INVESTIGATION ON TRANPORT AND MIXING PROCESSES OF WATER POLLUTANTS: AN ASSESSMENT OF EFFLUENTS FROM SOME INDUSTRIES IN KANO - NIGERIA

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ABSTRACT
Effluents from industries are one of the major factors contributing to the deterioration and pollution of water quality in Nigeria. Analysis and assessment of the transport and mixing processes of water effluents from some of the industries in Kano state-Nigeria are investigated using standard method of analysis and Buck Scientific Model Atomic Absorption Spectrometer for heavy metals. Effluents from the industries are transported from point sources to single stream. The analysis was meant to detect the presence of Na_2CO_3, Mg, TDS, Ca, Fe, Pb, PO_4, K, Na, and SO_4. The pH of the effluents was also evaluated. Water samples were taken at three different points along the streams from each site. The results showed that pH value varied significantly among sampling locations which ranged from 7.0 -13, whereas, the total dissolved solid (TDS) was between 5.12 - 1177ppm. Phosphate level ranges between 1.12 - 4.08mg/l. Carbonate level from all the industries ranges between 4.1 to 10.8mg/l which far exceed the recommended standard value of 0.007mg/l. Sulphate level ranges between 20.4 - 47.6mg/l. The results showed that sodium level from all the samples ranges between 18.7 - 31.8mg/l while calcium level ranges between 1.3 to 3.2mg/l. It was also observed that the values of lead from all the samples ranges between 0.011- 0.160 ppm while that of magnesium ranges between 12- 41 ppm. Iron level is mostly greater than the recommended range of 0.2mg/l and 0.3mg/l set by WHO and SON respectively. It was observed that the concentration of some of the pollutants increases as the water flow from the point source to the next stage as a result of the mixing processes of effluents coming from different sources while some decreases due to the sedimentation of the pollutants along the way as they are being transported from one point to another.
Keywords: Industrial effluents, Water Quality, Mixing Process, Pollution, Physiochemical parameters, Transport of pollutants.

INTRODUCTION

Industrial pollution resulting from effluents discharge or gaseous emissions is globally on the increase and is creating high environmental and health risks. Discharge of various industrial waste products into water streams and improper treatment of the industrial discharge often result in polluting water sources. Effluents discharge from industries are one of the major factors contributing to the deterioration of water quality in Nigeria. Kano is home to many industries that include food and beverages, pharmaceutical, chemical, textiles, tannery, rubber, iron and steels. The nature of effluents and emissions from such industries are varied and industry specific. Effluents discharged from the industries are released into water stream which is mostly used for irrigation.

Composite effluents from textile industries are found to consist of high concentrations of heavy metals, organic pollutants and toxic colours, which may affect the quality of surface water, soil, ground water and plant tissues (Bharti *et al*; 2013).

The surface water quality in a region can be affected by both point and nonpoint sources of pollution (Vadde *et al*, 2018). Waste water without any treatment may cause adverse effect on the health of humans, domestic animals, wildlife and environment. Contaminated ground water is known to cause deterioration of drinking water and impacts on soil systems, and crop productivity (Bharti *et al*; 2013).

Waste water from distillery and paper industries besides being useful sources of plant nutrients (N, P, K, S etc), these effluents often contain high amount of various traces of organic and inorganic materials as well as traces of toxic elements. These may accumulate in soils in excessive quantities for long term uses (Chhonkar *et al*, 2000).

Sa'eed and Mahmoud (2014) observed that the rate of discharge of pollutants into the environments, which ultimately find their way into water bodies is higher than the rate of purification. This could be due to rapid urbanization, industrialization and growing population.

Domestic wastes contribute increases in the mineral and organic matter content of natural waters. Typically, a single municipal use of a water will contribute about 300 mg/l of total dissolved minerals (Cl^-, Na^+, NH_4^+, NO_3^-, Ca^{2+}, SO_4^{2-} etc) to a water (Snoeyink and Jenkins; 1980). The contribution of dissolved salts by municipal use has an important influence on the degree to which waste water can be recycled (Snoeyink and Jenkins; 1980).

Water contamination is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (Aboyeji, 2013).The importance of water in our daily life makes it imperative to carry out thorough examinations to identify possible causes of water source pollution and proffer solutions. The role of industries in these regards need to be investigated to ensure compliance with safety standards. This study is aimed at determining the composition of the effluents from different industries as they are transported along the water stream.

