Ponds
WHO	World Health Organisation

Table of Contents

LIST OF FIGURES.

LIST OF TABLES.

CHAPTER ONE.

1.0 INTRODUCTION

1.2 Background of the study

The treatment of wastewater in the third world or the developing countries is still a great problem. This contributes to one of the major causes of illnesses to the people and degradation of the environment. Duckweed ponds are of the lowest cost compared to the other conventional methods of wastewater treatment, low-maintenance, highly efficient, entirely natural and highly ecologically sustainable to the environment (Awuah *et al.*, 2015). Duckweed species have shown characteristics that make duckweed based wastewater treatment very attractive. They are used not only for wastewater treatment but also for nutrient recovery. Ozengin and Elmaci (2007) says that the reason for this is the rapid multiplication of duckweeds is the high protein content of its biomass.

Tororo National Water and Sewage Cooperation (NWSC) has anaerobic, primary and secondary facultative ponds and artificial wetland. The treatment infrastructures are situated in Nyangole zone in Tororo municipality, along Mbale Road. The estimated wastewater flow into the treatment system is $400m^3$/day. Worst of it is that the wetland leaks (Seeps) probably due to the poor workmanship during its construction with a lot of nitrates, feacal coliforms and phosphates that are hazardous to the health of people, animals, aquatic life and the entire environment. This affects the retention time and the overall performance. (NWSC, 2013)

People have simply taken wastewater treatment just for granted by disposing off of untreated sewage and wastewater to water bodies such as lakes, rivers and streams because the existing methods of wastewater treatment are expensive and besides that there is no direct economic return to the people. This is also because most of the people in third world countries live below the poverty line of $ 1.90 per day or less (World Bank, july 9 2017). Duckweed pond systems are usually the most appropriate method of domestic and municipal wastewater treatment in developing countries, where the climate is most favorable for their operation; that is to say duckweed (lemna minor) grow best in tropical climates with temperatures ranging from 20^0C to 30^0C. Some wastewater discharges contain a large amount of non-biodegradable organic matter, which cannot be treated properly in a conventional biological wastewater treatment plant (Choi

References

Al-Nozaily, F. A. (2001) ‘Performance and Process Analysis of Duckweed-Covered Sewage Lagoons for High Strength Sewage: The Case of Sana’a, Yemen’, *IHE Delft,* (PhD Thesis).

Awuah, E. *et al.* (2015) ‘A Review of the Mechanisms of Faecal Coliform Removal from Algal and Duckweed Waste Stabilization Pond Systems’. doi: 10.3844/ajessp.2015.28.

Benjawan, L. and Koottatep, T. (2007) ‘Nitrogen removal in recirculated duckweed ponds system’, pp. 103–110. doi: 10.2166/wst.2007.360.

Caicedo, J. R. *et al.* (2000) ‘Effect of total ammonia nitrogen concentration and pH on growth rates of duckweed (Spirodela polyrrhiza)’, *Water Research*, 34(15), pp. 3829–3835. doi: 10.1016/S0043-1354(00)00128-7.

Caicedo, J. R., van der Steen, N. P. and Gijzen, H. J. (2005) ‘The effect of anaerobic pre-treatment on the performance of duckweed stabilization ponds.’, *Effect of Operational Variables …*, pp. 47–58. Available at: http://books.google.com/books?hl=en&lr=&id=-jXD1srZUvwC&oi=fnd&pg=PA55&dq=THE+EFFECT+OF+ANAEROBIC+PRE-TREATMENT+ON+THE+PERFORMANCE+OF+DUCKWEED+STABILIZATION+PONDS&ots=fCvUICSE9a&sig=XeZjxGunFswjY0vooZk8cD7pIvU.

Chaiprapat, S. *et al.* (2005) ‘R i n s d g s w t’, 48(6), pp. 2247–2258.

Cheng, J. J. and Stomp, A. M. (2009a) ‘Growing Duckweed to recover nutrients from wastewaters and for production of fuel ethanol and animal feed’, *Clean - Soil, Air, Water,* pp. 17–26. doi: 10.1002/clen.200800210.

Cheng, J. J. and Stomp, A. M. (2009b) ‘Growing Duckweed to recover nutrients from wastewaters and for production of fuel ethanol and animal feed’, *Clean - Soil, Air, Water*, 37(1), pp. 17–26. doi: 10.1002/clen.200800210.

