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Original Research Article

Industrial pollution and its implications for the water quality of River Galma: A case study of Dakace industrial layout, Zaria, Nigeria

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Abstract

The global population growth and rapid industrial development have led to the recognition and increasing understanding of the interrelationship between pollution, public health and environment. Organic pollution indicators and anions concentration of surface water from River Galma around Dakace industrial Layout, Zaria were monitored between May 2011 and May 2012 using standard analytical methods. The levels of Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) ranged from 4.16 to 6.82 mg/l, 2.66 to 4.28 mg/l and 7.08 to 12.76 mg/l respectively. Anions concentrations which include phosphate (PO_4^{3-}), nitate (NO_4^{2-}) and sulphates (SO_4^{2-}) were of the ranges 31.6-49.23 mg/l, 0.32-4.31 mg/l and 2.32-10.78 mg/l respectively. It was established from the results of this study that industrial discharges from Dakace industrial layout had significant 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.

Keywords: Dakace, Environment, Organic pollution, Public health, River Galma

INTRODUCTION

Majority of the water withdrawn by man are being used in one application or the other. Following each use of water, various forms of pollution contributes to the degradation of the water quality of our inland water bodies. With time such degradation could be temporal, that is, natural self purification mechanism becoming enough to ultimately restore its quality, but most often, either the pollutants is such that does not restore naturally or the share volume is sufficient to overload the self purification mechanism, in which case the water is more permanently degraded. Declining water quality has therefore become an issue of global concern. A wide range of contaminants/Pollutants are continuously introduced into the aquatic environment mainly due to increased industrialization, technological development, growing human population, oil exploration and exploitation, agricultural and domestic wastes run-off (Lima *et al.*, 2008). Industrial wastewaters and agricultural runoff entering a water body have a great deal of influence on the pollution status of the water body and affects the water quality as well as the microbial, aquatic flora and funa (Kanu and Achi, 2011). Effluents rich in decomposable organic matter, is the primary cause of organic pollution. An important pollution index of industrial wastewaters is the oxygen function measured in terms of chemical oxygen demand (COD), and biological oxygen demand (BOD_5), while the nutrient status of wastewater are measured in terms of nitrogen and phosphorus (Kanu and Achi, 2011). Pollution of inland water bodies by industrial, agricultural and municipal wastewaters is a common phenomenon in developing countries. In most developing countries of the world, the usual source of drinking water is stream, river and hand dung well (ground water) as there is rear access to treated water. Impairment of these water qualities poses threats and severe health implications not only to human but also to other organisms in the ecosystem. Polluted water is the major source for the spread of many epidemics and some serious diseases (Khan et al., 2012). 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 (Shivaraju, 2012). Water for human consumption must be free from microorganisms and chemical substances in concentration large enough to cause environmental imbalance and disease (Aremu et al., 2011). Hence, physicochemical properties of water are relevant parameters that directly or indirectly affect water quality and suitability of such water for various purposes. Rivers and streams are highly heterogeneous at spatial as well as temporal scales and several investigators have documented this heterogeneity focusing on the physicochemical dynamics of rivers (Singh et al., 2010). Though water is important to life, it is one of the most poorly managed resources of the world (Fakayode, 2005). Dakace industrial estate is a home to many industries. River Galma along Dakace axis receives effluents from different categories of industries as well as Agricultural runoff from the river basin which is a booming crop farming area in both dry and wet season (Nnaji et al 2007). This study was undertaken to examine the influence of the industrial estate on selected organic pollution parameters and nutrients of the River.

MATERIALS AND METHODS

Sampling 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 (Nnaji et al 2011). 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 (Nnaji et al 2007). 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 (Nnaji et al., 2011). 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. (Figure 1)

Sample collection and Preservation

The procedure for sample collection and analysis was adopted from (APHA 2005). 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. 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^oC.

