



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF

WATER RESOURCES ENGINEERING.

PERFORMANCE EVALUATION OF ZEOLITE COMPOSITE

AS A DOMESTIC WATER DISINFECTANT;

A CASE STUDY OF MASESE LANDING SITE.

BY:

ONYANGO MORIS WANYAMA

REG NO: **BU/UP/2021/0327**

SUPERVISOR:

MR. WANGI GEOFFREY MARIO

This final year report is submitted to Department of Water Resources Engineering in partial fulfillment of the requirements for the award of a Bachelor Degree of Science in Water Resources Engineering at Busitema University.

MAY 2025

Abstract.

Access to good, clean and safe drinking water is a critical challenge in many third world developing regions, including Uganda. The Masese Landing Site, situated on the shores of Lake Victoria, faces significant contamination issues in its domestic water sources due to pollution from agricultural runoff, inadequate sanitation, and industrial discharge. This study aims to evaluate the

effectiveness of zeolite nanocomposites in disinfecting water at Masese by focusing on their ability to remove key biological contaminants, such as *E. coli* and total coliforms, as well as chemical pollutants like nitrates and phosphates.

A detailed before-and-after experimental design will be employed, where water samples will be collected from Masese landing site and analysed for critical water quality parameters before and after treatment with zeolite nanocomposites. A paired t-test will be conducted to assess whether there is a statistically significant reduction in contaminants post-treatment, and a comparison will be made to the World Health Organization (WHO) guidelines for safe drinking water. The results will up-to-date understandings into the potential of zeolite-based technologies for improving water quality and safeguarding public health at Masese Landing Site.

Declaration.

I, Onyango Moris Wanyama, declare that this report is my original work and has not been presented for the award of a degree or any other qualification at any other university or institution. All the sources of information used in this report have been duly acknowledged.

Signature: _____

Date: 14th May 14, 2025

Approval.

I vouch that the work reported in this research has been written under my supervision is presented to the Department of Water Resources Engineering at Busitema University for approval.

MR. WANGI GEOFFREY MARIO;

A handwritten signature in blue ink, appearing to read 'Wangi', with a large, stylized flourish extending from the end.

DATE: 14TH May 14, 2025

Acknowledgement.

I would like to express my sincere gratitude to my supervisor, Mr. Wangi Geoffrey Mario, for his continuous support, guidance, and constructive feedback throughout the development of this research project. My appreciation also goes to the Department of Water Resources Engineering at Busitema University for providing the resources and facilities necessary for my study.

I am also grateful to my late father Mr. Wanyama Boniface for laying the foundation and framework for my academic career, my mother Malingha Proscovia, my lovely sister Wanyama Morine Hope and friends for their encouragement, understanding, and unwavering support during this academic journey.

Dedication.

This research is dedicated to my late father Mr. Wanyama Boniface whose love, sacrifice, and belief in my potential have been my greatest motivation throughout my academic journey. I also dedicate this work to my beloved elder sister Wanyama Morine Hope and my mother Madam Malingha Proscovia for their support to ensure this study is a success.

List of Acronyms.

WHO – World Health Organization

E. coli – *Escherichia coli*

RSM – Response Surface Methodology

CCD – Central Composite Design

BBD – Box-Behnken Design

SEM – Scanning Electron Microscopy

XRD – X-Ray Diffraction

FTIR – Fourier-Transform Infrared Spectroscopy

AgNPs – Silver Nanoparticles

UV-Vis – Ultraviolet-Visible Spectroscopy

SPR – Surface Plasmon Resonance

DO – Dissolved Oxygen

TDS – Total Dissolved Solids

EC – Electrical Conductivity

TC – Total Chlorine

FC – Free Chlorine

NTU – Nephelometric Turbidity Units

BOD – Biological Oxygen Demand

COD – Chemical Oxygen Demand

THMs – Trihalomethanes

MWE – Ministry of Water and Environment (Uganda)

UNBS – Uganda National Bureau of Standards

NWSC – National Water and Sewerage Corporation (Uganda)

GPS – Global Positioning System

ANOVA – Analysis of Variance

CFU – Colony Forming Units

CaCO_3 – Calcium Carbonate

AgNO_3 – Silver Nitrate

NaBH_4 – Sodium Borohydride

H_2O – Water

List of Figures.

