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The potential utilization of grey water for irrigation: A case study on the Kwame Nkrumah University of Science and Technology, Kumasi Campus

Godfred Owusu-Boateng*, Victoria Adjei

Faculty of Renewable and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi.

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ABSTRACT

The problems of shortages and quality deterioration of water, have led to an increased interest in the reuse of treated grey water in many parts of the world. This study examined the suitability of locally available materials (beach sand, oyster shells, and charcoal) to treat grey water samples collected weekly from three halls of residence (Unity Hall, Africa Hall, and Independence Hall) on Kwame Nkrumah University of Science and Technology (KNUST) campus for irrigation. Beach sand, oyster shells, and charcoal were employed in the construction of three vertical flow-through filter systems, each consisting of PVC pipes of height 100 cm and internal diameter 5.08 cm. The grey water samples were filtered and the levels of physicochemical parameters (pH, conductivity, TDS and salinity), nutrient and microbial counts determined over a three-week period. Results indicate that the measured physico-chemical parameters treated grey water were within the permissible limits for irrigation water. Also filtration process is effective in reducing phosphate, the total and faecal coliform levels in grey water from the halls of residence. These observations suggest that treated grey water from KNUST campus would support production when used as irrigation water.

1. Introduction

Nations are endowed with resources for survival, growth, and development. Among these resources is water, one of nature’s most important gifts to mankind. It is a finite and an invaluable resource. The importance of water to all living things underpins the global concern for its security. However, with the advent of population explosion, urbanization, and the increased competition among the different uses (domestic, industrial, and agricultural) of water, water is becoming a rare resource in the world without the possibility for an increase in its supply. It is estimated that in the year 2000, the urban areas of Ghana generated about 763,698 m^3 of wastewater each day, resulting in approximately 280 million m^3 of the wastewater over the entire year. Regional capitals accounted for another 180 million m^3 of generated wastewater. Only a small fraction of the generated urban wastewater is collected, and an even smaller proportion is being treated. Moreover, less than 25% of the 46 industrial and municipal treatment plants in Ghana were functional. Treatment plants for municipal wastewater are operated by local governments, and most of them are stabilization ponds. A biological treatment plant which was built in the late 1990s at Accra's Korle Lagoon only handles about 8% of Accra's wastewater (Awuah and Abrokwa 2008).

In recent years researchers are have began showing greater interest in treatment and reuse of wastewater. Wastewater management in Ghana has undergone a paradigm shift in terms of how

Wastewater is valued and managed. Waste water is being used in some countries for agriculture. Agricultural water needs represent the greatest percentage of global water use, and wastewater reuse is an attractive alternative with good potential to supplement freshwater supplies Finley et al (2009). According to the WHO (2006), such use is promoted by some factors mainly:

- Increasing water scarcity and stress, and degradation of freshwater resources due to from improper disposal of wastewater;
- Increased demand for food as a result of population increase;
- Environmental sustainability and eliminating poverty and hunger as prescribed by the Millennium Development Goals.
- Recognition of the value and importance of wastewater such as the nutrients content

Improper wastewater disposal which pollutes surface water and groundwater resources and degenerate water supply problems have created a serious conundrum for governments and the nation at large. These conditions among others such as improper wastewater disposal which pollutes surface water and groundwater resources and degenerate water supply problems have created a serious conundrum for governments and the nation at large. There is therefore the need to search for sustainable water management schemes by encouraging wastewater reuse while re-evaluating the uses to which potable water should be put.

Generally, grey water is used to refer to all wastewater generated from households with the exception of human solid or liquid wastes (referred to as sewage or black water). It is termed as such because of its cloudy appearance and from its status as being between fresh, potable water and sewage water (black water). Jefferson et al. (2004) found that, although similar in organic content to full domestic wastewater, grey water contain fewer solids and is less turbid than domestic wastewater, suggesting that more of its contaminants are dissolved. The use of grey water for agricultural and irrigation is occurring more frequently because of water scarcity and population growth (Keraita et al. 2003). According to Friedler (2004), grey water makes up about 60-70% of domestic wastewater volume in developed countries. Grey water reuse is one such strategy which is already in use by millions of farmers worldwide, and is estimated that 10% of the

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Corresponding author E-mail: boateng.irnr@knust.edu.gh

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world's population consumes foods irrigated with grey water (WHO, 2006).

