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Research Paper

Greywater generation and reuse among residents of low-income urban settlements in the Oforikrom Municipal Assembly, Ghana

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ABSTRACT

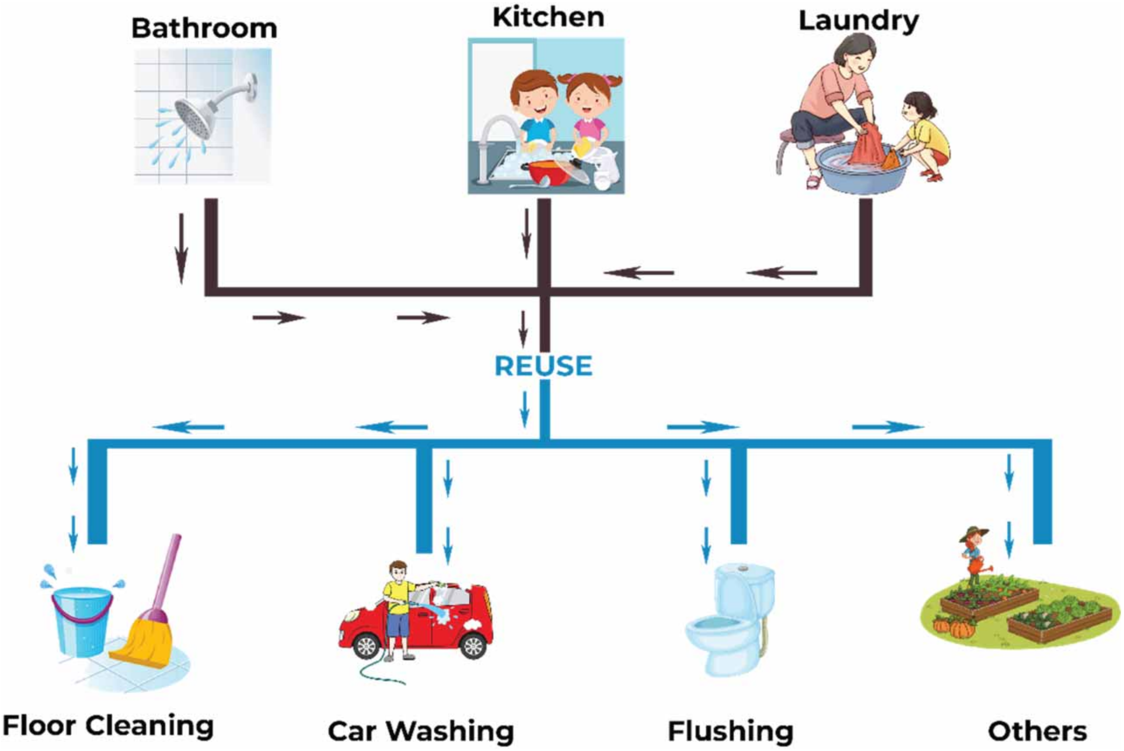
Greywater management in Ghana has yet to receive the needed attention even though its current generation and reuse practices pose severe environmental and public health concerns, including odour nuisance, groundwater pollution, and risks from pathogens. This study examined the current greywater generation and reuse patterns among low-income urban residents in Kumasi, Ghana. Data were collected from three communities (Ayeduase, Kotei, and Twumduase) through cluster sampling, and a total of 458 questionnaires were administered to households. The average amount of greywater generated for various activities in low-income urban settlements was 53.7 l/c/d. The results showed that greywater reuse is not common among the study participants, but those who reuse it prefer laundry to kitchen and bathroom greywater. The proportion of greywater reuse was estimated at 20.1%, with 2.6, 0.9, and 17.9% of households reusing greywater from the kitchen, bathroom, and laundry, respectively. Factors that significantly influenced greywater reuse included age, the community of residence, and the type of house. The study suggests that increased education and awareness about greywater treatment, reuse, and impacts in low-income urban communities could lead to increased participation in its management.

Key words: generation pattern, greywater, low-income urban settlement, reuse

HIGHLIGHTS

- The average amount of greywater generated in low-income urban settlements is determined.
- Data for planning are available.
- Factors influencing greywater reuse are determined.
- Community members have become aware of the opportunities for greywater reuse.
- Education needed for the implementation of greywater treatment and management systems.

GRAPHICAL ABSTRACT



INTRODUCTION

Globally, greywater presents itself as an abundant resource generated throughout the lives of people in their daily activities. Greywater generated in households has been estimated to account for 50–80% of domestic wastewater and may contain contaminants with the potential to cause health and environmental risks if not properly managed (Li *et al.* 2009; Yu *et al.* 2013; Oron *et al.* 2014). Compared to blackwater (water from the toilets) or solid waste, greywater has not received the necessary attention despite the associated health and environmental risks due to improper management or disposal practices, especially in low-income countries. The indiscriminate disposal of untreated greywater generated by households in low-income settlements is a significant sanitation issue that needs immediate attention. This is because greywater generated from these areas contains high contaminants such as microbial pathogens and heavy metals (Katukiza *et al.* 2013). The high levels of contaminants might be due to multiple water use within these low-income households (Katukiza *et al.* 2015).

In the sub-Saharan region and other developing countries, proper greywater management is given the least attention (Morel & Diener 2006; Hyde 2013). In urban and peri-urban Ghana, untreated greywater is mostly discharged into existing stormwater drains or sewers, making water bodies the primary receivers (Dwumfour-Asare *et al.* 2017a, 2017b). This leads to oxygen depletion, increased turbidity, eutrophication, and microbial and chemical contamination of the water bodies (Morel & Diener 2006). Especially in low-income settlements with no sewers or any means of greywater management, untreated greywater is openly disposed of into open drains, backyards, gutters, and compounds of houses. Data from the Ghana Statistical Services indicate that only 1–5% of greywater disposal practices are improved (GSS 2013), which means that the remaining 95% of untreated greywater ends up in our environment, posing severe health and environmental impacts.

