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EFFECT OF THE SUNYANI MUNICIPAL WASTE DUMPSITE ON SURFACE WATER QUALITY

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ABSTRACT
The concentration of some relevant water quality parameters were determined for the Awuo Kojo stream to assess the extent of impact that the municipal waste dumpsite within Sunyani municipality might have on the surface water quality for domestic consumption. The “Awuo Kojo” stream, is an important tributary of the Tano River within the Sunyani municipality. The dumpsite covered a total surface area of 68.23ha at a distance of 234.7m to the stream. Data was collected at three (3) different sampling location (downstream, midstream and upstream) for both rainy and dry seasons with upstream serving as a control. Laboratory analysis to measure the concentration of some water quality parameters was done in comparison with EPA water quality standards. The results, however show significantly ($p<0.05$) high level pollution of Physicochemical properties; Biological Oxygen Demand, Dissolved Oxygen, Phosphate, Nitrate, Iron and Zinc and micro biological parameters (Total Coliform and Fecal Coliform) at the various sampling location. However, the downstream and midstream that falls within the peripherals of the dumpsite were generally higher in concentration than Upstream (control) which were generally within the EPA water quality standard, except for pH, temperature and TDS that were statistically insignificant ($p>0.05$) across all sampling location and seasons. This however, implies that the location of the municipal waste dumpsite has a significant impact on the water quality of the “Awuo Kojo” stream and this impact was recognized across both seasons (rainy and dry), with rainy season experiencing significantly ($p<0.05$) high level of surface water pollution than the dry season.

KEY WORDS: water quality, Municipal, Dumpsite and Surface water.

INTRODUCTION

Water is the most essential element among the natural resources, and it is very critical for the survival and maintenance of all living organisms including human, food production, and economic development (Halder and Islam, 2015). The increasing demand of water for human survival and activities has made water an absolute necessity for life (UNEP/WHO, 1996). Today, there are many cities and countries worldwide facing an intense shortage of water and nearly 40 % of the world’s food supply are grown under irrigation and a wide variety of industrial processes depends on water for their operations. The environment, economic growth, and developments are all highly influenced by regional and seasonal availability and quality of water (Halder and Islam, 2015). Surface water and groundwater are the two main sources of water for all human activities. However, the quality and quantity of one affects the other as these two sources interact with each other in various forms. In many situations, surface-water bodies gain water and solutes from ground-water systems and in others, the surface-water body is a source of ground-water recharge and causes changes in ground-water quality. As a result, pollution of surface water can cause degradation of ground water quality and conversely pollution of ground water can degrade surface water (Winter *et al.*, 1998).

The quality of water which is expressed as the suitability of water to sustain various uses and processes has become a major issue of concern globally since majority of our surface water bodies are being polluted through several anthropogenic activities (UNEP/WHO, 1996). The quality of water is severely affected by human activities due to the rise of urbanization, population growth, industrial production, climate change, increase waste generation and an inadequate means of waste disposal (Halder and Islam, 2015). According to Halder and Islam (2015), the resulting water pollution is a serious threat to the well-being of both the environment and its population. As such pollution may cause infectious water-related diseases categorized as waterborne, water-hygiene, water-contact and water-habitat vector diseases like the tinea and trachoma which are both a skin and an eye disease respectively and other several diseases like the schistosomiasis (bilharziasis), diarrhoea and infant related diseases like methaemoglobinaemia resulting from a high concentration of nitrate in water (UNEP/WHO, 1996).

Poor sanitation is a major contributing factor to high levels of child mortality that occurs each year in the developing countries. Annually, 1.8 million children dies from pneumonia and diarrhea of which the WHO estimated that 88 % of diarrhea deaths are caused by poor sanitation and hygiene practices combined with unsafe water (Richards and Schafer 2008). In view of this the Sustainable Development Goal (SDG) 6 was developed with the aim of ensuring availability and sustainable management of clean water and sanitation for all (Loewe and Rippin, 2015). According to Halder and Islam (2015), the disposal of waste along streams and sensitive water course is a major anthropogenic factor in the pollution of several surface water in many developing countries turning most streams into sinks of liquid and solid waste through the action of surface run-off and leachate movement into water bodies because of inadequate or non-existence of surface water quality protection measures and related diseases like methaemoglobinaemia resulting from a high concentration of nitrate in water (UNEP/WHO, 1996).

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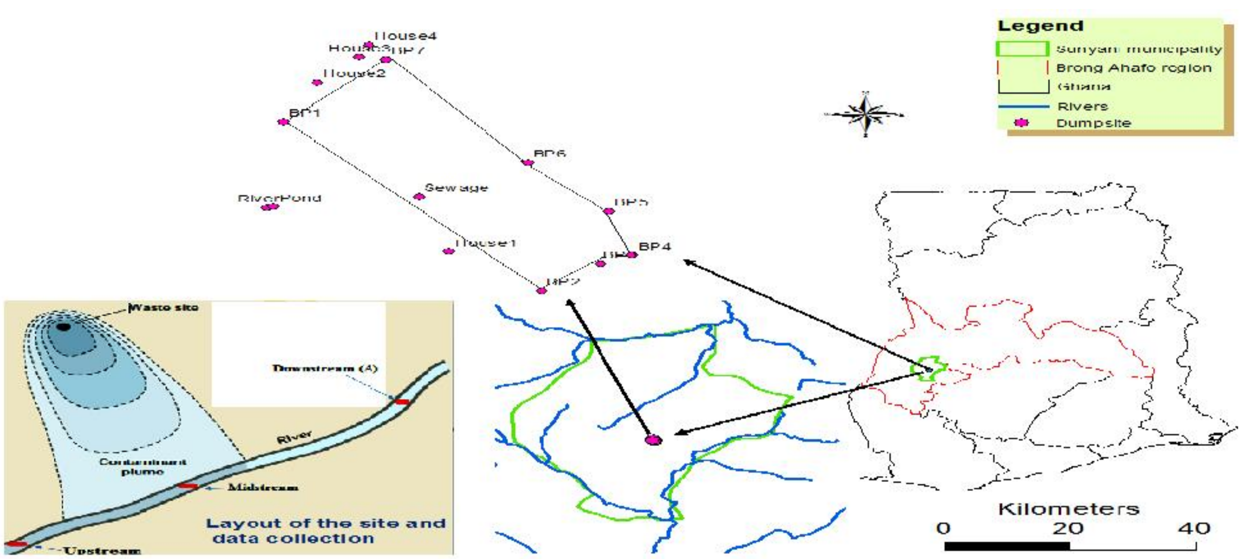
The municipality has one main waste pool where all wastes generated within the municipality are collected and disposed of, however the municipal dumpsite is situated uphill side of the “Awuo Kojo” stream which serves as a major source of water for some fringe communities and further flows into the Tano River which also serves as a major source of water for the municipality. It is on this basis this research was conducted to assess the effect of the Sunyani Municipal dumpsite on the quality of the “Awuo Kojo” stream. However, the focus of this study is to examine the effects of the Sunyani municipal waste dumpsite on surface water quality of the “Awuo Kojo” stream- a tributary of the Tano River by assessing the physical, biological and chemical properties of the stream.