Choi, Y. Y. *et al.* (2017) ‘Characteristics and biodegradability of wastewater organic matter in municipal wastewater treatment plants collecting domestic wastewater and industrial discharge’, *Water (Switzerland)*, 9(6). doi: 10.3390/w9060409.

Cui, W. and Cheng, J. J. (2015) ‘Growing duckweed for biofuel production: A review’, *Plant Biology*, pp. 16–23. doi: 10.1111/plb.12216.

Duckweed, R. and Duckweed, G. (no date) 'Guide to duckweeds', *Natural History*, pp. 5–6.

Farrell, J. B. (2012) 'Duckweed Uptake of Phosphorus and Five Pharmaceuticals : Microcosm and Wastewater Lagoon Studies', 2012, p. 194.

Goopy, J. P. and Murray, P. J. (2003) 'A review on the role of duckweed in nutrient reclamation and as a source of animal feed', *Asian-Australasian Journal of Animal Sciences*, 16(2), pp. 297–305. doi: 10.5713/ajas.2003.297.

Iqbal, S. (1999) 'Duckweed Aquaculture. Potentials, Possibilities and Limitations for Combined Wastewater Treatment and Animal Feed Production in Developing Countries', *SANDEC Report No. 6/99*, (6), pp. 1–89. doi: 10.1097/00010694-199403000-00012.

Journey, W. K., Skillicorn, P. and Spira, W. (1993) *Duckweed Aquaculture, A new aquatic farming system for developing countries.*

Journey, W. K., Skillicorn, P. and Spira, W. (2001) 'Biology of Duckweed', *Duckweed Aquaculture a New Aquatic Farming System for Developing Countries*, pp. 9–15.

Kesaano, M. (2011) 'Sustainable management of duckweed biomass grown for nutrient control in municipal wastewaters', *All Graduate Theses and Dissertations. Paper 879.* Available at: http://digitalcommons.usu.edu/etd/879.

Khellaf, N. *et al.* (2002) 'Tolerance to Heavy metals in the duckweed , Lemna minor', pp. 2–5.

Körner, S. and Vermaat, J. E. (1998) 'The relative importance of Lemna gibba L., bacteria and algae for the nitrogen and phosphorus removal in duckweed-covered domestic wastewater', *Water Research*, 32(12), pp. 3651–3661. doi: 10.1016/S0043-1354(98)00166-3.

Körner, S., Vermaat, J. E. and Veenstra, S. (2003) 'The Capacity of Duckweed to Treat Wastewater', *Journal of Environment Quality*, 32(5), p. 1583. doi: 10.2134/jeq2003.1583.

Ozengin, N. and Elmaci, A. (2007) 'Performance of Duckweed (Lemna minor L.) on different types of wastewater treatment', *Journal of Environmental Biology*, 28(2), pp. 307–314.

Verma, R. and Suthar, S. (2015) 'Impact of Density Loads on Performance of Duckweed Bioreactor : A Potential System for Synchronized Wastewater Treatment and Energy Biomass Production', 34(6). doi: 10.1002/ep.

Water, B. Y. N. and Corporation, S. (2015) ‘Management of sewage in urban areas’, (March).

Willett, D. (2005) ‘Duckweed-based wastewater treatment systems: design aspects and integrated reuse options for Queensland conditions’, p. 20.

Zhao, Y. *et al.* (2015) ‘Pilot-scale comparison of four duckweed strains from different genera for potential application in nutrient recovery from wastewater and valuable biomass production’, *Plant Biology*, 17(s1), pp. 82–90. doi: 10.1111/plb.12204.

Zimmo, O. R., van der Steen, N. P. and Gijzen, H. J. (2005) ‘Effect of organic surface load on process performance of pilot-scale algae and duckweed-based waste stabilization ponds’, *Journal of Environmental Engineering*, 131(4), pp. 587–594. doi: 10.1061/(ASCE)0733-9372(2005)131:4(587).

Zimmo, O. R., Van Der Steen, N. P. and Gijzen, H. J. (2004) ‘Nitrogen mass balance across pilot-scale algae and duckweed-based wastewater stabilisation ponds’, *Water Research*, 38(4), pp. 913–920. doi: 10.1016/j.watres.2003.10.044.

Zirschky, J. and Reed, S. C. (1988) ‘The Use of Duckweed for Wastewater Treatment’, *Journal (Water Pollution Control Federation)*, 60(7), pp. 1253–1258. doi: 10.2307/25043632.