THEORITICAL BACKGROUND
Determination of pH Value
pH is the term used to express the intensity of the acid or alkaline condition of a solution. The pH of about 95% of the naturally occurring waters is within the range of 6 – 9 according to Snoeyink and Jenkins (1980), or 6.5 – 8.5 according to WHO (2005), and SON (2007). Constant and well regulated pH is essential for the proper functioning of the many biological and chemical processes involved in water and wastewater treatment (Snoeyink and Jenkins; 1980). The pH value can be defined as the logarithm to base 10 of the reciprocal of the concentration; or pH value is equal to the logarithm of hydrogen-ion concentration with negative sign. This can be stated mathematically as (Ademoroti, 1996):

$$pH = -\log_{10}\left(\frac{1}{H^+}\right) \qquad (1)$$

where (H^+) is the hydrogen-ion concentration
Total Dissolved Solid
Total dissolved solid (TDS) is the term used to describe the inorganic salt and small amounts of organic matter present in solution in water.

The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrocarbonate, chloride, sulphate and nitrate anions. TDS in water supplies originate from natural sources, sewage, urban waste, agricultural run-off, and industrial waste water. The presence of TDS in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 - 600 mg/litre; fair, between 600 - 900 mg/litre; poor, between 900 - 1200 mg/litre; and unacceptable, greater than 1200 mg/litre (WHO, 2003). Concentration of TDS from natural sources have been found to vary from less than 30mg/litre to as much as 6000 mg/litre depending on the solubility of minerals in different geological regions (WHO,2003).

The Phosphate
Phosphorus occur in natural water, effluents and sludge almost entirely in phosphate forms. They are either of organic or inorganic origin. The various phosphate forms find their way into waste waters or effluent from sources such as laundry work from detergents, agricultural field through phosphates fertilizers and from processing factories where phosphates are used as food additives (Ademoroti, 1996). The phosphate level can be obtained from the plot of absorbance against concentration (Ademoroti, 1996):

$$PO_4^{3-} - P\,(\text{mg/l}) = \frac{Phosphate\ caliberation\ curve \times 1000 \times D}{ml\ sample} \qquad (2)$$

where D=dilution factor
The Sulphate
Sulphate are of considerable concern because they are indirectly responsible for two serious problem associated with the handling and treatment of wastewaters. These are odour and sewer-corrosion problems resulting from the reduction of sulphate by hydrogen under anaerobic condition (Ademoroti, 1996):

$$SO_4^- + oganic\ matter \xrightarrow[bacteria]{anaerobic} S^- + H_2O + CO_2 \qquad (3)$$
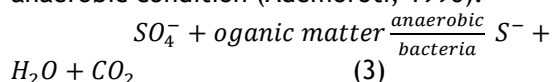
In fresh water, sulphate is often responsible for the hardness.
The Carbonate
The method of calculation of the percentage of CO_3 from titrations of the sample was used for the determination of carbonate. The percentage of the CO_3 was calculated as follows (Ademoroti, 1996):

$$\%CO_3 = \frac{\text{wt of Na}_2\text{co}_3 \text{ in sample}}{\text{g sample}} \times 100 \qquad (4)$$

Metals ions and Heavy Metals
Heavy metals in effluents are poorly soluble in water, and cannot be degraded; they tend to accumulate in soils and subsequently accumulate in plants. In addition, heavy metals persist in soil which then leach down into the groundwater and may induce enhanced antioxidant enzymatic activities in plants or become adsorbed with solid soil particles. Dispersion of heavy metals in irrigated soils and the plants that are growing results in the contamination of food that may be hazardous to humans and animals (Mahmoud and Ghoneim; 2016).

