IMPACTS OF EFFLUENTS ON URBAN TROPICAL RIVER: HEAVY METAL POLLUTION PERSPECTIVE

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Abstract: Surface water samples from Romi River were collected for 24 months (2015 - 2016) and analyzed quantitatively for the concentration of thirteen heavy metals namely: Arsenic (Ar), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni), Manganese (Mn), Mercury (Hg), Cobalt (Co),Calcium (Ca), Potassium (K)and Zinc (Zn) using Atomic Absorption Spectrophotometer (AAS). The analyzed data revealed that Ca, K, Mn and Co was found to be the most abundant in the river. In station 2 and its tributaries, Ar, Cd, Cr, Cu, Fe,Ni, Pb, Mn, Co, and Zn were recorded the highest. While station 1 had the highest concentration of Hg, station 3 had the highest of Mn. The result has shown that the water at Romi River and its tributaries is contaminated beyond safety level and therefore not suitable for drinking as recommended by World Health Organization (WHO). Chromium, Lead, Arsenic, Copper, Nickel, Iron concentration are all above acceptable limit at station 2 and 3. Zinc concentration on the other hand is within the acceptable limit in all the 5 stations. In general, the water quality assessment with respect to heavy metals conducted at the 5 selected stations revealed that water quality at station 1 is within permissible limit for drinking and other purposes. Station 2 and 3 however, were beyond the desirable limit due to presence of high concentration of copper, nickel, Iron, Arsenic Chromium, cobalt and Lead metals. This finding can be concluded that anthropogenic activities which include industrial effluents, residential waste discharge and others have brought about resource degradation and a decline in environmental quality.

Keywords: Water quality, effluents, heavy metal, urban, Romi River

Introduction

Fresh clean water has become a scarce natural commodity due to over exploitation and pollution (Aderogba, 2011). Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life including other animals' life and plant (Ahalya *et al*., 2017).

Water pollution by effluent has become a question of considerable public and scientific concern in the light of evidence of their extreme toxicity to human health and to biological ecosystems (Duruibe *et al*., 2007). The occurrence of heavy metals by industrial and municipal sewage effluents constitute a major source of metals entering aquatic media (Fevzi, 2009).Due to heavy metals such as lead, arsenic, selenium, cadmium, copper, zinc, uranium, mercury, and nickel serious health hazards are caused due to transfer of these contaminants into food chain. This changing environmental conditions and extreme use of agrochemical heavy metals are being accumulated in soils which are transferred to water system by leaching. Hence there should be regular assessment of these sewage effluents to ensure that adequate measures are taken to reduce pollution level to the minimum (Adamu *et al.*, 2015) as this could influence the current shorter life expectancy in the developing countries compared with developed nation (WHO, 2006).

The present study on heavy metals will be significant in that some of these may prove lethal to aquatic flora, fauna and ultimately humans who are usually at the top of the food chain. The receiving stream serves as a convenient means of cleaning the highly loaded sewage and carries waste away from its discharge point, such as municipal and industrial wastewater and runoff from agricultural and mining land. The need to know the quality of the water from the receiving stream has informed this study. The study will also provide information on the performance efficiency of Romi River.

Materials and Methods

Description of study area

Romi River is a major River in Chikun local government area of Kaduna State. Romi river lies within Longitude: 10°25' 35.3 N and Latitude: 7°20' 25.06E with elevation of 568 m above sea level. Romi River is a tributary of Kaduna River with the largest fresh water body flowing through Chikun. The river provides portable water to Romi and environs (Rido, Juji, Karatudu and Gonigora). Apart from improving water supply to the populace, it provides sand, fish as well as suitable sites for fadama farming resulting in the production of some highly favoured selected crops such as vegetables, rice and sugar cane etc. The river under study receives huge amount of untreated effluents from industries such as oil refineries, Kaduna petrol chemical company (KRPC) and others which are released directly or indirectly into the river. This may likely render the water unfit for drinking and agricultural role.

