International Journal of Development and Sustainability
Online ISSN: 2168-8662 – www.isdsnet.com/ijds
Volume 2 Number 2 (2013): Pages 711-728
ISDS Article ID: IJDS13031904

Special Issue: Development and Sustainability in Africa – Part 2

Environmental impacts of wastewater from urban slums: case study - Old Fadama, Accra

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Abstract

The burgeoning of slums in the developing world poses an urgent environmental threat due to insanitary conditions and rampant disposal of wastewater. To assess the potential environmental impacts, domestic wastewater from Ghana's biggest urban slum - Old Fadama was characterised throughout the dry and wet seasons. The study drew on a comprehensive assessment of the general sanitary conditions in the community to determine the sources of pollution and water quality monitoring. BOD_5 levels of wastewater from the study area were 545.63±99.88mg/L and 645.94±331.43mg/L in the dry and wet seasons respectively whereas COD levels were 1100.45±167.16mg/L and 1415.12±722.83mg/L in the dry and wet seasons respectively. *E-coli* levels were 4±1x10^6CFU/100mL and 4200±2400 x10^6CFU/100mL in the dry and wet seasons respectively whereas total coliform levels also showed the same trend with 9±2$10^6$CFU/100mL and 16800±5100$10^6$CFU/100mL in the dry and wet seasons respectively. The study identifies that wastewater from this community has potential deleterious environmental implications due to high levels of nutrients, oxygen-demanding substances and faecal coliforms. Pollutants were identified to be emanating predominantly from open defecation and indiscriminate waste disposal. Efforts should thus be directed towards improving sanitary conditions viz. access to toilet facilities, waste disposal mechanisms and best management practices for wastewater.

Keywords: Environmental impacts, Urban, Slum, Wastewater

Cite this paper as: Monney, I., Odai, S.N., Buamah, R., Awuah, E. and Nyenje, P.M. (2013), "Environmental impacts of wastewater from urban slums: case study - Old Fadama, Accra", *International Journal of Development and Sustainability,* Vol. 2 No. 2, pp. 711-728.

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1. Introduction

Whilst the urbanization trend in high-income countries is steadily increasing, that of middle- and low-income countries, especially on the African continent, is rapidly experiencing an unparalleled exponential growth (UN-HABITAT, 2004). As per estimates by the UN-HABITAT (2004), for the period of 2000 – 2030 the average annual urban population growth rate in high-income countries is 0.6% compared to 2.2% in the middle- and low-income countries. The explosion in urban population in this part of the world results in the burgeoning of urban slums. Sub-Saharan Africa (SSA), despite being the least urbanised region in the World (39.1% urban population) has nearly 72% of urban dwellers living in slums – the highest in the World (Duncan, 2008).

In Ghana, the urban slum population increased from 26% out of the 8.3million urban dwellers in 2001 to 45% in 2008 out of the 11.5million urban dwellers (GSS, 2008; UN-HABITAT, 2009; UN-HABITAT, 2010). At the current growth rates, Watkins (2008) asserts that, about 65% of Ghana's population will be living in urban centres by the year 2030, apparently accompanied by an increase in slum population. Driven by high rural-urban drift and lack of affordable housing, slums in Ghana are more pronounced in the national capital, Accra where about 58% of the city's 2.5million residents live in slums (UN-HABITAT, 2009; GSS, 2010; Anomanyo, 2004).

Generally, these are areas where people live in poorly constructed houses lacking vital social amenities especially those related to water and sanitation. The lack of sanitary facilities and waste management systems result in the rampant disposal of waste thereby polluting the environment, especially water resources (Amuzu, 1997; Boadi and Kuitunen, 2002). To effectively manage wastewater from such areas and thus prevent the adverse potential environmental impacts, an accurate knowledge of their characteristics is essential. This study therefore focuses on identifying the characteristics of wastewater flow, identifying possible contaminant sources of wastewater generated from an urban slum - Old Fadama (a suburb of Accra, Ghana) and outlining its potential environmental impact. This will establish the need for effective management systems to be put in place to curtail the environmental impacts, facilitate design of functional wastewater management systems and develop wastewater load reduction strategies.

2. Study area

Old Fadama is the largest squatter settlement in Ghana's capital, Accra. Geographically, the area lies between latitude 5º 33' 25.44" and 5º 33' 17.28" North and longitude 0º 13' 10.56" and 0º 13' 36.48" West and has an area of 0.313km^2 with a population of 79,684. It is located between the Odaw and Agbogbloshie drains at the upper reaches of the Korle Lagoon (Figure 1). The Lagoon covers a total surface area of about 0.6 km^2 and drains a total catchment area of about 400 km^2 (Figure 2). The catchment area has a high number of industries including breweries, textile factories and vehicle repair shops.