Inputs of metals contaminants occur from three generic sources: domestic, commercial and urban runoff. A review of available literature has quantified the extent and importance of these various sources and the inputs from different sectors. In general, urban runoff is not a major contributor of potentially toxic elements. Input from paved surface due to vehicle road abrasion, tyre and brake-lining wear have been identified and losses from Pb painted surfaces and Zn from roofing materials represent localised sources of these elements. Feaces contribute 60-70% of the load Cd, Zn, Cu and Ni in domestic waste water and >20% of the input of these elements in mixed waste water from domestic and industrial premises. Faecal matter typically contains 250 mg Zn kg^{-1}, 70 mg Cu kg^{-1}, 5 mg Ni kg^{-1}, 2 mg Cd kg^{-1} and 10 mg Pb kg^{-1}. The other principal sources of metals in domestic waste water are body care product, pharmaceuticals, cleaning product, and liquid waste (Thornton *et al*; 2001).

Table 1: Recommended standard values of some of the parameters given by World Health Organisation (WHO) and Standard Organisation of Nigeria (SON)

Parameters	WHO	SON
pH	6.5-8.5	6.5-8.5
TDS(mg/l)	50	500
Phosphate(mg/l)	10.00 - 20.00	_
Carbonate(mg/l)	0.007	_
Sulphate(mg/l)	400	100
Sodium(mg/l)	40	200
Calcium(mg/l)	200	_
Potassium	0.2	_
Iron (mg/l)	0.2	0.3
Magnesium	0.05	0.20
Lead(mg/l)	0.01	0.01

Study Area
Kano is a state in Nigeria, located between latitude $12°15'S$ and $12°35'N$ of the equator and longitudes $8°20'W$ and $8°27'E$ of the meridian. Sample were collected from some of the industrial estate/areas in Kano state. This includes; Challawa, Bompai, Sharada and Zaria road industrial areas. The study areas are shown in Figure 1.
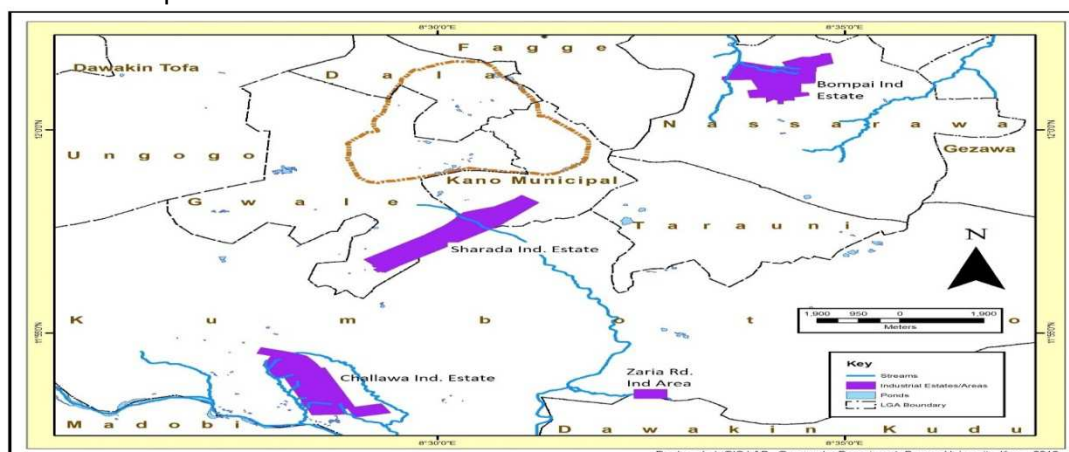
Figure 1. Study area of some of the industrial estate /areas in Kano state –Nigeria indicated by purple colour.

MATERIALS AND METHODS
Sampling
Forty six samples of industrial effluent were collected from different industrial estate/areas in Kano state. These comprises of two plastic industries, one agro industry, one pharmaceutical industry, one bottling industry, nine tanneries. The water samples were collected at three different points on the stream from the point sources with a view to determine changes in pollutants deposits as well as the transport and mixing processes of the pollutants. Samples were collected in rubber bottle containers which were first washed with nitric acid and then severally with clean water before taking to the laboratory for analysis.

Methods:
An Oakton pH11 (Model 754487) instrument was used for pH measurement and TDS determination. The Vanado-Molybdo-Phosphoric Acid calorimetric method was used in determining the phosphate in the samples (Ademoroti,1996). Gravimetric method was adopted for determining sulphates in the samples (Ademoroti,1996). Titration method was used to calculate the percentage of carbonate in the samples (Ademoroti, 1996).

