Nigerian Research Journal of Engineering and Environmental Sciences 5(2) 2020 pp. 743-759

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Assessment of the Impact of Industrial Effluents on the Water Quality of River Kaduna, Nigeria

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ARTICLE INFORMATION

Article history:
Received 14 Aug, 2020
Revised 03 Oct, 2020
Accepted 09 Oct, 2020
Available online 30 Dec, 2020

Keywords:
Impact
Industrial effluent
Pollution level
River Kaduna
Water quality

ABSTRACT

Discharge of untreated wastewater into water bodies often results in deterioration of the quality of the receiving water. This study assessed the impact of industrial effluent on the water quality of River Kaduna, Nigeria. Water samples were collected from 12 different locations along the river course including its tributaries, and from four selected industries within Kaduna metropolis discharging effluent into the river. Sampling was conducted in the dry season for a period of four months. Samples were analyzed using standard methods and parameters considered include pH, turbidity, total suspended solids (TSS), temperature, conductivity, total dissolved solids (TDS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nitrate, ammonia, phosphate and microbial (total and faecal coliforms). While some of the parameters analyzed (pH, temperature and nitrate) were within permissible limits of guideline values set by the Federal Environmental Protection Agency (FEPA) of Nigeria, many of them (TSS, conductivity, TDS, BOD_5, COD, ammonia, phosphate, total and faecal coliforms) were not. The value of most of the parameters (pH, DO, temperature, TSS, TDS, BOD_5, COD, nitrate, ammonia, phosphate and faecal coliform) analyzed were higher in the downstream of the sampling points after the industrial discharge points than the upstream. The downstream values of all the parameters were higher than their corresponding upstream values, indicating that discharge of industrial effluent may have impacted on the quality of the river water. Self-purification capacity of the river was not enough to reduce the pollutants levels to acceptable limits. This research shows that industrial effluent is potentially impacting the river water.

1. INTRODUCTION

Water is an essential ingredient for our wellbeing and a healthy life but unfortunately, pollution of this important resource is common throughout the world (EPHA, 2009). Over the last three decades, there has been increasing global concern on public health due to impacts attributed to water pollution, specifically, the global burden of diseases (Emigilati *et al*., 2015). It is estimated that about a quarter of the diseases facing mankind today occur due to prolong exposure to water pollution (WHO, 2004). Most of the water polluted-related diseases are however not easily detected, especially in developing countries (WHO, 2004). Some of them may have been acquired during childhood and later manifest themselves during adulthood (WHO, 2004).

Nigeria is the most populous nation in Africa with a population of more than 180 million. The country is endowed with high potential of water resources. The water resources potential of the country is estimated at 374 billion m^3/year, comprising both ground and surface water bodies (JICA, 2014). The surface water bodies provide resources for fishery, transportation, irrigation, recreation and domestic uses. Yet these surface water sources are often contaminated by rampant and uncontrolled discharges of domestic wastes, industrial effluents and anthropogenic activities as indicated by many researchers (Nefor and Obiukwu, 2005; Emoyan *et al.*, 2006; Nnaji *et al.*, 2007; Kan et al., 2007; Adeyemo *et al.*, 2008; Ebiare and Zejiao, 2010; Uzairu *et al.,* 2014).

Wastewater discharged into water bodies from industrial and anthropogenic activities has a lot of adverse effects on aquatic life and human health (Sam-Okyere, 2015). Industrial effluents are known to contain contaminants and their disposal to water bodies without proper treatment may result to exposure of humans to risk of contaminations (Kirby *et al.,* 2003). The discharge of industrial effluent into water bodies is one of the main causes of surface water pollution and degradation in developing countries including Nigeria (Uzairu *et al.,* 2014). Many of the developing countries lack proper regulations for disposal of domestic, industrial and hazardous wastes (WHO, 2004). For example, different regulations are put in place to protect fresh and marine water resources in Nigeria. However, these regulations have not been effective in controlling the indiscriminate dumping of effluent into open water bodies (Uzairu *et al.,* 2014).

Industrial pollution is one of the major problems affecting Kaduna State in Nigeria due to concentration of manufacturing industries. The rate at which industrial wastewaters are released into rivers is such that these water bodies can no longer undergo the natural self-purification process as good sources of surface water (Abubakari *et al.*, 2016). The industries together with municipal effluents often pollute most of these water bodies. The consequences are high nutrient levels leading to depletion of dissolved oxygen and release of harmful substances which include heavy metals that could bioaccumulate in living organisms in the water (Abalaka, 2015).

Pollution of rivers together with contamination of groundwater affects food production when such waters are used to irrigate crops, and pose great risk to public health (Binns *et al*., 2003). Parameters mostly checked for valuation of water quality and healthy ecosystem of rivers and other freshwater bodies can be grouped into physico-chemical, microbial and heavy metals (Chapman, 1992). However, in an attempt to contribute to understanding of the pollution problems in River Kaduna, this study focused on evaluating the physical and chemical parameters that define the quality of the freshwater body. Thus, the study carried out a comprehensive analysis of industrial effluent discharge along the River Kaduna, and potential impact it could have on the river ecosystem and public health in Kaduna State, Nigeria.

2. MATERIALS AND METHODS

2.1. Study Area

The study area covers Kaduna metropolis in Kaduna State, Nigeria which is located between latitude 9^{o} N and 12^{o} N of the equator and longitude 6^{o} E and 9^{o} E of the prime meridian. The River lies between longitude 8^{o}48'0" N and 5^{o}48'0" E. Geographically, the State lies close to the centre of Northern Nigeria. River Kaduna is a tributary of the Niger River which flows with low current during the dry season. It runs through Kaduna town from the north to south of the city covering an extensive area. The river has a storage reservoir (Kangimi

Dam) in the upper region where water is diverted into two points, the north and south water treatment plants to serve as source of drinking water with a capacity of 240 and 35 million litres per day respectively. Also, it is a major source of water for agricultural (i.e., fruit and vegetables) activities located in the upstream and downstream areas. The major drains carrying industrial effluents are situated at points beyond the Kaduna south water works. The river has a varying seasonal flow pattern with a flow of 2000 m^3/s in the rainy season and to as low as 1 m^3/s in the dry season (Essoka and Umaru, 2006). It is a major sink of most industrial effluents in the city (Essoka and Umaru, 2006). The concern for pollution is within the six months of the dry season (November to May) and particularly in March, which is the peak of the dry season. The river achieves a 200:1 dilution in the rainy season. However, during the dry season, the river becomes an open sewer for wastewater pollution (Emigilati *et al.*, 2015). The layout of the study area and sample collection points is shown in Figure 1.