METHODOLOGY

Study Area

The study was conducted at the Sunyani municipal waste dumpsite located at the waterloo near Sunyani Polytechnic GETFund Hostel which is about 15minutes drive from the main Central Business Centre (Boateng, 2014). The total surface area covered by the dumpsite was measured to be 236,823m^2 (23.6823ha) and the distance between the site and stream downslope was also measured to be 234.7m *(source; field, 2015).*Sunyani is a city in the West African republic of Ghana and is the capital of both the Sunyani East Municipal District and Brong Ahafo Region. It lies between Latitudes 7.20°N and 7.05°N and Longitudes 2.30°W and 2.10˚W. Sunyani also lies within the middle belt of Ghana between 750 (229 meters) to 1235 feet (376 meters) above sea level (googleearth.com). The city falls within the wet Semi-Equatorial Climatic Zone of Ghana. The mean monthly temperature varies between 23°C and 33°C with the lowest observed around August and the highest around March and April. The relative humidity is high, averaging between 75 and 80 % during the rainy seasons and between 75 and 80 % during the dry seasons of the year creating an ideal climate for luxurious vegetative growth. The city experiences a bi-modal rainfall pattern and the main rainy season between March and September and the minor between October and December (Assembly, 2008).



Data collection

The materials used for collecting the data are; 300ml of Voltic bottles, labelling materials, measuring tape and GPS were used on the field.

Method Used

The rainy and the dry seasons were considered in this experiment to assess if these seasons will have any significant influence on the extent of impact that the municipal dumpsite might be having on the surface water quality. In view of that, samples were collected for both seasons.

The First sample was collected for the rainy season on the 24th October 2015, in whose month high amount of rainfall was recorded and the second set of data samples were also collected for the dry season on the 21st December, 2015, where no rainfall was recorded during that month.

For both seasons, samples were collected at three different points and their geographic coordinates were also recorded. That is, upstream level (N 7.3114, W 2.3294), midstream (N 7.3093, W 2.3281) and downstream (N 7.3043, W 2.3254). Three samples were collected at each point respectively by filling 500ml of voltic bottle, obtaining a total of nine (9) samples. Samples were well labelled with their respective place of collection for easy identification of samples. Global Positioning System (GPS) coordinates were taken for each point and the samples collected were then placed in a plastic bag and iced to maintain temperature. The exercise was repeated again for the dry season and samples were transported to the Ghana Water Company Limited (GWCL), Sunyani for further analysis of the various water quality parameters that can be used to predict the quality state of the surface water.

Precautions taken

Some few precautions were taken to ensure credibility in the expected results. Such as;

- Bottles used were rinsed with distilled water to get rid of any dirt or contaminant that can influence results.
- Samples collected were iced to maintain temperature.
- Samples were well labelled for easy identification.

Global Positioning System

Handheld Global Positioning System (GPS) was used to pick coordinates along the boundaries of the site at every 100m interval and at every irregular point along the boundary. In addition, the handheld GPS was used to map all existing ground features (buildings, stream, and ponds) to know their proximity to the site boundary.

Chemical Analysis

Chemical analysis of all relevant water quality parameters were performed at the Ghana Water Company Limited (GWCL)-Sunyani, water quality laboratory.

Tools and equipment

HQ11d-HACH product pH meter, Wagtech, Automatic Autoclave, Durham's tube, incubator, Dissolved Oxygen meter and direct reading Spectrophotometer.

METHOD

Eleven (11) most relevant parameters were considered for the laboratory analysis; this includes some measureable physical parameters and organic indicators like; Temperature, Total Dissolved Solids (TDS), and Biological Oxygen Demand (BOD), microbiological parameters such as; Total Coliform (TC) and faecal coliform and some chemical parameters (Major cat ions and Anions); Iron (Fe), Nitrate, Phosphate, Dissolved Oxygen and pH.

Determination of Microbiological Parameters

Mac Conkey BROH and Brilliant Green Bile 2% broth were the chemicals used to detect and enumerate the presence of Total Coliform and Fecal Coliform respectively in the samples. 80g of the chemicals were weighed using the HACH weighing balance (ADP/L) and dissolved in 1Litre of distilled water, 10ml of the prepared Mac Conkey was transferred into Mac Coney bottle and an inverted Durham tube was inserted into the bottle containing the prepared Mc Conkey. The automatic Autoclave; an incubator was used to sterilize the Mc Conkey to ensure bacteria free under a temperature of 121^{0}C for 15mins and left for 24hours for it to cool before usage. Five (5) Mc Conkey sterilized samples were prepared for each sample collected from the field and well labelled in accordance to field label. 10ml of sample was added to the prepared Mc Conkey, it was then incubated using the BTL incubator for 24hours at a temperature of 37^{0}C, after 24hrs when there was a colour change and gas showing the presence of Total Coliform.

The same process was repeated for faecal coliform using the appropriate chemical media and temperature regulations under duration of 48hours.

Determination of pH and Temperature.

A HACH product, HQ11d pH meter instrument was used to determine the pH level of samples collected at each point. Before the pH meter was used, it was first calibrated using a pH buffer solution of 4, 7 and 10, this allow the pH meter to read between 0-10.

Collected samples from various points (downstream, midstream and upstream) were used to fill 100ml pH beaker and a probe was inserted into the beaker containing the samples and pressed to read, after which the instrument displays the results including the temperature.

