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Full Length Research Paper

The use of natural system for the treatment of greywater: A case study of Kpeshie Lagoon, Accra, Ghana

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Handling of wastewater (greywater and blackwater) in urban areas is a big problem. The La Sub Metro in Ghana is no exception. Due to lack of wastewater treatment facilities, almost all the wastewater in the Sub Metro is discharged into the Kpeshie Lagoon without pre-treatment. The objective of this study was to characterise greywater and determine the potential of receiving environment (Kpeshie Lagoon and surrounding soil) to treat the greywater prior to discharge into the sea. The dominant plant species in the receiving area were also identified. Characterisation of greywater was carried out after four weeks of sampling. Laboratory analyses carried considered colour, turbidity, pH, salinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), conductivity, total suspended solids (TSS), nutrients, faecal coliform, and trace metals. The results indicated that the lagoon had a high potential of treating greywater if managed well. High removal efficiencies were evident in nitrates (80%), colour (78%), BOD (74%), and turbidity (61%). The dominant species were *Sesevium portulacastum*, *Avicennia germinans*, and *Paspalum polystachyum*.

Key words: Greywater, lagoon, pollutant.

INTRODUCTION

Greywater is the wastewater from the kitchen, bath and laundry. It comprises wastewater generated from all of the house's sanitation equipment except for the septic tank (Wekimedia Foundation, 2009). According to Metcalf and Eddy (2003), wastewater is characterised by the physical, chemical and biological constituents. The characteristics however depend on the source of the greywater. Conceptually, greywater should have much lower concentrations of various potential pollutants than blackwater (water from the toilet).

The environmental impact of greywater is not as grave as that from blackwater since it does not contain human excreta. However, it has to be handled with care to avoid waterlogging, smell, and the uncontrolled release of chemicals and anthropogenic elements including microorganisms into the environment (Ridderstolpe, 2004). The treatment of greywater before discharge into the environment is imperative to safeguard public health and the environment. When well managed and treated, greywater can be reused under certain circumstances (NSW Health, 2005) such as irrigation. During greywater treatment, pollutants should be grossly reduced or totally eliminated.

Natural systems that are receiving bodies for wastewater produced from households include wetlands, lakes, streams, lagoons, and rivers. Natural treatment systems are a viable alternative that can produce effluents of high quality at a fraction of the capital cost and without requiring skilled operation. Their main limitation for application in industry is the fact that they take up lots of space.

Natural wastewater treatment systems are simple and low cost methods that utilise the physical, chemical and biological processes that occur in the natural environment between water, soil, plants, microorganisms and the

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atmosphere (Kadlec and Knight, 1996). Other techniques that can be used in treating greywater which are also energy-demanding are the application of trickling filters and biorotors.

Coastal lagoons are a component of interface water systems in coastal areas between oceans and rivers which serves as pollution sinks for upstream and local activities including industrial discharges, urban storm water collection, domestic discharges and agricultural drainage. As a result of these, lagoons bear the imprints of human activity demonstrated by increased sedimentation, toxic chemical contamination and eutrophication. This has serious influence on the ecological health of the lagoon (Annang, 2000).

In urban areas the handling of wastewater (greywater) is a big problem. Due to lack of waste water treatment facilities in the La Sub Metro, almost all the wastewaters are discharged into the Kpeshie Lagoon without receiving any kind of treatment. Greywater volumes are large and their content of environmentally hazardous or infectious substances is high as farmers upstream of the Lagoon use them to irrigate their farms. Inhabitants of the area also fish in the Lagoon, thereby increasing the risk of environmental problems and human contact with the unhealthy water conditions (Ridderstolpe, 2004).

The research aimed at the potential of natural systems for the treatment of greywater. The specific objectives were: to characterise greywater and determine the water quality of the Kpeshie lagoon; to characterise the soil receiving greywater at the study site; and to determine dominant plant species in the study area.

MATERIALS AND METHODS

Study site

The La Sub Metro is located in the Greater Accra Region of Ghana and has a population of 81,684 with about 5,543 homes with an annual population growth of 3.1% (Kpanja, 2006). The Sub Metro share boundaries with the following Sub Metros: Osu Clottey to the east, Ayawaso to the north and Teshie to the west.

The water bodies in this Sub Metro are the Africa Lake and the Kpeshie Lagoon. The Kpeshie Lagoon is less than 1 km^2 in surface area and is located at the outskirt of La Township. There are a number of hotels in this sub metro. The La pleasure beach transports its greywater and blackwater to an activated sludge system which is located around the junction of the lagoon. Kpeshie Lagoon is the receiving water body to the various drains in the Kpeshie catchment. Greywater that enters the lagoon has it sources from Burma Camp Community, La Community, Tebibiano Community, Teshie Camp 2 Community, Africa Lake, and from the mangrove swamp surrounding the lagoon (Figure 1).

The Africa Lake, which receives storm water from its environs, opens into the lagoon. The black water from Burma camp is channalled through sewers into a waste stabilization pond. La, Tebibiano and Teshie Camp 2 township mostly use pit latrines (30%), ventilated improved pits (46%), bucket latrines (2%), septic tanks systems (20%) and (2%) open defeacation. The lagoon opens into the sea, though it is sometimes closed with sand barriers by the traditional rulers in the Sub Metro. Almost all the greywater in the catchment finally end up in the Kpeshie lagoon (Kpanja, 2006).

Sampling points

Sampling points were selected to capture the major activities carried out along the stretch of the lagoon which would affect the water quality. The locations for sampling included S1, S2, S3, S4, S5, S6, S7, S8, S9 and S10. These are defined in Table 1.

Sampling and analysis

Sampling was done from October to November 2007. In all, four consecutive sampling were made on weekly basis. Samples of water were collected with plastic bucket at stations S8 and S9 due to site conditions. At all other stations, water samples were collected by dipping sampling bottles directly into the water body against the direction of flow. Water quality parameters analysed were biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, colour, pH, temperature, total suspended solids (TSS), conductivity, and nutrients. Winkler modification method was used to analyse BOD; closed tube method for COD; APHA (2003) standard methods for tubidity; tetra Con 325,330i for conductivity; gravimetric method for TSS; cadmium reduction method for nitrate; diazotization method for nitrite; nesslerisation method for ammonia; and orthophosphate Phos Ver 3 method for phosphorus. For trace metals, about 75 ml of samples were digested with 5 ml concentrated nitric acid and the concentration of the metal measured directly with atomic absorption spectrophotometer (Perkin Elmer 30303 AAS) at the water research institute laboratory in Ghana.

Samples for bacteriological (faecal coliform) analysis were collected in sterilised plain glass bottles and stored under ice. These were transported to the laboratory for analysis. The membrane filtration technique on *Escherichia coli* media was used. Incubating was at 45°C for 18 to 24 h and the yellow colonies were counted.

Soils samples as well as predominant plant species in the study were collected and identified. Soil samples were taken from S3, S4, S6 and S7 at the top, middle, and upper layers. The layers were then mixed together and analysed. Samples were taken between 0 to 45 cm deep at each of these locations. Also, flow rate measurement was carried out over a 24 h period for only station S5 for three consecutive times. Due to site limitations, the flow rate for the other stations which flow into the lagoon and the lagoon itself were not taken.