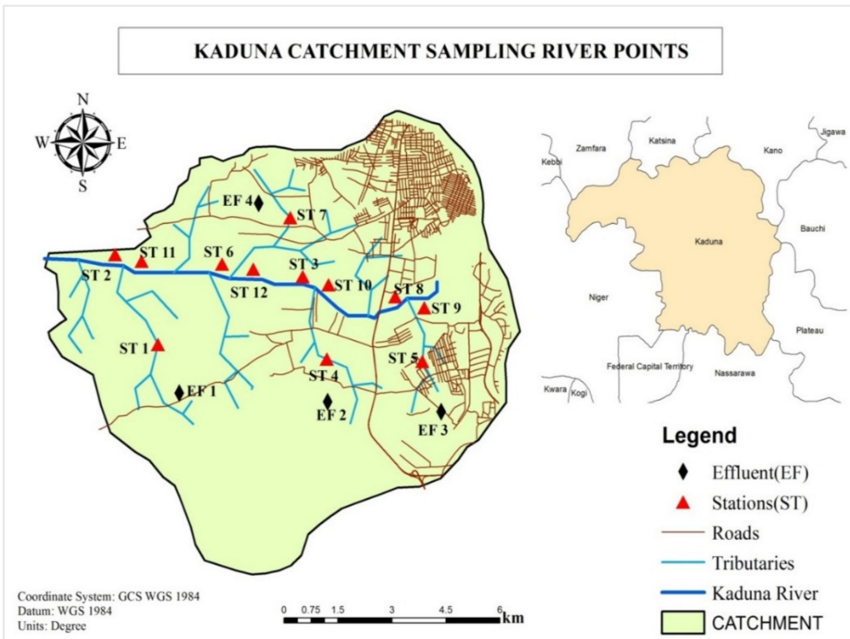

Figure 1: Map of Kaduna showing River Kaduna and sampling points

2.2. Samples Collection and Preparation

Samples were collected for a period of four months (November to February) from the effluent channels leading to the River and from twelve (12) sampling points ST1, ST2, ST3, ST4, ST5, ST6,ST7, ST8, ST9, ST10, ST11 and ST12 along the river (Table 1) and four (4) outfalls of industrial effluent discharge outlets (EF1, EF2, EF3 and EF4) (Table 2). Sampling was carried out along the river course that transverses communities like Kakuri and Kudendan industrial areas and effluent channel outlets of the four industries. GPS coordinates were also recorded at each sampling site. Plastic containers of two litres size were used for sample collection. Sampling was done based on procedures outlined in standard method for the examination of water and wastewater (APHA, 1992). During sampling, each container was rinsed with appropriate amount of sample before final collection. The samples were preserved in ice chest containers, protected from direct sunlight, and transported to the laboratory for analysis.

Table 1: Sampling ID and location

S/N	Sampling ID	Location
1	EF 1	Nice Top Paper Nigeria Limited
2	EF 2	Nigeria Brewery Plc. Kudendan plant
3	EF 3	Nigeria Brewery Plc. Kakuri plant
4	EF 4	CIBI Nigeria Limited
5	ST 1	Downstream of Nice Top Paper tributary before joining River Kaduna
6	ST 2	Upstream of Nice Top Nigeria Limited
7	ST 3	Upstream Nigeria Brewery Plc. Kudendan plant
8	ST 4	Downstream Nigeria Brewery Plc. Kudendan plant
9	ST 5	Downstream Nigeria Brewery Plc. Kakuri plant
10	ST 6	Upstream CIBI Nigeria Limited
11	ST 7	Downstream CIBI Nigeria Limited
12	ST 8	Upstream Nigeria Brewery Plc. Kakuri plant
13	ST 9	Mid-Stream after the discharge point of Nigeria Brewery Plc. Kakuri plant
14	ST 10	Mid-Stream after the discharge point of Nigeria Brewery Plc. Kudendan plant
15	ST 11	Mid-Stream after the discharge point of Nice Top Nigeria Limited
16	ST 12	Mid-Stream after the discharge point of CIBI Nigeria Limited

2.3. Analysis of Physico-chemical Parameters

The physico-chemical parameters were analyzed according to procedures outlined in the standard method for the examination of water and waste water (APHA, 1992). Parameters analyzed are those believed to have effects on drinking water quality and ecosystem of receiving water bodies referred by WHO (2004) and Federal Environmental Protection Agency (FEPA) of Nigeria effluent discharge guidelines of 1991 (FEPA, 1991). These parameters are electrical conductivity, suspended solids, dissolved solids, total solids, pH, dissolved oxygen, biochemical oxygen demand (BOD_5), and chemical oxygen demand (COD). Two basic techniques were used for the analysis were gravimetric and volumetric techniques. The gravimetric technique was used to analyze total solids, dissolved solids and suspended solids, while the volumetric technique was used to determine the level of BOD and COD.

2.4. Analysis of Microbiological Parameters

The membrane filtration method was used for the detection and enumeration of coliforms (Bartram and Pedley, 1996). This method is mostly recommended for microbial analysis of water and wastewater samples. The water and effluent samples were filtered through the membrane that is capable of retaining the bacteria. The membrane was incubated for a minimum of 14 hours on membrane lauryl sulphate media measuring device (MMD) at a temperature of 37 ℃ or 44 ℃ depending on the coliform being determined (total or faecal coliform respectively).

2.5. Quality Control

Measures were taken to ensure quality control throughout the entire sample collection, preparation and analysis. For each batch of samples collected and processed, blanks were prepared, and these blanks were used as guide in the analysis of and determining if the samples were contaminated. Replicate samples were collected throughout the sampling period, and this assisted in enhancing precision.

2.6. Data Analysis

The results obtained from the laboratory analysis were analyzed using Microsoft Excel. One way ANOVA with 5% significant level was used to determine whether there was significant difference between the locations and the results obtained from analysis of the river water quality.

3. RESULTS AND DISCUSSION

3.1. Physico-chemical Parameters

The physico-chemical and microbiological analyses of samples from four outfalls of industrial effluent discharge into the River Kaduna revealed the following values presented in Table 2.