Figure 3.1: Map showing location of study area (Masese Landing Site, Uganda)

Figure 3.2: Teenager fetching water from Lake Victoria

Figure 3.3: Researcher collecting water samples from deeper waters

Figure 3.4 & 3.5: Zeolite after activation process

Figure 3.6: Formation of silver nanoparticles (color change to grey)

Figure 3.7: Loading silver nanoparticles onto zeolite surface

Figure 3.8: UV-Vis spectrum showing AgNP peak at 403.09 nm

Figure 3.9: SEM image of zeolite-AgNP composite

Figure 3.10: ATR-FTIR spectrum of zeolite-silver nanocomposite

Figure 3.11: XRD pattern of zeolite-AgNP composite

Figure 3.3.1: Screenshot of Design of Experiment (DOE) conditions

Figure 4.1A: Frequency of *E. coli* in raw water samples

Figure 4.2.1A: Paired difference in *E. coli* before/after treatment

Figure 4.5.1: Fecal coliform counts vs. zeolite-Ag composite mass

Figure 4.5.2: Surface graph of optimization results

Figure 4.5.3: Experimental setup for water treatment tests

Table of content

Abstract.....	II
Declaration.....	III
Approval.....	IV
Acknowledgement.....	V
Dedication.....	VI
List of Acronyms.....	VII
List of Figures.....	VIII
Table of content.....	IX
Chapter 1: Introduction.....	1
1.1. Background of the study.....	1
1.2. Problem Statement.....	3
1.3. Project objectives.....	4
1.3.1. Main objective.....	4
1.3.2. Specific Objectives.....	4
1.4. Research questions.....	5
1.5. Significance of this research study.....	6
1.6. Scope and Limitations of the study.....	7
1.6.1. Study location and sample collections.....	7
1.6.2. Specific parameters tested.....	7
Literature review.....	8
2.1. Water contamination and public health.....	8
2.2. Zeolite as a water disinfectant.....	9
2.2.1. Properties of zeolite composites.....	9
2.2.2 Mechanism of Action in Contaminant Removal.....	10
2.3 Response Surface Methodology in Water Treatment Optimization.....	11
2.3.1 Principles of Response Surface Methodology (RSM).....	11
2.3.2 Previous Studies on Water Disinfection Using RSM.....	11
2.4 Regulatory Standards for Water Quality.....	12
2.4.1 WHO Guidelines on Drinking Water Quality.....	12
2.4.2 Ugandan Water Quality Standards.....	13
2.4.3 Chemical Contaminant Limits in Drinking Water.....	13
2.4.4 Role of Water Disinfection in Meeting Standards.....	14
2.4.5 Challenges in Meeting Water Quality Standards.....	14
2.4.6 Future Directions for Water Quality Improvement.....	15
Materials and Methodology.....	16
3.1. Study Area and Sampling.....	16
3.1.1. Description of Masese Landing Site.....	16
3.1.2. Sample collection Procedures and tools.....	17
3.2. Zeolite Composite preparation.....	20
3.2.1 Materials.....	20
3.2.2 Experimental Setup.....	21
Experiment 2: Synthesis of Silver Nanoparticles (AgNPs).....	21
Experiment 3: Loading Silver Nano Particles onto Zeolite.....	22
3.2.2 Characterization of Composite.....	23
Key Observations:.....	23
Fourier-Transform Infrared Spectroscopy (FTIR) Analysis.....	25
X-Ray Diffraction (XRD) Analysis.....	27
3.3. Experimental Design for Response Surface Methodology (RSM).....	28
Results and discussion.....	30
4.1. Descriptive statistics for raw water samples.....	30

4.2. Efficacy of Zeolite Nanocomposite on Microbial Removal	33
4.3. Results and Discussion on Domestic Water Quality	34
4.4. ANOVA Analysis of Treated Household Water Samples	37
4.5. Optimization of Zeolite/Ag Composite for Domestic Water Disinfection.	39
4.5.1 Data Summary and Observations	39
4.5.4 Optimization Analysis.	42
5.0 PROBLEMS ENCOUNTERED, CONCLUSIONS, AND RECOMMENDATIONS.	43
5.1 Problems Encountered.....	43
5.2 Conclusions.....	44
5.3 Recommendations.....	44
References	46
APPENDICES.....	49
APPENDIX 1. PHOTO LAB.....	49