Grey water reuse is a strategy that simultaneously alleviates the environmental and economic concerns of water usage and helps reduce the alarming global water menace. Generally, the reuse of grey water is particularly important to;

- Ease the mounting demand on limited freshwater reserves by substituting the use of freshwater for non-potable uses such as irrigation, dishwashing, laundry, car washing and toilet flushing since grey water is an inevitable wastewater that is generated daily irrespective of water availability in a locality.
- Reduce conflicts over water and reduce the demand for new water supply projects by substituting the demand for potable water.
- Reduce strain on septic tanks or treatment plants. Grey water reuse greatly extends the useful life and capacity of septic systems. For municipal treatment systems, decreased wastewater flow means higher treatment effectiveness and lower costs.
- Reclaim otherwise wasted nutrients. Loss of nutrients through wastewater disposal in rivers and streams is a highly significant form of erosion. Reclaiming nutrients in grey water helps to maintain the fertility of the land.
- Support plant growth because it contains nutrients, mainly nitrogen and phosphorus and has potential for use on agricultural crops, hence subsidizing commercial fertilizer use.
- Improve food production capacity all year round since grey water is available at all times, be it the dry or wet season.
- Economically provide significant savings in freshwater use and management. Thus, grey water reuse will go a long way to reduce the cost of obtaining freshwater and also help reduce payment of water bills.

The public is quite skeptical about the health safety or implications of grey water when reused (Brown and Davies 2007). Perceived health risk, perceived cost, operation regime, and environmental awareness religious and cultural values Laban (2010) are some of the factors that guide acceptability of grey water by the public.

The indispensable utilization of water for domestic hygiene including washing, bathing, etc comes with the production of grey water. When handled and managed well, it becomes an asset otherwise it is a menace. Potential uses may be available. Kwame Nkrumah University of Science and technology, being a large community of learning has a large population and therefore generates large quantities of grey water the quality of which and hence the possible uses including irrigation farms in the university community including the university's demonstration farms are not known. Determination of physicochemical and microbiological quality of grey water generated from the students' halls of residence and construction of a filter system for treating grey water samples collected are likely to bring to light the potentials of grey water.

2. Description of the study area

The study was executed on the Kwame Nkrumah University of Science and Technology (KNUST) which has laboratory for running various physicochemical and microbiological tests and availability of grey water and irrigation farm. Three out of the seven halls of residence were selected for the study. These halls were the Africa Hall (an all female hall), Unity Hall (an all male hall), and Independence Hall (a male-female hall). The choice of these halls introduced a balance in the composition of the halls of study.

