Greywater characterization and handling practices among urban households in Ghana: the case of three communities in Kumasi Metropolis

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ABSTRACT

Greywater management in Ghana receives little or no attention although untreated greywater is associated with environmental and public health risks. This paper assesses greywater characteristics and handling practices among urban households in three selected communities in Kumasi, the second largest city of Ghana. The study involved in-depth surveys (interviews and observations) with 90 households, and collection of 18 greywater samples from nine greywater sources for laboratory analysis. Average greywater generation is 43.36 ± 17 litres per capita per day, equivalent to 36% of average water consumption. Greywater is untreated before disposal (≈99%), and disposal is mainly (89%) into drains and onto streets. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels are high but give very low BOD/COD ratios (0.20 ± 0.07) indicating a very low biodegradability potential. Nutrient levels are high: 12 times (P) and 30 times (N) in excess of standard discharge limits. Other contaminants detected are heavy metals (Fe, Pb, Zn and Cd), microbes (total coliforms, *Escherichia coli* and *Salmonella* spp.), and organic micropollutants – benzalkonium chloride, parabens (methyl and propyl), sodium benzoate and hypochlorite – and details of the levels are discussed in the paper. Greywater reuse could be useful for biomass production, but it also presents a challenge and threat to natural biological processes and water sources.

Key words | contaminants, domestic greywater, Ghana, handling, quantity, reuse

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INTRODUCTION

Greywater contains pollutants and will pose health and environmental risks if not properly treated and disposed of. Meanwhile, large volumes of greywater are generated, accounting for 50–80% of residential wastewater (Roesner *et al.* 2006; Li *et al.* 2009; Yu *et al.* 2013; Oron *et al.* 2014), with potential reuse benefits. In urban areas, greywater reuse could serve as an alternative water source to ease urban water demand (Yu *et al.* 2013; Oron *et al.* 2014) and as a source of nutrients for irrigation (Li *et al.* 2008; Rodda *et al.* 2011). Already, increasing urban water demand compounded by climate change is resulting in strategies of finding alternative water sources (Rygaard *et al.* 2011; Ahmed & Arora 2012; Peloso & Morinville 2014). In Ghana, mostly urban area inhabitants are already experiencing water supply shortages (Peloso & Morinville 2014; Nyarko *et al.* 2016). Greywater reuse is becoming imperative in water-stressed areas of urban Ghana as in other sub-Saharan African countries (Hyde & Maradza 2013). In the sub-Saharan region and other developing countries, proper greywater management is not given any attention (Morel & Diener 2006; Hyde & Maradza 2013). Available figures from the Ghana Statistical Services indicate the existence of only 1–5% improved greywater disposal practices (GSS 2013a), thus implying huge environmental pollution consequences (Allen *et al.* 2010). The worst affected environmental component could be water bodies which are the main receivers of untreated wastewater in Ghana (Agyei *et al.* 2011).

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Generally, wastewater including greywater is considered as an asset because of the huge reuse potentials for various purposes, including domestic, industrial and agricultural options (Saravanan *et al.* 2011; Penn *et al.* 2013; Tiruneh 2014; Chen *et al.* 2015). However, there are public health concerns associated with reuse (formal and informal) of greywater because of the presence of contaminants such as pathogens, surfactants, boron, metals, endocrine disrupting compounds and xenobiotics (micropollutants) when the wastewater is not (properly) treated (Janzen *et al.* 2009; Trojan Technologies 2010; Maimon *et al.* 2014). Meanwhile, in Ghana there is a dearth of knowledge concerning greywater generation rates, characteristics, and existing treatment and/or reuse practices. This paper therefore describes greywater characterization and household management practices using a case study within three communities of the second largest metropolis in Ghana, Kumasi.

RESEARCH METHODOLOGY

Study areas

The study was conducted at Ayigya, Bomso and Kentinkrono, which are urban communities within the Oforikrom Sub-Metro in the Kumasi Metropolis of the Ashanti region, Ghana. Kumasi is the second largest city in Ghana. The housing conditions within the metropolis (city) according to the regional report of the 2010 National Population & Housing Census (GSS 2013b) are: highest proportion of households with pipe-borne water inside dwelling is 42.3%, and 18.4% have access to borehole/protected well water sources; main dwelling units are compound houses (55.2%) and separate houses (15.7%). The study communities have the following populations: 48,419 (Ayigya) 20,053 (Bomso), and 79,230 (Kentinkrono) (GSS 2013b).