Table 2: Parameters measured in samples from selected industries

Parameter	Nice Top Paper Nigeria Limited (EF1)	Nigeria Brewery Plc. Kudendan plant (EF2)	Nigeria Brewery Plc. Kakuri plant (EF3)	CIBI Nigeria Limited (EF4)	Maximum permissible limit by FEPA
pH	6.40	5.50	9.00	7.03	6-9
DO (mg/l)	7.78	1.10	0.90	7.07	5
Temperature	19.8	22.6	16.6	21.5	30^o
TSS (mg/l)	473	340	162	291	50
TDS (ppm)	487	2240	1751	532	1000
EC (μScm^{-1})	1064	4580	3715	1153	1500
Turbidity (NTU)	340	84	99	300	75
BOD (mg/l)	43	100	90	47	50
COD (mg/l)	310	1800	480	270	250
Nitrate (mg/l)	8	14	18	9	50
Ammonia (mg/l)	3.03	3.95	1.90	2.04	1.0
Phosphate (mg/l)	8.6	5.06	2.4	4.5	5
Total coliform (MPN/100ml)	920	1350	480	950	400
Faecal coliform (MPN/100ml)	402	450	500	1000	400

3.1.1. pH

From results presented in Table 2, it was observed, that the pH values of samples from outfalls of the industrial effluent discharge points were in most cases within the limit set by FEPA except for the effluent from the Brewery Plant in Kudendan which was below the limit. The low pH value from the Brewery Plant could be attributed to raw materials such as grains and yeast that are partially acidulous in nature (Abubakari *et al.*, 2016). Also, processes such as washing of bottles and cleaning, where cleaning detergents are used as well as addition of additives for preservation of beverages (e.g., Sodium benzoate C_6H_5COONa and common salt – NaCl) can contribute to low pH values (Ijeoma and Achie, 2011; Abubakari *et al*., 2016). Since most metabolic activities of aquatic organisms depend on pH, it implies that aquatic life of the river may be affected by the low pH. Additionally, the pH has great impact on the river water quality by affecting metals solubility, alkalinity and degree of hardness or softness of the water (Abubakari *et al*., 2016).
The pH levels recorded within River Kaduna at the time of the study ranged from 5.50 to 9.00 Station ST1 recorded the highest value of pH (7.84) which is the downstream of the paper processing plant while station ST12 which is the mid-stream recorded the lowest (6.0). All the pH values recorded during the study were

within the permissible level of FEPA Guidelines values of 6-9 as shown in Figure 2. Furthermore, there was no statistically significant difference between stations (p= 0.242).

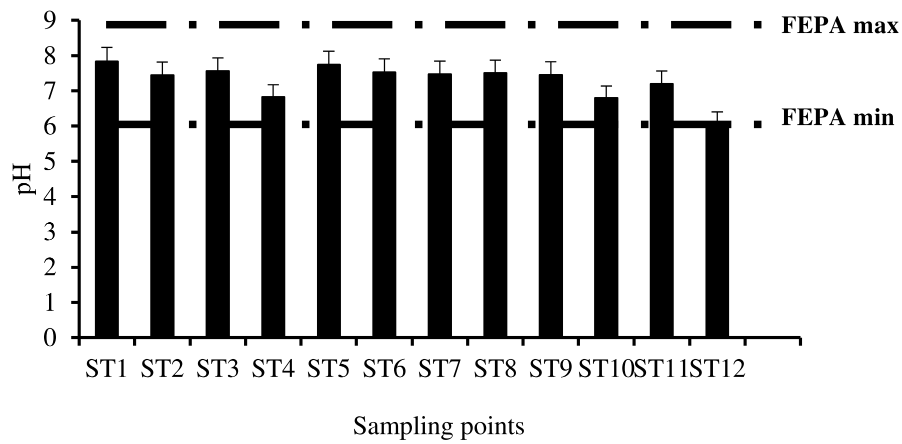

Figure 2: pH values recorded from the river sampling points

3.1.2. Dissolved oxygen (DO)

The dissolved oxygen concentrations at the effluent sampling points range between 0.90 mg/L (low) at site EF3 to 7.78 mg/l (high) at site EF1 as presented in Table 2. The DO values recorded at location EF4 (CIBI Nigeria Limited) and EF1 (Nice Top Papers Nigeria Limited) were slightly above the permissible level of FEPA of 5 mg/l, which is good for the river ecosystem. However, the DO values recorded at EF2 (the Brewery plant's effluent at Kudendan) was low below the FEPA limit. The low values of DO recorded in those industries indicate high microbial activity in the effluent from the industries (Abubakari *et al.*, 2016). This may contribute to depleting oxygen level in the receiving water body.

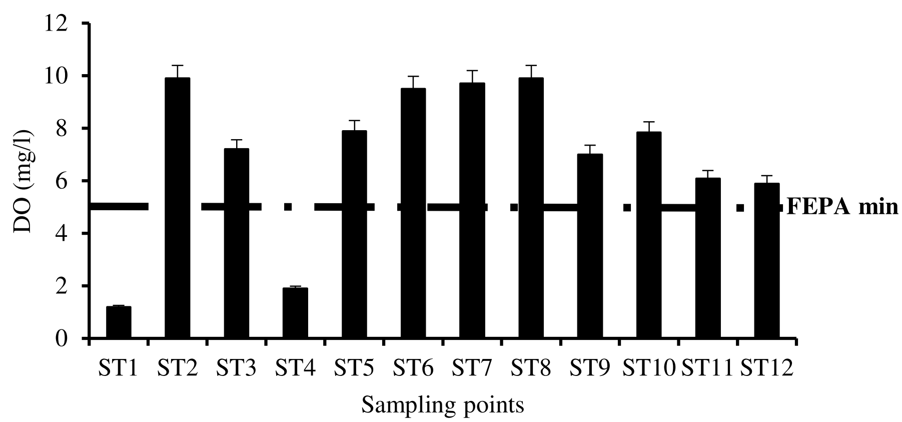

Figure 3: DO values recorded from the river sampling points

The DO levels recorded within the river sampling stations were between 1.20 mg/l to 9.90 mg/l. The highest DO levels were recorded at stations ST2 and ST8 located upstream of the paper processing and alcohol and beverages industries respectively, whereas the lowest values were recorded at ST1 and ST4. The DO levels observed in most of the stations were above the FEPA water quality guideline value of 5 mg/l as shown in Figure 3. However, the low levels of DO recorded at ST1 and ST4 downstream of the paper processing and alcohol and beverages industries could be attributed to the high level of nutrients and organic loads contents of effluents from those industries which may require high levels of oxygen for chemical oxidation and organic decomposition thereby depleting available oxygen in the river water (Emigilati *et al.*, 2015). Generally, the DO levels of most of the sampling stations can be considered satisfactory since most of the values were within acceptable limits set by FEPA. Analysis of the results shows that there was no significant difference between stations with a p-value of 0.191 ($p>0.05$).