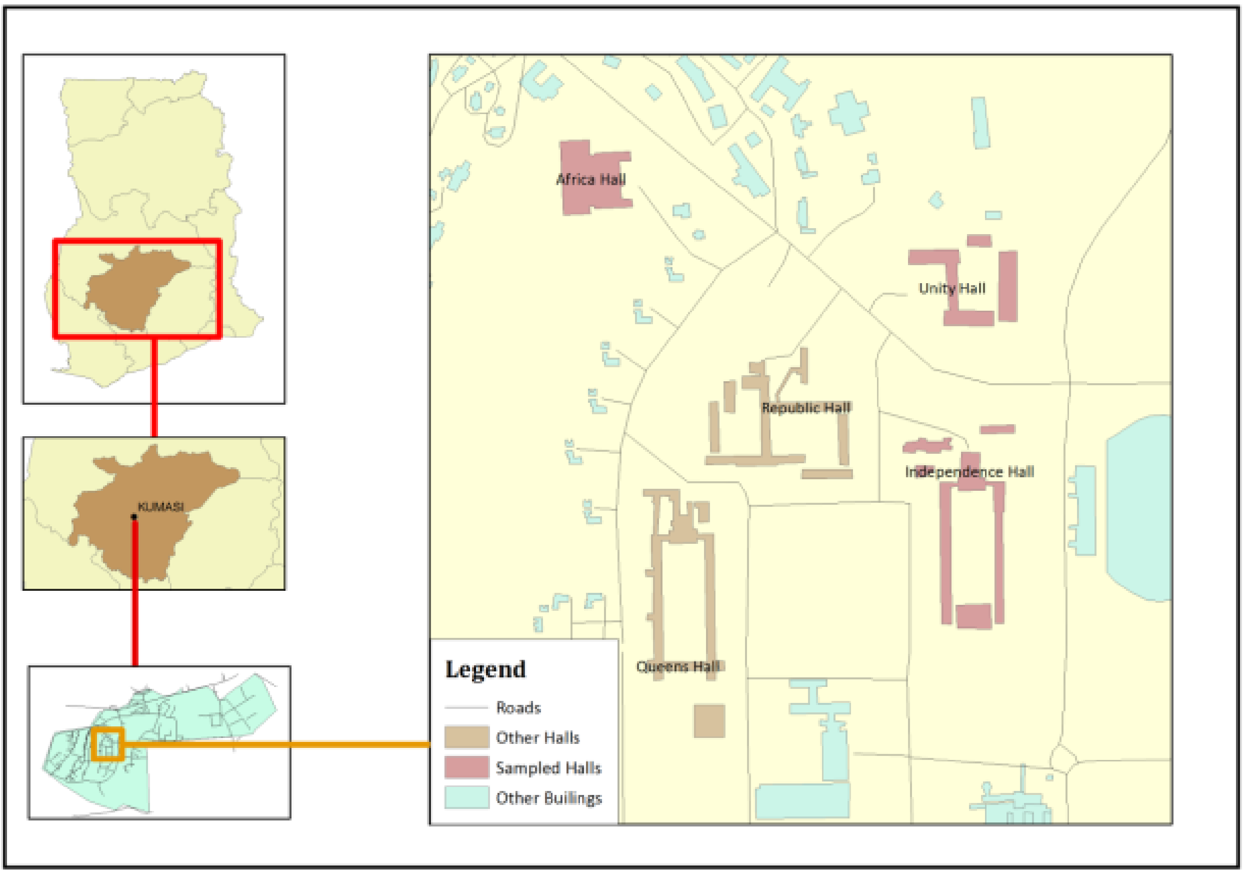

Fig. 1. Map of KNUST with grey water some sampling Sites (halls).

3. Methodology

The presence of contaminants of water for various designated uses necessitate primary treatment including filtration (Morel and Diener 2006). Three vertical flow-through sand filter systems were constructed using PVC pipes of internal diameter of 5.08 cm (2 inch) and a height of 100 cm. One end of each PVC pipe was closed with a 1 mm mesh size net and the other end left opened for the water feed. They were then clamped firmly into position and correctly labelled. Each sampling hall was designated a single filter unit.

3.1. Selection and pretreatment of filter media

According to Khalaphallah (2012), properly constructed sand filtration system consists of a tank, a bed of fine sand, and a layer of coarse aggregate (e. g. gravels) to support the sand. Therefore white

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beach sand, crushed oyster shells and charcoal were use in the construction of filtration system. The beach sand and oyster shells were thoroughly backwashed to ensure that they were free from any residual salts, organic matter or dirt. This was followed by sun drying to allow the solar radiation to inactivate any possible attached pathogen.

3.2. Packing of filter media

Each treatment unit was first and foremost underlain with a 15cm thick layer of crushed oyster shells of average size 7.49 mm. Aside supporting the sand, the oyster shells were to effectively withhold large particles of unbroken organic matter. Above the layer of oyster shells was laid a 15 cm thick middle layer consisting of charcoal of average size 11.92 mm. This layer of charcoal was introduced to trap carbon-based impurities (organic compounds) as well as inorganic and odorous compounds. This layer was then overlaid with a 50cm thick layer of beach sand.

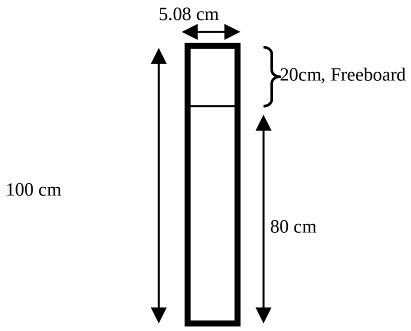

Fig. 2. Schematic diagram of filter column.

3.3. Collection of grey water samples

Grey water samples were collected over a three-week period from three halls of residence on campus- Independence Hall, Unity Hall and Africa Hall. Grey water samples were collected weekly from each hall. The levels of some physicochemical parameters (pH, conductivity, total dissolved solids (TDS), and salinity) of the untreated grey water were measured in situ with the multi-parameter probe prior to collection. The samples were collected into 1.5 litre plastic sampling bottles by placing them directly at the mouth of the receiving drains of each hall. The samples were transported on ice to the Faculty of Renewable Natural Resources for treatment.

3.4. Treatment of samples

Grey water samples from each of the halls were each fed into their respective filter units. The filtrate (treated grey water) was collected into well labeled receiving containers. Again, the multi-parameter probe was used to measure the levels of the physicochemical properties (pH, conductivity, total dissolved solids (TDS), and salinity) of the treated grey water. The entire sampling and treatment process was repeated weekly.

3.5. Laboratory analysis

Both the treated and untreated grey water samples of each sampled hall were analyzed for nutrient (nitrate and phosphate) and microbial counts (total and faecal coliform) loads.

3.6. Statistical analysis

All results were expressed as the mean ± standard deviation and displayed in bar charts. The raw untreated and grey water samples were subjected to the Student’s t-test to determine whether their means were statistically different from each other, using the GraphPad Prism 5 software.