The samples were investigated for presence of metal ions and heavy metals such as; CO_3, Mg, TDS, Ca, Fe, Pb, PO_4, P, K, Na, and SO_4 using Atomic Absorption Spectrometer (BUCK Scientific 210VGP). The sampling was conducted between the months of May-June, 2016.

RESULTS AND DISCUSSION
The results of pH measurement of the samples varied significantly among sampling locations. The pH was found to be within the range recommended by WHO (2005), and SON (2007). With exceptions in some sampling sites D, M, and N as shown in Figure 2. This result indicate that the water sample from these sites exhibited alkaline pH above the national standard. It has been reported that high pH values in streams and rivers increase the toxicity of ammonia to aquatic organisms (Esemikose and Akoji, 2014; Walakira and Okotokumu, 2011). This could be attributed to the cleaning agents such as addition of sodium sulphate, industrial soap, alum, caustic soda, sulphuric acid, forming acid, bicarbonate and ammonium in the process of transforming the material into leather product.
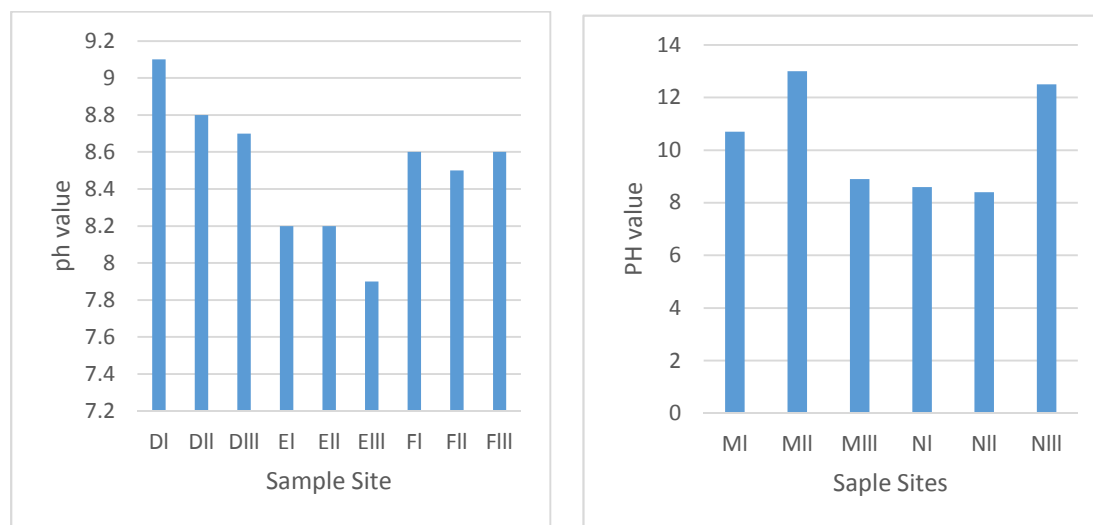
Figure 2. Graph of PH value along sites D, E, F, M, and N