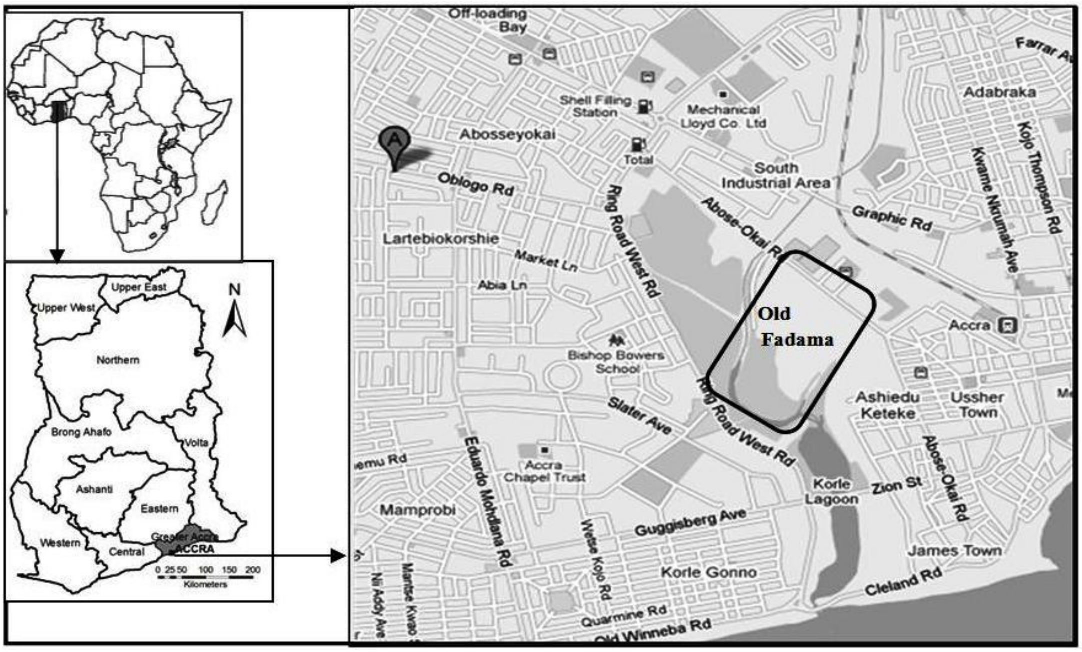

Figure 1. Map of study area

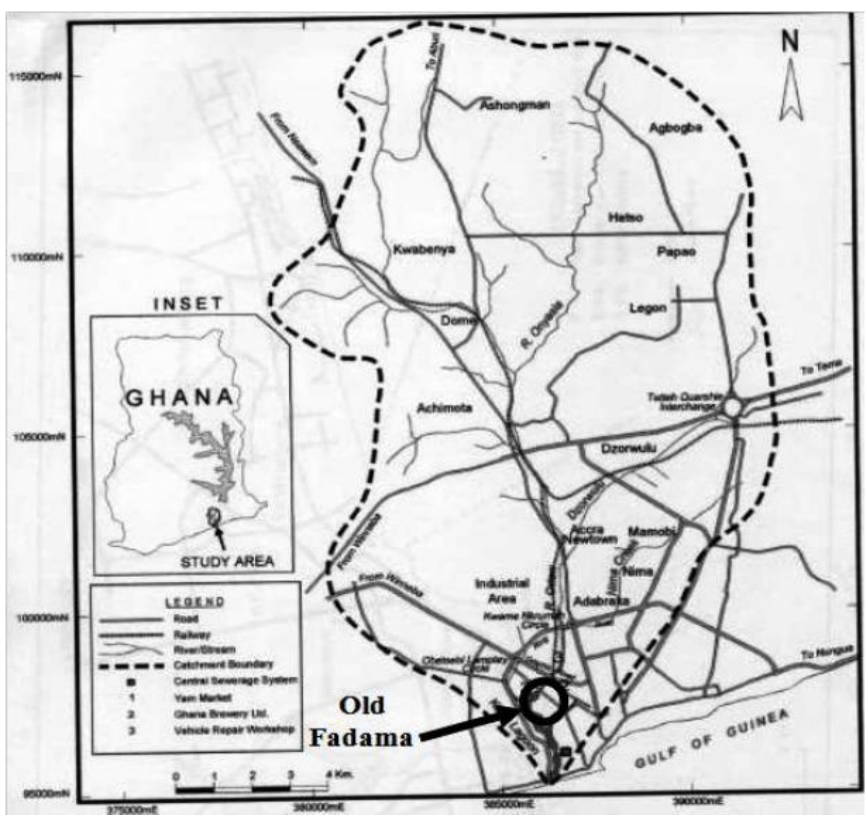

Figure 2. Catchment area of the Korle Lagoon (Source: Karikari et al., 2006)

3. Experimental procedure

The existing water supply and sanitation conditions in the study area were assessed through field observations, water/wastewater sampling and analysis, interviews, and questionnaire administration. Composite samples of wastewater were taken from three major drains in the community. Sampling was done on bi-monthly basis during the wet season (May, June and July) to determine the relative effect of rainfall and on monthly basis during the dry season (November, December and February). 27 composite samples (9 samples per location) were analysed throughout the sampling period.

The samples were collected into 1.5 litre clean plastic bottles. Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH were measured in-situ with a PC 300 Waterproof pH/Conductivity/TDS/Temperature meter while Dissolved Oxygen (DO) was measured with a WTW Oxi 340 oximeter. Samples were preserved in an ice box and transported to the laboratory and other analyses carried out within 24 hours after sampling. Ortho-phosphate, Nitrogen-Ammonia, Nitrate-Nitrogen and Iron were measured with a DR/2400 Spectrophotometer using appropriate reagent pillows. Bacteriological examinations (*Escherichia coli* and Total coliforms) were conducted by the Membrane filtration technique using Chromocult Coliform Agar as culturing medium. All the methodologies for field and laboratory analysis were conducted according to the Standard Methods for the Examination of Water and Wastewater (1999). Analyses of heavy metals namely Cadmium, Mercury, Lead, Copper and Zinc were carried out with a Buck Scientific Model 210 VGP Flame Atomic Spectrophotometer. 5mL of concentrated HNO_3 were initially added to 500mL of the samples to prevent adsorption of the metals to suspended solids. Digestion was carried out with di-acid mixture composed of HNO_3: $HClO_4$ in the ratio of 9: 4 on a hot plate and filtered with Whatman No. 1 filter paper. The resulting mixture was then diluted to 50mL with distilled water for the spectrophotometric analysis.

Average per capita water consumption of the community was determined from residents' daily expenditure on water converted into volumes gathered through questionnaires and field surveys. This was due to the fact that residents depend solely on water vendors for their daily supply of water. A return factor for wastewater generation was determined from the various water use activities by residents. Consequently, the pollution load of wastewater in the community was computed on the basis of the per capita wastewater generation and the concentration of contaminants in the wastewater from the equation: $Q = IFP$ as adapted from Smith and Scott (2005). I is the impact (in this case the concentration of contaminant), F is the amount of resource (per capita wastewater generated) and P is the population of the community. Single factor ANOVA with 5% significance level was used to establish the statistical significance of the seasonal variation of the parameters analysed.

4. Results and discussion

4.1. Status of sanitation in the slum

The community depends on pipe-borne water provided from informal water vendors supplied by Ghana Water Company Limited (GWCL) - main utility provider in Ghana, sachet water (packaged water in 500ml plastic bag) and water from mobile Tanker Operators for their daily water supply needs. These sources of water are all classified as unimproved as per WHO/UNICEF Joint Monitoring Programme (JMP). The pipe-borne water from GWCL, due to its intermittent flow, is stored in concrete tanks and sold to residents at GH¢0.3 per 18L – 19 times higher than GWCL domestic rates of GH¢0.88 per 1000L (US$1 = Gh¢1.5). In case of water shortage in the community, residents purchase water from private water tanker operators at GH¢1.5 per 18L – approximately 95 times the domestic rate approved by GWCL. Consequently, some residents (40% of 100 respondents to questionnaires) indicated that they rather purchase sachet water at GH¢ 0.9 per 15L for domestic activities in such situation.

The average per capita water consumption for the community is 50L/cap/day (ranging between 21 – 82L/cap/day) obtained from study questionnaires and observations due to lack of household connection to water supply. This value is comparable with that obtained for low income group in Ghana obtained by Oduro-Kwarteng and Nyarko (2009); 53 L/cap/day. The study found that the high cost of water affects per capita water usage in the community and possibly increases wastewater pollutant levels – a bucket of water could be used to wash several clothes/dishes before it is disposed of.