This exercise was repeated for all samples collected in both dry and rainy season to determine the pH and temperature of the surface water as parameters in determining its quality.

Determination of Total Dissolved Solids (TDS)

In the determination of Total Dissolved Solids (TDS), Wagtech instrument was used to detect the TDS of the stream at each point. The instrument was first and foremost calibrated using conductivity/TDS standard solution. Collected samples were then used to fill a 100ml beaker and a probe or electrode was inserted and pressed to read after which results was displayed in mg/L.

Determination of Chemical Parameters

Spectrophotometer direct reading instrument at the Laboratory was used to determine some relevant chemical parameters such as Nitrate, Phosphate, Total Iron, Manganese, Zinc, Potassium and Aluminium as water quality indicators.

Data Analysis

Results obtained from the chemical analysis were further subjected to statistical analysis using Microsoft Excel 2013 and Minitab version 17.0 software to analyze data and results were shown in graphs.

RESULTS

Total Coliforms

Results from one-way analysis of variance tests of total coliforms showed a significant difference ($p < 0.05$) among sampling locations and across different seasons of the study at 5% probability level. Generally, total coliforms in the different sampling locations were higher in the rainy season than in the dry season. Mean total coliforms were significantly higher in the downstream sampling point during the rainy season (740.00 $\pm$ 6.006) than in the dry season (680.00 $\pm$ 4.321). Mean total coliforms recorded in midstream sampling locations during the rainy and dry seasons were 720.00 $\pm$ 8.209 and 643.00 $\pm$ 5.052 respectively. However, upstream sampling points across the rainy (360.00 $\pm$ 5.212) and dry (300.00 $\pm$ 6.291) season's recorded significantly lower mean total coliforms. Also, the mean total coliforms for the sampling locations across the rainy and dry seasons were below the EPA standard (400 mg/l) as illustrated in Figure 2.

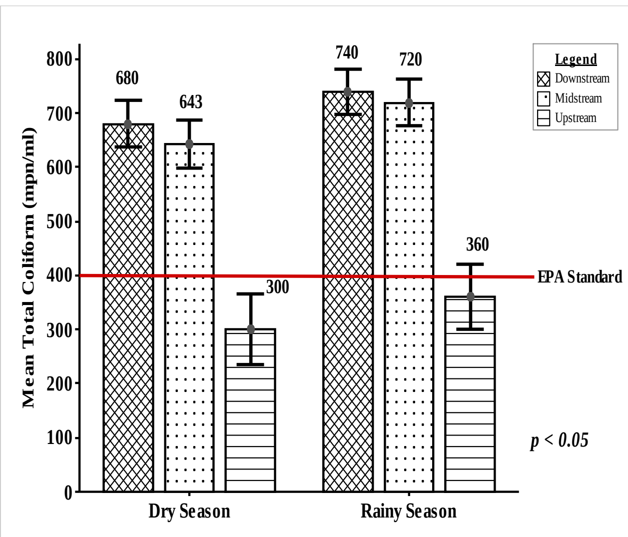


FIGURE 2: Total coliforms variations in water collected from different sampling locations at different seasons

Faecal Coliforms

Analysis of variance tests of faecal coliforms showed (Figure 3) significant difference ($p < 0.05$) between sampling locations and different seasons at 5% significance level. Results from Tukey's Pairwise Comparisons Test showed significantly higher mean levels of faecal coliforms in the downstream sampling location for the rainy season (520.00 $\pm$ 5.005) than in the dry season (downstream= 400.00 $\pm$ 7.017). The midstream sampling points for the rainy and dry seasons recorded mean fecal coliforms of 460.00 $\pm$ 9.093 and 380.00 $\pm$ 9.005 respectively. However, comparable lower mean levels of fecal coliforms were recorded in both the upstream sampling points for the rainy (72.00 $\pm$ 2.027) and dry (70.00 $\pm$ 3.081) seasons. Only the upstream sampling locations were below the EPA standard (100.00 mg/l).

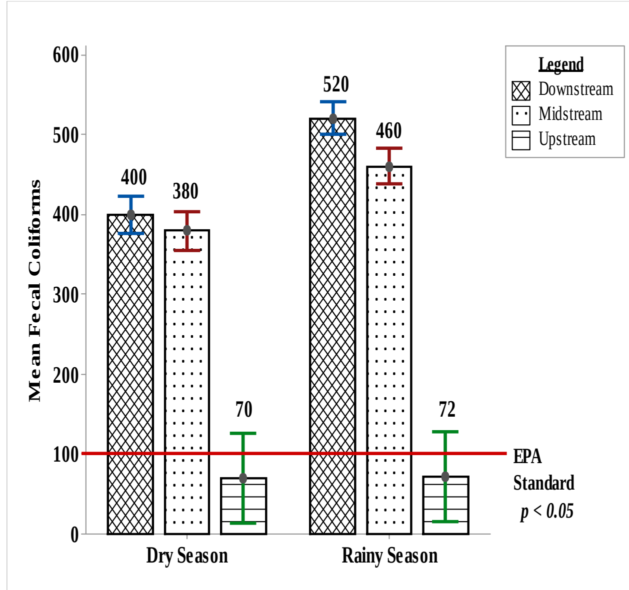


FIGURE 3: Faecal coliforms variations in water collected from different sampling locations at different seasons.

pH

Results in Figure 4 showed that pH variation between rainy and dry season was comparable. At 5% level of probability, the pH of the water collected at different sampling locations was not significant ($p > 0.05$). Higher pH values were recorded in the rainy season (downstream = 6.91 $\pm$ 0.214; upstream = 6.90 $\pm$ 0.218; and midstream = 6.83 $\pm$ 0.322) than in the dry season (upstream = 6.80 $\pm$ 0.341; midstream = 6.70 $\pm$ 0.148 and downstream = 6.60 $\pm$ 0.173). However, they were all within the acceptable standards of EPA (6.5-8.5).

