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Feasibility of Greywater Reclamation Using Local Plant Material in De-Centralised Recycling Systems for Maiduguri and its Environs

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Abstract: *Maiduguri is a semi-arid region that suffers from water shortage as a result of high temperature and low rainfall. Population growth with poor water management increases pressure on water resources. This study scaled the quantity of water used for domestic activities to characterize greywater generation volume in Maiduguri. A questionnaire was administered to 40 households across the four districts of Maiduguri: Two (2) from densely populated areas of Shehuri north and Gwange while the other two (2) from less densely populated areas of Bolori and Maisandari respectively. The outcome of the results revealed that about 46.8% of the resident sources of water are piped network from the treatment plant supply by the government while 40.39 % used private boreholes. With soak-away as a medium of greywater disposal constituting 52.5% while 44% of the inhabitant similarly used street due to lack of effective sewer system to dispose they greywater. A descriptive statistical distribution was used to analyze the numerical data obtained. The findings from the descriptive statistics revealed that the volume of water used for domestic activities from the two sources in (litres) stood at 533 in Gwange, 451 in Shehuri north, while 287 in Maisandari, and 287 in Bolori respectively. The volume of greywater produced in (litres) stood at 315 in Shehuri north, 387 in Gwange, Bolori 91, and 200 in Maisandari. Generation from all domestic activities stood at, ablution 7.0 %,53 bathing, kitchen 20% and laundry 20% in Shehuri north. While in Gwange ablution is 1.0%, bathing 61%, kitchen 8%, and laundry 30%. Similarly, in Bolori ablution 1.3%, bathing 63%, kitchen 24%, and laundry 12% while in Maisandari ablution 1.0 %, bathing 66 %, kitchen 17% and laundry 16% respectively. Base on pieces of literatures, Moringa oleifera and rice husk are therefore recommended to treat greywater in Maiduguri and its environs.*

Keywords: *Greywater, Laundry, Ablution and Bathing*

Introduction

The global water shortage is due to a combination of population expansion and economic growth with extensive use of water in agriculture, industry, and increasing standard of lifestyle, as while as climate change (Ahmadalipour, Moradkhani, & Magliocca, 2019). Water is defined as the most demanded basic need for living beings on earth. However, water is at the same time significant for domestic, agricultural, and industrial purposes (Hossain, & Mahmud 2019). Maiduguri water demand is estimated to rise to approximately 154,443 Million cubes per day by the year 2056, to meet this water demand, the combined supplied strength from the treatment plant of Maiduguri with other sources such as boreholes (public boreholes) stands at 31,973 Million cubes per day (Abdullah, Abubakar & Jones , 2019). Grossly it is inadequate to meet the projected household water demand of 154,443 Million cubes per day by the year 2056. The pressure on water resource are divide into two; demands-side pressure which are due to demographic growth which led to increasing in water demand for domestic, agriculture and industrial purposes. Similarly, the supplies-side pressure is due to drought, and climate change. Those demands will increase by 2025 to 35% while on the other hand, by 2050 it will reach up to 67% which are mostly from developing countries such as Africa (Boretti & Rosa, 2019). Climate change is considered to be potential factor that will increase pressure on water resources in not too distant future (Duran-Encalada. Paucar-Caceres, Bandala &Wright, 2017). However due to rural-urban migration, there will be continuous pressure on water demand in towns from the developing countries, and continuing with these demands, the problem would leave about 55% of the world population in water crisis (Guneralp, Lwasa, Masundire, Parnell & Karen., 2017). Domestic wastewater is known as greywater. Greywater is defined as domestic water waste originating from households such as laundry clothes, kitchen, washing dishes, and bathing excluding toilet wastewater (Ghaitidak & Yadav 2013). Dark and black water are considered to be domestic waste from toilets, bidet, kitchen sink, and dishwashers (Oteng-Peprah, de Vries & Acheampong, 2018). Similarly, James, Surendran, Ifelebuegu., Ganjian, & Kinuthia, (2017) described greywater as untreated household wastewater from showers, baths, kitchen, hand wash basin, laundry, and other known sources that have no contact with sewage without toilets. However, according to Craig and Richman (2017) wastewater from domestic activities such as dishwashing and laundry exclude sewage is called greywater. Greywater is now considered and recognizes as an essential source of water in most water-scarce nations (Spychała, Nie´c, Zawadzki, Matz, Hung, 2019). Greywater may represent up to 75% of the total domestic wastewater, accounting for up to 100–150 Litre/Population Equivalent/day(L/PE/day) in European Union and other high-income countries, and for smaller volumes in low-income countries (Boano, Caruso, Costamagna, Ridolfi, & Fiore, et al., 2020). And Nigeria is also considered to be a low-income nation. Globally, wastewater treatment and reuse have been re-emphasized for decades as effective mitigation solution of water scarcity (Hossain, Muhammed, Pramanik, & Nizamuddin, 2020). Recycling greywater for non-portable reuse provides strategies for alleviating the risk of water shortage and water demand. Greywater reuse can play a fundamental role, in converting a significant fraction of wastewater into a valuable water resource. The wastewater treatment system includes collection, effective treatment, and integrated recycling of treated wastewater for water management to overcome the potential shortages' of freshwater and to reduce water pollutant (Boano et al., 2020), hence sustainable management of water resource is therefore essential.

