

Indigenous plants for informal greywater treatment and reuse by some households in Ghana

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ABSTRACT

Poor greywater management is one of Ghana's sanitation nightmares due to longstanding neglect. This study looks at local practices of informal phytoremediation, and identifies commonly used plants and benefits. Our study collected data from 451 surveyed houses in nine communities within three regions, using structured questionnaires and extensive field observations. Greywater (kitchen, bathroom and laundry) is mainly disposed of into the open (46–66%), with few (4–24%) using septic tanks and soakaway systems. The majority of respondents (84%) perceived plants as agents of treatment and most could list 1–2 beneficial functions of the plants. A total of 1,259 plant groups were identified which belonged to 36 different plant species. The top five indigenous plants used are sugarcane, banana/plantain, taro, sweet/wild basil, and dandelion. The major plant benefits identified were food (84% of respondents) and medicine (62% of respondents). Statistically, no association was identified between the numbers of plants grown and their perceived plant roles ($\chi^2 = 6.022$, $p = 0.304$), with the exception of an association between plant numbers and benefits ($\chi^2 = 161.94$, $p < 0.001$). There is demand for improving local practices of using plants in greywater treatment and reuse, since native plants also come with other benefits.

Key words | benefits, greywater, indigenous plants, informal treatment, reuse

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INTRODUCTION

Greywater, like other wastewater streams, requires safe management in modern societies because of their large volumes, and the emerging complexity of contaminants from the increasing population and complex lifestyle (Nair 2008). In developing countries like Ghana, there is a huge infrastructure deficit in wastewater systems because of perceived prohibitive investment cost without due consideration of the full benefits of improved sanitation management (Agodzo *et al.* 2003; Nair 2008; Dwumfour-Asare *et al.* 2017). Ghana has very limited sewerage systems, and the two largest cities of Accra (1.96 million people) and Kumasi (1.47

million) (GeoNames *n.d.*) have less than 5% of their inhabitants connected to sewerage (Keraita & Drechsel 2004; Seidu *et al.* 2008; Agyei *et al.* 2011; Murray & Drechsel 2011). The balance relies on mainly onsite septic tank systems for handling blackwater (toilet waste). Practically, greywater or sullage, which is domestic wastewater from all sources except excreta or fecal matter (WHO *n.d.*; Al-Mamun *et al.* 2009), is seriously neglected. A recent official report identified a national coverage of acceptable greywater disposal (mainly via sewerage and soakaways) in Ghana to be only 6%, 9% and 3% coverage for national average, urban and rural areas respectively (GSS 2013). Clearly greywater could pose some environmental and public health risk in Ghana due to contaminants. At least 280 organic micropollutants can be detected in greywater (Etchepare & van der

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Hoek 2015) and such contaminants include pharmaceutical and personal care products, pesticides, agrochemicals, surfactants, artificial sweeteners, pathogens, etc., which are difficult to handle (Boyjoo *et al.* 2013; Luo *et al.* 2014; Cardenas *et al.* 2016).

A recent publication on greywater characteristics in Ghana shows that greywater discharge into water bodies is likely to adversely affect their natural biological processes (Dwumfour-Asare *et al.* 2017). However there is no comprehensive strategic policy or management framework for greywater treatment and disposal in Ghana, although some regulations such as the national building regulations, and some local byelaws, touch briefly upon specific disposals in certain contexts (GoG 2012; GWMA 2014). Overall, existing management practices are highly unsatisfactory, often using unimproved methods, and in some cases, no greywater treatment at all. This disregard for greywater management is worsened by ignoring technologies that are often technically sophisticated, expensive, and usually inapplicable to low-income settings (Cardenas *et al.* 2016). The prevailing situation in Ghana justifies the need to lobby for policy intervention and concerted actions using advocacy, research, innovations and investment in appropriate decentralized management technologies.

Indigenous people within their dwelling units have their own approaches or practices (whether appropriate or not) for handling greywater. Some of these practices have continued for centuries, but little or no documentation is known about them. This is a classical phenomenon for almost all indigenous knowledge in Ghana (Owusu-Mensah 2017). Unfortunately, knowledge on handling greywater by Ghanaians suffers the same fate and recently there have been calls for policy to protect indigenous knowledge especially from fading away (NGO News Africa 2017). The existing informal practices with greywater that can be broadly described as phytoremediation, appear popular amongst local people, especially in peri-urban areas. These native practices usually have improvised, vegetated, subsurface infiltration fields, within individual backyards. Unfortunately, this indigenous innovation has not captured much attention among researchers, sector practitioners or policy makers, as a potentially sustainable solution for greywater management.

Phytoremediation, also called phytotechnology (Conesa *et al.* 2012) in itself is not new. It existed before recorded civilization, and was first documented in Africa about 300 years ago (Sharma & Pandey 2014). Phytoremediation is simply defined as ‘the use of green plants to remove, contain, or render harmless, environmental contaminants’ (Schwitzgubel 2004; Truu *et al.* 2015), and is considered as one of the emerging, cost-effective and eco-friendly technologies (Conesa *et al.* 2012; Dhir 2013; Sharma & Pandey 2014; Truu *et al.* 2015). Although not commercially available in most developing countries (Mohan & Hosetti 2002; Erakhrumen 2007; Conesa *et al.* 2012) local people practice it by way of tradition in informal, and improvised forms. This paper, which forms part of an ongoing PhD research by the senior author, targets generating relevant knowledge to stimulate research and discussions on improving, and standardizing, the local practices of using plants for domestic greywater treatment in Ghana.