3.1.3. Temperature

Temperature is a very vital parameter that controls dissolution of gasses in water such as carbon dioxide and oxygen. The amounts and levels of chemical reactions are also affected by temperature. High temperature of up to 36 ^oC can affect microorganism (Chapman, 1992). The temperature values recorded in the industrial effluents ranged between 16.6 ^oC and 22.6 ^oC as presented in Table 2. The highest value was recorded at EF2 while the lowest was recorded at EF3. All the temperature values recorded in the industrial effluents were within the FEPA guideline of less than 30 ^oC. The temperature values recorded in the river ranged from 16.6 to 23.8 ^oC as shown in Figure 4. Stations ST3 (upstream) and ST10 (downstream) recorded the highest values of 22 ^oC and 23 ^oC respectively. The results were within the permissible level of FEPA guidelines value. Furthermore, the temperature difference between stations was statistically insignificant ($p=0.557$, $p>0.05$).

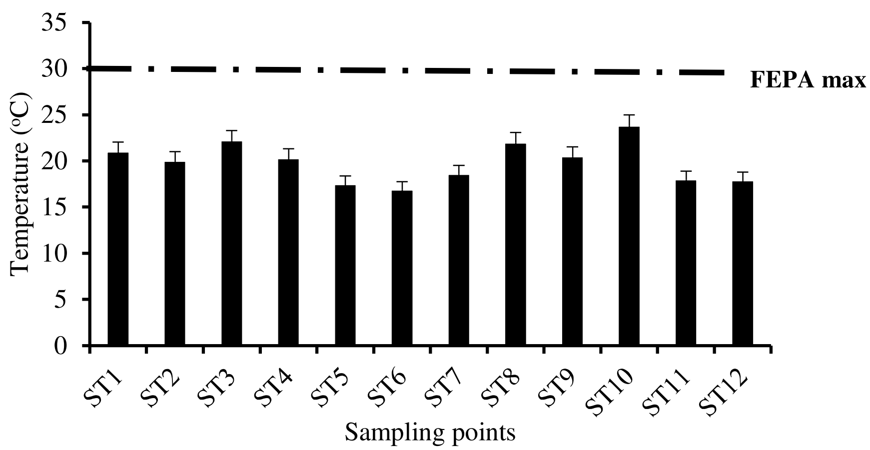

Figure 4: Temperature values recorded from the river sampling points

3.1.4. Total suspended solids (TSS)

The level of TSS in the effluent discharged by all the industries was well above the FEPA limit as presented in Table 2. Effluent mean concentrations of 162 mg/l, 340 mg/l, 291 mg/l and 473 mg/l were recorded at all the industrial outfall points as against the limit of 50 mg/l set by FEPA. The high concentration of TSS in the industrial effluents could be due to particles such as clay, silt, organic and inorganic compounds from the production processes of the industries that include paper making, brewing and manufacture of granite materials. The high concentration of TSS can affects light penetration in water and consequently food production (photosynthesis) by aquatic plants (Abubakari *et al.*, 2016). The high TSS values may indicate non-compliance with the established permissible discharge limit into receiving water bodies. The concentration of TSS found in the river water ranged from 112 mg/l to 401 mg/L (see Figure 5). The highest TSS value was recorded at ST5 and the lowest was recorded at ST2 located upstream of the paper processing industry. The TSS concentrations recorded were all above the FEPA guidelines value of 50 mg/l. The higher TSS concentrations recorded at stations downstream of the industries is an indication of industrial pollution as a result of raw materials used by these industries such as spent grains, yeast etc. When such effluents are discharged into the stream, light penetration reduces which may have implication for aquatic plants (Abubakari *et al.*, 2016). The difference between the TSS concentration among sampling stations were found to be statistically insignificant (p=0.638, p>0.05).

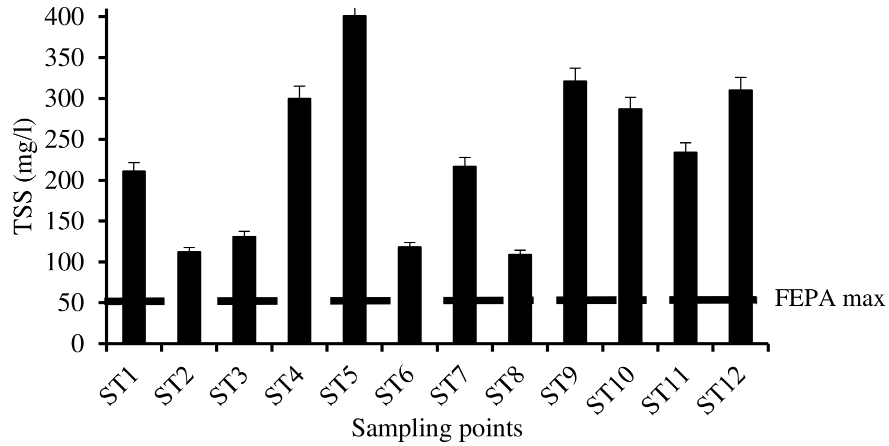

Figure 5: TSS Concentrations recorded from the river sampling points

3.1.5. Total dissolved solids (TDS)

The total dissolved solids (TDS) concentration recorded in the industrial effluent samples ranged between 487 ppm and 2240 ppm as presented in Table 2. The highest value was recorded at EF2 (Nigeria Brewery Plant, Kudendan) and the lowest TDS concentration value was recorded at EF1 (Nice Top paper Nigeria limited). The TDS values observed in the industrial effluent were within FEPA effluent quality guideline limit of 1000 ppm, except for stations EF2 and EF3. The high level of TDS could be attributed to nitrogenous wastes from the industries which may include partially digested food from inorganic solids such as chloride, nitrate, and phosphate anions (Abubakari *et al.*, 2016). The discharge of effluents from the industries without adequate treatment may have resulted in an increase in TDS and TSS level downstream as compared to upstream sites.

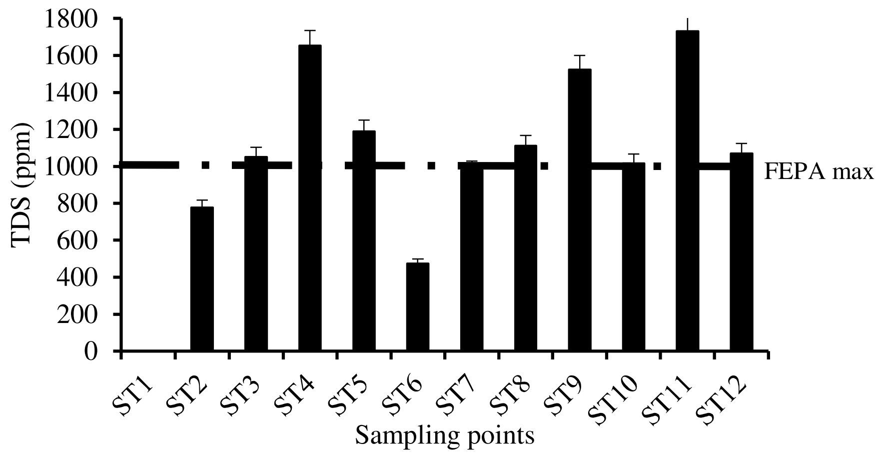

Figure 6: TDS concentrations recorded from the river sampling points

The total dissolved solids recorded in the river during the same period were between 476 ppm to 1732 ppm as shown in Figure 6. The highest value of 1732 ppm was recorded at site ST11 and the lowest value 476 ppm was recorded at site ST6 which is a station located upstream. The low TDS values recorded at ST2, ST6 and ST7 were within the FEPA limit of 1000 ppm. High values recorded in other stations were however above the FEPA limit. Furthermore, it was observed that the TDS values in the upstream stations were lower as compare to the downstream stations. This may be attributed to the discharge of effluents by the industries into the river. ANOVA results shows there is significant difference between stations as p-value is 0.029 ($p<0.05$).