Problem statement

Maiduguri is a Sahel savannah and is characterized as the driest zone for decades which is similarly known for water access problems and scarcities (Akinbile et al., 2019). Maiduguri and its environs lie within the Sahel savannah region and the area is characterized with high evaporation, evapotranspiration rate on an average of 2000mm per annum with a maximum rainfall of about 600 mm per year which is therefore classified as a dry area (Goni, Sheriff, Mohammed, Mohammed & Ibrahim, 2019). Portable water sources are mainly from surface water for which this community receives supplies from the water treatment plants of Lake Alua. This dam constitutes only 30% of supplies to the entire community of this area while the rest are been generated through boreholes. The rainfall usually lasts for 3 months only and the temperature remains high which usually triggers the evaporation rate to be high during the dry season resulting in water shortage (Akinbile et al., 2019). According to Mohammed (2009) study reported that there is an increase in temperature rate with a decrease in rainfall (drought), evapotranspiration, desertification as well as drying up of rivers that are taking place in Maiduguri and its environs. Water scarcity remained a major challenge during the dry season and many of the inhabitants use less than 25 liters per person per day (Hyeladi & Nwagilari 2014). The advancement of climatic crisis has further worsened the availability of water, vegetation, and agricultural production in Maiduguri. However, currently, there are more than 4 million people that are taking refuge in Maiduguri due to insurgency, in addition to the existing inhabitant populations of the city. Similarly, many of them do not have access to clean and hygienic water because of some environmental factors. Furthermore, 31,973 million cubes per day supplies from all known sources for this community as mention in the introduction part of this study is grossly inadequate to meet their household water demand in addition to the influx of these internally displaced persons of more than 4 million. Thus supply schemes from other sources should be considered as potential mitigation to cover those water demands capacity to enhance supplies in Maiduguri and its environs.

Study Area

Maiduguri is the state capital of Borno state Nigeria, the city is geographically located between the latitude of $10^{o}48'00''$N and Longitude of $11^{o}\ 20'\ 00''$E (Goni et al., 2019). Maiduguri is a Sahel savannah and is characterized as the driest zone for decades which is similarly known for water access problems and scarcities. Maiduguri and its environs lie within the Sahel savannah region and the area is characterized by a high evaporation rate, evapotranspiration on an average of 2000mm per annum with a maximum rainfall of about 600 mm per year. Figure 1.1 showed the map of the study area with their respective district areas. The average temperature of Maiduguri is 25.8^{0} C and 47^{0} C as the highest temperature, and this highest temperature was recorded around 1983. Subsequently, the lowest was recorded as 5^{0} C in 1979 (Babagana, 2017).

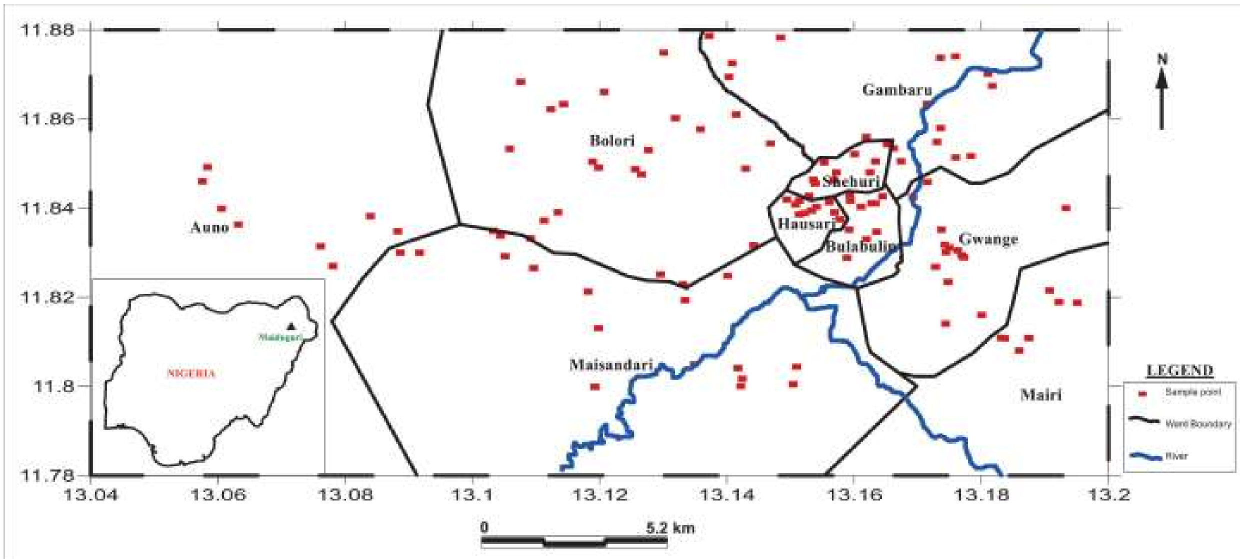

Figure 1.1 Map of Maiduguri and it's environ

Aim

The research aim is to evaluate the volume of greywater produced from a different source of water to recycle and to minimize and sustain domestic water supply in Maiduguri and its environs

The objective of the study

- To determine the sources of water supply in Maiduguri
- To estimate the quantity of water used for domestic activities by households for their domestic activities
- To evaluate the volume of greywater produced per household

Literature Review

Water resource management

Since the 1992 UN Earth Summit held in Brazil, people have continued to discuss the depletion of natural resources globally in broad terms due to population growth and the need to minimise the irrational use of water (UN 1992). There is increased concern for the development of wastewater reclamation systems to address water problems worldwide. Nowadays countries such as China and Indonesia are offering incentive and levies towards coherent and effective natural resource development; particularly recycling of wastewater effluent according to reused guidelines standards by individuals (Anderson, 2002). Similarly, the government of Australia offers a rebate incentive of $ 500 to an individual for the installation of greywater systems for reuse. It has been made mandated in Tokyo to install a Greywater recycling system for buildings covering an area of over 30,000m^2 (Oron, Adel, Agmon, Friedler &, Halperin et al., 2014).