Even though greywater contains some contaminants, it is widely used for domestic activities such as garden watering, ornamental uses in fountains and waterfalls, landscaping, lawn irrigation, toilet flushing, cleaning floors, washing vehicles, and cleaning bathrooms (Elhegazy & Eid 2020) when it is properly treated. Greywater treatment and reuse is a possible way of reducing health and environmental impacts and consuming potable water for other activities that do not require the use of treated water. In areas where water resources are scarce, treated greywater could be used as an alternative water source to supplement and reduce the pressure on the already scarce water resource (Oron *et al.* 2014). In some urban areas in Ghana, inhabitants are already experiencing shortages in water supply (Nyarko *et al.* 2016), which makes treatment and reuse of greywater a critical approach and practice to reduce the demand for potable water for purposes that do need high-quality water (Elhegazy & Eid 2020). The treatment and reuse of greywater come with the challenge of ensuring public health safety and associated regulations (Oh *et al.* 2015). Greywater is treated for reuse to reduce the demand for freshwater supply and promote the use of high-quality water for potable uses in arid and water-stressed areas (Al-Hamaiedeh & Bino 2010; Mandal *et al.* 2011).

There have been recent studies on greywater in developing countries focusing on characteristics, pollutant loads, generation rate, reuse options, and management practices (Morel & Diener 2006; Katukiza *et al.* 2015; Dwumfour-Asare *et al.* 2017a, 2017b; Oteng-Peprah *et al.* 2018a, 2018b; Dwumfour-Asare *et al.* 2020). However, there remain some research gaps in information related to current generation patterns, the prevalence of reuse, and factors that influence greywater reuse in typical low-income settlements in developing countries. This paper, therefore, seeks to present an overview of the generation and reuse of greywater in low-income urban settlements in the Ashanti region of Ghana.

METHODS

Study area

The study was conducted in the Ayeduase electoral area within the Oforikrom Municipal Assembly in the Ashanti Region of Ghana (Figure 1). The electoral area comprises three communities: Ayeduase, Kotei, and Twumduase. These communities are considered low-income urban settlements. These communities are mainly non-sewered, and onsite sanitation is mostly not water-based, but household latrines and public Kumasi Ventilated Improved Pits (KVIPs) are primarily used. The primary source of water supply within the study sites is groundwater through communal standpipes and hand-dug wells. This source of water is for commercial and domestic purposes. The disposal of greywater from these households is primarily carried out by releasing it into open drains and open areas and occasionally directing it into existing gutters located in front of the houses (GSS 2014). The survey employed specific household selection criteria, encompassing two main factors: willingness to

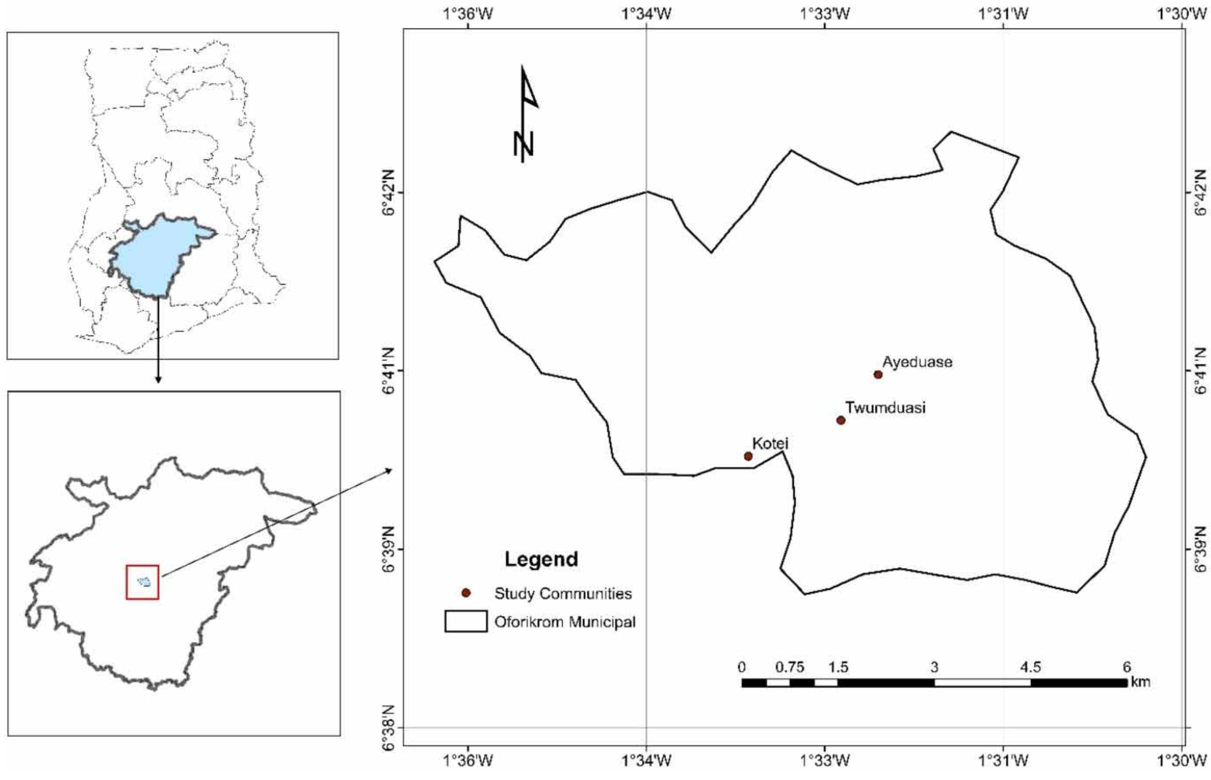


Figure 1 | Map of study sites for the household survey.

participate and residence within low-income communities in the Oforikrom Sub-Metro, which is situated in the Kumasi Metropolis of the Ashanti Region, Ghana.