RESEARCH METHODOLOGY

Study area description

Peri-urban areas, also called transition or interaction zones, adjoin urban areas, but are outside the formal urban boundaries and urban jurisdictions (Appiah-Effah *et al.* 2014). Peri-urban communities are difficult to define, and at times they are considered as abstract delineations because of diffuse settlement boundaries in the real world. These areas have communities with less infrastructure development and planning, and are characterised by backyard open spaces, planted with vegetation and crops, normally watered by residents. Some residents of these areas also use the planted vegetation for the disposal of their domestic greywater. The study areas selected for investigation were Asante-Mampong, Kokoben, and Aprozema in the Ashanti region, Fanti Nyankumasi in the Central region and five communities – Berekum area (Kato, Biadan, Kyiribaa, Kutre, and Senase) within the Berekum Municipality in the Brong Ahafo region, all of Ghana (Figure 1). These study sites were chosen based on prior knowledge of households practicing watering of indigenous plants or vegetation with greywater, and the fact

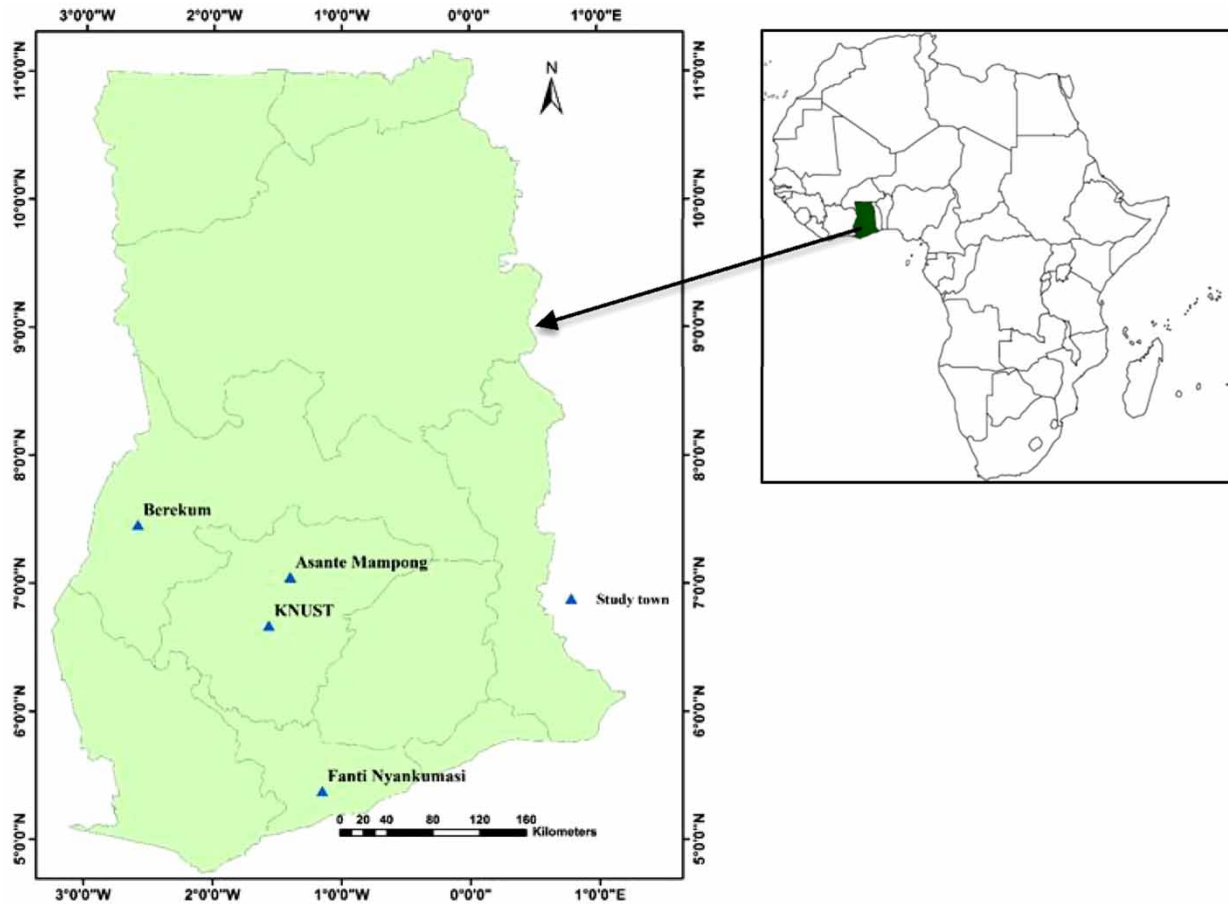


Figure 1 | Study was conducted in Ghana, from the western part of the Africa continent (Africa map adapted from [Basket of Africa \(2018\)](#)).

that they occur within the middle belt of Ghana transition and semi-deciduous ecological zones, which have a similar major soil class called Forest Ochrosols ([Awadzi *et al.* 2004](#); [Nuhu *et al.* 2012](#)). It is common to find similar plants species, native or indigenous, to those in the forest region of Ghana ([Campion & Venzke 2011](#)).