Global approach to wastewater

The wastewater management concept has become a global phenomenon that attempts to address problems of water demand and its stress. The world is heterogeneous, thus the effectiveness of these concepts vary from one region to the other even within the same country for water sustainability and improvement of environmental sanitation (Biswas, 2008; Gine-Garriga et al., 2013). Worldwide, there is a different approach from many countries to treat wastewater these include a complex, conventional (centralised) system and non-conventional (de-centralised) local systems installed at household levels (Langergraber & Muellegger 2005). Wilderer, (2001) added that building of centralised wastewater treatment systems could serve densely populated communities. However Letting, Lens, & Zeeman, (2001) study asserts that centralised systems are expensive forms of treatment for the local community. Therefore to sustain natural resource at the local level, Daigger's (2009) study suggested that decentralised treatments system could be used because the technologies involved in wastewater recycling is less expensive. There are two most common ways of tackling environmental waste and sanitation problems ''flush and forget'' including the continuous collection of sewage in underground pipe systems that are connected directly to treatment plants and ''drop and store'' dry sanitation (Anderson, 2002; Langergraber & Muellegger 2005; Ormerod 2016). Wastewater reuse application for agricultural irrigation purposes has supported the livelihoods of many farmers across the world (Sato, Qadir, Yamamoto, Edo,& Zahoor, 2013). In Pakistan, a study revealed that about 32,500ha (325,000,0000m^3) of land were irrigated with wastewater (Ensink, Mahood, Hoek, Rashid-sally, & Amerasinghle, 2004). Similar reports have indicated that about 73,000ha (730,000,000m^3) of land were irrigated from wastewater in India (Scott, Faruqui,& Raschid-Sally, 2004).

Greywater

Greywater is defined as domestic water waste originating from households such as laundry, kitchens, dishwashing, and bathing but excluding toilet wastewater (Ghaitidak & Yadav 2013). Similarly, Morel and Diener (2006) describe Greywater as untreated household wastewater from showers, baths, kitchens, hand wash, basins, laundry and other sources that have had no contact with sewage from toilets. However, Weiskel, (2014) described Greywater as wastewater from domestic activities such as dishwashing and laundry, excluding sewage. Greywater is now considered and recognised as an essential source of water in most water-scarce nations (Peters, 2015). Black-water is considered to be domestic waste from toilets, bidets, kitchen sinks and dishwashers (Allen, Smith, & Palaniappan, 2010).

Greywater quantity

Generally, water consumption depends on the availability of resources and living standards obtainable by the household. Generation of greywater depends on total water consumption, habits of the residents, and living standards (Table 1.1) present water consumption per capita per day and volume greywater generation in some developed and developing countries (Erisson et al., 2002). Al-Mughalle et al., (2012) study evaluating the quantities of Greywater produced from different sources in Sana'a Yemen. The study revealed that on average, the daily quantity of Greywater produced is 259 liters.

Table 1.1: Greywater generation and water consumption

Country	Place	WC Lcpd	GG Lcpd
Jordan	Amman	84	59
South Africa	-	104	80
Yemen	Sana'a	40	35
Senegal	Dakar	105	60
Australia	Perth	381	117
India	Calicut, Kottayam	162	79
India	Athiyannor	159	77

Ghaitidak and Yadav (2013:16) WC* water consumption: GG*greywater generation: Lcpd* litre per capita per day

Greywater accounts for 75% volume of wastewater estimated to be produced by household (Ghaitidak & Yadav 2013). Greywater generation in a households account for more than 70% of their water consumption and this depends on individual lifestyle (Tamnna, Abdul, Islam & Salwa 2011). Some literature reported that the typical Greywater generation volume varies between 90 to 120 l/d for high- income countries without water scarcity but depends on living standards, customs, installed water systems, and habits of the household. Table 1.2 shows different countries with different standards quantification of generation. However, the volume of Greywater in low- income countries such as Niger, Nigeria, Yemen, Oman, and Jordan with water challenges and simple forms of water supply can be as low as 20 to 30 l/P/d (Oteng-Peprah et al., 2018).

Table 1.2: Indoor household water used

Use	UK total used in (%)	US total used in (%)	China total used in (%)	Korea total used in (%)	Sweden Total used in (%)	Yemen total in (%)	Israel total in(%)
Bathing	26	30	23	20	33	54	20
Toilet	34	21	45	21	22	-	-
Kitchen	28	25	20	39	28	-	26
Laundry	12	24	11	20	17	38	13

Tamanna et al. (2011); Al-Muhalles et al. (2012); Friedler (2004).