Data collection and analysis

The data collection involved household surveys, field data collection and laboratory analyses of greywater samples. The household surveys focused on capturing data related to domestic greywater handling practices, generation rates, existing reuse options, and water and household chemicals consumption. Greywater samples were collected for laboratory analyses to determine the types and levels of contaminants in greywater. Random sampling was used to select 90 households, 30 each from the three communities for questionnaire surveys to capture relevant data pertaining to greywater management practices. Indicative greywater quantification for a day was carried out in eight households, four households each from two communities, Ayigya and Bomso. Quantification was done directly by collecting and measuring greywater from consenting households within houses from morning to evening (5.30 a.m. to 6.30 p.m.). Descriptive and inferential statistics (analysis of variance (ANOVA), one-sample *t*-test, and Fisher's exact test) were generated from the data using Microsoft Excel and SPSS (IBM SPSS Statistics Software 2012 version 21).

Greywater samples were taken mainly from laundry, bathroom, kitchen, and neighbourhood drains (as composite source) receiving greywater discharges (from about 20 households) within Bomso and Ayigya. In addition, greywater samples were collected from a salon (hair dressing shop) at Bomso. Time composite samples (USEPA 1992) were taken from the neighbourhood drain (composite source): sampling was done manually by collecting 18 aliquots of 100 ml discrete volumes of greywater at 30 minute intervals. Grab sampling was used for greywater from the bathroom, laundry, kitchen and salon (USEPA 1992). The samples were analysed for physicochemical and microbial parameters. The parameters pH and conductivity were all measured *in situ*. All samples were stored in an ice chest packed with ice cubes below 4 °C and transported to the laboratory within 4 h. Extensive laboratory analyses were carried out to characterize the greywater using *Standard Methods for the Examination of Water and Wastewater* (1999). Turbidity was measured with a Hanna turbidimeter (HI 93414); total suspended solids (TSS) were measured using the gravimetric method; chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) analyses were done using the open reflux titrimetric and dilution methods respectively; EDTA titrimetric method was used for the determination of Ca, and Mg while an SPSS flame photometer was used for Na. Heavy metals Fe, Pb and Zn were analysed with atomic absorption spectroscopy (Agilent 200 Series). Organic pollutants of methyl and propyl parabens, benzalkonium chloride and sodium benzoate were analysed with high pressure liquid chromatography. Other methods included total Kjeldahl nitrogen, molybdenum blue test for phosphate and Chromocult® Coliform Agar combined with membrane filtration.

RESULTS AND DISCUSSION

Profile of households

The survey targeted more female respondents (Table 1) because they mostly handle issues related to water and

Table 1 | Profile of households involved in the study

	Community and distribution of responses			
Parameters	**Items of measurement**	**Ayigya**	**Bomso**	**Kentinkrono**
Gender of respondents	Male, n (%)	11 (37%)	9 (30%)	9 (30%)
	Female, n (%)	19 (63%)	21 (70%)	21 (70%)
Age of respondents	Average (years)	45 ± 15	40 ± 14	46 ± 13
Household size	Average	5 ± 2	5 ± 3	4 ± 1
Household income*	Average (GHS/month)	1,460 ± 431	1,060 ± 460	1,517 ± 507
Toilet access	Household facility, n (%)	19 (63%)	17 (57%)	22 (73%)
	Public facility, n (%)	11 (37%)	13 (43%)	8 (27%)
Household toilet types	Water closet, n (%)	13 (68%)	10 (59%)	15 (68%)
	K/VIP, n (%)	6 (32%)	7 (41%)	7 (32%)
Water access level	In-plumbing, n (%)	13 (43%)	10 (33%)	14 (47%)
	Yard tap, n (%)	12 (40%)	11 (37%)	13 (43%)
	Public standpipe, n (%)	5 (17%)	9 (30%)	3 (10%)
Water consumption^{a,*}	Average (lpcd^{b})	124	76	159
Household water cost*	Average (GHS/month)	23	12	26
Water cost: % of total expenditure**	More than 3%, n (%)	5 (17%)	6 (20%)	12 (40%)
	Less than 3%, n (%)	25 (83%)	24 (80%)	18 (60%)

GHS1 = US$0.26 (2016); *ANOVA, $p < 0.001$; **Fisher's test, $p > 0.05$.
[a]Water consumption includes all domestic water uses as billed; [b]litres per capita per day.