Sample preparation and analysis

The Modified Winkler- Azide Method was used to analyse water samples for dissolved oxygen (DO) while Biochemical oxygen demand (BOD5) was determined by the difference between DO of samples immediately after collection and DO of samples after incubation at 20ºC for five days (APAH, 2005). Chemical oxygen demand (COD) was determined after oxidation of organic matter in strong tetraoxosulphate (VI) acid medium by $K_2Cr_2O_7$ at 148^0C, with back titration (Ademoroti, 2006). Cadmium reduction method was used to analyze water samples of nitrate (NO_3^-) content. Cadmium metal reduces nitrates in the sample to nitrite. Nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt complex with gentisic acid to form amber coloured solution. Test result was measured at 430 nm using HACH DR 2400 spectrophotometer (APHA, 2005). Phover 3 (ascorbic acid) method was used to analyze water sample of phosphate (PO_4^{3-}) content. Phosphates react with molybdate in an acid to produce a mixed phosphate/molybdate complex. Ascorbic acid then reduces the complex giving an intense molybdenum blue colour. Test result was measured at 880 nm using HACH 2400 spectrophotometer (APHA, 2005). Sulfaver 4 Method was used to analyze water sample of Sulphate (SO_4^{2-}) content. Sulphate ion in the sample reacts with barium in the sulfaver 4 to form a precipitate of barium sulphate. The amount of turbidity formed is proportional to the sulphate concentration. The sulfaver 4 also contains a stabilizing agent to hold the precipitate in suspension. Test result was measured at

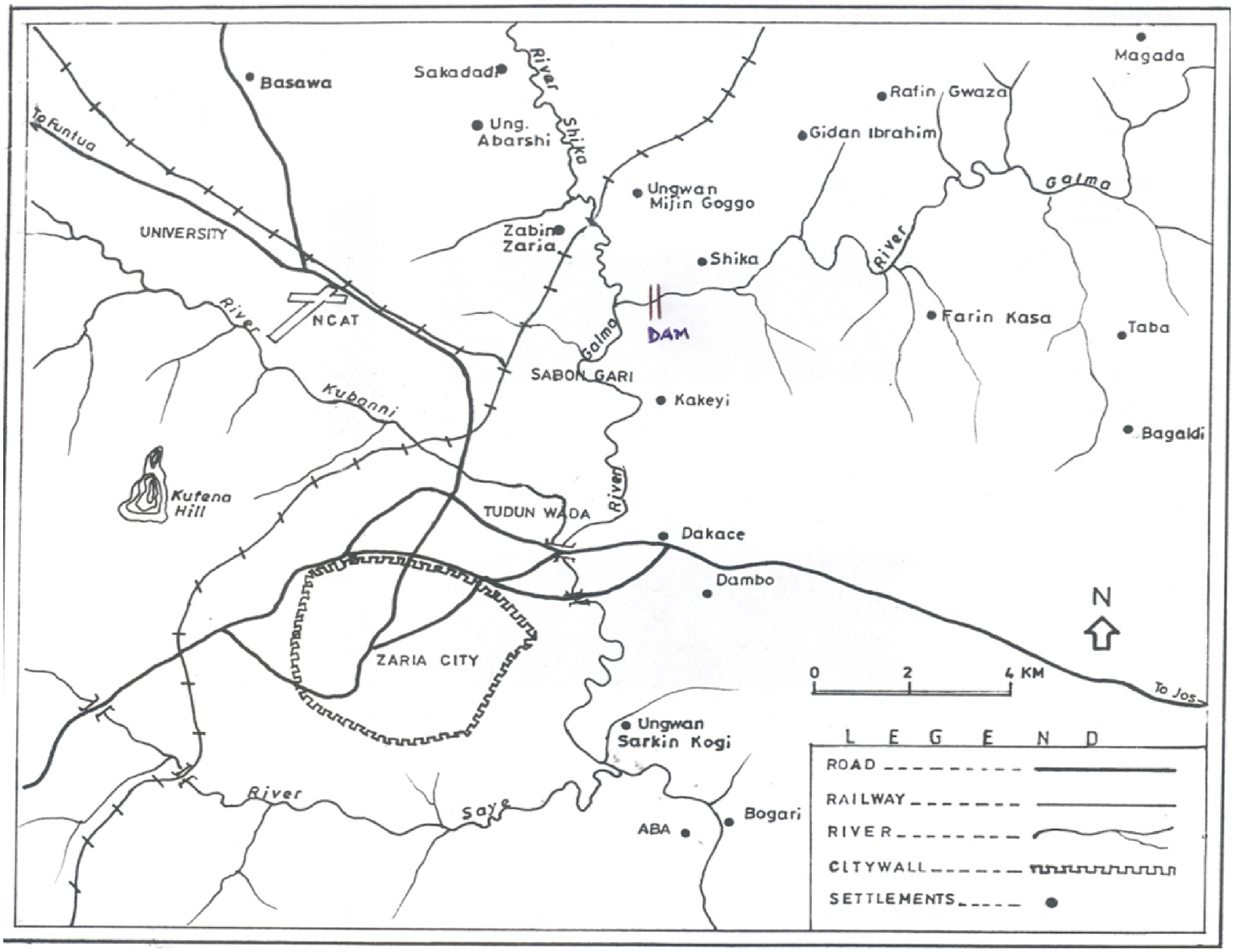

Figure 1. Zaria Showing Rivers and Settlements

450 nm using HACH DR2400 portable spectrophotometer (APHA, 2005).