Sample collection and analysis

Water sampling was done once a month from five established points labelled as stations (S) viz, S_1 (Rido upstream), S_2 (NNPC), S_3 (NNPC/Rido), S_4 (Juji) and S_5 (Romi downstream), between (January, 2015 to December, 2016). Sampling stations were selected to represent different environmental and ecological variations within the river. This will give better understanding on effect of natural and anthropogenic factors of the rivers and the state of their water quality. Station S_1 (Rido upstream) is mainly considered to be impaired by human activity (Obaroh *et al.*, 2015). Sampling station S_2 to S_5 located just after KRPC discharge tunnel along the river string, were petroleum wastewater, domestic waste and other waste, were discharge directly or carried by surface run-off into the river. Heavy metal was determined using standard and analytical of wet digestion using the Perkin Elmer Model of 306 Atomic Absorption Spectrophotometry (AAS).

Statistical analysis

The analysis was aided by statistical package for social sciences (SPSS) software version 16.0 and Paleontological Statistics (PAST) software version 1.95 were used to compare heavy metals characteristics among the sampling stations having carried out Shapiro-Wilk test of normality ($P<0.05$).

Results and Discussion

Heavy metal mean concentration ranges in the study area during January, 2015 to December, 2016 are shown in Table 1 while Table 2 depicts the health – based guidelines' and acceptable limit of metals according to WHO (1993).

Table 1: Heavy metals concentration µg/L (v/v)

Stations	Cr	Zn	Pb	As	Hg	Cu	Fe	Mn	Cd	Ni	Co	K	Ca
Rido	0.02^{c}	1.55^{c}	0.11^{bc}	0.00^{b}	0.05^{b}	0.93^{b}	0.55^{b}	2.14^{ab}	0.06^{b}	0.02^{b}	0.01^{b}	4.00^{ab}	10.70^{b}
NNPC	0.71^{a}	3.88^{a}	1.03^{a}	0.05^{a}	0.17^{a}	2.36^{a}	1.54^{a}	4.33^{a}	0.29^{a}	0.39^{a}	0.08^{a}	4.57^{ab}	40.00^{a}
NNPC/Rido	0.37^{b}	2.62^{b}	0.39^{b}	0.02^{b}	0.15^{a}	1.92^{ab}	1.03^{ab}	3.43^{ab}	0.19^{a}	0.05^{b}	0.05^{a}	5.22^{a}	30.58^{a}
Juji	0.05^{c}	1.36^{c}	0.08^{c}	0.00^{b}	0.10^{a}	1.85^{b}	0.72^{ab}	2.91^{b}	0.15^{a}	0.04^{b}	0.00^{b}	3.34^{b}	29.70^{a}
Romi	0.02^{c}	1.41^{c}	1.41^{c}	0.00^{b}	0.09^{a}	1.30^{ab}	0.71^{ab}	2.86^{b}	0.29^{a}	0.06^{b}	0.00^{b}	3.44^{b}	31.12^{a}
Season													
Wet	0.300	2.079	0.305	0.025	0.630	208.82	1.038	3.502	0.355	0.096	0.044	4.442	36.633
Dry	0.179	2.240	0.378	0.013	0.005	1.273	0.790	3.230	0.082	0.139	0.026	3.791	28.216

The alphabets a = ….., b = ……., c = ……., ab = ……

The mean surface water concentration for Cr, Cu, Pb, Zn, Fe, Ni, Mn, Cd, K, Ca and Mg is shown in Table 1. The results confirm the differences of heavy metal concentration in the different stations. The highest concentrations were found in station 2 (NNPC) follow by station 3, 4 and 5, respectively. The reported high concentration of these heavy metals above the acceptable limit of WHO (1993), Table 2, this could be attributed to the large effluent discharge by Kaduna petrol chemical company into the river (Adamu, 2015). The lowest concentration of Arsenic, Iron and Nickel were detected in station 1 (Rido). Station Rido is off the effluent discharge point.