3.1.6. Electrical conductivity (EC)

The electrical conductivity recorded in the effluent samples during the study ranged between 1064 µs/cm and 4580 µs/cm as presented in Table 2. The lowest value was recorded at station EF1 (Nice Top Nigeria Limited) and the highest value recorded at station EF2 (Nigeria Brewery Plant, Kudendan). However, the values recorded at station EF1 and EF4 were within the permissible limit of 1500 µs/cm by FEPA. The EC values recorded at station EF2 and EF3 were above the FEPA effluent guideline value. The high conductivity level observed in the effluent of those industries could be attributed to presence of inorganic solids such as chloride and phosphate anions, or sodium, calcium and aluminium cations (Lokhande *et al*., 2011). The EC values recorded in the river water ranged between 900 µs/cm and 2978 µs/cm as shown in Figure 7. The lowest value of EC was recorded at ST7, while the highest was recorded at ST1. The EC values recorded was observed to be above the permissible level of 1500µs/cm by FEPA, except for stations ST2 and ST7 whose values were within the set limit. The high trend of EC observed in the river water is an indication of impact of industrial effluent on the quality of water in River Kaduna. ANOVA analysis revealed that there was statistically significant difference between stations ($p=0.027$, $p< 0.05$).

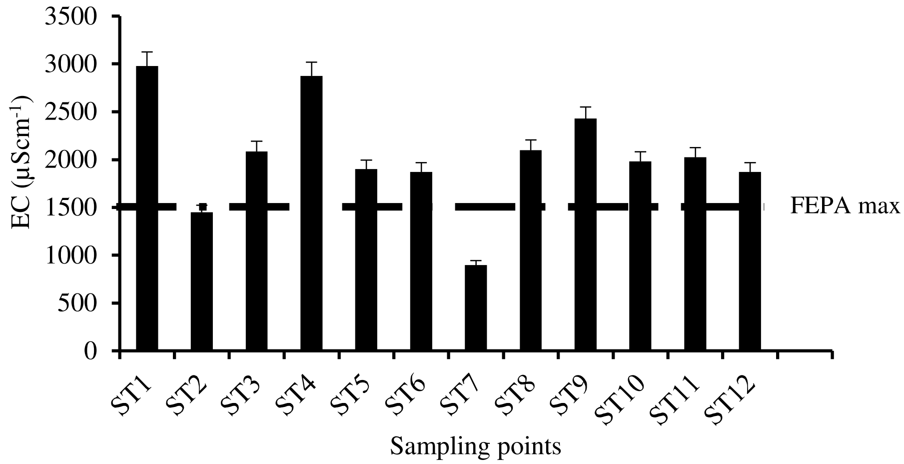

Figure 7: EC values recorded from the river sampling points

3.1.7. Turbidity

Turbidity in water is caused by the existence of suspended matters such as clay, silts, and fine particles of organic and inorganic matters, plankton and other microscopic organism. An industrial effluent with high turbidity values can contribute to influx of high amounts of suspended solids to receiving surface water bodies. The turbidity level recorded in the industrial effluents ranged between 84 NTU and 1000 NTU as presented in Table 2. The highest value of the turbidity was recorded at EFI (Nice Top papers Nigeria limited) and the lowest was recorded at EF2 (Nigeria Brewery Plant, Kudendan). The turbidity concentrations recorded in the industrial effluents were all above the FEPA effluent quality guideline of 75

NTU. On the other hand, the turbidity values recorded in the river water were between 30 and 170 NTU (Figure 8).

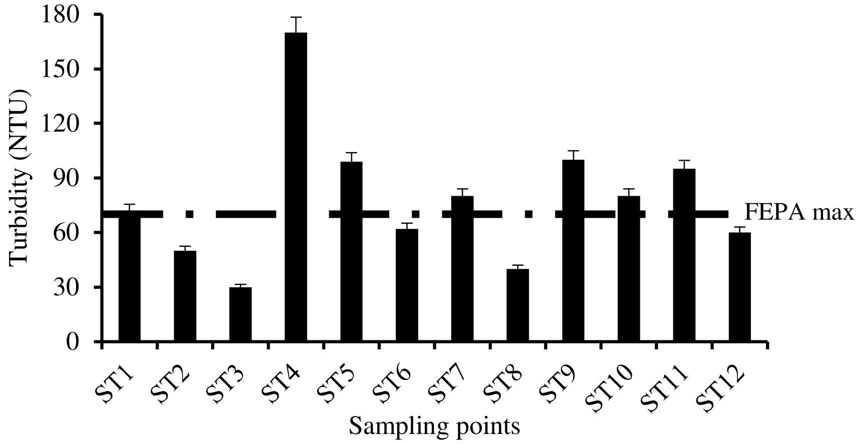

Figure 8: Turbidity levels recorded from the river sampling points

The highest turbidity value was recorded at ST4, and the lowest was recorded at ST3 which is upstream of the alcohol and beverages industries. The turbidity values recorded were above the FEPA permissible limit of 75 NTU, except for ST2, ST3 and ST8 located upstream which were below the limit. However, it was observed that the turbidity concentration levels at upstream location before the discharge points of the various industries were lower than at the downstream location just after the discharge points along all the tributaries where the industries are discharging their effluent. The high turbidity recorded at ST4 could be due to the discharge of the effluents from the Nigeria Brewery Plant Kudendan. High level of turbidity in water affects light penetration, plant productivity, and habitat quality. The higher level of turbidity can also inhibit photosynthesis by blocking sunlight. ANOVA analysis show that the difference between the stations with regards to turbidity was statistically insignificant ($p= 0.394$, $p>0.05$).

