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The impact of industrial effluents from Dakace industrial area on the physicochemical properties of River Galma, Zaria, Nigeria

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ABSTRACT

River Galma basin around Dakace Industrial Layout, Zaria, Nigeria, was studied between May 2011 and May 2012 to determine the Influence of Industrial effluents from the Industrial Area, on the water Quality of the River by comparing the levels of physico-chemical parameters of water quality in the upstream area before the identified effluent discharge points (Point sources) and downstream after the effluent discharge points. Results indicated that Temperature, Electrical Conductivity, Total Dissolved Solids, Total Suspended Solids, Alkalinity, pH, Turbidity and Chloride showed the range 21.4-35.2 °C, 32.00-182.00 µS/cm, 25.02-77.09 mg/l, 27.38-78.24 mg/l, 15.81-140.85 mg/l, 4.00-7.68, 32.30-458.00 NTU and 17.02-318 mg/l respectively. All the parameters examined showed significant seasonal variation ($P < 0.05$), Temperature being the only exception. Most of the parameters analyzed (Temperature, Electrical Conductivity, Total Dissolved Solids, Total Suspended Solids and Alkalinity) were found to be within World Health Organization (WHO) and US-EPA permissible limit for drinking water quality. pH, Turbidity and Chloride were however, seriously implicated. It was established from the results that industrial discharges had negative impact on the surface water quality of the river. Hence, extraction of water from the river for domestic and agricultural purposes requires some forms of physical and chemical treatment.

Key words: River Galma, Industrial effluent, Water quality, Physico-chemical parameters, WHO limits.

INTRODUCTION

A report by WHO on the global disease burden indicates that 24% of the disease burden is attributable to environmental factors. The key environmental factors implicated include; pollution of air, water and land resulting to potential exposure to chemical or biological agents in the form of toxic heavy metals, endocrine disruptors, carcinogens or airborne particulates [1]. Man have facilitated the dispersion and accumulation these undesirable substances in the environment. That our environment is under increasing pressure from human activities world over is by now beyond debate. With the rapid development in agriculture, mining, urbanization, and industrialization activities, surface water contamination with hazardous waste and wastewater has become a common phenomenon [2; 3]. Most industrial and municipal wastes end up in rivers, lakes and the sea, therefore the idea of continuous monitoring of water quality receives global attention [4]. Surface water pollution is an environmental problem on a global scale considering the fact that water pollution transcends international boundaries. While developed nations adopt stringent laws to control water pollution, the situation is different in most developing countries like Nigeria, waste treatment is not given the priority it deserves, Water bodies are constantly used as receptacles for untreated industrial and domestic waste, and (or) poorly treated effluent from industrial activities [5]. The consequence is increased water pollution, loss of aquatic life and uptake of pollutant by plant and animals which eventually get into the human body resulting in health related problems. Despite this inadequacy, the conservation and management of the available water bodies which most often than not act as supplement for the scarce pipe borne water is very poor [5].This situation is compounded by the fact that access to portable water remains one of the greatest challenges of the common man in most of these countries, and in many instances the raw river water is used as a source of drinking water [6]. Studies have shown that water sources are easily contaminated from anthropogenic activities [7; 8], the notion therefore that water, one of nature, greatest gift to man is inexhaustible and can assimilate and diffuse anything put into it is fast fading out [3]. Unregulated inputs of contaminants into the natural environment therefore pose a range of both short-term and long-term environmental risks. Water quality and human health are closely related. Polluted water is the major source for the spread of many epidemics and some serious diseases like cholera, tuberculosis, typhoid, diarrhea etc [9]. The World Health Organization (WHO) estimated in 1996 that every eight seconds a child dies from water – related disease and that each year more than five million people died from illnesses linked to unsafe drinking water or inadequate sanitation [10].

Water for human consumption must be free from microorganisms and chemical substances in concentration large enough to cause environmental imbalance and diseases [11]. Hence, physicochemical properties of water sample are relevant parameters that directly or indirectly affect water quality and suitability of such water for consumption, domestic, industrial and agricultural uses. Water is vital to our existence and its importance in our daily life makes it imperative that thorough microbiological and physio-chemical examinations be conducted on water. Potable water is the water that is free from disease producing microorganisms and chemical substances that are dangerous to health [12].

Reports on water quality of some rivers are available [13; 3; 6]. Though reports on water quality contamination of several coastal and inland waters in Nigeria abound, periodic monitoring of the effect of discharges on the water quality is absolutely necessary especially for Rivers like River Galma around Dakace where human population is high and industries are concentrated. This study investigates the influence of industrial discharges on the physico-chemical parameters of water quality of Galma River, a major tributary of river Kaduna in northern Nigeria.