Wastewater in this community is channelled through earth (unlined) drains often choked with solid waste thereby increasing their pollutant loads. Due to lack of skip containers in the community, refuse is dumped indiscriminately along the upper reaches of the Korle Lagoon which eventually gets washed into the Lagoon during the rainy season. Household toilet facilities in the community are non-existent as present in other slums worldwide, thus residents depend solely on public shared toilets – basically Kumasi Ventilated Improved Pits and Pan/Bucket Latrines. These types of facilities are classified as unimproved sanitation facilities due to their poor state of cleanliness and lack of privacy (according to the WHO/UNICEF Joint Monitoring Programme). This remark was confirmed by all respondents who patronised these facilities and verified by author's personal observation.

The community has 39 toilet facilities with 635 squat holes in all. This is grossly inadequate considering a total population of 79,684; with about 125 residents potentially using a squat hole in contrast with the recommended 50 users per squat hole (The Sphere Project, 2004). This indicates that the demand for these facilities exceed the service provided thus contributes to the practice of open defecation in the community.

4.2. Characteristics of wastewater

4.2.1. Physico-chemical parameters

Wastewater from Old Fadama showed a slightly alkaline pH during the study period (Table 1) possibly attributable to the presence of detergents and soapy water (Figure 3). On the average, pH of the wastewater was relatively lower during the dry season (7.58±0.22) as compared to the wet season (7.87±0.37) and also within the Environmental Protection Agency (EPA) effluent guideline value of 6-9 for discharge into waterbodies (EPA, 1997). This is acceptable since wastewater with low pH is difficult to treat by biological means and may also alter the concentration in natural waters (Metcalf and Eddy, 2003). Seasonal variation of pH of the wastewater was not statistically significant ($p > 0.05$).

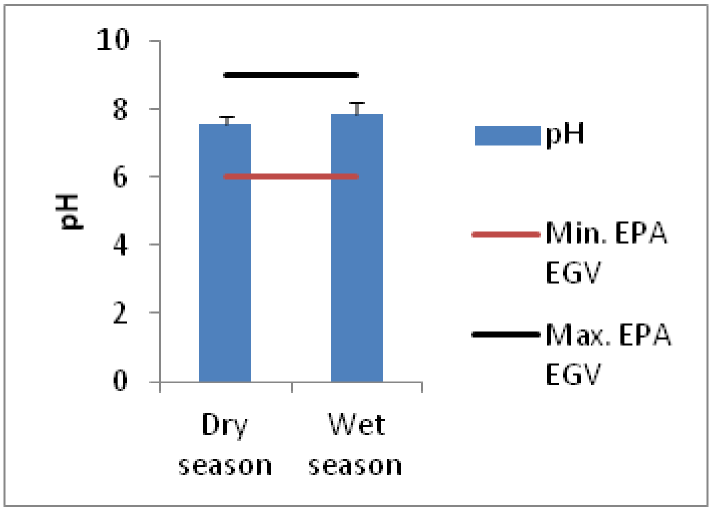

Figure 3. pH of wastewater

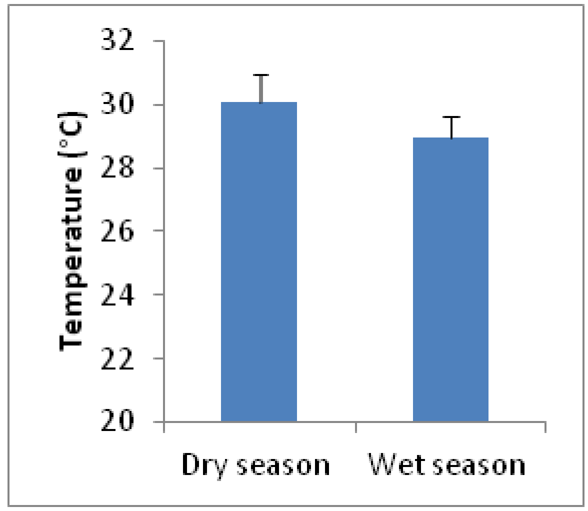

Figure 4. Temperature of wastewater

Average temperature values of 30.08±0.88°C and 28.93±0.7°C were recorded in the dry and wet seasons respectively for the wastewater from this community (Figure 4). These are relatively higher than the community's average ambient temperatures of 28°C and 25°C for the dry and wet seasons respectively. The difference between the wastewater temperature during the dry and wet season is seen to be influenced by the ambient temperature. According to Weiner et al. (2003), the discharge of heated effluents may considerably modify the ecology of the receiving stream or lake as well as decrease the solubility of oxygen in the water.

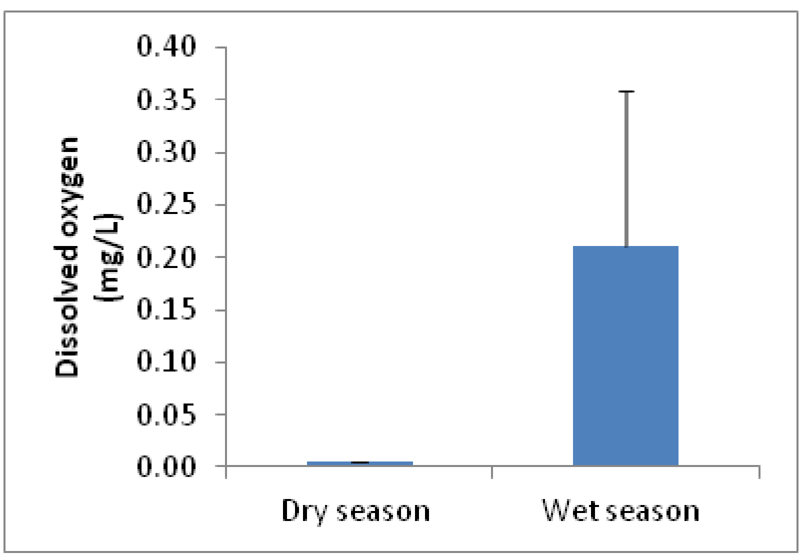

Figure 5. DO in wastewater

Wastewater from Old Fadama, during the study was predominantly anaerobic due to high levels of organics and low levels of DO especially in the dry season - <0.01mg/L (Figure 5). However, the relatively higher DO (0.21±0.15mg/L) recorded during the wet season could result from the effect of turbulence from rainfall-runoff, the lowered concentration of organics and the relatively lower temperature. Due to the low DO in the wastewater during the dry season, it showed a characteristic black-colour accompanied by foul odour as confirmed by Spellman (2003). The predominantly low DO of the wastewater is deleterious to aquatic life upon discharge into adjoining water bodies since it has the potential to cause a drop in DO levels in the water (depending on the volume). USEPA (2000) asserts that dissolved oxygen waters with extremely low DO are not able to support aquatic life.