4. Results and discussion

Water quality issues that can create real or perceived problems in agriculture include nutrient and sodium concentrations, heavy metals, and the presence of contaminants such as human and animal pathogens (Toze 2006). The ranges of the levels of the tested physicochemical parameters of the untreated and treated grey water over the entire sampling period are tabulated (Table 1). Adsorption of trace organic and inorganic compounds by the micro pores of the various filter media in the treatment system is thought to be the primary physicochemical mechanism for the removal of refractory compounds. Generally, these physico-chemical interactions are a function of surface area: the larger the surface area of the filter material, the greater the interaction.

4.1. Physicochemical parameters

4.1.1. pH

pH is an index of the concentration of hydrogen ions (H^+) in the water. It is defined as -log [H^+]. According to Bauderet al.,(2011), the lower the concentration of hydrogen ions in the water, the higher the pH value is or the more basic the water is and vice versa. Results of pH consistently increased for all treatments over the entire study period with Unity Hall recording the highest pH values at 9.16 and 9.09 for weeks one and two respectively. Generally, the normal pH range for irrigation water is from 6.5-8.5 (FAO, 1985); (USEPA, 200). Values for pH of untreated grey water for week one ranged from 6.77 to 7.88 with Independence Hall recording the highest pH value while Africa Hall recorded the least pH value. pH values of untreated grey water recorded for weeks two and three were in the ranges 7.57-8.43 and 7.19-7.43 respectively with Unity Hall recording the highest pH value in both weeks. Most of the activities involved washing. This made the grey water rich in surfactants (Gross et al., 2007). The observed pH ranges may be accounted for by the presence of soapy and soapless detergents which are often alkaline and therefore driving the pH to between 7 and 8 (Jefferson et al., 2004).

Table 1. Levels of the physicochemical parameters of untreated and treated grey water samples.

	Parameters	Africa Hall	Independence Hall	Unity Hall
Untreated Grey water	pH	6.77-7.57	7.19-8.19	7.04-8.43
	Conductivity(μS/cm)	246-319	242-652	195-402
	TDS (mg/L)	141-206	135-331	98-164
	Salinity(PSU)	0.07-0.15	0.12-0.31	0.09-0.16
Treated Grey water	pH	8.13-8.41	8.29-8.38	8.45-9.16
	Conductivity(μS/cm)	374-724	363-1355	424-1117
	TDS (mg/L)	234-368	260-429	218-295
	Salinity(PSU)	0.23-0.35	0.33-0.60	0.26-0.53

For the treated grey water samples, pH values recorded for the individual sampling weeks were: Week one (8.29-9.16), Week two (8.19-9.09) and Week three (8.13-8.45) respectively (Figure 3). The highest pH value for the treated grey water was recorded by Unity hall in week one, whiles Africa hall recorded the least pH value as 8.13 in week three. However, the pH values recorded for the treated grey water relatively increased over the entire sampling period. High pH’s above 8.5 are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ion concentrations, known as alkalinity [Bauderet al., 2011]. The increase in the pH values for the treated grey water therefore may be attributed to the dissolution of oyster shells which consist mainly of calcium carbonate ($CaCO_3$), in the grey water during

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treatment. As the oyster shells dissolved in the water, they might have released carbonate ions (CO_3^{2-}) which combined with the H+ ions present in the water to form hydrocarbonates. The formation of these hydrogen carbonates might have probably reduced the H+ ions levels in the water to raise the pH of the effluent water The difference in p-value ($p<0.05$) recorded for the pH levels of the untreated grey water and the treated grey water for weeks one and two were not statistically significant, but that of week three was statistically different. The permissible pH range for irrigation water as given by the FAO (1985) and USEPA (2004) is 6.5-8.5.

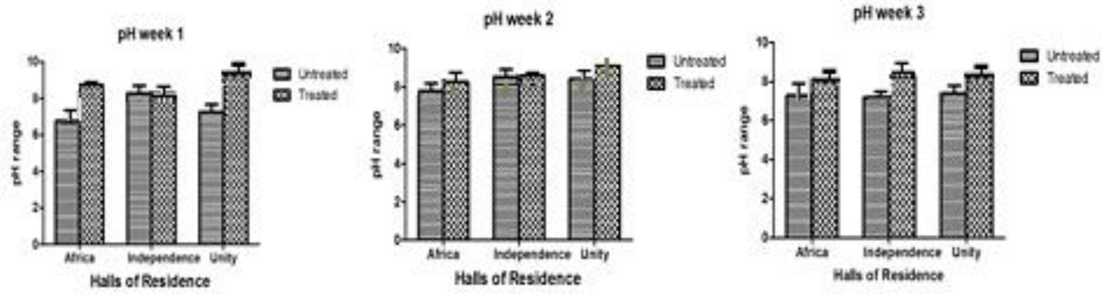

Fig. 3. pH levels for untreated and treated grey water from Africa, Independence and Unity Halls.