Greywater reuse in Africa for water management

Adewumi, Ilemobade, & Zyl., (2010) reported that in South Africa wastewater is collected, treated, and reuse for household, agriculture, and industrial usage. There port further indicated that there were three different approaches practiced for wastewater treatment in South Africa: Category (A) household reuse while Category (B) at district reuse (eg a project for zero waste in Western Cape Province) and category (C) for wide urban collection and reuse (eg central collection of wastewater for treatment of non-domestic and domestic sources in Kwazulu-Natal province). Similar efforts were reported in other African countries including Morocco (Tahri et al. 2010), Senegal (Scott et al., 2004), Ghana (Hyde, 2013), Tanzania (Kihila, Mtei, & Njau, 2014) and Tunisia, (Bahri & Brissaud, 1996). According to Sato et al., (2013), the availability of wastewater treatment and reuse information in Africa is one of the major problems because only three out of the 48 sub-Saharan African countries *(South Africa, Senegal, and Seychelles)* have data that are complete but these are old data. Thus, there is a need for wastewater treatment research to provide reliable data on water sustainability.

Greywater generation volume from developing countries

A Study conducted within rural and urban areas of China, India, Yemen, and Jordan showed that there is a higher generation of Greywater in urban areas than in the rural areas (Zeng et al., 2013; Halalshel et al., 2008; Al-Mughalles et al., 2012; Jamrah, Al-Omari, Al-Qasem, & Ghani, 2006). Comparing this data from those countries, with that of Australia (as shown in Figure 1.2) proves that the Greywater generation level is high in Australia.

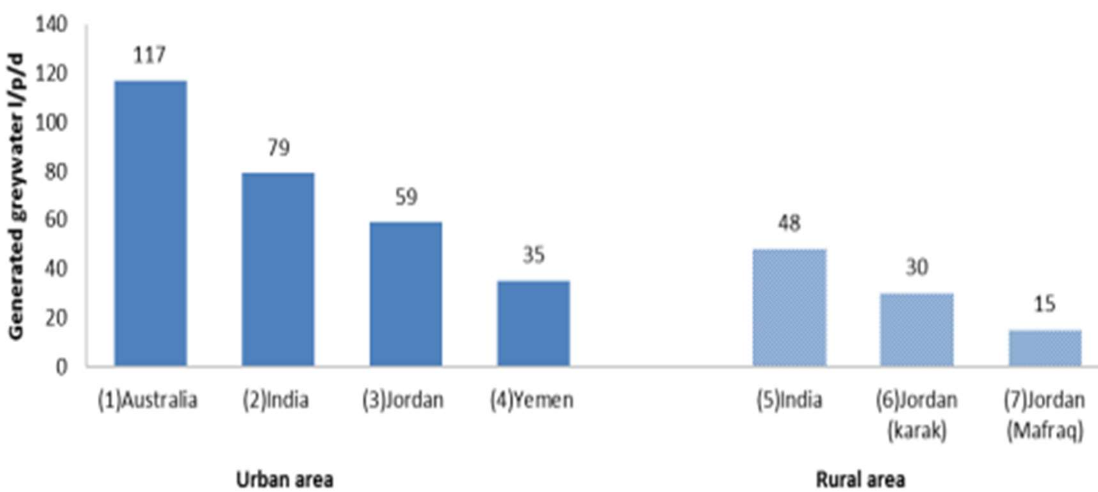

Figure 1.2: Levels of greywater generation in rural and urban areas. Albalawneh and Chang (2015)

Jamrah et al., (2006) maintain that the Greywater generation level constitutes almost 70% of domestic household freshwater consumption. The Greywater generation distribution from households is 47% from bathroom, shower, and washbasin while 26% is from laundry and washing machine, for kitchen and dishwasher is 27% respectively. (Ghaitidak & Yadav 2013: Jamrah et al., 2006). Greywater generation accounts for 50 to 80% of effluent produced by a household but depends on some environmental local conditions (Tilley Zurbrügg & Lüthi 2010).

Greywater treatments technologies

A sustainable assessment provides technologies that support scientific decisions toward future improvements in water reuse (Zijip, Posthuma, Deviles, Wintersen, & Swartjes., 2016).Wastewater treatment systems including collection, treatment, and recycling of treated wastewater for further reuse as a water management solution to overcome the shortage of fresh water and to reduce emissions pollutants (Masmoudi, Nolde, Ciroth & Bousselmi., 2020). In most countries, sustainability for better water quality involves huge costs but, simply technology will allow 85% reclamation of wastewater for domestic reuse as resource management for water sustainability (Parimal, 2017, Masmoudi, et al., 2020). Therefore recycling greywater for nonportable uses provides strategies for alleviating the risk of water shortage and water demand. Available technologies for wastewater treatments are usually categorized as physical, biological, and chemical systems. The appropriate technology system to be selected is based on the pollutants constitute parameter of the Greywater which includes, TSS, detergents, turbidity, suspended solid temperature, PH, TDS, BOD, COD, dissolved oxygen, colour, oil, and grease. According to Spychała et al., (2019) study, physical, chemical, and biological technologies are widely used for Greywater treatment and reused by following with some specification which dependent on the quantities

Natural materials used in wastewater treatments

A different natural material was reported as filter media for wastewater treatments for non-convectional treatments processes. The notable natural materials which have been tested and reported as filter medium were *Rice husk, red Maize, red beans*, *Moringa Oleifera, Pumpkin, Reed bed,* among others (Viana, Silveira,& Mourad , 2016, Kaetzl et al., (2019). These materials are employed in various chemical, physical and biological processes of wastewater treatments. For instance, *Moringa Oleifara* is a multipurpose small size tree that was reported to be inexpensive coagulant and has a good sorbent capacity for the removal of organics in wastewater treatments (Verma, Kumar, & Muneesh , 2020). Similarly, According to Hudock, Myers,& Brennan, (2019) study reported that *Rice husk* has a chemical composition of 75-90 % organic matter which is lignin and cellulose that is very cheap materials with a relative low bulk density of 87-97% as that of silicon. Another study by Mor, Chhoden, & Ravindra, (2016) reported that rice-husk ash was able to eliminate 89% of the inorganic phosphate released from the agricultural fields (fertilizer) and domestic household wastewater such as detergent in effluent. These inorganic phosphates are considered as one of the most hazardous and toxic chemicals of run-off wastewater.