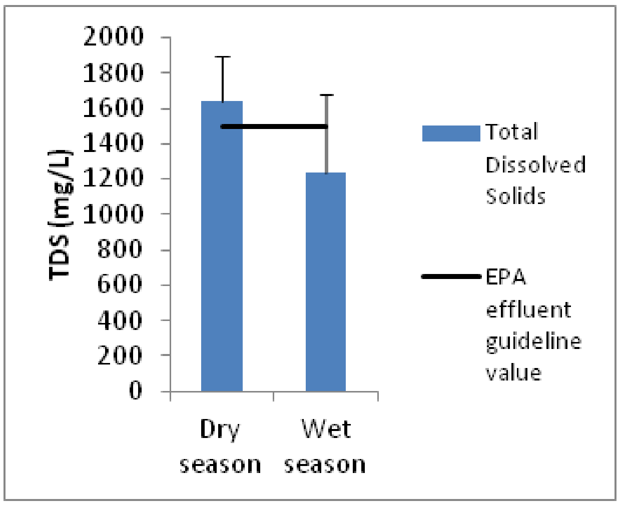

Figure 6. TDS of wastewater

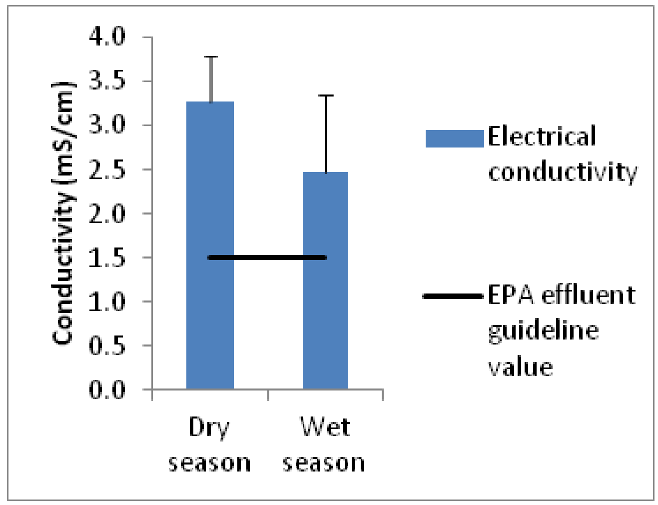

Figure 7. Conductivity of wastewater

The mean TDS of the wastewater for both the dry and wet seasons were 1640±260mg/L and 1233.84±444.7mg/L respectively, mostly exceeding the EPA effluent guideline value of 1500mg/L in the dry season (Figure 6). The lower concentration of TDS during the wet season could be due to the dilution effect of rainfall-runoff causing a reduction in the ions present in the wastewater. TDS showed a strong correlation with EC ($R^2 = 0.996$) corroborating the fact that EC is proportional to the concentration of ions (such as chloride, nitrate, and phosphate anions, or sodium, calcium, and aluminium cations) in solution (Spellman, 2003). The values of EC thus showed a similar trend as TDS (Figure 7). Average EC levels in the dry season (3.28±0.52mS/cm) were higher than that of the wet season (2.48±0.88mS/cm). This confirms studies by UNEP (2006) which asserts that conductivity declines during the wet season whereas dry periods leads to increased conductivity levels in water. Generally, EC values were consistently higher than the EPA effluent guideline value of 1.5mS/cm indicating the possibility to alter the conductivity of receiving waterbodies leading to salinity problems and eutrophication (GWA, 2009). Seasonally, the variation of EC and TDS of the wastewater was statistically significant ($p < 0.05$).

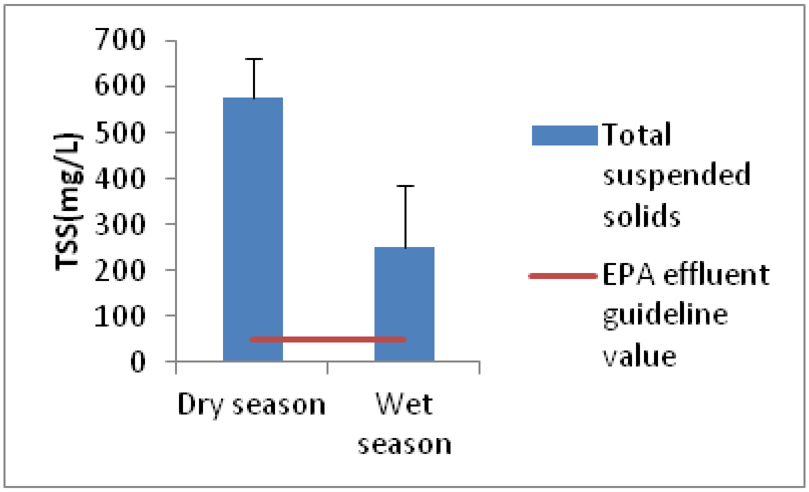

Figure 8. Total suspended solids in wastewater

Consistently higher levels of TSS were recorded in the wastewater as compared to the EPA effluent guideline value during the study (Figure 8). Particularly in the dry season, the average TSS value (575.58±88.12mg/L) was about 11 times greater than the EPA effluent guideline value (50mg/L) and about five times greater in the wet season (251.56±135.97mg/L). The high levels of TSS in the wastewater could be attributed to erosion of soil particles in the earth drains as the wastewater flows through it and the organic matter resulting from food waste, and other forms of human and animal waste. According to Bartram and Ballance (1996), TSS can be made up of either mineral or organic solids. Consequently, the decomposition of the organic component depletes the dissolved oxygen in water, resulting in anaerobic conditions and unpleasant odours (Weiner et al., 2003). This affirms the foul odour in the wastewater during the dry season when DO levels were very low.