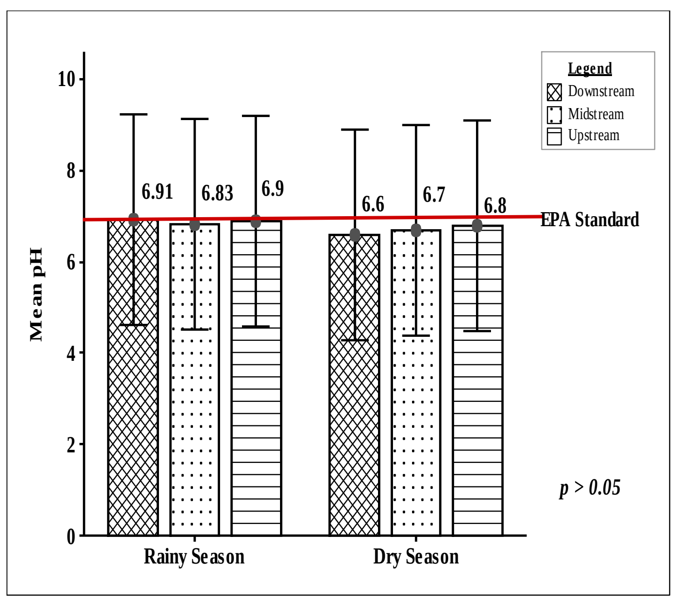


FIGURE 4: pH variations in water collected from different sampling locations at different seasons.

Iron (Fe)

One – way analysis of variance tests results showed statistically significant results ($p < 0.05$) in iron content of water collected from different sampling locations at different seasons. Significant higher mean iron was recorded in the downstream sampling point at the rainy season (2.80 $\pm$ 0.415). Mean iron recorded in the midstream collection point in the dry season was 1.90 $\pm$ 0.326. Comparable mean iron were recorded in the downstream sampling point for the dry season (1.40 $\pm$ 0.208) and midstream sampling point for the rainy season (1.20 $\pm$ 0.173). However, significant lower but comparable mean iron were recorded in the upstream sampling points for the dry (0.27 $\pm$ 0.013) and rainy (0.25 $\pm$ 0.068) seasons. Also, only the iron content of upstream sampling locations were below the EPA standard (0.3 mg/**l**) as shown in Figure 5.

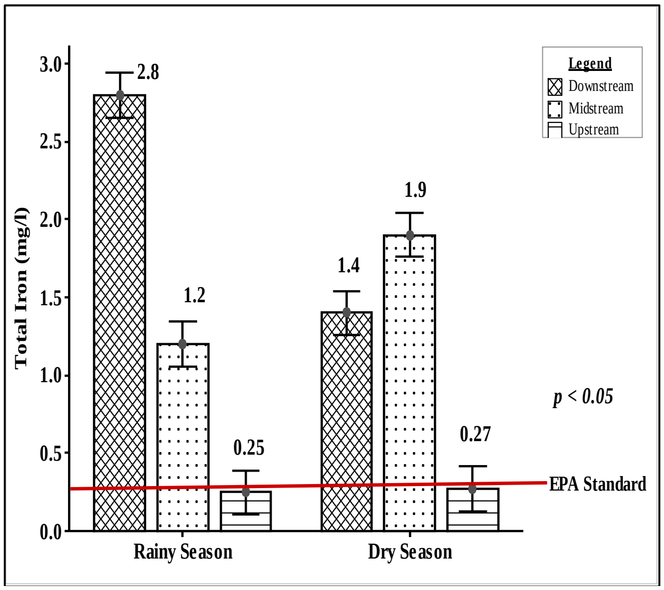


FIGURE 5: Iron (Fe) variations in water collected from different sampling locations at different seasons.

Biological Oxygen Demand (BOD)

Analysis of variance tests of biological oxygen demand showed (Figure 6) significant difference ($p < 0.05$) between sampling locations and different seasons at 5% significance level. Results from Tukey's Pairwise Comparisons Test showed significantly higher mean levels of BOD in the downstream sampling location for the rainy season (70.00 $\pm$ 0.044) than in the dry season (downstream = 60.00 $\pm$0.038). The midstream sampling points for the rainy and dy seasons recorded mean biological oxygen demand of 50.00 $\pm$ 0.093 and 40.00 $\pm$ 0.095 respectively. However, comparable lower mean levels of biological oxygen demand were recorded in both the upstream sampling points for the rainy (12.00 $\pm$ 0.027) and dry (10.00 $\pm$ 0.022) seasons. Only the downstream sampling locations were above the EPA standard (50.00 mg/l).

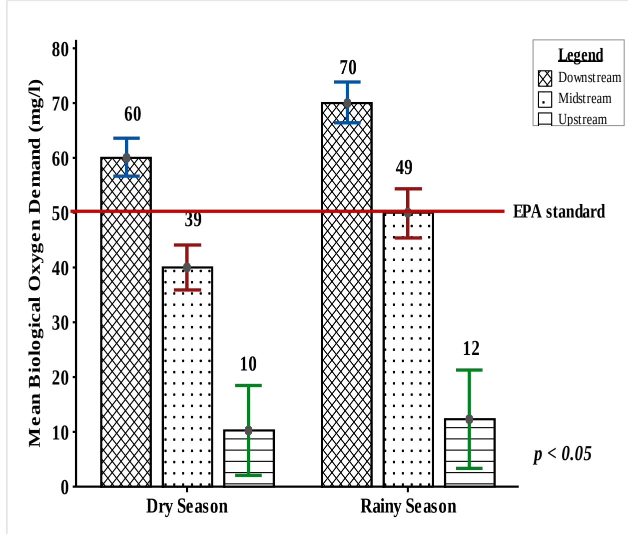


FIGURE 6: Variations of biological oxygen demand in water collected from different sampling locations at different seasons.

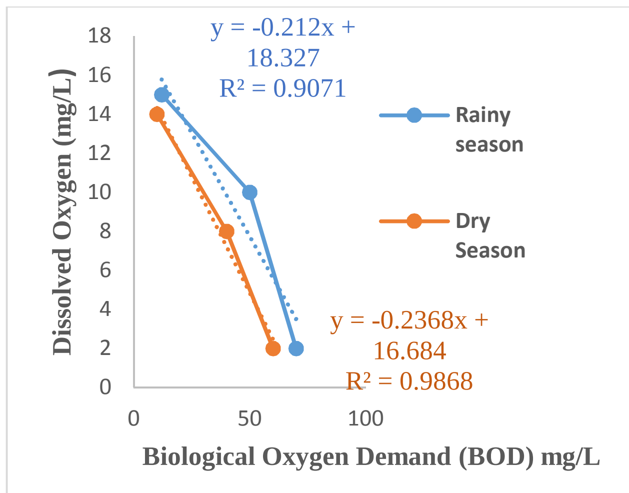


FIGURE 7: Correlation between DO and BOD for rainy and dry seasons.