Based on the regional report of the 2010 National Population and Housing Census (GSS 2014), the housing conditions in the city exhibit various characteristics. Most households, 42.3%, have access to pipe-borne water within their dwellings, while 18.4% rely on borehole/protected well water sources. In terms of dwelling types, compound houses make up 55.2% of the main dwelling units, followed by separate houses at 15.7%.

The population of the study communities is as follows: Kotei, with 48,419 residents, Ayeduase, with 20,053 residents, and Twumduase, with a population of 79,230 (GSS 2014).

Data collection

A cluster sampling method was adopted to collect data from the study communities. Each community was treated as a cluster, and households were randomly selected. Each community was divided into clusters using the existing road networks. Subsequently, households from these clusters were randomly selected to participate in the survey. A pen was spun in a central location in each cluster to determine the direction in which the enumerator would sample households. Every even-numbered household was sampled until the enumerator reached their quota of households or until they reached the boundary of the community. If the boundary was reached before reaching the quota, the enumerator returned to the central location within the cluster to repeat the process.

The household survey was conducted in the study communities over approximately 30 days from July to August 2022 using structured mobile phone-based questionnaires (Kobo Collect Application). The questionnaires were used to gather data during visits to the households. The questionnaires were piloted in three similar survey sites (Bomso, Ayigya, and Gyinyase) before the main study. The pilot helped to address gaps in the questionnaire, which helped to maximise outputs from the primary data collection exercise. The specific questions captured by the questionnaire included:

- *General household demographics*: number of people, occupation, educational level, and average income
- *Available services*: main water supply source and water use patterns
- *Greywater management*: greywater sources, greywater generation, awareness of greywater reuse, greywater reuse practices, and willingness to use treated greywater

The quantities were obtained by asking respondents about the quantities of greywater disposed of after the various activities. We estimated greywater generation rates (in litres/capita/day, l/c/d) for activities including cooking, dishwashing, bathing, laundry, cleaning floors, and car washing.

Three enumeration teams were formed; each consisted of three members, including at least one female. Each team was assigned a community. A total of 458 questionnaires were administered to households in these three communities. The study's sample size was calculated using Yamane's (1967) formula $n = N/(1 + Ne)^2$ at a 95% confidence level, where n is the sample size, N is the population size, and e is the level of precision (0.05). Informed consent and willingness to participate in the study were sought from the Unit Committee Chairmen, Assemblymen, and community members. Formal permission was also obtained from the Oforikrom Municipal Assembly (OFMA), formerly Oforikrom Sub-Metro, Kumasi. Ethical clearance for this study was obtained from the Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics, ensuring the protection of participants' rights and compliance with ethical guidelines.

Study variables

The dependent variable in this study is the reuse of greywater, which is defined as residents who reuse it for household activities such as cooking, dishwashing, bathing, laundry, cleaning floors, and car washing. Greywater reuse was recorded as a binary variable with '1' as reuse of greywater and '0' as otherwise.

The study considered 16 independent variables to help determine reuse among residents of low-income urban settlements in the Oforikrom Municipal Assembly, Ghana. The variables such as age group, gender, marital status, community, type of household, educational level, parity (number of births), household size, household income, household gets adequate water, water being readily available, cost of water, a bucket of water for washing, knowledge of greywater, willingness to reuse greywater, and challenges with reuse of greywater are used. These variables were selected because they have been used to determine the reuse of greywater in Ghana and elsewhere (Dwumfour-Asare *et al.* 2017a, 2017b).

Data analysis

The questionnaires and responses were downloaded from the online server (Kobo Collect Application) into an Excel spreadsheet and were cleaned and validated. Data were analysed using STATA statistical software version 16.0. Firstly, descriptive statistics comprising frequency, percentage, mean, and standard deviation were done to describe the general characteristics of the sampled population. At a 25% alpha level, a cross-tabulation (using either X^2 or Fisher exact where necessary) was done to determine the relationship between explanatory variables and greywater management practices. At the cut-off point of 25%, any key explanatory variable that had no association with the outcome variable was not entered into the logistic regression model. At a 95% confidence interval, two logistic regression models were built. Model I was a bivariate calculation between the outcome variable and the key explanatory variable. Before running the logistic regression Model II, the multicollinearity test was conducted to ascertain the correlation between explanatory variables and reported in the Variance Inflation Factor (VIF). The results showed no evidence of multicollinearity between our key explanatory variables (mean VIF = 1.40, maximum VIF = 2.25, minimum VIF = 1.03) (see Appendix 1). In Model II, the effect of other variables was controlled. The results for the regression models were reported in odds ratio. The odds ratios were interpreted as having a higher likelihood to reuse greywater for any purpose when the odds were above 1 and *vice versa*. To ascertain the model fit, the Hosmer–Lemeshow post-estimation test was applied, and the results indicated no evidence of poor fit.

RESULTS

Table 1 presents the socio-demographic characteristics of the 458 respondents that participated in the study. Descriptively, more than one-third (36.0%) were in the age category of 18–30 and nearly a quarter (22.7%) were aged 31–40, with a mean age of 38.4. Nearly three-fourths (74.7%) were females, nearly half (49.6%) were married, and more than one-third (40.4%) had obtained secondary/high school education. A little above one-third (34.5%) dwell at the Kotei community, which was close to half (43.2%), had household size of 6–10, and close to half had given birth to four or more children. More than one-third (39.3%) dwell in compound houses, nearly two-thirds (61.8%) were self-employed, and nearly three-fourths (73.1%) earn 800 Ghana cedis or below every month.

