



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

By

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CONTENTS

LIST OF FIGURES	IX
LIST OF TABLES	IX
DEDICATION	X
DECLARATION	XI
EXECUTIVE SUMMARY	XIII
ACKNOWLEDGMENT	XV
LIST OF PUBLICATIONS	XVI
EXTENT OF INVOLVEMENT IN PUBLICATION	XVII
CHAPTER 1	1
Introduction.....	1
1.1 Introductory Background.....	1
1.2 Research Questions.....	3
1.2.1 Poor Water quality for household use in Africa	3
1.2.2 Poor environmental sanitation contaminates drinking water sources.....	5
1.2.3 Surface water microbiology, poorly documented in rural Africa.....	6
1.2.4 Problems and Challenges for Conventional Water Treatment	11
1.3 <i>Moringa oleifera</i> Availability and growth requirements	12
1.3.1 Origin and Geographical Distribution	12
1.3.2 Classification	12
1.3.3 Vernacular names	13

1.4 Anatomical Description of <i>Moringa oleifera</i>	13
1.5 Availability of <i>M. oleifera</i> seeds in water treatment	14
1.6 Production vis-à-vis International Trade	15
1.6.1 Ecology of <i>Moringa oleifera</i>	16
1.6.2 Artificial Propagation of <i>M. oleifera</i>	16
1.6.3 Diseases and pests.....	17
1.6.4 Conservation Strategies for <i>Moringa Oleifera</i>	18
1.6.5 Breeding.....	18
1.6.6 Genetic Resource base for <i>Moringa oleifera</i>	18
1.7 <i>Moringa</i> Phytodisinfectant–Sand Filter water treatment.....	20
1.8 Aims/Objectives of the project	23
1.8.1 Significance /Contribution to the discipline	24
1.8.2 Theoretical framework and Methods	25
1.9 Indigenous Knowledge, Science and Technology	26
CHAPTER 2	28
Literature Review	28
2.0 Summary.....	28
2.1 Introduction/Background.....	29
2.1.1 Overview of the importance of Water	30
2.1.2 Sources of water.....	31
2.1.3 Microbes in surface water, public health implications	31
2.1.4 Effects of untreated wastewater on drinking water sources	32
2.2 A review of Water Treatment in Nigeria and Cameroon.....	34
2.2.1 Introduction to Water and Wastewater Purification Methods	35
2.2.2 Boiling/heating and its setbacks	38

2.2.3 Solar-air Treatment (SODIS).....	38
2.2.4 The Halogens and their application in water disinfection	38
2.2.5 Quaternary Ammonium Compounds and Chlorine Solutions.....	39
2.3 Filtration Process.	39
2.3.1 Slow sand filter: Historical evolution	40
2.3.2 The advantages and defects of the slow sand filter	42
2.3.3 Basic filter Materials and Rationale for use.....	43
2.3.4 Candle Filter (porous ceramics), its setbacks	44
2.4 Coagulants in Domestic Water Treatment.....	44
2.4.1 A survey of Indigenous Plant materials in Water purification	45
2.5 The historical use of <i>Moringa oleifera</i> plant in water treatment rural Africa .	48
2.5.1 Seeds of Moringa Oleifera.....	49
2.5.2 Botanic Description / Detail Anatomy of <i>Moringa Oleifera</i>	52
2.5.3 Chemical Constituents of <i>Moringa oleifera</i> (lam).....	53
2.5.4 <i>Moringa oleifera</i> dosing in water treatment.....	54
2.6 Conclusion and Recommendation	56
CHAPTER 3	57
Methodology.....	57
3.1 Microbial and Physicochemical analyses of water samples.	57
3.1.1 Plant collection, processing and selection for detail studies.....	58
3.2 Processing <i>Moringa oleifera</i> plant biomaterials.....	59
3.2.1 Coagulation studies using <i>Moringa oleifera</i> powder on turbid water .	59
3.3 Construction of Experimental Rigs.....	60
3.4 Preparation of Synthetic Contaminated Water	62
3.4.1 Preparation of <i>Aeromonas hydrophila</i> for Disinfection studies	62

3.4.2 Preparation of Synthetic Contaminated water using Soil	63
3.4.3 Preparation of turbid water using bentonite for Coagulation studies ..	63
3.4.4 Preparation of synthetic hybrid turbid and contaminated water	64
3.4.5 Preparation of model hybrid turbid water with bentonite and soil.	64
3.4.6 Data collection frequency from the rig experiments.	64
3.5 Solvent Extraction of <i>Moringa oleifera</i> (MO) Seeds.	65
3.5.1 In-vitro antibacterial assay	66
3.5.2 Determination of Minimum Inhibitory Concentration (MIC)	66
3.5.3 Preliminary Phytochemical analysis of <i>Moringa oleifera</i> extracts.....	67
3.5.4 Chromatographic analyses.	67
3.6 Construction of a Pilot System	68
Chapter 4.....	70
<i>A Moringa oleifera</i> disinfectant sand filter Integration. A review of an alternative Sustainable technology for household water treatment	70
Chapter 5.....	80
Application of photodisinfectants in water treatment in rural Cameroon	80
Chapter 6.....	89
Indigenous Plant based Coagulants and sand filter media for surface water treatment in Bamenda, Cameroon.....	89
Chapter 7.....	95
Integrated phytodisinfectant sand filter Drum for household water treatment in Subsaharan Africa.....	95
Chapter 8.....	104
Alternative Perspectives in water and waste water treatment: Phytocoagulant sand filter alternative for water and water treatment.	104
Chapter 9.....	106
Natural materials for sustainable water pollution management.....	106
Chapter 10.....	140

