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The influence of industrial effluents from Dakace industrial area on the heavy metal profile of River Galma, Zaria, Nigeria

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ABSTRACT

This study examined the influence of discharges from Dakace industrial area on the heavy metal profile of River Galma, Zaria, Nigeria. Water samples were collected from both upstream and downstream along the main stream drainage channel, traversing past Dakace industrial area between May 2011 and May 2012. The samples were digested according to standard methods and analyzed for Lead (Pb), Zinc (Zn), Copper (Cu) and Nickel using Schemadzu atomic absorption spectrophotometer (model 6800, Japan). The range of concentrations (mg/l) of these metals was: Pb, (0.025-4.12), Zn (0.018-1.12), Cu (0.02-0.56) and Ni (0.00-2.55). Significant ($P < 0.05$) seasonal variation in metal levels was observed, but the spatial variation was not statistically significant (ANOVA, $P > 0.05$), indicating that effluent discharged from Dakace industrial area had no significant influence on the heavy metal profile of the river. Lead and nickel contents of the water were several folds above the maximum contaminant Levels established by World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). Copper and nickel concentrations recorded were found to be above the Australian and New Zealand Environment and Conservation Council limits for irrigation water. Continuous use of water from the study area for drinking or irrigation therefore poses serious toxicological risk. The implications of these findings for public health are fully discussed.

Key words: industrial discharges, Dakace, metal profile, toxicological risk, public health

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INTRODUCTION

Industrialization has long been accepted as a hallmark of civilization due to its substantial contributions to economic growth and human welfare, but it carries with it inevitable costs and problems in terms of environmental degradation. Significant adverse effects are elicited on the environment when industrial wastes are discharged directly or indirectly into the environment. The level of environmental degradation arising from industrial discharges into River and other surface water bodies which are frequently used as sinks is alarming. The release of untreated or poorly treated industrial waste into water courses alters the physical, chemical and biological characteristics of the receiving water body [1; 2; 3]. Consequently, water bodies which are major receptacles of such industrial wastes have become highly polluted. Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, like serving as drinking water, and/or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish [4]. Undoubtedly, this could disturb the ecological balance of such an environment [5]. The resultant effects of this on public health and the environment at large are usually great in magnitude [6]. Studies have revealed that chemical pollutants enter the water bodies through point and non point (diffuse) sources which are difficult to control [7]. Out of all pollutants of water, metals pose the greatest threat to man and the environment. This is because these chemical elements are not easily removed from raw water by conventional treatment processes [8].

Heavy metal pollution is a global issue, although severity and levels of pollution differ from place to place. At least 20 metals are classified as toxic with half of them discharged into the environment at concentrations that pose great risks to human health [9]. The danger of heavy metal pollutants in water lies in two aspects of their impact. Firstly, heavy metals have the ability to persist in natural ecosystems for an extended period. Secondly, they have the ability to accumulate in successive levels of the biological chain, thereby causing acute and chronic diseases. Some heavy metals contained in effluents have been found to be carcinogenic while others equally present are poisonous depending on the dose and duration of exposure [9].

Rapid population growth in Sub-Saharan Africa has brought about a tremendous increase in urbanization with attendant increase in the volume of domestic and industrial waste-water. Water pollution is primarily associated with domestic and industrial waste [10]. Both types of waste-water pose threats to water quality which may be classified into health hazards and sanitary nuisances [10]. Unfortunately, the countries still lacks adequate technology, resources and manpower required to effectively manage these wastes in an environmentally friendly manner. Pollution reduces the potentials of water as a resource for the various uses. This is because pollution causes the water to become unsuitable for various uses and also difficult and more expensive to treat to acceptable quality for use [11]. Man's activities have increased the loading of municipal and industrial contaminants to the nation's waters; River Galma is one of such water bodies. It is therefore clear that, if a pollution control programme is to be effective, then periodic monitoring of the levels/concentration of the chemical elements in Rivers Galma is absolutely necessary. River Galma play a significant role as it serve not only the source of water supply for domestic, industrial and agricultural purposes but also utilized for the disposal of municipal and industrial waste, thus under tremendous pressure. Dakace industrial estate is a home to many industries. River Galma along Dakace axis thus 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 [12]. This study was undertaken to examine the influence of the industrial area on the heavy metal profile of the River.

