

# Sustainable wastewater management

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## Summary

The findings in this study examine sustainable wastewater management in Ghana by exploring the option of greywater reuse at the household level. Urbanization in developing countries has brought about an increase in demand for potable water. Associated with this increase in demand is the generation of greywater resulting from the myriad of water use activities. The greywater discharged are mostly left untreated and mostly end up in rivers and other aquatic ecosystems that are sources of livelihood for humans and livestock which can lead to health risks. The main aim of this study is to explore the possibilities of reusing greywater to achieve sustainability as stated in the sustainable development goal 6 which is to ensure sustainable management of water and sanitation for all.

### Chapter 2

Chapter two reviews relevant literature on greywater characteristics, treatment systems, reuse strategies and user perception. The chapter places special emphasis on greywater systems in developing countries. It emerged from this review that there is a wide variation in greywater characteristics and generation rates and this is influenced by lifestyle, fixtures used and climatic conditions. There are many technologies for treating greywater, however, available technologies have mostly been designed for a targeted pollutant. The study further established that most of the treatment systems were applicable on a large scale and this discourages household greywater treatment and reuse intentions. Considering the variations in characteristics and quality, it is, therefore, necessary to establish the quality of greywater before implementing any treatment or possible reuse scheme. The study further identified the impact of public perception as a key element in implementing greywater reuse. The study concludes that greywater treatment and reuse if embraced can lead to substantial decline in over-reliance on freshwater resources for potable and non-potable purposes.

### Chapter 3

An assessment of greywater quality is necessary to decide on which contaminant to remove. This chapter presents the quality assessment and generation rates of greywater within the study area. This assessment involved grouping of households into households that had water on their premises and households that had to move out of their premises to access water. There were significant differences between the two groups of households with water consumption of houses with access at home being 82.51l/c/d and 36.65l/c/d for those who relied on external sources and return factors of 74.16% and 88.75% respectively. The study showed the majority of the pollutants in the greywater within the study area exceeded the Ghana EPA discharge guidelines and therefore not suitable for discharge without prior treatment. The discharged greywater was also identified not to be suitable for direct irrigation based on the salinity and sodium hazard analysis. Principal component analysis conducted on the data indicated that the characteristics of the greywater were influenced by cooking and cleaning practices, personal hygiene, biodegradability, frequency of water use before disposal and sanitary practices in the bathroom. The study concluded that the practice of discharging greywater into the environment is detrimental to the environment and a health risk to both humans and livestock. It is, therefore, necessary to start exploring household greywater treatment in such areas before final disposal or possible reuse.

### Chapter 4

This chapter explores the application of two different locally available agricultural waste materials as sorbent material in reducing the BOD<sub>5</sub> and COD of the greywater. These two parameters were chosen

because they have been the parameters that are used to assess the level of pollution of wastewater before it is finally discharged. The two agricultural waste materials (tropical almond shell and palm kernel shells) which are common in the study area were used for the preparation of activated carbon. A batch adsorption study was conducted on greywater sample from the study area and reduction of as high as 76% BOD<sub>5</sub> and 65% COD were obtained. From the study, it emerged that the palm kernel shell had larger internal surface and was able to perform better as compared to tropical almond shells. The equilibrium concentration for BOD<sub>5</sub> ( $q_e = 22.88\text{mg/g}$ ) and COD ( $q_e = 34.00\text{mg/g}$ ) was achieved by palm shell activated carbon. The adsorption data were fitted to the adsorption isotherms and the best model that fitted this process was the Freundlich isotherm. The Freundlich isotherm model described BOD<sub>5</sub> ( $R^2 = 0.98$ ) removal and COD ( $R^2=0.65$ ) removal with palm kernel shell as the adsorbent. The reduction of BOD ( $R^2=0.99$ ) and COD ( $R^2=0.97$ ) followed pseudo-second order kinetics. The study identified palm kernel activated carbon to be a better material for removal of BOD<sub>5</sub> and COD.