3.1.8. Biochemical oxygen demand (BOD)

The biochemical oxygen demand in the industrial effluent ranged from 100 mg/l (high) to 43 mg/l (low) as presented in Table 2. The highest BOD_5 value was recorded at EF2 (Nigeria Brewery Plant Kudendan) and the lowest was recorded at EF1 (Nice Top paper Nigeria limited). The BOD_5 values recorded in the industrial effluent were above the FEPA effluent guideline value of 50 mg/l, except for stations EF1 and EF4 that recorded lower values. The high BOD_5 concentration recorded at those sites may be due to the Brewery industry wastes that produce large quantities of degradable organic nutrient. The impact of high concentration of BOD can cause anaerobic condition which may affect aquatic ecosystem, fish, smell and other aesthetic values of the water. The BOD_5 concentrations recorded in the river water ranges from 30 mg/L to 120 mg/L (Figure 9). The highest value was recorded at ST5 (located downstream immediately after the discharge point of the alcohol and beverage industries) and the lowest value was recorded at ST8 (upstream). The high BOD_5 concentration observed in stations located downstream of the industries were all above the permissible limit of 50 mg/l set by FEPA. The high BOD concentration at the sampling locations could be attributed to discharge of industrial effluents with high level degradable organics. The concentration difference between stations was not statistically significant ($p=0.414$, $p> 0.05$).

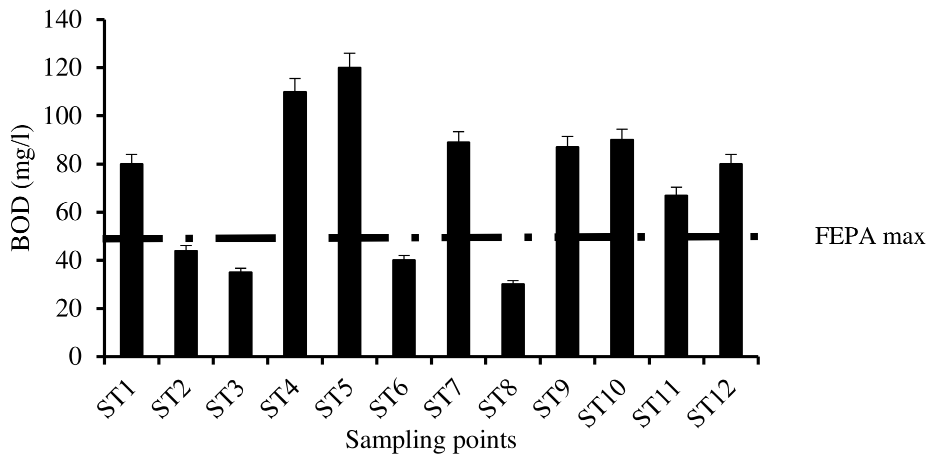

Figure 9: BOD levels recorded from the river sampling points

3.1.9. Chemical oxygen demand (COD)

The chemical oxygen demand concentrations of the industrial effluents were between 270 mg/l and 1800 mg/l as presented in Table 2. The highest COD concentration was recorded at EF2 and the lowest value was recorded at EF4. These results recorded were all above the acceptable limit of 250 mg/l set by FEPA. The high level of COD recorded in the Brewery Plant at Kudendan may be due to inadequate treatment of wastewater from the industry. The presence of high level of COD in the industrial effluents is an indication of presence of wastes such as organic and inorganic solids and chemicals which must have been added during processing operations by the industries (Attiogbe *et al.*, 2009; Diya'uddeen *et al.*, 2014). The COD concentrations of the river water during the study were between 150 mg/l and 600 mg/l as shown Figure 10.

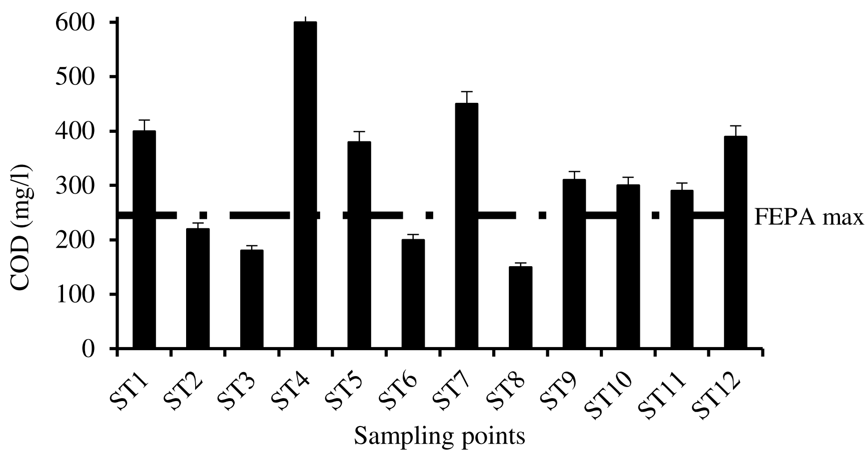

Figure 10: COD concentrations from the river sampling points

The highest concentration was recorded at ST4 (located downstream immediately after the discharge point of the alcohol and beverage industries) and the lowest concentrate was observed at ST8 (located upstream). The results recorded at the downstream points were above the FEPA water quality guideline of 250 mg/L. The high level of COD concentration at those sampling points is an indication of discharge of wastewater from the industries along the river course. The high COD concentration can increase turbidity level, clog fish gills and affect other aquatic life. Analysis of the results using ANOVA shows that there is no statistically significant difference in the concentration between stations ($p=0.781$, $p> 0.05$).

3.2. Nutrients

3.2.1. Nitrate

The concentration of nitrate in the effluent of the industries varied from 8 mg/l at EFI (Nice TOP Paper Nigeria Limited) to 18 mg/l at EF3 (Brewery Plant at Kakuri) as presented in Table 2. The values recorded were all within the permissible level of EFPA effluent quality guideline value of 50 mg/l. Industrial wastes containing food remains, preservatives and organic compounds rich in nitrogen can be major sources of nitrate. Despite the low levels of nitrate in the effluents, its presence in water is a good pointer of nutrient pollution. High concentration of nitrate has a harmful effect on living organism (Peter, 1998). Also, nitrate can pose great risk to public health since its presence in high concentrations can support the growth of algae in the water which can damage water quality (Bastawy *et al.,* 2006). The nitrate concentration was found to be between 0.8 mg/L and 32 mg/L as shown in Figure 11. The lowest nitrate concentration was recorded at site ST8 and the highest was observed at ST5 which is located downstream after the discharge point of the alcohol and beverages industries. The nitrate values in the river water from all the sampling points were all within the FEPA limit of 50 mg/L. Although, nitrate concentration at all the sampling points were within the FEPA however it was observed that the level of nitrate was higher at downstream locations after the discharge points of the industries compared to the upstream sites along the river course. The higher values observed downstream after the discharge points of the industries indicates that industrial wastewater is having impact on the quality of water in the river. Analysis of the results using ANOVA shows that the variation of concentration of nitrate was insignificant along the sampling stations ($p= 0.296$, $p>0.05$).