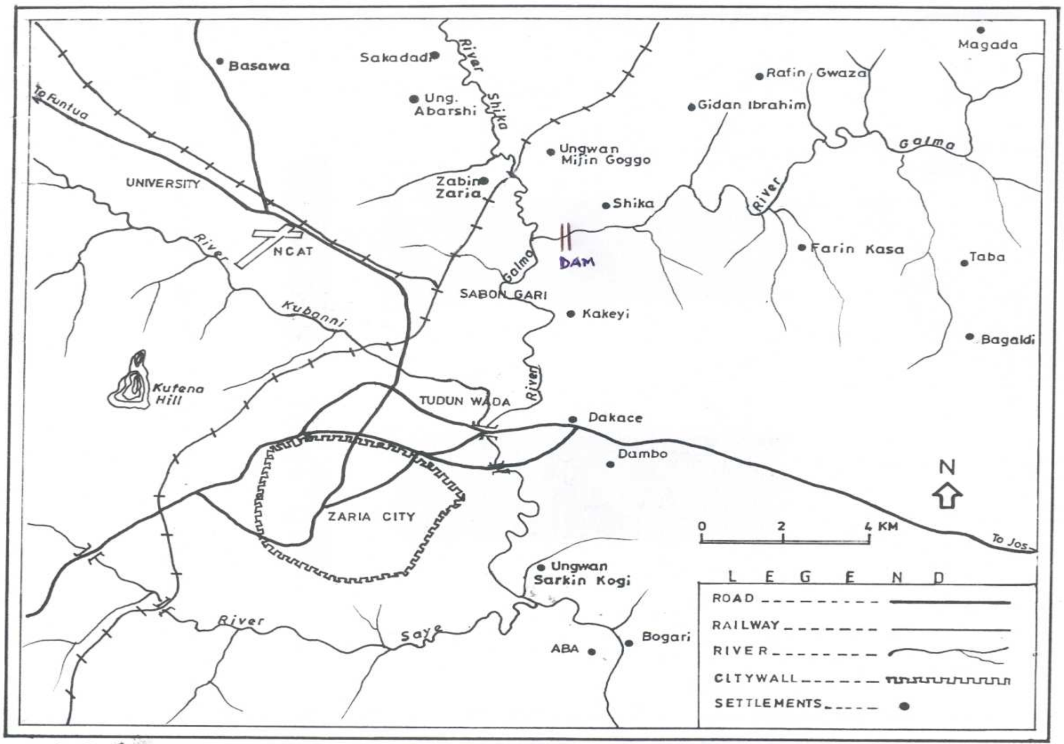

FIG. 1 ZARIA SHOWING RIVERS AND SETTLEMENTS.

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 [13]. 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 [12]. 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 [13]. 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 APHA [14]**.** 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 on monthly basis. Collected water sample was poured into the washed 2-litre polypropylene container. Temperature was 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). Each sample was fixed with 5mls of concentrated nitric acid and 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

The samples were digested according to Standard methods for the examination of water and wastewater, American Public Health Association [14]. Each sample was thoroughly mixed, 20 ml was transferred into a conical flask, 10 ml concentrated nitric acid was added and brought to slow boiling before evaporating on a hot plate to lowest volume (5 – 10 ml). Concentrated nitric acid was added as necessary until digestion was complete as shown by light colour clear solution. The digest was filtered into 50ml volumetric flask and made up to the mark.

Sample Analysis

Metal concentration in the digests was determined by Atomic Absorption Spectrophotometry, using schemadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) equipped with Zeaman background correction and graphite furnace at National Research Institute for Chemical Technology (NARICT), Zaria-Nigeria. The calibration curve was prepared by running different concentrations of standard solutions. The instrument was set to zero by running the respective reagent blanks. Average values of three replicates were taken for each determination and were subjected to statistical analysis

Analytical Quality Assurance

In order to check the reliability of the analytical methods employed for metal determination, one blank and combine standards were run with every batch to detect background contamination and monitor consistency between batches. The result of the analysis was validated by digesting and analyzing Standard Reference Materials, animal blood coded IAEA-A-13 following the same procedure. The analyzed values and the certified reference values of the elements determined were compared to ascertain the reliability of the analytical method employed. The reagent used for sample preservation and digestion, viz. HNO_3 (Riedel-deHaën, Germany), was of analytical grade.

