



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES AND MINING ENGINEERING

**DESIGN AND FABRICATION OF A SOLAR-POWERED WATER
FILTRATION SYSTEM FOR RURAL AREAS**

CASE STUDY: AMUDAT DISTRICT

BY

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A final year project report submitted to the Department of Water Resources Engineering in partial fulfilment of the requirement for the award of a bachelor of science in Water Resources Engineering at Busitema University.

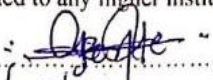
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ABSTRACT

Clean water access remains a critical challenge in rural areas such as Uganda's Amudat District, where residents face high incidences of waterborne diseases due to reliance on contaminated sources. This study focused on the design, fabrication, and evaluation of a solar-powered water filtration system tailored for such communities. The system integrates renewable energy with multi-stage filtration and ultraviolet disinfection to purify water. Laboratory tests demonstrated the system's effectiveness in reducing turbidity from over 8 NTU to below 2 NTU, removing over 85% of total suspended solids (TSS), and achieving complete elimination of total coliforms and *E. coli*, thus meeting NWSC standards. Electrical conductivity levels slightly improved, and pH remained within the safe range. The system was powered by a 240W solar panel and a 160 W submersible pump, ensuring off-grid functionality with minimal friction losses in 1-inch HDPE pipes. A cost-benefit analysis showed a Benefit-Cost Ratio (BCR) of 5.19, affirming the system's economic viability. While intermittent sunlight posed operational challenges, integrating a battery backup is recommended. The solution offers an affordable, eco-friendly, and scalable option for delivering safe water in off-grid rural settings.

DECLARATION

I OLEPEK GEORGE declare that the work in this project proposal was my original work and has not been presented to any higher institution of learning for any academic award.

SIGNATURE: 

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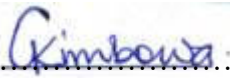
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APPROVAL

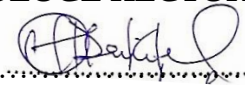
I hereby certify that this project is original and final year report of OLEPEK GEORGE, BU/UP/2021/O436. It has been done under the supervision of my supervisors and is ready for submission to the department of Water Resources Engineering.

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DEDICATION

I dedicate this final year project proposal to my beloved family my father Obwokor Edward, my mother Amogin Grace and my sister Ashango Esther for their unwavering love, support, and encouragement. They have been the driving force behind my academic pursuits. May the almighty god bless the abundantly.

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LIST OF ABBREVIATION

AC Alternating Current

DC Direct Current

EC Electrical Conductivity

GPM Gallons Per Minute

HDPE High-Density Polyethylene

LPM Litres Per Minute

MD Membrane Distillation

MWE Ministry of Water and Environment

NDP III National Development Plan III

NWCS National Water and Sewerage Corporation

PV Photovoltaic

RO Reverse Osmosis

SDGs Sustainable Development Goals

UBOS Uganda Bureau of Statistics

UF Ultrafiltration

UNHS Uganda National Household Survey

UNICEF United Nations International Children's Emergency Fund

WHO World Health Organization

References

- A, S. M., Kazi, T., Anas, P., & Shifa, S. (2018). Treatment of Water Using Various Filtration Techniques: Review Study Construction Management Practices Treatment of Water Using Various Filtration Techniques: Review Study. *Construction Management Practices*, October, 1–6. https://www.researchgate.net/publication/349104297_Water_security_and_its_scarcity_A_review
- Alkaisi, A., Mossad, R., & Sharifian-Barforoush, A. (2017). A Review of the Water Desalination Systems Integrated with Renewable Energy. *Energy Procedia*, 110(December 2016), 268–274. <https://doi.org/10.1016/j.egypro.2017.03.138>
- Aqlan, A. M., Aqlan, M., & Momin, A. E. (2021). Solar-powered desalination, a novel solar still directly connected to solar parabolic trough. *Energy Reports*, 7, 2245–2254. <https://doi.org/10.1016/j.egypr.2021.04.041>
- Ardani, K., Denholm, P., Mai, T., Margolis, R., Silverman, T., & Zuboy, J. (2021). Solar Futures Study. *U S Department of Energy*, September, 1–279.
- Aziz, A., Aizaz, S., Shah, A., Hussain, A., Alam, S. T., Islam, M., Hafeez, M., & Rehman, U. (2023). *Solar-Driven Advancements for Water Purification: Harnessing Sustainable Energy for Potable Water Provisioning*. 19(08).
- Chikwendu, O. C., & Ezindu, C. D. (2024). *Design and Fabrication of a Portable Solar Powered Water Purification System*. 20(4), 49–58.
- Dikgale, K. (2020). *DEVELOPMENT OF SOLAR POWERED WATER PURIFICATION SYSTEMS*.
- Diogo, F., Santos, A., & Azevedo, M. (2014). *Solar-powered desalination systems*. https://www.aler-renovaveis.org/contents/lerpublication/ulfc112531_tm_francisco_azevedo.pdf
- Dong, Y., Dai, X., Zhao, L., Gao, L., Xie, Z., & Zhang, J. (2021). Review of transport phenomena and popular modelling approaches in membrane distillation. *Membranes*, 11(2), 1–27. <https://doi.org/10.3390/membranes11020122>
- Godoi, F. C., Prakash, S., & Bhandari, B. R. (2021). Final report Final report. In *Review of 3D printing and potential red meat applications* (Vol. 1, Issue 23 February 2021). <http://libdcms.nida.ac.th/thesis6/2010/b166706.pdf>
- Gökçekuş, H., Kassem, Y., Godwin, M. H., & Babangida, A. (2022). Economic analysis of an off-grid solar PV for small scale desalination unit. *Future Technology*, 1(3), 26–43. <https://doi.org/10.55670/fpml.futech.1.3.5>
- Hasan, A., & Dincer, I. (2020). A new performance assessment methodology of bifacial photovoltaic solar panels for offshore applications. *Energy Conversion and*