Sources of water supply and availability

The Ghana Water Company Limited (GWCL) has the responsibility and mandate to deliver treated water to residents in urban areas of Ghana. However, some households still lack access to water supplied by GWCL. Mechanised boreholes in dwellings (47.6%) and public standpipes (41.3%) were the main sources of water available in the study areas. GWCL pipe in dwellings (3.5%), hand-dug wells (1.3%), and tanker/vendor supply (6.3%) were also other sources of water supply in the study areas (Figure 2).

Greywater generation patterns

The study investigated the pattern of greywater generation by household in the study communities. The average quantities of greywater generated for cooking, dishwashing, bathing, laundry, floor cleaning, and car washing were 5.2, 3.8, 16.2, 13.0, 3.7, and 11.8 l/c/d, respectively. The highest value (16.2 l/c/d) was observed for bathing, while the lowest value (3.7 l/c/d) was seen for floor cleaning. Cumulatively, the average greywater generation per person per day was 53.7 l. Figure 3 shows the variations in the average quantities of greywater generated for various activities among the communities.

Proportion of the reuse of greywater

Descriptively, the proportion of the reuse of greywater was 20.1%. Specifically, 2.6, 0.9, and 17.9% of households reused greywater from the kitchen, bathing, and laundry, respectively (Table 2).

Table 3 presents the bivariate analysis of the determinants of the reuse of greywater. Age group, gender, community, type of household, educational level, marital status, parity, household size, monthly income, water readily available, cost of water per month, knowledge of greywater, and a bucket of water for washing were associated with the reuse of greywater at a 25% significance level. All the remaining variables were statistically not associated with the reuse of greywater.

Table 4 presents the logistic regression results of determinants of greywater reuse. Respondents aged 41–50 years compared to 18–30 years [odds ratio (OR) = 3.92, 95% CI = 2.09–7.37], those who dwell in Twumduase compared to Ayeduase [OR = 3.15, 95% CI = 1.64–6.03], and those who live in flat/apartment compared to compound house [OR =

Table 1 | Socio-demographic characteristics of respondents

Variables	Frequency ($n = 458$)	Percentage (%)
Age group (in years)		
18–30	165	36.0
31–40	104	22.7
41–50	94	20.5
≥ 51	95	20.8
Gender		
Male	116	25.3
Female	342	74.7
Marital status		
Never married	162	35.4
Married	227	49.6
Separated/divorced	39	8.5
Widowed	30	6.5
Educational level		
No formal education	54	11.8
Basic education	137	29.9
Senior Secondary School/Senior High School	185	40.4
Tertiary/Higher Education	82	17.9
Community		
Ayeduase	154	33.6
Kotei	158	34.5
Twumduase	146	31.9
Household size		
1–5	173	37.8
6–10	198	43.2
11–15	61	13.3
≥ 16	26	5.7
Parity		
0	163	35.6
1–3	88	19.2
≥ 4	207	45.2
Household type		
Compound house	180	39.3
Detached house	121	26.4
Flat/apartment	74	16.2
Semi-detached house	83	18.1
Employment status		
Unemployed	31	6.8
Casual worker	27	5.9
Farming	7	1.5
Public/civil servant	99	21.6
Private company	11	2.4

(*Continued.*)

Table 1 | Continued

Variables	Frequency ($n = 458$)	Percentage (%)
Self-employed	283	61.8
Monthly income (GH¢)		
Not applicable	31	6.8
≤ 800	335	73.1
801–1,500	59	12.9
1,501–2,500	17	3.7
≥ 2,500	16	3.5