Table 2: The health–based guidelines' and acceptable of metals (WHO, 1993)

Toxic metal	Health-based Guideline (mg/L)	Requirement (Acceptable Limit) (mg/L)	Requirement (Acceptable Limit) (µg/L)
Arsenic (As)	0.01	0.01	10
Cadmium (Cd)	0.003	0.003	3
Chromium (Cr)	0.05	0.05	50
Copper (Cu)	2.0	0.05	50
Iron (Fe)	No guideline	0.3	300
Lead (Pb)	0.01	0.01	10
Nickel (Ni)	0.02	0.02	20
Zinc (Zn)	3.0	5	5000

Chromium: In Table 2 WHO (1993) has recommended an acceptable limit of 0.05 mg/L (50 µg/L) of chromium in drinking water. The study data reveal that chromium concentration varies from 0.71 to .02 µg/L. Water quality of station 2 on Romi river have the highest maximum value 0.71 µg/L concentration. Concentration of chromium was above the acceptable limit of drinking water in only station 2. The monthly concentration of chromium in 2015 and 2016 is shown in Fig. 1. The highest chromium concentration of (1.84) was recorded in August at station 3 while 2016, the concentration of chromium ranged between 1.60 in January at station 2 (fig. 8). Station 2 had values above one in January, August, October, and December, also station 3 recorded value above one in January. Wet season recorded the highest value 0.30 µg/L. Atapour (2012), Banerjee *et al.* (2016) and Pinto da Silva *et al.* (2017) reported case; 4.9 µg/kg in South Eastern Iran, 0.02 µg/L Subharnarekha River, India and 17.86 µg/L in Southern Brazil respectively, which are both lower and higher than the one we have obtained in a similar fashion.

Zinc: 5 mg/L (5000 µg/L) is the acceptable concentration limit of zinc in drinking water by WHO (1993). Zinc concentration varies from 1.36 to 3.88 µg/L. Maximum zinc concentration is recorded at station 2 of Romi river. In the study area, all the water quality samples having zinc concentration is within the acceptable and permissible limits of WHO (1993) Standard and there is no toxicity of Zn in the river water. Zinc in 2015 varied between (0.2) in January (station 1 and 2), February at station 2 and March (station 4), the highest value (4.51) was recorded in March at station 2. Zinc concentration was higher during the dry season than wet season figure 1. Abdel Gawad *et al.* (2018) reported a bit lower concentration of 0.033 µg/L in research carried out in Lake Manzala, Egypt. Similarly, 0.034 mg/L and 23.05 µg/L were reported by Cobbina *et at.* (2015) from studies carried out in Northern Ghana and Yin *et al*. (2018) from Chaohu Lake in China, respectively.

Lead: In 2015, lead low value (0.01) in March was obtained in wet season while higher values (0.39) were recorded in dry season Fig. 2. WHO (1993) recommended an acceptable limit of 0.01 mg/L (10 µg/L) for lead in drinking water. Lead concentration is maximum (1.41 µg/L) at station 5 of Romi river. Much higher values were reported by Pinto da Silva *et al.* (2017), 14.96 µg/L, Atapour (2012) 45.1 µg/kg and then lower concentration by Abdel Gawad (2018) 0.0406 µg/L.

Arsenic: The Arsenic concentration values for 2015 are shown in Fig. 2. The Arsenic concentration values were higher during the first three months reaching their maxima (0.07) in February at station 2. In 2016 recorded the highest value (0.34) in January at station 2. Generally, Arsenic values from station 2 and 3 were appreciably higher than other stations during the period of study 0.01 mg/L (10 µg/L) is the acceptable concentration limit of arsenic in drinking water (WHO, 1993). The arsenic concentration varies from 0.00 to .05 µg/L. Maximum arsenic concentration (0.05, 0.02 µg/L) were observed at station 2 and 3, respectively on Romi river. In the study area, station 2 and 3 of the river water quality samples are reported to have arsenic concentration above the acceptable limits of WHO, therefore, the river water is toxic of arsenic. Comparatively, the values obtained in our study, in spite of the fact that it exceeded the permissible limit as recommended by WHO, it is much lower in contamination than the ones reported by Ali *et al.;* (2016), 23.36 µg/L, Yin *et al*. (2018), 8.21 µg/L. But it is within the range obtained by Cobbina *et al.* (2015), 0.031 mg/L in Northern Ghana.