References

- Agency, U. S. E. P. (2024). Technical Fact Sheet: Draft National Recommended Human Health Ambient Water Quality Criteria for PFOA, PFOS, and PFBS, (December), 3–5.
- Ahmed, K., Pal, A., Hasan, T., & Baran, B. (2021). Microporous and Mesoporous Materials Zeolite-graphene composite adsorbents for next generation adsorption heat pumps. *Microporous and Mesoporous Materials*, 313(January), 110839. <https://doi.org/10.1016/j.micromeso.2020.110839>
- Almeida, M., Erthal, R., Padua, E., Silveira, L., & Am, L. (2008). Talanta Response surface methodology (RSM) as a tool for optimization in analytical chemistry, 76, 965–977. <https://doi.org/10.1016/j.talanta.2008.05.019>
- Analysis, I. P. (2022). Natural Zeolite for The Purification of Saline Groundwater and Irrigation Potential Analysis, 1–19.
- Ashbolt, N. J. (2004). Microbial contamination of drinking water and disease outcomes in developing regions, 198, 229–238. <https://doi.org/10.1016/j.tox.2004.01.030>
- Babu, K., Maina, S., Wahiti, R., & Yan, X. (2021). Water quality assessment , multivariate analysis and human health risks of heavy metals in eight major lakes in Kenya. *Journal of Environmental Management*, 297(June), 113410. <https://doi.org/10.1016/j.jenvman.2021.113410>
- Baguma, G., Musasizi, A., Twinomuhwezi, H., Gonzaga, A., Nakiguli, C. K., Onen, P., ... Omara, T. (2022). Heavy Metal Contamination of Sediments from an Exoreic African Great Lakes ' Shores (Port Bell , Lake Victoria), Uganda, 407–421.
- Castelletti, A., Pianosi, F., Sessa, R. S., & Antenucci, J. P. (2010). A multiobjective response surface approach for improved water quality planning in lakes and

- reservoirs, 46, 1–16. <https://doi.org/10.1029/2009WR008389>
- Edition, T., & First, I. T. H. E. (2008). Guidelines for Drinking-water Quality, 1.
- Farhan, M., Al-gheethi, A., Mohamed, R., Noman, E., Talip, B. A., & Bakar, A. (2020). Materials Today : Proceedings Optimizing of heavy metals removal from car wash wastewater by chitosan-ceramic beads using response surface methodology, (xxxx), 1–5.
- Goals, S. D. (2023). *World Health Statistics*.
- Karimifard, S., Reza, M., & Moghaddam, A. (2018). Science of the Total Environment Application of response surface methodology in physicochemical removal of dyes from wastewater: A critical review. *Science of the Total Environment*, 640–641, 772–797. <https://doi.org/10.1016/j.scitotenv.2018.05.355>
- Materials Today : Proceedings 5 NANO 2021 – EXPRESSION OF CONCERN – PART 2. (2023), 80, 7853. <https://doi.org/10.1016/j.matpr.2023.03.123>
- Matsuura, T., Othman, H. D., Puteh, M. H., Arif, M., Pauzan, B., Ismail, A. F., ... Protection, E. (2018). PT.
- Nor, S., Arifin, H., Maya, R., Radin, S., & Rohaizad, N. (2019). ScienceDirect Effects of Direct Discharge of Domestic Greywater to Nearby Water Body.
- Polymer, E. A. (n.d.). Mechanical Seal Replacement.
- Sharafee, M., Farhan, S., & Shahadat, M. (2019). Journal of Water Process Engineering Cellulose / bentonite-zeolite composite adsorbent material coating for treatment of N-based antiseptic cationic dye from water. *Journal of Water Process Engineering*, 29(October 2018), 100764. <https://doi.org/10.1016/j.jwpe.2019.02.004>
- Shi, J., Yang, Z., Dai, H., Lu, X., Peng, L., & Tan, X. (2018). Uncorrected Proof Uncorrected Proof, 1–15. <https://doi.org/10.2166/wst.2018.249>
- Sodha, V., Shahabuddin, S., Gaur, R., Ahmad, I., & Bandyopadhyay, R. (2022). Comprehensive Review on Zeolite-Based Nanocomposites for Treatment of Effluents from Wastewater.
- Wahaab, A., & Badawy, I. (2004). Water Quality Assessment of the River Nile System : An Overview, 100, 87–100.
- Winckel, T. Van, Cools, J., Vlaeminck, S. E., Joos, P., Meenen, E. Van, Steen, K. Van Den, ... Blust, R. (2021). Towards harmonization of water quality management: A comparison of chemical drinking water and surface water quality standards around the globe Elena Borreg a, 298(February).

<https://doi.org/10.1016/j.jenvman.2021.113447>

Rai, M., Yadav, A., & Gade, A. (2009). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*, 27(1), 76–83.

Wang, Y., et al. (2012). Preparation of zeolite-supported silver nanoparticles for antimicrobial application. *Colloids and Surfaces B: Biointerfaces*, 90, 313–318.

Zhang, W., et al. (2008). Zeolite-encaged Ag nanocomposites for water disinfection. *Water Research*, 42(18), 4591–4599.