4.1.2. Total dissolved solids (TDS), salinity and conductivity

Water salinity, conductivity and total dissolved solids (TDS) are interrelated. The content of salts dissolved in water as well as the parameters derived from its presence in water such as conductivity and total dissolved solids (TDS) determine the chemical characteristics of the water. Water salinity refers to the total amount of salts dissolved in water but it does not indicate which salts are present in it. Salts contribute to the conductivity of water by dissolving to release positively charged ions(e.g. Ca^{++}, Na^{+}) and negatively charged ions(e.g. Cl^{-}, NO_3^{-}), which conduct electricity. The electrical conductivity of water on the other hand estimates the total amount of solids dissolved in water.

Results showed increasing trends in the salinity, conductivity, and TDS levels of the treated grey water relative to the untreated grey water. Values for TDS were highest at 331 mg/L and 429 mg/L for untreated grey water and treated grey water respectively (Figure 4). Both values were each recorded at Independence Hall. The difference in p-value ($p<0.05$) for the untreated grey water and the treated grey water samples over the three-week sampling period showed a significant variation. The permissible TDS level for irrigation water as given by Rowe and Abdel-Magid (1995) is in the range of 500 to 2000 mg/L.

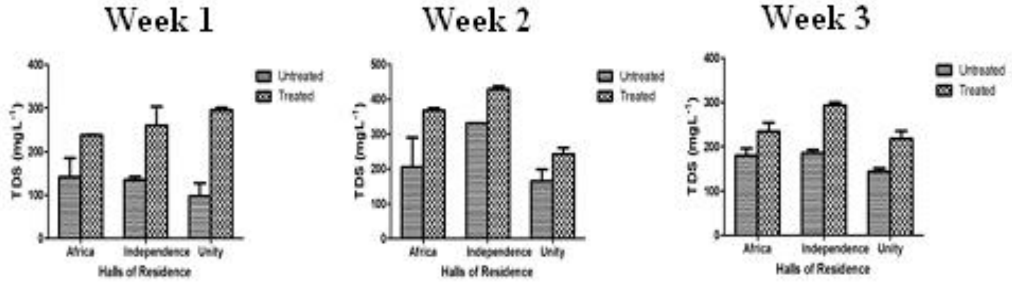

Fig. 4. TDS levels for untreated and treated grey water from Africa, Independence and Unity Halls.

Generally, the salinity levels of the treated grey water were higher relative to that of the untreated grey water. For the untreated grey water, Africa Hall recorded the least salt concentration (0.07 PSU), and Independence Hall recorded the highest salt concentration at 0.31 PSU. For the treated grey water, Africa Hall recorded the lowest salinity values; 0.23 PSU, 0.35 PSU, and 0.24 PSU for weeks 1, 2, and 3 respectively throughout the sampling period, while Independence Hall recorded the highest salt concentrations; 0.35 PSU, 0.60 PSU, and 0.333 PSU weeks 1, 2, and 3 respectively (Figure 5). Salinity concentrations between the untreated grey water and treated grey water were significant. The permissible salinity level for irrigation water as given by the FAO (1985) ranges from 0.7 to 3.0 PSU.

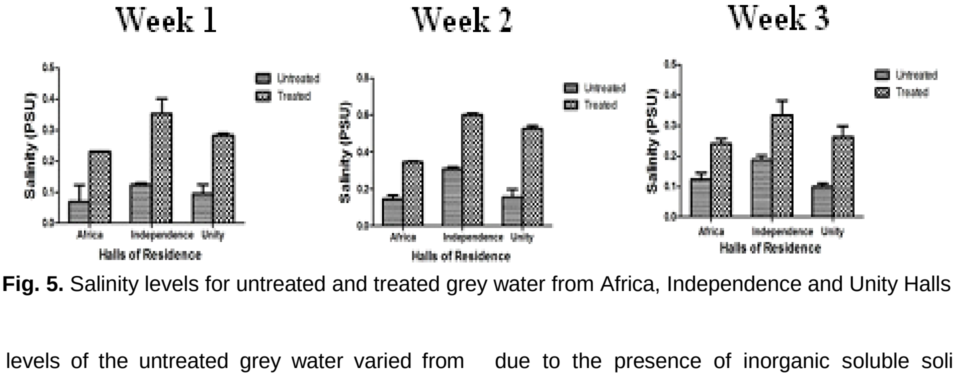

Fig. 5. Salinity levels for untreated and treated grey water from Africa, Independence and Unity Halls.