Iron: Acceptable limit of iron is 0.3 mg/L (300 µg/L). The occurrence of iron in Romi river water ranges 0.55–1.54 µg/L. All the samples are above the acceptable limit prescribed by WHO (1993) table 2. Station 2 recorded the highest Iron concentration was maximum 1.54 mg/L. Monthly variations of iron in 2015 and 2016 are shown in Fig. 4. The values varied between 0.13 in March and 5.41 in December at station 2, appreciable low values were obtained in dry season while higher values were recorded in wet season. In 2016, the iron concentration was lowest (0.01) in July at station 4. Generally, there was an appreciable higher iron concentration in station 2 and 3 than the other 3 stations (Table 2). This is lower than 2.24 mg/L obtained in the by Abubakar *et al.* (2015). In a study conducted within Kaduna Metropolis in 2015. It is also far lower than what was obtained by Pinto da Silva (16.93 mg/L) in the Sao Joao River basin, Southern Brazil.

Cadmium: In 2015, Cadmium was reported at station 4 in May to November and at station 5 with the value 0.722 µg/L in September (Fig. 5).

In 2016, Cadmium highest value 5.42 µg/L was recorded in January at station 2. Generally, the cadmium values were high during wet season than dry season (Fig. 5). 0.58 µg/L and 0.004 mg/L were reported by Yin *et al.* (2018) and Banerjee in China and India, respectively.

Nickel: The highest nickel concentration. 39 µg/L is observed in station 2. The five water quality stations in Romi river recorded Nickel values as: Station 1 (0.02 µg/L); Station 2 (0.39 µg/L); Station 3 (0.05 µg/L); Station 4 (0.04 µg/L); Station 5 (0.06 µg/L). Water quality of station 1 has nickel concentrations within the acceptable limits of WHO, 1993 guidelines propose 0.02 mg/L (0.02 µg/L) of nickel in drinking water (Fig. 5). Yin *et al.* (2018) also reported higher concentrations of Ni, 26.17 µg/L. 7.44 µg/kg was also reported by Atapour in her study the south eastern Iran. This means that several studies conducted around the world have revealed elevated levels of heavy metals beyond the acceptable limit as recommended by WHO (1993).

Copper: Figure 3 show the monthly concentration of copper. Copper concentration was found between 0.93 and 2.36 µg/L. The low values of Cu indicate that there is no significant source of pollution. The maximum Cu concentration was found 2.36 µg/L at Station 2 on Romi river and minimum (0.93 µg/L) at Station 1 on Romi river. It may be attributed to domestic sewage and runoff from extensive farmed areas (Wang *et al*., 2009). Among the five water quality samples, only Station 2 (2.36 µg/L) have copper concentration above the acceptable limits of WHO, 1993 during the whole study period (Table 2).

High concentration of calcium, potassium and magnesium are due to surface run-off, nature of bed rock and increased precipitation has been reported in inland water. Hanaa (2000) and Sabine (2009) reported that the ultimate source of body trace element is generally rock and the concentration of the trace element in rock. Heavy metals such as cadmium, chromium and lead greatly affect the water quality of the river (Kuforiji, 2013; Vilia-Elena, 2006).