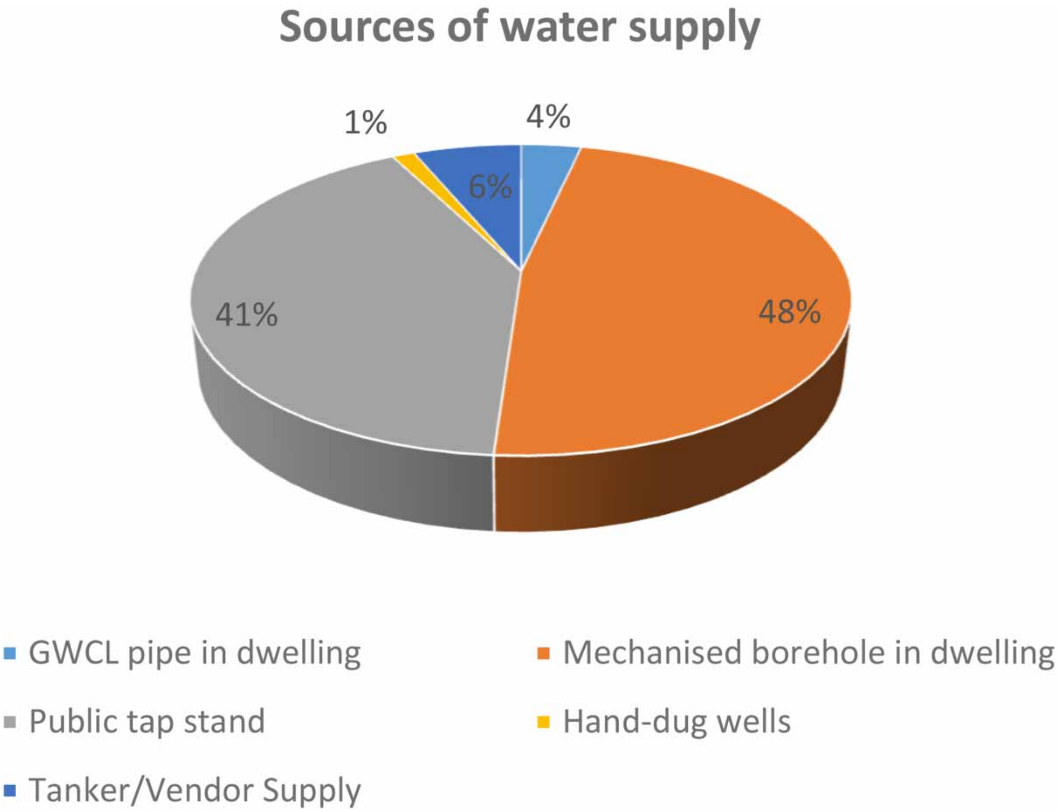


Figure 2 | Pie chart showing the sources of water supply in the study areas.

2.88, 95% CI = 1.60–5.20] had increased odds of the reuse of greywater. Respondents who were married compared to never married [OR = 1.75, 95% CI = 1.03–2.98], respondents who had given birth to 1–3 children compared to no child [OR = 2.68, 95% CI = 1.40–5.15], and those with a household size of 6–10 compared with 1–5 [OR = 1.70, 95% CI = 1.01–2.86] had higher odds of the reuse of greywater. Respondents who reported water is not readily available to them daily compared to those who reported it is available [OR = 2.29, 95% CI = 1.21–4.32] and those who use between 11–30 buckets of water for washing compared to those who use 1–10 buckets [OR = 2.09, 95% CI = 1.26–3.48] had higher odds of the reuse of greywater. Additionally, male respondents compared to females [OR = 0.34, 95% CI = 0.18–0.66] and respondents who earn 801–1,500 Ghana cedis monthly compared to those earning 800 or below [OR = 0.25, 95% CI = 0.09–0.70] had decreased odds of the reuse of greywater.

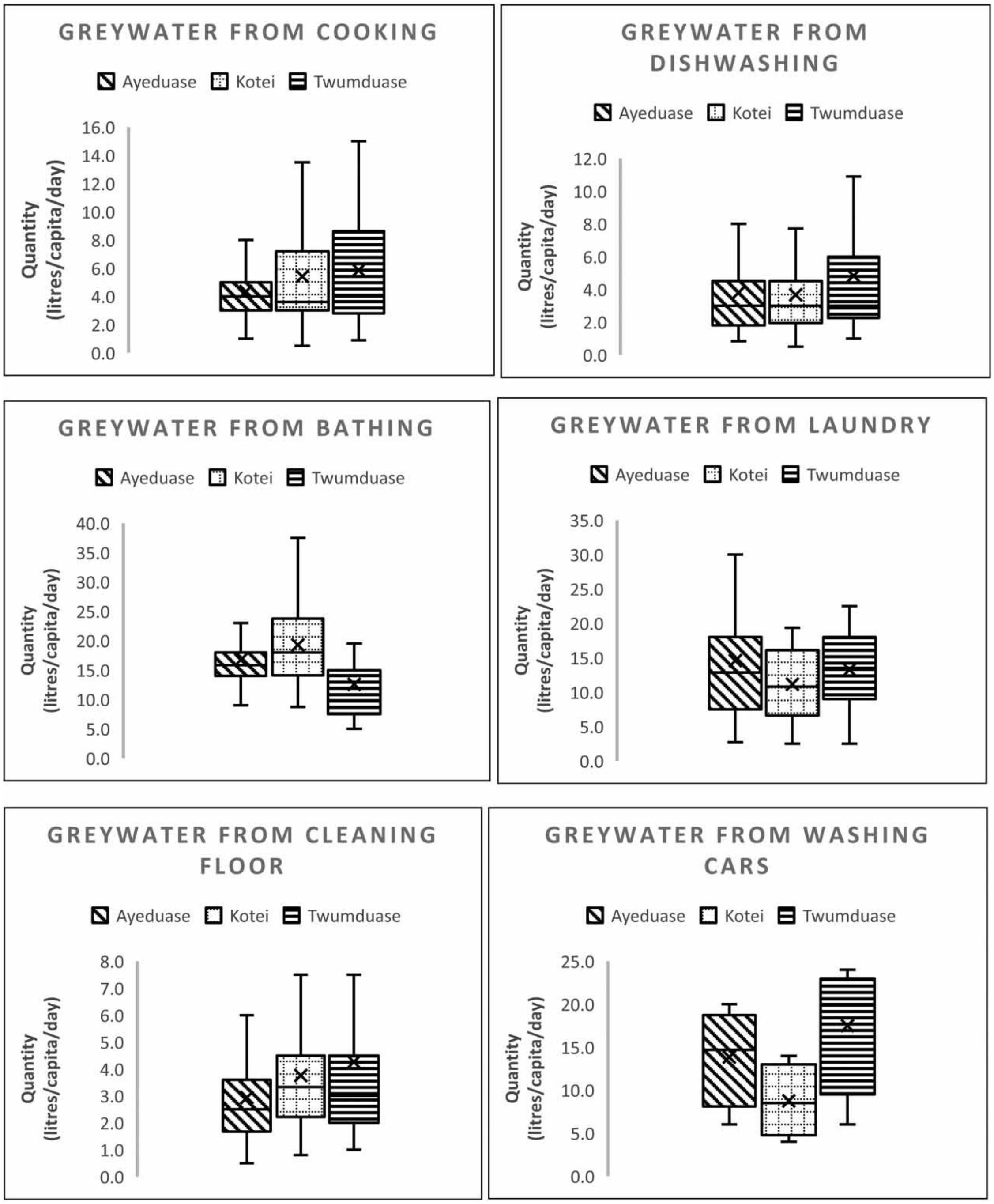


Figure 3 | Box and whisker plots showing greywater generation patterns. *Note: l/c/d, litres/capita/day.*