Respondents from Asante-Mampong were dominated by participants located at the periphery of the municipal capital. The Kokoben-Apromase communities have peri-urban characteristics, and they are about a 20 minute drive from the Kwame Nkrumah University of Science and Technology (KNUST) Campus, within the Kumasi city. The peri-urban communities of Berekum Municipality exhibited features that are similar to rural settings of the other study communities. Typical rural areas are characterised by settled places outside cities and bigger towns ([Appiah-Effah *et al.* 2014](#)).

Sampling, data collection and analysis

A household survey was conducted with 451 respondents from peri-urban homes in the five study communities. The data collection exercise took place between April 2016 and April 2017. The surveys involved interviews and observations centred on greywater disposal practices, use of local plants in the greywater disposal (by irrigation or subsurface infiltration) and other key related themes. The households were purposively selected using the snowball sampling technique that uses 'referrals among people who share or know of others who possess some characteristics that are of research interest' ([Biernacki & Waldorf 1981](#)). This is because our sampling required insiders (link-tracers) who had knowledge of houses that use native plants in greywater disposal. This criteria and link-tracers allowed the identification and location of our special population

(respondents) as the basis for this sampling approach (Biernacki & Waldorf 1981; Faugier & Sargeant 1997; Handcock & Gile 2011). The sampling approach was also supported by asking around the vicinities for potential respondents, and/or link-tracers, in places where a respondent is not able to identify the next potential respondent. The principal focus of the study was on the use of indigenous plants/vegetation in greywater disposal rather than the study communities or sites. All data processing and analysis were carried out using Microsoft Excel and SPSS (IBM Mac version 21). The analyses of vegetation involved plant identification and nomenclature (at times using local names that were captured during field surveys), by relying on appropriate databases (Brunken et al. 2008; CSIR 2017; Kew 2017), literature sources (published and grey) (Amisah et al. 2002; Bonsu 2011; Amagloh & Nyarko 2012; Berhow et al. 2012; Lim 2013; Gadegbeku et al. 2014; CSIR-G 2016; WOW Magazine 2016) and Google search engine (with images). The analysis carried out on the data included descriptive statistics using cross tabulations and pivot tables, distributions and trends, 95% confidence intervals, Tukey's Hinges percentile analysis, χ^2 tests at 5% significance level with effect size measures of Cramer's Phi and V (Kotrlik et al. 2011). The study, which forms part of PhD research, received ethical clearance from the Committee on Human Research, Publication and Ethics from KNUST.

RESULTS AND DISCUSSION

Profile of study households

The gender distribution of respondents is 66% females and 34% males ($N=451$). The survey specifically targeted female respondents because they are the ones largely responsible for sanitation issues in the home (Dwumfour-Asare et al. 2017). The average age of respondents was 43 years with 95% confidence interval (CI) 41.5–44 years (Table 1). The majority of the respondents were married 67% ($n=301$) whilst the rest (33%) were single, separated, divorced or widowed.

The majority of the respondents were self-employed (56%, $N=451$), followed by unemployed 25% ($n=111$) and the balance in paid employment (17%) or retired

Table 1 | Some biodata of respondents

Parameters	Mean \pm standard deviation	95% CI
Age of respondents (in years)	42.8 \pm 13.7	41.5–44.0
Number of households in a house	3.3 \pm 2.0	3.1–3.5
Number of people in the house	9.8 \pm 5.4	9.3–10.3
Household size of respondent	4.5 \pm 1.8	4.3–4.6

CI, confidence interval.

(2%). The average household size of 4.5 is close to the national figure of 4.4 (2010 Census data) and typical of household sizes of rural areas in Ghana (GSS 2014). The average number of households in a house or dwelling unit is around 3 (CI 3.1–3.5) and this translates into about 14 persons per house, supporting the view that most Ghanaian households live in compound or tenement houses (GSS 2014).

The majority of households (61%, $n=276$) have access to toilet facilities for use in their houses. Moreover, the majority of these toilets were improved sanitation facilities comprising 38% ($n=107$) Ventilated Improved Pit Latrine (VIP) and 18% ($n=50$) Flush toilets. The low number of wet (flush) toilet facilities is comparable to the national figure, which is around 15% (GSS 2012; 2014). The availability of wet toilet systems suggest a potential opportunity exists for households to reuse greywater to flush toilets, as was found in similar studies (Kabange & Nkansah 2015; Dwumfour-Asare et al. 2017).

Greywater handling and disposal practices

All the major greywater streams, namely kitchen, bathroom and laundry, are disposed of in a similar manner, as reported in the 2010 census report (GSS 2013) and Dwumfour-Asare et al. (2017). This includes disposal by septic tanks, soak pits (soak-away or catch pits), stormwater gutters or drains, and open discharge onto streets and communal areas in compounds (GSS 2013; Dwumfour-Asare et al. 2017). Almost all houses (99.1%, $n=451$) have their greywater sources separated, with the minority having both no source separation (0.2%, $n=1$), and partial separation of sources (0.7%, $n=3$). The main disposal practices for greywater sources are: discharge into open spaces within a

compound (46–66%) and use of septic tanks and soakaway systems (4–24%). The disposal into the open is mainly from the kitchen (46%, $n = 208$) and laundry (66%, $n = 296$) sources. The septic tanks and soakaway systems were used for greywater from bathroom sources. When all open space disposals (streets, compounds, bushes, and open drains) are aggregated, about three-quarters of households use unimproved disposal practices.