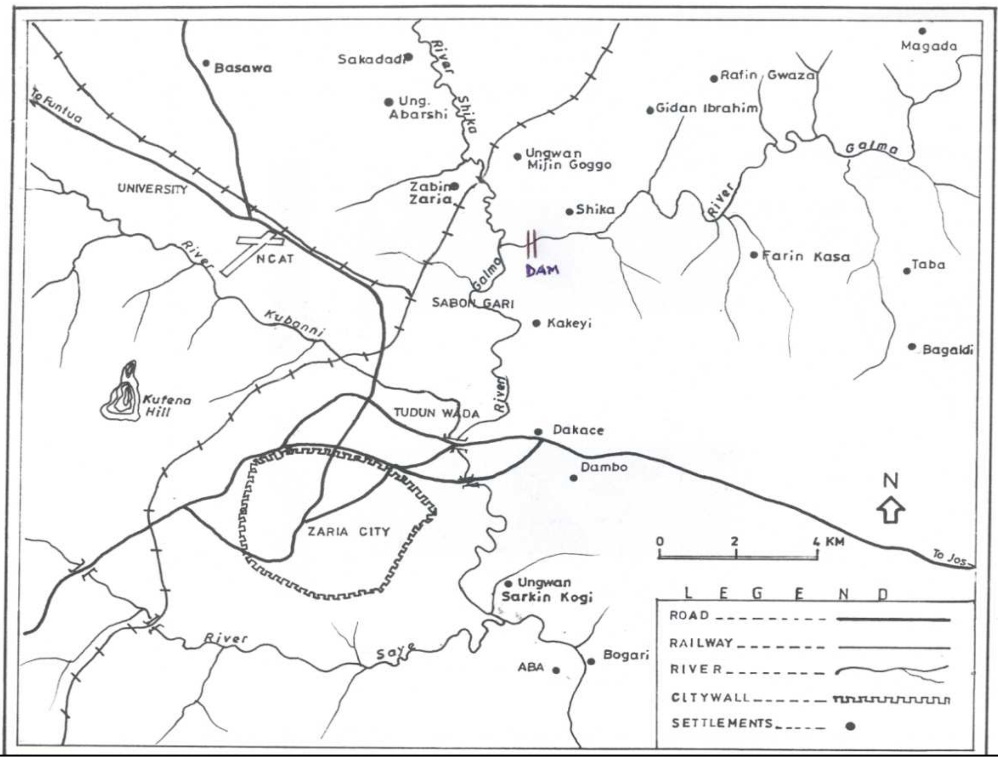

Figure 1: ZARIA SHOWING RIVERS AND SETTLEMENTS

MATERIALS AND METHODS

Study Area

River Galma is the main drainage channel in Zaria since other rivers and streams discharge into it. Zaria is in the North central Kaduna state of Nigeria and is located at latitude 11º3'N and longitude 7º40'E, 128 km South- East of Kano and 64 km North-East of Kaduna City [14]. River Galma is located at the southeastern part of Zaria and its source is the Jos Plateau. The Zaria dam is located on River Galma [15]. Dakace industrial area habours a number of wet industries such as oil mills, packaging, food and beverages industries. Effluents from these industries are discharged through drains and canal that empties into the River. The Galma river basin is a booming agricultural area. Crops are planted on both sides of the riverbank throughout the year. Fertilizers, herbicides and insecticides are used on these crops and are eventually washed into the river via surface runoff [14]. The river is a major source of water supply to a number of communities located along its course. It is used for irrigation, fishing, bathing and even drinking

Sample collection and Preservation

The procedure for sample collection and analysis was adopted from [16]**.** Four sampling points 200 meters apart were established along Galma River around Dakace industrial area after identifying effluent discharge points (point sources) from the industries. Sampling point A was 200 meters upstream from the first point source. Sampling point B was at the first point source. Sampling point C was after the second and third identified effluent discharge points and sampling point D was 200 meters from sampling point C. Sample containers were thoroughly washed with detergent, rinsed with water followed by distilled water before soaking in 5% nitric acid for about 24 hours. Water sample was collected from each of the four sampling points by simple scooping using plastic bucket. Collected water sample was poured into the washed 2-litre polypropylene container. Electrical conductivity, temperature and total dissolved solids were determined on site using HACH conductivity / TDS meter (model 44600.00, USA), pH was also determined on site electronically using Zeal–tech digital pH meter (model 03112, India). The samples were kept in cooler stock with ice block and transported to the Environmental Laboratory of National Research Institute for Chemical Technology, (NARICT) Zaria, Nigeria, at temperature of < 4^{o}C.

Sample preparation and analysis

Chloride was determined using Morh's method, one hundred (100) milliliters of water sample was measured into a 250ml conical flask and pH was adjusted to 8 with 1MNaOH. 1 ml of K_2CrO_4 indicator was then added and titrated with $AgNO_3$ solution. A blank titration was carried out using distilled water. Chloride (mg/l) was calculated according to APHA [16]. Alkalinity was done according to Ademoroti, [17]. 100ml of sample was measured into 250ml conical flask. Two drops of methyl orange was added, shaken, titrated with 0.02M tetraoxosulphate (VI) acid to a pH of 4.6 and alkalinity calculated. In the determination of Total suspended solid, a glass fibre filter paper 5.5mm diameter was dried to a constant weight in an oven at 105^{0}C. It was then cool to room temperature in a desiccators and the weight noted. A gooch funnel about the same size of the glass fibre was prepared. Rubber adapter and a filtering flask were fixed and connected to vacuum pump. The glass fibre was carefully placed in the funnel. A 100ml of a well shaken sample was quickly filtered. The glass fibre was carefully removed, dried to a constant weight at 105^{0}C and suspended solid calculated according to Ademoroti [17].