After adjusting for other covariates, a similar observation was recorded where respondents aged 41–50 compared to 18–30 years had higher odds of the reuse of greywater [adjusted odd ratio (AOR) = 5.92, 95% CI = 2.44–14.38]. Additionally, respondents from the Kotei community compared to Ayeduase [AOR = 2.91, 95% CI = 1.41–6.00] and those who live in flats/apartments compared to compound houses [AOR = 3.28, 95% CI = 1.64–6.55] had increased odds of the reuse of greywater. However, respondents who earn more than GHS 800 (USD 100) monthly compared to those who earn less had lower odds of the reuse of greywater [AOR = 0.23, 95% CI = 0.07–0.72].

Table 2 | Proportion of the reuse of greywater

Variables	Frequency ($n = 498$)	Percentage (%)
Reuse of greywater		
No	366	79.9
Yes	92	20.1
Reuse of kitchen greywater		
No	446	97.4
Yes	12	2.6
Reuse of laundry greywater		
No	376	82.1
Yes	82	17.9
Reuse of bathing greywater		
No	454	99.1
Yes	4	0.9

DISCUSSIONS

The average greywater generation per person per day was determined by estimates from households. The generation rates provide useful information for planning and management strategies. This study's greywater generation rates lie within the reported range in literature (Jamrah *et al.* 2006; Alsulaili & Hamoda 2015; Oteng-Peprah *et al.* 2018a, 2018b). The finding is comparable to generation rates as reported by Oteng-Peprah *et al.* (2018a, 2018b) for Africa and the Middle East, which range between 14 and 161 l/c/d. This study also reveals a generation rate of 54.3 l/c/d compared to the estimates of 40.42-60.11 l/c/d reported by Dwumfour-Asare *et al.* (2017a, 2017b) in a recent study conducted in Kumasi. This daily per capita generation exceeds the range reported for households in Ghana (18.8–25 l/c/d) (Hyde 2013) and peri-urban settlements of Kampala, Uganda (14–16 l/c/d) by Kulabako *et al.* (2011). The difference in reported generation rates could be ascribed to factors such as geographical location, living standards, customs, and habits, as well as the general lifestyle of the people. Furthermore, the study revealed variation in greywater generation from sources such as cooking, dishwashing, bathing, laundry, floor cleaning, and car washing. The generation rate from the various sources was high for bathing (16.2 l/c/d), followed by laundry (13.0 l/c/d), car washing (11.8 l/c/d), cooking (5.2 l/c/d), and dishwashing (3.7 l/c/d), whereas floor cleaning (3.7 l/c/d) recorded the least. A similar trend was observed by Jamrah *et al.* (2006) in their assessment of greywater variability in Amman, Jordan and Kulabako *et al.* (2011) in peri-urban settlements in Kampala, Uganda. In this study, the high generation rate for laundry greywater indicates a higher frequency of water use for laundry activities per week.

According to the study, households were generally opposed to greywater reuse. However, the greywater quantity generated by households could be enough for reuse purposes such as cleaning floors, gutters, bathrooms, and toilet flushing within dwellings. Compared with similar studies in Ghana and other countries, our results showed a lower proportion of greywater reuse among study participants. Whereas greywater reuse among participants in this study was found to be 20.1%: Dwumfour-Asare *et al.* (2017a, 2017b) and Kulabako *et al.* (2011) recorded 62 and >50% in their respective studies. It should be noted that although greywater reuse is not a popular practice among our study participants, those who reuse prefer laundry (17.9%) to kitchen (2.6%) and bathroom (0.9%) greywater. The laundry greywater is mostly used for cleaning floors, bathrooms, washing cars, and flushing toilets. These results align with those reported in Kumasi by Dwumfour-Asare *et al.* (2017a, 2017b), who also observed higher greywater reuse practices with laundry sources compared to the bathroom. However, no reuse was reported for kitchen greywater by Dwumfour-Asare *et al.* (2017a, 2017b). The low greywater reuse among our study participants could be attributed to the perceived health risk associated with greywater. According to Oteng-Peprah *et al.* (2020), one of the barriers to greywater reuse is the issue of public health risk. This is also in agreement with the study by Massoud *et al.* (2018), who cited human contact with wastewater as a crucial determinant of greywater reuse. They found that people who perceived that reusing greywater could affect human health were less likely to reuse. A similar reason was cited by Jamrah *et al.* (2006). This may be a legitimate concern because the health risk associated with greywater is widely established