The range of TDS in most of the sampling sites are below the recommended values of 500mg/l by WHO (2005) and SON (2007) except for sites C, E, G, as seen in Figure 3 and 4 as well as sites J , K and L which were higher than the recommended values set by WHO and SON .The abnormal value of TDS on this sites can result in the reduction of water clarity which could lead to the decrease in photosynthetic activities, objectionable taste and even increase in temperature of water (Sa'eed and Mahmoud,2014).
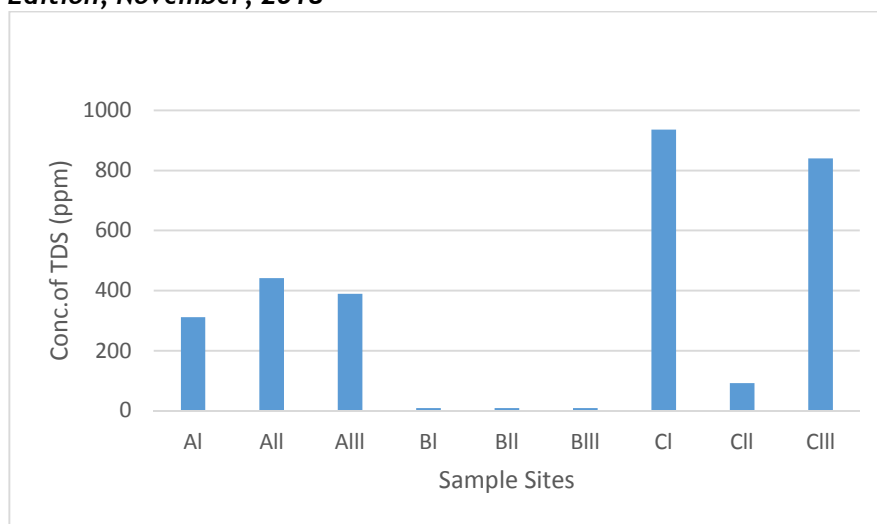
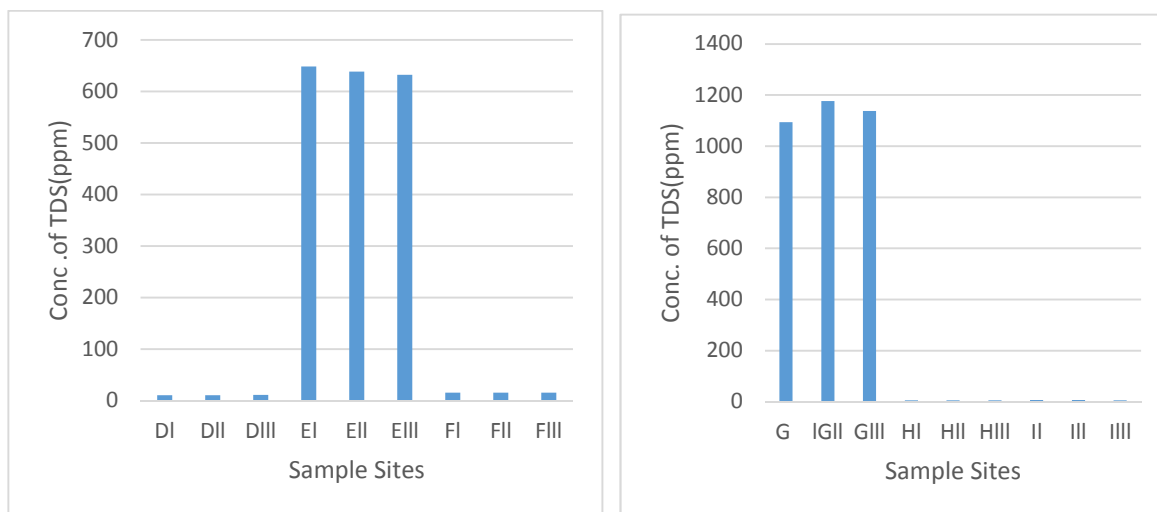Figure 3. Graph of the concentration of TDS along sites A, B, and C

Figure 4. Graph of the concentration of TDS along sites D, E, F, G, H, and I

The phosphate concentrations varied significantly among sampling locations. The phosphate levels are within the recommended values for the discharge of effluents (10-20 mg/l) (WHO, 2006). As seen from Figure 5, Site C exhibits the highest phosphate value (4.08 mg/l) and this could be attributed to the cleaning process by the use of heavy detergents.
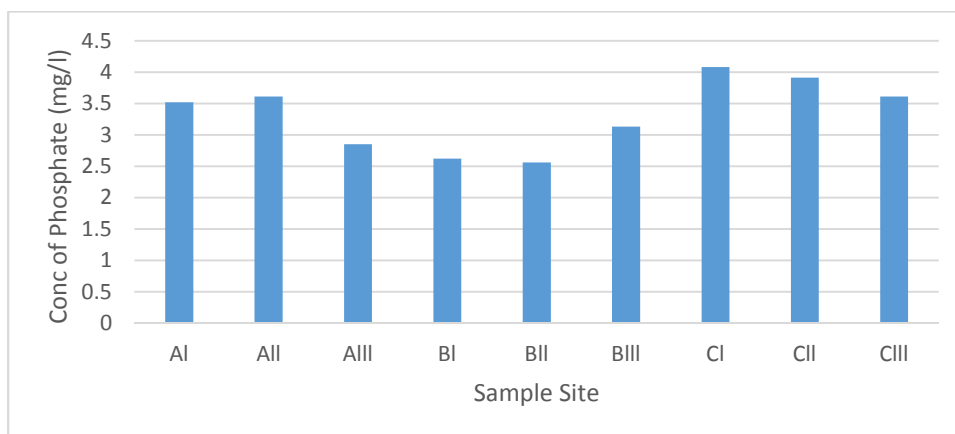