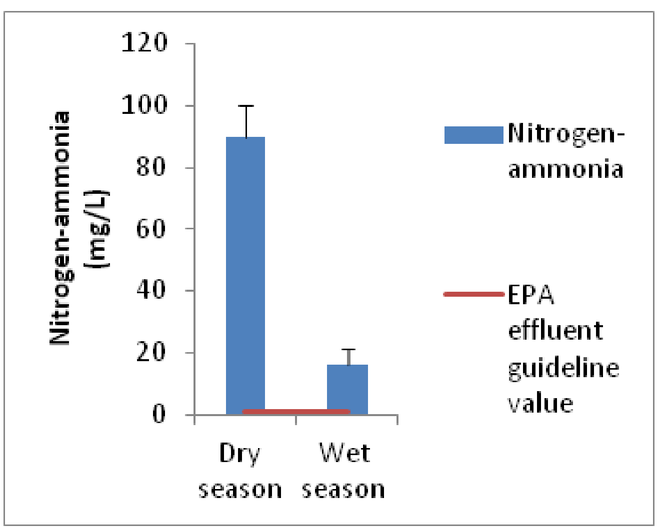

Figure 9. Nitrogen-ammonia in wastewater

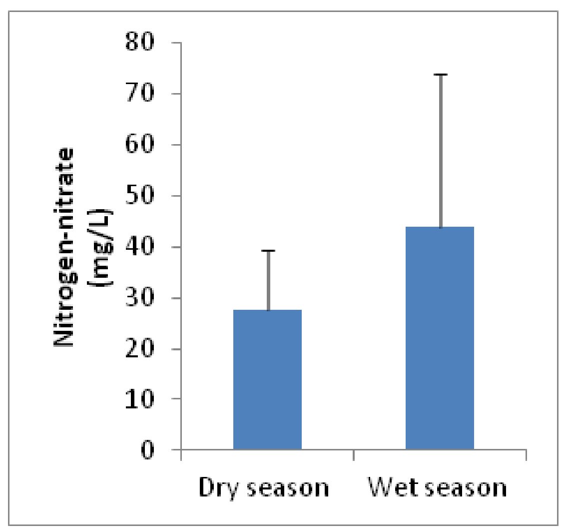

Figure 10. Nitrogen-nitrate in wastewater

Average concentrations of Nitrogen-ammonia in the wastewater during the dry and wet seasons were 89.87±10.46mg/L and 16.39±5.02mg/L respectively as against an EPA guideline value of 1mg/L (Figure 9). Seasonal variation of Nitrogen-ammonia in the wastewater was statistically significant ($p < 0.05$). The average concentration of Nitrogen-nitrate also showed a statistically significant seasonal variation ($p < 0.05$) although it recorded higher levels in the wet season (43.87±30.07mg/L) as compared to the dry season (27.74±11.70mg/L) in contrast to Nitrogen-Ammonia (Figure 10). These trends in Nitrogen-ammonia and Nitrogen-nitrate are in conformity with assertions from available literature (Stendahl, 1990; Liu, 1999) which explain that the conversion of ammonia to nitrite and eventually to nitrate depends on the availability of oxygen for oxidising bacteria to oxidise ammonia to nitrate. Thus, the relatively higher levels of DO in the wastewater during the wet season enhanced the decomposition of ammonia to nitrate resulting in higher levels of nitrate in the wet season as compared to the dry season. According to Stendahl (1990), the process of converting ammonia to nitrate consumes significant amounts of DO resulting in reduced DO levels. Therefore, the disposal of wastewater with such high levels of Nitrogen-ammonia into waterbodies has the likelihood to deplete available DO for aquatic life. Shaw et al. (2004) identified fertilizer and animal wastes on agricultural lands, human wastes from sewage treatment plants or septic systems and lawn fertilizers. In the study area however, the potential sources of Nitrogen-ammonia in the wastewater include human and animal waste and organic solid waste resulting from food debris.

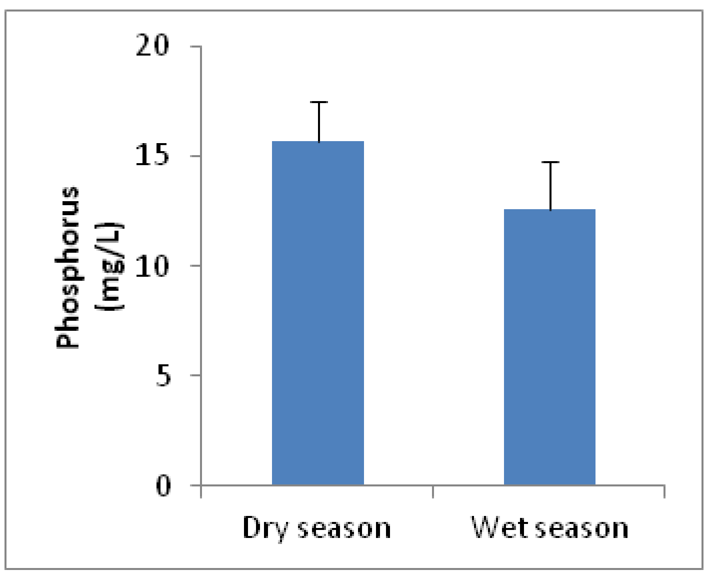

Figure 11. Phosphorus in wastewater

Phosphorus (in the form of orthophosphate) in wastewater had average values of 15.70±1.82mg/L in the dry season and 12.59±2.22mg/L in the wet season. Although phosphorus is an essential nutrient for plant growth and for biological metabolism, Tjandraatmadja et al. (2010) argue that, excessive discharge into aquatic environments can result in excessive algae growth, eutrophication and the depletion of oxygen in water bodies. Moreover, studies (Spellman, 2003; Metcalf & Eddy, 2003), have shown that in surface waters, phosphates act as fertilizer, promoting the growth of undesirable algae populations or algal blooms. Upon decomposition of this organic matter, DO levels in the water body decreases leading to the demise of fishes and other aquatic species. Literature (Salvato et al., 2003) has it that, phosphorus is usually associated with plant remains, animal wastes or fertilizer. Other potential sources of phosphates in wastewater as stated by Tjandraatmadja et al. (2010) include, cleaning products, cosmetics, medicated shampoos, food products, faeces and urine are also. All these sources (except fertilizer), as observed at the study area, contribute to the high levels of phosphorus in the wastewater poses potential deleterious risks to aquatic life in receiving waterbodies.