Statistical Analysis:

All statistical analyses were done by SPSS software 17.0 for windows.

RESULTS AND DISCUSSION

To evaluate the accuracy and precision of the analytical procedure employed, standard reference material of animal blood coded IAEA-A-13 was analyzed in like manner to our samples. The analyzed values and the certified reference values of the elements determined were very close (Table 1), suggesting the reliability of the method employed.

TABLE 1 Results of analysis of reference material (animal blood IAEA-A-13) compared to the certified reference value (mg/kg)

Element (mg/kg)	Pb	Ni	Cu	Fe	Zn
A Value	0.20	1.20	4.45	2389	14.2
R value	0.18	1.00	4.30	2400	13.0

A Value = Analyzed value *R* Value = *Reference value.*

The Mean concentration and standard deviation of lead, zinc, copper and Nickel alongside pH and Temperature of water samples from the four established sampling points along River Galma, around Dakace Industrial Estate, are presented in Table 2. The spatial and seasonal distributions of these elements in the river are shown in Figures 2, 3, 4 and 5 respectively. The results obtained shows that, the overall temperatures 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 observed all through the study were found to be above World Health Organization (WHO) and European (EU) standard of 25°C for domestic water supply [15]. Surface Water temperature above 40 **^{O}C** depicts polluted water [16]. The water temperature observed in this study is therefore within the permissible limit of water temperature for inland waters. Increase in temperature leads to increase in solubility. At high temperatures total dissolved solid is increased as more solute goes into solution [17]. No statistically significant seasonal or spatial variation in temperature was also observed in the study (ANOVA, $P > 0.05$). 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 [18]. 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[13]. Udiba et al [19] reported arrange of 25.5-31.4 for the Calabar river estuary.

Table 2: 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
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
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
Lead	1.27±1.08	0.78±0.33	1.73±1.19	0.56±0.37	1.81±2.09	0.96±0.72	1.36±0.99	0.64±0.19
Zinc	0.60±0.33	0.23±0.10	0.51±0.53	0.26±0.22	0.36±0.46	0.32±0.05	0.56±0.44	0.31±0.14
Copper	0.22±0.26	0.09±0.05	0.25±23	0.08±0.04	0.29±0.23	0.22±0.21	0.24±0.21	0.06±0.06
Nickel	0.70±0.76	0.15±0.13	0.93±1.16	0.14±0.04	1.06±1.31	0.17±0.10	1.06±1.31	0.08±0.07

The pH of water is very important in the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity [17]. 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. Mean pH value was found to be higher in the wet season than dry season but the difference was not statistically significant at 95 % confidence level. All through, 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 World Health Organization (WHO) and United State Environmental protection Agency (US EPA) as standard pH of water, making it suitable for portability with respect to pH [20]. 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. A similar range of pH values (5.94-7.34) was reported for Calabar River [19]. pH ranges of 7.43-7.60 and 6.88-7.59 were reported for River Ona and River Alaro in Ibadon, Nigeria [18]. 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 [13] pH has profound effect on water quality as it affects the solubility of metals, alkalinity and hardness of water. Metals tend to be more soluble and more reactive at lower pH.

Lead concentration in the present study fluctuated from 0.025 mg/l to 4.12 mg/l with a mean value of 1.54±1.22 mg/l in the dry season and from 0.15 mg/l to 1.52 mg/l with a mean value of 0.74± 0.41mg/l in the wet season (Table 2). The mean lead concentration per sampling points for the dry and wet seasons were found to be 1.27±1.08 mg/l and 0.78±0.33 mg/l for sampling station 1, 1.73±1.19 mg/l and 0.56±0.37 mg/l for sampling station 2, 1.81±2.09 mg/l and 0.96±0.72 mg/l for station 3, and 1.36±0.99 mg/l and 0.64±0.19 mg/l for sampling station 4 (Figure 2). Statistically significant seasonal variation in lead levels was observed in the study ($P < 0.05$), lead levels in the dry season being significantly higher than the wet season values. Lead levels actually reached their maximum value in the month of January when the water level was considerably low. NO statistically significant spatial variation in lead levels was observed in the study (ANOVA, $P > 0.05$). The fact that the difference in lead levels between Sampling station 1 (200 meters before the first indentified effluent discharge point) and the other sampling stations downstream was not significant indicates that, effluents discharged into the river from Dakace industrial estate had no significant influence on the overall lead levels of the River. However the lead content of River Galma observed in this study was found to be higher when compared to World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) of 0.01 mg/l for portable water [15; 21], the water is thus not fit for drinking purposes. As observed in table 2, mean lead concentration of River Galma was below the Australian and New Zealand Environment and Conservation Council limit of 2.0 mg/l for irrigation water [22]. The river therefore poses no significant risk with respect to lead contamination when used for irrigation. Lead affects the peripheral nervous system (especially motor nerves) and the central nervous system. Peripheral nervous system effects are more prominent in adults and central nervous system effects are more prominent in children [19; 23; 24].