In vitro Sensitivity of <i>Aeromonas hydrophila</i> to five Polarity based Solvent extracts of <i>Moringa oleifera</i> , Alum and Chlorine.....	140
Chapter 11.....	158
Phytochemical constituents and comparative antifungal activity of polarity based solvent extracts of <i>Moringa oleifera</i> seeds, alum and chlorine on <i>Aspergillus fumigatus</i> isolate from Wastewater.....	158
Chapter 12.....	173
An appropriate technology transfer. A sustainable low cost phytodisinfectant- sand filter alternative for water purification.....	173
Chapter 13.....	176
Impact and conclusions.....	176
References.....	179
APPENDICES	192
Appendix 1: Summary of Disinfection of Pathogen Contaminated water pretreated with <i>Moringa</i> extracts before Sand filtration rig (at 45 minutes residence time)The results are submitted for future publication.	192
Appendix 2: Coagulation (turbidity removal) levels from Synthetic model turbid water using MO extracts pretreatment and Sand filtration	193
Appendix 3: Coagulation and Disinfection of Synthetic turbid water with MO extracts –sand filtration.....	194
Appendix 4: Coagulation and disinfection of model synthetic turbid water with MO extracts sand filtration.....	195
Appendix 5: Treatments with aqueous sequential MO extract sand filtration	196
Appendix 6: Treatments with MO salt extract sand filtration	197
Appendix 7: Treatments with MO crude extract sand filtration	198
Appendix 8: Treatment with Sand filter (sand filtration) control	199
Appendix 9: Synthetic turbid water with bentonite treated with crude MO seed solution and alum.....	200
Appendix 10: Drying <i>Moringa</i> extracts in liquid nitrogen	201
Appendix 11: Experimental rigs using for water treatment.....	202

Appendix 12: A range of culture media used in the experiments.....	203
Appendix 13: Pictures of the GTC Pilot MO-Sand Filter system	204
Appendix 14: Poster presentation of this research during the Chemical Engineering Conference (CHEMECA,2010).....	205
Appendix 15: Risk Assessment involved in the Research work on A Sustainable Low-cost Phytodisinfectant-Sand filter alternativeFor Water Purification	206

LIST OF FIGURES

Figure 1: Children in Bambui, Cameroon, fetching polluted water for household use.	1
Figure 2: Global water supply coverage	5
Figure 3: Sanitation global coverage	5
Figure 4: (a) Moringa seeds and (b) plants	21
Figure 5: Protein structure active coagulant-flocculant ingredient from Moringa seed	22
Figure 6: Particle size distribution curve for Moringa (1) and sand (2)	26
Figure 7: Moringa oleifera seeds and trees, widespread in Sub-Saharan Africa	28
Figure 8: The mechanism of water sedimentation	36
Figure 9: Diagram of coagulation, flocculation and sedimentation	36
Figure 10: Steps of cloth filtration method of treating surface water	40
Figure 11: The formation and function of the biological layer in a slow sand filter	42
Figure 12: Chemical structure of active antimicrobial component in Moringa	50
Figure 13: Moringa seed pod (Yongabi, 2006)	51
Figure 14: Bench scale laboratory rig to demonstrate Moringa-sand filtration	57
Figure 15: Body filter	61
Figure 16: Water filter	61
Figure 17: Location of Cameroon in Africa	68
Figure 18: Community participation and interest on the pilot water project	69
Figure 19: Moringa plant and seed pod (Yongabi et al., 2011)	70
Figure 20: Anti bacterial activity of <i>M. oleifera</i> extracts on <i>E. coli</i> and <i>A. hydrophila</i>	80
Figure 21: Indigenous African plants used to purify water (<i>Carica papaya</i> and <i>Jatropha</i>)	89
Figure 22: Moringa treated water and sand filter setup for household use	95
Figure 23: Back and front covers of a published book emanating from this Research work.	104
Figure 24: First ecological water treatment unit using phyto disinfectant-sand filter system	106
Figure 25: Community mobilization with school children	176
Figure 26: Pilot water filter system (Yongabi et al., 2012)	176

LIST OF TABLES

Table 1: Summary of microorganisms and diseases with Public Health Significance	7
Table 2: Diseases usually related to natural standing or flowing surface water	10
Table 3: Health risks associated with selected water borne pathogens	11
Table 4: Attributes of <i>Moringa peregrina</i> compared with some common <i>Moringa</i> species	19

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, ISSN 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 Sensitivity 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 Microalgae 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 preceded 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.

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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, ISBN 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