FACULTY OF ENGINEERING

DEPARTMENT OF WATER RESOURCES ENGINEERING

FINAL YEAR PROJECT

TO DEVELOP A DECISION SUPPORT TOOL FOR SIZING AND MATERIAL SELECTION OF RAINWATER HARVESTING TANKS FOR OPTIMAL WATER QUALITY AND COST

Case study: Njuki Hostel, Busitema University

By

NYESIGYE SANDRAH - BU/UP/2019/1871

SUPERVISED

By

Mr. WANGI GODFREY MARIO

Final Year Project proposal Report submitted to the Department of Water Resources Engineering in partial fulfillment of the requirement for the award of a Bachelor of Science degree in Water Resources Engineering at Busitema University.

DECLARATION

I NYESIGYE SANDRAH declare that this project report is my own research and has neither been used nor submitted in any institution or university for any academic award.

Signature.....

Date.....18/03/2024.....

CamScanner

APPROVAL

I hereby certify that this final year research project report as original and individual work of **NYESIGYE SANDRAH (BU/UP/2019/1871).** It has been under my supervision and it is ready for submission to the Department of Water Resources Engineering.

SUPERVISOR

MR. WANGI GODFREY MARIO

SIGNATURE…. 

DATE…18th…/…March……/…2024……

ACKNOLEDGEMENT

I take this opportunity to concede the Almighty GOD who has gifted me with life and has enabled me to reach this academic height as He has been the provider of all the necessary requirements. Great thanks to my beloved family and friends for their endless encouragement and moral support and for their prayers and piece of advice given to me in the course of this project.

My sincere gratitude also goes to my supervisor Mr. WANGI GODFREY MARIO for his continuous guidance, time and support during this research. His advice and tireless effort in following up the progress of this project was quite instrumental for its success. Great thanks to Mr. Maseruka Bendicto for his guidance, time, support and encouragement during this research. More thanks extend to the entire staff staff of the Water Resources and Minning Engineering department and the entire university at large.

Lastly but not least, we outspread our gratitude to our fellow students in the Water Resources class, for your sustained support and cooperation.

TABLE OF CONTENT

Contents

LIST OF TABLES

LIST OF FIGURES

1 CHAPTER ONE

1.1 Introduction

This research involves discussions on relationship between tank size and material on harvested rainwater quality, approach for optimal sizing of rainwater harvesting tank, and approach for optimal selection of tank material (cost). This chapter consists of; Background, problem statement, main objective, specific objectives, scope of the study and finally the justification.

1.2 Background

The majority of the world's water supplies have not increased during the past century; in certain situations, they may have even dropped as a result of pollution. The world's population and human requirements are expanding, and climate change is predicted to lead to an increase in temperature and a decrease in rainfall in several regions, particularly the Mediterranean countries (Khan et al., 2017). Due to the anticipated imbalance between water supply and demands, which will only get worse over the next few years, all available water sources should be taken into account going forward (Tsihrintzis & Baltas, 2020). It is relatively inexpensive to use rainwater harvesting, which is the collection and storage of rainwater for potable or non-potable in-house uses (Zabidi et al., 2020). Rainwater harvesting also presents as a sustainable water management practice because it may reduce runoff volumes and peaks (of course, this assumes that the tank is empty, which may not be the case throughout the entire rainy season), and the resulting redistribution of water (Tsihrintzis & Baltas, 2020). While potable uses are also widespread in many countries, they may necessitate the proper treatment of harvested rainwater depending on its quality (Kusumawardhana et al., 2021). Untreated harvested rainwater can be used for non-potable uses such as toilet flushing, clothing washing, other household uses, garden irrigation, etc. In general, caution should be used based on the final usage to reduce dangers to the public's health (Tsihrintzis & Baltas, 2020). RWH systems in large commercial buildings may be more financially sustainable than smaller household systems, according to financial assessments. It has been determined that design techniques based on straightforward procedures result in tank sizes that are significantly larger than an ongoing simulation(Jain, 2019). The tanks installed are large for their corresponding demand level and catchment size, according to a comparison between the actual tank sizes and those calculated using continuous simulation. Tanks that are too large can result in exorbitant system capital expenditures, which now prevent the adoption of new systems (Ward et al., 2018).