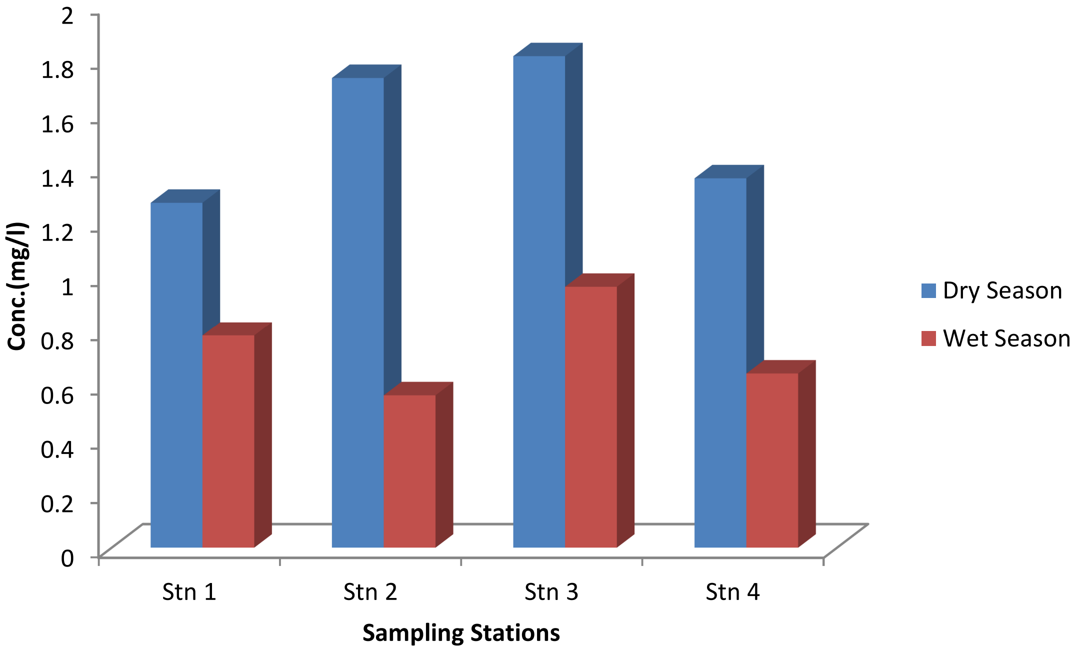

Figure 2: Spatio-seasonal variation of Lead in River Galma around Dakace industrial area, Zaria, Nigeria

