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Grey Water Re-Use: A Sustainable Option for Addressing Household Water Scarcity in Makurdi Town, Benue State, Nigeria

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Abstract
Water scarcity is a fundamental problem for many countries around the world. This paper examined the possibility of adopting and using grey water as an option for addressing household water scarcity in Makurdi town. The study utilized mainly primary data sourced using a structured questionnaire. Systematic random sampling was employed for questionnaire administration (200 households), using a ratio of 1:5 households. The study quantitatively estimated the average amount of water consumed by households for different purposes. The study also estimated potential amount of grey water that can be generated by households. Findings show that mean daily water consumption of households falls below the 115 litres/cap/day internationally recommended minimum requirement. Also the daily total grey water production of 776.9 litres for householdsis below what is obtainable in other parts of the world. This amount of grey water can however compliment fresh water supplies. The paper concludes that with technological advancement and public acceptance, grey water can be a potential water saving option.

Keywords: *Water scarcity, water consumption, grey water, grey water use potential, Makurdi*

1. Introduction

Water is one of the essential needs of man and it is unarguably the most important resource needed for survival. Water is needed to support socio-economic activities such as agriculture, mining, food production and for maintaining healthy ecosystems (Ahile et al, 2015).

The demand for water is growing while fresh water is becoming scarce. Globally, water demand is predicted to increase significantly over the coming decades (UN-Water, 2017), surpassing the available water supply, creating scarcity of the resource.It is forecasted that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress (UN-Water, 2007).

According to the latest United Nations estimates, Nigeria's population stands at 190.7 million, equivalent of 2.55% of the total world population (Worldometers, 2017). This has implications for an increased demand for water to meet various needs, particularly domestic and agricultural needs. The consequence is that the country's limited water resources will be placed under great stress.

To cope with the current and future water scarcity, there is need to look for alternative water sources and work towards achieving high level of sustainability. One of such alternatives is the reuse of wastewater. According to Asano (2002) wastewater reuse accomplishes two fundamental functions: the treated effluent is used as a water resource for beneficial purposes; and the effluent is kept out of streams, lakes, and beaches; thus reducing pollution of surface and groundwater. The use of waste water is aimed at safeguarding water for future generations through efficient use of water (Abenu et al, 2016).

The recycling of grey water, a type of waste water, promotes water conservation(Cates, 2012). Grey water is any water, other than toilet wastes, draining from a household. It includes water from sinks, showering, bathing, washing dishes and clothes (Aljaradin and Selim, 2011).The use of domestic grey water as an alternative source of water makes a significant contribution towards the reduction of portable water use, since over 80% of freshwater withdrawn and used is transformed to wastewater (Emenike et al, 2016).

In Makurdi town, water consumption averages over 250,000 Lpd (Ocheri,2006; Ahile et al, 2015).This is an indication that there is a potentially high volume of household wastewater that can be generated and reused to meet domestic water needs especially for non-portable applications. Unfortunately there seems to be little awareness on the use

of grey water as an alternative source of water in Makurdi town. This claim is validated by the paucity of literature on the subject matter.

This paper therefore assesses the grey water use potential of Makurdi town as an option in checking scarcity of water. The study has the following objectives:

- To determine the level of water consumption for different purposes in the study area.
- To determine the percentage of the population that has adopted the use of grey water.
- To determine the principal sources and utilization avenues of grey water in Makurdi town.
- To determine grey water use potential of Makurdi town.
- To determine the barriers to grey water use in Makurdi town.

2. Materials and Methods

2.1. Study Area

Makurdi town, the capital of Benue Sate in north central Nigeria, lies between Lat.7^{0}44N and Long. 8^{0}54N (see fig. 1). Makurdi is drained by the River Benue which bisects the town into two parts-north and south banks. Other minor rivers that drain the town, and in turn empty their waters in the River Benue includes: Rivers Idye, Genebe, Urudu, Kpege and Kereke.

Makurdi's climate is hot and humid, prompting high evaporation leading to high rainfall which occurs between the months of April and October. The average rainfall amount ranges between 1000mm-1300mm. The implication is that residents of Makurdi should ordinarily have a lot of water at theirdisposal. Unfortunately, water from rainfall and the rivers is not harnessed for supply to households, hence there is perennialscarcity ofwater. Residents of Makurdi therefore need to recycle/reuse water in order to partially address their water scarcity problems.