wastewater at the household level in the Ghanaian context. The average age of respondents in the three communities was 40 years or above indicating that our interviewees were household members capable of giving valid and useful information. Ayigya and Bomso have the same average household size of five while in Kentinkrono it is four; meanwhile these household sizes are comparable to the regional figure of four (GSS 2013b). There is a stark difference in the average household income, which is also statistically significant from the ANOVA table ($p = 0.00$ & $F = 8.491$) (Table 1). Most households interviewed have household toilet facilities, 57–73%, and the rest use public toilets (Table 1). In addition, most of the household toilet facilities were wet systems (i.e. water closets, 59–68%), which could offer opportunity for greywater reuse by toilet flushing. The majority of respondents (70–90%) had household water supply through in-plumbing (33–47%) and yard taps (37–43%). The per capita water consumption levels contrast significantly ($p = 0.00$ and $F = 11.606$) in the ANOVA test; Bomso and Kentinkrono have the lowest and highest consumptions, respectively (Table 1).

The cost of water incurred corresponds to the level of consumption by the households. The highest average expenditure on water came from Kentinkrono, which is GHS3 (GHS: Ghanaian cedi; GHS1 = US$0.26) per month more than the amount spent by households of Ayigya but about twice the amount spent by Bomso respondents (Table 1). The results also show that the cost differences are statistically significant (from ANOVA with $p < 0.001$ and $F = 15.145$). However, the majority of the households ($n = 67$, 74%; $p = 0.101$), although not statistically significant, spent 3% or less of their expenditure on water, indicating that most of the respondents were able to afford their water supply. This is based on the water affordability benchmark of 3% of total household expenditure on water (Fankhauser & Tepic 2005). On toilet use, the majority of respondents (64%, $n = 54$) had access to their own household toilets. Again, among these household toilets the majority (66%, $n = 38$) are water closets (a wet sanitation system) and the rest (34%, $n = 20$) are Kumasi ventilation improved pit latrines (K/VIPs) (a dry sanitation option).

Greywater generation rates

The greywater generation rates are determined from estimation by households and field quantification. The boxplot (Figure 1(a)) shows differences in greywater estimates by households among the three communities. There is statistically significant variation ($p = 0.014$) between the mean greywater estimates. The basic statistics show the average quantity of greywater in litres per capita/day (lpcd) of 40.42 ± 20.34 (95% confidence interval (CI), 32.82–48) with median 35;

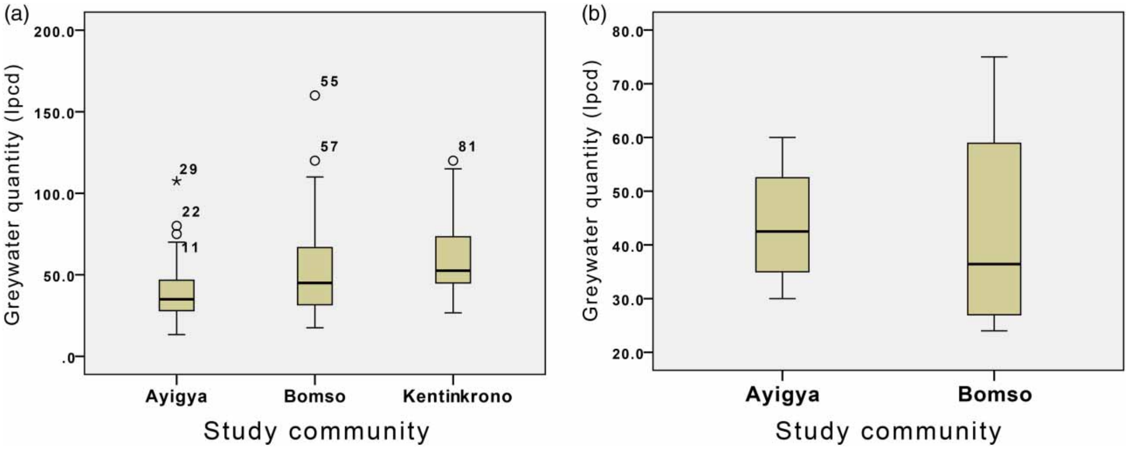

Figure 1 | (a) Greywater generation rates based on households' estimates, with ANOVA of F = 4.470 and $p = 0.014$; (b) greywater generation rates from the field with ANOVA of F = 0.004 and $p = 0.954$.

