A Sustainable Low-Cost Phytodisinfectant-Sand Filter Alternative for Water Purification

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DEDICATION

To my delightful children:

Othniel David, Chris Francis and Marie Faustina

"The pursuit of truth and beauty is a sphere of activity in which we are permitted to remain children all our lives."

Albert Einstein

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any University or Tertiary Institution and, to the best of my knowledge, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. I acknowledge that copyright of published works contained within this thesis (as listed below) resides with the copyright holders of those works:

Yongabi Kenneth, Lewis David and Harris Paul (2010). **Alternative Perspectives in Water and Wastewater Treatment.** Lambert Publishing, ISSBN 978388387857, pp129, Germany.

Yongabi, K.A., Lewis, D.M and Harris, P.L (2011). **Integrated Phytodisinfectant-Sand Filter Drum for Household Water Treatment in Sub-Saharan Africa.** Journal of Environmental Science and Engineering, 5: 947-954.

Yongabi, K.A., Lewis, D.M and Harris, P.L (2011). ***Moringa oleifera* Disinfectant-Sand Filter Integration: A Review of an Alternative Sustainable Technology for Household Water Treatment.** Journal of Environmental Science and Engineering, 5: 1100-1108

Yongabi, K.A., Lewis D.M and Harris, P.L (2011). **Application of Phytodisinfectants in Water purification in rural Cameroon.** African Journal of Microbiology Research, Vol.5 (6) pp 628-635, available online: http//www.academicjournals.org/ajmr

Yongabi, K.A., Lewis, D.M and Harris, P.L (2011). **Indigenous plant based coagulants and sand filter media for surface water treatment in Bamenda, Cameroon.** African Journal of Biotechnology, Vol.10 (43), pp 8625-8629, available online: http//www.academicjournals.org/AJB

Kenneth Yongabi, David Lewis Paul Harris (2012). **Natural Materials for Sustainable Water Pollution Management.** Water Pollution, Prof.Nuray Balkis

(Ed.), ISBN: 978-953-307-962-2, InTech, available online: http://www.intechopen.com/books/water-pollution/natural-materials-for-sustainable-water-pollution-management. pp 157-188

Yongabi, K.A., Lewis, D.M (2012) **In Vitro Sensistivity of *Aeromonas hydrophila* to five polarity based solvent extracts of *Moringa oleifera*, Alum and Chlorine.** Submitted for publication in Chemical Engineering Science Journal.

Yongabi, K.A., Lewis, D.M (2012) **Phytochemical constituents and comparative antifungal activity of polarity based solvent extracts of *Moringa oleifera* seed, Alum and Chlorine on *Aspergillus fumigatus* isolate from wastewater.** Submitted for publication in Chemical Engineering Science Journal.

Signature: _____

Kenneth A.Yongabi

Date: _____

EXECUTIVE SUMMARY

In Sub-Saharan Africa, 80-90% of all infectious diseases are water borne. Governments in these countries spend a significant proportion of their budgets importing alum and chlorine from western nations for municipal water treatment. More than 1.2 million people lack safe drinking water in developing countries. Apart from high cost of treating water in sub-Saharan Africa, waterborne microorganisms are developing resistance to currently used disinfectants such as chlorine. To meet the United Nations Millennium Development Goals (MDG) of providing safe drinking water, alternative and complimentary approaches such as the application of *Moringa oleifera* plant materials and sand filters are being studied. Previous research regarding the application of *Moringa oleifera* (MO) seeds have focused on the isolation of bioactive coagulant ingredients for more than four decades, with little attention directed toward field application in small and large scale water treatment applications. Slow sand filters take more than two weeks to generate clean water but there have been few studies directed towards integrating *Moringa oleifera* and other plant disinfectants with sand filters to generate clean water in a relatively short retention times at faster flow rates, generating a more compact filter unit.

This research sought to fill this knowledge gap. Quantitative research techniques were applied to test a Moringa-sand filter column for its disinfection activity on separate synthetic contaminated water containing *E. coli*, *Aeromonas hydrophila*, total heterotrophic soil bacteria and fungi. The constructed Moringa-sand filter column was analyzed for its coagulant activity using synthetic turbid water made from bentonite and soil. Further research into documentation of indigenous knowledge and the use of indigenous medicinal plants in Cameroon with a history of use in purifying water was carried out at both the Phytobiotechnology Research Laboratories in Bamenda, Cameroon and the Microalgae Research Laboratory of the School of Chemical Engineering, Adelaide University. The coagulant and disinfection ability of the plants using surface contaminated water was carried out at the Phytobiotechnology Research Laboratories in Cameroon, followed by in-vitro antimicrobial activity of the organic extracts using microbial isolates from stream water in Bamenda, Cameroon. The coagulant and disinfection potential of *Moringa oleifera* seed extracts were superior to other plant materials. To this effect, further studies on *Moringa oleifera* seeds were planned and executed at the Microagae Laboratory, School of Chemical Engineering, Adelaide University. Extracts of *Moringa* seed powder using solvents of varying polarity revealed more than 85% in-vitro antibacterial activity against *E. coli*