RESULT AND DISCUSSION

The mean and standard deviation of results obtained for Organic pollution indicators and anion concentration of surface water from River Galma around Dakace industrial Estate, Zaria are presented in Table 1.

Oxygen molecules are dissolved in water and measured as dissolved oxygen. The presence of dissolved oxygen in lakes and rivers is good because the survival of most aquatic plants and animals depends on a sufficient level of oxygen dissolved in it. Dissolved oxygen (DO) is therefore a good indicator of healthy water quality (Neighborhood Water Quality 2000). Dissolved Oxygen content in the present study fluctuated from 4.09 mg/l to 6.82 mg/l with a mean value of 4.88±1.06 mg/l in the dry season and from 4.52 mg/l to 6.81 mg/l with a mean value of 5.41±0.80 mg/l in the wet season (Table 1). The mean DO values for the dry and wet seasons were found to be 6.61±0.21 mg/l and 6.72±0.12 mg/l for station 1, 4.25±0.06 mg/l and 5.01±0.09 mg/l for station 2, 4.20±0.11 mg/l and 4.82±0.23 mg/l for station 3 and, 4.48±0.28 mg/l and 5.10±0.10 mg/l for station 4 (Figure 2). No statistically significant seasonal variation in DO levels was observed in the study ($P < 0.05$). Dissolved oxygen actually reached their maximum value during wet season when the water level was considerably high at sampling station 2 and reached minimum during the dry season at sampling station 4 with comparatively low water levels. Statistically significant spatial variation in DO levels was observed in the study with DO levels at sampling station 1 being significantly higher than DO levels at sampling station 2, 3 and 4 (ANOVA, $P < 0.05$). The decrease in DO levels from the first indentified effluent discharge point (Sampling station 2) downstream indicates that effluents discharged into the river from Dakace industrial

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
Dissolved Oxygen	6.62±0.21	6.73±0.12	4.25±0.06	5.01±0.09	4.20±0.11	4.82±0.22	4.48±0.28	5.10±0.10
BOD	3.18±0.07	2.80±0.14	4.08±0.06	3.83±0.76	4.13±0.13	3.83±0.13	4.08±0.10	3.37±0.07
COD	8.02±0.23	7.22±0.17	10.46±0.26	9.47±0.32	11.18±1.38	9.80±0.62	10.92±1.49	8.66±0.30
Nitrate	2.77±0.82	0.99±0.78	3.47±0.68	1.09±0.87	3.77±0.86	1.18±0.89	3.36±0.51	0.89±0.82
Phosphate	41.95±7.56	36.48±3.34	43.47±6.83	38.48±3.45	44.80±6.99	39.09±3.52	39.47±3.52	36.53±3.34
Sulphate	7.55±0.90	3.70±0.90	8.98±1.45	3.96±1.08	9.25±1.41	4.07±1.09	7.98±1.74	3.72±1,04