Methods for sizing the rainwater harvesting tank vary from country to country (Tsihrintzis & Baltas, 2020). For example, in the UK, the BS 8515 2009 Code of Practice is used, which states that the capacity of the rainwater harvesting storage tank must be the least of either 5% of the annual rainwater yield (ARY) or 5% of the annual rainwater demand (ARD) (http://oasis-rainharvesting.co.uk/ sizing_the_tank). Larger tanks are not allowed, because of the risk of bacteria breeding which may cause health hazards.

The storage tank is the most expensive and crucial part of a RWHS; it also determines the system's volume and time reliability. Therefore, a RWHS's performance and user acceptance are impacted by the storage tank's right sizing. The typical catchment (i.e., roof) area and rainfall intensity, the two most important parameters for estimation of optimum storage size for RWHS, vary widely within the country (Khan et al., 2019).

rainwater harvesting systems and securing favorable municipal regulations. This will guarantee everyone has access to clean water.

6 References:

Akvopedia, F. (2020). *Reinforced concrete reservoir*. 6–7.

Behzadian, K., Kapelan, Z., Mousavi, S. J., & Alani, A. (2018). Can smart rainwater harvesting schemes result in the improved performance of integrated urban water systems? *Environmental Science and Pollution Research*, *25*(20), 19271–19282. https://doi.org/10.1007/s11356-017-0546-5

Bottles, P. (2019). Plastic tanks. *Metal Finishing*, *107*(11), 47. https://doi.org/10.1016/s0026-0576(09)80382-6

Boyd, S. P., & Vandenberghe, L. (2017). *Convex optimization*. Cambridge university press.

Buchberger, S., Omaghomi, T., Wolfe, T., Hewitt, J., & Cole, D. (2015). *Peak Water Demand Study*. International Association of Plumbing and Mechanical Officials.

Campisano, A., & Modica, C. (2018). Optimal sizing of storage tanks for domestic rainwater harvesting in Sicily. *Resources, Conservation and Recycling*, *63*, 9–16. https://doi.org/https://doi.org/10.1016/j.resconrec.2012.03.007

Chavan, R. S., Tewari, S., Khedkar, C. D., & Bhatt, S. (2015). World Health Organization. In *Encyclopedia of Food and Health* (1st ed., Issue January). Elsevier Ltd. https://doi.org/10.1016/B978-0-12-384947-2.00761-3

Cheng, C.-L., & Liao, M.-C. (2020). An Evaluation Indicator of Rainwater Harvesting Systems in Northern Taiwan. *Journal of Asian Architecture and Building Engineering*, *8*(1), 229–236. https://doi.org/10.3130/jaabe.8.229

Chun, Y. H. (2019). Multi-attribute sequential decision problem with optimizing and satisficing attributes. *European Journal of Operational Research*, *243*(1), 224–232. https://doi.org/10.1016/j.ejor.2014.11.007

Coombes, P., Dunstan, H., Spinks, A., Evans, C., & Harrison, T. (2016). *Key messages from a decade of water quality research into roof collected rainwater supplies*.

De Césaro Oliveski, R., Krenzinger, A., & Vielmo, H. A. (2017). Comparison between models for the simulation of hot water storage tanks. *Solar Energy*, *75*(2), 121–134. https://doi.org/10.1016/j.solener.2003.07.009

Deegoda, I., Buddika, S., Yapa, H., Navaratnam, S., & Zhang, G. (2023). Review on the Application of Organic Fibers as Substitutes for Asbestos in Thin Fiber Cement Sheets from a Sri Lankan Perspective. *Sustainability*, *15*(13). https://doi.org/10.3390/su151310235

Di Chiano, M. G., Marchioni, M., Raimondi, A., Sanfilippo, U., & Becciu, G. (2023). Probabilistic Approach to Tank Design in Rainwater Harvesting Systems. *Hydrology*, *10*(3). https://doi.org/10.3390/hydrology10030059

Domestic, S., Use, W., Bank, W., & Shadeed, S. (2021). *Optimal Sizing of Rooftop Rainwater Harvesting Tanks for*.