Dissolved Oxygen

Dissolved oxygen differed significantly across all the sampling locations ($p < 0.05$). Generally, mean levels of dissolved oxygen recorded at different sampling points were higher in the rainy season than in the dry season (Figure 8). Comparable higher mean levels of dissolved oxygen were recorded in the upstream sampling points for the rainy (15.00 $\pm$ 0.191) and dry season (14.00 $\pm$ 0.178). The mean dissolved oxygen in the midstream sampling points for the rainy (10.00 $\pm$ 0.333) and dry season (8.00 $\pm$ 0.267) were also statistically insignificant. However, comparable mean lower levels of dissolved oxygen were recorded in both downstream sampling points for the rainy (2.00 $\pm$ 0.406) and dry seasons (2.00 $\pm$ 0.406). However, there was a strong negative correlation for both rainy and dry seasons at R^2=-0.95 and R^2=-99 respectively.

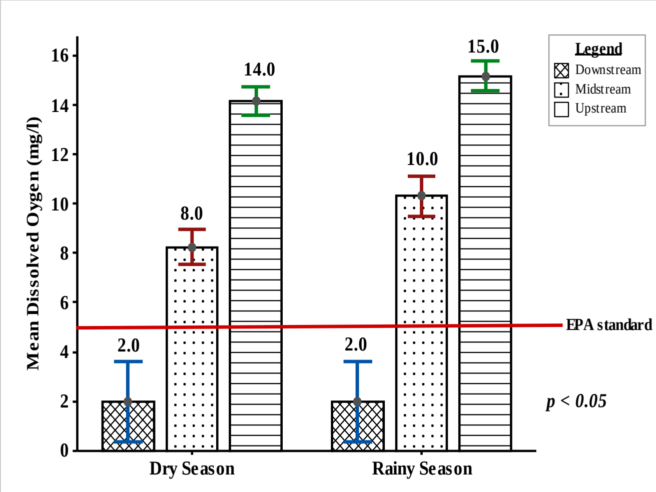


FIGURE 8: Dissolved oxygen variations in water collected from different sampling locations at different seasons.

Nitrate

One – way analysis of variance tests of nitrate showed (Figure 9) significant difference ($p < 0.05$) between sampling locations and different seasons at 5% significance level. Tukey's Pairwise Comparisons Test showed significantly higher mean levels of nitrate concentration in the downstream sampling location for the rainy season (62.40 ± 0.452) than in the dry season (downstream = 59.40 ± 0.504). The midstream sampling points for the rainy and dry seasons recorded mean nitrate concentration of 47.20 ± 0.852 and 44.20 ± 0.697 respectively. However, comparable lower mean levels of nitrate were recorded in both the upstream sampling points for the rainy (4.80 ± 0.052) and dry (4.60 ± 0.022) seasons. Only the downstream sampling locations were above the EPA standard (50.00 mg/l).

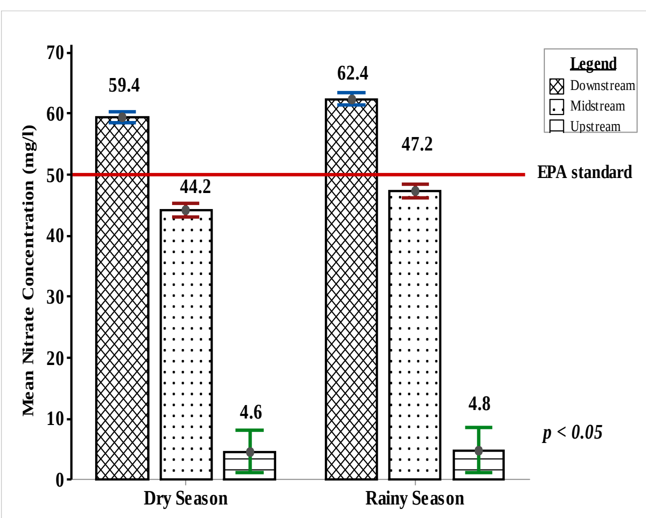


FIGURE 9: Variations of nitrate in water collected from different sampling locations at different seasons.

Phosphate

Statistically significant results at 5% significance level were found in phosphate composition of water in the different sampling locations ($p < 0.05$) over the rainy and dry seasons. Significant higher phosphate was recorded for the downstream sampling point at the rainy season (3.4 ± 0.238) than upstream sampling points (rainy season = 1.2 ± 0.212 and dry season = 1.0 ± 0.301) and the downstream sampling point at the dry season (2.7 ± 0.211). However, mean phospahte in the midstream sampling point at rainy (3.2 ± 0.225) and dry season (3.0 ± 0.187) were comparable. Both the upstream sampling points for the dry and rainy seasons were below the EPA standard (2.0 mg/l) as illustrated in Figure 10.

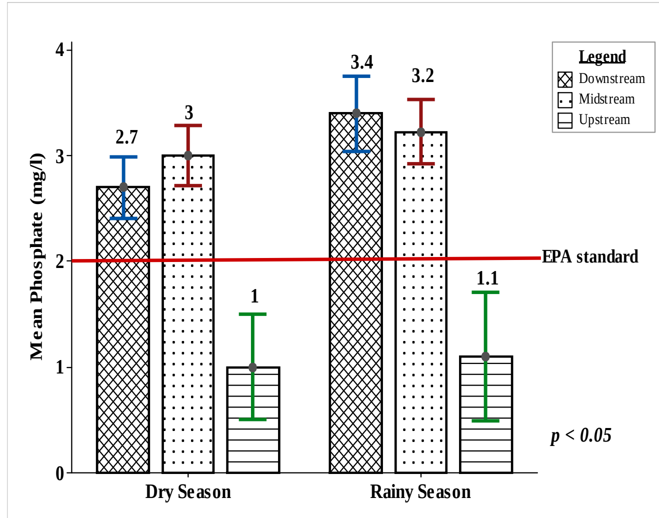


FIGURE 10: Phosphate variations in water collected from different sampling locations at different seasons.