53.01 ± 34.6 (95% CI, 41.2–64.83) with median 45; and 60.11 ± 25 (95% CI, 51.1–69.2) with median 52 for Ayigya, Bomso and Kentinkrono, respectively (Figure 1(a)). Clearly there are wide ranges within and across the communities suggesting that the estimates could be less useful. Although the field quantification is limited to a small number of households ($N = 8$) from two communities, it could be considered to be more indicative and useful for greywater quantity discharges from households. The ANOVA shows no significant difference ($p = 0.954$) in the average greywater discharges from the field quantification results (Figure 1(b)) although the ranges differ widely. The average greywater quantities (lpcd) were 43.75 ± 12.5 (95% CI, 23.56–63.64) with median 42.5, and 42.96 ± 22.76 (95% CI, 6.75–79.18) with median 36.43 for Ayigya and Bomso, respectively.

Although obvious, the assumption was that greywater quantity generation rates measured directly from the field are more accurate than estimates given by household surveys. Since no statistically significant differences existed between the means of actual field greywater generation rates, the overall mean (43.36 ± 17 lpcd) was therefore taken as the test (true) value and compared with households' estimates. From the one-sample *t*-test (Table 2), there is a statistically significant difference between the field measured greywater generation rates and those estimated by households via surveys. The households overestimated the greywater generation rates by an average of about 8 lpcd, and this difference lies between 95% CI of 2–13 lpcd. When the test value is taken as the existing greywater generation rate (43.36 lpcd) for the study communities, the greywater quantity is about 36% of respondents' average water consumption (120 lpcd). This study reveals a higher greywater generation rate than the estimates of 18.8–25 lpcd provided by a recent study (Hyde & Maradza 2013). However, the greywater quantity in the current study represents a fraction (36%) of total water consumption, far below the known levels of 50–80%. This could be due to the limited sample size and/or because there is less greywater quantity generation during weekdays than at weekends. However, the greywater quantity generated in the study sites could be enough for reuse purposes such as toilet and urinal flushing within dwellings and this could reduce water demand by at least 30–38% (Al-Jayyousi 2003; Jefferson *et al.* 2004; Gisi *et al.* 2016).

Table 2 | One-sample *t*-test for actual field and households' estimated greywater quantity

Test value = 43.36 lpcd

				95% confidence interval of the difference	
t	**df**	**Sig. (2-tailed)**	**Mean difference**	**Lower**	**Upper**
2.765	89	0.007	7.8182	2.200	13.436

Greywater handling practices

The main greywater sources among all respondents were laundry, bathroom and kitchen sources, and mostly these sources are used to define greywater (WHO 2015; Benami *et al.* 2016). The majority of responding households (62%, $n = 56$), although not statistically significant ($p = 0.795$) from the Fisher's test, considered greywater to be a potential alternative source of water if treated. These same respondents claim they reuse greywater at home for various purposes. However, comparatively few respondents (16%,

$n = 14$; $p = 0.076$) do collect and/or store the greywater before reuse. Greywater reuse has no significant association with collecting and/or storing greywater ($p > 0.05$). The practices of reuse are more common with laundry sources (57–67%, $n = 17–20$) but less with bathroom greywater (30%, $n = 9$ for Bomso only) and no reuse was reported of kitchen greywater. Non-existence of kitchen greywater reuse is probably similar to other studies (Albalawneh & Chang 2015). Meanwhile, some specific greywater reuses reported included mopping/scrubbing (36%, $n = 32$), flushing toilets (26%, $n = 23$) and watering lawns (8%, $n = 7$). None of the households practised greywater irrigation for any edible biomass production except the very few that use greywater to water their lawns.

Also there was an observation of high health risk concerns among respondents; the majority of respondents (67%, $n = 60$), although not statistically significant ($p = 0.750$), perceived that it was unsafe to irrigate vegetables (crops) with greywater (Table 3). This perception is legitimate because public health risks of greywater irrigation for edible biomass are widely established (Pinto & Maheshwari 2010; Benami *et al.* 2016; Cook 2016), especially when greywater is not treated.

The general greywater disposal practices by multiple responses are: 1% use septic tanks (i.e. improved), 17% use soak pits, and 89% dispose into storm water gutters or drains and onto streets. The disposal practices among responding households are similar to the reports from the 2010 National Population and Housing Census in that more people practise haphazard and unimproved methods of disposal (GSS 2013a). This situation can be partly attributed to the non-existence of sewerage systems (water-borne sanitation) in these areas (Carden *et al.* 2008) as the whole of Ghana (including the cities) has poor sewerage coverage of less than 5% (Murray & Drechsel 2011).