Figure 5. Graph of the concentration of phosphate along sites A, B and C

The carbonate level from all the industries far exceed the recommended standard value of 0.007mg/l as seen from Figure 6.This could be attributed to the decomposition of the materials used in tannery production industries and also the mixing processes of the pollutants from various industries. High level of carbonate can leads to cancer.
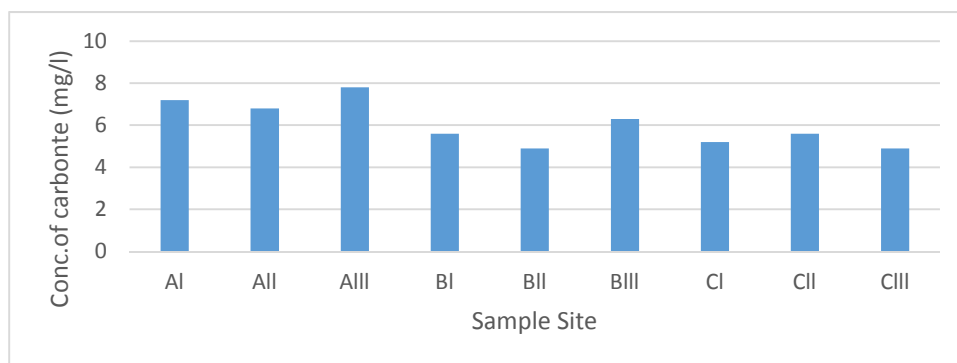
Figure 6. Graph of the concentration of carbonate along sites A, B and C

The concentration of sulphates are all less than the permissible limits of 400mg/l by WHO (WHO, 2008). Typical result for sampling sites A, B, and C are shown in Figure 7.
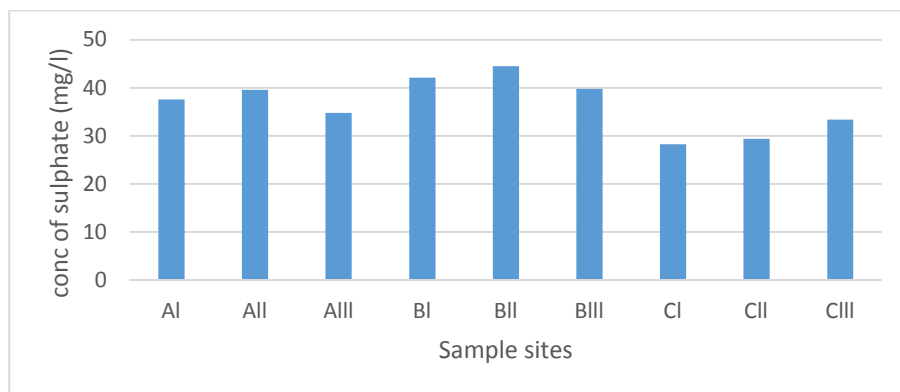
Figure 7. Graph of the concentration of sulphate along sites A, B and C