(ATCC11775) strain (indicator of faecal contamination of water) and 95% against *Aeromonas hydrophila* strain (known to resist chlorination) compared to control of both organisms of 65% for aluminum sulphate and 80% for sodium hypochlorite. Phytochemical screening and chromatographic analyses were carried out to elucidate the possible bioactive disinfectant ingredient in *Moringa* seeds. These experiments were conducted as proof of concept and were preceeded by an evaluation of the microbial content of surface water at Bambui and Mile 6 Mankon water sources used for household chores in Bamenda, Cameroon, for total bacterial counts, *E. coli* and coliform counts. A pilot low cost disinfectant sand filter system was set up at the Government Technical College, Njinikom, in Cameroon; to test its disinfectant and coagulant efficiency using total bacterial count, *E. coli*, coliform and fungal counts, pH, turbidity and to provide a capacity building on dissemination of this knowledge at household level in Cameroon.

Data was collected every 24 hours for a period of a month for the bench experiments using sand filters and for field work for 12 months on the pilot plant. The mean bacterial counts, pH, turbidity and a catalogue of plant materials used in water treatment were recorded.

The main findings of this research are presented as a series of six publications consisting of four peer-reviewed journal articles, a book, a book chapter as well as two manuscripts submitted for publication:

The main findings of this research were applied in a pilot water project at Government Technical School Njinikom, Boyo division, Cameroon. It was found in the pilot study that *Moringa* pretreated water filtered through sand media met both the Australian and the World Health Organization guidelines for drinking water. The broad lessons for water purification are that the use of locally available natural coagulants and disinfectants in resource limited countries has a great potential of improving the economy and health of the people. This research has demonstrated the efficacy of both plant based coagulants, disinfectants and sand filter media through extraction, in vitro bioassay, purification and integration of the two systems. It is highly recommended that governments in poor countries should take up this technology. It will require commitment of countries to strengthen the natural water coagulation technology in a holistic, integrated approach and to support initiatives including empowering and enabling local scientists to build up this system at the grassroots level.

ACKNOWLEDGMENT

A number of people participated in this research. Most importantly, I thank the principal, staff and students of the Government technical college, Njinikom, Cameroon, who worked relentlessly toward the construction of the *Moringa* pilot water treatment plant. I remain grateful to the technical staff of the School of Chemical Engineering, The University of Adelaide, who were very supportive towards the design and fabrication of the experimental Moringa-sand filter rigs. In particular, I owe thanks to Jason, Jeff, Mike and Andrew Wright. My greatest thanks are reserved for Ass.Prof. David Lewis and Mr. Paul Harris, who accepted supervision of me. Their persistent support and enduring patience provided an extraordinary inspiration and made this work a truly exceptional learning curve for me. I enjoyed David and Paul's wonderful blend of social, industrial and academic experience. To Dr. William Donohue for his academic and social support throughout my stay at Adelaide.

To Jess, Brendan and Frances (above L-R), with whom I worked closely on this project. They have been very inspirational with their thoughtful questions. Their interests in sustainable engineering are unequivocal. We were privileged to have one of our Honors students on the water quality testing component of this project, Brendan Moore, receive the prize for best poster and Honors Thesis presentation.

To Dianne Parish for her interest in this work and who encouraged Brendan, Jess and Frances to contact me. To Dana Thomsen, the Harris' family and the good people of Gawler Baptist Church for their moral support throughout my stay at Adelaide.

The entire students, Administrative and academic staff of the school of Chemical Engineering were very supportive throughout my stay in Adelaide and I thank them all.

To God, is all the glory for the gift of life.

LIST OF PUBLICATIONS

The following publications have arisen from the research conducted during the study period and are included in the thesis as individual chapters, contributions of co-authors are described in authorship statements that appear prior to each article.