However, according to Hudock et al., (2019) study, *Rice husk* has a good adsorbent in the treatment of wastewater with a very high removal efficiency of the photochemical property. The study further demonstrated that rice husk's optimal surface area, chemical composition, and price point contribute to its good candidacy for water and wastewater treatment, and how variables such as pH and rice husk preparation can affect the maximum adsorption capacity. The study concluded that rice husk will be a potential filter to reach economies of scale in developing nations and the resulting implications for the global drinking water supply. Similarly, an experimental study by Kaetzl et al., (2019) on farm-wastewater treatment demonstrated that in most developing countries, common agro-residues such as rice husk biochar have been implemented efficiently as two-stage anaerobic filter materials in Sub-Saharan Africa countries. These processes were very cost-effective and efficient in the removal of chemical oxygen demand up to 94% and such treated water was reused for irrigation purposes. *Moringa oleifera* seeds contain cationic proteins that can be used for water and wastewater treatment, furthermore, the oil content of *Moringa oleifera* seeds is high, and the properties of this oil render it useful for many applications such as in the treatment of wastewater (Magalhães et al., 2020).

Vieira, Marcelo., Salva, Bergamasco., Araoju, Fagundes-Klen, (2009) study employed *Moringa Oleifara* as an effective and inexpensive sorbent in the removal of organics in wastewater treatments, and the study used *Moringa* as coagulants in the treatments process. Similarly, the study has found the adsorption power that can able to keep the PH level of water at 5-8. The study further recorded a removal efficiency of 98 % for both turbidity and color at high turbid wastewater. Mani, Meikandaan, Gowrishankar,& Kanchanabhan , (2019) further reported that *Moringa Oleifera* has removal efficiency in high turbid wastewater from 100 NTU to 5.9 NTU before filtration and after filtration to 5 NTU which served as natural coagulants. However, the study revealed a Coliform removal of 89.96 %.

According to Yusuf, Obalowu, & Abubakar, (2020) study magnetic field and *Moringa* seed powder reduced the turbidity, COD, alkalinity, ammonia nitrate, pH, BOD, sulphate ions as while as total coliform in wastewater. Thus, a combination of magnetic field and *Moringa* seed powder for wastewater treatment gave better and consistent percentage reduction of physical, chemical, and bacteriological properties. The study thereby recommended both combination of magnetic field and *moringa* seed powder for wastewater treatment in Nigeria. Another experimental study by Verma et al., (2020) evaluate the extracted components of *Moringa oliefera* and applied them to wastewater, the results revealed that in turbidity wastewater the removal efficiency of 99.2% and 99% in case of oiled and de-oiled seeds applied as coagulant concentrations of 2% and 1% respectively. Similarly lowered suspended solids up to 96.8% and 96.2% were observed when the same doses were applied while no raise in COD values were noticed in both cases. However, a slight reduction of 12.5% and 16.6% in BOD values were there at 1% applied concentration of stock solution for both oiled and de-oiled seeds. Reduction in COD was only observed in the case of de-oiled seeds which were up to 25.3% at an applied concentration of 1.5%. Also, no alteration in pH was seen which makes Moringa oleifera a suitable coagulant as no post-treatment is required. However, the study further revealed that the Moringa *oleifera* leaf has no positive results were obtained in each of the parameters tested.

Magalhães et al., (2020) study further confirmed and revealed that *Moringa oleifera* seed is promising when use for wastewater treatment and in the removal of oil and grease from wastewater as a more affordable, sustainable, and natural alternative to commercial flocculants.

Methodology

Primary Data collection tools / Justification

The researcher used open-ended questions for the collection of primary data to quantify the volume of greywater generation from domestic activities from a different sources of water in the study area. An open-ended question was used to determine the quantity of water used in a bucket for laundry and bathing was asked and the main reason was to determine the volume of water used by households to quantify greywater from the respondents. This question was make open in order to allow the people of the study area to answer questions in their own words which they provide more valuable and richer information because there is no available data on water usage from the study area. However, the quantity of water used in (bucket) for kitchen and (kettle) for ablution was asked because these are the containers used by the people of the study area to fetch water which will guide the researcher to determine the quantity of water used in quantifying the daily volume of water used to produce the Greywater.

Sample Frame

Samples of 120 people across the four districts of the study area were contacted to participate in the survey. One hundred and twenty 120 participants were identified as potential responders across the four districts. The online link of the survey was handed through the email address and WhatsApp numbers of the people of the study area through ward heads, and village heads of their respective district areas. For the analysis, the statistician suggested that a sample size greater than or equal to 30 provides a good sample distribution (Saunders, Lewis, & Thornhill, 2012). Bartunek, Rynes,& Ireland, 2006 added that a minimum of thirty 30 samples is adequate for statistical analysis which provides an essential rule of thumb for a small category of the sample within a whole sample. Therefore for this reason, out of the 120 samples, the sample of 50 respondents will be considered as the study population for the analysis of this research to avoid delay in they are responses. This is because some individual WhatsApp contact may not be active during the period of this survey. Therefore researcher limited the analysis to forty 40 participants. However, there is no personal or official interaction between the researcher and the selected respondents except via this research work. This is because the population of more than a hundred is enormously higher for the researcher to know them as individuals or friends as they are all scattered across the study areas.