The levels of sodium concentration from all the samples ranged between 18.7-31.8 mg/l where stage lll of site K recorded the highest sodium concentration as seen in Figure 8. Although it is reported that sodium is essential to human life, there is no agreement on its maximum daily requirement. However, it has been estimated that a total daily intake of 120-140 mg will meet the daily need of growing infants and young children and 50 mg for adults respectively (Sa'eed and Mahmoud, 2014).
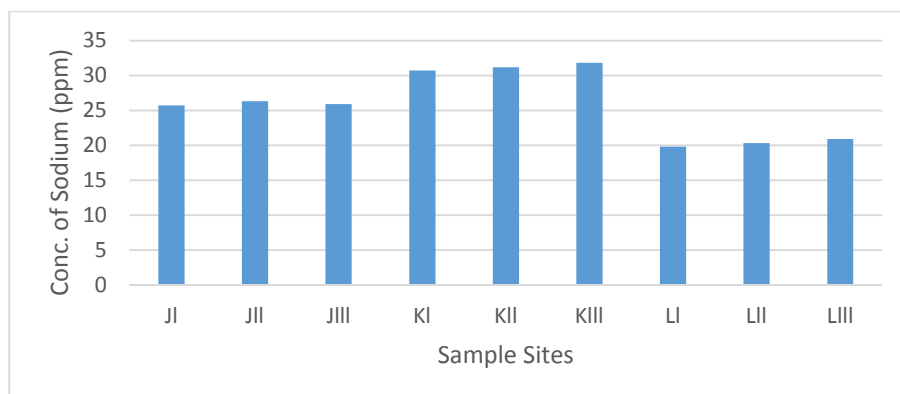
Figure 8. Graph of the concentration of sodium along sites J, K and L
Calcium level it ranges between 1.3-3.6 mg/l where stage ll of site N recorded the highest value of 3.6 mg/l as seen in Figure 9.
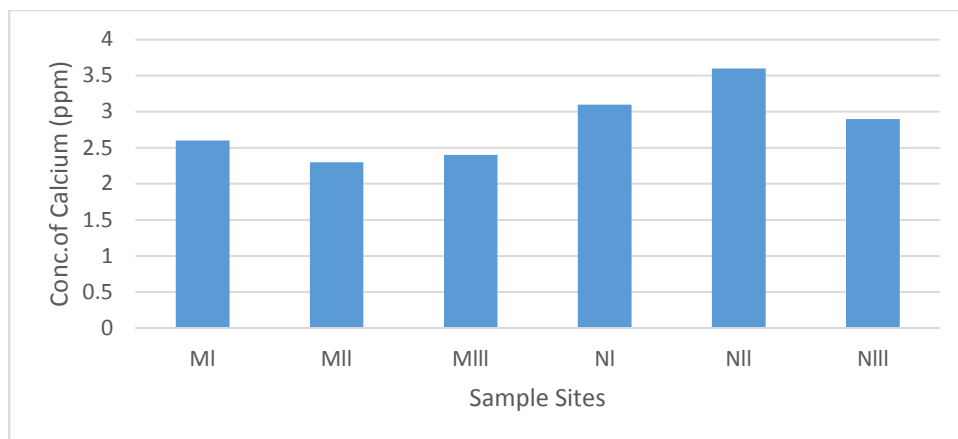
Figure 9. Graph of the concentration of Calcium along sites M and N

For potassium stage ll of site B and ll of site N recorded the highest concentration of potassium at about 2.7mg/l each, as seen from Figure 10. From the result it was observed that the concentration of potassium is not that high, even though excessive amount can be hazardous to the health.
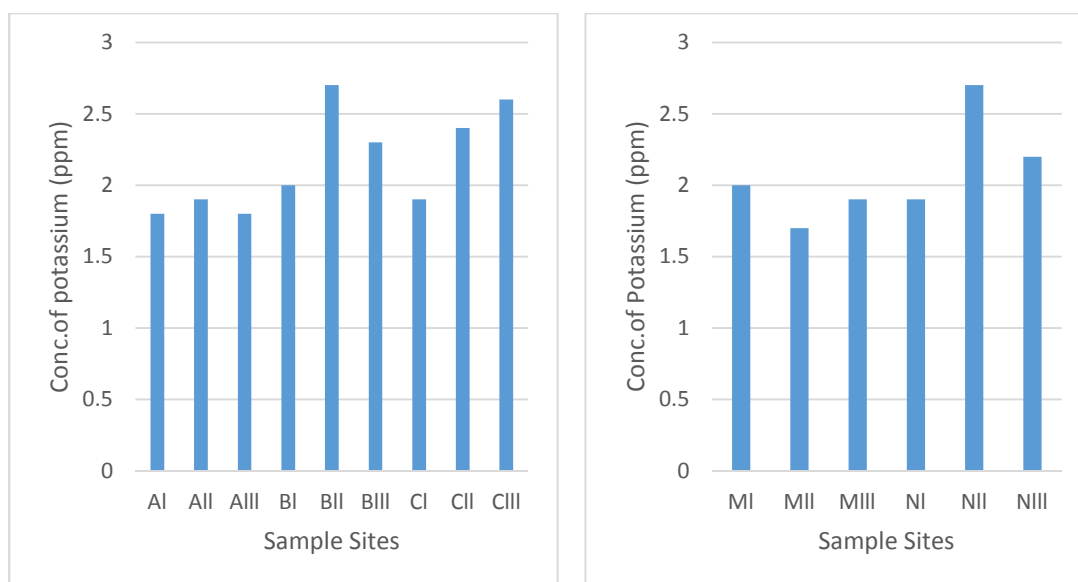