RESULTS AND DISCUSSION

The mean and standard deviation of results obtained for physico-chemical parameters of the water sampled from River Galma around Dakace industrial area are presented in Tables 1. The results obtained shows that there is a wide variation in the quality of drinking water from the River. The overall temperature ranged from 21.4°C to 35.2°C with a mean value of 28.27±4.32°C during the dry season and from 22.3°C to 31.5°C with a mean value of 27.02±2.43°C during the wet season. The mean temperatures for the dry and wet seasons were found to be 28.26±4.47°C and 28.47±3.13°C for station 1, 28.16±4.63°C and 27.03±2.26°C for station 2, 28.18±4.81°C and 27.31±2.36°C for station 3, and 28.48±4.81°C and 27.26±2.48°C for station 4 (Figure 2). The difference in temperature between the dry and wet season was not statistically significant ($P > 0.05$). No statistically significant spatial variation in temperature was also observed in the study (ANOVA, $P > 0.05$). The slightly lower mean dry season temperature observed in station 1 compared to mean wet season temperature may be due to the Harmatan that was severe between December and February in the area and that the other sampling stations did not follow the trend may be due to discharge of effluents of slightly higher temperature at the identified point sources. The mean temperature values reported for the different sampling points in this study were within the WHO standards of 30 ^{O}C-

35 ^{O}C for drinking water quality [18]. Similar temperatures have been reported for other rivers in Nigeria. Average temperatures of 28°C and 26°C were reported for River Ona and River Alaro in Ibadon, Nigeria [19]. A mean temperature of 28.5°C was reported for downstream area of River Galma while 25.7°Cwas recorded for upstream area of river Galma in 2011[14]. Udiba et al [20] reported arrange of 25.5-31.4 for the Calabar river estuary. Temperature impacts both the chemical and biological characteristics of surface water. Increase in temperature leads to increase in solubility. At high temperatures TDS is increased as more solute goes into solution. It also affects how much oxygen the water can hold. Cold water holds more oxygen. Extreme changes in temperature can place stress on the organisms within an ecosystem. Therefore, temperature is important to aquatic plants and animals and the overall health of the water [21]. Surface Water temperature above 40 ^{O}**C** depicts polluted water [22]. The water temperature observed in this study is therefore within the permissible limit of water temperature for inland waters.

Table 1: Physico-chemical parameters of water samples collected from River Galma round Dakace Industrial Estate, Zaria, Nigeria

Sampling Stations / Parameters	Sampling Point 1		Sampling Point 2		Sampling Point 3		Sampling Point 4	
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
Temperature	28.26±4.47	28.47±3.13	28.16±4.63	27.03±2.26	28.18±4.81	27.31±2.36	28.48±4.81	27.26±2.48
pH	6.63±1.05	6.78±0.18	6.44±1.23	6.69±0.10	6.54±0.99	6.67±0.30	6.26±1.40	6.65±0.28
Electrical conductivity	103±52.37	70±39.70	136±57.81	67.5±37.75	135±42.00	73±39.11	134.75±46.75	81.75±21.88
Total Dissolved Solids	49.45±10.07	30.32±4.52	59.06±13.20	34.06±7.75	65.88±15.1	35.01±7.77	61.70±15.56	35.51±9.65
Total Suspended Solid	34.6±7.43	66.44±3.50	38.92±9.55	70.22±1.90	43.26±13.0	74.78±4.90	40.18±8.77	68.49±0.34
Turbidity	37.43±5.09	265.25±95.32	39.49±1.57	273.25±5.64	44.38±2.69	278.5±5.40	42.02±2.69	282.5±13.19
Alkalinity	40.55±23.92	29.19±16.94	59.69±53.99	23.95±6.02	56.51±41.5	22.02±4.28	57.69±5.71	23.67±7.80
Chloride	152.61±1.45	83.82±5.60	137.14±1.33	72.73±6.03	137.14±1.0	55.22±4.72	74.11±5.59	82.81±2.91

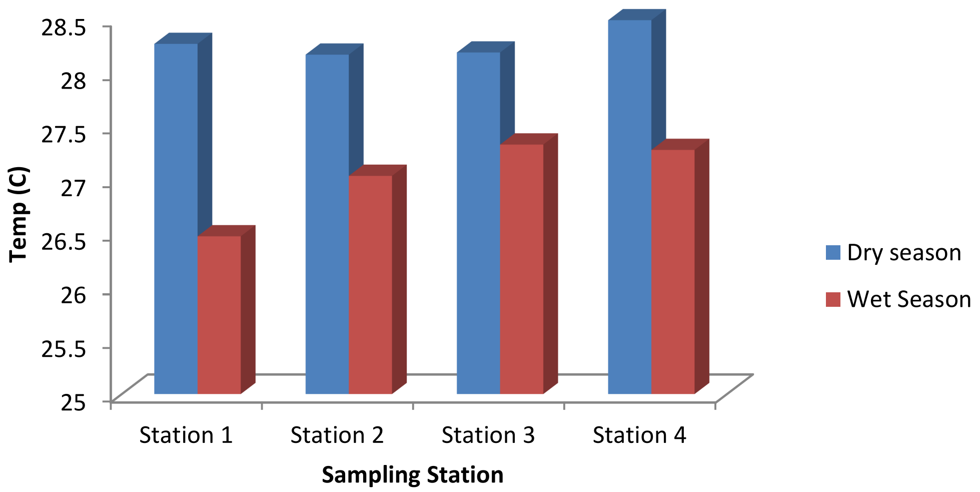

Figure 2: Spatio-seasonal variation of temperature of River Galma around Dakace industrial area