RESULTS AND DISCUSSION

Flow rate measurement

Continuous fluctuations were observed in the daily flow rate measurement (Figure 2). The average daily influent flow from S5, La Community, was 647.65 m^3/s. The fluctuations were due to the daily activities around the S5 channel. The graph shows a decrease in flow rates due to low consumption of water by inhabitants at night time. On the contrary it peaked between 7 to 10 am and 3 to 9 pm. It peaked at these periods because water-related activities take place at these times. In the evening the flow was low because of the obvious decline in water-related activities. During the time of sampling no rainfall was observed. The area of the La drain was 1.94 m^2 hence the hydraulic loading rate to the lagoon was 333.84 m/s. Due to site limitations, the flow rates for the

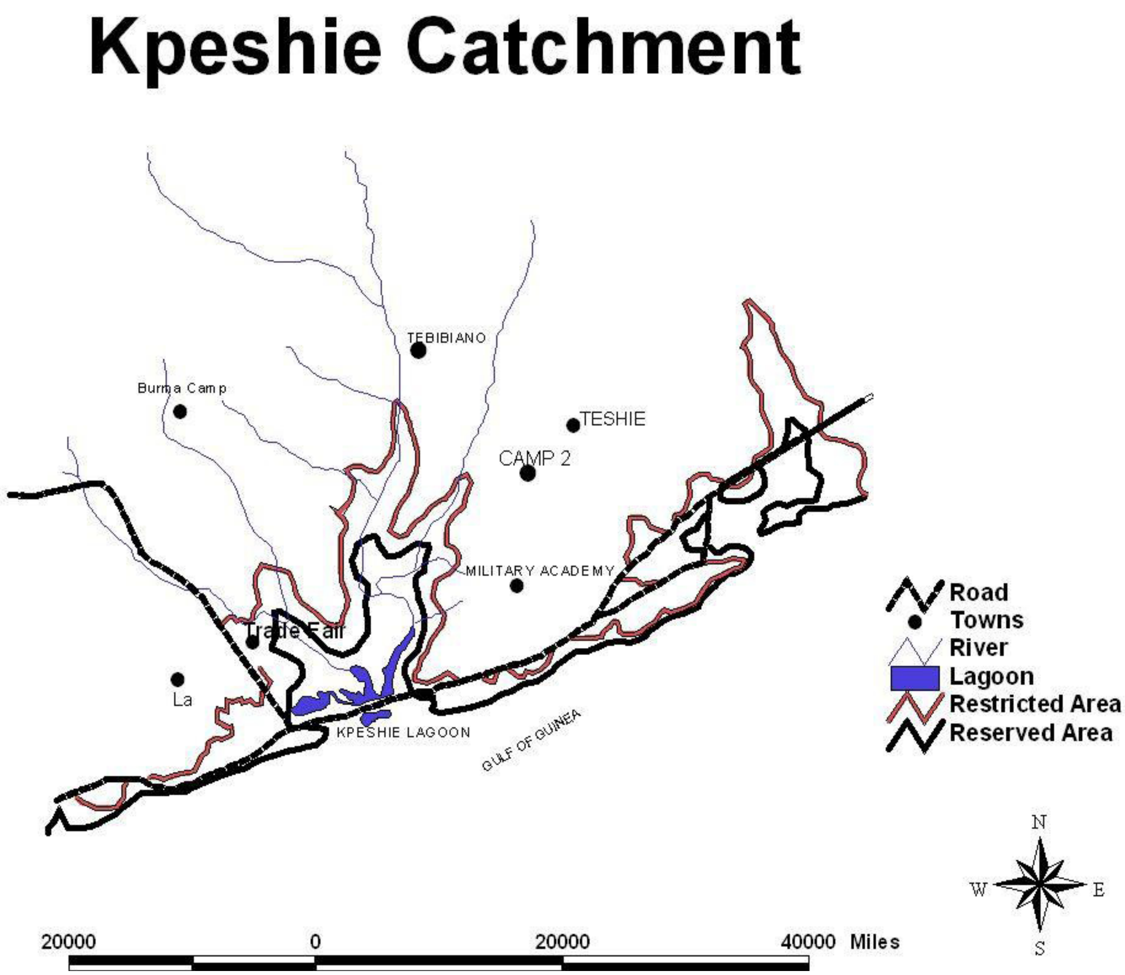

Figure 1. Map of Kpeshie catchment area.

Table 1. List of sampling points and their locations.

Station	Location
S1	Tebibiano channel, north side of the lagoon
S2	Teshie camp 2, east side of lagoon
S3	Burma camp channel, west north side of the lagoon
S4	Mangrove swamp, upstream of the lagoon
S5	La drain, west side of the lagoon
S6	Africa Lake, west side of lagoon
S7	After Africa Lake
S8	Junction, where all the sources get into the lagoon
S9	Main body of lagoon
S10	Effluent of lagoon into the sea

other sampling points and the effluent were not taken.

Characteristics of greywater

Greywater production and its degree of pollution are mainly determined by the habits of the consumers and it is a result of personal hygiene and detergents used. Characteristics of the greywater at both the influent (S1, S2, S3, S4, S5, S6, and S7) and effluent (S10) were somewhat within the Environmental Protection Agency (EPA) Ghana (2000) guidelines (Table 2). There was no

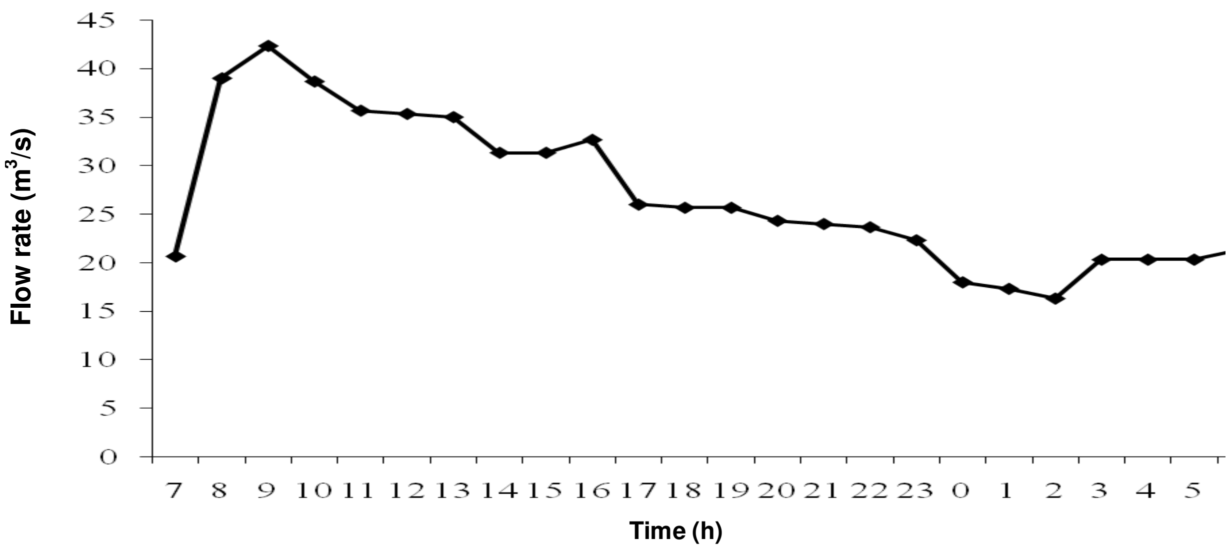

Figure 2. Flow rate measurement.