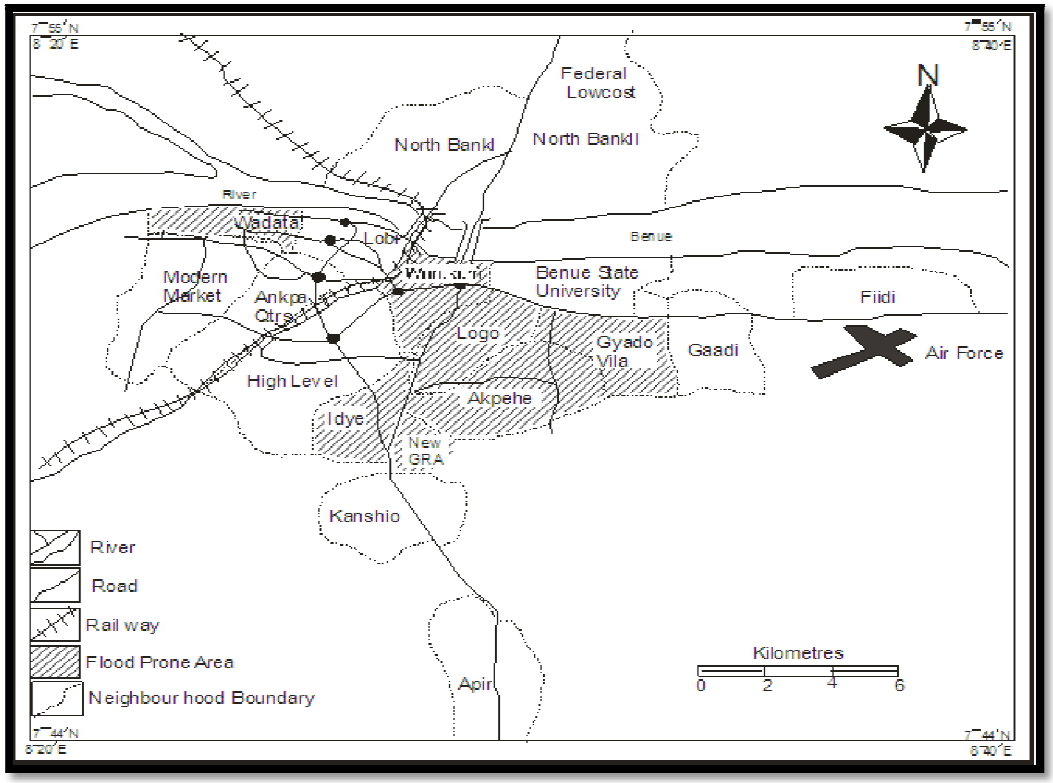

Figure 1: Map Showing Neighborhoods in Makurdi Town. (Source: Ministry of Lands, Makurdi.)

2.2. Methodology

The study utilized mainly primary data sourced using a structured questionnaire which was administered to household heads (both male and female), selected from ten neighbourhoods in Makurdi town. Systematic random sampling was employed for questionnaire administration, using a ratio of 1:5 households. The survey covered a total of 200 households but only 180 questionnaire were retrieved from the field for analysis. The sample size was drawn based on related works carried out in the study area (Akpa,2013). The questionnaire was designed to elicit information on socio-demographic characteristics of respondents, sources of water available to households, and estimated amount of water used for different purposes. Other information elicited include the number of people who have adopted the use of grey water, principal sources and utilization avenues of grey water reuse and the barriers to grey water use. Results were presented using descriptive statistics; particularly mean and percentages. The study also adopted (with modifications) (Pasakhala, Harada, Fujii et al, 2013) formula for computing grey water use potential as follows:

$Gwp = [D_C * (Td_C + Ld_C)] + [B * (Tb + Lb)] + [L * Tl]$ (1)

Where,

D_C = Amount of water consumed for Dish washing and cooking (L/H/day).

B = Amount of water consumed for bathing (L/H/day).

L = Amount of water consumed for laundry (L/H/day).

Td_c= ratio of reused water for toilet from dish washing and cooking.

Tb = ratio of reused water for toilet from bathing.

Tl = ratio of reused water for toilet from laundry.

Ld_C = ratio of reused water for laundry from dish washing and cooking.

Lb = ratio of reused water for laundry from bathing.

Assumptions

$Tl = 1$ (2)

$Td_c = Tb = \frac{(Dt-L)}{(D_C+B)}$ (3)

If $L > [(1 - Td_c) * D_C] + [(1 - Tb) * B]$

$Ld_c = 1 - Td_w$ (4)

$Lb = 1 - Tb$ (5)

If $L < [(1 - Td_C) * D_C] + [(1 - Tb) * B]$

$Ld_C = Lb = \frac{L}{[(1-Td_C)*D_C]+[(1-Tb)*B]}$ (6)

$Sd_C = 1 - Td_C - Ld_C$ (7)

$Sb = 1 - Tb - Lb$ (8)

Where Dt stands for water demand for toilet (L/household/day);$Sd_C$and Sbstands for ratio of surplus of grey water from dish washing/cooking and bathing respectively.