pH ranged from 4.00 to 7.68 with a mean value of 6.47±1.09 in the dry season and from 6.17 to 7.00 with a mean value of 6.70±0,21 in the wet season. The mean pH values for the dry and wet seasons were found to be 6.63±1.05 and 6.78±0.18 for station 1, 6.45±1.23 and 6.69±0.10 for station 2, 6.54±0.98 and 6.67±0.30 for station 3 and, 6.26±1.40 and 6.66±0.28 for station 4 (Table 1, Figure 3). Mean pH value was found to be higher in the wet season than wet season but the difference was not statistically significant at 95 % confidence level. The higher wet season pH values may be due to dilution as a result of larger volume of water in the wet season. All through the study, pH of surface water from station 1 (200 meters from the first identified effluent discharge point) fell within the pH range (6.5-8.5) assigned by EPA as standard pH of water, making it suitable for portability with respect to pH [23]. Sampling stations 2, 3 and 4 recorded slightly acidic pH values that were outside the acceptable range of pH values for unpolluted waters in the dry season. This observation may be attributed to the discharge of effluents with low pH values into the river. The observed spatial variation in pH was not statistically significant (ANOVA, P > 0.05). A similar range of pH values (5.94-7.34) was reported for Calabar River [20]. pH ranges of 7.43-7.60 and 6.88-7.59 were reported for River Ona and River Alaro in Ibadon, Nigeria [19]. Mean value of 6.98±0.36 was reported for the downstream area of river Galma and 7.5±0.27 for the upstream area in 2011 [14]. Although not definitive, pH of aquatic system is an important indicator of the water quality and the extent of its pollution. pH has profound effect on water quality as it affects the solubility of metals, alkalinity and hardness of water. The survival of aquatic organisms is also greatly influenced by the pH of the water bodies in which they are found. This is because most of their metabolic activities are pH dependent [20; 24; 25]. If the surface water pH shift too far either way from the acceptable range (6.5-8.5), highly mobile aquatic organism tend to migrate to safer environments while the life of sedentary organisms are susceptible to loss. At lower pH, sulphides present in water begin to evolve as hydrogen sulphide resulting in toxic conditions. Again at lower pH the corrosive effect of the discharges on concrete is increased, Metals generally tend to be more soluble and more reactive at lower pH. Discharges are therefore preferred to be more alkaline.

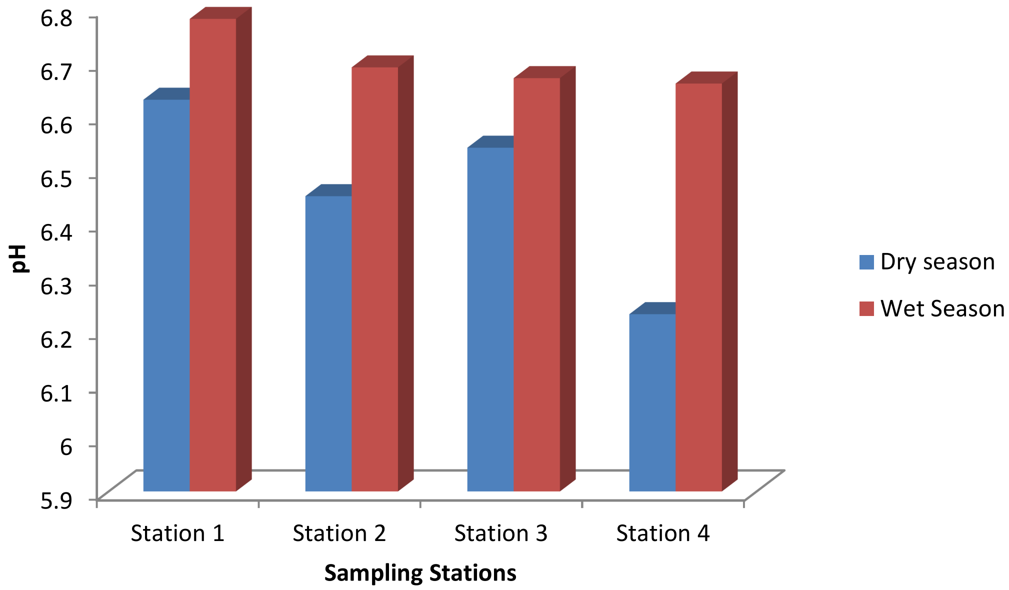

Figure 3: Spatio-seasonal variation of pH of River Galma around Dakace industrial area

Electrical conductivity ranged from 42 µS/cm to 182 µS/cm with a mean value of 127.19±49.79 µS/cm in the dry season and from 32 µS/cm to 110µS/cm with a mean value of 73.06±32.13 µS/cm in the wet season. The mean conductivity values for the dry and wet seasons were found to be 103.00±5.23 µS/cm and 70.00±3.97 µS/cm for station 1, 136.00±5.78 µS/cm and 67.50±3.77 µS/cm for station 2, 135.00±4.20 µS/cm and 73.00±3.91 µS/cm for station 3 and, 134.75±4.68 µS/cm and 81.75±2.19 µS/cm for station 4 (Table 1). Electrical conductivity was significantly higher in the dry season than wet season (P < 0.05). The lower conductivity values observed during the wet season may be due to dilution as a result of increase in the volume of water. Conductivity values were minimum at sampling station 1 and maximum at sampling station 3 (Figure 4) in dry season. The increase in conductivity from sampling station 2 downstream may be due the influence of effluent discharged into the river from the identified point sources at sampling stations 2 and 3. The observed spatial differences across the sampling stations were not statistically significant (ANOVA, P > 0.05). In the present study, the conductivity values were less than the recommended standard of 750 µS/cm [26], hence with respect to electrical conductivity, the water can safely be used for domestic and agricultural purposes. Similar electrical conductivity ranging from 93 µS/cm to 120 µS/cm in the downstream area and from 80 µS/cm to 103 µS/cm in the upstream area of River Galma was previously reported [14]. Conductivity of water is a measure of the ability of the water to conduct electricity due to the presence of ionic solutes. The magnitude of the conductivity therefore is a useful indication of the total concentration of the ionic solute.