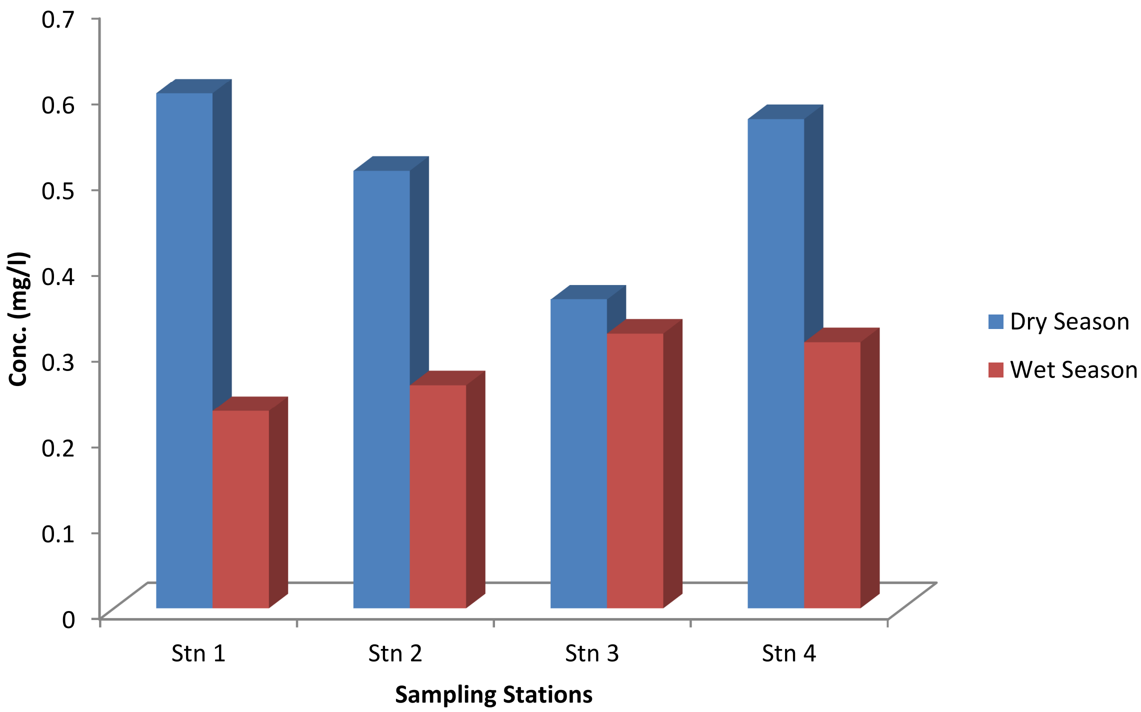

Figure 3: Spatio-seasonal variation of Zinc in River Galma around Dakace industrial area, Zaria, Nigeria

Children are more at risk for lead poisoning because their smaller bodies are in a continuous state of growth and development. The classic signs and symptoms in children are loss of appetite, abdominal pain, vomiting, weight loss, constipation, anemia, kidney failure, irritability, lethargy and behavioral problems. Slow development of normal childhood behaviors, such as talking and use of words, and permanent mental retardation are also commonly seen [25]. Lead exposure in young children has been linked to learning disabilities. Lead affects both the male and female reproductive systems. In men, when blood lead levels exceed 40µg/dL, sperm count is reduced and changes occur in volume of sperm, their motility, and their morphology. A pregnant woman's elevated blood lead level can lead to miscarriage, prematurity, low birth weight, and problems with development during childhood [26]. Kidney damage occurs with exposure to high levels of lead. In acute poisoning, typical neurological signs are pain, muscle weakness, paraesthesia, and, rarely, symptoms associated with encephalitis [27]. Oronsaye et al., [28] reported a lower range of 0.05 to 0.07 mg/l for Ikpoba river dam, Benin City, Nigeria. Concentration ranging from 0.095 to 0.084 was reported for River challawa, Kano, Nigeria [10] and 0.039 to 0.256mg/l for streams that receive effluents from different categories of industries in Nakawa - Ntinda industrial area of Kampala, Uganda [29]. A mean value of 0.03 ± 0.02 mg/l was reported for lower river Niger drainage in North central Nigeria [30].