#### Chapter 5

The performance of a fixed-bed column packed with palm kernel activated carbon for the reduction of BOD<sub>5</sub> and COD in greywater was evaluated using column breakthrough data at different flow rates and bed depths. The Yoon-Nelson, Thomas, Adams Bohart and Bed Depth Service Time (BDST) models were used to evaluate the design parameters of the column. A maximum uptake capacity of 35mg/g and 54mg/g was achieved for BOD<sub>5</sub> and COD respectively. The Yoon-Nelson model provided a superior description of the kinetic data as compared to the Thomas model. The study concluded that the activated carbon prepared from palm kernel shell which is an agricultural waste material can be used to reduce the BOD<sub>5</sub> and COD concentrations in greywater. the design of a fixed-bed column for BOD<sub>5</sub> and COD removal from greywater can be based on these models.

#### Chapter 6

This chapter explored the determinants that influenced people's intentions to reuse greywater for either potable or non-potable purposes. This study adopted a socio-cognitive model known as the theory of planned behaviour (TPB) in identifying the construct that influences one's choice of reuse application thus potable or non-potable applications. The study was conducted taking into consideration the role of cultural practices, educational background, source of water and religious beliefs. It emerged that participants generally had a positive intention towards greywater reuse; however, potable reuse had a very strong negative intention indicating the unwillingness to reuse greywater for potable purposes. The study identified attitude and behavioural control as the two main constructs that affect intentions to reuse greywater for both reuse applications. It further emerged from the study that to promote greywater reuse, one intervention method that targets the two reuse applications is not likely to lead to effective outcomes. Interventions are to be targeted at the specific reuse application with its associated factors. From the study, it emerged that non-potable reuse approaches might be easier to implement as compared to potable reuses largely due to the perceived health risk associated with potable reuses. To promote potable reuses, the best mode of approach will be to address it from the perceived health risk and further enhance trust in the ability of the individual. The study concludes with a recommendation for assessing the willingness of households to adopt greywater treatment and reuse systems to promote household treatment.

## Chapter 7

This chapter explored the willingness of households to adopt a greywater and reuse system. The study adopted the theory of planned behaviour (TPB) in its original form and an extended model including personal norms. The personal norm was selected because it has been argued to improve the predictive ability in determining willingness for pro-environmental behaviours. Data was collected from 478 household heads within the study area. The results from analyzing the data using structural equation modelling indicated that the extended model with personal norms gave an improved fit and explained a higher percentage of the variance in the data as compared with the original TPB model. Although, all the four factors thus attitude, personal norms, subjective norms and perceived behavioural control seemed to all contribute to the intentions, however, attitudes and personal norms seem to be the dominant determinants. This indicates that to promote household participation in greywater treatment and reuse, it is imperative to tailor intervention methods around personal norms and attitudes. The results of this study can be applied by stakeholders who intend to promote greywater reuse in developing countries.

## Chapter 8

This chapter summarizes the main findings from the different studies, the different methodologies adopted in data collection and analysis and the recommendations. From the main findings of this study, it can be concluded that greywater is discharged into the environment without treatment. Some of the pollutants analyzed in the greywater were above the regulatory limit of discharge without treatment and this is detrimental to both human and livestock. It also identified a locally available waste material which has a high potential of being used to reduce the BOD<sub>5</sub> and COD levels in greywater. It further emerged from the study that, attitude and perceived behavioural control were the two main factors that influenced one's choice of either reusing greywater for potable or non-potable purposes. The willingness of households to adopt a treatment system at home was assessed. It emerged that attitude and personal norms were the two main factors that could be used in promoting household participation of greywater and reuse schemes. The study recommends the design a fully functional domestic greywater treatment and reuse system using the media studied in this research as the adsorptive media on a pilot scale. It further recommends a study that will explore the regenerative method of the media once it loses its treatment capacity and the proper disposal methods. It further recommends an institutional approach to greywater treatment and reuse which will address issues such as policy, economics, treatment quality guidelines and installation and design codes for buildings that will be interested in adopting this concept.