Temperature

One – way analysis of variance tests at 5% level of probability showed no significant difference (*$p > 0.05$*) in the temperature of water collected at different sampling locations as illustrated in Figure 11. Generally, the temperature was higher in the rainy seasons (upstream = (29.1 ± 0.203; midstream = 29.0 ± 0.199; and downstream =28.9 ± 0.146) than in the dry seasons (downstream = 28.2 ± 0.024; midstream = 27.6 ± 0.092 and upstream = 27.2 ± 0.092).

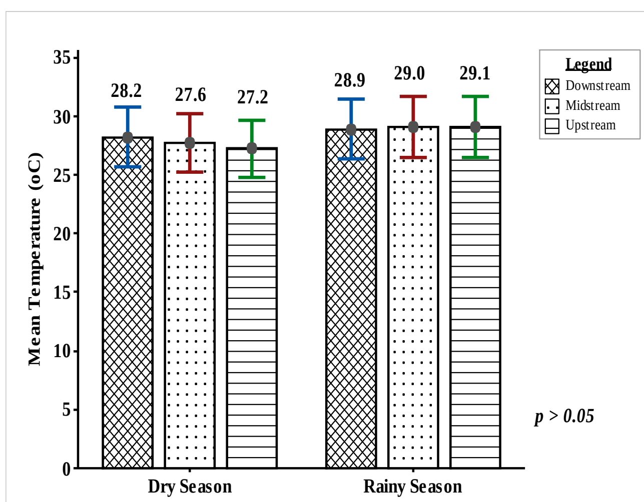


FIGURE 11: Temperature variations in water collected from different sampling locations at different seasons.

Total Dissolved Solids

Results from one-way analysis of variance tests of total dissolved solids showed a significant difference ($p < 0.05$) among sampling locations and across different seasons of the study at 5% probability level. Generally, total dissolved solids in the different sampling locations were higher in the rainy season than in the dry season. Mean total dissolved solids was significantly higher in the downstream sampling point during the rainy season (410.00 ± 3.526) than in the dry season (362.00 ± 4.809). Mean total dissolved solids recorded in midstream sampling locations during the rainy and dry seasons were 308.00 ± 4.409 and 287.00 ± 5.052 respectively. However, upstream sampling points across the rainy (220.00 ± 5.212) and dry (190.00 ± 6.291) season recorded significantly lower mean total dissolved solids. Also, the mean total dissolved solids for the sampling locations across the rainy and dry seasons were below the EPA standard (1000 mg/l) as illustrated in Figure 12.

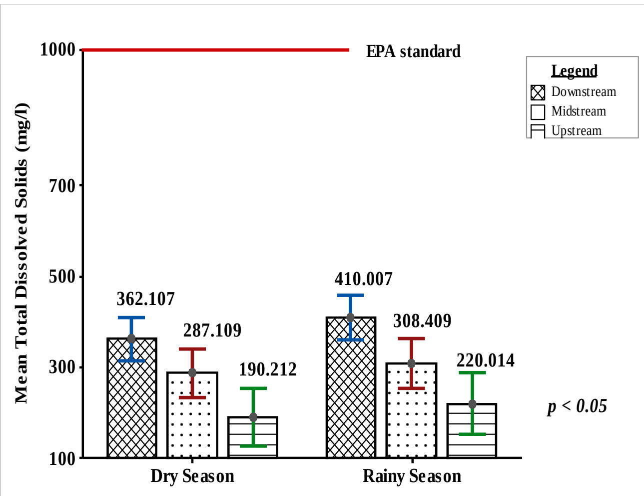


FIGURE 12: Total dissolved solids in water collected from different sampling locations at different seasons.

DISCUSSION

The general objective of this study was to evaluate the present status of the surface water quality and the extent to which the rainy or dry season influence the quality. The results are discussed below in the context of comparison with the standards for surface water quality of local water supply according to the Environmental Protection Agency (EPA), Ghana.

Total Coliform

Results from one-way analysis of variance tests of total coliforms showed a significant difference ($p < 0.05$) among sampling locations and across different seasons of the study at 5% probability level. Generally, total coliforms in the different sampling locations were higher in the rainy season than in the dry season. Mean total coliform was significantly higher in the downstream sampling point during the rainy season (740.00 ± 6.006) than in the dry season (680.00 ± 4.321). This higher variation of count can be attributed to high surface run-off during rainy seasons. However, upstream sampling points across the rainy (360.00 ± 5.212) and dry (300.00 ± 6.291) season's recorded significantly lower mean total coliforms. Also, the mean total coliforms at the upstream were below the permissible level set by EPA for both rainy and dry seasons. The results indicate clearly that the total coliform count increases along the stream, that is, from upstream to downstream. The higher count of total coliform at the midstream and downstream can be attributed to anthropogenic activities (surface run-off, defecation and domestic waste waters disposal) that take place at the midstream and downstream especially during the rainy seasons when run-off is high (WRC, 2003). The values recorded at the midstream and downstream indicate significant and increasing risk of infectious disease transmission when the water is used for domestic purposes. However, similar studies was conducted in Nigeria on the effect of solid waste dumpsite on river water quality, which also shown high level of total coliform bacteria for both seasons (Nkwocha *et al.*, 2011).

Faecal Coliform

Faecal coliforms have been shown to represent 93–99% of coliform bacteria in faeces from humans, poultry, cats, dogs and rodents (WRC, 2003).The variations among the sampling locations and seasons were statistically significant at the 5% level.

