FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 5, October, 2024, pp 41 - 60
DOI: https://doi.org/10.33003/fjs-2024-0805-2659

DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF A LOW-COST AND SUSTAINABLE HOUSEHOLD WATER TREATMENT SYSTEM

[1]Idi, M. D., [2]Akinmusere, O. K., [3]Akanni, A. O., [4]Bolorunduro, K. A., [5]Olayanju, O. K., [6]Williams Bello, U. P., [7]Abah, J. U. and *[7]Oke, I. A.

[1]Land, Air and Water Consulting Engineers, B105 Ramat Shopping Complex, Maiduguri, Borno State, Nigeria
[2]Department of Civil and Environmental Engineering, Elizade University, Ilara – Mokin, Nigeria
[3]Civil Engineering Department, Federal Polytechnic, Ile- Oluji, Nigeria
[4]Department of Civil Engineering, Federal University, Oye- Ekiti, Ekiti State, Nigeria
[5]Department of Civil Engineering, Redeemer's University, Ede, Nigeria
[6]Federal Ministry of Works and Housing Highway Construction and Rehabilitation Department, Nigeria
[7]Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

*Corresponding authors' email: okeia@oauife.edu.ng

ABSTRACT

This study designed, fabricated and evaluated a household water treatment system (HWTS) with a primary aim of improving access to potable water. Typical turbid water samples were collected from Opa River in Ile-Ife, Nigeria. The collected turbid water samples were subjected to treatment by the fabricated household water treatment system. Effects of selected operational factors on the performance of the system was evaluated and optimized using Taguchi technique. The optimum values of the factors were utilized for the full treatment of typical water samples using the system and similar system available commercially. The performance of the system was based on the ability to remove the pollutant from the turbidity water samples. Cost analysis was conducted for the fabricated household water treatment system and similar types that are commercially available. The study revealed that the performance of the system was between 98.8% and 100 % with an overall performance of 99.5 %. Time of settlement, pore Size of the filter, Concentration Coagulant and Turbidity of the Raw water had impact on the performance of HWTS. Significance of the factors were in-order of pore Size of the filter > time > Concentration Coagulant and > Turbidity of the raw water. It was concluded that the performance of the HWTS was perfect compared with the commercially available filter. The HWTS is economically effective and sustainable (0.0575 US$ per day) compared to commercially available HWTS (0.0639 – 0.1187 US$ per day). There was no significant difference between the performance (individual and overall) of fabricated and commercially available at 99 % confidence level.

Keywords: Sustainable household water treatment system, Potable water, Filtration, Typical surface water, Orthogonal array

INTRODUCTION

Water is a natural available resource of fundamental and great importance, which supports all living things on earth (Binbin et al., 2024; Deng, 2021). Water creates wealth and jobs opportunities through recreation, fisheries, production of potable water and tourism, (Chunwate et al., 2021; Bitew et al., 2018). Water is an essential nutrient that has principally been considered in terms of its physiological essential (Mahal et al., 2019; Bain et al., 2014; Bamisile et al., 2023; Bartram and Cairncross, 2010; Benwic et al., 2018; Binbin et al., 2024; Young et al., 2021; Chunwate et al., 2021; World Health Organization, 2008, 2019; 2017; 2016; 2012; UNICEF and WHO, 2019; 2021; 2022; UNESCO, 2022; 2018; 2019; 2017; UN, 2021; 2019l 2020; Mshelia et al., 2024; Kabiru et al., 2021; Diyammi, 2023; Estévez et al., 2022; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024). A reliable access to clean water in sufficient quantities and quality is also critical for many nutrition-related behaviours and activities (Moe and Rheingans, 2006; Panella, 2020; Miller et al., 2021).

Globally, water security is under severe pressure as a result of a complex of circumstances such as rapid population growth, hydrological conditions, increased per-capita water use, rural–urban migration, over-abstraction of groundwater, pollution of water resources, climate change and variability (Kujinga et al., 2013; Diyammi, 2023; Mutono et al., 2021; Miller et al., 2021; Moe and Rheingans, 2006). In Sub-Saharan Africa, over 51% of its population are lacking access to a safe supply of water and over 41% lacking adequate sanitation (Murray et al., 2020; Mutono, 2022: Luqi et al., 2024; Maes and Preston-Whyte, 2023; Mahal et al., 2019). As a matter of facts water insecurity will continue to have effects on Africa for numerous years to come as it has been projected that by 2025, over 16% of the population in Africa is expected to be subjected to water insecurity (Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023). Global efforts and resolutions to enhance water security by organizations such as the United Nations have yielded little or no positive results (Murray et al., 2020; Mutono, 2022: Luqi et al., 2024; Maes and Preston-Whyte, 2023; Mahal et al., 2019).

Despite all the efforts, policies and programmes by various organisations to improve access to adequate water supply, sanitation and hygiene around the world, there are still more people, which are lacking safe water, adequate sanitation and hygiene due to the presence of water stress (Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Bain et al., 2014; Bamisile et al., 2023; Bartram and Cairncross, 2010; Benwic et al., 2018; Binbin et al., 2024; Panella, 2020; Peter-Varbanets et al., 2009; Ritchie and Roser, 2019; 2021; and 2022; Odetola, 2023; Odwori, 2019 ; Ojomo et al., 2015; Okogwu, et al., 2022; Okoh et al., 2022 ; Omotoye, 2024: Nchor and Ukam, 2024 ; Ngasala et al., 2020; Nientiet, 2013; Clasen et al., 2007; Clasen et al., 2006; Clasen et al., 2007; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024). Figure 1a and b present distributions of water stress around the World. Figure 1c shows the pathway of water security. It is well established that water quality is a critical issue for ecological stability and human well-being. Human activities have increasingly polluted water sources (surface and groundwater), which serves as a vital source of freshwater globally and sustaining various societal sectors. With contaminants, notably heavy metals, which is presenting potential health hazards to communities reliant on these water sources (Mshelia et al.,2024; Bain et al., 2014; Bamisile et al., 2023; Bartram and Cairncross, 2010; Benwic et al., 2018; Binbin et al., 2024; Estévez et al., 2022; Huang et al., 2021).

These activities and presence of heavy metals gave rooms for centralized water treatment and distribution networks in urban and cities worldwide to remove these pollutants. Drinking water from unprotected or untreated sources could transmit waterborne diseases like diarrhea, cholera, dysentery, typhoid, and polio (WHO, 2019; Murray et al., 2020; Ritchie & Roser, 2021; Bartram & Cairncross, 2010; Cairncross et al., 2010). Drinking water from unprotected or untreated sources could transmit waterborne diseases like diarrhea, cholera, dysentery, typhoid, and polio (WHO, 2019; Murray et al., 2020; Ritchie & Roser, 2021; Bartram & Cairncross, 2010; Cairncross et al., 2010). In the rural areas, centralized water treatment systems are very challenging in terms of implementation and significantly increased cost due to the scarce population density and infrastructural complexities in rural areas (Lawrencia et al., 2022; Bain et al., 2014; Bamisile et al., 2023; Bartram and Cairncross, 2010; Benwic et al., 2018; Binbin et al., 2024; Estévez et al., 2022; Huang et al., 2021).

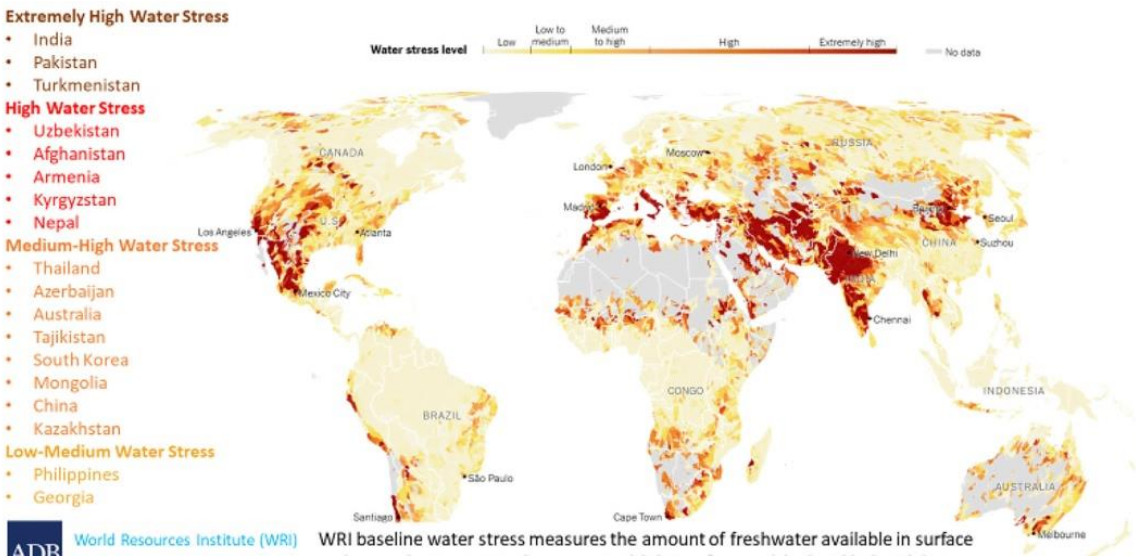

Figure 1a: Some Countries with high baseline Water Stress (Source Panella, 2020)

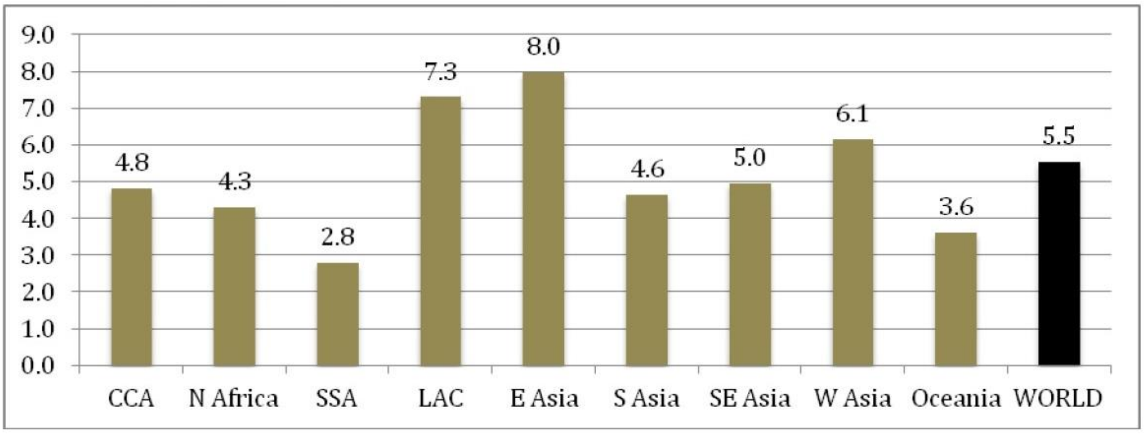

Figure 1b: Benefit- cost ratios of interventions to attain universal access of improved sanitation by region and World (Source: WHO, 2012)

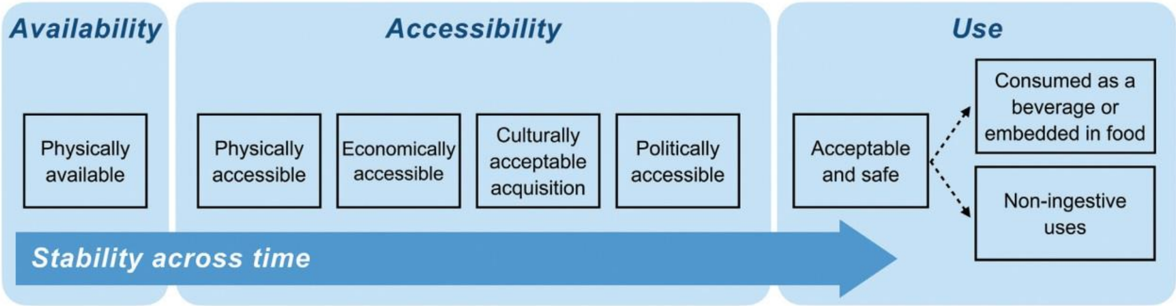

Figure 1c: Primary domains of water security (Source: Miller et al., 2021)

It has been reported that improve access to water supply and sanitation facilities in the developing world has provided a greater costs and economic benefits than any other interventions (Lindley and Davies, 1995; Hutton et al., 2007; Clasen et al., 2007; Mutono, 2022; Diyammi, 2023; Franz et al., 2024; Kelly et al., 2023; Hutton et al., 2007; Fewtrell et al., 2005; Clasen et al., 2007; Clasen et al., 2006; Clasen et al., 2007; Bitew et al., 2018; Boateng et al., 2013; Boguniewicz-Zablocka and Capodaglio, 2017; Brown and Sobsey, 2007; Brown and Sobsey, 2012; Brown et al., 2009). This report reveals and indicates that rural areas lacking centralized water treatment and distribution networks could benefit from adopting decentralized lower cost and safe water treatment systems such as household water treatment system (Bubicha and Mwaura, 2021; Cairncross et al., 2007; Cairncross et al., 2010; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024).