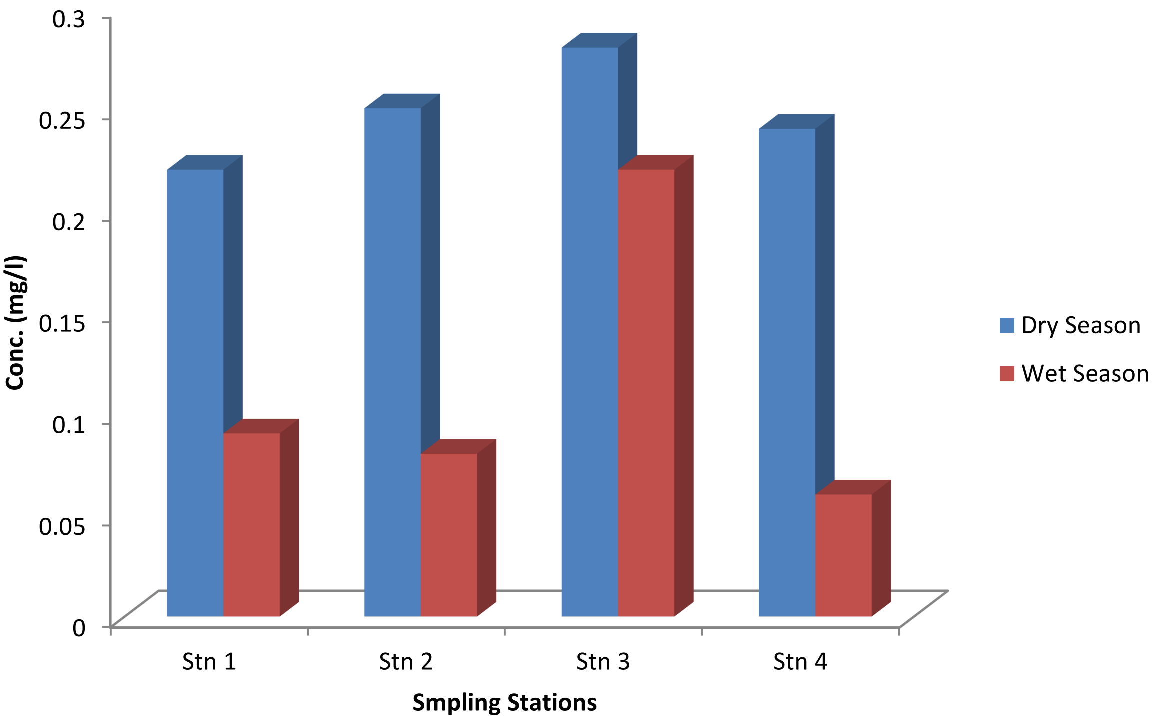

Figure 4: Spatio-seasonal variation of Copper in River Galma around Dakace industrial area, Zaria, Nigeria

The overall concentration of zinc ranged from 0.018 mg/l to 1.12 mg/l with a mean value of 0.51±0.39 mg/l during the dry season and from 0.09 mg/l to 0.51mg/l with a mean value of 0.28±0.13 mg/l during the wet season (Table 2). The mean zinc concentration per sampling points for the dry and wet seasons were 0.60±0.33 and 0.23±0.10 for station 1, 0.51±0.53 and 0.26±0.22 for sampling station 2, 0.36±0.46 and 0.32±0.05 for sampling station 3 and, 0.56±0.44 and 0.31±0.14 for sampling station 4 (Figure 3). The mean zinc concentration was higher in the dry season than wet season but the difference was not statistically significant ($P > 0.05$). No statistically significant spatial variation in zinc levels was also observed in the study (ANOVA, $P > 0.05$). This again indicates that effluents discharged into the river from Dakace industrial estate did not have any significant influence on the overall zinc levels of the River. Zinc content of River Galma observed in this study was found to be lower when compared to World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) of 3 mg/l for portable water [15; 21]. The mean zinc concentration of River Galma for both wet and dry season was below the Australian and New Zealand Environment and Conservation Council limit of 2.0 mg/l for irrigation water [22]. The river therefore poses no significant risk with respect to zinc contamination when used for irrigation. Our observation is in agreement with Dan'azumi and Bichi [10] who reported zinc concentration ranging from 0.247 to 2.227 mg/l for River Challawa in Kano Nigeria. A lower range of 0.07 to 0.90 mg/l was reported for Ikpoba river dam, Benin City, Nigeria [28]. Mean value of 2.72 ± 0.57 mg/l was reported for lower river Niger drainage in North central Nigeria [30]. Zinc is an important element the body needs to function properly. A small amount of Zinc is necessary for a balanced human diet. However, exposure to excess amount of Zinc can result to Zinc poisoning. Zinc is an intestinal irritant, and the first sign of Zinc poisoning is usually intestinal distress. This includes vomiting, stomach cramps, diarrhea, and nausea. Further symptoms of Zinc poisoning are low blood pressure, urine retention, jaundice, seizures joint pain, fever, coughing, and a metallic taste in the mouth as well as induced Copper deficiency [31; 32]
The results obtained in the present study showed that copper content of water samples were ranged from 0.061 mg/l to 0.56 mg/l with a mean value of 0.25±0.20 mg/l during dry season and from 0.02 mg/l to 0.46 mg/l with a mean value of 0.11±0.12 mg/l during the wet season (Table 2). The mean copper concentration per sampling points for the dry and wet seasons were 0.22±0.26 mg/l and 0.09±0.05 mg/l for station 1, 0.25±23 mg/l and 0.08±0.04 mg/l for