Table 2. Characteristics of greywater from the study site.

Parameter	Average influent	Effluent	Treatment (%)	EPA Ghana (2000)
Temperature (℃)	29.11±0.34	30±0	3.06	<3 above ambient
pH	7.84±0.09	7.55±0.2	3.70	6-9
Conductivity (µS/cm)	17102.79±3426.46	25315±8351.32	48.02	1500
Turbidity (NTU)	72.14±20.47	28.3±6.58	60.77	75
Salinity (mg/l)	13.06±2.93	15.58±4.8	19.30	
Colour (TCU)	74.64±13.73	16.25±5.45	78.23	20
TSS (mg/l)	92.39±26.48	52±31.36	43.72	50
BOD (mg/l)	63.79±26.49	16.45±5.51	58.47	50
COD (mg/l)	236.99±66.35	136.23±31.44	42.52	250
NH_3-N (mg/l)	2.88±0.48	2.04±0.05	29.17	1
NO_3-N (mg/l)	2.04±0.49	2.12±1.2	3.92	75
NO_2-N (mg/l)	0.1±0.03	0.02±0.01	80	
PO_4-P (mg/l)	1.24±0.26	2.78±2.23	124.19	2
Cadmium mg/l	0.003±0.002	0.002±0	33.33	0.1
Lead (mg/l)	0.01±0.0005	0.005±0	50	0.1
Manganese (mg/l)	0.61±0.13	0.187±0.061	69.34	0.1
Copper (mg/l)	0.01±0	0.008±0.003	20	2.5
F. Coliforms (FC/100 ml)	$1.64x10^5±4.80x10^5$	$2.80x10^5±1.10x10^5$	70.73	400

basis for comparison for salinity and NO_2-N since EPA Ghana has not assigned any limit.

Comparative characteristics of the greywater at various points and effluent reveal that there was a form of treatment, though, not all effluent parameters were within the EPA Ghana (2000) recommended limit. These improvements were indications of the potential treatment of the lagoon by dilution and other microbiological activities. However, the temperature, conductivity, salinity, NO_3-N, PO_4-P, and faecal coliform of the influent were relatively better than the effluent. This could be due to accumulation of pollutants in the sediments.

Temperature and pH

Mean temperature ranged from 27 to 31.5℃. The highest temperature was recorded at S5 and the lowest recorded at S4. The lowest temperature may be attributed to the shade from the mangrove swamp, while the highest temperature may be due to the activities within the community and the washing bay along the sampling

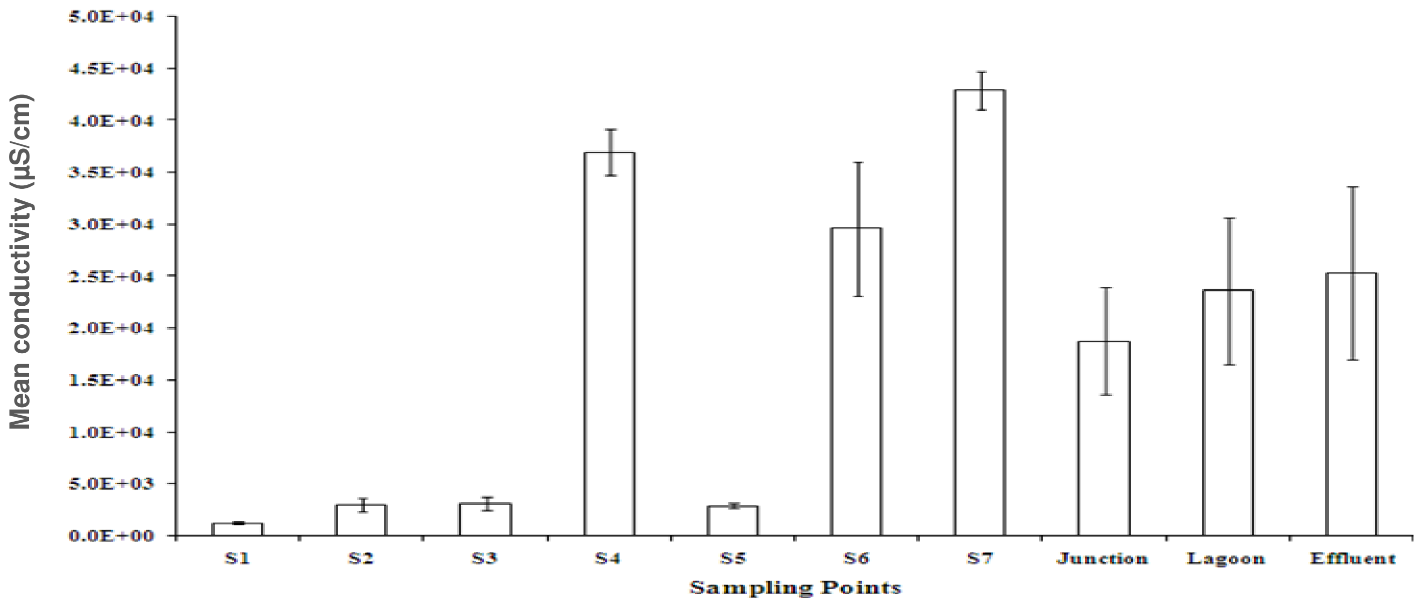

Figure 3. Conductivity of greywater from study site.

point. The temperature of the lagoon and the effluent were 29.25 and 30°C respectively. These values were above the EPA Ghana (2000) guidelines of 3°C above ambient of 25°C for discharge into water bodies.

All the waters that were analysed were alkaline. The waters had mean pH values that ranged between 7.3 and 8.4 which were all within the EPA guidelines. These values are relatively normal for costal waters.

Conductivity

Conductivity of water determines the ability of the water to conduct electrical current. The mean conductivity values ranged between 1233.75 and 42900 uS/cm (Figure 3). The lowest conductivity was recorded at S1 because the greywater may have less dissolved ions. S7 on the other hand, recorded the highest conductivity. This may be due to the presence of other dissolved compounds due to the presence of farms. Also, there was a refuse dump site close to S7. Mitsch and Gosselink (2000) established that anions such as chloride, nitrate, phosphate and sulphate and cations such as sodium, calcium, magnesium, and iron contribute to the over all conductivity. The conductivity of the effluent was 25315 uS/cm. The conductivity levels for the influents and effluent were unsatisfactory compared to EPA guideline value of 1500uS/cm, though there was some form of treatment. According to Kiely (1998) conductivity ranges for rivers, estuarine waters and seawaters are 100-1000, 200-2000 and 40000 uS/cm respectively; hence these values are relatively good for coastal waters. Seawater influence and other dissolved ions may be factors contributing to the low effluent quality.

Salinity

Salinity of water determines the suitability of water for irrigation (Metcalf and Eddy, 2003). The water has a mean salinity ranging between 0.6 and 32.9 mg/L (Figure 4), which was below the EPA Ghana guideline value of 250 mg/l.

The Lagoon recorded the highest level of salinity. This was as a result of refluxes of seawater which is stored in the lagoon, leading to accumulation and increase in salinity level. The sample points S4, S6 and S7 had relatively high salinity but the concentration reduces as it gets to the junction of the lagoon. This may be due to the uptake of the dissolved ions by plant species around these sampling points. The concentration of the effluent could be influenced by the sea water which is the main receiving water body.

