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Research article

Greywater characterization and generation rates in a peri urban municipality of a developing country

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ABSTRACT

The quantity and quality of combined greywater from houses with in-house water supply and houses that rely on external sources of a peri-urban area in a developing country were determined. Data for quantity of greywater was collected from 36 households while 180 samples of greywater were collected from 60 households between December 2016 and February 2017. The results indicate that, average water consumption from households with in-house access was 82.51 ± 12.21 $Lc^{-1}d^{-1}$ while households which rely on external sources was 36.64 ± 4.31 $Lc^{-1}d^{-1}$ with return factors of 74.16% and 88.57% respectively. Quality analysis also showed significant differences between greywater from the two sources with most of the quality parameters exceeding the regulatory limit. The ratio between biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) ranged between 0.22 and 0.59 for greywater from in-house sources and 0.23–0.62 for external sources indicating low biodegradability of the greywater. The nutrients recorded exceeded the trigger levels for eutrophication while significant levels of microorganisms such as *E. Coli* and *Salmonella* spp. were also detected in both streams. Direct reuse of greywater for irrigation was found to be unsuitable based on the salinity and sodium hazard analysis. Principal component analysis of the data indicated that the characteristics of the combined greywater in the study area is influenced by cooking and cleaning practices, personal hygiene, biodegradability, frequency of water use before disposal and sanitary practices in the bathroom. The greywater discharged is detrimental to the environment and poses a health risk to humans and livestock. There is therefore the need for authorities involved to prioritize greywater management and treatment in peri-urban areas of developing countries.

1. Introduction

The united nations define a peri-urban area as an area between consolidated urban and rural region (UNICEF, 2012). In developing countries, it is where poverty and social displacement are more common, a frontline between the problems of the city and the rural areas. The growth of these peri-urban areas in developing countries are associated with sanitation challenges such as solid waste, excreta collection and management, and wastewater management for the relevant institutions. Due to the disparities in economic and social status associated with peri-urban areas in developing countries, certain basic amenities like water supply within a house is not automatic for every house. Houses without piped water in their dwelling will have to resort to other sources of water such as from water vendors, springs, streams among others. Many of these peri-urban areas in developing countries are saddled with wastewater management largely due to the non-existence of sewer network. The primary focus on peri-urban areas by authorities has remained solid waste and excreta management which is aimed at improving the sanitary conditions and improving public health. However, this is in sharp contrast to greywater management which accounts for the high volumetric flux of wastewater generated in non-sewered areas. There is a clear lack of planning in addressing greywater management in peri-urban areas in developing countries mostly arising from lack of commitment or by the overwhelming rapid growth associated with these areas. Lack of proper management of greywater in peri-urban areas of developing

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countries has led to indiscriminate discharge of greywater, which has contributed to public health issues arising out of uncontrolled and unmonitored discharges. These discharges result in both short term and long-term effects on both environment and human (Gross et al., 2005; Scott and Jones, 2000). It also affects water resources and soils due to the presence of surfactants (Mohamed et al., 2013), and heavy metals (Aonghusa and Gray, 2002; Eriksson et al., 2010) in high concentrations. Nutrient buildup in water bodies as a result of greywater discharge may lead to eutrophication which is detrimental to aquatic environment. Kohler (2006) identified sodium polyphosphate which is a major ingredient in soaps to be a major contributor of nutrients in eutrophication. Studies conducted by (Escher and Fenner, 2011; Taghipour and Mosaferi, 2013) identified a distortion in the ecological balance due to toxicity of food chain caused by accumulation of heavy metals and micro-pollutants in the environment which negatively affects both plants and animals alike after long exposure times. Long periods of exposure to pathogens and microorganisms in greywater has been reported to cause diseases that results in either mortality or morbidity (Birks and Hills, 2007; Ottoson and Stenstrom, 2003). Many studies have all analyzed greywater without cognizance to the source of water and the lifestyle patterns. Research on greywater characterization and quantity generations has largely focused on sources such as kitchen, bathroom, hand wash basin (Abedin and Rakib, 2013; Katukiza et al., 2014), water use fixtures such as washing machines, dishwashers (Abedin and Rakib, 2013; O'Toole et al., 2012) and location or type of settlement such as peri-urban and slums, (Antonopoulou et al., 2013; do Couto et al., 2013; Katukiza et al., 2014; Ramona et al., 2004).