Results from Tukey's Pairwise Comparisons Test showed significantly higher mean levels of faecal coliforms in the downstream sampling location for the rainy season (520.00 ± 5.005) than in the dry season (downstream = 400.00 ± 7.017). This can be attributed to higher surface run-off and sedimentation of human excreta (faeces) and other organic waste during rainy season. The midstream sampling points for the rainy and dry seasons recorded mean fecal coliforms of 460.00 ± 9.093 and 380.00 ± 9.005 respectively. However, comparable lower mean levels of fecal coliforms were recorded in both the upstream sampling points for the rainy (72.00 ± 2.027) and dry (70.00 ± 3.081) seasons. The high count of fecal coliform at the midstream and dwonstream can be attributed to indiscriminate defecation and waste disposal coupled with surface run-off down the stream especially during rainy seasons (WRC, 2003). Only the upstream sampling locations were below the EPA standard (**100.00 mg/l**). The value recorded at the upstream indicates clearly that the main cause of fecal contamination is due to disposal of human waste into the stream. The sigficantly high count of faecal coliform increases the risk of transmitting infectious disease if consumed or used for domestic purpose.

pH

Variations in *p*H at all sampling locations and seasons were statistically insignificant (fig. 4) at 5% level. However, higher pH values were recorded in the rainy season (downstream = 6.91 ± 0.214; upstream = 6.90 ± 0.218; and midstream = 6.83 ± 0.322) than in the dry season (upstream = 6.80 ± 0.341; midstream = 6.70 ± 0.148 and downstream = 6.60 ± 0.173). This can be attributed to dissolution of acid by rain (run-off) or introduction of substances which might have altered the acid-base equilibria resulted in the reduced acid-neutralizing capacity and, hence, raising the *p*H. The values measured at all sampling stations and seasons are within the permissible level of EPA (6.5-8.5). Downstream values were lower than upstream values in all the sampling periods. The generally higher values of the *p*H could be due to the release of acid-forming substances such as sulphate, phosphate, nitrates, etc. into the water.

Arimoro *et al,* (2006), stated that microbial decomposition of organic waste in water results in low *p*H, that is, increase acidity. The values measured at the various sampling locations showed that the water is slightly acidic thereby indicating possible decomposition of organic waste in the water. The results showed that the acidic level of the stream could increase if indiscriminate waste disposal continues in the future.

Iron (Fe).

There is statistically significant difference ($p < 0.05$) in iron content at all sampling locations in the different seasons. Significant higher mean iron was recorded in the downstream sampling point at the rainy season (2.80 $\pm$ 0.415). The significantly high amount of iron could be due to sedimentation as a result of surface run off after rainy period (Kensa, 2012). Mean iron recorded in the midstream collection point in the dry season was 1.90 $\pm$ 0.326. Comparable mean iron were recorded in the downstream sampling point for the dry season (1.40 $\pm$ 0.208) and midstream sampling point for the rainy season (1.20 $\pm$ 0.173). However, significant lower but comparable mean iron were recorded in the upstream sampling points for the dry (0.27 $\pm$ 0.013) and rainy (0.25 $\pm$ 0.068) seasons. Also, only the iron content of upstream sampling locations were below the EPA standard (0.3 mg/l) as shown in Figure 5. The acceptable value of iron at the upstream shows less or no anthropogenic disturbance unlike the midstream and the downstream. According to WRC (2003), the concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminium and the occurrence of several heavy metals, notably manganese. Hence, the high values recorded at the midstream and downstream can be attributed to the high turbidity and *p*H level resulting from discharge of waste at these locations (midstream and downstream). Even though Iron in its natural state do not have adverse effect on human health, higher level resulting from contamination can have serious health problems.

Biological Oxygen Demand (BOD)

BOD measures the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidize the organic matter to a stable inorganic form demand. However, High levels of BOD causes the depletion of natural oxygen (Deborah Chapman, 1996). The analysis of variance tests of biological oxygen demand showed (Figure 6) significant difference ($p < 0.05$) between sampling locations and different seasons at 5% significance level. Results from Tukey's Pairwise Comparisons Test showed significantly higher mean levels of BOD in the downstream sampling location for the rainy season (70.00 $\pm$ 0.044) than in the dry season (downstream = 60.00 $\pm$ 0.038) and this may be attributed to high level leachate of untreated organic waste into water bodies during the rainy season (Adeleye & Adebiyi, 2003), and these organic waste could form sludge which may have decomposed through activities of micro-organisms, depleting oxygen levels from the bottom waters (Waldichuk, 1974). The midstream sampling points for the rainy and dry seasons recorded mean biological oxygen demand of 50.00 $\pm$ 0.093 and 40.00 $\pm$ 0.095 respectively. Comparably, lower mean levels of biological oxygen demand were recorded in both the upstream sampling points for the rainy (12.00 $\pm$ 0.027) and dry (10.00 $\pm$ 0.022) seasons. Only the downstream sampling locations were above the EPA standard (50.00 mg/l). Nkwocha *et al.,* (2011) and Iwuoha *et al,*(2013) both conducted a similar studies on *"the effect of solid waste dumpsite on river water quality"* and *"Impact of waste dump on the sediment and surface water quality of Otamiri river"* respectively both in Nigeria. Their results, however shows high level of BOD and an indirect decrease in dissolved oxygen in both rainy and dry seasons which justifies the results obtained in this research.

Dissolved Oxygen

Mccaffrey (1997) stated that, the amount of oxygen in water, to a degree, shows its overall health. That is, if oxygen levels are high, one can presume that pollution levels in the water are low. Conversely, if oxygen levels are low, one can presume there is a high oxygen demand and that the body of water is not of optimal health. From the results, Dissolved oxygen differed significantly across all the sampling locations ($p < 0.05$). Generally, mean levels of dissolved oxygen recorded at different sampling points were higher in the rainy season than in the dry season (Figure 8). Comparably, higher mean levels of dissolved oxygen were recorded in the upstream sampling points for the rainy (15.00 $\pm$ 0.191) and dry season (14.00 $\pm$ 0.178), this may be due to the low level of biological processes. The mean dissolved oxygen in the midstream sampling points for the rainy (10.00 $\pm$ 0.333) and dry season (8.00 $\pm$ 0.267) were also statistically insignificant. However, comparable mean lower levels of dissolved oxygen were recorded in both downstream sampling points for the rainy (2.00 $\pm$ 0.406) and dry seasons (2.00 $\pm$ 0.406) and this can be attributed to the high level of Biological oxygen demand as a results of waste discharges high in organic matter and nutrients leading to a decrease in DO concentrations at both mid and downstream (Deborah Chapman 1996).