Figure 10. Graph of the concentration of potassium along sites A, B and C

The heavy metals detected are Pb, and Fe. It was seen from Figures 11, that the levels of lead from all the samples ranges between 0.011-0.160 mg/l. This values are higher than the recommended standard value of 0.01mg/l by WHO (2008); SON (2007) and Emagbetere *et al,* (2014). So also, the magnesium in all samples are higher than the recommended values of 0.05, and 2.00 mg/l by WHO, and SON respectively. This may be as a result of the discharge of untreated or not properly treated effluent from sewage and industries. The heavy metals can also originate from corrosion of brass and metal fittings in certain types of industries that deal with metals. But for the case of iron, the samples are mostly greater than the recommended range of 0.2mg/l and 0.3mg/l set by WHO and SON respectively (WHO, 2002; SON, 2007). High level of heavy metals in streams can cause delay in physical and mental development in humans along with learning difficulties in children and it can cause kidney problem, high blood pressure in adults and is toxic to the central and peripheral nervous systems.
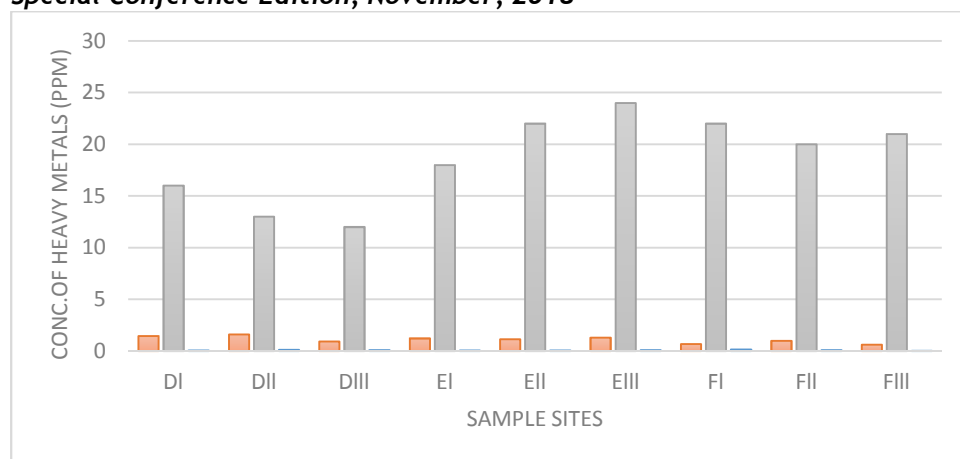
Figure 11. Graph of metals Fe, Mg and Pb concentration along sites D, E and F

CONCLUSION

Analysis and assessment of water pollutants from some industrial estate/areas in Kano state was carried out. This analysis was able to identify the various sources and types of water pollutants in the study area using AAS technique. The result showed that, some of the polluting agents are within WHO, NAFDAC and SON recommended safety limit while some are not. This clearly illustrates the impact of the different category of industries with respect to the different polluting agents concentrations and treatment.

It was generally observed that most of the industries that have high concentration of Carbonate, Sulphate, phosphate and TDS are the tannery production industries. It was also clear that the effluent from these industries are not properly treated before being released to the water streams. The study reveals that concentration of some of the polluting agents increases as they flows from the point source to the next stage as a result of the mixing processes of effluents coming from different sources while some decreases due to the sedimentation of the pollutants along the stream as they are being transported from one point to another.

Moreover, most of the heavy metal identified from the sample are higher than the recommended standard value which is believed to be as a result of the discharge of untreated effluent from industries, chemical contaminant from the treated effluents, corrosion of metals of all kinds and refuse which may include lead battery. Based on the determined parameters the water discharged from the industries are mostly polluted resulting from the transport and mixing processes of pollutants. These pollutants are discharged from different channels to the main water body (River) which is mostly used by people for different activities. So, much precaution should be taken on the use of water from the streams and rivers.

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