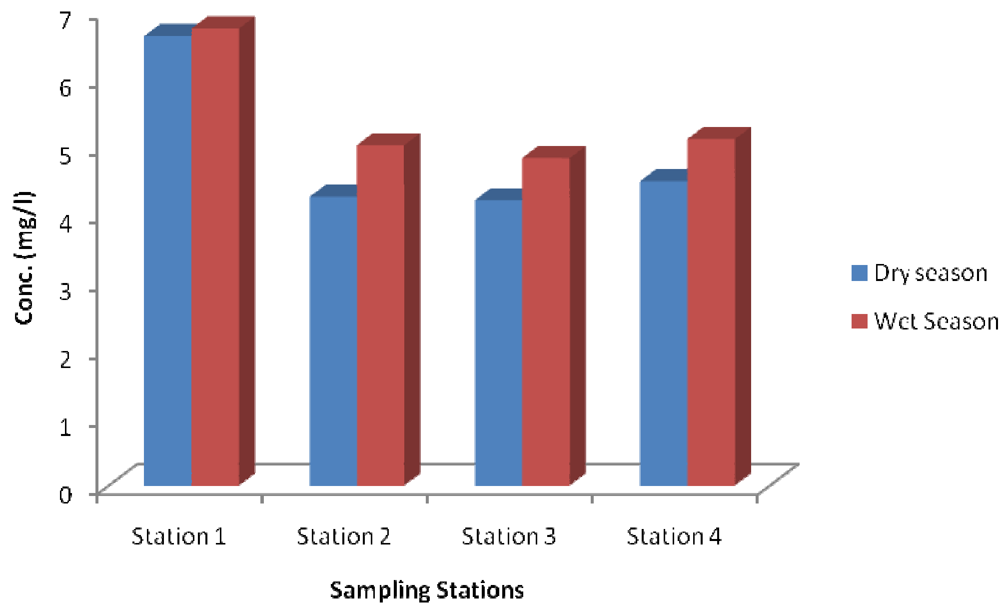

Figure 2. Spatio-seasonal variation of DO of River Galma around Dakace industrial area

estate had significant influence on the overall DO levels of the River. The DO levels at sampling station 1(200 meters before the identified effluent discharge points) was observed to be above the required standard for sustaining aquatic life which is stipulated at 5mg/l all through the study, a concentration below this value as observed at the sampling stations after the effluent discharge points, especially in the dry season, adversely affects aquatic biological life, while concentration below 2mg/l may lead to death for most fishes (Chapman, 1997; Idris et al 2013). The WHO permissible limit for DO is 5.00mg/l -7.00mg/l (Singh, et al., 2010). Our observation is in agreement with Idris et al., (2013) who reported a range of 3.67±0.20mg/l to 7.00±0.22 mg/l for River Gorax in Minna, Nigeria and Osibanjo et al., (2011) who reported a range of 4.86-6.37 mg/l and 4.88-7.46 mg/l for River Ona and River Alaro in Ibadan, Nigeria. Mean dissolved oxygen values of 5.78±0.54 mg/l and 5.62±0.78 mg/l were

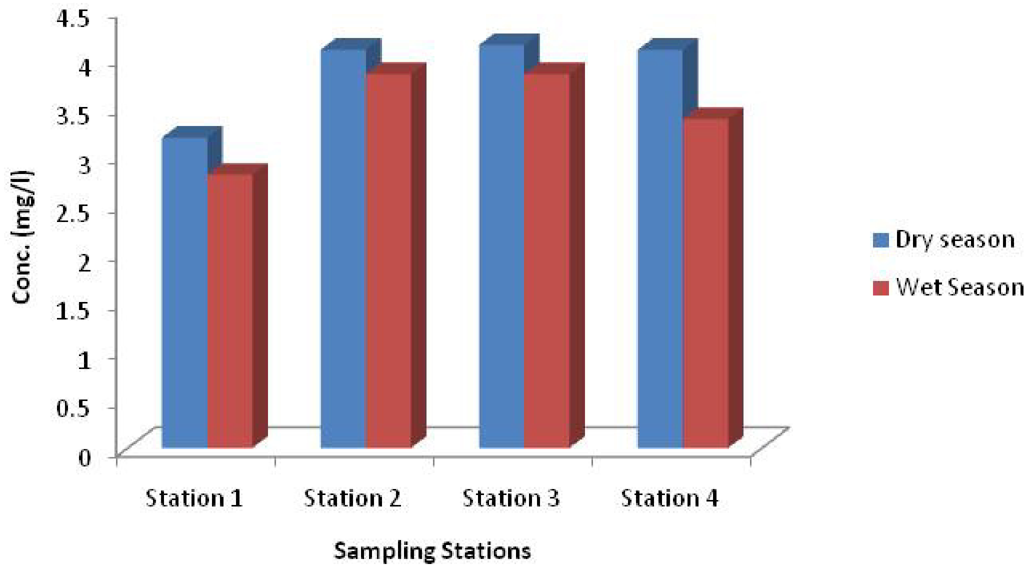

Figure 3. Spatio-seasonal variation of BOD of River Galma around Dakace industrial area

previously reported for the downstream and upstream areas of River Galma (Nnaji et al 2011) while a mean value of 6.5mg/l was reported for Gumti in Uttar, Pradesh (Anukool and Shivani 2011). Evaluation of DO is crucial to the survival of aquatic organisms and ultimately in establishing the degree of freshness of a river (Fakayode, 2005).