Unlike the centralized water treatment system, which is dependent on the availability of large water resources and huge facilities, decentralized systems are feasible with limited water resources and few facilities which are portable (Bain et al., 2014; Bamisile et al., 2023; Bartram and Cairncross, 2010; Benwic et al., 2018; Binbin et al., 2024; Julianne et al., 2024; Clasen et al., 2007; Clasen et al., 2006; Clasen et al., 2007; Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Bitew et al., 2018; Boateng et al., 2013; Boguniewicz-Zablocka and Capodaglio, 2017; Brown and Sobsey, 2007; Brown and Sobsey, 2012; Brown et al., 2009; Bubicha and Mwaura, 2021; Cairncross et al., 2007; Cairncross et al., 2010). Household water treatment system as a decentralised system is usually known as point-of-use water treatment system, which often provide a more practical and feasible co-existing water provision solution to obtain safe drinking water at home in localities facing intermittent water supply or remote areas, (Peter-Varbanets et al., 2009; WHO, 2017). The household water treatment system is one of the proven cost-effective interventions that has been adopted in many low- and middle-income countries worldwide (Rosa et al., 2016). Household water treatment and handling is an important component of a global strategy to provide safe water to millions of people who live without adequate water currently.

Household water treatment at the point of use also helps to improve drinking water quality for millions who suffer due to contamination of their drinking water (Sisay et al 2022; Dubois et al., 2010; Gebremichael et al., 2021; .Ali et al., 2021; Bitew et al., 2018; Boateng et al., 2013; Boguniewicz-Zablocka and Capodaglio, 2017; Brown and Sobsey, 2007; Brown and Sobsey, 2012; Brown et al., 2009; Bubicha and Mwaura, 2021; Cairncross et al., 2007; Cairncross et al., 2010; Clasen et al., 2006; Clasen, 2015; Clasen, 2010; Clasen, 2019; Clasen et al., 2009; Crider et al., 2023; Crump et al., 2005; Dawuda et al., 2024; Deng, 2021; Wimalawansa, 2018; Wainaina, 2018; Vanderzwaag et al., 2009; Thomas-Possee et al., 2024; 2020; Thomas-Possee, 2023; Stafford and Gately, 2011; Solomon et al., 2020; Sisay et al., 2022; Sobsey et al., 2008; Opryszko et al., 2010;Ritter et al., 2017; Rosa et al., 2021: Legge et al., 2022: Levy et al., 2014;Lincoln et al., 2022: Lindley and Davies, 1995; Du et al., 2018; DuBois et al., 2010; Eticha et al., 2022; Figueroa and Kincaid, 2010; Freeman et al., 2012; Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024) There are various Household water treatment systems such as chlorination, boiling, coagulation and sedimentation, coagulation and filtration (sand, membrane, nanofiltration), disinfection with ultraviolet ray and filtration only. Out of all these household water treatment systems, filtration systems have been frequently adopted based on specific factors such as membrane technologies, as efficient separation techniques, have been widely applied in several areas, especially for water treatment (drinking water and wastewater treatment) including disinfection, distillation or media filtration, membranes have shown significant performances in different applications, the drive to improve the membrane success requires membranes with better materials and performances. The combination of properties such as permeability, selectivity, fouling resistance, chemical and thermal stability, low cost and easy manufacturing should lead to improved characteristics, its simplicity, applicability of the system in the rural areas, cost effective with high performance and availability of materials (Bitew et al., 2018; Boateng et al., 2013; Boguniewicz-Zablocka and Capodaglio, 2017; Brown and Sobsey, 2007; Brown and Sobsey, 2012; Brown et al., 2009; Bubicha and Mwaura, 2021; Cairncross et al., 2007; Cairncross et al., 2010; Clasen et al., 2006; Clasen, 2015; Clasen, 2010; Clasen, 2019; Clasen et al., 2009; Crider et al., 2023; Crump et al., 2005; Dawuda et al., 2024; Deng, 2021; Wimalawansa, 2018; Wainaina, 2018; Vanderzwaag et al., 2009; Thomas-Possee et al., 2024; 2020; Thomas-Possee, 2023; Stafford and Gately, 2011; Solomon et al., 2020; Sisay et al., 2022; Sobsey et al., 2008; Opryszko et al., 2010; Ritter et al., 2017; Rosa et al., 2021: Legge et al., 2022: Levy et al., 2014; Lincoln et al., 2022: Lindley and Davies, 1995; Du et al., 2018; DuBois et al., 2010; Eticha et al., 2022; Figueroa and Kincaid, 2010; Freeman et al., 2012; Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024).

Access to a safely managed water supply is a key part of Sustainable Development Goals (SDGs) 3, 6, 13, 14 and 16, which are associated with increased household consumption of water, improved hygiene practices and lower incidence of diarrhoeal disease. While progress towards SDGs continue to improve globally, this progress is not equitable and some countries currently with less than 95% access to a basic water supply, and some are not on target to reach universal coverage by 2030. An important factor limiting access to safe water is the poor sustained functionality of water supply interventions (Malgorzata et al., 2024; Khan et al., 2024; Xu et al., 2024; Liu and Ma, 2024; Franz et al., 2024;Theodory, 2022; Sánchez et al., 2023; Shaheed et al., 2018: Legge et al., 2022: Levy et al., 2014;Lincoln et al., 2022: Lindley and Davies, 1995; Kowenje et al., 2022; Kumar, 2023; Lalta and Rahul, 2018;Lawrencia et al., 2023;Légaré-Julien et al., 2018; Grady et al., 2015; Gregory et al., 2024; Haushofer et al., 2021; García-Ávila et al., 2023; Gebremichael et al., 2021; Gondo and Kolawole, 2022; Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Abubakar, 2019; Ahmed et al., 2024; Aini et al., 2007; Akinyemi et al., 2018; Alhassan and Dandi, 2022; Ali et al., 2021; An et al., 2014; Awang et al., 2020; Ayuba et al., 2024). With growing challenges to water availability and safety of clean water due to climate change, pollution, and infrastructure degradation, a broader conceptualization of water and its diverse uses of water, there is a need to sustainably achieve global Sustainable Development Goals 3, 6, 13, 14 and 16 (Miller et al. 2021; Kujinga et al., 2013; Dalampira and Nastis, 2019). the factors influencing the permeate quality, membrane performance and their optimization are rarely explained in the literature. A limited number of reported laboratory-scale studies pointed out that the membrane type and material, pore size, pretreatment of feed water, and fouling control methods have affected the permeate quality and membrane performance (Grady et al., 2015; Gregory et al., 2024; Haushofer et al., 2021; García-Ávila et al., 2023; Gebremichael et al., 2021; Gondo and Kolawole, 2022; Chisimkwuo et al., 2024; Kujinga et al., 2014; Chitaka et al., 2023; Asefa et al., 2023; Abubakar, 2019; Ahmed et al., 2024). The key objectives of this study are to design, fabricate a low cost household water treatment system, evaluate its performance in removing selected pollutants, evaluate effects of selected on the performance of the system, optimized the selected factors, examined the performance of the optimum values of the selected factors in the purification of typical surface water and perform cost analysis as a way of sustainably achieve global Sustainable Development Goals.

MATERIALS AND METHODS

Fabrication of A Household Filtration System

A simple filtration water treatment system at household level consisting of raw water tank, polypropylene filter (manufactured by Solex Water Technology with its casing) or membrane and treated water storage tank was sketched, designed and fabricated (Figure 2a and b).

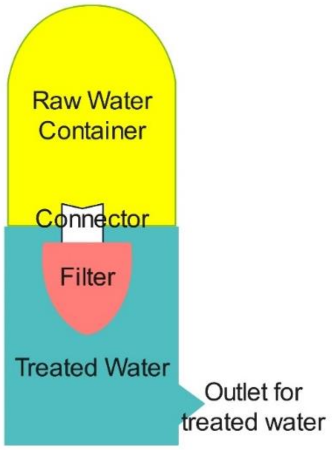

Figure 2a: A sketch of the household system

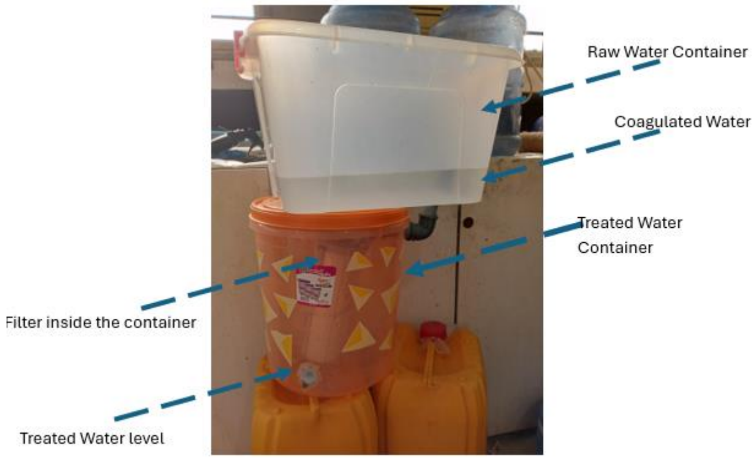

Figure 2b: Front view of the fabricated household water treatment system

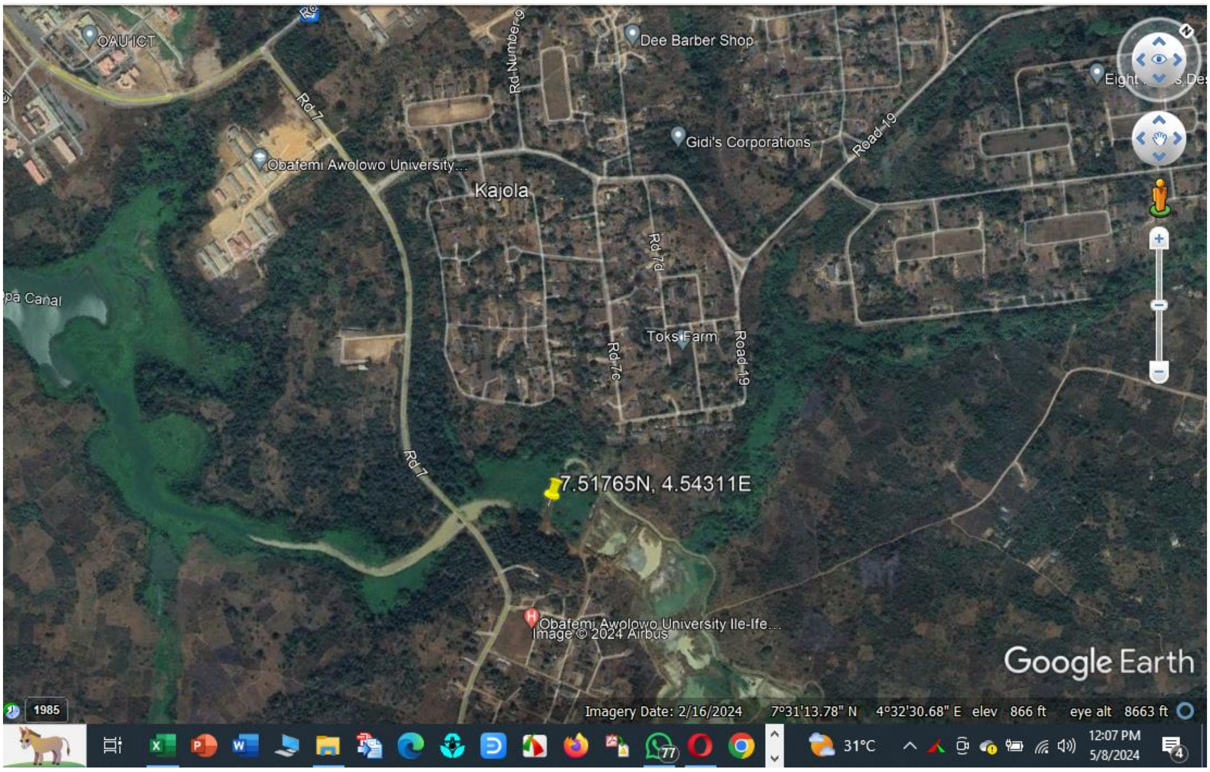

Figure 3: Aerial View of the location (Goggle Earth Pro Map, 2024

Laboratory Scale Treatment and Effects of Selected Factors: Typical turbid water samples were collected from Opa river in Obafemi Awolowo University, Ile-Ife (Figure 3). The collected turbid water samples were subjected to household treatment system fabricated. Effects of selected operational factors (Time (settlement time after addition of coagulant), Pore Size of the filter, Concentration Coagulant and Turbidity of the Raw water) on the performance (ability to remove turbidity of the raw water only) of the system was evaluated using $L_{16}\,4^4$ (Table 1) and analyzed using analysis of variance (ANOVA), mean, standard deviation, skewness and signal noise (SN). These selected operational factors were optimized using Taguchi technique and the optimum values of the factors were utilized for the full treatment of water samples from the same source using the system and similar system available commercially at Jumai online store. The individual and overall performance of the system and similar system were based on ability to remove lead, zinc, cadmium sulphate, colour, turbidity, salinity and chloride, hardness, total solid**,** suspended solids and dissolved solids from the raw water samples.