However, the differences in quality and quantity between greywater from houses fitted with household taps and those that rely on other external sources of water in a peri-urban area in a developing country remains uninvestigated. According to the UNDP (2017), about 663 million people lack access to improved water and a majority of this fraction are in developing countries. This is an indication that greywater discharges from peri-urban areas in developing countries should not be treated as all coming from one source as has always been the case in many studies that have characterized greywater quality and quantities.

The objective of this study therefore is to characterize greywater and quantify its pollutant loads for these two categories in a typical peri-urban area of a developing country within sub-Saharan Africa and provide the relevant data necessary to policy makers to inform decision and influence policy.

2. Materials and methods

2.1. Study area

This study was conducted in the Komenda Edina Eguafo Abirem (KEEA) municipality of the Central region of Ghana during the periods of December 2016–February 2017. KEEA is located in the central region of Ghana between longitude 1° 20′ West and 1° 40′ West and latitude 5° 05′ North and 15° North and covers an area of 452.5 km^2 with a population of 144,705 (GSS, 2014). It is located within the coastal belt of the country along the Atlantic Ocean and it is drained by the Benya lagoon. Potable water supply to the area is exclusively by Ghana Water Company Limited (GWCL) which has a network coverage of less than 40% within the municipality while other areas which are not connected to the GWCL lines resort to alternative water supply systems such as groundwater, streams and springs, rainwater and water vendors. Greywater is discharged through open gutters and undeveloped plots. Other methods of disposal also include direct irrigation of certain plant species such as *Musa Balbisiana*, *Carica Papaya* among others and open discharge onto compounds in areas where there are no gutter or undeveloped plots. Majority of residents use on-site sanitation systems such as septic tanks and household latrines while others rely on public sanitation facilities. These practices are mostly common in peri-urban areas in developing countries within the sub-Sahara Africa, Latin America, and Asia. There is no wastewater management system in place and wastewater is discharged without any regulation. This survey was done in different towns/villages within the study area in order to have a cross-sectional variation in water use and greywater generation rates and also mimic similar conditions in other developing countries.

2.2. Selection of households: characterization

Greywater samples were collected from all six zonal councils within the study area. A total of one hundred and eighty (180) samples were collected from the study area. Sixty households were selected to participate in the study within the six zonal councils after consultation with local leaders within the community. The criteria for selecting these households were willingness to participate in the study, households with in-house access, households that rely on outside sources, households with children under age 3, households that have greywater from kitchen, hand wash basin and bathrooms going through one discharge point. Volunteers were asked to discharge water used for laundry into this drain during the periods of data collection.

2.3. Selection of households: volume estimation

Volume estimation was done by recruiting two sets of volunteers – those with in-house access and those who rely on an outside source. Criteria for selection of volunteers with in-house access was willingness to participate in the study. With respect to those who rely on outside sources, the criteria for selecting such volunteers were willingness to participate, willingness to use special 20L buckets provided for the study to collect both potable and greywater after use.

2.4. Collection of greywater samples: quality estimation

Greywater samples (n = 180) were collected and stored in sterilized 0.5L sample bottles and 0.2L sterilized glass bottle for oil and grease analysis. The sampling points indicated with round dots are shown in Fig. 1. These samples were stored in laboratory ice chest with ice packs and transported to the laboratory for analyses within 24 h.

2.5. Collection of greywater samples: volume estimation

A total of 18 households with in-house access were provided with a special digital flow meter – white-line smart flowmeter. The discharge spouts of their wastewater discharge lines were retrofitted in order to install this flowmeter. This flowmeter is not disturbed by solids and has a very low sensitivity (0.5 Lmin^{-1}). However, the drawback of this flowmeter is its inability to read more than 1000L. Volunteers were alerted of this and were given a tally card to record the number of times it resets itself after recording 1000L. The volume recorded on the water meter supplied by GWCL is taken before the study was initiated in order to estimate the volume of water that will be used by the household. Sampling points represented by triangle are presented in Fig. 1. Participants were also asked to note any day when there was no water supply.

A total of 18 households that relied on outside sources were selected in this study. These households were given special 20L buckets for use during the study period to help estimate the