Table 3 | Bivariate analysis of determinants of the reuse of greywater

Variable	No	Yes	X^2/Fisher exact	*P*-value
Age group (in years)			29.304	<0.001
18–30	145 (39.6)	20 (21.7)		
31–40	78 (21.3)	26 (28.3)		
41–50	61 (16.7)	33 (35.9)		
≥ 51	82 (22.4)	13 (14.1)		
Gender			10.883	<0.001
Female	261 (71.3)	81 (88.0)		
Male	105 (28.7)	11 (12.0)		
Community/place of residence			15.474	<0.001
Ayeduase	139 (38.0)	15 (16.3)		
Kotei	118 (32.2)	40 (43.5)		
Twumduase	109 (29.8)	37 (40.2)		
Type of household			30.727	<0.001
Compound	144 (39.3)	36 (39.1)		
Detached	109 (29.8)	12 (13.1)		
Flat/apartment	43 (11.8)	31 (33.7)		
Semi-detached	70 (19.1)	13 (14.1)		
Educational level			10.568	0.014
No formal	45 (12.3)	9 (9.8)		
Basic	108 (29.5)	29 (31.5)		
Senior Secondary School/Senior High School	138 (37.7)	47 (51.1)		
Tertiary/Higher Education	75 (20.5)	7 (7.6)		
Marital status			5.229	0.156
Never married	138 (37.7)	24 (26.1)		
Married	174 (47.5)	53 (57.6)		
Separated/divorced	32 (8.7)	7(7.6)		
Widowed	22 (6.0)	8 (8.7)		
Parity			9.654	0.008
0	142 (38.8)	21 (22.8)		
1–3	63 (17.2)	25 (27.2)		
≥ 4	161 (44.0)	46 (50.0)		
Household size			4.850	0.183
1–5	145 (39.6)	28 (30.4)		
6–10	149 (40.7)	49 (53.3)		
11–15	51 (13.9)	10 (10.9)		
≥ 16	21 (5.7)	5 (5.4)		
Income			19.641	<0.001
≤ 800	283 (77.3)	82 (89.2)		
801–1,500	55 (15.0)	5 (5.4)		
≥ 1,501	28 (7.7)	5 (5.4)		
Get adequate water			0.730	0.785
No	10 (2.7)	356 (97.3)		

(*Continued.*)

Table 3 | Continued

Variable	No	Yes	X^2/Fisher exact	*P*-value
Yes	3 (3.3)	89 (96.7)		
Water is readily available			6.768	0.009
Daily	333 (91.0)	75 (81.5)		
Not daily	33 (9.0)	17 (18.5)		
Cost of water per month (GHC)			0.139	0.166
< 50	308 (84.2)	82 (89.1)		
51–100	55 (15.0)	8 (8.7)		
> 100	3 (0.8)	2 (2.2)		
Bucket for washing			8.273	0.004
1–10	155 (42.5)	24 (26.1)		
11–30	210 (57.5)	68 (73.9)		
Knowledge of greywater			1.379	0.240
No	286 (78.1)	77 (83.7)		
Yes	80 (21.9)	15 (16.3)		
Willingness to use greywater			0.803	0.370
No	206 (56.3)	47 (51.1)		
Yes	160 (43.7)	45 (48.9)		
Challenges with the use of greywater			0.882	0.348
No	327 (89.3)	79 (85.9)		
Yes	39 (10.7)	13 (14.1)		

Note: Figures in brackets are percentages.

(Jamrah *et al.* 2006; Kulabako *et al.* 2011; Alsulaili & Hamoda 2015; Dwumfour-Asare *et al.* 2017a, 2017b; Oteng-Peprah *et al.* 2018a, 2018b). Greywater is associated with pathogenic microorganisms such as bacteria, protozoa, helminths, and other enteric viruses, which can cause diseases, especially when greywater is not treated (Dwumfour-Asare *et al.* 2017a, 2017b).

According to the study, the greywater reuse practice was significantly influenced by age, the community of residence, the type of house, and household income. Age greatly impacts greywater reuse, as reported in many studies. In this study, age was found to be a significant determinant of greywater reuse with an AOR of 5.92 ($p < 0.001$) for those aged 41–50 and 3.03 ($p < 0.05$) for those aged 18–30 years. This is in agreement with the study by Bakare *et al.* (2016), who identified a significant association between age and greywater use in a low-cost housing development in Durban, South Africa. Similarly, this outcome is consistent with other studies by Dolnicar *et al.* (2011), Rock *et al.* (2012), and Akpan *et al.* (2020), who showed a positive association between age and public acceptance to reuse wastewater. However, the results contrast with the findings by Zabala *et al.* (2019) and Alcon *et al.* (2010, 2012), who did not find a relationship between these two parameters. Compared to that of Bakare *et al.* (2016), who recorded greater association with the 20–29 age group, this study found a higher likelihood of reusing greywater with respondents aged between 41 and 50 years. A probable explanation might be that this age group is well-informed, educated, or has a greater awareness of greywater reuse than other age groups considered in this study.

The community of residence was also revealed to be a significant factor in determining greywater reuse among research participants. Previous research has demonstrated considerable differences in greywater reuse in different countries (Jamrah *et al.* 2006; Kulabako *et al.* 2011; Bakare *et al.* 2016; Dwumfour-Asare *et al.* 2017a, 2017b; Massoud *et al.* 2018). In this study, respondents in Kotei and Ayeduase were more likely to reuse greywater than their counterparts in Twumduase. Similar to the present study, disparities in greywater reuse in different administrative regions of Amman, Jordan, have been identified (Jamrah *et al.* 2006). This result is also consistent with a Nevada study that found greater support for reusing reclaimed wastewater for irrigation, lawn watering, and other reasons among suburban residents than among their urban and rural counterparts (Redman *et al.* 2019). According to Rock *et al.* (2012), geographical location substantially influences