Laboratory Analysis and Concentration Determination

In the analysis all chemicals and reagents used in this research study had a chemical purity of 95% or above. Distilled water was used in the preparations of primary and secondary standard solutions. All equipment used in the experiments were calibrated and the coefficient of determinations of these calibrations (relationship between expected and obtained values) were 96 % or above. In the calibration and determination of pollutants, standard solutions were prepared utilising procedures and methods specified in the Standard Methods for Water and Wastewater Examination such as APHA (2019) and Van Loosdrecht et al. (2016). In preparation of the standard solution the following chemicals were used turbidity (hydrazine sulphate, $[(NH_2)_2\ H_2SO_4]$ and hexamethylenetetramine, $[(CH_2)_6N_4]$, colour (Potassium chloroplatinate (K_2PtCl_6), Cobaltous chloride ($CoCl_2\ 6H_2O$), Hydrochloric acid (HCl) and Sodium hydroxide (NaOH) as stated APHA (2019).

Table 1: The arrangement of $L_{16}\,4^4$ orthogonal array for the Taguchi Technique

Experiment	Code of Factors and their studying levels				Value of Factors and their studying levels				Performance (%)
	Time (A)	Pore Size of the ceramic filter (B)	Concentration Coagulant (C)	Turbidity of the Raw water (D)	Time (minutes)	Pore Size of the ceramic filter (10^{-6} m)	Concentration Coagulant (mg/l)	Turbidity of the Raw water (NTU)	
1	1	1	1	1	10	0.5	30	500	
2	1	2	2	2	10	1	45	1000	
3	1	3	3	3	10	5	55	1500	
4	1	4	4	4	10	10	60	2000	
5	2	1	2	3	15	0.5	45	1500	
6	2	2	1	4	15	1	30	2000	
7	2	3	4	1	15	5	60	500	

8	2	4	3	2	15	10	55	1000
9	3	1	3	4	20	0.5	55	2000
10	3	2	4	3	20	1	60	1500
11	3	3	1	2	20	5	30	1000
12	3	4	2	1	20	10	45	500
13	4	1	4	2	45	0.5	60	100
14	4	2	3	1	45	1	55	500
15	4	3	2	4	45	5	45	2000
16	4	4	1	3	45	10	30	1500

Performance Evaluation of the Filtration System

The performance of the system was based on ability to remove the pollutant (turbidity) from the water. The performance was computed as follows:

$$P(x) = 100\left(\frac{X_i - X_f}{X_i}\right) \quad (1)$$

Where; X_i is the initial concentration of pollutant (mg/l); X_f is the final concentration (mg/l) and P(x) performance of the system or percentage of the pollutant by the system. Overall efficacy of the system was computed using geometric mean of the system for all the pollutants as follows:

$$P_{all} = \left(\prod_{i=1}^{N} P(x_i)\right)^{\frac{1}{N}} \quad (2)$$

Statistical Computation of Parameters

The choice of this statistical measure as the quality characteristic is analysed based on the need to control both the mean level of the process, and the variation around this mean. The SN is an objective measure that has been used to investigate the statistical properties of factors being experimented on. Mean and standard deviation, skewness and SN were calculated using equations (3 - 6) respectively.

$$\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N} \quad (3)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \overline{X})}{N}} \quad (4)$$

$$\mu = \frac{\sum_{I=1}^{N}(X_i - \overline{X})^3}{(N-1)\sigma^3} \quad (5)$$

$$SN_i = -10\,log\,X_i^2 \quad (6)$$

Computation of Average of the level: The sum and average of various levels of the selected factors were computed using equations (7 to 13) as follows:

$$G_{si} = \sum_{i=1}^{4} R_{si} \quad (7)$$

$$X_{avsi} = 0.25 \times G_{si} \quad (8)$$

Where; G_{si} is the sum of the performance of factor "s" and level "i" ; R_{si} is the performance of factor "s" and level "i and X_{avsi} is the average performance of factor "s" and level "i"

Determination of Effects of the Factors and Computations of Statistical Values

Effects of operational factors (Time, Pore Size of the filter Concentration of the Coagulant and Turbidity of the Raw water) that can influence performance of the system were evaluated using L_{16} 4^4 orthogonal array (Table 1). The effects were analysis using analysis of variance (ANOVA). The total sum of squared deviations (SST) is calculated from the total average SN ratios $(SN)T_{avg}$. as per the following equation

$$SST = \frac{1}{N}\left(\sum_{i=1}^{N}\left(X_i - \overline{X_T}\right)^2\right) \quad (9)$$

Where, X_i is the SN of experiment i; SST is the total sum of squared deviations of SN; N is the number of the experiment and X_T is the overall average of the SN. This total sum of squared deviation, SST, occurs due to the sum of squared deviations due to each control factor (SS_A, SS_B, SS_C, SS_D and SS_E) and the sum of squared deviations due to error, (SS_e) The sum of squared deviation due to the factor is calculated as by

$$SSF_i = \frac{1}{N_j}\sum_{j=1}^{N_j}\left(\overline{X_j} - \overline{X_T}\right)^2 \quad (10)$$

Where: F_i is the factor i (A, B, C, D------------N) X_j is the average of the response of the factor F_i at level j and j is the level of the factor F_i (1, 2, ------------N_j) .

The sum of squared deviation due to the error (SS_e) and degree of freedoms are calculated as by

$$SS_e = SST - SSA - SSB - SSC - - - - SSN \quad (11)$$

$$d_{Tfe} = N - 1 \quad (12)$$

$$d_{Ffe} = N_j - 1 \quad (13)$$

In order to investigate the magnitude of the influence of each factor on the strength and leaching toxicity of solidified soil, the results of the orthogonal test were subjected to an extremum deviation analysis, and the significance of the influence of each factor was reflected by the extremum deviation, Ra, with a larger Ra indicating a more significant influence. Taking the extremum deviation analysis of unconfined compressive strength as an example, the following formula is used to calculate the Ra (Shi et al., 2023):

$$R_a = Kmax - Kmin \quad (14)$$

R_a is the difference between the maximum and minimum values of the average performance at all levels of a factor,

Cost Analysis

Cost analysis, which consist of initial and operational costs was conducted for the fabricated household water treatment system and similar types commercially available. The cost was conducted in local currency (Naira; ₦) and convert to equivalent US Dollar at the rate of one US dollar (US $) equivalent to ₦1500.00 for easy evaluation by international readers. The equivalent cost of similar household filtration units was obtained from the Jumai online store (Figure 4). The detail of the source and initial costs are presented at the appendix.

RESULTS AND DISCUSSION

Performance Evaluation of the Filtration System

Table 2 presents the mean, standard deviation, SN, Skewness and loge of the standard deviation. The table revealed that the average (mean) performance of the system was in the range of 32.03 % and 98.14 % of turbidity removal. The minimum 32.03 % of turbidity removal occurred in experiment number 8 when the time was 15 minutes, pore size of the fibre filter was 10 x 10^{-6} m concentration of the coagulant used was 55 mg/l and the turbidity of the raw water was 1000 NTU. This result established that pore size of the filter was a negative factor for the performance of the household water treatment system, which indicate that the higher the pore size of the filter the lower the efficacy of the household water treatment system. The higher performance 98.14 % of turbidity removal took place at experiment number 14 when the time was 45 minutes, pore size of the fibre filter was 1.0 x 10^{-6} m concentration of the coagulant used was 55 mg/l and the turbidity of the raw water was 500 NTU. This result revealed that treatment time (settlement time after addition of coagulant) was positive factor for the performance of the household water treatment system, which indicate that the higher the settlement time after addition of coagulant the higher the efficacy of the household water treatment system. Experiment numbers 14 and 16 revealed that turbidity of the raw water and concentration of the coagulant were negative factors that reduce and influence the performance of the system. These results from experiments numbers 14 and 16 established that increase in the concentration of the coagulant and turbidity contribute to more pollutants such as dissolved solids, colloidal particles, floating and suspended solids in the raw water to be removed. These observations and results were similar to observations and results in literature such as Okogwu et al. (2022); Odwori (2019); Ngasala et al. (2020); Lawrencia et al. (2023); Kelly et al. (2023); García-Ávila et al. (2023); Eticha et al. (2022); DuBois et al. (2010); Crump et al. (2005); Clasen et al. (2006); Brown et al. (2009). Clasen et al. (2006); Brown and Sobsey (2007); Benwic et al. (2018); Bain et al. (2014); Asefa et al. (2023); An et al. (2014); Alhassan and Dandi (2022); Aini et al. (2007) and Abubakar (2019). The Table revealed that the standard deviation was between 0.357 and 7.248. Skewness were mixture of both positive and negative skewness and SN was between -30.111 and -39.837. Distributions are symmetric when the right side of the distributions are similar to the left side of the distributions and the Skewness value is equivalent to 0 ((normal distribution) This indicates that the median, mean and mode have the same value. When the Skewness is greater than 0, it is right-skewed or that the right tail is longer than the left tail.

When the Skewness is less than 0, then it is left-skewed or that the left tail is longer than the right tail. The results indicate that the experiments have no normal distribution, but rather have both right and left skewed distributions. It has been recommended (Gardiner and Gettinby, 1998) that:

i. Parallel analysis of means and standard deviation (through the natural logarithm of the standard deviation) should be carried out to argue the analysis of SN because SN helps in separating location (differences in the location or point) and dispersion (differences in the dispersion or distribution) effects;
ii. Analysing mean response enables average performance to be assessed, while logarithm of the standard deviation analysis provides information on the performance variability, which are affected by the tested factors; and help in improving residual normality.

The standard deviation from the performance revealed that the variability was at the lowest level. The skewness established that the performance of the household water treatment system was not single sided but rather both sided, which indicate the performance of the household water treatment system was above average. SN values revealed that there is significant performance of the household water treatment system and there is a change in both location and dispersion between the performances (Warton et al., 2011; Tsai and Liao, 2019; Park and Ding, 2021).

Table 2: The performance of the household water treatment system and statistical computations

Experiment	Operational Factors				Performance (%)			Statistical Computations				
	A	B	C	D	1	2	3	Average	SD	Skewness	Ln SD	SN
1	1	1	1	1	85.00	85.89	85.81	86.57	0.492	-1.675	-0.708	-38.747
2	1	2	2	2	90.70	90.84	90.16	91.57	0.357	-1.453	-1.031	-39.235
3	1	3	3	3	63.38	61.46	59.19	62.34	2.099	-0.257	0.741	-35.896
4	1	4	4	4	73.60	67.69	62.29	68.86	5.656	0.137	1.733	-36.759
5	2	1	2	3	81.12	81.82	80.81	83.25	0.519	1.072	-0.657	-38.408
6	2	2	1	4	82.56	82.83	81.48	84.29	0.713	-1.453	-0.338	-38.516
7	2	3	4	1	53.72	53.13	51.10	54.65	1.371	-1.376	0.316	-34.752
8	2	4	3	2	33.5	30.32	26.27	32.03	3.624	-0.355	1.288	-30.111
9	3	1	3	4	90.02	89.13	86.10	91.42	2.057	-1.376	0.721	-39.220
10	3	2	4	3	90.89	86.11	80.04	88.68	5.436	-0.355	1.693	-38.957
11	3	3	1	2	62.78	63.84	62.32	65.98	0.778	1.072	-0.251	-36.388
12	3	4	2	1	79.24	79.65	77.62	81.84	1.070	-1.453	0.068	-38.259
13	4	1	4	2	87.74	88.28	85.59	91.20	1.427	-1.453	0.355	-39.200
14	4	2	3	1	96.88	98.29	96.26	98.14	1.037	1.072	0.036	-39.837
15	4	3	2	4	68.58	62.21	54.12	65.64	7.248	-0.355	1.981	-36.343
16	4	4	1	3	61.18	60.00	55.95	63.04	2.743	-1.376	1.009	-35.993

Figure 4: A Similar household water treatment available online at Jumai inline store

These observations confirmed the essential of Taguchi as stated in literature (Ahmad et al., 2019; Zheng et al., 2017; Valentukeviciene et al., 2019; Shunmugesh and Panneerselvam, 2017; Shukla and Singh, 2017; Sharda and Kumar, 2015; Shanmugaraja and Tharoon, 2018; Nandagopal and Kailasanathan, 2016; Molaei et al., 2017; Kishore et al., 2017; Kiran et al., 2014; Jenarthanan 2017; Gopal and Soorya, 2018; Gardiner and Gettinby, 1998; Derdour et al., 2018; Deepanraj et al., 2017; Segu et al., 2013; Khalifa and Lawal, 2016; Mangal and Sharma, 2018: Lokesh and Mallik, 2017). In summary, the performance established the conclusion and observation on fabricated household water treatment a possible solution is offered by process intensification, substantially shrinking equipment size, a design approach offering concrete benefits in processing and manufacturing, boosting water treatment plant efficiency, saving

Energy and cost, reducing capital costs, minimizing environmental impact, increasing safety, and maximizing the raw materials exploitation (Pendergast and Hoek, 2011; Drioli et al., 2011; Lalia et al., 2013; Zularisam et al., 2006; Ezugbe and Rathilal, 2020).