Characteristics of greywater

The greywater characterization involved assessment of the main use physicochemical and microbial parameters and selected organic micropollutants. The physicochemical qualities are provided in Tables 4 and 5 for the two study sites used. The findings from the two sites are similar when compared against the Ghana Environmental Protection Agency (GEPA) draft guidelines for wastewater discharges (GEPA n.d.). Most greywater discharges from almost all sources are failing according to GEPA standards in almost all parameters. With pH and electrical conductivity (EC), most sources met GEPA standards but one or two discharge sources failed marginally (Tables 4 and 5). Moreover, attention should be given to key parameters such as nutrient (nitrogen and phosphorus) levels and BOD/COD ratio to reduce the impact on the receiving aquatic environment. The higher BOD and COD levels coupled with very low BOD/COD ratios (far less than 0.5, i.e. 0.20 ± 0.07) challenge biodegradation (Kulabako *et al.* 2011; Boyjoo *et al.* 2013), especially under natural environmental self-purification conditions. The very low biodegradation observed is similar to studies from Uganda with mean BOD/COD ratio range of 0.13–0.25 (Kulabako *et al.* 2011), and in low income communities of Accra, Ghana, with BOD/COD ratio of 0.29, but for high and middle income communities the BOD/COD ratios were more than 0.80 (Mohammed *et al.* 2015). Thus, greywater composition can be highly variable depending on household activities, lifestyle and use of chemicals (Etchepare & van der Hoek 2015). Also, the nutrients are far in excess of the GEPA limits, by 12 times (P) and 30 times (N), signalling caution regarding potential algal bloom and eutrophication in receiving water bodies. However, the nutrient characteristics offer great potential for reuse in irrigation because they fall well within the recommended limits of 2–32 mg/l (N) and 0.6–27 mg/l (P) (Mohamed *et al.* 2013).

The findings on heavy metals and microbial loads of the greywater from the two sites are presented in Tables 6 and 7. On the heavy metals content, the greywater from all sources or streams in both study sites contained some metals but their levels met the Ghana standards (GEPA norm),

Table 3 | Perceptions of greywater reuse for vegetable irrigation

	Distribution of responses *n* (%)				
Study communities	**Contaminated**	**Dirty**	**Not healthy**	**Polluted**	**Fisher's exact test (*p*)**
Ayigya ($n = 18$)	5 (28%)	3 (17%)	9 (50%)	1 (6%)	0.610
Bomso ($n = 21$)	10 (48%)	5 (24%)	5 (24%)	1 (5%)	
Kentinkrono ($n = 21$)	7 (33%)	4 (19%)	6 (29%)	4 (19%)	
Overall ($N = 60$)	22 (37%)	12 (20%)	20 (33%)	6 (10%)	

Table 4 | Physicochemical parameters of greywater from Bomso

Parameter	Units	Ghana EPA guidelines	Composite	Laundry	Bathroom	Kitchen	Salon
pH	–	6–9	7.8	9.1	6.8	8.8	6.4
EC	μS/cm	1,500	1,147	3,530	1,148	3,130	374
TSS	mg/l	50	2,360	3,610	476	4,720	372
Turbidity	NTU	75	386	729	549	528	532
BOD	mg/l	50	248.3	268.5	139.3	269	132.5
COD	mg/l	250	1,510	2,210	400	2,180	580
BOD/COD[w]	–	NA	0.16	0.12	0.35	0.12	0.23
Total Kjeldahl nitrogen	mg/l	1.0[b]	13.7	12.8	7.7	14.5	8.1
Mg	mg/l	NA	1.72	0.52	1.94	5.67	1.74
Total P	mg/l	2	13.2	12.2	11.3	13	22.6

NA, not available; [b]ammonia level; [w]0.20 ± 0.09.