EC, 2002 Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning the quality of bathing water. COM(2002) 581 final. http://europa.eu/eurlex/en/com/pdf/2002/com2002_0581en01.pdf. (2015). *EAP Task Force PROPOSED SYSTEM OF SURFACE WATER QUALITY STANDARDS FOR MOLDOVA: Technical Report*. www.oecd.org/env/eap

Evans, C., Coombes, P., Dunstan, H., & Harrison, T. (2017). Identifying the major influences on the microbial composition of roof harvested rainwater and the implications for water quality. *Water Science and Technology : A Journal of the International Association on Water Pollution Research*, *55*, 245–253. https://doi.org/10.2166/wst.2007.115

Guo, Y., & Baetz, B. W. (2016). Sizing of rainwater storage units for green building applications. *Journal of Hydrologic Engineering*, *12*(2), 197–205.

Hashim, H., Hudzori, A., Yusop, Z., & Ho, W. S. (2017). Simulation based programming for optimization of large-scale rainwater harvesting system: Malaysia case study. *Resources, Conservation and Recycling*, *80*, 1–9.

Hasse, R. (2019). *Rainwater Reservoirs above Ground Structures for Roof Catchment*.

HDPE. (2018). *Blog*. 1–11.

Hoko, Z. (2015). An assessment of the water quality of drinking water in rural districts in Zimbabwe. The case of Gokwe South, Nkayi, Lupane, and Mwenezi districts. *Physics and Chemistry of the Earth, Parts A/B/C*, *30*(11), 859–866. https://doi.org/https://doi.org/10.1016/j.pce.2005.08.031

Jain, S. K. (2019). *Determination of reservoir storage capacity*. 1–10.

joint waterproofing for Watertight Concrete Systems & White Box Concepts. (2019).

Judeh, T., Shahrour, I., & Comair, F. (2022). Smart Rainwater Harvesting for Sustainable Potable Water Supply in Arid and Semi-Arid Areas. *Sustainability (Switzerland)*, *14*(15). https://doi.org/10.3390/su14159271

Khan, S. T., Baksh, A. A., Papon, M. T. I., & Ali, M. A. (2019). Rainwater Harvesting System: An Approach for Optimum Tank Size Design and Assessment of Efficiency. *International Journal of Environmental Science and Development*, *8*(1), 37–43. https://doi.org/10.18178/ijesd.2017.8.1.917

Khan, S. T., Baksh, A. A., Papon, T. I., & Ali, M. A. (2017). *Rainwater Harvesting System : An Approach for Optimum Tank Size Design and Assessment of Efficiency*. *8*(1), 37–43. https://doi.org/10.18178/ijesd.2017.8.1.917

Koul, B., Yadav, D., Singh, S., Kumar, M., & Song, M. (2022). Insights into the Domestic Wastewater Treatment (DWWT) Regimes: A Review. *Water (Switzerland)*, *14*(21). https://doi.org/10.3390/w14213542

Kusumawardhana, A., Zlatanovic, L., Bosch, A., & van der Hoek, J. P. (2021). Microbiological health risk assessment of water conservation strategies: A case study in Amsterdam. *International Journal of Environmental Research and Public Health*, *18*(5), 1–17. https://doi.org/10.3390/ijerph18052595

Ling, M.-P., Hsu, H.-T., Shie, R.-H., Wu, C.-C., & Hong, Y.-S. (2019). Health Risk of Consuming Heavy Metals in Farmed Tilapia in Central Taiwan. *Bulletin of Environmental Contamination and Toxicology*, *83*, 558–564. https://doi.org/10.1007/s00128-009-9829-y

Maurya, A. (2021). *Design of Rainwater Harvesting for a Residential Building in Composite Climate*. *10*(09), 655–685. https://www.ijert.org/design-of-rainwater-harvesting-for-a-residential-

building-in-composite-climate

Mobin, M., Khan, M., Anjum, H., Rahman, H., Marzan, M., & Islam, M. A. (2022). Knowledge, Attitudes, and Practices in Relation to Mosquito-Borne Diseases in Bangladesh. *International Journal of Environmental Research and Public Health*, *19*(14). https://doi.org/10.3390/ijerph19148258

Mosley, L. (2017). Water Quality of Rainwater. *SOPAC Miscellaneous Reports, February*, 1–19.