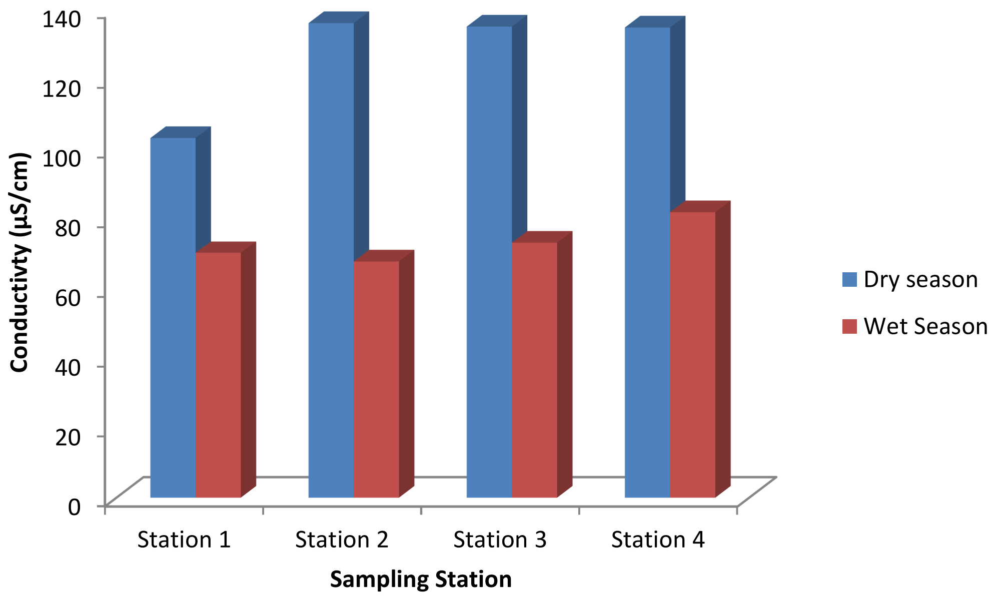

Figure 4: Spatio-seasonal variation of Conductivity of River Galma around Dakace industrial area

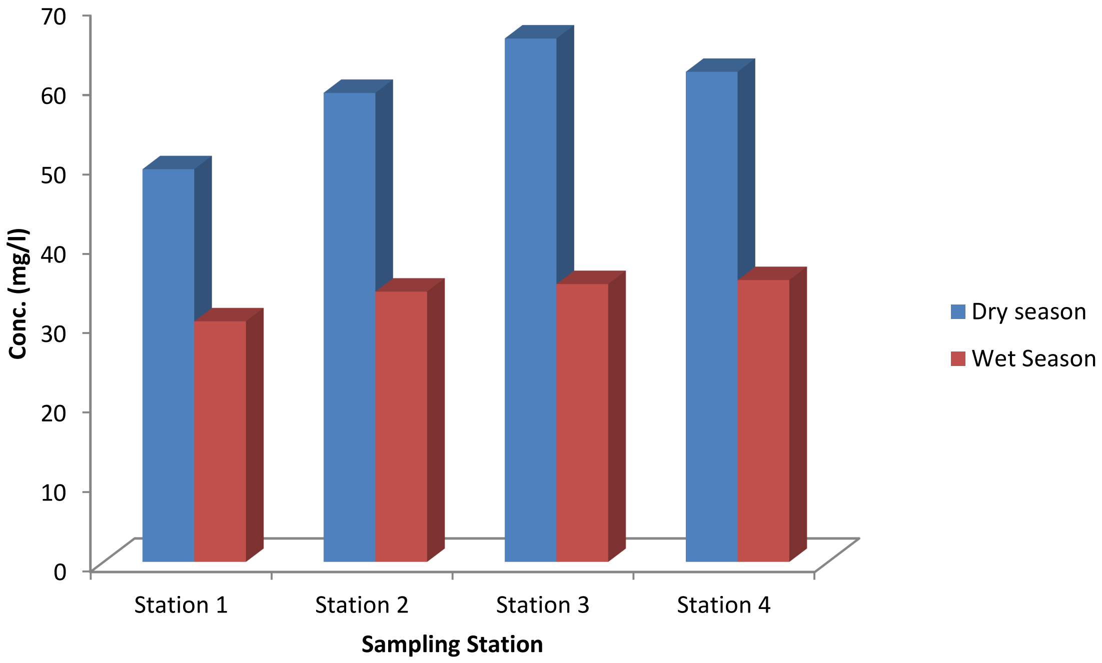

FIG. 5: Spatio-seasonal variation of TDS of River Galma around Dakace industrial area

Total dissolved solids (TDS) ranging from 36.65 mg/l to 77.09 mg/l with a mean value of 59.02±13.70 in the dry season and from 25.02 mg/l to 44.42 mg/l with a mean value of 33.72±7.43 in the wet season were observed. The mean TDS values for the dry and wet seasons across the sampling stations were 49.45±10.07 mg/l and 30.33±4.52 mg/l for station 1, 59.06±13.20 mg/l and 34.06±7.75 mg/l for station 2, 65.88±15.10 mg/l and 35.02±7.77 mg/l for station 3 and, 61.70±15.50 mg/l and 35.51±9.65 mg/l for station 4. TDS was significantly higher in the dry season than the wet season. This observation may also be due to dilution as a result of increase in water volume in the wet season. Higher mean temperature was recorded in the dry season. Solubility increases with increase in temperature. This may also account for the TDS values in the dry season. TDS values were minimum at sampling station 1 and maximum at sampling station 3 (Figure 5) in dry season. The increase in TDS from sampling station 2 downstream may also be due the influence of effluent discharged into the river from the identified point sources at sampling stations 2 and 3. The observed spatial differences across the sampling stations were not statistically significant (ANOVA, $P > 0.05$). Mean values of 74.2±33.79 mg/l and 94.8±22 mg/l were previously reported for the downstream and upstream areas of River Galma respectively [14]. A higher TDS values ranging from 280 mg/l to 4220 mg/l was reported for the Calabar river estuary [20]. TDS is the measure of total inorganic salts and other substances that are dissolved in water. The total dissolved solid of all water samples were found to be in agreement with the environmental protection agency standard of 500 mg/l. Total dissolved solid in drinking water has been associated with natural sources, sewage urban runoff, industrial waste water and chemical used in the water treatment process [18; 24], though of aesthetic rather than health hazards [23; 18].