Table 5 | Physicochemical parameters of greywater from Ayigya

Parameters	Units	Ghana EPA guidelines	Composite	Laundry	Bathroom	Kitchen
pH	–	6–9	8.2	9.6	6.8	9.7
EC	μS/cm	1,500	1,045	351	1,544	863
TSS	mg/l	50	1,820	2,170	440	3,020
Turbidity	NTU	75	378	400	342	204
BOD	mg/l	50	265.3	258.5	205.3	249.5
COD	mg/l	250	1,260	1,410	840	1,860
BOD/COD[w]	–	NA	0.21	0.18	0.24	0.13
Total Kjeldahl nitrogen	mg/l	1.0[b]	16.3	15.4	23.9	29.5
Mg	mg/l	NA	0.33	1.00	0.88	1.05
Total P	mg/l	2	18.5	23.2	12.5	10.8

NA, not available; [b]ammonia level; [w]0.19 ± 0.05.

Table 6 | Heavy metals and microbes in greywater from Bomso

Parameter	Unit	Ghana EPA guidelines	Composite	Laundry	Bathroom	Kitchen	Salon
Heavy metals							
Fe	mg/l	10.0	0.22	0.129	0.233	0.355	0.367
Pb	mg/l	0.1	0.048	0.099	0.087	0.095	0.064
Zn	mg/l	10.0	0.038	0.044	0.076	0.055	0.044
Cd	mg/l	<0.1	0.001	0.001	0.001	Nil	0.001
Microbial							
Total coliforms	$\mathrm{Log_{10}}$ cfu/100 ml	2.6	8.2	8.3	7.4	7.9	7.5
E. coli	$\mathrm{Log_{10}}$ cfu/100 ml	1.0	6.5	6.0	6.3	Nil	Nil
Salmonella spp.	$\mathrm{Log_{10}}$ cfu/100 ml	NA	6.7	6.5	6.5	Nil	Nil

NA, not available; Nil, not detected.

Table 7 | Heavy metals and microbes in greywater from Ayigya

Parameter	Units	Ghana EPA guidelines	Composite	Laundry	Bathroom	Kitchen
Metals						
Fe	mg/l	10	0.469	0.236	0.347	0.211
Pb	mg/l	0.1	0.088	0.034	0.063	0.059
Zn	mg/l	10	0.099	0.057	0.069	0.068
Cd	mg/l	<0.1	0.001	0.001	0.003	0.001
Microbial						
Total coliforms	Log_{10} cfu/100 ml	2.6	7.9	6.3	7.7	6.4
E. coli	Log_{10} cfu/100 ml	1.0	7.0	5.5	6.0	Nil
Salmonella spp.	Log_{10} cfu/100 ml	NA	6.3	5.0	6.0	Nil

NA, not available; Nil, not detected.

indicating they were safe for environmental discharge. However, greywater discharge must be monitored closely for potential environmental (bio)accumulation and magnification, especially in the case of Pb, the level of which is comparatively closer to the permissible discharge limit (for kitchen and laundry sources, 0.099 and 0.095 mg/l). The metal contamination could originate from detergents and personal care products (Boyjoo *et al.* 2013). All greywater sources were contaminated with at least one type of the three microbes (total coliforms, *Escherichia coli* and *Salmonella* spp.) and their detected loads were far above the GEPA permissible levels for wastewater discharges (Tables 6 and 7). Consistently, *E. coli* and *Salmonella* spp. were not found in greywater from kitchen sources and the hairdressing salon source. This suggests that the two sources could not be linked with faecal contamination or cross-contamination, both of which potentially exist with the other greywater sources.

Presence of organic micropollutants

The presence and the levels of selected organic micropollutants also known as xenobiotic organic compounds are given in Table 8. The findings show that all greywater sources contained benzalkonium chloride (BAK) unlike the other detected contaminants, and this supports the fact that BAK has a wide use in household cleaning products (Barceló 2005). The BAK load has a wide range of 1.2–6.3 mg/l (3.87 ± 2.30) and is actually higher compared with levels reported in literature although it is among the dominant contaminants in greywater (Leal *et al.* 2010; Gisi *et al.* 2016). Although the other four contaminants were detected in comparatively fewer greywater sources, their levels were also higher than given in literature and higher than recommended levels. In all instances, sodium hypochlorite (bleach) on average presented the highest contaminant load of 7.4–8 mg/l (7.58 ± 0.29) (Table 8). All

Table 8 | Selected organic micropollutants levels from different greywater sources