Turbidity

High levels of turbidity in domestic and industrial effluents contribute large amounts of suspended solids into receiving water bodies. The mean turbidity was in the range of 22.75 and 282.92 NTU. The influents and effluent were within the EPA guidelines of 75 NTU (Figure 5). However, S5 exceed the EPA guidelines. This might be due to the lack of plant species around the channel to serve as a filter medium. The treated greywater is evident in the effluent quality. The quality of the effluent could be attributed to sedimentation taking

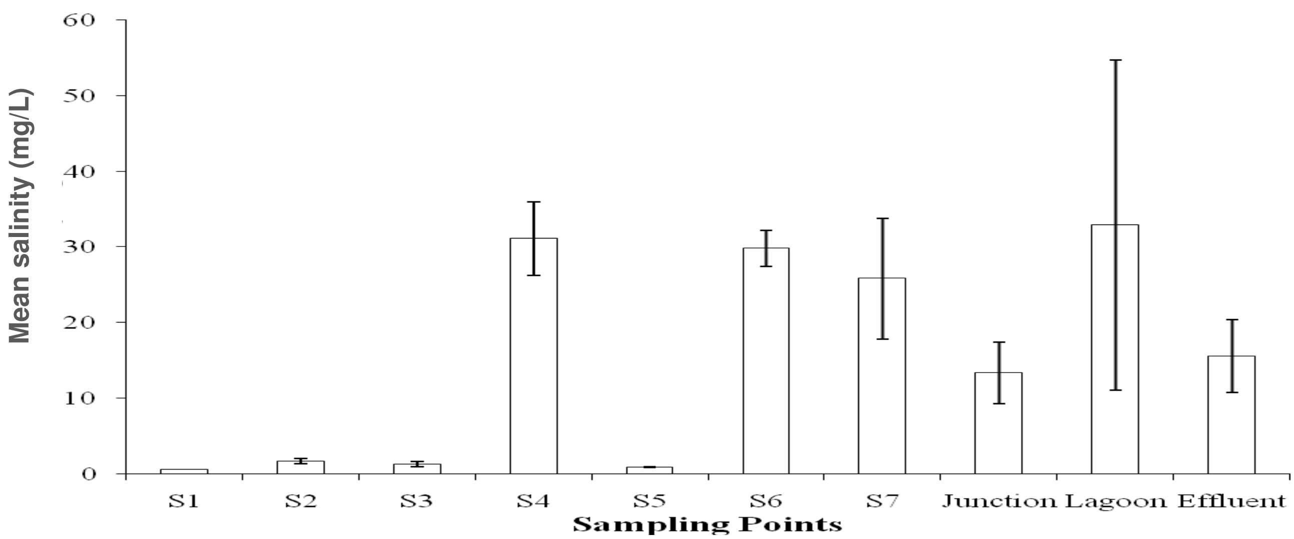

Figure 4. Salinity of greywater from study site.

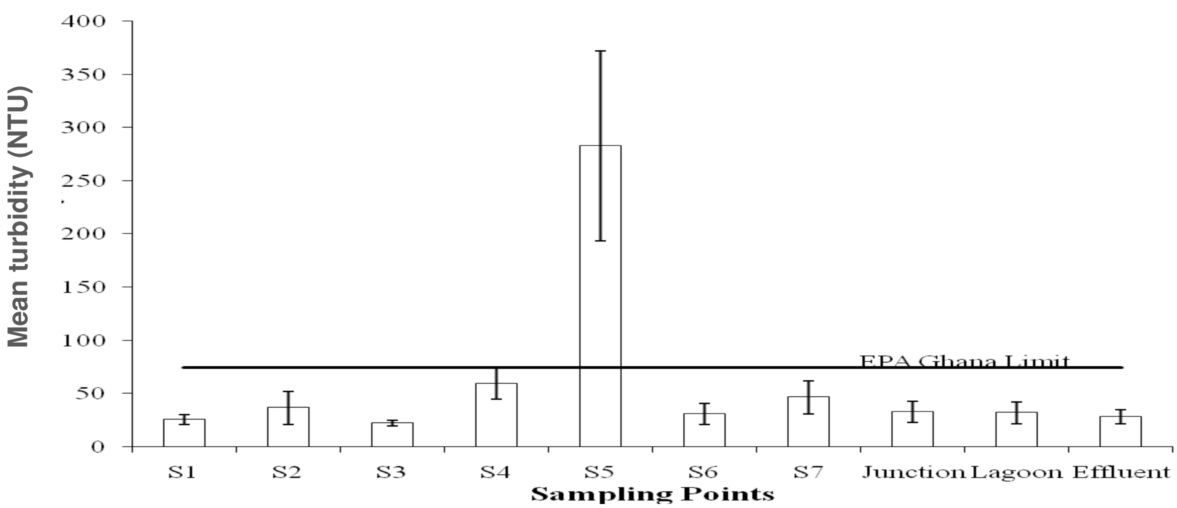

Figure 5. Turbidity of greywater from the lagoon.

place in the lagoon as a result of the lagoon's low velocity and the removal of sediments by plant species around the lagoon.

Colour

The lowest concentration of colour was recorded at the outfall and the highest at S5 (Figure 6). The mean colour concentration for the influent and effluent ranged from 26.25 to 225 TCU respectively. The effluent was within the EPA Ghana (2000) permissible limit. Nevertheless, all other sampling points exceeded the limit of EPA Ghana (2000).

The concentration at S4 might be due to the decay of fallen leaves that introduce some amount of colour to the greywater. High concentration at S5 could also be attributable to activities in the community such as dyes and soiled clothes introduced to household greywater; and oil and grease from fuel stations and washing bays along the S5 drain. On the other hand, the improved colour content of the effluent implies that there has been dilution of the greywater in the lagoon and also refluxes from sea water could influence the quality of the effluent.

Total suspended solids (TSS)

Mean TSS for influent and effluent was in the range of 11 and 370.75 mg/L. S5 was the highest polluted site with suspended solids (370.75 mg/L) (Figure 7). The drain at S5 suffered residue (degradable and non degradable)