Effects of Selected Factors and Optimization

Table 3 presents statistical analysis of the effects of the selected factors (time, pore size of the filter concentration of the coagulant and turbidity of the raw water) on the performance and SN of the household water treatment system. The Table revealed that the average performance of the system for treatment time at level 1 was 77.33 % and at level 4 was 79.51 %, which indicates that as the time increases the performance of the system improves making time a positive factor. The average performance of the system when the pore size of the filter was at level 1 was 88.11 % and 61.44 % at level 4, which indicates that this factor reduces and influences the performance negatively meaning that an increase in the pore size reduces the performance. Average performances of the system were 74.97 % and 80.30 % when concentration of the coagulant and turbidity of the raw water were at their lowest level. At the highest levels of the two factors the average performances were 75.85 % and 77.55% which indicates that turbidity of the raw water is a negative factor, which reduces the performance of the system and reverse is the case of the concentration of the coagulant. The values of R_a for the factors were 29.23, 18.42, 9.59 and 10.11, for Pore Size of the ceramic filter (10^{-6} m), settlement time (minutes), Concentration of the Coagulant (mg/l) and initial turbidity of the raw water, respectively. These results indicate that the order of impact of these selected operational factors are Pore Size of the ceramic filter greater than settlement time greater than initial turbidity of the raw water and greater that concentration of the coagulant.

The trends and sequences were the same for SN values. The values of the SN established that pore size of the filter make noise greater (from -38.93 to -33.47) that any other factors, indicates that pore size of the filter is an important factor for the system. Tables 4 and 5 show the results of the ANOVA for the performance and the SN. Table 4 revealed that F-values for these factors (time, pore size of the filter, concentration of the coagulant and turbidity of the raw water) were $F_{3,3} = 2.40$, $F_{3,3} = 8.98$, $F_{3,3} = 0.55$, and $F_{3,3} = 0.67$, respectively based on the performances of the system and $F_{3,3} = 1.78$, $F_{3,3} = 15.29$, $F_{3,3} = 0.18$, and $F_{3,3} = 1.81$, respectively based on the SN (Table 5).

These results established that pore size of the filter is a significant factor that impacts on the performance of the system at 95 % and 97.5 % confidence levels based on the performance of the system and SN, respectively. These results also indicate that filter of lower pore size is the best for the system. The Table and the F-values established that the level of significance is in the order of pore size of the filter greater than time greater than turbidity of the raw water greater than concentration of the coagulant. These results indicate that pore size of the filter and time are two factors that must be considered in the treatment of the surface water using this household treatment system. However, quantity of the treated water should be evaluated in the next studies. Figures 5 and 6 present Taguchi technique of optimization based on the performance of the system and based on SN. Figure 5a presents the effects and optimization of pore size filter using Taguchi technique. The Figure revealed that the pore size filter is a negative factor that influence the performance the system. It was established that the optimum (maximum) pore size of the filter is 5 x 10^{-6} m (Figure 6a), which indicates that the system perform best at pore size below 5 x 10^{-6} m. Figure 5b presents the effects and optimization of dosage using Taguchi technique. The Figure revealed that the dosage of the coagulant is a positive factor that influence the performance the system.

Table 3: Statistical Analysis of the effects of the selected factors on the performance and SN of the household water treatment system

Experiment	A	B	C	D	Average Performance (X, %)	$(X-Av.X)^2$	SN (Y)	$(Y-Av.Y)^2$
1	1	1	1	1	86.57	120.400	-38.59	3.939
2	1	2	2	2	91.57	255.105	-39.15	6.495
3	1	3	3	3	62.34	175.560	-36.04	0.319
4	1	4	4	4	68.86	45.341	-37.34	0.539
5	2	1	2	3	83.25	58.649	-39.19	6.701
6	2	2	1	4	84.29	75.653	-39.33	7.424
7	2	3	4	1	54.65	438.606	-32.81	14.365
8	2	4	3	2	32.03	1897.937	-30.50	37.244
9	3	1	3	4	91.42	250.353	-39.09	6.166
10	3	2	4	3	88.68	171.321	-39.17	6.588
11	3	3	1	2	65.98	92.461	-34.45	4.641
12	3	4	2	1	81.84	38.984	-31.87	22.364
13	4	1	4	2	91.20	243.660	-38.86	5.109
14	4	2	3	1	98.14	508.521	-39.72	9.741
15	4	3	2	4	65.64	99.138	-35.35	1.559
16	4	4	1	3	63.04	157.552	-34.18	5.865
Sum								
Level 1	309.34	352.44	299.88	321.20	-151.12	-155.73	-146.55	-143.00
Level 2	254.22	362.68	322.29	280.78	-141.84	-157.38	-145.57	-142.97
Level 3	327.92	248.61	283.93	297.32	-144.58	-138.66	-145.35	-148.58
Level 4	318.03	245.77	303.40	310.21	-148.13	-133.90	-148.19	-151.11
Average								
Level 1	77.33	88.11	74.97	80.30	-37.78	-38.93	-36.64	-35.75
Level 2	63.56	90.67	80.57	70.19	-35.46	-39.34	-36.39	-35.74
Level 3	81.98	62.15	70.98	74.33	-36.15	-34.66	-36.34	-37.15
Level 4	79.51	61.44	75.85	77.55	-37.03	-33.47	-37.05	-37.78
Maximum	81.98	90.67	80.57	80.30	-35.46	-33.47	-36.34	-35.74
Minimum	63.56	61.44	70.98	70.19	-37.78	-39.34	-37.05	-37.78
Ra	18.42	29.23	9.59	10.11	2.32	5.87	0.71	2.04
			Performance			SN		

Table 4: Results of ANOVA based on Performance

	Time	Pore Size of the Ceramic Filter	Concentration of the Coagulant	Turbidity of the Raw Water	Error	Total
Sum of Square	816.08	3059.65	186.02	226.93	340.56	4629.24
Degree of freedom	3	3	3	3	3	15
Mean Sum of Square	272.03	1019.88	62.01	75.64	113.52	
F-Value	2.40	8.98	0.55	0.67		

Table 5: Results of ANOVA based on SN

	Time	Pore Size of the Ceramic Filter	Concentration of the Coagulant	Turbidity of the Raw Water	Error	Total
Sum of Square	12.34	105.97	1.25	12.57	6.93	139.06
Degree of freedom	3	3	3	3	3	15
Mean Sum of Square	4.11	35.32	0.42	4.19	2.31	
F-Value	1.78	15.29	0.18	1.81		

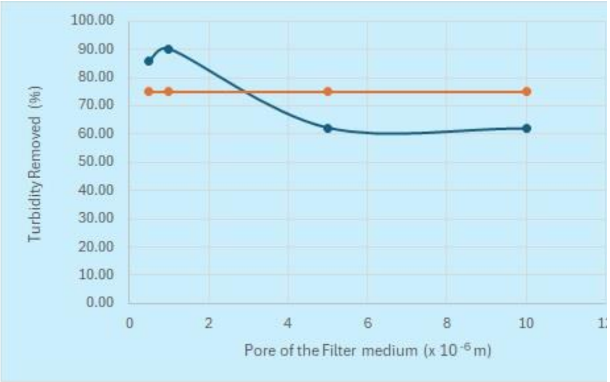

Figure 5a: Effects and optimization of pore size filter using Taguchi technique

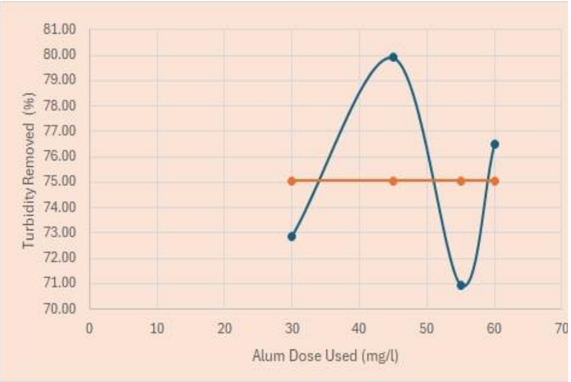

Figure 5b: Effects and optimization of alum dosage using Taguchi technique

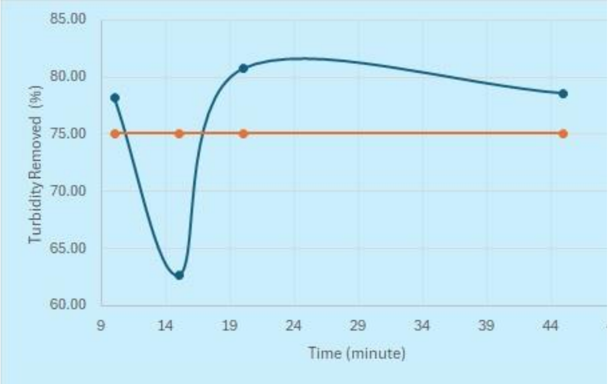

Figure 5c: Effects and optimization of treatment time using Taguchi technique

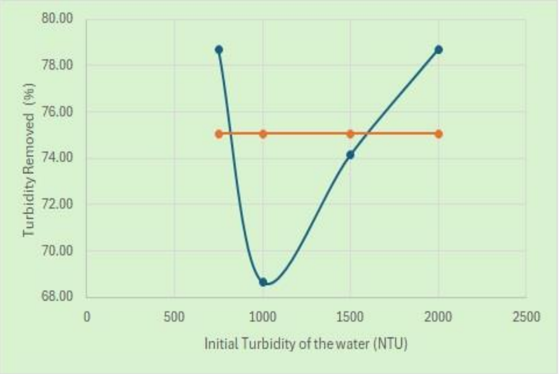

Figure 5d: Effects and optimization of initial turbidity of the raw water using Taguchi technique

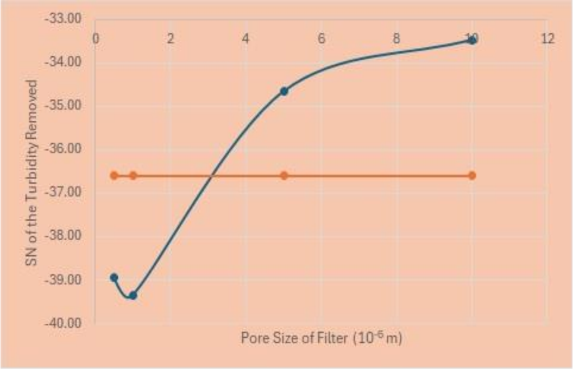

Figure 6a: Effects and optimization of pore size filter using SN technique

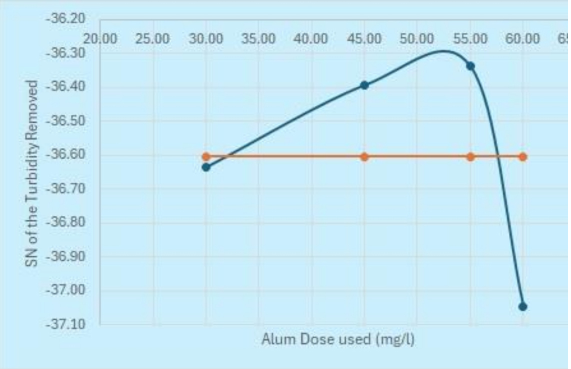

Figure 6b: Effects and optimization of alum dosage using SN technique

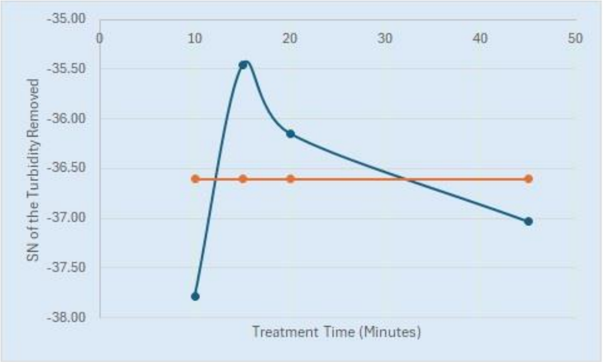

Figure 6c Effects and optimization of treatment time using SN technique

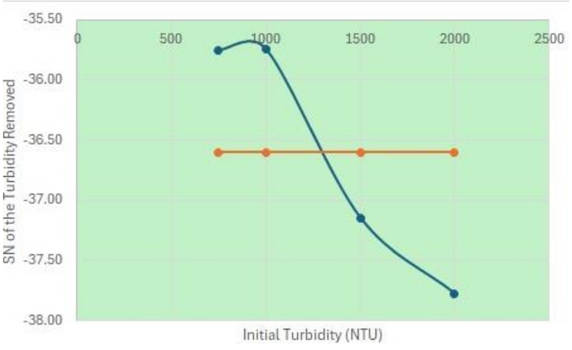

Figure 6d: Effects and optimization of initial turbidity of the raw water using SN technique

Figure 7: The view of the household water treatment plant fabricated

It was established that the optimum (maximum) dosage of the coagulant is 55.0 mg/l (Figure 6b), which indicates that the system perform best at optimum dose of below 55.0 mg/l. Figure 5c presents the effects and optimization of treatment time using Taguchi technique. The Figure revealed that the treatment time is a positive factor that influence the performance the system. It was established that the optimum (minimum) treatment time is 20 minutes (Figure 6c), which indicates that the system perform best at treatment time above minutes. Figure 5d presents the effects and optimization of initial turbidity of the raw water using Taguchi technique. The Figure revealed that the initial turbidity of the raw water is a negative factor that influence the performance the system. It was established that the optimum (minimum) initial turbidity of the raw water is 1500 NTU (Figure 6d), which indicates that the system perform best at initial turbidity of the raw water above 1500 NTU.