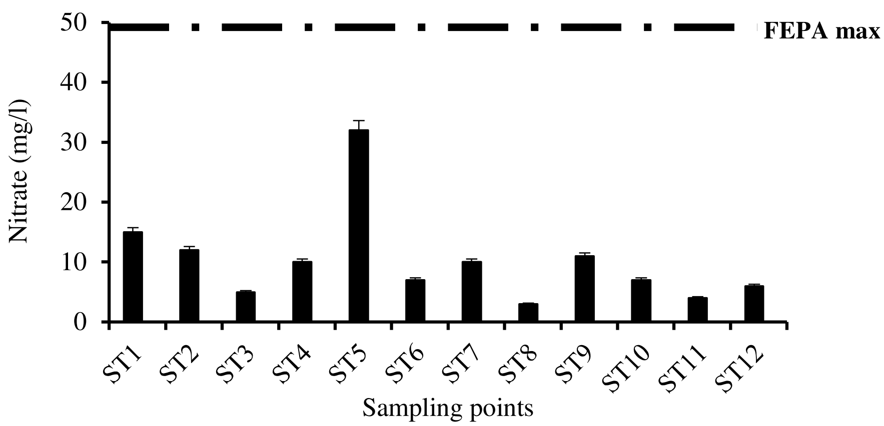

Figure 11: Nitrate level recorded from the river sampling points

3.2.2. Ammonia

The concentrations of ammonia – nitrogen in the industrial effluents were found to be between 1.90 mg/l and 3.95 mg/l as presented in Table 2. The highest value was recorded at EF2 (Brewery Plant at Kudendan) and the lowest concentration value was recorded at site EF3 (Brewery Plant at Kakuri). The ammonia – nitrogen concentration in the industrial effluent recorded throughout the study period were all above the acceptable limit of 1 mg/l set by FEPA. The high level of ammonia – nitrogen concentration in the industrial effluent could be due to organic load and use of ammonium bicarbonate as one of the raw materials used by the industries. The high ammonia levels in the effluent discharged may cause algal bloom or eutrophication in the river. The concentration of ammonia –nitrogen in the river water was found to be between 0.14 mg/L and 4.5 mg/L as shown in Figure 12. The highest concentration was recorded at ST4 (downstream of Brewery Plant at Kakuri) and the lowest was observed at ST10. The ammonia – nitrogen recorded in most of the sampling points along the river were within the permissible limit of 1 g/l set by FEPA, except for sampling points ST4 and ST5. The sampling points recorded values of 3 mg/L and 4.5 mg/L respectively. The higher concentration level recorded in the two sampling points may be due to effluents discharged by the alcohol and beverages industries. Because the sampling points (ST4 and ST5) are located immediately after the discharge points of these industries. ANOVA analysis shows that there is no statistically significant difference between sampling points in terms of concentration ($p = 0.702$, $p > 0.05$).

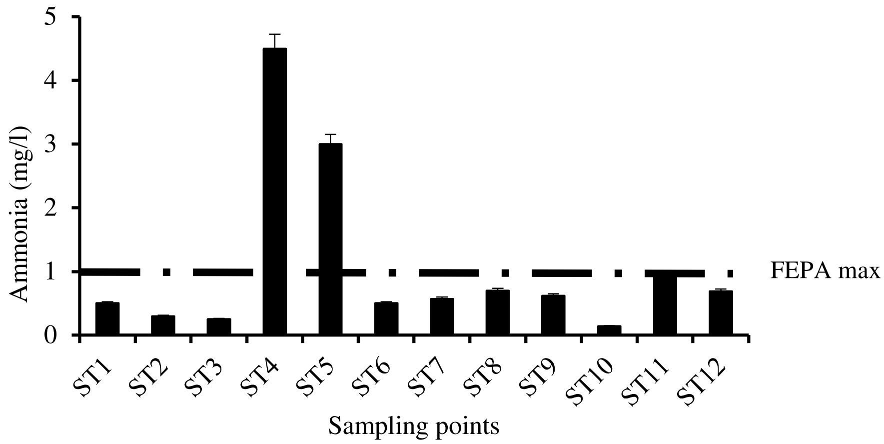

Figure 12: Ammonia concentration recorded from the river sampling points

3.2.3. Phosphate

The concentrations of phosphate recorded in the industrial effluents were between (2.4 mg/l and 8.6 mg/l) as presented in Table 2. The highest concentration recorded was at EFI (Nice TOP Paper Nigeria Limited) and the lowest value was recorded at EF3 (Brewery Plan at Kakuri). The Phosphate concentrations recorded during the study period were within the FEPA limits of 5 mg/l except for sampling point EF1.

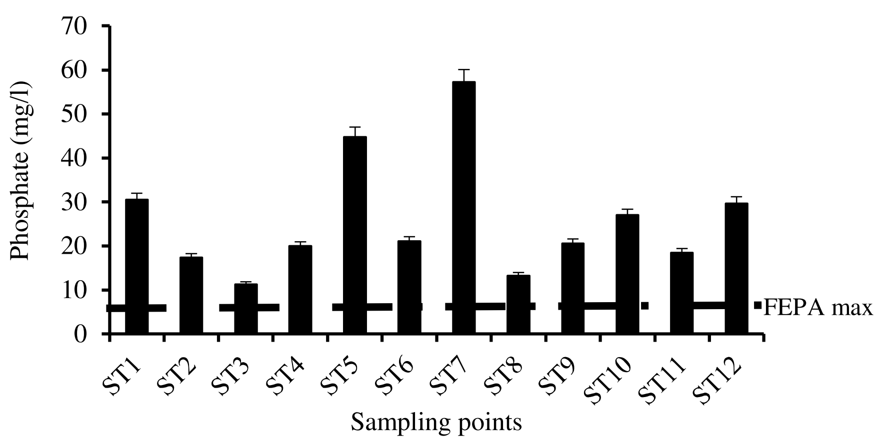

Figure 13: Phosphate concentrations recorded from the river sampling points

The high level of phosphate concentration recorded at EF1 may be due to use of phosphate containing substances by some of the industries in the manufacturing processes and detergents for washing and cleaning. Concentrations of phosphate recorded in the river water ranged between 11.31 mg/l to 57.25 mg/l as shown in Figure 13. Highest phosphate concentration was obtained at ST7, whereas the lowest concentration was obtained at ST3. The phosphate concentrations recorded in the river water were all above the permissible limit of 5 g/l set by FEPA. However, the concentration levels obtained at sampling points upstream of the industries are far lower than that those of the downstream. The high levels of phosphate may be due to the discharge of effluents from the industries. Phosphate concentration greater than 0.1 mg/l is regarded as unacceptable in most freshwater system (Ipeaiyeda and Onianwa, 2011). Phosphate combining with the available nitrate can cause an increase in algae growth and eutrophication. Results of ANOVA analysis show that there is no significant difference between sampling points ($p=0.097$, $p> 0.05$).