The only improved or appropriate final disposal options identified in this study were the use of soakage (soakaway) pits (0.2–23%) and septic tanks (0.2–2.4%) systems. In Ghana, the minimum requirement for greywater disposal is by the use of soakage pits as defined in local authorities' sanitation bylaws and the national building regulations (GoG 2012; GWMA 2014). The building regulation recommends seepage (soakage) pits when the soil and subsoil conditions are favourable (GoG 2012), but does not give details for their construction/installation, although these may be found in a World Health Organization publication (Fagan 2015).

Greywater use apart from using it to water indigenous plants

All the households interviewed used greywater for watering at least an indigenous plant, as this was the criterion for their participation in the current study. However, a relatively large number of households (12.4–63.4%, $n = 56$ –284) reuse greywater for other domestic end uses, but without any treatment (Table 2). The greywater source used most for alternative end uses was the laundry stream (63.4%, $n = 284$), whilst the least was the bath stream (12.4%, $n = 56$). This behaviour is likely attributed to the ease of collection and/or the useful volumes. Laundry sources are generated in vessels like buckets, whilst bath sources are discharged directly from the bathroom floors, the point of generation. The greywater from kitchens is usually in low quantities, and contains more contaminants (oil and grease etc.) and therefore has low appeal for reuse. Common end uses for alternative greywater uses are watering down dust, followed by cleaning/scrubbing, and 'others' (Table 2). Of the greywater from baths that was allocated to alternative uses, most was generated from bathing toddlers and children in basins and vessels. The findings

Table 2 | The main alternative end uses of greywater flows, other than watering indigenous plants

Greywater source	Main specific end use
Kitchen	16% ($n = 74$) – watering compound against dust 2% ($n = 7$) – others (quenching fire – firewood and charcoal) 82% ($n = 370$) – none
Bath	11% ($n = 50$) – watering compound against dust 1% ($n = 6$) – cleaning/scrubbing floor and flushing toilet 88% ($n = 395$) – none
Laundry	41% ($n = 186$) – cleaning/scrubbing floor 19% ($n = 84$) – watering compound against dust 3% ($n = 14$) – others (washing bike and flushing toilet) 37% ($n = 167$) – none

confirm that some households find greywater (untreated and treated) useful for end uses such as toilet flushing, watering lawns, car washing, and fire extinguishing, especially in places where water supply could be scarce and/or erratic (Kulabako *et al.* 2011).

The Ghana National Building Regulation promotes reuse of treated wastewater, including greywater, for non-domestic end uses such as water for cooling, toilet flushing, lawns, parks, fire-fighting and certain industrial purposes (GoG 2012). However, the current regulations do not encourage domestic reuse practices observed in this study, and this should be food for thought for policy makers, and other influential stakeholders.

For those households that did not reuse greywater (36%, $n = 161$) other than watering native plants, there are three main reasons for avoiding greywater use (Figure 2). The majority perceived greywater to be unsafe or not efficacious (73%, $n = 117$), followed by 'seeing no reason for reuse' (24%, $n = 39$), and then lack of awareness that greywater could be reused (3%, $n = 5$) (Figure 2). These results largely confirm similar health risk concerns and perceptions from other greywater reuse surveys, especially if the greywater is untreated (Kabange & Nkansah 2015; Dwumfour-Asare *et al.* 2017).

Indigenous plants use in greywater disposal

The main greywater source for watering indigenous plants is bath water. This was well supported by the visual evidence

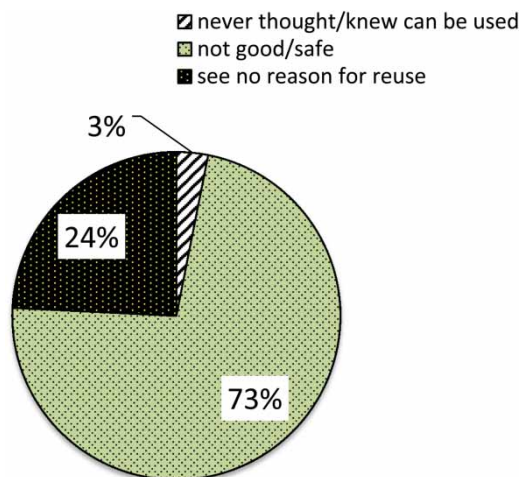


Figure 2 | Main reasons for non-reuse of greywater, other than watering plants.

of planted vegetation along the disposal courses for bathroom greywater, in all 451 houses visited in the study. The respondents' level of awareness for any specific roles or functions played by plants in the greywater disposal was assessed (Table 3).