Practical Evaluation of the System

Figure 7 presents the view of the household water treatment plant fabricated. Table 6a presents the individual and overall performances of the fabricated household water treatment plant and commercially available household water treatment plant. The Table revealed that the performance of these systems were between and for both individual and overall performance. The overall performance of the fabricated household water treatment plant was 0.9950 while overall performance of the commercially available was between 0.9951 and 0.9952. Statistical evaluation of the performances revealed that there was no significant difference between the performance fabricated household water treatment plant and the performance of commercially household water treatment plant (Table 6b) at a 99 % confidence level. The performance revealed that processes are capable of removing hardness, heavy metals, suspended particles and a number of other organic and inorganic substances in one single treatment step, which agree literature (Gheibi et al., 2023; Ezugbe and Rathilal, 2020; Pendergast and Hoek, 2011; Catia et al., 2022; Zularisam et al., 2006; Dharupaneedi et al., 2018; Lalia et al., 2013; Hube et al., 2020; Tan and Rodrigue, 2019; Castelletto and Boretti, 2021) that microfiltration porous either asymmetric or symmetric are capable to eliminate bacteria, fat, colloids particle, organics, oil and grease, and other micro-particles

Cost Analysis

Table 7 shows the summary of the cost analysis (the detail of the cost analysis is as presented at the appendix). The Table revealed that the cost of filtration units was between 0.0575 US$ per day for locally fabricated unit and 0.1187 US$ per day for commercially available filtration unit based on the 2 years lifespan. Table 9 shows the results of the cost analysis. The Table shows that there was a significant difference between cost of the fabricated household water treatment plant and cost of commercially household water treatment plant at 95 % confidence level.

Table 6a: Individual and overall performance of the system in removing selected pollutants

Serial Number	Water quality Performance	Raw Water	Local	A	B	C	Local	A	B	C
1	Turbidity (NTU)	6500	10	10	10	10	0.998	0.998	0.998	0.998
2	Colour (CU)	400	5	5	5	5	0.999	0.999	0.999	0.999
3	Bacteriological Examination (MPN/100ml)	150	0	0	0	0	1.000	1.000	1.000	1.000
4	Cadmium	0.45	0	0	0	0	1.000	1.000	1.000	1.000
5	Lead	0.68	0	0	0	0	1.000	1.000	1.000	1.000
6	Zinc	2.45	0.42	0.42	0.42	0.42	1.000	1.000	1.000	1.000
7	Suspended Solids	1658.66	0.08	0.06	0.07	0.06	1.000	1.000	1.000	1.000
8	Dissolved solids	168.98	80.2	78.2	78.6	80.6	0.988	0.988	0.988	0.988
9	Total Solid	1827.64	80.28	78.26	78.67	80.66	0.988	0.988	0.988	0.988
10	Hardness	560.78	80.2	80.2	80.2	80.2	0.988	0.988	0.988	0.988
11	Fe	5.78	0.06	0.08	0.04	0.08	1.000	1.000	1.000	1.000
12	Electrical Conductivity(S/cm)	178	101	98	98	97	0.984	0.985	0.985	0.985
13	Salinity(%)	0.01	0	0	0	0	1.000	1.000	1.000	1.000
14	sulphate	68	60	58	58	56	0.991	0.991	0.991	0.991
						Product	0.9375	0.9388	0.9387	0.9385
						Overall	0.9950	0.9952	0.9951	0.9951

Table 6b: ANOVA result of the filtration units

Source of Variation	Sum of Square	Degree of freedom	Mean Sum of Square	F-value	P-value	F critical at 95% confidence level
Between Filtration Units	3.14×10^{-7}	3	1.05×10^{-7}	0.000443	0.999987	4.125892
Within Filtration Units	0.014142	60	0.000236			
Total	0.014142	63				

Table 7: Summary of the cost analysis

Description	Naira (₦)	Dollar	Life Span (Years)	Cost per day (US$)
Locally fabricated	62950.00	41.97	2	0.0575
Rico Water Purifier Filter And Dispenser -(20 Litres)	90000.00	60.00	2	0.0822
Quinix Water Purifier Filter $ Dispenser 20L + Akaline pH Tester	70000.00	46.67	2	0.0639
Quinix Water Purifier Filter And Dispenser - 18L + Akaline pH Tester	71000.00	47.33	2	0.0648
Tiens Water Purifier Filter & Dispenser With Alkaline PH	81000.00	54.00	2	0.0740
Mineral Water Purifier/Filter/dispenser 32Litres	130000.00	86.67	2	0.1187

Table 8: ANOVA of the cost of filtration units

Source of Variation	Sum of Square	Degree of freedom	Mean Sum of Square	F-value	P-value	F critical at 95% confidence level
Between the cost of Filtration Units	2.12×10^{10}	1	2.12×10^{10}	71.4715	7.24×10^{-6}	10.04429
Within the cost of Filtration Units	2.97×10^{9}	10	2.97×10^{8}			
Total	2.42×10^{10}	11				

CONCLUSION

It can be concluded that the overall performance of locally fabricated household filtration unit was 0.995, and cost of 0.0575 US $ per day (₦86.25), compared with 0.1187 US $ per day (₦178.05), which makes it sustainable. Factors that influence the performance of the locally fabricated household filtration system are time and concentration of the coagulant as positive factors, pore size of the filter and turbidity of the raw water as negative factors. The pore size of the filter was a significant factor that influence the performance of the locally fabricated household filtration system. There was no significant difference between the overall performances of the locally fabricated household filtration and commercially available online, there was significant difference between the cost per day of the locally fabricated household filtration and commercially available online. There is a need to evaluated the quantity (volume) of the treated water produced per unit time and factors that influence the quantity of treated water produced per unit time.

ACKNOWLEDGEMENT

The authors wish to acknowledge Temilayo Abidemi Onayemi (CVE/2016/066), Samuel Adedamola Ajayi (CVE/2016/018), Olusola Adisa Owoso (CVE/2016/070), Oluwapelumi Samuel Olatawura (CVE/2016/060), Abdulahi Alao Oladepo (CVE/2017/102), Akinkunmi Oladipo David (CVE/2016/086), Abdulazeez Oriyomi Agunbiade (CVE/2016/016), Sheriff Olamide Adelu (CVE/2016/006), and Soliu Olalekan Abdulrahmon (CVE/2016/001) of Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife for their role in the collection of water samples and preliminary studies of the system

REFERENCES

Abubakar, I. R. (2019). Factors influencing household access to drinking water in Nigeria. Utilities Policy, 58, 40–51. https://doi.org/10.1016/j.jup.2019.03.0

Ahmad, Z., Noma, T., Paek, S., Cho, K. T., Taguchi, D., Iwamoto, M.,Al-Muhtaseb, S. A. (2019). Stability in 3D and 2D/3D hybrid perovskite solar cells studied by EFISHG and IS techniques under light and heat soaking. Organic Electronics, 66, 7–12. https://doi.org/10.1016/j.orgel.2018.12.009

Ahmed, A. O., Abdullahi, M. D., Umar, A., Sani, A. M. and Adamu, A. D. (2024). Performance Evaluation Of Activated Carbon Produced From Corncob, Cow Bone, And Coconut Shell As A Filter Medium FUDMA Journal of Sciences (FJS) Vol. 8 No. 3, June, 2024, pp 226 – 234 https://doi.org/10.33003/fjs-2024-0803-2334

Aini, M. S., Fakhrul-Razi, A., Mumtazah, O., and Chen, J. C. M. (2007). Malaysian households' drinking water practices: A case study. International Journal of Sustainable Development and World Ecology, 14(5), 503–510. https://doi.org/10.1080/13504500709469749

Akinyemi, B. E.,Mushunje, A and . Fashogbon, A. E (2018) Factors explaining household payment for potable water in South Africa, Cogent Social Sciences, 4:1, 1464379, https://doi.org/10.1080/23311886.2018.1464379

Alhassan, E. H., and Dandi, S. O. (2022). Efficiency of Indigenous Water Treatment Methods in Rural Communities in Northern Ghana. In From Traditional to Modern African Water Management: Lessons for the Future (pp. 135-147). Cham: Springer International Publishing.

Ali G, Bashir M.K, Abbas S, and Murtaza M (2021) Drinking-water efficiency, cost of illness, and peri-urban society: An economic household analysis. PLoS ONE 16(9): e0257509. https://doi.org/10.1371/journal.pone.0257509

An Thuan, D. O., Kuroda, K., Hayashi, T., Tran Thi Viet, N. G. A., Oguma, K., and Takizawa, S. (2014). Household survey of installation and treatment efficiency of point-of-use water treatment systems in Hanoi, Vietnam. Journal of Water Supply Research and Technology-AQUA, 63(2), 154–161. https://doi.org/10.2166/aqua.2013.011

APHA,(2019) "Standard Method for the Examination of Water and Wastewater", 23rd edn, America Water Works Association and Water Pollution Control Federation, Washington DC.

Asefa, L., Ashenafi, A., Dhengesu, D., Roba, H., and Lemma, H. (2023). Household water treatment practice and associated factors among rural Kebeles (villages) in west Guji zone, southern Ethiopia: Community based cross-sectional study. Clinical Epidemiology and Global Health, 22, 101311.

Awang, H., Abdullah, P. S., and Abdul Latiff, Z. A. (2020). A preliminary study of local behaviour, perceptions and willingness to pay towards better water quality in Pasir mas, Tanah Merah, and Jeli, Malaysia. In Proceedings of the 2nd International Conference on Tropical Resources and Sustainable Sciences, 10–11 August 2020, Universiti Malaysia Kelantan, City Campus, Malaysia. IOP Conference Series: Earth and Environmental Science, Volume 549.

Ayuba, C. Gwasmen, A., Saliu I. and Umar, J. H. (2024). Mapping Of Flood Risk Zones In Kafanchan Town, Jema'a Local Government Area, Kaduna State, Nigeria FUDMA Journal of Sciences (FJS) Vol. 8 No. 3, June, 2024, pp 147 – 159 https://doi.org/10.33003/fjs-2024-0803-2481

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., and Bartram, J. (2014). Fecal contamination of drinking-water in low- and middle-income countries: A systematic review and meta-analysis. PLoS Medicine, 11(5), e1001644. https://doi.org/10.1371/journal.pmed.1001644

Bamisile, O., Cai, D., Adun, H., Taiwo, M., Li, J., Hu, Y., and Huang, Q. (2023). Geothermal energy prospect for decarbonization, EWF nexus and energy poverty mitigation in East Africa; the role of hydrogen production. *Energy Strategy Reviews*, *49*, 101157.

Bartram, J., and Cairncross, S. (2010). Hygiene, sanitation, and water: Forgotten foundations of health [policy forum]. PLoS Medicine, 7(11),e1000367. https://doi.org/10.1371/journal.pmed.1000367

Benwic, A., Kim, E., Khema, C., Phanna, C., Sophary, P., and Cantwell, R. E. (2018). Factors associated with post-treatment E. coli contamination in households practising water treatment: A study of rural Cambodia. International Journal of Environmental Health Research, 28(2), 178–191. https://doi.org/10.1080/09603123.2018.1453055

Binbin, F., Maolin, Y., Zhilong, Y., Haiyun, Z., Peitao, Z., Wu, Z., and Yan, D. (2024) Hydrothermal Dechlorination of Polyvinyl Chloride in Plastic Mixtures: Generation of Environmentally Benign Precursors Environmental Engineering Science 2024 41:7, 278-287

Bitew, B. D., Gete, Y. K., Biks, G. A., and Adafrie, T. T. (2018). The effect of SODIS water treatment intervention at the household level in reducing diarrheal incidence among children under 5 years of age: a cluster randomized controlled trial in Dabat district, northwest Ethiopia. *Trials*, *19*, 1-15.