Stratified probability sampling

The researcher does not consider the entire city of Maiduguri as a target population because of its size. Therefore stratified sampling was used in sampling the target population, in particular stratified random was adopted for easy sampling technique for the estimation of a wider area such as Maiduguri. Khan et al. (2015) this technique is more convenient for the stratification of variables such as demography (geographical region, ethnicity, socioeconomic) or other regular criteria that are generally practiced in a research survey. The researcher, therefore, stratified the Maiduguri community based on the socioeconomic status of district areas. Maiduguri is divided into four districts based on the distribution of housing density. The housing density is defined as the number of dwellings per unit area or residential density. However the Ministry of land and survey has designed residential layouts for the Maiduguri community which categorized the areas into land size as high (30x 15m) medium (30x25) and low (30x40), the areas are Shehuri north as (high), Bolori (low), Maisandari (low) and Gwange (high) district according to the inhabitant's population (Waziri, 2012). Figure 1.3 presents the conceptual diagram used for the sample selection; the target population of 1,120 is across these four areas and from each of these areas 10 is selected randomly from the outcome of response where **K**th represent sampling interval and can be obtained when the total number of population is divided by several districts **n**.

10 was selected from **K**th from the each of the four districts, hence the first district was randomly selected, and thereafter every 10th household was selected from **K**th in each of the area's districts

Kth $=\frac{N}{n}$ .... (1)

Kth $= \frac{1120}{4} = 280$ .... (2)

Kth = sample interval

N= population size

n= number of districts.

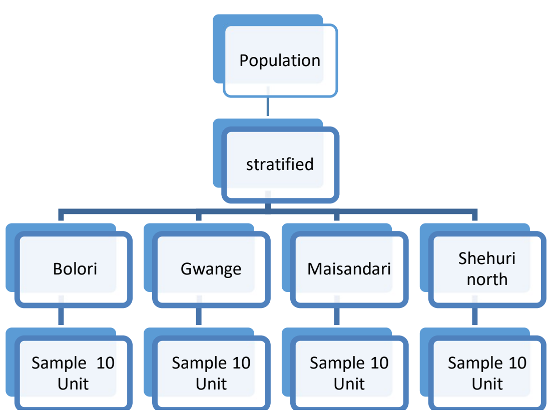

Figure 1.3 Stratify sample selection (Saunders, et al., 2012)

Data analysis techniques

Descriptive statistics: was used to estimate the average quantity or volume of water used for domestic activities that lead to becoming greywater. The researcher used numerical information from the result of the survey to analyze the data. The quantities were evaluated using the formula for mean to model greywater recycling systems. The mean is applied to determine the average volume of water used per individual in a household. Thus the technique that was used includes frequencies, mean, and percentages.

The Household volume of water used = $\sum x_1 + x_2 + x_3 + x_4 ....x_n$ .... (3)

Quantity of water used by individual = $\sum \frac{x_1 + x_2 + x_3 + x_4}{n}$ .... (4)

- $\sum x_n$ is the sum of data point represent the sample household
- n is the total number of people per household

Conversion from weeks to days = $\sum \frac{x_n}{n_i}$ .... (5)

- n_i is the numbers of the days of the week

Results and discussion

The overall survey sample

A hundred (100) % was recorded as all the respondents answered and returned the Questionnaire. Overall response of the survey was rate at 100 % on the sample of 40 people who were contacted from different strata of the study area. Majority of these participants both from the densely and less densely populated areas have more than 5 occupants living in each of the house which is presented in table 1.4. Information on the response to the survey will be analysed to reflect the objective of this research.

Table 1.4: frequency of people living per your household

S/N	Number of people in household	Frequency	Percentage (%)
1	2	4	6.45
2	3	6	9.68
3	4	8	16.13
4	5	22	67.74
	TOTAL	**40**	**100**

Source of domestic water in Maiduguri

The outcome of the survey showed that 46.8% of Maiduguri residents' common source of domestic water is pipe borne water, which is from the water treatment plant of the study area as earlier mentioned in the statement of problem. It is the pipe network system that supplies water to Maiduguri residents. However, this system supplies only 30 % of this community as earlier mentioned while 12.81% from other means. Some households, particularly in the less-densely populated areas without pipe network water depend on shallow boreholes. This constitutes 40.39% of the study population.

Source of water collection

Some households in Maiduguri can neither afford to pipe the public water system into their houses nor drill shallow boreholes. Therefore government has provided public reservoir at some strategic location for this group of people to access water; however the outcome of the survey further revealed that 37.5% of Maiduguri residents used public reservoir to collect they daily water. Access to water supply from reservoirs is often difficult for residents living far from the reservoirs. Most households in this group constituting 37.5% are always moving in search of water and they are unable to meet their household water demand. This corroborates the report by WHO &UNICEF 2017 that Mostly in African countries, people travel far distance to access water which they usually devote more than 30 minutes to have one trip collections. Consequently, a system of water that has no pipe network connection to the community the collection time is near to an hour which prevents most family in meeting their daily water demands and about 884 million (13%) of the world population collect water from a very far distance and is unprotected.