The majority of respondents (84%, $n = 378$) claimed they knew what plants were doing to the 'dirty' water (greywater) discharged from their residence. The average number of beneficial functions performed by plants, according to respondents, is 1.6 (CI 1.48–1.72). Thus, each participant could mention approximately two functions performed by the plants in the greywater disposal. Also, the Tukey's Hinges analysis, which collaborated well with the weighted average percentiles, was found to be 1, 1, and 2 stated functions for the lower hinge (25th percentile), mid-hinge (50th percentile), and upper hinge (75th percentile) respectively (Table 4). Thus, most respondents (75%) were able to

Table 3 | Household responses on the roles/functions of planted native vegetation to greywater

Specific functions of plants	Distribution of responses, n (%) ^a
1 Treat greywater	351 (78%)
2 Remove odour	159 (35%)
3 Remove 'poison/danger'	100 (22%)
4 Remove particles	77 (17%)
5 Absorb water	22 (5%)
6 Kill germs	13 (3%)

^aMultiple responses were allowed.

Table 4 | Percentiles (weighted average and Tukey's Hinges) of plants' roles and beneficial functions

Statistics	Percentiles					
	5	10	25	50	75	90 95
Weighted average roles	0	0	1	1	2	4 4
Tukey's Hinges roles			1	1	2	
Weighted average beneficial functions	1	1	2	3	4	6 6
Tukey's Hinges beneficial functions			2	3	4	

mention 1–2 roles played by native plants in their current greywater disposal practices. Moreover, the top 25% of respondents could list as many as four beneficial functions of the plants (Table 4). The findings are interesting and support the existence of informal indigenous knowledge, which could be explored further by scientific study. Moreover, the underlining fact is that plants in subsurface infiltration systems offer some level of treatment for wastewater, and this kind of technology falls under the practice of phytoremediation.

The main plant functions that were identified by the respondents are listed in Table 3.

The most familiar plant function was 'treat greywater', followed by 'remove odour' and the rest in the order presented in Table 3. The number of responses decreased sharply after the top two common functions, probably because respondents considered that the remaining functions were covered, or defined, as part of treating greywater. This explanation is consistent with the previous discussion of the Tukey's Hinges analysis, where the majority of respondents knew only one or two plant roles, and only a minority could list more than two plant functions. Overall, we suggest that there is widespread native knowledge of greywater phytoremediation, albeit at an elementary level.

The people understand that greywater is directly used to irrigate indigenous plants, and these plants in return treat the greywater. However, the terminal state of the greywater is still haphazard disposal with no scientific proof of treatment after irrigating with plants. The haphazard final disposal is not necessarily due to reuse on plants but lack of priority for safe greywater disposal. This is because the underlying and principal intention for the use of vegetation

in greywater disposal may not be for treating and/or ensuring safe disposal per se, but rather irrigating the plants for other gains (discussed in detail in the next subsection). Perhaps it is for this reason that some respondents (a minority of 16%) claim no knowledge of what plants do to their greywater. Nevertheless, deepening local understanding to improve native phytoremediation practices seems highly worthwhile in order to reduce unsafe management of greywater.

Indigenous plants identified: numbers, types, and derived benefits

The total number of plant groups identified at the 451 houses visited during the field survey was 1,259. The plant numbers are more than twice the number of houses visited because most houses had concurrently planted two or more different plant species at the main greywater disposal sites. The descriptive statistics show the mean 2.8 ± 1.4 with the range of 5 (1–6) plants per house, with the majority (80.3%, $n = 362$) practicing plant polyculture compared with a much smaller number (19.7%, $n = 89$) practicing monoculture. Moreover, the number or type of plants grown was not dependent on knowledge of the treatment offered by the plants per se, but rather on the benefits derived from plants (as discussed previously). The statistics show no significant association ($\chi^2 = 6.022$, $p = 0.304$) between the number of plants grown and the known role of plants to ‘treat greywater’.

The results presented in Table 5 support the view that households use vegetation in greywater disposal apparently for the benefits that plants produce, rather than wastewater treatment. Only one house reported no benefits derived from the plants, although four different plants were grown onsite for greywater disposal. More observations are made around two and more plants numbers and derived benefits, and these translate into statistically significant association between numbers of plants grown and derived plant benefits ($\chi^2 = 161.94$, $p < 0.001$) (Table 5).

From the total plant group numbers of 1,259 (Figure 3), 36 different plant species were identified (Table 6). However, for the purpose of simplicity in this study, some plants have been regrouped based on related local uses (e.g. vegetables – Corchorus and Amaranthus), fruit crop (e.g. mango and orange), and species (e.g. banana and plantain, basil, garden eggs and turkey berries) into 30 main plant categories (Table 6). All the plants identified in the survey are locally available, and households intentionally planted almost all of them. Very few were self-sowing volunteer species that were nevertheless allowed to grow with the planted species.