sampling station 2, 0.29±0.23 mg/l and 0.22±0.21 mg/l for sampling station 3 and, 0.24±0.21 mg/l and 0.06±0.06 mg/l for sampling station 4 (Figure 4). No statistically significant ($P > 0.01$) seasonal variation was observed in the study. Copper concentration was slightly higher at the point sources (sampling stations 2 and 3) suggesting anthropogenic input but the variation was not statistically significant (ANOVA, $P > 0.05$) indicating that the influence of industrial activities at Dakace industrial estate on the copper levels of river Galma was not significant. Copper concentration recorded in the study was found to be below the maximum contaminant Levels of 2mg/l and 1mg/l established by World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) respectively [15; 21]. The level of copper in River Galma around Dakace industrial estate is thus considered low enough as to have no effect on drinking water quality. However, was found to be slightly above the Australian and New Zealand Environment and Conservation Council limit of 0.2 mg/l for irrigation water [22]. Continuous use of the water for irrigation could therefore pose toxicological risk in terms of copper intoxication over time. Plants consumed by people as food are known to accumulate heavy metals by uptake to levels that present risks to consumers. Although copper toxicity in humans is rare, aquatic organisms are potentially at risk from exposures [29]. Copper concentration recorded in this study was also found to be in agreement with Dan'azumi and Bichi [10] who reported concentrations ranging from 0.022 to 0.390 for River Challawa in kano, Nigeria. Lower concentrations ranging from of 0.01 to 0.04 mg/l was recorded for Ikpoba river dam, Benin City, Nigeria and 0.015 to 0.52 mg/l for streams that receive effluents from different categories of industries in Nakawa - Ntinda industrial area of Kampala, Uganda [29]. Mean value of 2.17 ± 0.73 mg/l was reported for lower river Niger drainage in North central Nigeria [30]. Both acute and chronic exposure to Copper leads to it induced toxicity. Most of the absorbed Copper is stored in the liver and bone marrow. Liver, bone and the central nervous system are the primary targets of Copper induced toxicity. Acute Copper toxicity causes vomiting, diarrhea, hypertension, and cardiovascular collapse. Abnormal accumulation of Copper in the tissue and blood causes Wilson disease [17].