Chapter 4 – Article 1

Yongabi, K.A., Lewis, D.M and Harris, P.L. 2011. A *Moringa oleifera* disinfectant-sand filter integration: A review of an alternative Sustainable technology for household water treatment. Journal of Environmental Science and Engineering, 5: 1100-1108

Chapter 5 – Article 2

Yongabi, K.A., Lewis D, M and Harris, P.L 2011. Application of Phytodisinfectants in Water purification in rural Cameroon. African Journal of Microbiology Research, Vol.5 (6) pp 628-635, available online: http//www.academicjournals.org/ajmr

Chapter 6 – Article 3

Yongabi, K.A., Lewis, D.M and Harris P.L 2011. Indigenous plant based coagulants and sand filter media for surface water treatment in Bamenda, Cameroon. African Journal of Biotechnology, Vol.10 (43), pp 8625-8629, available online: http//www.academicjournals.org/AJB

Chapter 7 – Article 4

Yongabi, K.A., Lewis, D.M and Harris, P.L 2011. Integrated phytodisinfectant-Sand filter Drum for household water treatment in sub-Saharan Africa. Journal of Environmental Science and Engineering, 5: 947-954.

Chapter 8 – Article 5

Yongabi Kenneth, Lewis David and Harris Paul, 2010. Alternative perspectives in water and waste water treatment. Lambert publishing, ISSBN 9783838387857 pp 129, Germany. Available at http://trove.nla.gov.au/work/151508978?versionId=165164257

Chapter 9 – Article 6

Kenneth Yongabi, David Lewis and Paul Harris 2012. Natural materials for sustainable water pollution management. Water pollution. Prof. Nuray Balkis (Ed.), ISBN: 978-953-307-962-2, InTech, available online: http://www.intechopen.com/books/water-pollution/natural-materials-for-sustainable-water-pollution-management

Chapter 10 – Article 7

Yongabi, K.A., Lewis, D.M and Donohue, W (2012) In Vitro Sensitivity of *Aeromonas hydrophila* to five polarity based solvent extracts of *Moringa oleifera*, Alum and Chlorine. Submitted for Publication in Chemical Engineering science Journal.

Chapter 11 – Article 8

Yongabi, K.A., Lewis, D.M (2012) Phytochemical Constituents and Comparative antifungal activity of polarity based solvent extracts of *Moringa oleifera* seeds, Alum and Chlorine on *Aspergillus fumigatus* isolate from wastewater. Submitted for Publication in Chemical Engineering science Journal.

Additionally, a poster on "Cheap biocoagulant sand filter system for water purification in low income earning countries" was presented at Chemical Engineering conference (CHEMECA), 2010 in Adelaide (Appendix 14)

EXTENT OF INVOLVEMENT IN PUBLICATION

The bench scale laboratory work was done in the microalgae laboratory, School of Chemical Engineering, The University of Adelaide. The survey of indigenous biocoagulants and laboratory screening for antimicrobial activity was carried out at the Phytobiotechnology Research Laboratories, Bamenda, Cameroon.

All the peer-reviewed articles, book and book chapter are multi-authored but I am the lead author on each. Descriptions of the involvement of each author and their agreement to the inclusion of the manuscript in this thesis are provided in the authorship statement at the start of each chapter in which each manuscript is reproduced in this thesis. A brief overview of the involvement of the authors in each article is provided below.

Article 1: This was carried out by me and is based on my research findings with advice and editorial assistance from Dr. David Lewis and Paul Harris.

Article 2: Drawn from the research work I did in Cameroon and Adelaide. I wrote the article and Dr. David Lewis and Paul Harris went through the draft and provided editorial comments.

Article 3: I drafted this article, and both Dr. David Lewis and Paul Harris edited the draft.

Article 4: I drafted this article; Dr. David Lewis provided a critique. The final draft was re-edited by Dr. David Lewis and Paul Harris and the quality greatly improved.

Article 5: I prepared and submitted the draft of this article. Significant modifications to the Manuscript were required as a result of the reviewers' comments, and I undertook the process of revising the manuscript. Dr. David Lewis and Paul Harris approved the final product.

Article 6: This chapter was drafted by me and Dr. David Lewis and Paul Harris went through and approved its publication.

Article 7: I prepared the manuscript and Drs. David Lewis and William Donohue made editorial comments. I revised the manuscript before submission.

Article 8: I prepared the manuscript and Dr. David Lewis went through for editing. His comments were incorporated into the work before submission.

All the chapters of this work are the result of my research work with editorial advice from Dr. David Lewis and Paul Harris

Kenneth Yongabi.
October, 2012