- Management*, 220(February), 112972.
<https://doi.org/10.1016/j.enconman.2020.112972>
- Hussain, F., Othman, M. Y. H., Sopian, K., Yatim, B., Ruslan, H., & Othman, H. (2019). Design development and performance evaluation of photovoltaic/thermal (PV/T) air base solar collector. *Renewable and Sustainable Energy Reviews*, 25, 431–441. <https://doi.org/10.1016/j.rser.2013.04.014>
- Jansen, T., & Paul Wiegand, R. (2014). Bridging the gap between theory and practice. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 3242, 61–71. https://doi.org/10.1007/978-3-540-30217-9_7
- Kundu, D. K., Mola, A. P. J., & Gupta, A. (2016). Failing arsenic mitigation technology in rural Bangladesh. *Water Policy*, 18(6), 1490–1507. <https://doi.org/10.2166/wp.2016.014>
- McNelís, B., & Derrick, A. (2019). Solar Water Pumping: Clean Water for Rural Areas. *2nd ASEAN Science & Technology Week, February*, 19.
- Mekhilef, S., Saidur, R., & Safari, A. (2019). A review on solar energy use in industries. *Renewable and Sustainable Energy Reviews*, 15(4), 1777–1790. <https://doi.org/10.1016/j.rser.2010.12.018>
- Nations, U. (2023). *UN Water* (Issue March).
- Puretec, R., & Balance, M. (2024). *The Basics – Reverse Osmosis What is Reverse Osmosis ?* <https://puretecwater.com/wp-content/uploads/2024/04/Reverse-Osmosis-The-Basics-032024-1.pdf>
- Quila, M., Mukherjee, S., & Pramanik, S. (2024). A Portable Solar Water Purifier with Reverse Osmosis and Ultra Violet Disinfection System. *SSRG International Journal of Mechanical Engineering*, 11(7), 48–55. <https://doi.org/10.14445/23488360/IJME-V11I7P105>
- Sansaniwal, S. K. (2022). Advances and challenges in solar-powered wastewater treatment. *International Journal of Ambient Energy*, 43(1), 958–991. <https://doi.org/10.1080/01430750.2019.1682038>
- Schäfer, A. I., Shen, J., & Richards, B. S. (2018). Renewable energy-powered membrane technology in Tanzanian communities. *Npj Clean Water*, 1(1), 1–10. <https://doi.org/10.1038/s41545-018-0026-6>
- Sreewirote, B., Suttisinthong, N., & Ngaopitakkul, A. (2019). The Application of Solar Cells for Water Filtration System. In *MATEC Web of Conferences* (Vol. 260). <https://doi.org/10.1051/matecconf/201926003002>
- Tian, Z., Liu, F., Tian, C., Ma, Z., Jia, L., & Zhang, R. (2020). Experimental investigation

- on cooling performance and optimal superheat of water source gas engine-driven heat pump system. *Applied Thermal Engineering*, 178, 115494. <https://doi.org/10.1016/j.applthermaleng.2020.115494>
- Uddin, M. G., Nash, S., Olbert, A. I., Truong, B. T. nguyên và môi, Bái, Ủy ban nhân dân tỉnh Yên, Bái, U. tỉnh Y., TN&MT, B., Singh, R., Andaluri, G., Pandey, V. C., Jane Doolan, B. H., Đặng, N. T., Kumar, V., Parihar, R. D., Sharma, A., Bakshi, P., Sidhu, G. P. S., Bali, A. S., Karaouzas, I., ... WHO. (2022). The global water crisis and human rights. *Social Sciences Information Review*, Vol 69(2), 3–19.
- UNHCR. (2023). *A guide to UNHCR 's Global Report in 2023*.
- UNICEF. (2020). FIVE YEARS INTO THE SDGs PROGRESS ON HOUSEHOLD DRINKING WATER, SANITATION AND HYGIENE. In *Launch version July 12 Main report Progress on Drinking Water , Sanitation and Hygiene*. <http://apps.who.int/bookorders>.
- Vigneswaran, S. (2020). *TRADITIONAL AND HOUSEHOLD WATER PURIFICATION METHODS. II*, 1–6.
- Vigneswaran, S., Kandasamy, J., & Rogerson, M. (2022). Water and Wastewater Treatment Technologies-Filtration Technologies in Wastewater Treatment. *Encyclopedia Life Support Systems (UNESCO-EOLSS)*. <https://www.eolss.net/sample-chapters/eolss-samplechapters.aspx>
- Wasfy, K. I. (2017). Brackish Water Desalination Using Reverse Osmosis System. *Misr Journal of Agricultural Engineering*, 34(4), 1783–1800. <https://doi.org/10.21608/mjae.2017.96124>
- WHO. (2018). *WHO global water, sanitation and hygiene*. https://www.who.int/water_sanitation_health/publications/global-water-sanitation-and-hygiene-annual-report-2018/en/
- Zekry, A., Shaker, A., & Salem, M. (2018). Solar Cells and Arrays: Principles, Analysis, and Design. In *Advances in Renewable Energies and Power Technologies: Volume 1: Solar and Wind Energies* (Vol. 1, Issue August). <https://doi.org/10.1016/B978-0-12-812959-3.00001-0>
- Zhu, T., Guo, Y., Wang, C., & Ni, C. (2020). Inter-hour forecast of solar radiation based on the structural equation model and ensemble model. *Energies*, 13(17). <https://doi.org/10.3390/en13174534>