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in water to break down organic material present in water sample at certain temperature over a specific time period (Idris et al., 2013). BOD is an effective indicator of organic quality of water (Idris et al., 2013; Clair *et al*., 2003). The overall BOD ranged from 3.11 mg/l to 4.19 mg/l with a mean value of 3.87±0.42 mg/l during the dry season and from 2.66 mg/l to 3.97 mg/l with a mean value of 3.46±0.45 mg/l during the wet season (Table 1). The mean BOD for the dry and wet seasons were found to be 3.17±0.07 mg/l and 2.80±0.14 mg/l for station 1, 4.08±0.06 mg/l and 3.83±0.08 mg/l for station 2, 4.13±0.13 mg/l and 3.83±0.14 mg/l for station 3, and 4.08±0.10 and 3.37±0.07 mg/l for station 4 (Figure 3). A statistically significant ($P < 0.05$) seasonal variation in BOD levels was observed with the BOD levels in the dry season being significantly higher than the wet season. The lower BOD values obtained during the wet season may be because of the high volume of water that greatly diluted the effluents making its impacts on BOD levels less significant. A statistically significant spatial variation in BOD levels was also observed in the study (ANOVA, $P > 0.05$). BOD level at sampling station 1 was found to be significantly lower than BOD levels at sampling station 2, 3 and 4. The increase in BOD levels from the first indentified effluent discharge point (Sampling station 2) downstream indicates that effluents discharged into the river from Dakace industrial estate have significant influence on the overall BOD levels of the River. Desirable limit for BOD is 4.0 mg/l and permissible limit is 6.0 mg/l according to Indian standards. BOD demand below 3 mg/l is required for the best use water (Kumar et al., 2010). The BOD values recorded in this study were found to be within the permissible limit (6.0mg/l) but above 3mg/l required for best use of water. Based on BOD classification of aquatic bodies, unpolluted (BOD < 1.0mg/l), moderately polluted (BOD 2-9 mg/l) and heavily polluted (BOD > 10mg/l) (Adegoke et al., 2007), River Galma around Dakace industrial Area may be designated moderately polluted by organic matter. Higher BOD values ranging from 4.3-5.7mg/l and 4.5-6.0mg/l were previously reported for the upstream and downstream areas of river Galma (Nnaji et al., 2011). Idris et al., 2013 reported a range of 1.85±0.04 to 3.47±1.32 for River Gorax in Mina, Nigeria. A range of 1.4 - 4.5 mg/l was reported for rivers of Utterakhand (Kumar, 2010). Discharge of effluent with a high oxygen demand directly into surface water, overloads the sensitive balance maintained in the water. Oxygen is stripped from the water causing oxygen dependent plants, bacteria, fish as well as the river or stream itself to die. The outcome is an environment populated by non-oxygen dependent (anaerobic) organisms leading to toxic water conditions. Dissolved oxygen depletion in water can encourage microbial reduction of nitrates to nitrites and sulphate to sulphide giving rise to odour problems. It can also cause increase in iron II concentration.

A measure of the amount of oxygen required for complete oxidation to carbon (IV) oxide and water of organic matter present in a sample of water, waste water or effluent called chemical oxygen demand (COD) is another parameter used to assess the oxygen demands

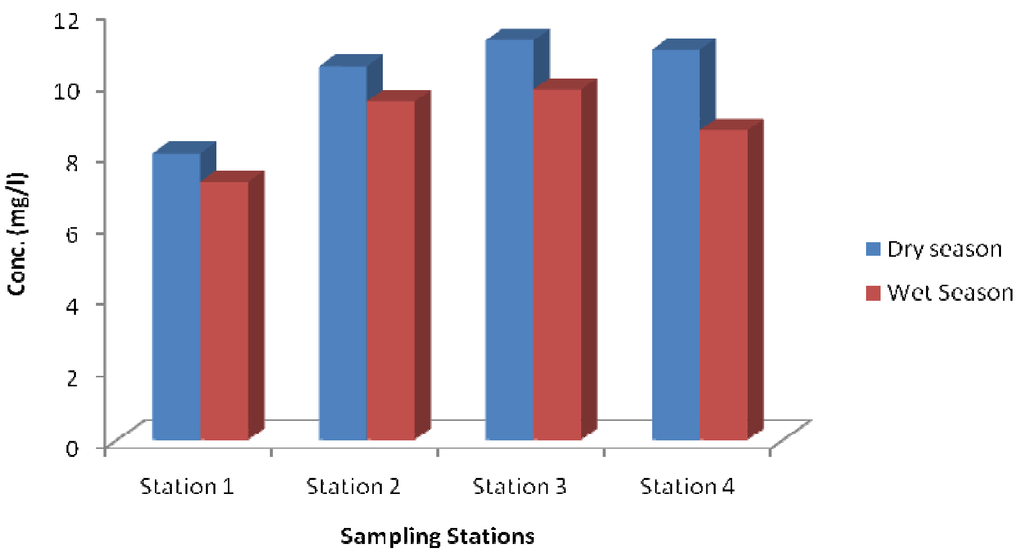

Figure 4. Spatio-seasonal variation of COD of River Galma around Dakace industrial area