Boateng, D., Tia-Adjei, M., and Adams, E. A. (2013). Determinants of household water quality in the Tamale Metropolis, Ghana. *Journal of Environment and Earth Science*, *3*(7), 70-77.

Boguniewicz-Zablocka, J., and Capodaglio, A. G. (2017). Sustainable wastewater treatment solutions for rural communities: Public (central-ized) or individual (on-site)—Case study. Economic and Environmental Studies, 17(44), 1103–1119. https://doi.org/10.25167/ees.2017. 44.29

Brown, J., and Sobsey, M. (2007). Improving Household Drinking Water Quality: Use of Ceramic Water Filters in Cambodia (41024).WSP Field Notes, Issue. UNICEF Retrieved from https://documents1.worldbank.org/curated/en/211941468216599631/pdf/410240KH0ceramic0filters01PUBLIC1.pdf

Brown, J., and Sobsey, M. D. (2012). Boiling as household water treatment in Cambodia: A longitudinal study of boiling practice and microbiological effectiveness. The American Journal of Ropical Medicine and Hygiene, 87(3), 394–398. https://doi.org/10. 4269/ajtmh.2012.11-0715

Brown, J., Proum, S., and Sobsey, M. D. (2009). Sustained use of a household-scale water filtration device in rural Cambodia. Journal of Water and Health, 7(3), 404–412. https://doi.org/10.2166/wh.2009.085

Bubicha, M. J., and Mwaura, F. (2021). Characterization and monetization of Mount Marsabit ecosystem watershed services, Marsabit County, Kenya. East African Journal of Science, Technology and Innovation, 2(3).

Cairncross, S., Cumming, O., Jeandron, A., Rheingans, R., Ensink, J., Brown, J. and Amery, J. (2007). DFID evidence paper: water, sanitation and hygiene. *Department for International Development, London, UK*.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C., and Schmidt, W.-P. (2010). Water, sanitation and hygiene for the prevention of diarrhoea. International Journal of Epidemiology, 39(suppl_1), i193–i205. https://doi.org/10.1093/ije/dyq035

Castelletto, S., and Boretti, A. (2021). Advantages, limitations, and future suggestions in studying graphene-based desalination membranes. *RSC advances*, *11*(14), 7981-8002.

Catia, A.i, Valerio, P., Gerardo, C., Stefano, C., Vincenza, C., and Sudip, C.,(2022) Arsenic removal from groundwater by membrane technology: Advantages, disadvantages, and effect on human health, Groundwater for Sustainable Development, 19, 2022, https://doi.org/10.1016/j.gsd.2022.100815.

Chisimkwuo J., Pokalas P. -D T, Tal M. P. and Ohakwe J. (2024). A New Inverse Two-Parameter Lindley Distribution And Its Application. FUDMA Journal of Sciences (FJS) Vol. 8 No. 3, June, 2024, pp 214 – 218 https://doi.org/10.33003/fjs-2024-0803-2333

Chitaka, T. Y., Onianwa, P. C., and Nel, H. A. (2023). Marine litter sources and distribution pathways. The African Marine Litter Outlook, 35.

Chunwate, B.T, Madaki, R.B. and Kabiru, M.D (2021). Access to Pipe-Born Water Evaluation in Akwanga Local Government Area of Nasarawa State, Nigeria. Journal of Geography, Environment and Earth Science International. 25(8): 1-9.

Clasen T, Brown J, and Collin S (2006). Preventing diarrhoea with household ceramic water filters: assessment of a pilot project in Bolivia. International Journal of Environmental Health Research, 16(3):221–239.

Clasen, T. (2015). Household water treatment and safe storage to prevent diarrheal disease in developing countries. Current Environmental Health Reports, 2(1), 69–74. https://doi.org/10.1007/s40572-014-0033-9

Clasen, T. F. (2010). Household Water Treatment and the Millennium Development Goals: Keeping the Focus on Health. Environmental Science and Technology, 44(19), 7357–7360.

Clasen, T. F. (2019). Household Water Treatment And Safe. *Water and Sanitation-Related Diseases and the Changing Environment: Challenges, Interventions, and Preventive Measures*, 199.

Clasen, T., Bartram, J., Colford, J., Luby, S., Quick, R., and Sobsey, M. (2009). Comment on “household water treatment in poor populations: Is there enough evidence for scaling up now?” [correspondence/rebuttal]. Environmental Science and Technology, 43(14), 5542–5544. https://doi.org/10.1021/es9008147

Clasen, T., Haller, L., Walker, D., Bartram, J., and Cairncross, S. (2007). Cost-effectiveness of water quality interventions for preventing diarrhoeal disease in developing countries. *Journal of water and health*, *5*(4), 599-608.

Clasen, T., Nadakatti, S., and Menon, S. (2006). Microbiological performance of a water treatment unit designed for household use in developing countries. Tropical Medicine and International Health, 11(9), 1399–1405. https://doi.org/10.1111/j.1365-3156.2006.01699.x

Clasen, T., Schmidt, W.-P., Rabie, T., Roberts, I., and Cairncross, S. (2007). Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. BMJ, 334(7597), 782. doi:10.1136/bmj.39118.489931.be

Crider, Y. S., Tsuchiya, M., Mukundwa, M., Ray, I., and Pickering, A. J. (2023). Adoption of point-of-use chlorination for household drinking water treatment: a systematic review. *Environmental health perspectives*, *131*(1), 016001.

Crump, J. A., Otieno, P. O., Slutsker, L., Keswick, B. H., Rosen, D. H., Hoekstra, R. M., and Luby, S. P. (2005). Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhoea in areas with turbid source water in rural western Kenya: cluster randomised controlled trial. *Bmj*, *331*(7515), 478.

Dalampira, E. and Nastis, S.A (2019) “Mapping Sustainable Development Goals: A network analysis framework”. Sustainable Development 2019, 1–10

Dawuda, K. D., Adakole, J. A., Auta, J. and Japhet, W. S. (2024). Spatio-Temporal Evaluation Of Feroro Stream Water Quality, Chikun Local Government Area Of Kaduna State, Nigeria FUDMA Journal of Sciences (FJS). . 8 (3), 6 - 17 https://doi.org/10.33003/fjs-2024-0803-2452

Deepanraj, B., Sivasubramanian, V., and Jayaraj, S. (2017). Multi-response optimization of process parameters in biogas production from food waste using Taguchi – Grey relational analysis. Energy Conversion and Management, 141, 429–438.

Deng, Y. (2021). Making waves: Principles for the design of sustainable household water treatment. Water Research, 198, 117151. https://doi.org/10.1016/j.watres.2021.117151

Derdour, F. Z., Kezzar, M., and Khochmane, L. (2018). Optimization of penetration rate in rotary percussive drilling using two techniques: Taguchi analysis and response surface methodology (RMS). Powder Technology. https://doi.org/10.1016/j.powtec.2018.08.030

Dharupaneedi, S. P., Kotrappanavar Nataraj, S., Nadagouda, M., Raghava Reddy, K., Shukla, S. S., and Aminabhavi, T. M. (2018). Membrane-based Separation of Potential Emerging Pollutants. Separation and Purification Technology. https://doi.org/10.1016/j.seppur.2018.09.003

Diyammi, M. P. (2023) The assessment of community participation on the management of water supply project in Tanzania: A case of Kwimba District in Mwanza region. Journal of Sociology and Development, Vol. 5, No. 1

Drioli, E., Stankiewicz, A. I., and Macedonio, F. (2011). Membrane engineering in process intensification—An overview. Journal of Membrane Science, 380(1-2), 1–8. https://doi.org/10.1016/j.memsci.2011.06.043

Du, W., Cohen, A., Shen, G., Ru, M., Shen, H., and Tao, S. (2018). Fuel use trends for boiling water in rural China (1992–2012) and environmental health implications: A National Cross-Sectional Study. Environmental Science and Technology, 52(21), 12886–12894. https://doi.org/10.1021/acs.est.8b02389

DuBois, A. E., Crump, J. A., Keswick, B. H., Slutsker, L., Quick, R. E., Vulule, J. M., and Luby, S. P. (2010). Determinants of use of household-level water chlorination products in rural Kenya, 2003–2005. *International Journal of Environmental Research and Public Health*, *7*(10), 3842-3852.

Estévez, S., Gonz alez-García, S., Feijoo, G., and Moreira, M. T. (2022). How decentralized treatment can contribute to the symbiosis between environmental protection and resource recovery. Science of the Total Environment, 812, 151485. https://doi.org/10.1016/j.scitotenv.2021.151485

Eticha, M., Geremew, A., Dirirsa, G., Bayu, K., Girma, H., and Mengistu, D. A. (2022). Household water treatment practice and associated factors among households dependent on unimproved water sources in Ameya district, Oromia, Ethiopia. *Journal of Water, Sanitation and Hygiene for Development*, *12*(5), 432-442.

Eykens, L., De Sitter, K., Dotremont, C., Pinoy, L., and Van der Bruggen, B. (2017). *Membrane synthesis for membrane* *distillation: A review. Separation and Purification Technology, 182, 36–51.* https://doi.org/10.1016/j.seppur.2017.03.035

Ezugbe, O. E., & Rathilal, S. (2020). Membrane technologies in wastewater treatment: a review. *Membranes*, *10*(5), 89.
Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., and Colford, J. M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet infectious diseases*, *5*(1), 42-52.

Figueroa M.E., and Kincaid D.L. (2010). Social, Cultural and Behavioral Correlates of Household Water Treatment and Storage. Center Publication HCI 2010-1: Health Communication Insights, Baltimore: Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs.

Franz Zirena V., Tatiana E. L. P., Oscar D. Vera L., Leonardo V. Junqueira, N. Cahui G., Reynaldo S. Leon, I. Maldonado, C. Nely C. Q., and Valdemar L. T. (2024) Antibiotic Ciprofloxacin in Irrigation Water: Its Effect on Medicago sativa (Alfalfa), Including Carbon Fixation and Root Growth Environmental Engineering Science 2024 41:7, 271-277

Freeman MC, Trinies V, Boisson S, Mak G, and Clasen T (2012) Promoting Household Water Treatment through Women's Self Help Groups in Rural India: Assessing Impact on Drinking Water Quality and Equity. PLoS ONE 7(9): e44068. https://doi.org/10.1371/journal.pone.0044068

García-Ávila, F., Cabello-Torres, R., Iglesias-Abad, S., García-Mera, G., García-Uzca, C., Valdiviezo-Gonzales, L., and Donoso-Moscoso, S. (2023). Cleaner production and drinking water: Perspectives from a scientometric and systematic analysis for a sustainable performance. South African Journal of Chemical Engineering, 45(1), 136-148.

Gardiner, W. P. and Gettinby, G. (1998). Experimental Design Techniques in Statistical Practice, 2nd edn, Harwood Publishing, Chichester.

Gebremichael, S. G., Yismaw, E., Tsegaw, B. D., and Shibeshi, A. D. (2021). Determinants of water source use, quality of water, sanitation and hygiene perceptions among urban households in North-West Ethiopia: A cross-sectional study. Plos one, 16(4), e0239502.

Gheibi, M., Chahkandi, B., Behzadian, K., Akrami, M., and Moezzi, R. (2023). Evaluation of ceramic water filters' performance and analysis of managerial insights by SWOT matrix. *Environmental Industry Letters*, *1*(1), 1-9.

Gondo, R., and Kolawole, O. D. (2022). Household water access and COVID-19 in Karoi town, Zimbabwe. Scientific African, 16, e01145.

Gopal, P. M., and Soorya Prakash, K. (2018). Minimization of cutting force, temperature and surface roughness through GRA, TOPSIS and Taguchi techniques in end milling of Mg hybrid MMC. Measurement, 116, 178–192. https://doi.org/10.1016/j.measurement.2017.11.011

Grady, C. A., Kipkorir, E. C., Nguyen, K., and Blatchley, E. R. (2015). Microbial quality of improved drinking water sources: Evidence from western Kenya and southern Vietnam. Journal of Water and Health, 13(2), 607–612. https://doi.org/10.2166/wh.2014.206

Gregory E. Onaiwu and Ayidu, N. J. (2024) Advancements And Innovations In Pm2.5 Monitoring: A Comprehensive Review Of Emerging Technologies FUDMA Journal of Sciences (FJS) Vol. 8 No. 3, June, 2024, pp 243 – 255 https://doi.org/10.33003/fjs-2024-0803-2505

Haushofer, J., Kremer, M., Maertens, R., and Tan, B. J. (2021). *Water treatment and child mortality: Evidence from kenya* (No. w29447). National Bureau of Economic Research.