Mosley, L. (2020). *Water quality of rainwater harvesting systems*. Citeseer.

Motlagh, A. M., & Yang, Z. (2019). Detection and occurrence of indicator organisms and pathogens. *Water Environment Research : A Research Publication of the Water Environment Federation*, *91*(10), 1402–1408. https://doi.org/10.1002/wer.1238

Muklada, H., Gilboa, Y., & Friedler, E. (2018). Stochastic modelling of the hydraulic performance of an onsite rainwater harvesting system in Mediterranean climate. *Water Science and Technology: Water Supply*, *16*(6), 1614–1623.

Ndiritu, J., Moodley, Y., & Guliwe, M. (2017). Generalized storage–yield–reliability relationships for analysing shopping centre rainwater harvesting systems. *Water*, *9*(10), 771.

Nguyen, A.-T., Reiter, S., & Rigo, P. (2014). A review on simulation-based optimization methods applied to building performance analysis. *Applied Energy*, *113*, 1043–1058. https://doi.org/https://doi.org/10.1016/j.apenergy.2013.08.061

Nicoletti, M. (2020). Three scenarios in insect-borne diseases. In *Insect-Borne Diseases in the 21st Century* (pp. 99–251). https://doi.org/10.1016/B978-0-12-818706-7.00005-X

Nnaji, C. C., Emenike, P. C., & Tenebe, I. T. (2019). An Optimization Approach for Assessing the Reliability of Rainwater Harvesting. *Water Resources Management*, *31*(6), 2011–2024. https://doi.org/10.1007/s11269-017-1630-9

Ntale, H. K., & Naturinda, D. N. (2019). *The rainwater harvesting strategy for Uganda The rainwater harvesting strategy for Uganda*.

Oviedo-Ocaña, E. R., Dominguez, I., Ward, S., Rivera-Sanchez, M. L., & Zaraza-Peña, J. M. (2018). Financial feasibility of end-user designed rainwater harvesting and greywater reuse systems for high water use households. *Environmental Science and Pollution Research*, *25*(20), 19200–19216. https://doi.org/10.1007/s11356-017-8710-5

Ph, D., & Te, C. (2014). *Quality of Harvested Rainwater and Application of Point of Use* (Issue March).

Quote, A. (2020). *Blog*. *5000*.

Quote, R. A. (n.d.). *Menu Texas Metal Tanks is proud to manufacture the best looking and highest quality tank for your rainwater or well water storage needs* . 23–25.

Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023). Rainwater Harvesting and Treatment: State of the Art and Perspectives. *Water*, *15*(8). https://doi.org/10.3390/w15081518

Rieradevall, J., Gasol, C. M., Gabarrell, X., Morales-pinzón, T., & Lurue, R. (2015). *Resources , Conservation and Recycling Financial feasibility and environmental analysis of potential rainwater harvesting systems : A case study in Spain*. *69*(2012), 130–140. https://doi.org/10.1016/j.resconrec.2012.09.014

Rodrigues, C., & Cunha, M. Â. (2017). Assessment of the microbiological quality of recreational

waters: indicators and methods. *Euro-Mediterranean Journal for Environmental Integration*, *2*(1), 25. https://doi.org/10.1007/s41207-017-0035-8

Sample, D. J., & Liu, J. (2020). Optimizing rainwater harvesting systems for the dual purposes of water supply and runoff capture. *Journal of Cleaner Production*, *75*, 174–194. https://doi.org/https://doi.org/10.1016/j.jclepro.2014.03.075

Sathya, K., Nagarajan, K., Carlin Geor Malar, G., Rajalakshmi, S., & Raja Lakshmi, P. (2022). A comprehensive review on comparison among effluent treatment methods and modern methods of treatment of industrial wastewater effluent from different sources. *Applied Water Science*, *12*(4), 70. https://doi.org/10.1007/s13201-022-01594-7