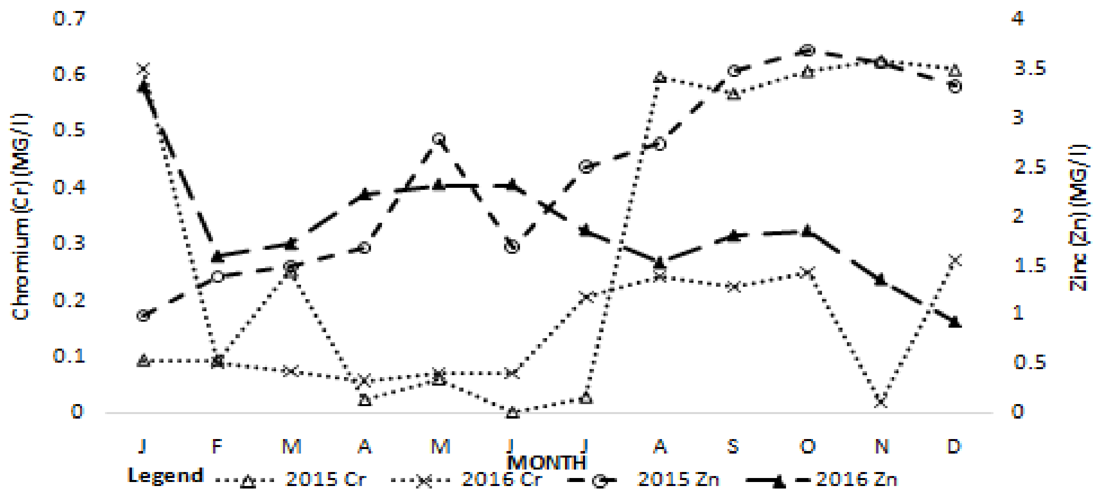

Fig. 1: Monthly concentration of chromium and zinc in Romi River, Kauna (2015 – 2016)

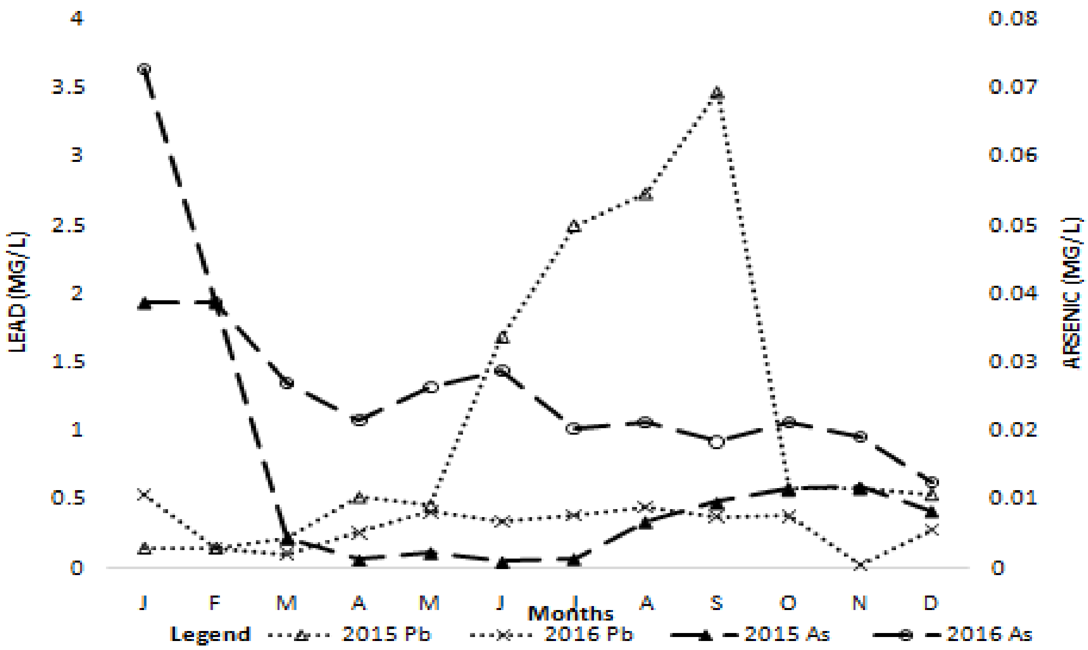

Fig. 2: Monthly concentration of lead and arsenic in Romi River, Kaduna (2015 – 2016)