Temperature

One – way analysis of variance tests at 5% level of probability showed no significant difference ($p > 0.05$) in the temperature of water collected at different sampling locations as illustrated in Figure 4.10. Generally, the temperature was higher in the rainy seasons (upstream = (29.1 $\pm$ 0.203; midstream = 29.0 $\pm$ 0.199; and downstream = 28.9 $\pm$ 0.146) than in the dry seasons (downstream = 28.2 $\pm$ 0.024; midstream = 27.6 $\pm$ 0.092 and upstream = 27.2 $\pm$ 0.092). Gray et al., (1999) emphasized that growth of bacteria requires that a portion of the electron donor be oxidized to provide the energy needed for biomass synthesis. Energy is also needed for cell maintenance. This oxidation and subsequent use of the energy resulted in the conversion of that energy into heat. Therefore direct seepage of organic waste into water bodies can increase water temperature. The high temperature at the downstream during the rainy season can be attributable to seepage of organic waste resulting from surface run off. Again, locations with high temperature have low dissolved oxygen (figure 11). Temperature has a direct effect on amount of dissolved oxygen in the water (Mccaffrey, 1997). Temperature itself does not have any health effect on human health but gives an idea on the presence of other substances in water.

Nitrate.

According to Chapman (1996), the determination of nitrate in surface waters gives a general indication of the nutrient status and level of organic pollution. From the results (Figure 9), the variations among sampling locations and seasons were statistically significant at 5% significance level. Turkey's Pairwise Comparisons Test showed significantly higher mean levels of nitrate concentration in the downstream sampling location for the rainy season (62.40 $\pm$ 0.452) than in the dry season (downstream = 59.40 $\pm$ 0.504) and this can be attributed to high levels of surface run-off from the site into the river from the early rains (WRC, 2003). The midstream sampling points for the rainy and dry seasons recorded mean nitrate concentration of 47.20 $\pm$ 0.852 and 44.20 $\pm$ 0.697 respectively. However, comparably lower mean levels of nitrate were recorded in the upstream sampling points for both the rainy (4.80 $\pm$ 0.052) and dry (4.60 $\pm$ 0.022) seasons. Only the downstream sampling locations were above the EPA standard (50.00 mg/l) this may be due to the leachate from both solid and liquid waste from the site into the downstream area (WRC, 2003) and (Chapman, 1996) . The high nitrate level at the downstream indicated a decrease in pH value at the downstream (Arimoro, Ikomi, & Osalor, 2006). This however indicate high level of organic pollution at downstream location that may pose adverse health effect.

Phosphate

According to EPA (2001), the significance of phosphorus is principally in regards to the phenomenon of eutrophication (over-enrichment) of lakes and to a lesser extent, rivers. The results (figure 10) shows a statistically significant results at 5% significance level was found in phosphate composition of water in the different sampling locations ($p < 0.05$) over the rainy and dry seasons. Significant higher phosphate was recorded for the downstream sampling point during the rainy season (3.4 $\pm$ 0.238) than upstream sampling points (rainy season = 1.2 $\pm$ 0.212 and dry season = 1.0 $\pm$ 0.301) and the downstream sampling point at the dry season (2.7 $\pm$ 0.211). However, mean phospahte in the midstream sampling point at rainy (3.2 $\pm$ 0.225) and dry season (3.0 $\pm$ 0.187) were comparable, this might be as results of farmers along the banks of the midstream and downstream area probably uses fertilizer, in addition to the presence of the on-site sewage disposal units which has the potential of being leached into the stream (Mccaffrey, 1997). However, the upstream sampling points, where no farming activity and sewage disposal units were observed phosphate levels were below the EPA standard (2.0 mg/l) for both seasons as illustrated in Figure 10.

Total Dissolved Solids (TDS).

TDS content in water indicate the ability of water to dissolve the organic and inorganic constituents. A high concentration of dissolved solids increases the density of dissolving water and reduces the solubility of oxygen gas, creating danger for aquatic life (Bangash *et al.*, 2006). From the results, the variations of TDS among sampling locations and seasons were statistically significant at 5% level. Generally, total dissolved solids in the different sampling locations were higher in the rainy season than in the dry season. High values of TDS in the rainy seasons can be attributed to sedimentation resulting from run off. Mean total dissolved solids was significantly higher in the downstream sampling point during the rainy season (410.00 $\pm$ 3.526) than in the dry season (362.00 $\pm$ 4.809). The high TDS values at the downstream indicate the presence of dissolved substances resulting from surface run off. Mean total dissolved solids recorded in midstream sampling locations during the rainy and dry seasons were 308.00 $\pm$ 4.409 and 287.00 $\pm$ 5.052 respectively. However, upstream sampling points across the rainy (220.00 $\pm$ 5.212) and dry (190.00 $\pm$ 6.291) season's recorded significantly lower mean total dissolved solids. The value of TDS gives an idea on the electrical conductivity of the water and for that matter the presence of heavy metal in the water (EPA, 2001). The values of TDS recorded at all sampling locations and seasons were within the EPA permissible level (1000 mg/l) as illustrated in Figure 12. This therefore shows that the presence of heavy metals could be minimal.

CONCLUSION

The study was aimed at assessing the effect of the Sunyani municipal waste dumpsite on the surface water quality of the "Awuo Kojo" stream which is a main tributary of the Tano River. This was successfully achieved by measuring some key biological, physical and chemical parameters of the stream in comparison with the EPA water quality standards.

The research findings proved that, the physicochemical and microbiological properties of the stream at both midstream and downstream were observed to be significantly higher ($p<0.05$) at a significant level of 5% than the EPA water quality standards for both rainy and dry season as compared to the upstream (control) which were within the acceptable limits of EPA standards for domestic use, with the exception of pH and TDS which were recognized to be within the EPA Standards at all sampling location and in all seasons. However, it was also recognized that the rainy season significantly influenced ($p<0.05$) the level of pollution at the site as compared to the dry season. Based on the scientific facts gathered it can be concluded that the Sunyani municipal waste dumpsite has significant effect on the water quality level of the "Awuo Kojo" stream. There is therefore the need for water resource managers in collaboration with the municipal Assembly to adopt an integrated water treatment approach such as the disinfection of the stream, coagulation, filtration, oxidation, adsorption and other water treatment processes that can help towards the achievement of SDG 6; in ensuring availability and sustainable management of water and sanitation for all.

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