The top ten plants identified by the study are: sugarcane, banana/plantain, taro, sweet/wild basil, dandelion, tobacco, leaf of life, cocoyam/tannia, aloe vera, coconut/African oil palm, lemon grass, pepper/tomato/okro, and mango/orange (Figure 3). All the plants identified are used in Ghanaian communities for food and medicinal purposes, including the top ten plants listed. Our findings follow these plants uses, because the respondents reported that

Table 5 | Test for association between number of plant types and plants’ benefits

Number of plant types	Number of plants’ benefits – Distribution, <i>n</i> (%)					Total	χ^2 (<i>p</i>)
	None	One	Two	Three	> Three		
1	0 (0)	41 (41.4)	18 (25)	21 (18.8)	9 (5.4)	89 (19.7)	161.94 (0.000)
2	0 (0)	41 (41.4)	25 (34.7)	37 (33)	16 (9.6)	119 (26.4)	
3	0 (0)	12 (12.1)	17 (23.6)	24 (21.4)	41 (24.6)	94 (20.8)	
4	1 (100)	5 (5.1)	11 (15.3)	18 (16.1)	45 (26.9)	80 (17.7)	
5	0 (0)	0 (0)	1 (1.4)	12 (10.7)	53 (31.7)	66 (14.6)	
6	0 (0)	0 (0)	0 (0)	0 (0)	3 (1.8)	3 (0.7)	
Total	1 (100)	99 (100)	72 (100)	112 (100)	167 (100)	451 (100)	

Phi coefficient = 0.599.

Cramer’s V = 0.300.

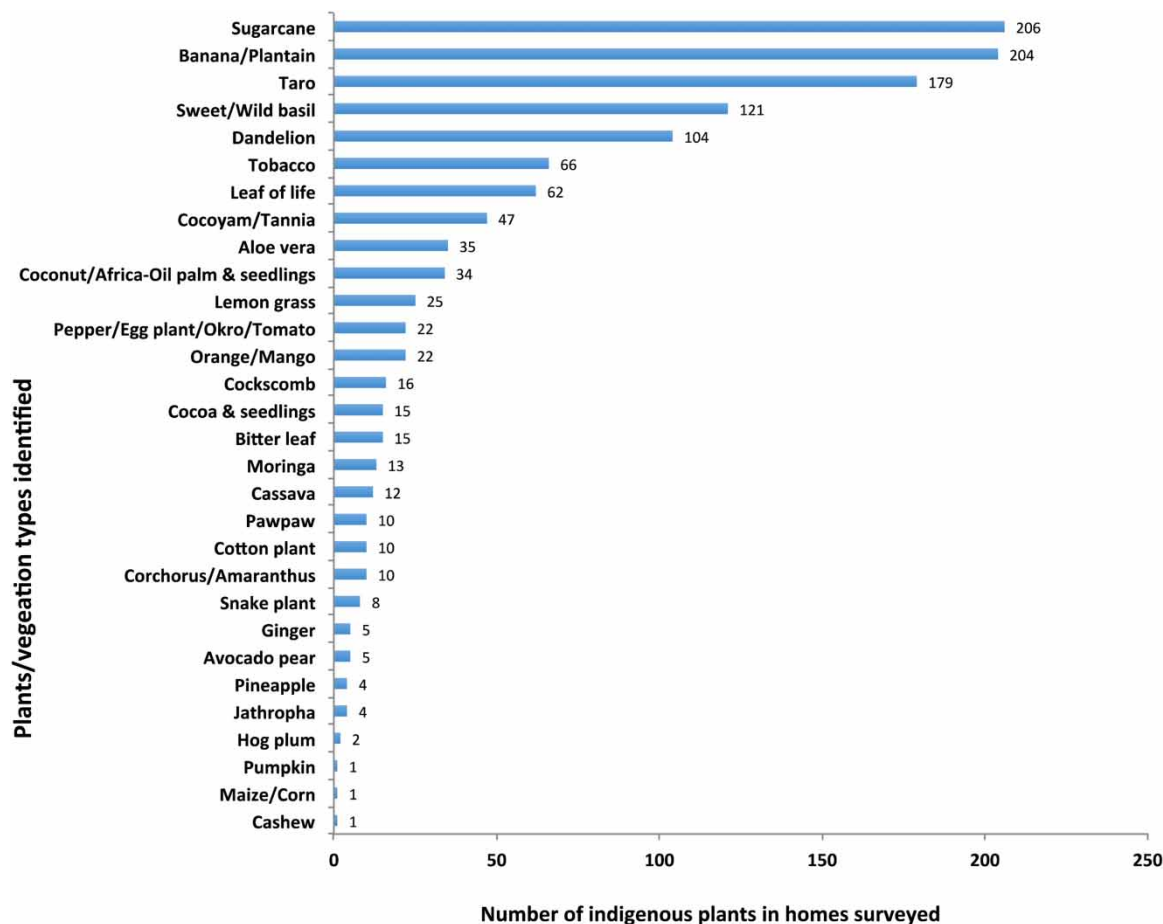


Figure 3 | Indigenous plants used for 'informal' greywater treatment.

the main benefits they derive from indigenous plants were food (84%, $n = 379$), and medicine (62%, $n = 281$) (Figure 4). Thus, the results support the earlier statistical assertions that the plants are primarily grown for agronomic uses, particularly for food and medicine. This does not contradict the respondents' perception and understanding that plants help treat the greywater. However, it emphasises people's overarching interest in the basic advantages of water and nutrients supplied from greywater to plants.