Semaan, M., Day, S. D., Garvin, M., Ramakrishnan, N., & Pearce, A. (2020). Optimal sizing of rainwater harvesting systems for domestic water usages: A systematic literature review. *Resources, Conservation and Recycling: X*, *6*(November 2019), 100033. https://doi.org/10.1016/j.rcrx.2020.100033

Simon, H. A. (2018). *Theories of Decision-making in Economics and Behavioral Science, in "American Economic Review", 49*.

Stewart, C., Kim, N. D., Johnston, D. M., & Nayyerloo, M. (2016). Health hazards associated with consumption of roof-collected rainwater in urban areas in emergency situations. *International Journal of Environmental Research and Public Health*, *13*(10). https://doi.org/10.3390/ijerph13101012

Stewart, R. A. (2016). Verifying potable water savings by end use for contemporary residential water supply schemes. *Waterliness Report Series*, *61*.

Stirling, W. C., & Goodrich, M. A. (2016). Satisficing games. *Information Sciences*, *114*(1), 255–280. https://doi.org/https://doi.org/10.1016/S0020-0255(98)10048-8

Stofkova, J., Krejnus, M., Stofkova, K. R., Malega, P., & Binasova, V. (2022). Use of the Analytic Hierarchy Process and Selected Methods in the Managerial Decision-Making Process in the Context of Sustainable Development. *Sustainability (Switzerland)*, *14*(18). https://doi.org/10.3390/su141811546

Storage, C. W. (2022). *What Are Concrete Tanks Used For ? What are some uses for concrete tanks ?* 6–9.

Thomas, T. H., & Martinson, D. B. (2018). *Roofwater harvesting: a handbook for practitioners*. http://www.ircwash.org/resources/roofwater-harvesting-handbook-practitioners

Thomas, T., & Kiggundu, N. (2017). Constraints to domestic roofwater harvesting uptake in Uganda: An assessment. *People-Centred Approaches to Water and Environmental Sanitation: Proceedings of the 30th WEDC Conference*, 450–453.

Toledo, R. D. S., Martins, F. D. C., Ferreira, F. P., de Almeida, J. C., Ogawa, L., Dos Santos, H. L. E. P. L., Dos Santos, M. M., Pinheiro, F. A., Navarro, I. T., Garcia, J. L., & Freire, R. L. (2017). Cryptosporidium spp. and Giardia spp. in feces and water and the associated exposure factors on dairy farms. *PloS One*, *12*(4), e0175311. https://doi.org/10.1371/journal.pone.0175311

Tsihrintzis, V. A., & Baltas, E. (2020). *Determination of rainwater harvesting tank size DETERMINATION OF RAINWATER HARVESTING TANK SIZE*. *October*.

Walter, K. (2023). What Is Lead Poisoning? *Jama*, *329*(12), 1040. https://doi.org/10.1001/jama.2023.1543

Ward, S., Memon, F. A., & Butler, D. (2018). *Rainwater harvesting : model-based design evaluation*.

85–96. https://doi.org/10.2166/wst.2010.783

Wierzbicki, A. P. (2017). A mathematical basis for satisficing decision making. *Mathematical Modelling*, *3*(5), 391–405. https://doi.org/https://doi.org/10.1016/0270-0255(82)90038-0

Zabidi, H. A., Goh, H. W., Chang, C. K., Chan, N. W., & Zakaria, N. A. (2020). A review of roof and pond rainwater harvesting systems for water security: The design, performance and way forward. *Water (Switzerland)*, *12*(11), 1–22. https://doi.org/10.3390/w12113163

Zajaczkowski, P., Mazumdar, S., Conaty, S., Ellis, J. T., & Fletcher-Lartey, S. M. (2018). Epidemiology and associated risk factors of giardiasis in a peri-urban setting in New South Wales Australia. *Epidemiology and Infection*, *147*, e15. https://doi.org/10.1017/S0950268818002637