Preferred source of domestic water

Participants were asked whether water from the chosen source is enough for their family activities, the results of the survey showed that 82% of the residents agreed that the preferred source of water system is enough for their family activities per day. However, 40.39% are privately owned borehole, this has made the chosen source to be sufficient. 15% disagreed that the chosen source is adequate; these are people that collect water from the public reservoirs and this is usually time-consuming. Such households experience water shortages in this study area.

Water scarcity during a specific season

Participants from study area were asked whether they experience water scarcity during a specific season, 55% disagree experiencing water scarcity while 27% agreed and 12% strongly agreed and realised to be experiencing water scarcity during a specific season. This may be attributed to the high temperature with low rainfall of less than 600 mm as reported by the Nigerian Meteorological Service (NIMet), 2018. Therefore shortfall between water requirement and availability result in domestic water stress while acknowledging this portrayal of seasonal water scarcity, there is need for water sustainability which the study is focusing on.

Disposal of wastewater

The outcome of the survey on the wastewater disposal system in Maiduguri showed that, the 52.5% of the residents used soak-away as a medium or system for wastewater disposal and this is usually from the less densely populate areas where there is adequate land mass to construct central soak-away in their houses to collect domestic wastewater. This finding is similar to Abubakar, (2017) study that, in Nigerian wastewater is disposed through toilet connected to sewer or to septic tank (soak-away), this are the usual methods of wastewater disposal. Similarly 44% of the inhabitants disposed wastewater on the street. This is due to lack of functional sewer systems and enough land mass to construct central soak-away to collect and dispose their wastewater and majority of the sewer system are ineffective as reported by Aken and Shehuram, (2018), while 3.2% of the population study used other mechanism. Soak-away and street are the major media used by the resident of the study area. The possible challenges with these types of disposal system are that, it is hard to quantify volume of Greywater generated and Wastewater from soak -away usually containing black water.

Daily domestic activities performed by household

Participants were asked to indicate if the following activities are performed in their house on daily basis; ablution, laundry, and bathing the result of the survey showed that 93.5% residents perform ablution on daily basis this is due to fact that, Maiduguri is a Muslim dominated community that perform five daily prayers that makes the activity to be often which generate wastewater. However, the result of the survey further revealed that 79 % of the residents perform bathing on daily basis which is due to high temperature and low humidity of the area. Laundry is often performed especially in families with infants in whom it becomes necessary to perform laundry activities on daily basis. These are common domestic activities that consume water and generate greywater. This however depends on individual lifestyle, household occupancy, access and pattern of water usage that determine the greywater generation level from those activities.

Quantity of water for domestic activities

Participants were asked for the quantity of water used in kettle for ablution per day. The study takes into consideration, their culture and religion. Ablution can be defined as washing of all expose part of body with clean water. 51% of the respondents used medium-sized kettle of water for ablution per day which is equivalent to 2.5 litres of water across the four areas. (Figure 1.4) is the frequency volume of water used for ablution. However, 37% of the respondents used larger kettle for ablution per day and this is equivalent to 5 litres per day. These respondents are mostly from the densely populated areas where majority of the occupants have some dependents while 12% of population study used small kettle which is 1.5 litres. This finding of 5 litres used by entire household is against the study by Suratkon, Chan and Rahman (2014) that 5 litres is the average water volume required for a single ablution in Malaysia. The outcome of the survey showed that only 2.5 litres of water used by household of more than 4 people in the less populated area while 5 litres in densely populated areas. Shettima, 2018 reported the various size of kittle as (larger 5 litres, medium 2.5 litres, and small 1.5 litres). Thus, there is water scarcity among Maiduguri inhabitants.

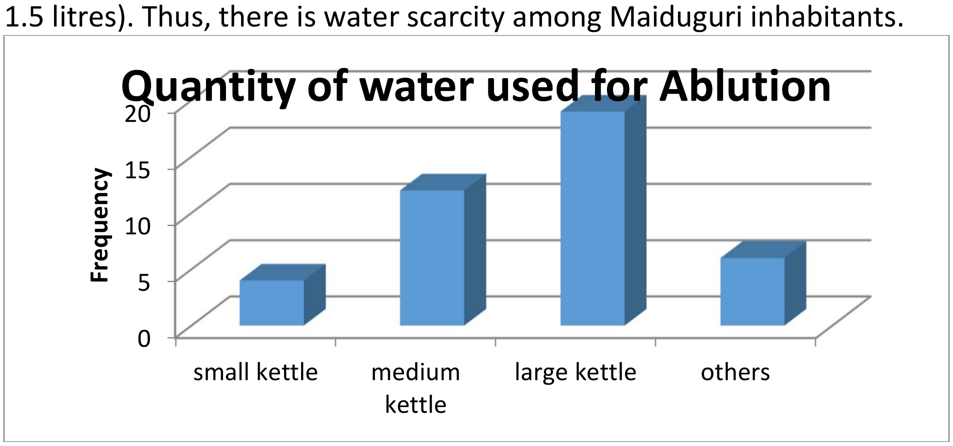

Figure 1.4 frequencies for quantity of water usage for ablution

Quantity of water used for kitchen

Residents of Maiduguri were asked about the quantity of water used in a bucket for kitchen per day. However, 77.50 % of the respondents used a larger bucket of water and this is equivalent to 25 litres. About 12.5% of the responders used a medium bucket which is 16 litres and 5.0% used small bucket which is equivalent to 10 litres Figure 1.5 depicts frequency volume of water used for kitchen, the rate of water usage for this activity is as a result of number of occupant in household for which the study evaluated the number to be more than 5 per household.