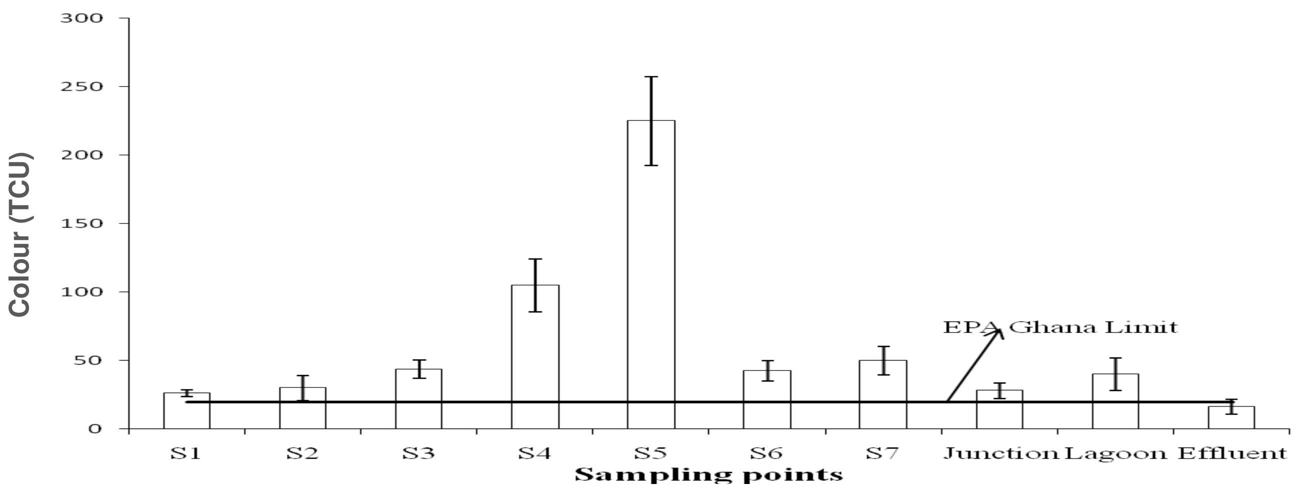

Figure 6. Colour of greywater from the lagoon.

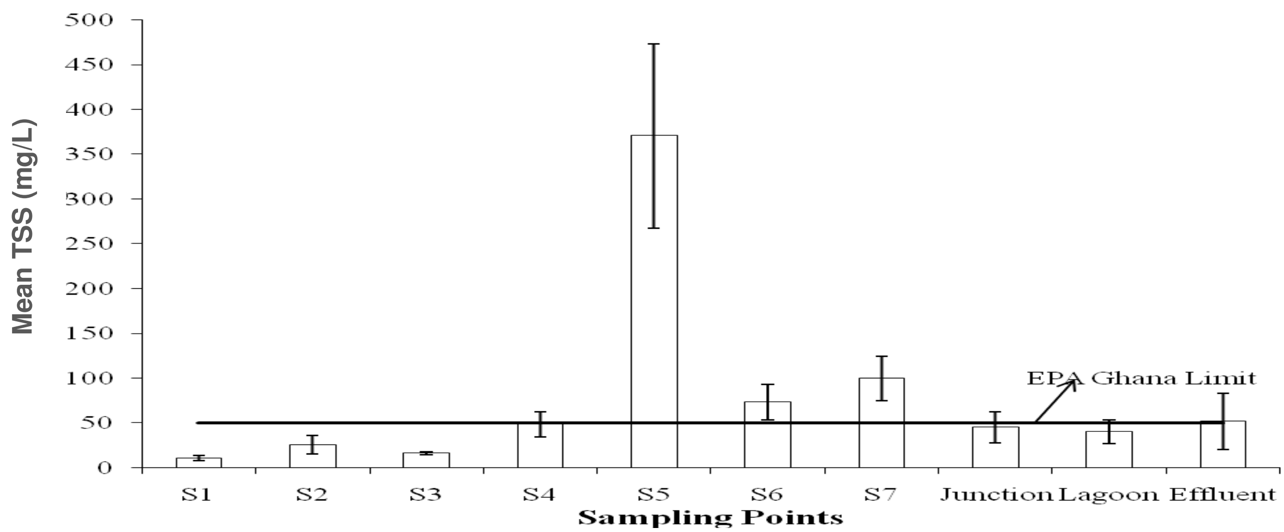

Figure 7. TSS of greywater from the lagoon.

from a refuse dump upstream. There was also the dumping of solid waste close to S7, hence the high mean value. S1, S2, S3, and S4 were all within the EPA permissible limit of 50 mg/L. It can be inferred from Figure 7 that there was improvement in the effluent quality. This may be due to quiescent conditions in the lagoon aiding sedimentation of suspended matter and also removal by the plant species surrounding the lagoon.

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD)

The mean BOD of the sampling points is illustrated in Figure 8. The only sampling point of exceeding concentration of BOD was S5. The high pollution of a major organic waste dumping site was due to high organic matter content, as human waste was seen in the greywater throughout the sampling period. All other sample points were of acceptable concentration according to EPA Ghana (2000) guidelines. The concentration of S5 reduced after traveling 60 m to S8, the junction of the lagoon. This signifies that the lagoon, being a pollutant sink is able to treat the wastewater by means of biodegradation of organic matter with the aid of microorganisms. It should be noted that the release of excess amounts of organic matter into surface waters could result in a significant depletion of oxygen and subsequent mortality of fishes and other oxygen dependent aquatic or marine organisms (De Busk, 1999).

Also, the mean COD was in the range of 50.05 and 938.6

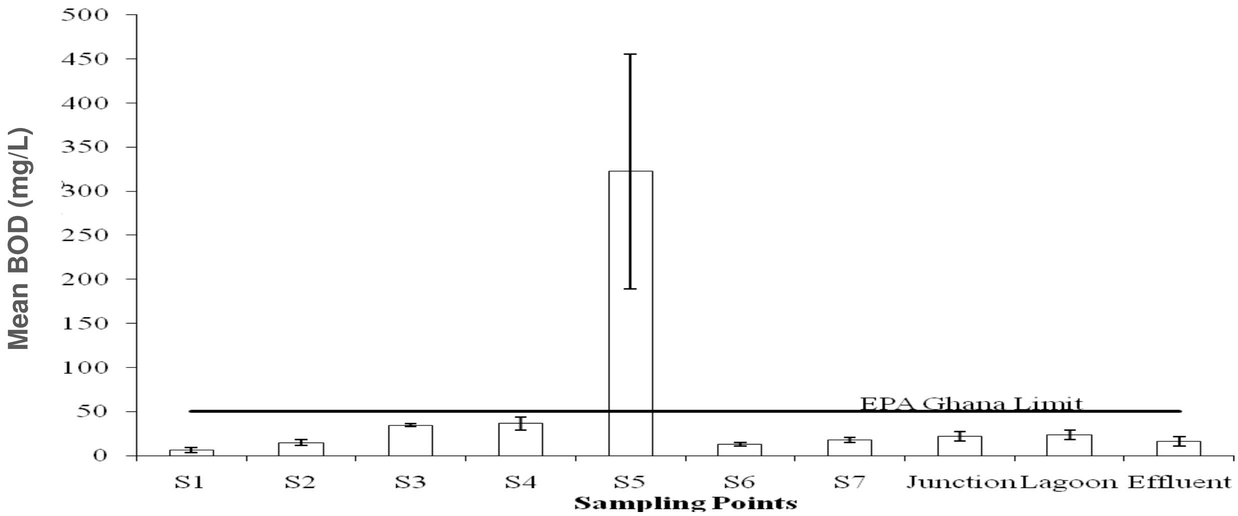

Figure 8. BOD of greywater from the lagoon.