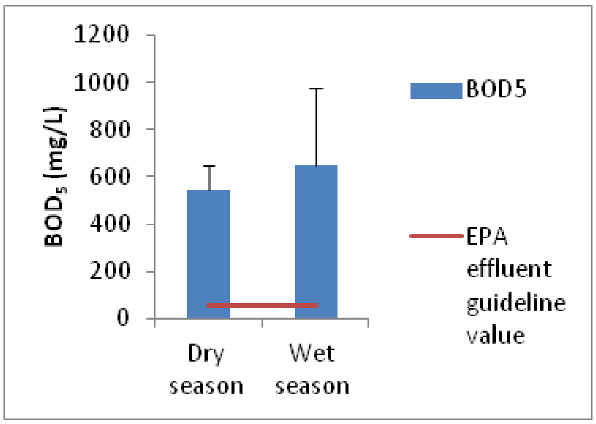

Figure 12. BOD_5 in wastewater

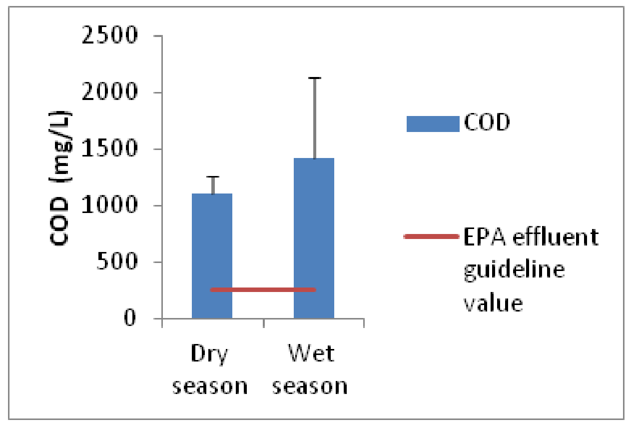

Figure 13. COD in wastewater

BOD levels in the wastewater were 545.63±99.88mg/L and 645.94±331.43mg/L during the dry and wet seasons respectively being consistently higher than the EPA effluent guideline value of 50mg/L. COD also showed the same trend with levels as high as 1415.12±722.83mg/L in the wet season and 1100.45±167.16mg/L in the dry season compared to an EPA effluent guideline value of 250mg/L. On the average, the COD/BOD value of the wastewater was 2.3 with 72% of the values being more than 2. According to Stendahl (1990), COD/BOD values of wastewater indicates how biologically degradable the wastewater is and hence its suitability for biological treatment. COD/BOD values less than or equal to 2 shows the presence of relatively easily degradable substances while high values indicate that the substances are difficult to break down. Per the COD/BOD values recorded this means the wastewater contains substances that are not easily degradable and thus will make biological treatment difficult. Seasonal variations of BOD and COD of the wastewater were statistically significant ($p < 0.05$). BOD, as explained by Reynolds et al. (2002), is the level of organic content in wastewater measured by the demand for oxygen that can be consumed by living organisms in the wastewater whereas COD measures the amount of oxidizable matter present in wastewater (Spellman, 2003). The breaking down or stabilization of such constituents consequently utilizes the dissolved oxygen in the water causing its depletion resulting in the generation of odour. Thus, wastewater with high BOD content is characterized by low oxygen content and high biological activity. This, apart from explicating the low levels of BOD and hence COD in the wastewater during the dry season when there were low DO levels in the wastewater also shows the potential risks the wastewater poses to aquatic environments.

4.2.2. Bacteriologial quality of wastewater

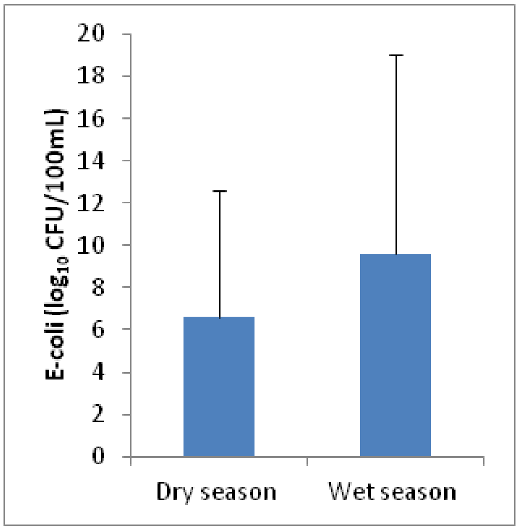

Figure 14. *E. coli* in wastewater

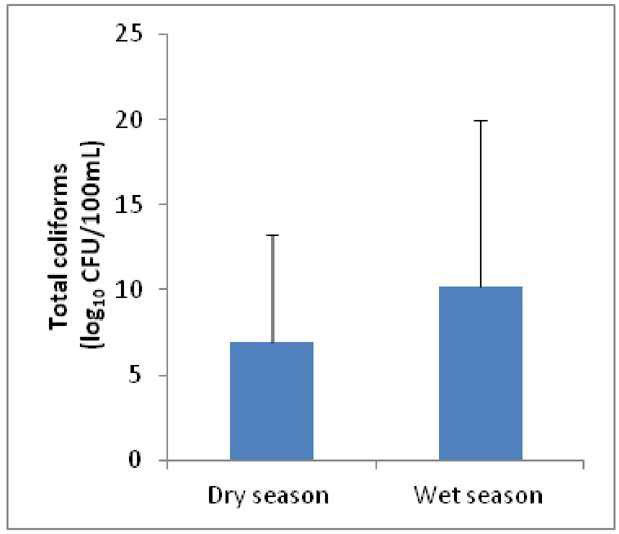

Figure 15. Total coliforms in wastewater

Higher coliform levels (*E. coli* and total coliforms) were generally recorded in the wet season in the wastewater as compared to the dry season with statistically significant seasonal variations ($p < 0.05$). *E-coli* levels were $4 \pm 1x10^6$CFU/100mL in the dry season and 4200 ± 2400 $x10^6$CFU/100mL in the wet season (Figure 14). Total coliform levels also showed the same trend with 9 ± 210^6CFU/100mL in the dry season and 16800 ± 510010^6CFU/100mL in the wet season (Figure 15). Consistently, the levels of *E. coli* and total coliforms were higher than their EPA effluent guideline values of 0 and 400CFU/100mL respectively. Strauss (2000) reported that the presence of faecal coliforms is an indicator of faecal contamination. Thus, the higher levels of *E-coli* in the wastewater during the wet season is attributable to runoff conveying human and animal waste in the community into the wastewater stream.

Although most microorganisms (bacteria, protozoa) are responsible and also beneficial for biological treatment processes of wastewater (Liu, 1999; Lee, 2007), Awuah (2006) argue that depending on the dose and susceptibility of the host, some of these organisms found in wastewater can cause diseases of the gastrointestinal tract such as typhoid and paratyphoid fever, dysentery, diarrhoea and cholera. The levels of E-coli in the wastewater were found to be within the range of infectious dose (10^6-10^{10}) as reported by Awuah (2006) indicating the potential health threat it poses even to human life.