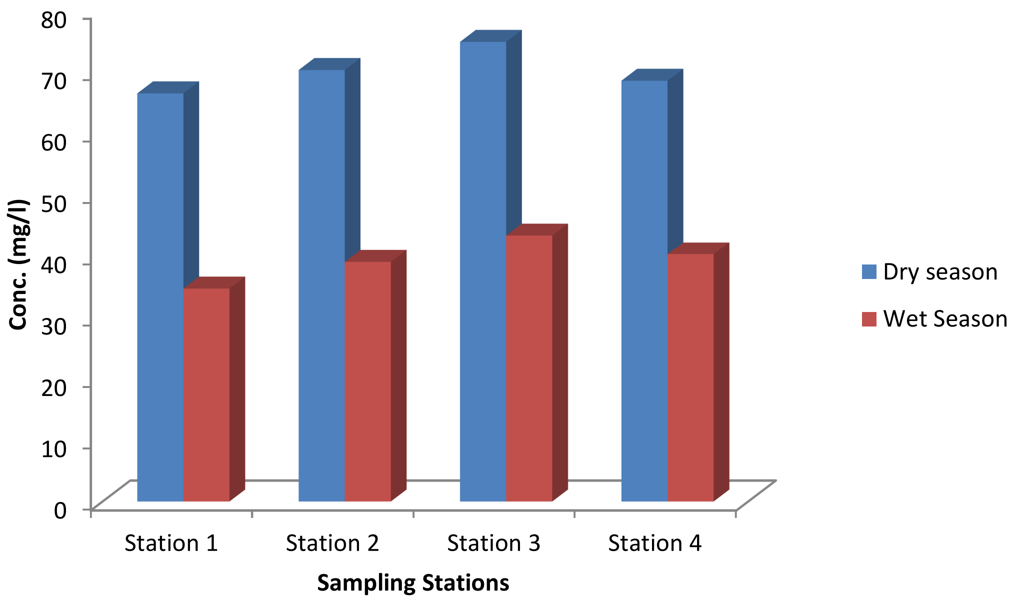

FIG. 6: Spatio-seasonal variation of TSS of River Galma around Dakace industrial area

Total Suspended Solids (TSS) ranged from 27.38 mg/l to 58.55 mg/l with a mean value of 39.24±9.44 mg/l in the dry season and from 61.27 mg/l to 78.24 mg/l with a mean value of 69.04±4.19 mg/l in the wet season. The mean TSS values for the wet and dry seasons were found to be 66.44±3.51 mg/l and 34.60±7.43 mg/l for station 1, 70.22±1.90 mg/l and 38.92±9.55 mg/l for station 2, 74.78±4.90 mg/l and 43.26±13.09 mg/l for station 3 and, 68.49±0.34 mg/l and 40.18±8.77 mg/l for station 4. TSS values were significantly higher in the wet season than dry season ($P < 0.05$). The higher TSS values observed during the wet season may be due to runoff. TSS values were minimum at sampling station 1 and maximum at sampling station 3 (Figure 6) in dry season. This thus indicates that effluent discharge from the point sources have influence on the water quality of the river. The difference in TSS values across the sampling stations was however not statistically significant (ANOVA, $P > 0.05$). The Total Suspended Solids previously obtained for upstream area water (mean, 47.4±20.52 mg/L) and downstream area water (mean, 30.1±27 mg/L) of River Galma were generally lower than the values obtained in this study in the wet season. Much higher suspended solid value (250mg/kg) was reported for the upstream of both River Ona and River Alaro in Ibadon Nigeria [19]. The total suspended solid found in water is the sum of the total quantity of insoluble matter contained in the water. It consist of silt, clay, fine particles of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solid may adversely affect growth and reproduction rates of aquatic fauna and flora. Even a thin layer of settled solids can form a blanket that interferes with the penetration of sunlight and deprives sections of the river or lake bed of oxygen. Plant and aquatic life dies and decomposition sets in, leading to toxic water conditions. Additionally, suspended solids also serve as a place of attachment for bacteria [18]. It was observed that, in all cases, suspended solid contents were greater than the dissolved solids which according to Osibanja et al [19], may indicate turbulence in the water bodies during sampling and probably because the suspended solids are largely non-settleable.