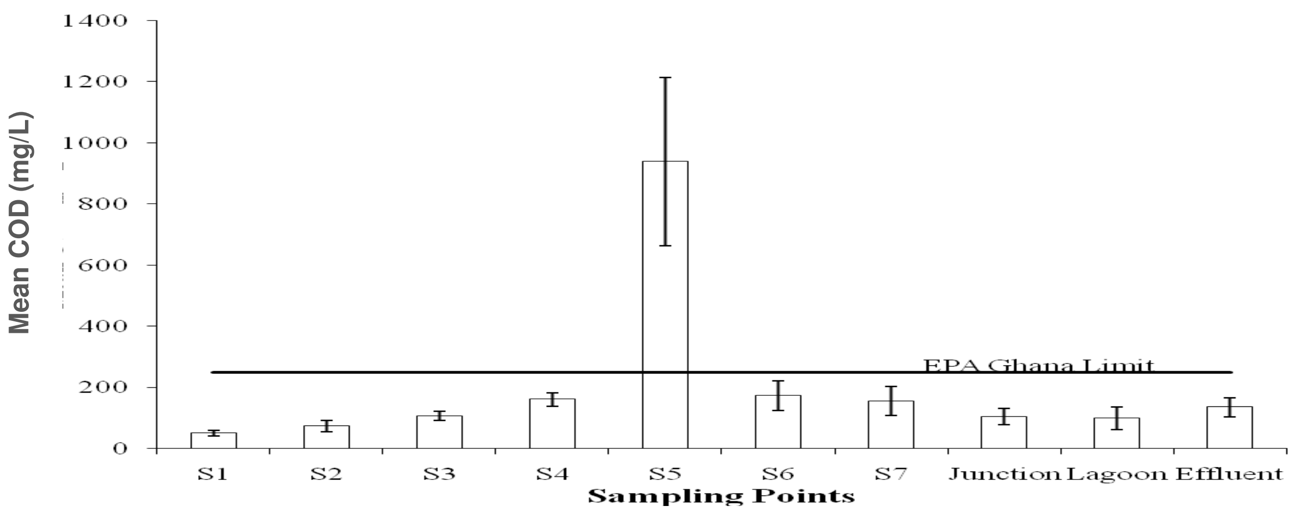

Figure 9. COD of greywater from the lagoon.

mg/L. The lowest and highest concentrations of COD were recorded at S1 and S5 respectively (Figure 9). S5 exceeded the EPA Ghana (2000) limit of 250 mg/l. The highest mean COD at S5 could be due to pollution of greywater from washing bays along S5. Russell (2006) reported that washing of automobile cars introduce many compounds into an already polluted greywater from a community. However, other sampling points were within the recommended limit by the EPA Ghana (2000). The lagoon is able to treat the wastewater but S5 needs pretreatment to improve upon effluent quality of the lagoon. The common interferences for COD, which causes it to be higher than BOD, include sulphides, sulphites, thiosulphates, and chlorides (Russell, 2006).

Asano et al. (2007) established that BOD/COD ratio of untreated wastewater ranges from 0.3 to 0.8. If ratio is 0.5 or greater it means wastewater can be easily treated by biological means. If ratio is below 0.3 then waste have some toxic components. In the case of this study, the BOD/COD ratio was 0.12 signifying that the greywater contains some toxic substances hence cannot be easily treated by biological mean. Pre-treatment of the incoming greywater may be needed.

Ammonia- nitrogen (NH_3-N)

The mean ammonia-nitrogen ranged between 0.98 and 4.21 mg/L. All sampling points fell outside the EPA Ghana (2000) guideline limit of 1.0 mg/L except S1 (Figure 10). S3 recorded the highest ammonia concentration and this is as a result of farming activities

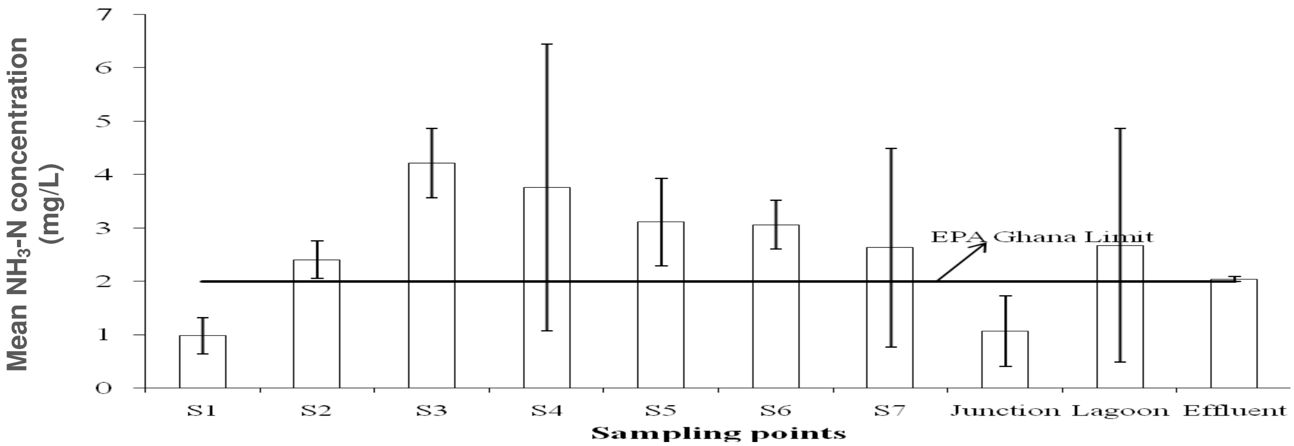

Figure 10. NH_3-N of greywater from the lagoon.

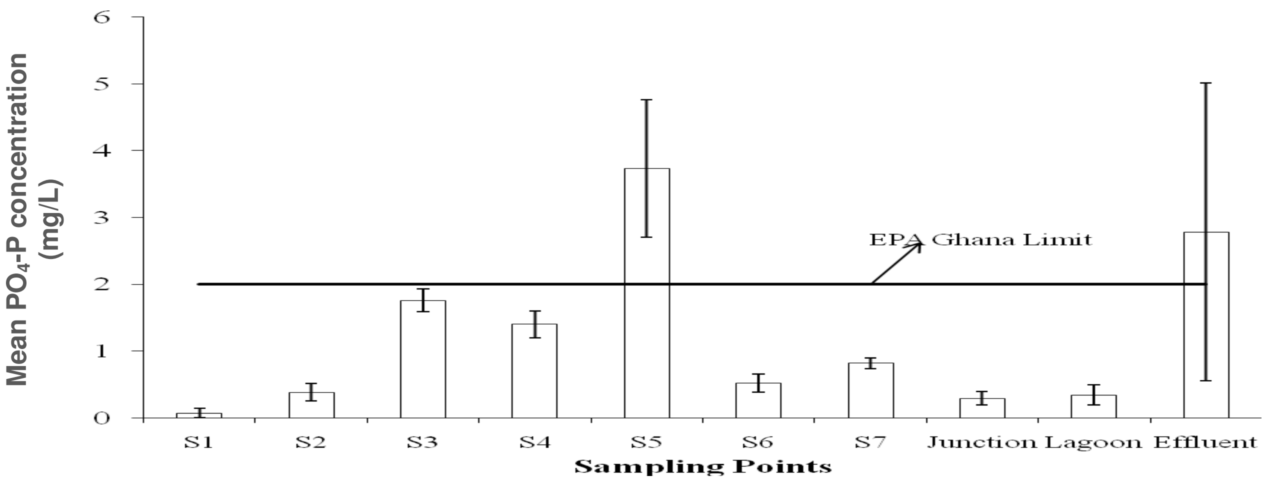

Figure 11. PO_4-P of greywater from the lagoon.

upstream. The farmers use fertilisers on their farm and the residue runs off into the S3 channel whenever they irrigated their crops with the greywater. Open defecation around S4, S5 and S6 contributed to its relatively high concentration.