The conductivity levels of the untreated grey water varied from 196µS/cm to 652µS/cm, while that of the treated grey water varied from 363µs/cm to 1355µS/cm (Figure 6). Independence hall recorded the highest conductivity value in both untreated grey water and treated grey water. The difference in p-value ($p <0.05$) recorded for the conductivity levels of the untreated grey water and the treated grey water were statistically significant. The permissible conductivity level for irrigation water as given by the EPA (1995) is 800µS/cm. The relatively higher levels of salinity, conductivity, and TDS in the treated grey water samples than the untreated grey water samples may be due to the presence of inorganic soluble solids such as chloride, nitrate, sulfate, anions or sodium, magnesium, and calcium cations in the filter substrate through which the grey water percolated US.EPA (2012).

4.1.3. Nutrients

Grey water can contain nutrients including nitrogen and phosphorus Maimonet al., [2010]. Although wastewater can generally contain elevated concentrations of nitrogen and phosphorus (nutrients) and potassium not much nutrients (usually less than 5 mg/L) occur in grey water (Surendran and Wheatley, 1998).

Fig. 6. Conductivity levels for untreated and treated grey water from Africa, independence and Unity Halls.

4.1.4. Nitrate

Nitrate values recorded during the study period for untreated grey water ranged from 0.33mg/L to 1.5mg/L whereas nitrate values recorded for treated grey water relatively increased from 0.43mg/L to 2.19mg/L. Similar to pH, conductivity, TDS, and salinity, nitrate levels increased consistently in the filtered grey water throughout the study period. The highest increase was recorded in week three at 2.19mg/l. Bhumbla (1999), reported that nitrate in water is present as highly soluble salts. Therefore, when water moves on the surface of a soil, it dissolves some nitrates that are originally present in the surface layers of the soil and the dissolved nitrates move along with the water in the soil. This may have contributed to the consistent increase of nitrate levels in the filtered grey water.

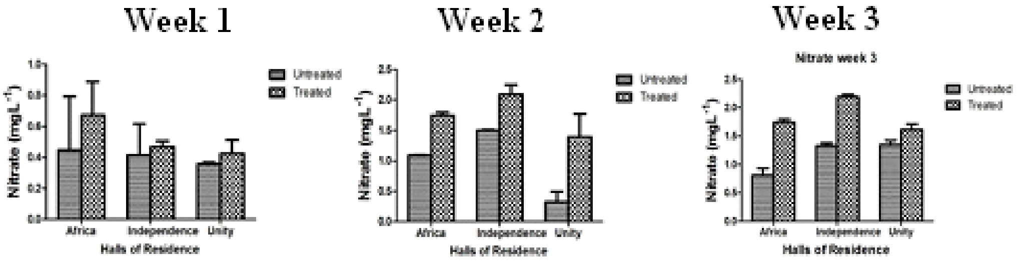

Fig. 7. Nitrate levels for untreated and treated grey water from Africa, Independence and Unity Halls.

The difference in p-value recorded for weeks one and three were not statistically different from the untreated grey water and the treated grey water, but that of week two were statistically different. The permissible nitrate level for irrigation water as given by the (EPA, 1995) is 10mg/L.

4.1.5. Phosphate

The levels of the effluent phosphate decreased at the end of each filtration process. Results indicated that reductions in phosphate levels was higher in week one (from 5.76 to 3.51mg/l) and week two (from 1.85 to 1.09mg/l). The level was higher in untreated grey water the treated (at 5.95mg/L and 5.25 mg/L respectively) (Figure 8). The high pH recorded may account for this observation. At high pH levels, phosphate may be locked up in the soil as insoluble forms of calcium and magnesium. Phosphate (PO_4^{3-}) is a triple negatively charged anion which means that it is strongly attracted to positively charged cations like calcium, magnesium, iron and aluminium. The fact is that when PO_4^{3-} forms a bond with these other minerals it becomes insoluble, locked-up, and does not travel along with the soil water.

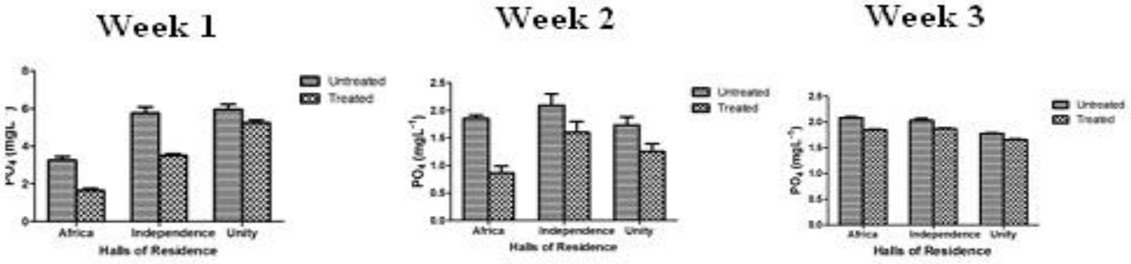

Fig. 8. Phosphates levels for untreated and treated grey water from Africa, Independence and Unity Halls.