4.2.3. Heavy metals in wastewater

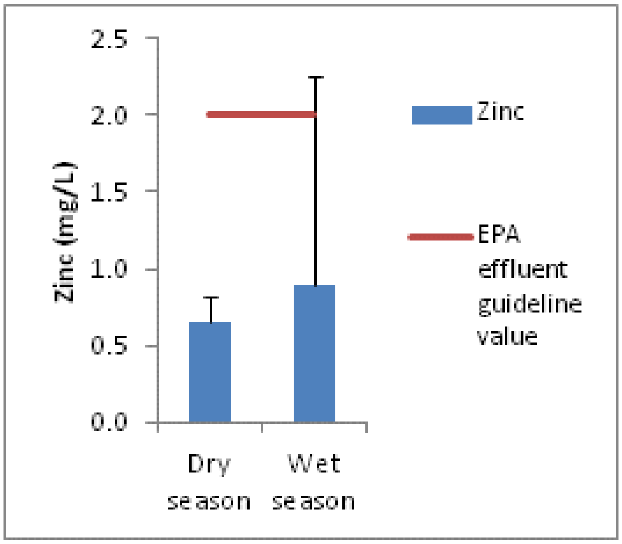

Figure 16. Zn in wastewater

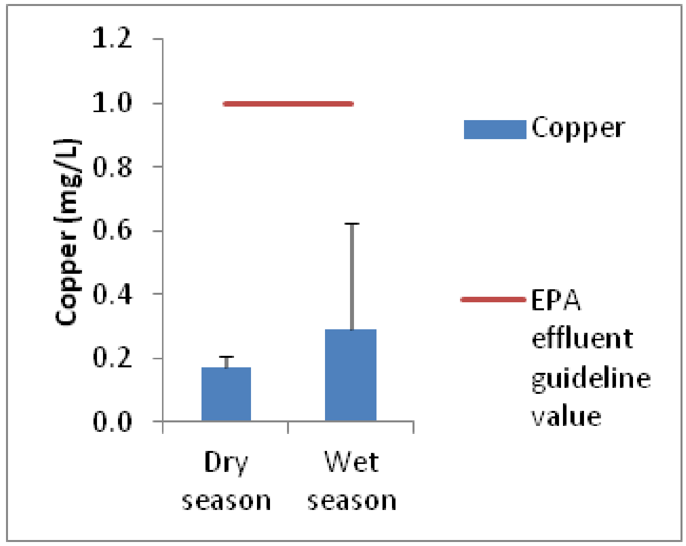

Figure 17. Cu in wastewater

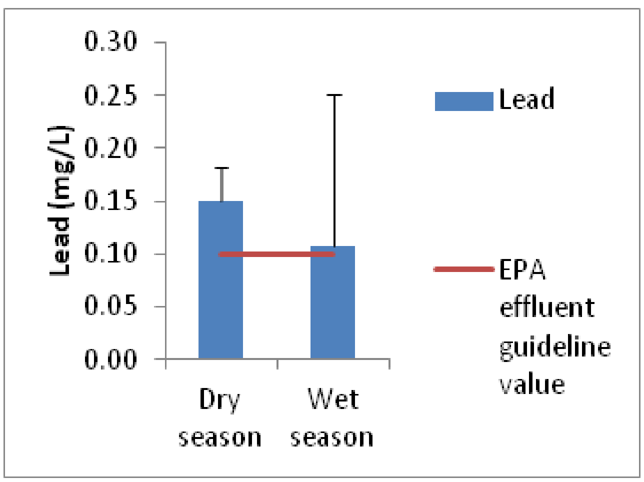

Figure 18. Pb in wastewater

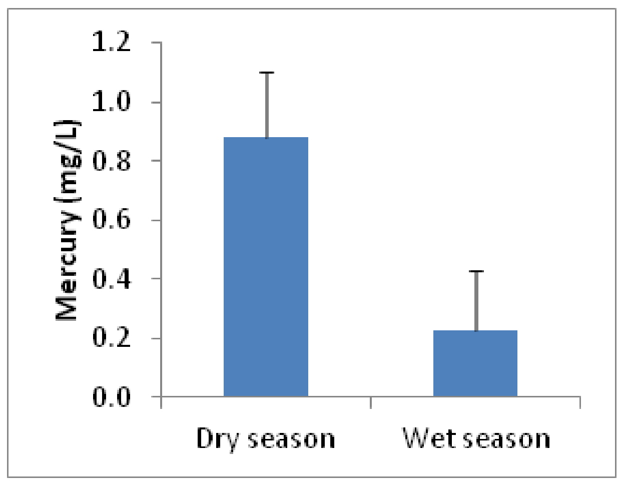

Figure 19. Hg in wastewater

The presence of inorganic contaminants in surface water affects aquatic life primarily due to their non-degradable and toxic nature. While some of these contaminants viz. Cu and Zn are important micronutrients for plants and microorganisms, others such as Cd, Hg and Pb pose deleterious health effects above certain thresholds (Kar et al., 2008).