3. Results

3.1. Estimated Level of Water Consumption for Different Purposes in Makurdi Town

The study attempted to estimate the level of water consumption for selected water uses in Makurdi town. This is because the amount of water consumed will give an indication into how much of grey water can be produced by a household. From table 1, findings show that majority of respondents (86.1%) use about 1-50 litres of water daily for dish washing/cooking. This indicates that not so much water is consumed for dish washing. For bathing, findings show that majority of the respondents (55.5%) use about 51-100 litres of water daily. Findings also show that 53.9% which is the majority of opinions sampled on water use for laundry, use about 51-100 litres of water daily. For drinking, majority (53.9%) of respondents sampled use about1-50 litres of water daily, while 43.9% of respondents use between 51-100 litres of water daily. Similarly, findings also show that majority (47.2%) of respondents sampled for toilet flushing use about 51-100 litres of water daily.

Volume of Water Consumed (In Litres)	**Purposes of Water Use**				
	Dish washing/cooking	Bathing	Laundry	Drinking	Toilet flushing
1-50	155 (86.1%)	43 (23.8%)	33 (18.3%)	97 (53.9%)	43 (23.8%)
51-100	20 (11.1)	100 (55.5%)	97 (53.9%)	79 (43.9%)	105 (58.3%)
101-150	4 (2.2)	23 (12.8%)	41 (22.8%)	3 (1.7%)	22 (12.2%)
151-200	1 (0.6)	14 (7.8%)	9 (5%)	1 (0.6%)	15 (8.3%)
Total	180 (100%)	180 (100%)	180 (100%)	180 (100%)	180 (100%)

Table 1: Distribution of Water Use for Different Purposes by Respondents

Table 2 shows mean daily water use for different purposes. Findings show that on the average, 34.1 litres of water are used daily for dish washing/cooking. Findings similarly show that an average of 77.1, 82.7 and 49.9 litres of water is consumed daily for bathing, laundry and drinking respectively. This demonstrates that more is used for laundry, toilet flushing and bathing than the other uses.

		Dish Washing/Cooking		Bathing		Laundry		Drinking		Toilet Flushing	
Vol. of water (in litres)	Class mid-point (x)	Frequency (f)	Fx	F	Fx	F	fx	f	fx	F	Fx
1-50	25.5	155	3952.5	43	1096.5	33	841.5	97	2473.5	43	967.5
51-100	75.5	20	1510	100	7550	97	7323.5	79	5964.5	105	7927.5
101-150	125.5	4	502	23	2886.5	41	5145.5	3	376.5	22	2761
151-200	175.5	1	175.5	14	2457	9	1579.5	1	175.5	15	2632.5
Total		180	6140	180	13990	180	14890	180	8990	180	14288.5
Mean		34.1		77.7		82.7		49.9		79.3	

Table 2: Mean Daily Water Use (In Litres) for Different Purposes in Makurdi Town

3.2. Water Consumption for Various Purposes across Size of Household

The study also assessed water consumption for different purposes across size of household as shown in table 3. Findings show a progressive increase in water consumption across the various household sizes. For instance, households having more than 15 persons consumed averagely about 463.9 litres of water/day, while households having between 1-5 persons consume on average about 265.6 litres of water/day. The same applies to households with 6-10 persons and 11-15 persons. This clearly shows that the size of a household determines the amount of water the household consumes.

Size Ofhousehold	Dish Washing/Cooking	Bathing	Laundry	Drinking	Toilet Flushing	Total
1-5	33.2	64.1	79.1	9.1	80.1	265.6
6-10	40.7	73.1	86.0	11.5	93.5	304.8
11-15	68.0	90.5	75.4	12.2	91.5	337.6
>15	75.5	118.9	125.5	15.5	128.5	463.9

Table 3: Water Consumption for Various Purposes across Size of Household

3.3. Use of Grey Water in Makurdi Town

The study also sought to find out the percentage of the population that use grey water. Respondents were asked to answer 'Yes' if they use grey water and 'No' if they don't. From table 4, findings show that 65% of respondent sampled use grey water while 35% of respondents don't use grey water.

The study probed to find out why this group of respondents don't use grey water. From table 5, findings show that 42.2% of respondents don't use grey water because they don't know it's usefulness, 14.4% of respondents feel the use of grey water is unhygienic and for 27.2% of respondents, grey water is not just appealing to them. Findings also show that 15.6% of the respondents felt they have enough water in their homes so it was needless using grey water, while less than 1% of the respondents cited the cost of treating grey water as a major barrier.

Response	Frequency	Percentage (%)
Yes	117	65
No	63	35
Total	180	100

Table 4: Distribution of Population That Use Grey Water

Reason	Frequency	Percentage (%)
It's unhygienic	26	14.4
I have enough water	28	15.6
I don't know it's usefulness	76	42.2
Not just appealing to me	49	27.2
It's costly to treat	1	0.6
Total	180	100

Table 5: Barriers to Grey Water Use in Makurdi Town

3.4. Sources and Utilization Options of Grey Water in Makurdi Town

Table 6, shows principal sources which households grey generate grey water which they use. Findings show that about 76.1% of grey water generated comes from washing/laundry, 17.2% is generated from bath tubs, while only 6.7% is generated from water used to wash dishes or kitchen sinks.