The difference in p-value ($p<0.05$) recorded for weeks one and two showed no statistical difference between the untreated grey water and the treated grey water, but that of week three was statistically different. The permissible phosphate level for irrigation water as given by the EPA (1995) is 10mg/L.

4.1.6. Microbial quality

Microbial and chemical contamination of grey water poses a potential risk to human health [Dixon et al., 2000]. There were no recorded values for both total and faecal coliform for the treated grey water in weeks one and two. Filtration processes remove most microorganisms from waste water. Casanova et al. (2001), recounted that grey water contain relatively mildly less pathogenic microbial such as faecal coliforms, enterococci, and bacteriophages. In week two, no coliform count was recorded for both the untreated and treated grey water. In week three, Africa Hall and Independence Hall recorded equal faecal coliform counts of 2.35 x104CFU/100mL for the treated grey water. The highest total coliform count (2.35 x 105 CFU/100ml) in week three was recorded for the treated grey water samples with Unity Hall. There were no recorded coliform values for Unity Hall's treated grey water in week three. Also according to Huisman and Wood (1974), it is essential to maintain a constant flow of water through a sand filter system which provides oxygen and food to the organisms that make up the 'schmutzdecke' layer and biological zone living within the top part of the sand and are responsible for much of the removal of disease-causing organisms. However, under stagnant conditions where the filter system is not constantly fed with water to be treated, the biological zones can start to die off. This absence biological zone may inhibit the filter system from effectively removing microorganisms from the treated effluent.

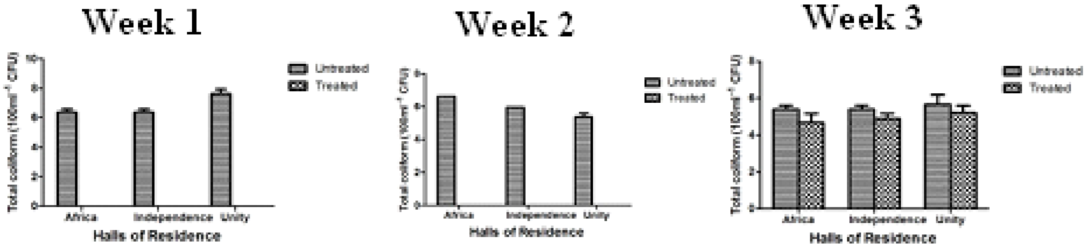

Fig. 9. Total coliform count for untreated and treated grey water from Africa, Independence and Unity Halls.

The difference in p-value (p<0.05) showed no statistical difference of the coliform count between the untreated grey water and the treated grey water. The permissible coliform level for irrigation water as given by WHO (2006) is 1*103 CFU/100mL.

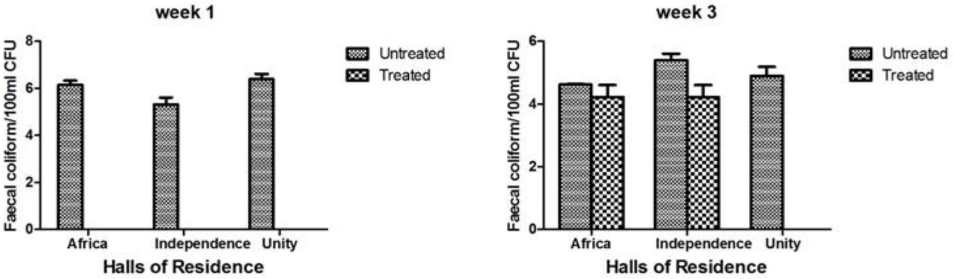

Fig. 10. Faecal coliform count for untreated and treated grey water from Africa, Independence and Unity Halls.

5. Conclusion

The study revealed a considerable decrease in phosphate levels in treated grey water over three-week study period and contains appreciable levels of TDS, salinity, conductivity, and nitrate at higher levels than that of untreated grey water. Most of the measured physico-chemical parameters in the treated water were below the threshold for hazard as determined by globally acceptable irrigation water standards, although there were some increases. Also treated grey water was generally void of both total and faecal coliform. Therefore treated grey water from KNUST campus does not appear to pose threat to crops as irrigation water suggesting that it can support irrigation.