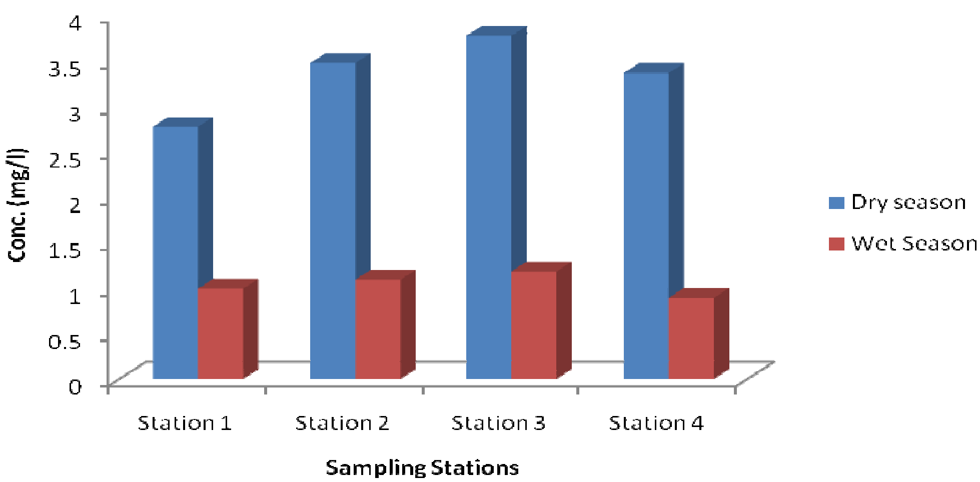

Figure 5. Spatio-seasonal variation of Nitrate of River Galma around Dakace industrial area

of water or waste water (Ezike et al 2012). COD in the present study fluctuated from 7.78 mg/l to 12.76 mg/l with a mean value of 10.15±1.57 in the dry season and from 7.08 mg/l to 10.56 mg/l with a mean value of 8.78±1.08 mg/l in the wet season (Table 1). The mean COD values for the dry and wet seasons were found to be 8.02±0.22 mg/l and 7.21±0.17 mg/l for station 1, 10.46±0.26 mg/l and 9.47±0.33 mg/l for station 2, 11.18±1.38 mg/l and 9.80±0.63 mg/l for station 3 and, 10.92±1.49 mg/l and 8.66±0.30 mg/l for station 4 (Figure 4). COD displayed statistically significant seasonal ($P > 0.05$) and spatial variations (ANOVA, $P < 0.05$). Seasonal variations showed a comparatively higher dry seasons value. The dilution of the industrial effluents by the large volumes of river water at the peak of the wet season could also be responsible for the lower COD values. Spatial variations disclosed increasing trend from station 2 (the first identified point source), confirming the impact of industrial discharges on the original quality of the rivers. Higher mean COD values of 91.80mg/l and 40.80 mg/l were reported for River Onna and River Alareo in Ibadan Nigeria (Osibanjo et al., 2011). An average COD value of 129.3 was reported for River Gorax, Mina, Nigeria (Idris et al., 2013). A range of 15.41 to 17 .28 was recorded for River Gumti in Uttar Pradesh (Anukool and Shivani 2011).

The maximum permissible limit of nitrate in drinking water is 10 mg/l (UNEP 1999). The nitrate contents of River Galma ranged from 1.85 to 4.31 mg/l in the dry season with a mean value of 3.27mg/l and from 0.32 to 2.48 mg/l with a mean value of 1.04 in the wet season (Figure 5). Nitrate content of the River in the dry season was found to be significantly higher than wet season. No