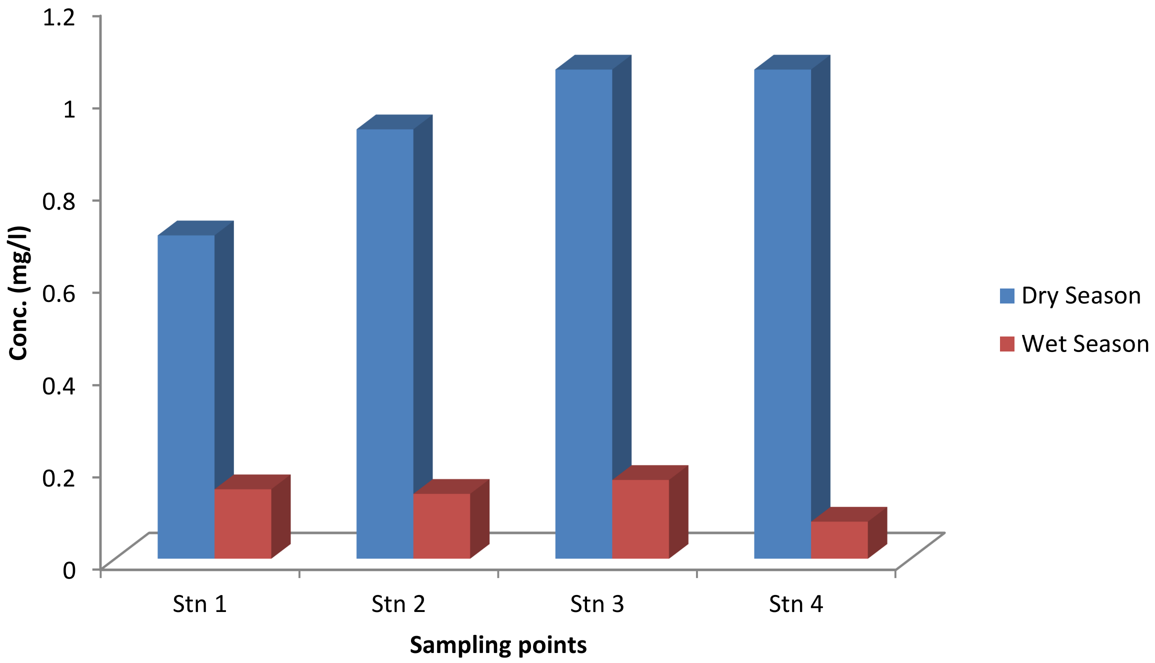

Figure 5: Spatio-seasonal variation of Nickel in River Galma around Dakace industrial area, Zaria, Nigeria

Small amounts of Nickel are needed by the human body to produce red blood cells, however, when the concentration exceeds a certain threshold, it elicits toxic effect [17]. Nickel concentration ranging from 0.01 to 2.55 mg/l with a mean value of 0.94±0.99 mg/l in the dry season and from 0.00 to 0.29 mg/l with a mean value of 0.14±10.09 mg/l in the wet season was recorded in the study (Table 2). The mean nickel concentration per sampling points for the dry and wet seasons were 0.70±0.76 mg/l and 0.15±0.13 mg/l for station 1, 0.93±1.16 mg/l and 0.14±0.04 mg/l for sampling station 2, 1.06±1.31 mg/l and 0.17±0.10 mg/l for sampling station 3 and, 1.06±1.31 mg/l and 0.08±0.07 mg/l for sampling station 4 (Figure 5). Nickel concentration was significantly ($P < 0.05$) higher in the dry season than the wet season. The decrease in nickel levels during the wet season may be as a result of dilution due to large volume of water in the wet season. Nickel level reached its minimum in the month of August when the water level was at its peak and its maximum at the peak of the dry season in the month of February. The difference in nickel levels across the sampling stations was not statistically significant (ANOVA, 0.05). Nickel content of water samples from River Galma was several folds above the maximum contaminant Levels of 0.02mg/l established by World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) [15; 21]. It was also found to be higher than the Australian and New Zealand Environment and Conservation Council limit of 0.2 mg/l for irrigation water [22]. The use of this water for drinking or irrigation purpose therefore constitutes serious health and environmental risk with respect to nickel intoxication. A lower range of 0.05 to 0.11 mg/l was reported for Ikpoba river dam, Benin City, Nigeria [28]. Mean value of 0.78 ± 0.12 mg/l was reported for lower river Niger drainage in North central Nigeria [30]. Acute over exposure to Nickel is not known to cause any health problems, but chronic exposure can cause decreased body weight, heart and liver damage, thyroid disease, cancer and skin irritation. Other toxic effects of Nickel observed following chronic exposure include chronic bronchitis, emphysema, reduced vital capacity and asthma. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains [32]

Metal concentration in the study followed the trend Lead > Nickel >Zinc > Copper. Positive correlation was observed between the concentrations of Lead and zinc (r = 0.290), Lead and Copper (r = 0.71) and between Lead and Nickel (r = 0.423). Zinc concentration correlated positively with the concentrations of copper (r = 0.782) and nickel (r = 0.847). The correlation between nickel and copper was also found to be positive. However, only the correlations between zinc and nickel, Zinc and copper and between copper and nickel were statistically significant at 99 % confidence level suggesting that same source may be responsible for the present of these metals at the concentrations determined.

CONCLUSION

The present study has shown that the influence of Discharges from Dakace industrial area Zaria on the heavy metal profile of River Galma is not significant. However, lead and nickel contents of the water were several folds above the maximum contaminant Levels established by World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). Copper and nickel concentrations recorded were found to be above the Australian and New Zealand Environment and Conservation Council limits for irrigation water. Continuous use of water from the study area for drinking or irrigation could therefore pose toxicological risk with respect to lead, copper and nickel intoxication. It is therefore recommended that, this River should be put under surveillance since it is the only source of fresh water in this area.

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