Reference

Awuah E., Abrokwa K.A, Performance evaluation of the UASB sewage treatment plant at ames Town (Mudor), Accra. Reviewed paper, 33th WEDC International conference. Access to sanitation and safe water: global partnerships and local actions, (2008), pp. 20-26.

Bauder T.A., Colorado State University extension water quality specialist; Waskom R.M., director, Colorado Water Institute; Sutherland, P.L., USDA/NRCS area resource conservationist; and Davis, J.G., Extension soils specialist and professor, Soil and Crop Sciences (2011).

Bhumbla D.K., Agriculture Practices and Nitrate Pollution of Water, West Virginia University Extension Service (1999). Available at: http://www.caf.wvu.edu/wforage/-nitratepollution/nitrate.html, (Accessed October 2, 2012).

Brown R.R., Davies P., Understanding community receptivity to water re-use: Ku-ring-gai Council case study, Water Science and Technology 55 (2007) 283–290.

Dixon A., Butler D., Fewkes A., Robinson M., Measurement and modeling of quality changes in stored untreated grey water, Urban Water 1 (2000) 293-306.

Domenech L., Sauri D., Socio-technical transitions in water scarcity contexts: Public acceptance of grey water reuse technologies in the Metropolitan Area of Barcelona, Resources, Conservation and Recycling. (2010).

FAO, Water quality for agriculture. Irrigation and Drainage paper 29 Rev. 1. Food and Agriculture Organization of the United Nations, Rome, (1985), pp. 174.

Finley S., Barrington S., Lyew D., Reuse of domestic grey water for the irrigation of food crops, Water, Air, & Soil Pollution 199 (2009) 235-245.

Friedler E., Quality of individual domestic grey water streams and its implication for on-site treatment and reuse possibilities. Environmental Technology, 25 (2004) 997-1008.

Gross A., Kaplan D., Baker K., Removal of chemical and microbiological contaminants from domestic grey water using a recycled vertical flow bioreactor (RVFB), Ecological Engineering 31 (2007) 107–114.

Health considerations, Available at: http://www.emro .who.int/ceha/pdf/Greywter% 20English%202006.pdf. (Accessed: October 11, 2012).

James (Mudor) T., Accra. Reviewed paper, 33th WEDC International Conference. Access to sanitation and safe water: global partnerships and local actions (2008) 20-26.

Jefferson B., Palmer A., Jeffrey P., Stuetz R., Judd S., Grey water characterization and its impact on the selection and operation of technologies for urban reuse. Water Science & Technology 50 (2004) 157-164.

Keraita B., Drechsel P., Amoah P., Influence of Urban Wastewater on Stream Water Quality and Agriculture in and around Kumasi, Ghana, Environment and Urbanization, 15 (2003) 171-178.

Khalaphallah R., Grey water treatment for reuse by sand filtration: study of pathogenic microorganisms and phage survival (2012).

Laban P., Can local people accept grey water technology? In: Grey water Use in the Middle East, McIlwaine and Redwood (eds). IDRC. (2010).

Morel A., Diener S., Grey water management in low and middle-income countries, review of different treatment systems for households or neighbourhoods-Sandec Report No. 14/06. Sandec (Water and Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science and Technology), Dübendorf, Switzerland (2006).

Protection Agency and U.S. Agency for International development, Washington D.C. World Health Organization, Overview of grey water management: Health considerations, (2006). Available at: http://www.emro.who.int/ceha/pdf/Greywter%20English%202006.pdf. (Accessed: October 11, 2012)

Rowe D.R., Abdel-Magid I.M., Handbook of Wastewater Reclamation and Reuse. CRC Press, Inc (1995), p. 550.

Toze S., Reuse of effluent water – benefits and risks. CSIRO Land and Water, CSIRO Centre for Environment and Life Sciences (2006). (Accessed: November 8, 2012).

USEPA, Guidelines for water reuse, U.S. Environmental Protection Agency, Washington DC, (2004).

USEPA, Manual Guideline for water reuse (1995), EPA/625/R-92/004, U.S. Environment

USEPA, Water: Monitoring and Assessment (2012), Conductivity. Available at: www.water.epa.gov. (Accessed: April 19, 2013).

WHO, Guidelines for the safe use of wastewater, excreta and grey water (2006). Available at: http://www.who.int/water_sanitation health/-wastewater/gsuww/en/index, (Accessed: September 18, 2012)

WHO, Regional Office for the Eastern Mediterranean *Overview of grey water management: Health considerations* (2006). Available at: http://www.emro.who.int/ceha/pdf/Greywter%20English%202006.pdf. (Accessed: October 11, 2012).

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