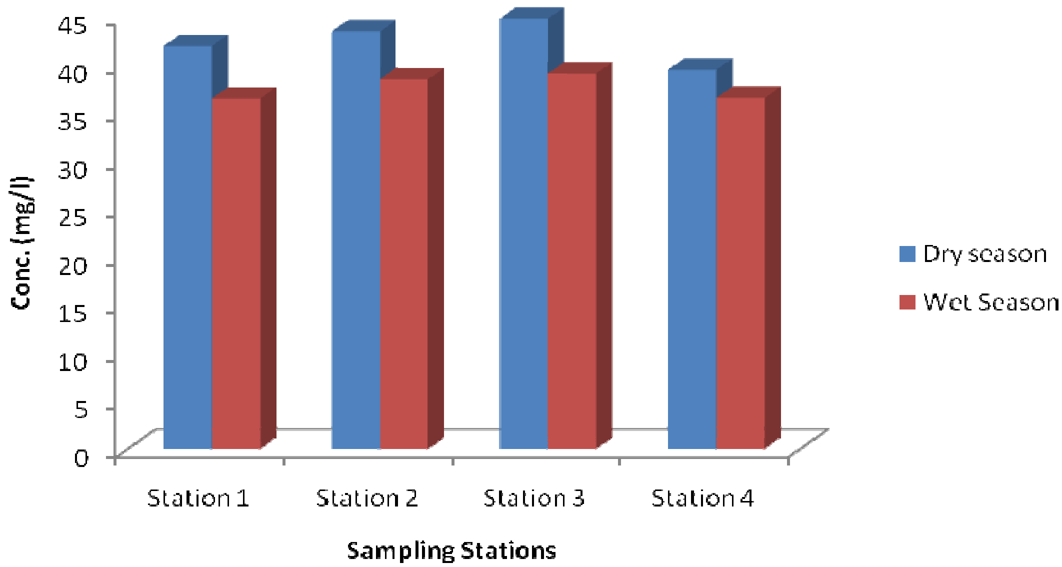

Figure 6. Spatio-seasonal variation of phosphate of River Galma around Dakace industrial area

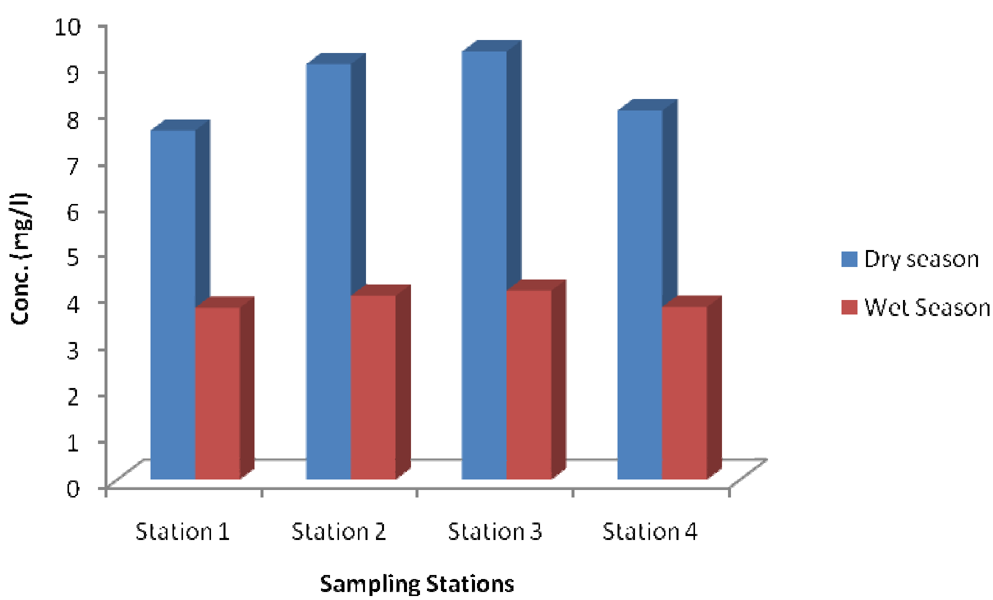

Figure 7. Spatio-seasonal variation of Sulphate of River Galma around Dakace industrial area

statistically significant spatial variation was observed during the study. This indicates that industrial effluent from Dakace industrial area had no influence on the nitrate content of the river. The increased usage of nitrogen-based fertilizers, herbicides and other agricultural wastes from the farms on the river basin as well as urban runoff seems to have significantly contributed to the elevated nitrate levels in the river. However, the values for nitrate were all lower than the upper limit of 10 mg/l set by UNEP (1999). The amount of nitrate in water indicates the biological contamination of water. Similar mean nitrate values of 1.95±0.3mg/l and 4.61±2.47 mg/l were previously reported for the downstream and upstream areas of river Galma (Nnaji, 2011), mean values of 6.26 mg/l and 3.75 mg/l were reported for river Alaro and river Onna in Ibadon, Nigeria (Osibanjo et al., 2011) and concentration ranging from 8.81±1.66 to 15.80±0.67 mg/l reported for River Gorax in Minna, Nigeria (Idris et al 2013). Excessive concentrations of nitrate in lakes, streams and rivers greater than about 5mg/l can cause excessive growth of algae and other plants, leading to accelerated eutrophication and occasional loss of dissolved oxygen (Knepp and Arkin, 2006, Idris et al., 2013). Nitrate concentration above drinking water quality limits can lead blue-baby syndrome (Idris et al., 2013).