High ammonia concentration in wastewater is converted to nitrites and nitrates and quickly absorbed by plants (Awuah, 2006). Volatilisation process takes place in the course of travelling to the lagoon and this is seen in the concentration at the junction. Though the effluent quality of ammonia nitrogen is above the EPA Ghana (2000) permissible level, the concentration is an improvement on the influent.

Nitrate-nitrogen (NO_3-N)

Mean influent and effluent NO_3-N was 0.83 and 3.84 mg/L respectively. The nitrate concentrations of all the sampling points were relatively low and within the EPA Ghana (2000) guideline value of 75 mg/l hence acceptable. This may be due to denitrification by bacteria, where nitrate is converted into gaseous nitrous oxide and molecular nitrogen into the atmosphere under anaerobic conditions.

Phosphate-phosphorus (PO_4-P)

The mean phosphate was between 0.07 and 3.73 mg/L (Figure 11). The high concentration of phosphate at S5 could be attributed to the continuous use of detergents for washing of cars at the washing bays just along the S5 channel and from domestic greywater. Crop vegetation at the upstream of S3 also could contribute to the high levels of phosphate, as a result of the use of fertilisers on the farm. In aquatic environment, phosphorus is normally removed by plant uptake, adsorption by clay particles and

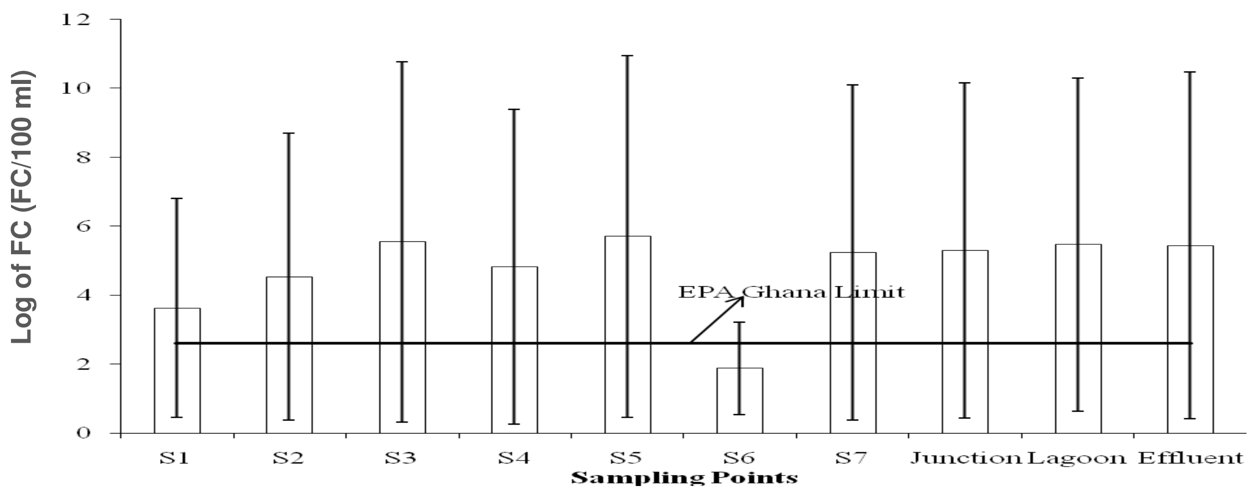

Figure 12. Faecal coliforms of greywater from the lagoon.

organic matter; chemical precipitation by Ca^{2+}, Fe^{3+}, Al^{3+}; and microbial uptake (Awuah, 2006; Iqbal, 1999).

There was a significant variation between the lagoon and the effluent in terms of concentration. The high concentration of phosphate may be due to re-suspension of phosphorus due to high pH and DO (Mara and Pearson, 1986; Reed et al., 1988; Awuah, 2006). High phosphate concentrations at the effluent could be attributed to a by-pass greywater discharge from the La Pleasure Beach Hotel.

Faecal coliforms

The mean faecal coliforms count for the study area was between 7.65×10^1 and 5.12×10^5 FC/100 mL. Figure 12 shows the faecal coliforms concentration at the study area. S5 and S6 recorded the highest and lowest faecal coliform count respectively. The exceptional faecal coliform recorded at S5 and S3 indicates the disposal of wastewater (blackwater) by inhabitants into S5 and S3. Human waste was seen in the greywater samples taken at these sampling points. Coliform bacteria in environmental samples, is an indication that pathogenic organisms associated with faecal contamination may be present (Asano et al., 2007). Field results showed open defecation in the study area and these were washed by the incoming greywater into the lagoon. The relatively low faecal coliform count in samples from S1 and S6 might be due to the pH of 7.9 and 8.4 respectively and the effect of direct sunlight.

According to Millipore (1991), permissible limits for various water uses are as follows: 200 FC/100 ml for primary contact (swimming) and 5000 FC/100 ml for secondary contact (fishing, boating). The lagoon is a source of income for the inhabitants of La community and is actually for fishing, of which body contact with the water should be secondary but it is classified as primary body contact. This is because no boat is used for fishing and the average faecal coliform count was far above the permissible limit of 5000 FC/100 ml according to WHO guidelines (2006). The high unacceptable faecal coliforms count at the effluent may be due to open defecation around the outfall.

Cadmium and lead

The average cadmium level for the greywater was within the EPA Ghana guideline limit of 0.1 mg/L. The mean cadmium levels were between 0.002 and 0.005 mg/L at all sampling points. This shows that the wastewater that enters the lagoon is not polluted with high cadmium concentrations. The effluent quality was acceptable according to the EPA limits.

The concentration of lead in the greywater was satisfactory since it was within the recommended levels required by the EPA Ghana (2000) guideline. The mean values ranged between 0.005 and 0.008 mg/L.

Copper

Mean copper concentration was between 0.006 and 0.015 mg/L. Adsorption and chemical precipitation, are mechanisms of heavy metal removal according to Crites et al. (2005), hence the low concentration of copper might be due to these mechanisms of treatment. The levels of copper were acceptable and within the EPA Ghana limit.

Manganese

Comparable to the EPA Ghana guidelines, the concentration of manganese was unsatisfactory. The mean manganese values for this study ranged from 0.1