Hou D, Xu M, Wang M, Li X, Li S, Wang J and Cao M (2024), Research on ecological restoration and green reclamation technology of goaf in phosphorus mines. Front. Environ. Sci. 12:1343185. doi: 10.3389/fenvs.2024.1343185

Huang, Y., Li, P., Li, H., Zhang, B., and He, Y. (2021). To centralize or to decentralize? A systematic framework for optimizing rural wastewater treatment planning. Journal of Environmental Management, 300, 113673. https://doi.org/10.1016/j.jenvman.2021.113673

Hube, S., Eskafi, M., Hrafnkelsdóttir, K. F., Bjarnadóttir, B., Bjarnadóttir, M. Á., Axelsdóttir, S., and Wu, B. (2020). Direct membrane filtration for wastewater treatment and resource recovery: A review. Science of The Total Environment, 710, 136375. https://doi.org/10.1016/j.scitotenv.2019.136

Hutton G, Haller L, and Bartram J.(2007). Global cost-benefit analysis of water supply and sanitation interventions. J Water Health. 2007 Dec;5(4):481-502. https://doi.org/10.2166/wh.2007.009 . PMID: 17878562 .

Jenarthanan, M. P., Gokulakrishnan, R., Jagannaath, B., and Ganesh Raj, P. (2017). Multi-objective optimization in end milling of GFRP composites using Taguchi techniques with principal component analysis. Multidiscipline Modeling in Materials and Structures, 13(1), 58–70. doi:10.1108/mmms-02-2016-0007

Julianne N. A., Daniel E. G., Yuan Y., and Tessa L. (2024) Confluence of Sustainability and Academic Conferencing: An Environmental Life Cycle Assessment of the 2022 AEESP Conference Environmental Engineering Science 2024 41:7, 261-270

Kabiru, M. D., Madaki, R. B., and Chunwate, B. T. (2021). Access to Pipe-Born Water Evaluation in Akwanga Local Government Area of Nasarawa State, Nigeria. Journal of Geography, Environment and Earth Science International, 25(8), 1-9.

Kelly, J., Tsilahatsy, M., Carnot, T., Fidelos, R. W., Randriamanampy, G., Charlier, A. Z., . and Legge, H. (2023). Low-cost domestic rainwater harvesting in rural southeast Madagascar: A process and outcome evaluation. PLOS Water, 2(10), e0000053.

Khalifa, A. E., and Lawal, D. U. (2016). Application of response surface and Taguchi optimization techniques to air gap membrane distillation for water desalination—A comparative study. Desalination and Water Treatment, 57(59), 28513–28530. https://doi.org/10.1080/19443994.2016.1189850

Khan S, Kamal M, Noor S and Afzal S.M (2024), Assessment of heavy metals and its treatment through phytoremediation in groundwater along River Kabul in district Charsadda. Front. Environ. Sci. 12:1392892. https://doi.org/10.3389/fenvs.2024.1392892

Kiran, T. S., Prasanna K., M., Basavarajappa, S., and Viswanatha, B. M. (2014). Dry sliding wear behavior of heat treated hybrid metal matrix composite using Taguchi techniques. Materials and Design, 63, 294–304. https://doi.org/10.1016/j.matdes.2014.06.007

Kishore, R. A., Sanghadasa, M., and Priya, S. (2017). Optimization of segmented thermoelectric generator using Taguchi and ANOVA techniques. Scientific Reports, 7(1). https://doi.org/10.1038/s41598-017-16372-8

Kowenje, C., Haarstrick, A., Biswick, T., Ajeagah, G., Ojwach, S., Odeku, O. A., and Baba, G. (Eds.). (2022). *From Traditional to Modern African Water Management: Lessons for the Future*. Springer International Publishing.

Kujinga, K., Vanderpost, C., Mmopelwa, G., and Wolski, P. (2014). *An analysis of factors contributing to household water security problems and threats in different settlement categories of Ngamiland, Botswana. Physics and Chemistry of the Earth, Parts A/B/C, 67-69, 187–201.* https://doi.org/10.1016/j.pce.2013.09.012

Kumar, A. (2023). Water Accessibility and Contamination in Rural India: A Comprehensive Analysis of Population Coverage, Water Supply Schemes and Water Quality. Journal of Rural and Industrial Development, 11(2).

Lalia, B. S., Kochkodan, V., Hashaikeh, R., and Hilal, N. (2013). *A review on membrane fabrication: Structure, properties and performance relationship. Desalination, 326, 77–95.* https://doi.org/10.1016/j.desal.2013.06.016

Lalta, P., and Rahul, K. (2018). Study on Breaking Load of Single Lap Joint Using Hybrid Joining Techniques for Alloy Steel AISI 4140 and Mild Steel: Taguchi and Neural Network Approach. Strojnícky Casopis – Journal of Mechanical Engineering, 68(1), 51–60. https://doi.org/10.2478/scjme-2018-0005

Lawrencia, D., Maniam, G., Chuah, L. H., and Poh, P. E. (2023). Critical review of household water treatment in Southeast Asian countries. WIREs Water, 10(4), e1640. https://doi.org/10.1002/wat2.1640

Légaré-Julien, F., Lemay, O., Vallée-Godbout, U., Bouchard, C., and Dorea, C. C. (2018). Laboratory efficacy and disinfection by-product formation of a coagulant/disinfectant tablet for point-of-use water treatment. *Water*, *10*(11), 1567.

Legge, H., Fedele, S., Preusser, F., Stys, P., Muzuri, P., Schuberth, M., and Dreibelbis, R. (2022). Urban water access and use in the Kivus: evaluating behavioural outcomes following an integrated WASH intervention in Goma and Bukavu, Democratic Republic of Congo. International Journal of Environmental Research and Public Health, 19(3), 1065.

Levy, K, Anderson, L, Robb, K.A, Cevallos, W, Trueba, G, and Eisenber,g J.N. (2014).Household effectiveness vs. laboratory efficacy of point-of-use chlorination. Water Res. 2014 May 1;54:69-77. https://doi.org/10.1016/j.watres.2014.01.037. Epub 2014 Jan 31. PMID: 24561887; PMCID: PMC3975601.

Lincoln, S., Andrews, B., Birchenough, S. N., Chowdhury, P., Engelhard, G. H., Harrod, O., . and Townhill, B. L. (2022). Marine litter and climate change: Inextricably connected threats to the world's oceans. *Science of The Total Environment*, *837*, 155709.

Lindley, E., and Davies, S. E. (1995). Cost-Effective Water-Quality Modelling of Potable Water Distribution Systems. Water and Environment Journal, 9(5), 470–476. https://doi.org/10.1111/j.1747-6593.1995.tb01485.x

Liu K and Ma F (2024), The impact of the digital economy on environmental pollution: a perspective on collaborative governance between government and Public. Front. Environ. Sci. 12:1435714. https://doi.org/10.3389/fenvs.2024.1435714

Lokesh, T., and Mallik, U. S. (2017). Dry sliding wear behavior of Al/Gr/SiC hybrid metal matrix composites by Taguchi techniques. Materials Today: Proceedings, 4(10), 11175–11180. https://doi.org/10.1016/j.matpr.2017.08.084

Luqi M., Zhixin G., Yetong L., Boyan L., Qingqing H., Lijie Z., Xu Q., and Yuebing S. (2024)Inhibition of Cadmium Accumulation in Wheat Shoots by Propineb Fungicide Application Environmental Engineering Science 2024 41:7, 288-295

Maes, T., and Preston-Whyte, F. (2023). *The African Marine Litter Outlook* (p. 224). Springer Nature.

Mahal, M. H., Thamer, H. A., Mohammed, H. E., Hassen, O. A., and Hassan, M. A. (2019). Effect of Non-filtered Drinking Water on Some of the Kidney Functions Compared to Filtered Water in Some People in Bishan Village. *Indian Journal of Public Health*, *10*(11), 3355.

Małgorzata S., Wojciech A., Danuta S., Daniel K., Żaneta P., Sylwia F.-K., Aneta L.,(2024). Drinking water safety evaluation in the selected sub-Saharan African countries: A case study of Madagascar, Uganda and Rwanda, Science of The Total Environment,947, https://doi.org/10.1016/j.scitotenv.2024.174496.

Mangal, S. K., and Sharma, V. (2018). Optimization of MR fluid Yield stress using Taguchi Method and Response Surface Methodology Techniques. IOP Conference Series: Materials Science and Engineering, 310, 012008. https://doi.org/10.1088/1757-899x/310/1/012008

Miller, J. D., Workman, C. L., Panchang, S. V., Sneegas, G., Adams, E. A., Young, S. L., and Thompson, A. L. (2021). Water security and nutrition: current knowledge and research opportunities. Advances in Nutrition, 12(6), 2525-2539.

Moe C L, and Rheingans R D.(2006) Global challenges in water, sanitation and health. J Water Health. 2006;4 Suppl 1:41-57. PMID: 16493899.

Molaei, N., Razavi, H., and Chehreh Chelgani, S. (2017). Designing different beneficiation techniques by Taguchi method for upgrading Mehdi-Abad white barite ore.

Mineral Processing and Extractive Metallurgy Review, 39(3), 198–201. https://doi.org/10.1080/08827508.2017.1399889

Mshelia Y. M., Mbursa A. and Abah B. (2024). Assessment Of Heavy Metal Contamination And Health Risk Associated With Selected Borehole Water Proximal To A Dumpsite In Giwo, Bauchi State. FUDMA Journal of Sciences (FJS) Vol. 8 No. 3, June, 2024, pp 66 – 70. https://doi.org/10.33003/fjs-2024-0803-2318

Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abegaz, K. H., Abolhassani, H., Aboyans, V., Abreu, L. G., Abrigo, M. R. M., Abualhasan, A., Abu-Raddad, L. J., Abushouk, A. I., Adabi, M., and Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990-2019: A systematic analysis for the global burden of disease study 2019. The Lancet, 396(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2

Mutono, N. (2022). Urban Water Demand, Supply and Health Outcomes in Nairobi County, Kenya (Doctoral dissertation, University of Nairobi).

Mutono, N., Wright, J. A., Mutembei, H., Muema, J., Thomas, M. L., Mutunga, M., and Thumbi, S. M. (2021). The nexus between improved water supply and water-borne diseases in urban areas in Africa: a scoping review. AAS Open Research, 4.

Nandagopal, K., and Kailasanathan, C. (2016). Analysis of mechanical properties and optimization of gas tungsten Arc welding (GTAW) parameters on dissimilar metal titanium (6Al 4V) and aluminium 7075 by Taguchi and ANOVA techniques. Journal of Alloys and Compounds, 682, 503–516. https://doi.org/10.1016/j.jallcom.2016.05.00

Nchor, J. U., and Ukam, L. E. (2024). Decreasing Access to Water and Coping Strategies for Shortage in the Informal Settlements of Calabar, Nigeria. Sustainability, 16(11), 4603.

Ngasala, T. M., Masten, S. J., Cohen, C., Ravitz, D., and Mwita, E. J. (2020). Implementation of point-of-use water treatment methods in a rural Tanzanian community: A case study. Journal of Water, Sanitation, and Hygiene for Development, 10(4), 1012–1018. https://doi.org/10.2166/washdev.2020.141

Nientiet, S. (2013). Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a human rights based approach and their applicability in camps for displaced populations.

Odetola, L. O. (2023). Water Quality Perceptions and Water-Related Practices Among African Refugee Women: A Qualitative Study. The University of North Carolina at Greensboro.

Odwori, E. O. (2019). Assessment of Point of Use Household Water Treatment Technologies in Nzoia River Basin, Kenya. *International Research Journal of Advanced Engineering and Science*, *4*(3), 478-486.

Ojomo, E., Elliott, M., Goodyear, L., Forson, M., and Bartram, J. (2015). Sustainability and scale-up of household water treatment and safe storage practices: Enablers and barriers to effective implementation. International Journal of Hygiene and Environmental Health, 218(8), 704–713.

Okogwu, O. I., Elebe, F. A., and Nwonumara, G. N. (2022). An efficient low-cost–low-technology whole-household water collection and treatment system. Water Supply, 22(2), 1327-1336.

Okoh, E. O., Envuladu, E. A., Miner, C. A., Mohammed, A., Ode, G. N., and Zoakah, A. I. A Comparative Study on the Effect of Household Water Treatment on Diarrhoea Morbidity among Under-Fives in Plateau State, Nigeria Using Two Treatment Modalities.

Omotoye, E. (2024). A Short Article on Marine Litter: From Land to Sea.

Opryszko, M. C., Majeed, S. W., Hansen, P. M., Myers, J. A., Baba, D., Thompson, R. E., and Burnham, G. (2010). Water and hygiene interventions to reduce diarrhoea in rural Afghanistan: a randomized controlled study. *Journal of Water and Health*, *8*(4), 687-702.