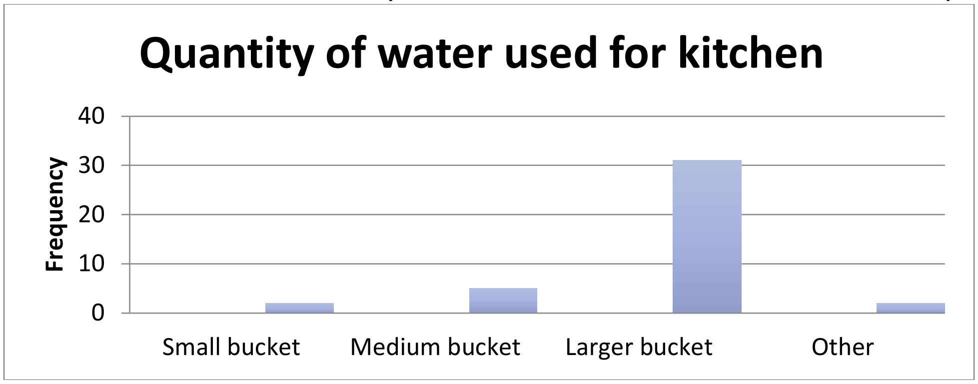

Figure 1.5 frequency water used for kitchen.

Volume of water used in the generation of greywater

Respondents from the study area were asked about the sources of water they use to perform their different daily domestic activities. Several domestic activities were included in the questions, such as ablution, kitchen, laundry, and bathing with their source of water. The result of the descriptive statistical analysis revealed that the mean volume of water used for laundry on a weekly basis in Shehuri north district from pipes water system stood at 188 litres per household while those with borehole stood at 301 with a standard error of 47 & 206 respectively. Table 1.5 showed the quantity of water used for domestic activity from the study area which is proportional to the quantity of greywater produced at 70% volume of water used reported by Tamnna et al. (2011) that the Greywater generation in a households account for more than 70% of water consumption and is from individual lifestyle.

Table 1.5 quantity of water used from the study area

Districts	**Volume of water used from pipe & borehole water system (litres)**	**Greywater produced @ 70 % volume of domestic water used (litres)**
Shehuri north	451	315
Gwange	553	387
Bolori	130	91
Maisandari	287	200

The findings of (91, 200, 315, and 387) litres of Greywater generated across the study areas are in line with Al-Mughalle et al., 2012 study in Yemen (2015) and Ghaitidak and Yadav (2013:16), the study has evaluated the quantities of Greywater produced from different sources in Sana'a of Yemen and the study further revealed that on average, the daily quantity of Greywater produced is 259 liters. Where Greywater has also account for 75% of wastewater volume estimated to be produced by households. However Table 1.5 presents the percentage quantity of greywater generated in this research and these findings in (table 1.6) is consistent with the studies by Tamanna et al. 2011; Al-Muhalles (2012) and Friedler (2004) in UK, China, US, Israel, and China (in table 1.7) respectively.

Table 1.7: Indoor household water used

Use	UK total used in (%)	US total used in (%)	China total used in (%)	Korea total used in (%)	Sweden Total used in (%)	Yemen total in (%)	Israel total in(%)
Bathing	26	30	23	20	33	54	20
Toilet	34	21	45	21	22	-	-
Kitchen	28	25	20	39	28	-	26
Laundry	12	24	11	20	17	38	13

Tamanna et al. (2011); Al-Muhalles et al. (2015); Friedler (2004).

Table 1.7 Percentage contributions from all sources

Used	Shehuri north (%)	Gwange (%)	Bolori (%)	Maisandari (%)
Ablution	7.0	1.0	1.3	1.0
Bathing	53	61	63	66
Kitchen	20	8	24	17
Laundry	20	30	12	16

Conclusion

The study concluded that the major activities that generate wastewater in Maiduguri are laundry, ablution, bathing, and kitchen. The volumes of water used for these domestic activities from (pipe and borehole) water system in (litres) stood at 451 in Shehuri north, Gwange 553, Bolori 130, and Maisandari 287 respectively. The quantity of greywater produced in (litres) stood at 315 in Shehuri north, 387 in Gwange, Bolori 91, and 200 in Maisandari. The generation percentage from all domestic activities stood at, ablution 7.0 %, 53 bathing, kitchen 20% and laundry 20% in Shehuri north. While in Gwange ablution is 1.0%, bathing 61%, kitchen 8%, and laundry 30%. Similarly, in Bolori ablution 1.3%, bathing 63%, kitchen 24% and laundry 12% while in Maisandari ablution 1.0 %, bathing 66 %, kitchen 17% and laundry 16%. However, this community allows wastewater to flow freely on the street or via poorly constructed sewer system without an adequate water management system. Although this community received a supply of water from a single treatment plant and the plant supplies water to only 30% of Maiduguri residents. Similarly, WHO reported that they are needed for water management across the globe because this resource continued to deflect as a result of growth in population and human activities? Therefore, there is the need for water management to recycling wastewater both at local and national levels to sustain the domestic water supply. However, best on the available literature, rice husk, and Moringa Oleifera is recommended for greywater treatment for the study area.

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