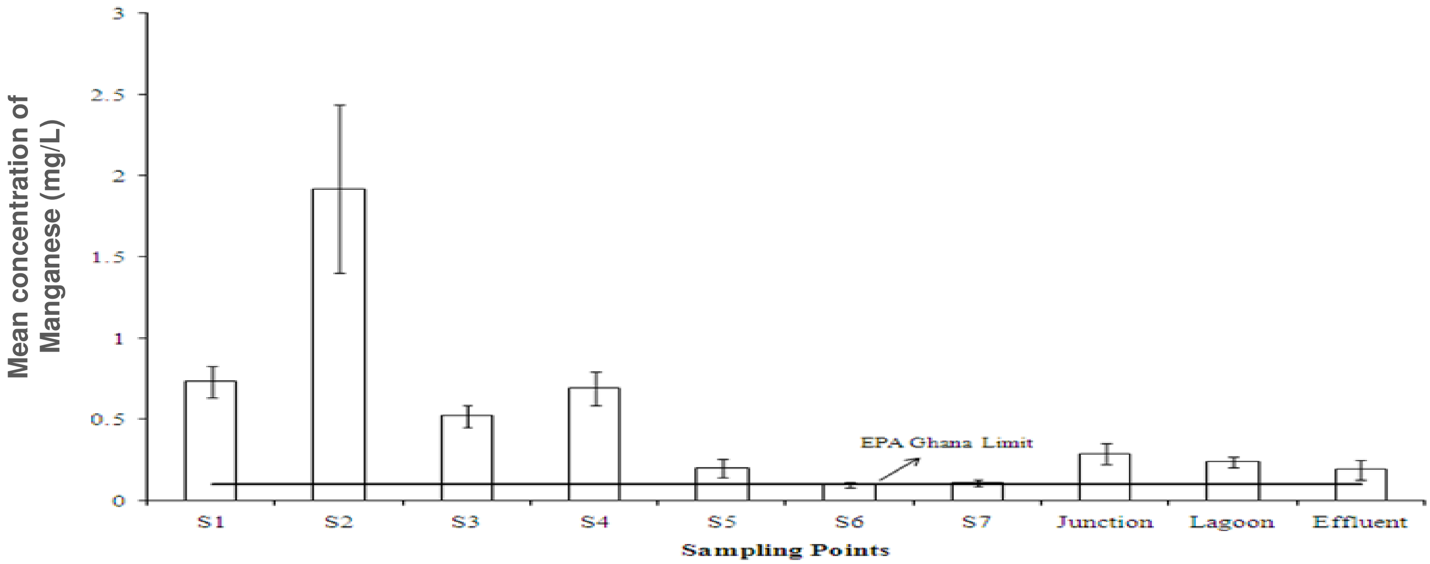

Figure 13. Manganese of greywater from the lagoon.

to 1.9 mg/L (Figure 13). According to Metacalf and Eddy (2003), manganese is toxic to a number of crops at a few tenths mg/L, but only in acid soils. Considering the soil analysis, S3 has acidic soil of pH 6.37 and there was farming activities at the upstream where farmers use the wastewater on their crops. This may be toxic to some of the crops on the farm, though this was not investigated.

The high levels of manganese, especially at S2 may be due to the anaerobic conditions resulting in the decrease in the redox potential in transforming manganese from manganic to manganous compounds which are soluble (Mitsch and Gosselink, 2000) as shown in the equation:

$$MnO_2 + 2e^- + 4H^+ \rightarrow Mn^{2+} + 2H_2O$$

Species identification

One of the most important requirements for pollutants removal in a natural wetland, which is also a natural treatment system, is the type of emergent plant species present. The role plants play in treatment process is to provide attachment for organism's growth to assist in the decomposition of organic matter (Crites et al., 2005). The under listed plant species were dominant in the study area and apparently contributed to the pollutants removal.

1) *Sesevium portulacastum* (Sea Purslane)
2) *Avicennia germinans* (Black Mangrove)
3) *Paspalum polystachyum* (Koda Grass)

The plant species closest to the lagoon was *Avicennia germinans.* Kadlec and Knight (1996) and Mitsch and Gosselink (2000) established that a wetland without plant species will have limited potential for particulate and dissolved pollutants reduction. There is a large number of plant species that may be suitable for treatment in wetlands but evaluation studies on them are few to date (Mitsch and Gosselink, 2000).

Soil characteristics

Physical analysis

The soil texture of a wetland is based on the percentage of sand, silt and clay content (www.ag.ndsu.edu). The type of soil at the mangrove swamp was clay loam, with the following percentages: sand 23%, silt 39%, and clay 38%. Since the area closest to the lagoon was the mangrove swamp, its soil characteristics was used for this discussion. Crites et al. (2005) established that adsorption and chemical precipitation are mechanisms of heavy metal removal. The physical characteristics of the soil played a major role in the removal of trace metals through adsorption and chemical precipitation; hence the low concentrations of trace metals in the greywater except manganese. Generally, 15% of clay is suitable and recommended for wetland treatment systems (Kadlec and Knight, 1996).

Chemical analysis

A number of metals are required in small amounts for plant and animal growth. Some of these micro nutrients may be found in certain types of wastewater. The analysis conducted indicated that the soil is mainly organic. Removal of metals in wetlands may occur

Table 3. Soil characteristics.

Parameter	Concentration
Na (mg/kg)	0.02
K (mg/kg)	1104
P (mg/kg)	55.1
pH	7.6
O/M (%)	3.03
O/C (%)	1.76
N (%)	0.25
EC µS/cm	12.18
Cd (mg/kg)	<0.002
Mn (mg/kg)	0.04
Pb (mg/kg)	<0.005
Cu (mg/kg)	<0.005

through a number of processes; including plant uptake, soil adsorption, and precipitation. Wetland soils are potentially effective traps or sinks for metals due to the relative immobility of most metals in wetland soils (DeBusk, 1999).

According to Kadlec and Knight (1996), chemical reactivity relates to the surface electrical charge of the soil particle and soil charge is typically highest in clays and organic soil particle. The electrical conductivity was as high as 12.18 dS/m, which confirms the salinity of the soil, hence no agricultural activity in the mangrove.

The organic matter and organic carbon of the soil was 3.03 and 1.76% respectively (Table 3). According to DeBusk (1999), this is utilised by a wide array of micro organisms as a source of energy to break down organic carbon to carbon dioxide. The high level may be due to the decay of fallen leaves from mangrove swamp and open defaecation in and around the mangrove.

The pH value was 7.6 which is moderately alkaline and the range of 5.6-8 is suitable for most plants (Crites et al. 2005). Available potassium and phosphorus were 1104 and 55.1 mg/kg respectively, indicating high concentrations. The high levels may be attributed to farming activities upstream, where excess fertiliser was run off contaminating the soil. Percentage nitrogen (% nitrogen) and available sodium were 0.25 and 0.017 respectively. These were found to be adequate. Cd, Cu and Pb were between <0.002 and <0.005 mg/kg. The low concentrations may be due to the uptake by plants species present. The concentration of manganese was 0.04 mg/kg.

CONCLUSION AND RECOMMENDATION

The lagoon has a high potential of removing pollutants and could be used for better treatment of greywater if it is well managed by the La Sub Metro authorities. The removal efficiencies of nitrite, colour, BOD, Mn and turbidity were between 61 and 80%. TSS, COD, NH_3, Cd, Pb, Cu had their removal efficiencies between 20 and 50%. Conductivity, salinity, PO_4, NO_3 and faecal coliforms were the only parameters that increased in their concentration.

The plant species around the lagoon played a major role in the treatment process by taking up some pollutants such as trace metals and nutrients from the incoming greywater. The soil type, which spanned from clay loam to sandy loam, also contributed to the treatment process by removing some pollutants such as the trace metals, phosphates, nitrites, and ammonia through soil adsorption and precipitation.

The communities are admonished to desist from defecating and dumping refuse into the lagoon. The Sub Metro should provide toilet facilities and refuse containers to curb such habits. Also, the community needs to be educated on the economic and environmental importance of the lagoon. The mangrove and other plants around the lagoon should not be removed. The lagoon should also be dredged occasionally to ensure efficient performance. Greywater should be pre treated by introducing a primary sedimentation tank, especially for greywater from sample point S5 (La community) before discharged into the Lagoon.

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