Phosphate content of River Galma in the study ranged from 30.32- 48.42 mg/l in the dry season with a mean value of 42.43mg/l and from 31.60 to 42.34mg/l with a mean value of 37.64 mg/l (Table 1). The difference in phosphate levels between dry and wet season was statistically significant at 95% confidence level. Slight increase in phosphate level (Figure 6) was observed at station 2 and station 3 (the effluent discharged points). This indicates that effluent discharged into the river had influence on the phosphate content of the water. Analysis variance (ANOVA) revealed that the difference in phosphate levels across the sampling stations was not statistically significant at 95% confidence level ($P > 0.05$). Lower mean values of 4.61±2.47mg/l and 5.16±1.25 were previously reported for upstream and downstream areas of river Galma (Nnaji et.l 2011). A mean value of 4.62±2.07 mg/l was reported for River Alaro in Ibadon, Nigeria (Fakayode, 2005). High level of phosphate has also been reported to encourage eutrophication which could further deplete the dissolved oxygen levels of the rivers (Fakayode, 2005; Osibanjo et al., 2011). Critical levels of phosphorus in water above which eutrophication is likely to be triggered, are approximately 0.03 mg/l of dissolved phosphorus and 0.1 mg/l of total phosphorus (Idris et al., 2013). Phosphate content of River Galma is significantly high, the river could be said to be at a highly eutrophic state, in which the growth of photosynthetic aquatic micro- and macro organisms are stimulated to nuisance levels. Possible sources of phosphate might involve extensive land application of phosphorus based agrochemicals, the use of phosphoric acid and phosphate salts as industrial raw materials as well as the release of phosphates from phosphorous detergents discharged along with the sewage waste. Excessive concentration of phosphate in water may cause vomiting and diarrhea, stimulate secondary hyperthyroidism and bone loss (Subin and Husna, 2013).

Sulphate is associated with respiratory illness (Sivaraju, 2012). Therefore the recommended limit of sulphate content in the drinking water is 200 to 250 mg/L (Sivaraju, 2012). The results obtained in the present study showed that sulphate content in water samples were ranged from 6.42 to 10.78 mg/l with a mean value of 8.44 during dry season and from 2.32 to 5.29 mg/l with a mean value of 3.86 mg/l during the wet season (Table 1). The seasonal variation was observed to be statistically significant ($P < 0.05$). Data obtained in the study revealed that sulphate concentration also increased slightly (Figure 7) at station 2 and station 3 (the effluent discharged points) indicating the influence of effluents discharged from Dakace industrial estate. The observed spatial variation was not statistically significant (ANOVA, $P > 0.05$). Sulphate concentration of River Galma was found to be within permissible limit all through the study and thus pose no health hazard. However, the average levels of sulphate in the study were higher than the natural background sulphate levels of 1.0 – 3.0 mg/l reported for unpolluted rivers in similar studies (Offiong and Edet 1998). Osibanjo et al., (2011) reported the ranges 2.94-8.08 and 5.88- 7.35 for River Onna and River Alaro in Ibadon, Nigeria. Excessive content of sulphate in water can cause laxative effect and may contribute to the corrosion of distribution systems (Subin and Husna, 2013).

CONCLUSION

Point sources of pollution affect water quality due to high organic and nutrient pollution. The discharge of industrial effluents into River Galma around Dakace Industrial layout, Zaria has invariably resulted in the presence of high concentrations of pollutant in the water. Most of the pollutants have been shown to be present in concentrations, which may be toxic to different organisms. High levels are generally recorded below effluent discharge points and reduces downstream due to the rivers self cleansing capacity. It is therefore recommended that the disposal of industrial wastes without pretreatment should be discouraged. Imposition of direct charges on industrial effluents by the regulating agency, as well as continuous monitoring and surveillance is imperative in order to ensure the protection of water resources from further degradation.

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