Apart from one house, all 450 households were motivated by one or more specific plants benefits, such as providing food, medicine, shade/shelter, aesthetics, fodder and hedge/fence (Figure 4). In a later part of the data collection, a limited number of respondents (50) were asked which of the plant parts were used for food and medicine. A small number were not using any plant parts (12%, $n = 6$) whilst a sizable majority depended on the leaves (66%,

$n = 29$), fruits (52%, $n = 23$), followed by roots and tubers (45%, $n = 20$). Further interviews with the same 50 homes revealed a very low awareness of potential health risk associated with consuming plants watered with greywater (5/50, 10%). Although literature supports that greywater irrigated plants may pose some risks, including microbial and chemical loads (Cook 2016; Benami *et al.* 2016), people are often not well informed. This is particularly so in Ghana where there is a dearth of knowledge on the level of risk that is associated with consumption of indigenous plants watered with greywater.

Potential for indigenous plants use in greywater treatment

The findings suggest that more can be done with the lesser known indigenous plants in the areas of green technologies. Exploring the plants with phytoremediation designs such as

Table 6 | List of the different indigenous plants identified in the householder survey

	English common names	Scientific names	Local names/ how it is known
1	Aloe vera	<i>Aloe vera</i>	Aloe vera
2	Amaranthus ^a	<i>Amaranthus cruentus</i>	Alefu
3	Avocado	<i>Persea americana</i>	Paya
4	Banana/Plantain ^b	<i>Musa spp.</i>	Kwadu/Brodie
5	Bitter leaf	<i>Vernonia amygdalina</i>	Onyono/Bonyono
6	Cashew	<i>Anacardium occidentale</i>	Cashew
7	Cassava	<i>Manihot esculenta</i>	Bankye
8	Chilli pepper ^c	<i>Capsicum spp.</i>	Mmako
9	Cockscomb	<i>Celosia spp.</i>	Akomfentiko
10	Cocoa	<i>Theobroma cacao</i>	Kookoo
11	Coconut/Africa-Oil palm & seedlings ^b	<i>Cocos nucifera/Elaeis guineensis</i>	Kube/Abe
12	Cocoyam/Tannia	<i>Xanthosoma sagittifolium</i>	Mankeni/Menkeni
13	Cotton plant	<i>Gossypium hirsutum</i>	Asaawa dua
14	Corchorus (Jute leaves) ^a	<i>Corchorus olitorius</i>	Ayoyo
15	Dandelion	<i>Lactuca teraxacifolia</i>	Dandelion
16	Garden eggs/Wild egg plant or Turkey berries ^c	<i>Solanum spp.</i>	Nyadua/Abeduru or Kwahu nsusuaa
17	Ginger	<i>Zingiber officinale</i>	Akekaduro
18	Hog plum	<i>Spondias mombin</i>	Atoa/Atuaa
19	Jathropha	<i>Jatropha gossypifolia</i>	Nkrandedua
20	Leaf of life	<i>Bryophyllum pinnatum</i>	Egoro
21	Lemon grass	<i>Cymbopogon spp.</i>	Fever aduro/esre
22	Maize/Corn	<i>Zea mays</i>	Aburoo
23	Mango ^d	<i>Mangifera indica</i>	Amango
24	Moringa	<i>Moringa oleifera</i>	Moringa
25	Okro ^c	<i>Abelmoschus esculentus</i>	Nnkruma
26	Orange ^d	<i>Citrus spp.</i>	Ankaa
27	Pawpaw	<i>Carica papaya</i>	Bofre
28	Pineapple	<i>Ananas comosus</i>	Abrobe
29	Pumpkin	<i>Cucurbita pepo</i>	Efre
30	Snake plant/Mother-in-law's tongue	<i>Sansevieria trifasciata</i>	Owo aduro/dua
31	Sugarcane	<i>Saccharum officinarum</i>	Ahwidie
32	Sweet basil ^e	<i>Ocimum basil/canum</i>	Akokomesa
33	Taro	<i>Colocasia esculenta</i>	Brobe/Kookoo
34	Tobacco	<i>Nicotiana tabacum</i>	Bonto
35	Tomato ^d	<i>Solanum lycopersicum</i>	Nntoosi
36	Wild basil ^e	<i>Ocimum gratissimum</i>	Numnum

Common, scientific and local names are reported.

^aRegrouped as Corchorus/Amaranthus.

^bAlready grouped.

^cRegrouped as pepper/egg plant/okro/tomato.

^dRegrouped as orange/mango.

^eRegrouped as sweet/wild basil.

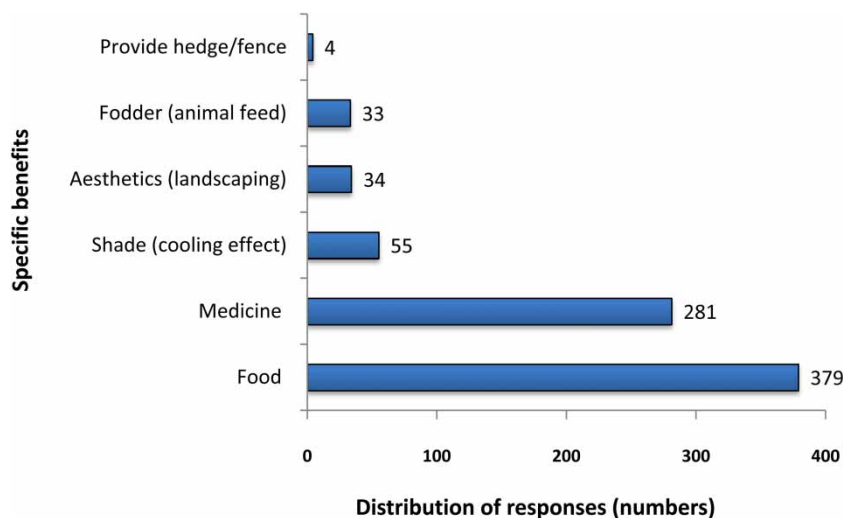


Figure 4 | Specific benefits derived from plants used in greywater disposal.