Site	Greywater source	Benzalkonium chloride* mg/l	Sodium benzoate mg/l	Methyl paraben mg/l	Propyl paraben mg/l	Sodium hypochlorite mg/l
Bomso	Salon	6.3	Nil	1.8	1.3	Nil
	Kitchen	6.8	Nil	Nil	Nil	Nil
	Bathroom	1.5	Nil	Nil	Nil	Nil
	Laundry	1.9	Nil	Nil	Nil	8.0
	Composite	2.5	2.6	Nil	0.8	7.4
Ayigya	Kitchen	5.4	Nil	Nil	Nil	Nil
	Bathroom	6.3	0.4	Nil	Nil	Nil
	Laundry	1.2	Nil	1.6	Nil	7.5
	Composite	2.9	Nil	Nil	Nil	7.4

Nil, not detected; *3.87 ± 2.30 (both sites), 3.80 ± 2.54 (Bomso), 3.95 ± 2.33 (Ayigya).

these contaminants are commonly used as surfactants, antimicrobial preservatives and antioxidants in cosmetics, toiletries, detergents, pharmaceuticals and food used in homes (Armstrong & Froelich 1964; Eriksson *et al.* 2003; Brausch & Rand 2011; Błędzka *et al.* 2014). Their concern to environmentalists is that continuous exposure in the aquatic environment could lead to toxic, oestrogenic, endocrine and carcinogenic effects (Brausch & Rand 2011; Błędzka *et al.* 2014).

Advocacy for increased investment in sanitation (greywater included)

There is a need to give more attention to greywater management in Ghana especially in cities and urban areas where large volumes of greywater are generated because of increasing population growth and rapid urbanization. The characteristics of greywater in the current study present serious challenges to natural biological processes and a threat to natural water sources. Meanwhile, greywater has reuse opportunity for biomass production because of its nutrient content, and also water reclamation for non-potable domestic uses to ease urban water supply stress. Households and/or homeowners are not safely managing greywater like blackwater. While provisions exist for onsite treatment systems for blackwater management, there is no consideration for greywater. Currently, there are very limited wastewater treatment plants to receive any greywater streams. For the city of Kumasi, only two suburbs have sewerage systems (only for blackwater), namely Kwame Nkrumah University of Science and Technology, and Asafo (Awuah *et al.* 2014). These two systems have challenges of over-subscription, abuse and abysmal performance.

One of the reasons for the low investment in wastewater treatment is the perceived high investment cost. Yet, the benefits of sanitation are usually not mentioned. A starting point towards finding a lasting solution is advocacy for increased investment in sanitation (including greywater) based on the benefits, policy support for innovation/appropriate low-cost technologies for different service levels (household, neighbourhood cluster, community or citywide level), setting greywater treatment and reuse standards/guidelines, and promoting local research on technologies and investment planning. For instance, this paper is part of the lead author's ongoing research work on the use of constructed wetlands as an emerging household-level technology for greywater treatment.

CONCLUSIONS FOR POLICY AND PRACTICE

The average greywater generation rate from households studied is around 43 lpcd, representing about 36% of the average water consumption. Greywater from laundry and bathrooms is suitable for specific reuses that include floor cleaning/mopping, flushing toilets and watering lawns. Household-level greywater management is abysmal, because there is no treatment before disposal (≈99%), and discharge is largely (89%) by throwing into storm water drains and onto the streets. The greywater sources did not meet most of the key wastewater discharge limits (BOD, COD and nutrients) according to the Ghana Environmental Protection Agency guidelines. The BOD and COD levels are high but the low BOD/COD ratios (the average 0.20 ± 0.07 is far less than 0.5) could limit biodegradation especially under natural biological environmental conditions. The higher nutrient (nitrogen and phosphorus) levels in excesses of the GEPA discharge limits indicate a greater threat to receiving water bodies. Meanwhile, the higher nutrient content offers great reuse potential for irrigation purposes. The greywater sources are contaminated with heavy metals and microbes including total coliforms, *E. coli* and *Salmonella* spp. While all greywater sources failed the GEPA microbial limits where detected, the levels of metals (Fe, Pb, Zn and Cd) were within their respective discharge limits. Five micropollutants, BAK, parabens (methyl and propyl), sodium benzoate and hypochlorite, were detected in greywater at levels higher than expected although not extensively detected in all greywater sources except for BAK.

Some benefits could be derived from reuse of the greywater; however, the low biodegradability (BOD/COD ratio) may limit natural biological processes, and without any treatment the greywater may threaten natural water sources. Greywater management in Ghana especially for urban settings needs conscious policy intervention and actions including research on appropriate urban household-level (decentralized) management options.

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