Table 7, shows the ways through which households utilize the grey water they generate. Findings show that 62.7% of grey water generated is used for toilet flushing, 12.2% is used for wetting streets, 10% of grey water generated is used for washing of cars/bikes, while the other uses account for 15.1%.

Source	Frequency	Percentage (%)
Washing	137	76.1
Bath tubs	31	17.2
Dish washing/cooking	12	6.7
Total	180	100

Table 6: Principal Sources of Grey Water in Makurdi Town

Use of Grey Water	Frequency	Percentage (%)
Flushing toilets	113	62.7
Washing bikes/cars	18	10
Irrigating gardens	7	3.8
Wetting streets	22	12.2
Watering flowers	14	7.7
Laundry	6	3.3
Total	180	100

Table 7: Utilization Options for Grey Water in Makurdi Town

3.5. Grey Water Use Potential in Makurdi Town

Every household produces a certain amount of grey water that can be used particularly for non- potable applications. If this is consciously done, the volume of grey water that will be produced will go a long way in addressing water scarcity problems of most households.

Grey water production (Gwp) in (L/household/day) was calculated based on equations (1) to (8). The calculation was conducted for four household sizes i.e 1-5, 6-10, 11-15, and >15 persons as shown in table (8).The results of the calculation shows that total grey water production in Makurdi is about 776.9 litres per day. This excludes the surplus grey water that is not accounted for. The quantity of grey water produced will increase the availability of water.

Size of Household	D_C	B	L	D	T	$Td_c = Tb$	$Ld_c = Lb$	$Sd_c = Sb$	Gwp
1-5	33.2	64.1	79.1	9.1	80.1	0.01	0.82	0.17	160.1
6-10	40.7	73.1	86.0	11.5	93.5	0.07	0.81	0.13	185.5
11-15	68.0	90.5	75.4	12.2	91.5	0.11	0.52	0.37	175.4
>15	75.5	118.9	125.5	15.5	128.5	0.02	0.65	0.33	255.9

Table 8: Calculation of Grey Water Use Potential

4. Discussion of Results

Water plays a very important role in human life. Unfortunately this resource is in short supply in most places around the world; as water demand exceeds the supply. World projections of water availability show that they will be a sharp decline by the year 2025 if the current use pattern continues (Ringler et al, 2009).

In Nigeria, daily per capita consumption of water varies between 10-27 litres with an average of 46 litres (Ayoade and Oyebande, 1983). The actual amount of water used may be greater depending on the ease and convenience of supply(Ayoade and Oyebande, 1983). In Makurdi town, water consumption for households and particularly businesses exceeds the above stated average (Ocheri, 2006). People sometimes go out of their way to get water to meet their needs. This still doesn't meet the internationally recommended minimum requirements of 115 litres/capita/day (Ayoade and Oyebande).

Despite the shortfall in water requirements, water consumption in Makurdi already indications that there is a potentially high amounts of grey water that can be produced for use particularly for non-potable purposes.In most places, particularly in the developed world, grey water is used to mitigate water shortages. For instance, in a highly populated county like Los Angeles, an estimated 800 million gallons of grey water are produced daily (Cohen, 2009). In Asia and the middle-east, huge amounts of grey water are produced daily and used particularly for irrigation farming (Khatun and Amin, 2011; Aljaradin and Selim, 2011,Al-Jayyousi, 2003).The 776.9 litres of grey water produced by households on a daily basis in Makurdi town falls far below what is obtained in other places. This is because there is little awareness about grey water reuse; the perception towards grey water reuse is also negative for most residents.

The major barrier to grey water use in Makurdi town is remains the lack of awareness of the importance of grey water (see table 5) as a potential fresh water saving option. Another barrier is the fear of contacting water borne diseases. This situation is common in most African countries as opposed to the developed nations. With technological advancement and public acceptance, grey water can be a potential water saving option.

5. Conclusion

This study examined the potential of grey water as option in addressing the water scarcity problem in Makurdi town. Water is consumed in Makurdi for different purposes on a daily basis, with toilet flushing and laundry taking the highest percentage. This water consumption however doesn't meet the internationally recommended amount of 115 litres/capita/day. Households can generate grey water from the fresh water they consume. If managed properly, grey water could be a sustainable option for address water scarcity in Makurdi town.

The study therefore recommends that Government should invest in technology that will promote water recycling in most Nigerian cities. Individuals should also be encouraged to install grey water collection and recycling systems in their homes. This will reduce pressure of the already stressed fresh water sources.

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