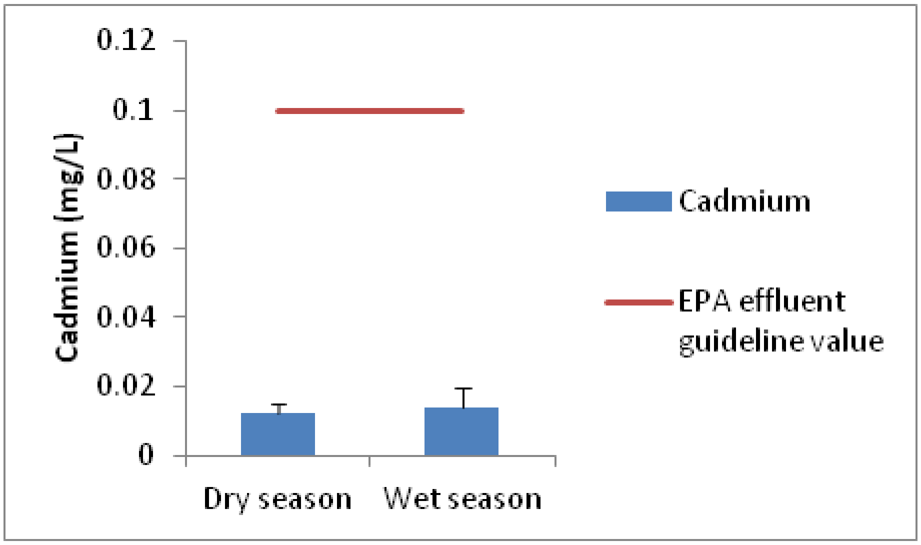

Figure 20. Cd in wastewater

Levels of Zn and Cu in the wastewater were predominantly below their respective EPA effluent guideline values of 1.0mg/L and 2.0mg/L during both seasons (Figures 16 and 17). Among the toxic heavy metals in the wastewater, namely Pb, Cd and Hg, only Pb exceeded its EPA effluent guideline value of 0.1mg/L during the wet season (Figure 18) with only Hg showing a statistically significant ($p < 0.05$) seasonal variation in the wastewater. The presence of these toxic heavy metals in the wastewater, according to Spellman (2003), can kill off the micro-organisms that are needed for biological treatment of wastewater and thus stop the treatment process. Sa'idi (2010), in his study on the metal concentrations that affect the protozoan community in the activated sludge found that at 5.23mg/L Cd is able to cause disappearance of 50% of 16 protozoan species and a reduction of the cell density of the remaining species. Moreover, 6.98mg/L of Pb, 6.12mg/L of Cu and 81mg/L of Zn also caused 65%, 89% and 80% cell mortalities respectively. Protozoans also, as per Sa'idi (2010) are known to enhance the quality of activated sludge effluent through the predation on bacterial biomass in the mixed liquor. Comparing the levels of these heavy metals found in the wastewater in this study to those by Sa' idi (2010), it can be asserted that they are not enough to stop biological treatment by activated sludge. Waste stabilisation ponds on the other hand can resist up to at least 30mg/L of heavy metals without reducing their treatment efficiency (Mara and Pearson, 1987). When ingested, Cd is known to cause kidney damage (WHO, 2007) whiles Pb inhibits enzymes and also damages the nervous system and the kidneys (Holm et al., 2002; Akan et al., 2009).

The average per capita wastewater generation rate is 40L/cap/day computed from an average per capita water consumption of 50L/cap/day and a return factor of 80%. This is somewhat more than that obtained by Carden et al. (2007) in low income areas in South Africa (25L/cap/day) and that of Nguendo Yongsi (2009) in low income areas in Cameroon (30L/cap/day).

Compared with the results from other studies in high-density, low-income communities, the wastewater from this community contains relatively higher levels of contaminants (Table 2). These indicate its ruinous potential to both human health and the environment.

Table 1. Potential pollution load of wastewater from Old Fadama (n = 27)

Parameters (mg/L)	Concentration of contaminants (mg/L) Mean ± SD		Potential Pollution Load (kg/day) Mean ± SD	
	Dry season	Wet season	Dry season	Wet season
TSS	575.58 ± 88.12	251.56 ± 135.97	1834.59 ±280.88	801.82 ± 433.39
Nitrogen-ammonia	89.87 ± 10.46	16.39 ± 5.02	286.45 ± 33.34	52.25 ± 16.01
Nitrogen-nitrate	27.74 ± 11.7	43.87 ± 30.07	88.42 ± 37.30	139.83 ± 95.85
Phosphorus	15.70 ± 1.82	12.59 ± 2.22	50.05 ± 5.81	40.13 ± 7.08
COD	1100.45 ± 167.16	1415.12 ± 722.83	3507.54 ±532.80	4510.5 ± 2303.92
BOD_5	545.63 ± 99.88	645.94 ± 331.43	1739.12 ±318.36	2058.85±1056.39

5. Conclusions

The study concludes that wastewater from Old Fadama has the potential to adversely affect the environment. The high BOD and COD levels in particular pose a huge threat to aquatic environment through depletion of DO levels when the untreated wastewater finds its way into waterbodies. This is due to high levels of organics in the wastewater emanating from food waste, animal and human waste that find their way into drains conveying wastewater. The presence of nutrients (nitrogen and phosphorus) in high amounts also has the potential to disrupt aquatic life through nutrient enrichment. The presence of earth channels in the community also conveys soil particles and other particulate matter during rainstorm which could contribute to silting up of adjoining waterbodies necessitating regular dredging - as is currently happening to the Korle Lagoon. Moreover, the eventual disposal of solid waste into drains conveying wastewater could also deprive receiving waterbodies of their aesthetic beauty. High levels of coliforms - (within infectious dose limits) in the wastewater are particularly undesirable not only to the environment but potentially to human health as well.

The study thus recommends that, the use of soakage pits for wastewater disposal in the community should be adopted by the community to prevent their direct disposal into waterbodies. The cost of water should be regulated by the urban water utility provider (GWCL) through the formation of water vending associations in the community for effective monitoring of their operations. Access to toilet facilities needs to be improved to reduce (if not completely forestall) the spate of open defecation in the community. The provision of communal skip containers for waste collection would also contribute to reduce the amount of waste that end up in drains conveying wastewater thereby reducing their pollutant loads. All these would require intensive health education of the residents on the importance of sanitary environment.

Table 1. Comparison of wastewater characteristics in the study area with results from other studies

Parameters	Units	Ghana (This study)		Ghana (Awuah et al., 2002)	South Africa		
		Dry season (Mean±SD)	**Wet season (Mean±SD)**	**KNUST grey water**	**Carden et al. (2007)**	**Eriksson et al. (2002)[a]**	**Källerfelt & Nordberg (2004)[a]**
pH		7.58±0.22	7.87±0.37	7.5±0.2	3.3 – 10.9	5.0 - 8.7	6.1 - 7.0
EC	mS/cm	3.28±0.52	2.48±0.88	-	0.28-17.63	0.32 - 20.	0.83 – 1.32
Temp.	°C	30.08±0.88	28.93±0.7	29.2±0.7	-	-	-
DO	mg/L	<0.01	0.21±0.15	2.7±0.9	-	-	-
TDS	mg/L	1640±260	1233.84±444.7	-	-	-	-
TSS	mg/L	575.58±88.12	251.56±135.97	212.0±20.8	-	6.4 - 330	69.0 - 1 420
NH_3 - N	mg/L	89.87±10.46	16.39±5.02	8.4±1.8	0.2 - 44.7	0.03 - 25.4	
NO_3-N	mg/L	27.74±11.7	43.87±30.07	0.7±0.06	-	-	-
Phosphorus	mg/L	15.7±1.82	12.59±2.22	11.8±4.0	0.7 - 769	0.6 - 68	14.8 - 56.2
BOD_5	mg/L	545.63±99.88	645.94±331.43	198.3±33.3	-	-	-
COD	mg/L	1100.45±167.16	1415.12±722.83	399.0±108.4	32 - 11 451	13 - 549	530 - 3 520
E-coli	10^8CFU/ 100mL	4±1[b]	41.67±23.66	1.5±0.2[b]	-	-	-
Total coliforms	10^8CFU/ 100mL	9±2[b]	167.6±51.19	2.7±0.6	-	-	-

Sources: [a] Carden et al. (2007) [b] Concentrations presented in 10^6CFU/100mL [c] Concentrations presented in organisms per litre

Acknowledgement

The authors of the study are grateful to the Netherlands Ministry of Development Cooperation (DGIS) through the UNESCO-IHE Partnership Research Fund for providing the needed financial support. We also commend Associate Prof. Dr. Jan Willem Foppen (UNESCO-IHE, The Netherlands) for his constructive comments and suggestions which resulted in a substantial improvement of this paper.

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