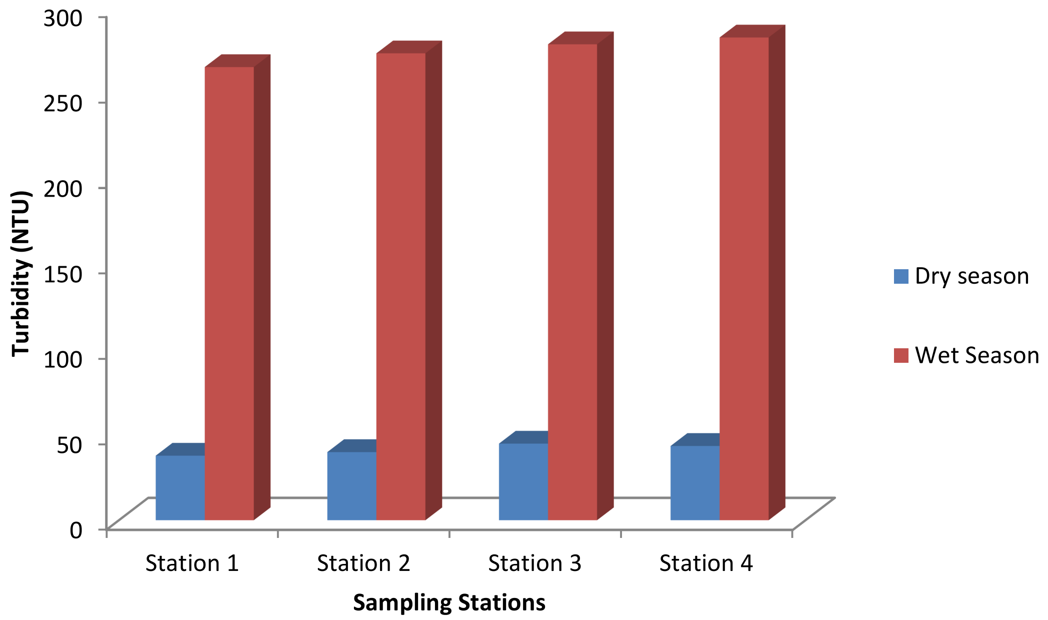

FIG. 7: Spatio-seasonal variation of turbidity of River Galma around Dakace industrial area

Turbidity values ranging from 32.30 NTU to 52.14 NTU with a mean value of 41.08±6.43 NTU in the dry season and from 158.00 to 458.00 NTU with a mean value of 274.87±10.38 NTU in the wet season were recorded in the study. The mean Turbidity values for the dry and wet seasons across the sampling stations were 37.43±5.09 NTU and 265.25±9.53 NTU for station 1, 39.49±1.57 NTU and 273.25±10.09 NTU for station 2, 44.38±2.69 NTU and 278.50±13.07 NTU for station 3 and, 43.02±2.69 NTU and 282.50±13.15 NTU for station 4 (Figure 7). Turbidity was significantly higher in the wet season than the dry season ($P < 0.05$). This observation may be due to runoffs. Spatial variation in turbidity values was not statistically significant at 95% confidence level. A range of 2.5-7.0 was reported for streams and rivers used for drinking and swimming purposes in Abeokuta, Nigeria [18]. Turbidity represents an important aspect of water quality. It is a measure of the cloudiness of a liquid as a result of particulate matter being suspended within it. The EPA standard set for drinking water is a turbidity 0-5 NTU [23]. A turbidity >5 NTU is considered unhealthy. The high turbidity observed with the surface waters did not agree with EPA standards on turbidity. High turbidity is often associated with higher levels of disease causing microorganism such as bacteria and other parasites [18]. Rivers may get contaminated from soil runoff, which thereby increases its turbidity.

Alkalinity ranged from 16.99 mg/l to 140.85 mg/l with a mean value of 53.60±4.20 mg/l in the dry season and from 15.81 mg/l to 54.72 mg/l with a mean value of 24.73±9.41 mg/l in the wet season. The mean alkalinity values for the dry and wet seasons were found to be 40.95±2.39 mg/l and 29.29±1.65 mg/l for station 1, 59.69±1.53 mg/l and 23.95±6.02 mg/l for station 2, 56.51±4.15 mg/l and 22.02±4.28 mg/l for station 3 and, 57.26±5.77 mg/l and 23.67±7.81 mg/l for station 4. Alkalinity values were significantly higher in the dry season than wet season ($P < 0.05$). Alkalinity values were found to increase downstream from sampling station 1 (Figure 8) indicating that the effluent discharged from the industrial estate had observed influence on the alkalinity value. The spatial difference however was not statistically significant at 95% confidence level. A higher mean alkalinity value of 111.75 mg/l was reported for River Ona and River Alaro in Ibadon Nigeria [19]. Alkalinity measures a water sample's ability to neutralize hydrogen ions (its acid-neutralizing ability). Alkalinity may be caused by dissolved strong bases such as sodium hydroxide or potassium hydroxide (and other hydroxide-containing compounds) and also it may be caused by dissolved carbonates, bicarbonates, borates, and phosphates [10]. In the present study all water samples showed that the range of alkalinity was within the EPA permissible limit (200 mg/l).

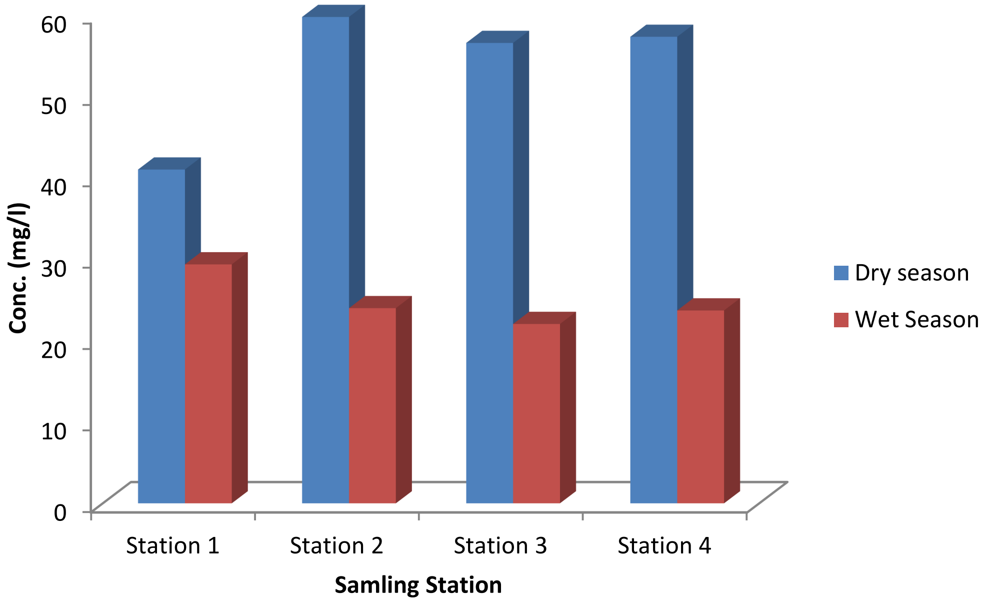

FIG. 8: Spatio-seasonal variation of Alkalinity of River Galma around Dakace industrial area