Panella, T. (2020). Development for water, food, and nutrition security in a competitive environment—An Asian perspective. Irrigation and Drainage. https://doi.org/10.1002/ird.2559

Park, C. ,and Ding, Y. (2021). Location and Dispersion Analysis. In: Data Science for Nano Image Analysis. International Series in Operations Research & Management Science, vol 308. Springer, Cham. https://doi.org/10.1007/978-3-030-72822-9_5

Pendergast, M. M., and Hoek, E. M. V. (2011). *A review of water treatment membrane nanotechnologies. Energy & Environmental Science, 4(6), 1946.* https://doi.org/10.1039/c0ee00541j

Peter-Varbanets, M., Zurbrügg, C., Swartz, C., and Pronk, W. (2009). Decentralized systems for potable water and the potential of membrane technology. Water Research, 43(2), 245–265. https://doi.org/10.1016/j.watres.2008.10.030

Ritchie, H., and Roser, M. (2019). Urbanization. Retrieved from https://ourworldindata.org/urbanization

Ritchie, H., and Roser, M. (2021). Clean water. Our World in Data Retrieved from https://ourworldindata.org/water-access

Ritchie, H., and Roser, M. (2022). Plastic pollution. Our World in Data Retrieved from https://ourworldindata.org/plastic-pollution

Ritter, M., Camille, E., Velcine, C., Guillaume, R. K., and Lantagne, D. (2017). Optimizing household chlorination marketing strategies: A randomized controlled trial on the effect of price and promotion on adoption in Haiti. *The American journal of tropical medicine and hygiene*, *97*(1), 271

Rosa S., G. O., Loureiro, H. O., Soares, L. G., de Andrade, L. H., and Santos, R. G. L. (2021). Evaluation of an alternative household water treatment system based on slow filtration and solar disinfection. Journal of Water and Health, 20, 157–166. https://doi.org/10.2166/wh. 2021.211

Sánchez, C., Bianchi, E. C., Rodriguez-Sanchez, C., and Sancho-Esper, F. (2023). Are advertising campaigns for water conservation in Latin America persuasive? A mixed-method approach. International Review on Public and Nonprofit Marketing, 1-29.

Segu, D. Z., Kim, J.-H., Choi, S. G., Jung, Y.-S., and Kim, S.-S. (2013). Application of Taguchi techniques to study friction and wear properties of MoS2 coatings deposited on laser textured surface. Surface and Coatings Technology, 232, 504–514. https://doi.org/10.1016/j.surfcoat.2013.06.00

Shaheed, A., Rathore, S., Bastable, A., Bruce, J., Cairncross, S., and Brown, J. (2018). Adherence to point-of-use water treatment over short-term implementation: parallel crossover trials of flocculation–disinfection sachets in Pakistan and Zambia. *Environmental science and technology*, *52*(11), 6601-6609.

Shanmugaraja, M., and Tharoon, T. (2018). Application of Taguchi and RSM techniques for optimising the parameters of pressure die casting process. International Journal of Productivity and Quality Management, 25(3), 387. https://doi.org/10.1504/ijpqm.2018.095654

Sharda, A., and Kumar, S. (2015). Experimental investigation of U value of double-glazed window with inter-pane blinds using Taguchi techniques. Energy Efficiency, 9(5), 1145–1161 https://doi.org/10.1007/s12053-015-9413-8

Shi, Q.H, Yang, X.J, Zhao, Z, Fan, H.H, Meng, M.Q, and Ma, X.Y (2023) Optimization ratio of industrial waste and sodium persulfate for synergy in solidification/stabilization of petroleum-contaminated soil. China Environmental Science 43(4):1791-1801, https://doi.org/10.19674/j.cnki.issn1000-6923.20221011.001

Shukla, R., and Singh, D. (2017). Experimentation investigation of abrasive water jet machining parameters using Taguchi and Evolutionary optimization techniques. Swarm and Evolutionary Computation, 32, 167–183. https://doi.org/10.1016/j.swevo.2016.07.002

Shunmugesh, K., and Panneerselvam, K. (2017). Optimization of Machining Process Parameters in Drilling of CFRP Using

Multi-Objective Taguchi Technique, TOPSIS and RSA Techniques. Polymers and Polymer Composites, 25(3), 185–192. doi:10.1177/096739111702500301

Sisay W/tsadik, D., Debela, B. G., Ali Ewune, H., and Hareru, H. E. (2022). Determinants of household-level water treatment practices in Southern Ethiopia. *Environmental Health Insights*, *16*, 11786302221109399.

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M., and Elliott, M. A. (2008). Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. Environmental Science and Technology, 42(12), 4261–4267. https://doi.org/10.1021/es702746n

Solomon, E. T., Robele, S., Kloos, H., and Mengistie, B. (2020). Effect of household water treatment with chlorine on diarrhea among children under the age of five years in rural areas of Dire Dawa, eastern Ethiopia: a cluster randomized controlled trial. *Infectious Diseases of Poverty*, *9*, 1-13.

Stafford, U., and Gately, M. (2011). New Techniques and Technologies for Scaling Up Household Water Treatment. Proceedings of the Water Environment Federation, 2011(3), 212–217. https://doi.org/10.2175/193864711802863788

Tan, X., and Rodrigue, D. (2019). A review on porous polymeric membrane preparation. Part I: production techniques with polysulfone and poly (vinylidene fluoride). *Polymers*, *11*(7), 1160.

Theodory, T. F. (2022). Emerging and persistent challenges in water resources governance in rural Tanzania: The Mgeta subcatchment of the Upper Ruvu Basin. Norsk Geografisk Tidsskrift-Norwegian Journal of Geography, 76(2), 110-124. https://doi.org/10.1080/00291951.2022.2048067

Thomas-Possee,, M. L., Channon, A. A., Bain, R. E., Nyamai, M., and Wright, J. A. (2020). Household-reported availability of drinking water in Africa: A systematic review. Water, 12(9), 2603.

Thomas-Possee, M. L. H. (2023). *Domestic drinking water availability in Sub-Saharan Africa: Investigating drivers and indicators* (Doctoral dissertation, University of Southampton).

Thomas-Possee, M. L., Channon, A. A., Bain, R. E., and Wright, J. A. (2024). Household, neighbourhood and service provider risk factors for piped drinking-water intermittency in urban and peri-urban Zambia: A cross-sectional analysis. PLOS Water, 3(2), e0000127.

Tsai, S. F., and Liao, C. T. (2019). Detection of location and dispersion effects from partially replicated two-level factorial designs. *Journal of Quality Technology*, *52*(3), 281–292. https://doi.org/10.1080/00224065.2019.1571349

UN. (2019). The sustainable development goals report 2019. United Nations Retrieved from https://unstats.un.org/sdgs/report/2019/The Sustainable-Development-Goals-Report-2019.pdf

UN. (2020). The sustainable development goals report 2020. United Nations Retrieved from https://unstats.un.org/sdgs/report/2020/The Sustainable-Development-Goals-Report-2020.pdf

UN. (2021). Asia and the Pacific SDG Progress report 2021. United Nations ESCAP Retrieved from https://www.unescap.org/sites/default/d8files/knowledgeproducts/ESCAP_Asia_and_the_Pacific_SDG_Progress_Report_2021.pdf

UNESCO World Water Assessment Programme. (2017). The United Nations world water development report 2017: Wastewater: The untapped resources. UNESCO, United Nations Educational Retrieved from http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2017-wastewater-the-untapped-resource/

UNESCO World Water Assessment Programme. (2019). The United Nations world water development report 2019: Leaving No one behind.

UNESCO, United Nations Educational Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000367306

UNESCO. (2018). Policy briefs on internal migration in Southeast Asia. United Nations Educational, Scientific and Cultural Organization Retrieved from https://bangkok.unesco.org/index.php/content/policy-briefs-internal-migration-southeast-asia

UNICEF and WHO. (2019). Progress on household drinking water, sanitation and hygiene 2000–2017: Special focus on inequalities. United Nations Retrieved from https://www.unicef.org/reports/progress-on-drinking-water-sanitation-and-hygiene-2019

UNICEF and WHO. (2021). Household. Retrieved from https://washdata.org/data/household#!/

UNICEF and WHO. (2022). Drinking Water. UNICEF and WHO, Joint Management Programmed (JMP) Retrieved from https://washdata.org/monitoring/drinking-water

Valentukeviciene, M., Zurauskiene, R., and Boussouga, Y. A. (2019). Fluoride removal from groundwater by technological process optimization. *Ecological Chemistry and Engineering S*, *26*(1), 133-147.

Van Loosdrecht, M.C.M, Nielsen, P.H,Lopez- Vazquez, C.M and Brdjanovic, D. (2016) "Experimental Methods in Wastewater Treatment". 1st Edition, International Water Publishing Alliance House, London.

Vanderzwaag, J. C., Bartlett, K. H., Atwater, J. W., and Baker, D. (2009). Evaluation of Field Testing Techniques Used in a Household Water Treatment Study in Posoltega, Nicaragua. Water Quality Research Journal, 44(2), 122–131 https://doi.org/10.2166/wqrj .

Wainaina, G. K. (2018). *Comparative Analysis of Factors That Influence Consistent Use of Household Water Treatment and Storage in Northern Kenya* (Master's thesis).

Warton, D. I., Wright, S. T., & Wang, Y. (2011). *Distance-based multivariate analyses confound location and dispersion effects. Methods in Ecology and Evolution, 3(1), 89–101.* https://doi.org/10.1111/j.2041-210x.2011.00127.x

WHO (2012) . Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage. Available on https://www.who.int/publications/i/item/WHO-HSE-WSH-12.01

WHO. (2016). Results of round 1 of the WHO international scheme to evaluate household water treatment technologies. World Health Organization Retrieved from https://apps.who.int/iris/handle/10665/204284

WHO. (2017). Diarrhoeal disease: Key facts. World Health Organization Retrieved from https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

WHO. (2019). Drinking-water. World Health Organization Retrieved from https://www.who.int/news-room/fact-sheets/detail/drinking-water

Wimalawansa, S. J. (2018). Provision Of Clean Water Through Reverse Osmosis: Cost-Effective Interim Solution To Overcome Water-Pollution-Related Diseases. *European Journal of Biomedical*, *5*(2), 988-998.

World Health Organization. (2008). *Water quality interventions to prevent diarrhoea: Cost and cost-effectiveness* (No. WHO/HSE/WSH/08.02). World Health Organization.

Xu, K., Yang, M, Yang, J, Nataliia, B, Cai, Y, Zhang, H and Wang, Y (2024), Mapping scholarly publications of energy conservation and emission reduction in support of the sustainable development goals (SDGs). Front. Environ. Sci. 12:1421990. https://doi.org/10.3389/fenvs.2024.1421990

Young, S. L., Miller, J. D., Frongillo, E. A., Boateng, G. O., Jamaluddine, Z., and Neilands, T. B. (2021). Validity of a four-item household water insecurity experiences scale for assessing water issues related to health and well-being. The American Journal of Tropical Medicine and Hygiene, 104(1), 391–394. https://doi.org/10.4269/ajtmh.20-0417

Zheng, Y., Gu, F., Ren, Y., Hall, P., and Miles, N. J. (2017). Improving Mechanical Properties of Recycled Polypropylene-based Composites Using Taguchi and ANOVA Techniques. Procedia CIRP, 61, 287–292

Zielinski, M.; Kazimierowicz, J.; Debowski, M. (2023). Advantages and Limitations of Anaerobic Wastewater Treatment—Technological Basics, Development Directions, and Technological Innovations. Energies 2023, 16, 83. https://doi.org/10.3390/en16010083

Zularisam, A. W., Ismail, A. F., and Salim, R. (2006). *Behaviours of natural organic matter in membrane filtration for surface water treatment — a review. Desalination, 194(1-3), 211–231.* https://doi.org/10.1016/j.desal.2005.10.030

APPENDIX

Cost of production	Unit	Quantity	Amount		
			Naira	Dollar	
5000 ml Container (2 mm thick)	4500	2	9000	6.00	
1 inch plastic Adaptor (2 mm thick)	1250	1	1250	0.83	
1 inches plastic Elbow (2 mm thick)	1350	2	2700	1.80	
Operational and Maintenance Cost	25000	1	25000	16.67	
10inch Ceramic Water Filter Candle For Gravity Purifier Cleaning Replacement Part	25000	1	25000	16.67	
		Total	62950	41.97	
Rico Water Purifier Filter And Dispenser - (20 Litres)	90000	1	90000	60.00	https://www.jumia.com.ng/quinix-water-purifier-filter-and-dispenser-18l-akaline-phtester-8375035.html

Quinix Water Purifier Filter $ Dispenser 20L + Akaline PHTester	70000	1	70000	46.67	https://www.jumia.com.ng/quinix-water-purifier-filter-dispenser-20l-akaline-phtester-14090806.html
Quinix Water Purifier Filter And Dispenser - 18L + Akaline PHTester	71000	1	71000	47.33	https://www.jumia.com.ng/quinix-water-purifier-filter-and-dispenser-18l-akaline-phtester-8375035.html
Tiens Water Purifier Filter & Dispenser With Alkaline PH	81000	1	81000	54.00	Tiens Water Purifier Filter & Dispenser With Alkaline PH | Jumia Nigeria
Mineral Water Purifier/Filter/dispenser 32Litres	130000	1	130000	86.67	https://www.jumia.com.ng/generic-mineral-water-purifierfilterdispenser-32litres-77812536.html