constructed wetlands and vegetated subsurface infiltration systems looks promising. Although this study did not examine the treatment efficacy of the existing informal treatment systems, there is strong perception from the people that their greywater disposal practices offer some agronomic benefits like food and medicine from plants. However, scientific proof about claims of treatment and also the safety of biomass consumption are required. Experts have identified that one of the gaps in vegetated filter bed technologies is finding ways to integrate value-added crops (Langergraber 2015). Our current study suggests that we may not be too far from finding some value-added plants for such technology locally in Ghana. According to the IWA newsletter on Wetland Systems for Water Pollution Control, ‘a tremendous incentive for stewardship of constructed wetlands in developing countries will be created if we get a net positive cash flow off wetland crops’ (Langergraber 2015). We can say that a promising research area is emerging in Ghana, and probably in sub-Saharan Africa, where safe greywater management is a huge challenge.

Although the use of less known native plants in constructed wetlands is a grey area, we could explore monoculture systems and/or integrate these plants (sugarcane, taro, cocoyam, basil, dandelion, aloe vera, lemon grass etc.) with conventional constructed wetland plants such as reed grass (*Phragmites*), vetiver grass, and typha. The lead author is currently exploring such a research area in his PhD study.

The planting practices identified from our survey are similar to the mixed vegetation system commonly found in natural wetlands in Ghana (Campion & Venzke 2011; Campion & Owusu-Boateng 2013). The potential for integrated, value-added indigenous constructed wetlands for greywater treatment is high, because they are a natural progression of existing practices amongst many of the households.

The study also revealed that very few homes (8%, $n = 37$) have challenges with the existing practices. However, some complained of plants harbouring reptiles and other unwanted animals (36%, $n = 13$), and that plants were badly affected by dry seasons (61%, $n = 22$). Solutions to these challenges are straightforward and include plant husbandry and a more uniform distribution of the greywater.

It is encouraging that a substantial number of respondent households (44%, $n = 199$) expressed interest in adopting technology changes that would improve upon their existing practices. The majority of these optimists ($n = 164$) were willing to pay for improvements to their informal treatment systems. Eighteen people could not give an explicit amount, but indicated a willingness to ‘buy at any price’. However, the majority were willing to pay an extra GHS 5–500 with a mean of GHS 66 (around USD 15) suggesting this figure (or the median value of GHS 50, i.e. about USD 12) defines the acceptable upper price point of new technologies). While the lower quartile (25th percentile) was willing to pay GHS 20, the upper quartile (75th percentile) was ready with GHS 100 per treatment system. Hence, improvements

and/or new technology must be both affordable and socially acceptable. Examples of these technologies could include constructed wetlands, bioretention, bioinfiltration, biofilter, rain gardens and cells in homes, communities, towns and urban neighbourhoods, by adopting similar systems used in Singapore for treating and discharging surface runoff from drainage areas like parks, roadside, planting verges, civic squares, etc. (Hunt *et al.* 2015).

CONCLUSIONS AND IMPLICATION FOR PRACTICE AND POLICY

The main greywater disposal practices in Ghana are largely unimproved, with only low usage rates of 0.2–23% for septic tanks and soak pit systems, respectively. Apart from the greywater being used to water plants as part of the disposal process, other uses identified (without pre-treatment) were cleaning/scrubbing floors, and watering down dust within the compound of the house. The main reservations for alternative end uses among some people were mainly perceived health risks, and the inconvenience of linking greywater from its source(s) to its use. There is considerable potential for improving the existing, informal practices of using vegetated subsurface infiltration as a treatment technology for greywater disposal. Households use a diverse range of plants, at least 36 different species, in their greywater disposal systems. Several of these plants have been identified as potential candidates (e.g. sugarcane, taro, cocoyam, basil, dandelion, aloe vera, lemon grass, etc.) for further research into greywater treatment technologies, such as constructed wetlands.

Although households strongly believe their plants treat greywater during disposal, such claims require scientific proof, as well as a risk assessment of plant consumption for food and medicine. Uses of plant biomass for food and medicine are the main value-added benefits to households, and seem to be the paramount reason for the use of plants in greywater disposal. Few people have challenges with the existing informal practice of plants use in greywater treatment, and those concerns could be easily solved with better irrigation design and plant husbandry practices. There is a positive willingness among respondents to pay for improvement to their greywater disposal systems. The

majority have indicated a willingness to pay GHS 100 (about US\$23) for an improved technology, with value-added benefits. Refinement of indigenous knowledge and practice of informal treatment of greywater using plants is warranted, and several native plants could be explored for use in simple and also more sophisticated technologies.

As part of the initiative to improve local disposal practices, it is recommended that a clear and robust design and installation standard and guidelines should be developed, communicated and enforced.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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