3.3. Microbiological Parameters

3.3.1. Total coliform (TC) and faecal coliform (FC)

Analysis of the industrial effluents revealed low value of TC of 480 MPN/100 ml at EF3 (Brewery Plant at Kakuri) and a high value of 1350 MPN/100 ml at EF2, the industrial effluent of Brewery Plant at Kudendan as presented in Table 2. Similarly, the FC recorded ranged between 402 MPN/100 ml at EF1 (Nice Top Paper Nigeria Limited) and 1000 MPN/100 ml at EF4 (CIBI Nigeria Limited) (Table 2). All the values recorded for both TC and FC in the industrial effluents were above the FEPA limit of 400 MPN/100 ml. The TC levels observed in the river water were found to be between 470 MPN/100 ml at ST4 and 1600 MPN/100 ml at ST11 (Figure 14). Also, the FC values recorded ranged between 490 MPN/100 ml at ST4 and 1600 MPN/100 ml at ST10 as shown in Figure 15. The total and faecal coliforms recorded both in the river water were all above the FEPA water quality and effluent quality guideline values of 400 MPN/100 ml. The high level of coliform concentration could be attributed to the high organic matter content which serves as food for bacteria growth. The presence of high coliforms is an indication of the present of microbial nutrients which obviously can promote growth of coliforms. This condition can result in high health risk to human pose by these categories of microorganisms especially when the river water is used for irrigation in growing crops like vegetables (Mosley *et al.,* 2005). ANOVA analysis shows that there was no statistically significant difference between the stations in terms concentration levels both TC ($p=0.698$, $p> 0.05$) and FC ($p= 0.60$, $p> 0.05$).

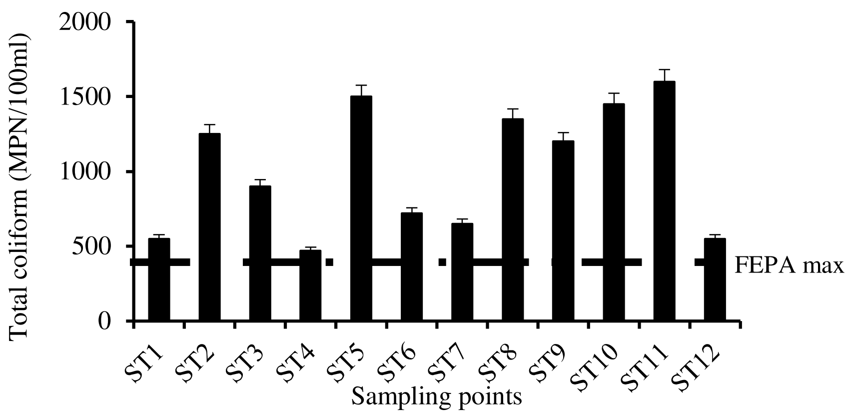

Figure 14: Total Coliform values recorded in the river water

M. Deinmodei et al. / Nigerian Research Journal of Engineering and Environmental Sciences
5(2) 2020 pp. 743-759

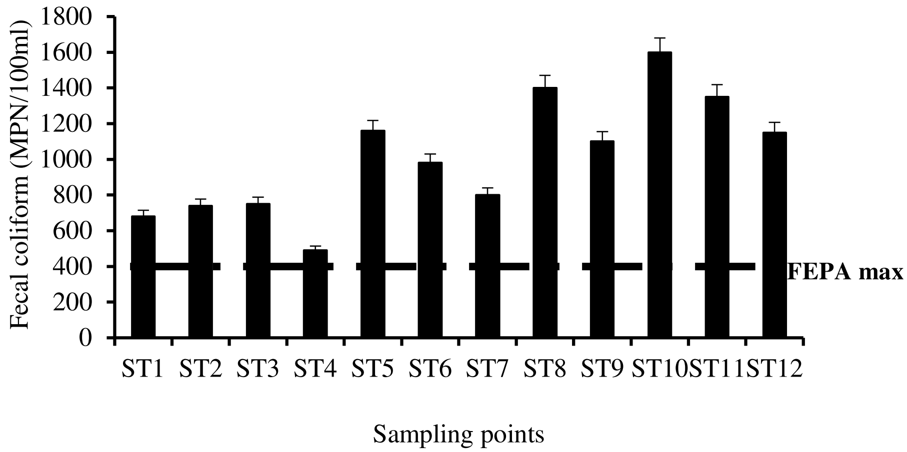

Figure 15: Faecal Coliform values recorded in the river water

4. CONCLUSION

Results of analysis from this study show that effluent discharges from surrounding industries have a negative impact on the water quality of River Kaduna. This can be explained by the fact that there were increases in concentration of some of the parameters analyzed downstream after each discharge points as compared to upstream sampling locations. Although, some of the parameters analyzed during the study period were within the permissible limits set by the Federal Environmental Protection Agency (FEPA, 1991) guideline values however many were not. The continued discharge of effluents by these surrounding industries into River Kaduna without any form of pre-treatment may result in accumulation of contaminants that may affect the lives of human as well as aquatic flora and fauna in the river. Moreover, compliance of the river raw water quality with the FEPA guidelines revealed that the BOD, COD, DO, TSS, phosphate and microbial parameters (total and faecal coliforms) were all above the FEPA water quality guidelines. These are important parameters often used as indicators of pollution level of river systems. This may be interpreted to mean that the health of people who use the river water for domestic and other purposes could be at risk. River Kaduna is an important source of water to the communities along its course. Considering the impact of contamination especially discharges from surrounding industries, regulating agencies need to intensify effort to monitor and enforce the appropriate regulations and pollution laws in order to protect the river and guide against further deterioration of the river water quality.

5. ACKNOWLEDGMENT

The authors wish to express appreciation for the funding support provided by the Regional Water and Environmental Sanitation Centre, Kumasi (RWESCK), at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, which is funded by the Government of Ghana and the World Bank under the Africa Centres of Excellence Project. The authors also wish to thank the National Water Resources Institute (NWRI), Nigeria, for providing opportunity and support for the study that led to the generation of knowledge and information presented in this article.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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