Table 4 | Logistic regression results of determinants of the reuse of greywater

	Model I		Model II	
Variables	**OR**	**95% CI**	**AOR**	**95% CI**
Age group (years)				
18–30 (ref.)	1	1	1	1
31–40	2.42**	[1.27–4.60]	3.03*	[1.30–7.05]
41–50	3.92***	[2.09–7.37]	5.92***	[2.44–14.38]
≥ 51	1.15	[0.54–2.43]	1.72	[0.64–4.65]
Gender				
Female (ref.)	1	1	1	1
Male	0.34***	[0.18–0.66]	0.57	[0.26–1.25]
Community				
Ayeduase (ref.)	1	1	1	1
Kotei	3.14***	[1.65–5.97]	2.91**	[1.41–6.00]
Twumduase	3.15***	[1.64–6.03]	2.02*	[1.01–4.20]
Type of household				
Compound house (ref.)	1	1	1	1
Detached house	0.44*	[0.22–0.89]	0.48	[0.22–1.03]
Flat/apartment	2.88***	[1.60–5.20]	3.28**	[1.64–6.55]
Semi-detached house	0.74	[0.37–1.49]	0.95	[0.43–2.11]
Educational level				
No formal education (ref.)	1	1	–	–
Basic	1.34	[0.59–3.06]	–	–
Senior Secondary School/Senior High School	1.70	[0.77–3.75]	–	–
Tertiary/Higher Education	0.47	[0.16–1.34]	–	–
Marital status				
Never married (ref.)	1	1	1	1
Married	1.75*	[1.03–2.98]	0.98	[1.30–7.05]
Separated/divorced	1.26	[0.50–3.17]	0.55	[2.44–14.38]
Widowed	2.09	[0.83–5.24]	1.72	[0.64–4.65]
Parity				
0 (ref.)	1	1	1	1
1–3	2.68**	[1.40–5.15]	1.36	[0.61–3.04]
≥ 4	1.93*	[1.10–3.39]	0.79	[0.30–2.10]
Monthly income (GH¢)				
≤ 800 (ref.)	1	1	1	1
801–1,500	0.25**	[0.09–0.70]	0.23*	[0.07–0.72]
≥ 1,501	0.61	[0.23–1.63]		
Household size				
1–5 (ref.)	1	1	1	1
6–10	1.70*	[1.01–2.86]	0.92	[0.40–2.11]
11–15	1.02	[0.46–2.24]	0.82	[0.25–2.75]
≥ 16	1.23	[0.43–3.54]	0.68	[0.16–2.94]

(*Continued.*)

Table 4 | Continued

Variables	Model I		Model II	
	OR	95% CI	AOR	95% CI
Water is readily available				
Daily (ref.)	1	1	1	1
Not daily	2.29*	[1.21–4.32]	2.01	[0.92–4.42]
Cost of water/month				
1–50 (ref.)	1	1	–	–
51–100	0.55	[0.25–1.19]	–	–
> 100	2.50	[0.41–5.23]	–	–
Knowledge of greywater				
No (ref.)	1	1	–	–
Yes	0.70	[0.38–1.28]	–	–
Bucket of water for washing				
1–10 (ref.)	1	1	1	1
11–30	2.09**	[1.26–3.48]	1.71	[0.94–3.12]
Goodness-of-fit test				
Hosmer–Lemeshow test		$X^2 = 7.52$		P-value = 0.251

Ref., reference; 95% CI, 95% confidence intervals in brackets; OR, odds ratio; AOR, adjusted odds ratio
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, 1 = reference category.

wastewater reuse for applications such as fire hydrants, watering non-edible crops, restoring wildlife habitat, and preserving riparian ecosystems.

Regarding housing type, the study finding showed that respondents who live in flats/apartments had increased odds of reusing greywater. This is consistent with a study on factors that influence wastewater management and reuse in Kenya, which demonstrated that the type of housing plays a significant role in wastewater reuse practices by peri-urban folks (Angatia 2013).

Comparable to this, a study that assessed the public perception of treated wastewater reuse in developing counties identified monthly and annual incomes as factors affecting the public acceptance of wastewater reuse (Akpan *et al.* 2020). Similar studies from Ongata Rongai, Kenya, (Angatia 2013), Murcia Region, Spain, (Zabala *et al.* 2019), and Arizona (Rock *et al.* 2012) also found an association between income and wastewater reuse. In addition, other works by Hurlimann (2008), Garcia-Cuerva *et al.* (2016), and Hills *et al.* (2002) also found a link between individual income and the acceptability of reclaimed water reuse. In this study, we found that respondents who earn GH¢ 801–1,500 monthly had lower odds of reusing greywater than those who earn GH¢ 800 or less. This also corroborated the study by Zabala *et al.* (2019) who found that lower income was associated with a higher willingness to reuse reclaimed water. In contrast, higher household income is correlated with greater support for recycled water use, according to Rock *et al.* (2012)'s study. We argue from our finding that the lower odds recorded for respondents in the GH¢ 801–1,500 monthly income group may be due to their ability to afford potable water for other purposes rather than reusing greywater.

Strength and limitations

The study's strength resides in its novelty in assessing greywater generation and reuse among residents of low-income urban settlements in Ghana and accounting for various factors associated with greywater reuse. However, there are certain limitations to the study. First, the study design (i.e. cross-sectional) prevents causal conclusions from being taken from the findings. Secondly, pooled respondents are likely to have recall bias and social desirability flaws. Additionally, the cross-sectional nature of the study design restricted the effort to unravel the reasons behind some of the observations.

CONCLUSION

This research investigated the current patterns of greywater generation and reuse among residents of low-income urban areas in Kumasi, Ghana. A study on greywater generation and reuse is crucial in addressing sanitation issues, as greywater contains high levels of contaminants such as microbial pathogens and heavy metals. The average amount of greywater generated for various activities in these low-income urban settlements was found to be 54.3 l/c/d. The average quantities of greywater generated for cooking, dishwashing, bathing, laundry, floor cleaning, and car washing were 5.2, 3.8, 16.2, 13.0, 3.65, and 3.7 l/c/d, respectively. The reuse of greywater in these settlements was low at 20.1%, compared to other reported rates. Factors such as age, community of residence, and type of household were found to significantly influence the reuse of greywater. To improve the implementation of greywater treatment and management systems, it is recommended that public education and awareness campaigns be conducted to increase the understanding of the benefits of treating and reusing greywater. There should also be increased public engagement, participatory planning, and monitoring to ensure the effective implementation of greywater management systems and the development and enforcement of appropriate greywater management policies involving all stakeholders.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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