Chloride content of River Galma fluctuated from 17.02 mg/l to 318.87 mg/l with a mean value of 126.89±10.80 in the dry season and from 18.22 to 160.15mg/l with a mean value of 73.65±4.60 mg/l in the wet season. The mean chloride values for the dry and wet seasons were found to be 152.61±14.52 mg/l and 83.82±5.60 mg/l for station 1, 137.15±13.34 mg/l and 72.73±6.03 mg/l for station 2, 137.45±10.58 mg/l and 55.22±4.72 mg/l for station 3 and, 74.11±5.60 mg/l and 82.81±2.91 mg/l for station 4. A significant seasonal variation in chloride levels was observed with the mean dry season value being significantly higher than the mean wet season value ($P < 0.05$). The chloride actually reached their maximum value during dry season at sampling station 2 (Figure 9) when the water level was considerably low and reached minimum during the wet season at sampling station 4 with comparatively high water levels. No significant spatial variation was observed in the study (ANOVA, $P < 0.05$). The decrease in chloride levels downstream indicates that effluents discharged into the river from the identified point source around Dakace industrial estate had no influence on the overall chloride concentration of the River. Our observation is in agreement with Shittu [18] who reported a range of 112mg/l-220mg/l for water used for drinking and swimming purposes in Abeokuta, Nigeria. A range of 7.48mg/l – 11.78mg/l was reported for River Oni and River Alaro, in Ibdon , Nigeria [19]. The chloride content or limit recommended by WHO and EPA is 250mg/l [23; 27]. The chloride content of River Galma around Dakace industrial Estate was found to be within the WHO and EPA acceptable limit except in the month of March and early April. Chlorides inhibit the growth of plants, bacteria and fish in surface waters; high levels can lead to breakdown in cell structure and can easily render aridity to exposed terrestrial ecosystems [2; 28]. High Chloride concentrations may lead to development of kidney stones and cardiovascular disease [2].

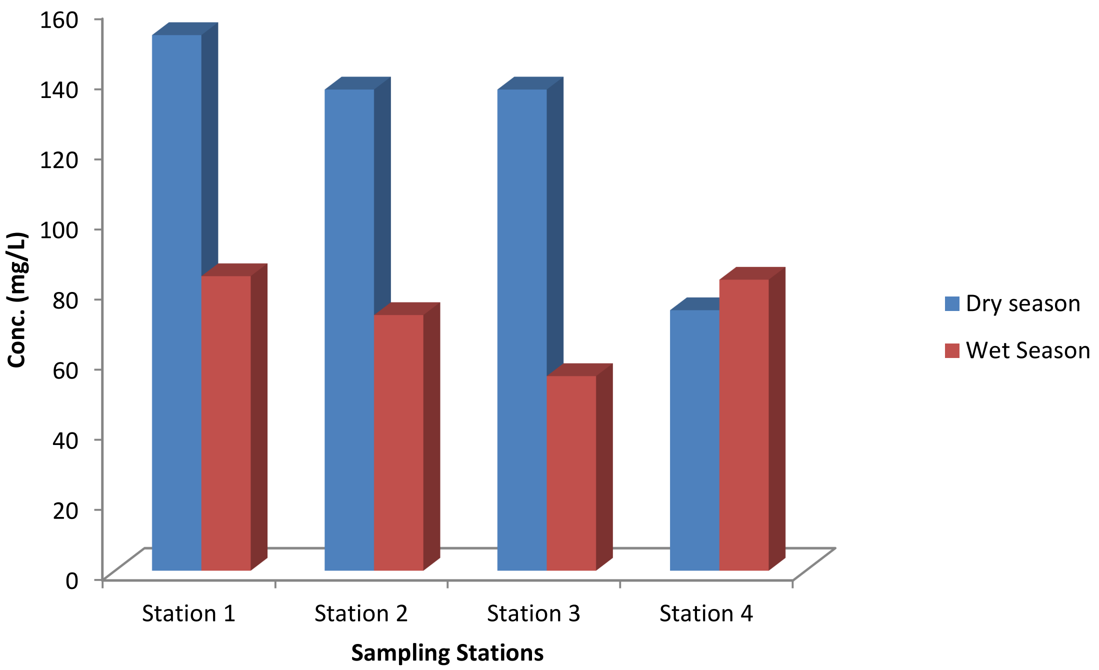

FIG. 9: Spatio-seasonal variation of Chloride of River Galma around Dakace industrial area

CONCLUSION

Pollution of inland water bodies by industrial and municipal wastewaters is a common phenomenon in developing countries. The assessment of the quality of River Galma around Dakace industrial Estate, Zaria, Nigeria revealed that the River was affected by industrial discharges. The levels of a few of the parameters monitored were generally higher than the acceptable limits. It will be unsafe to exploit water from this river for domestic and agricultural purposes without some forms of physical and chemical treatments.

Acknowledgement
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