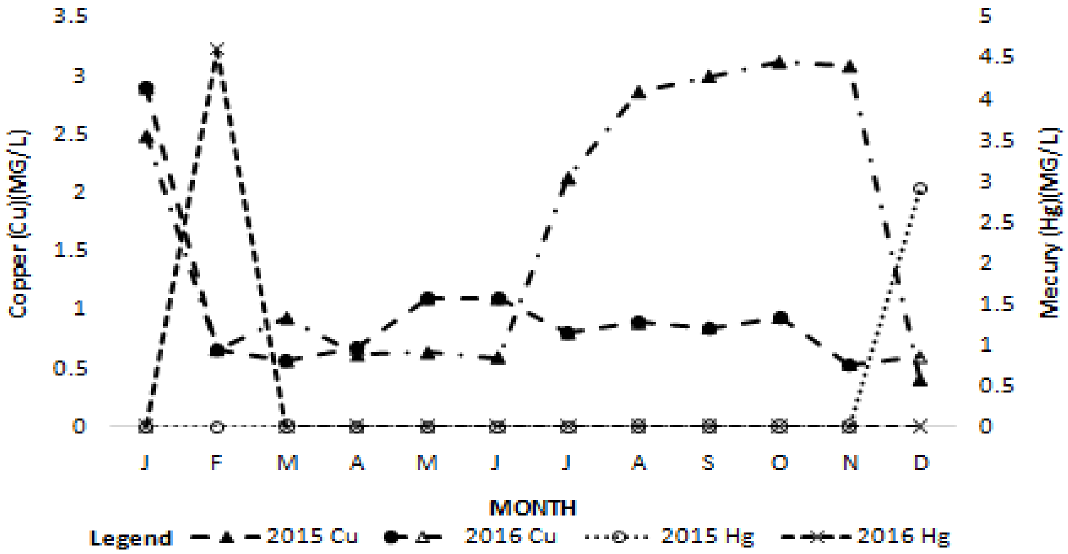

Fig. 3: Monthly concentration of copper and mercury in Romi River, Kaduna (2015 – 2016)

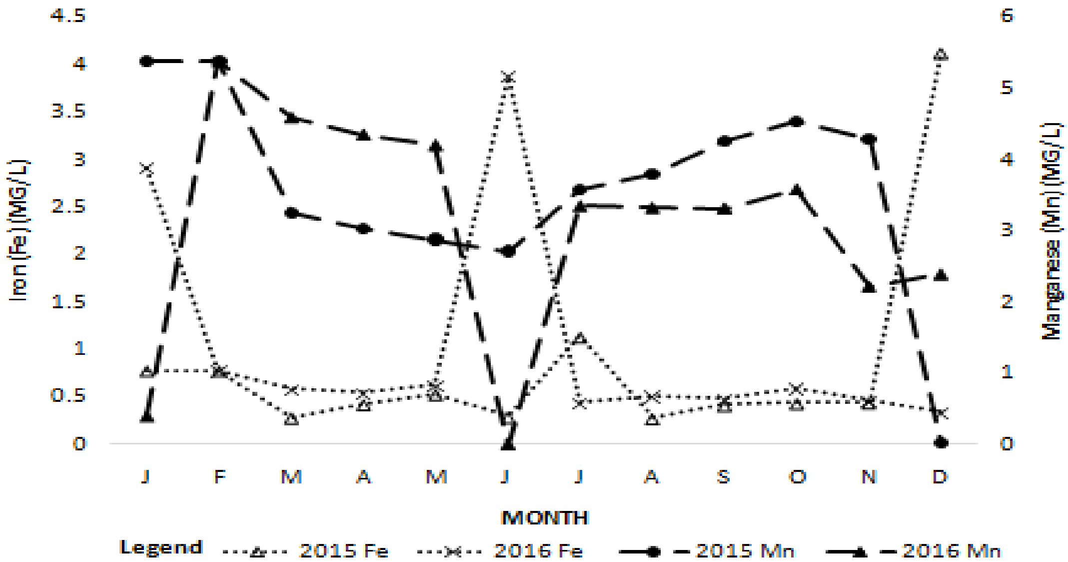

Fig. 4: Monthly concentration of Iron and manganese in Romiriver, Kaduna (2015 – 2016)

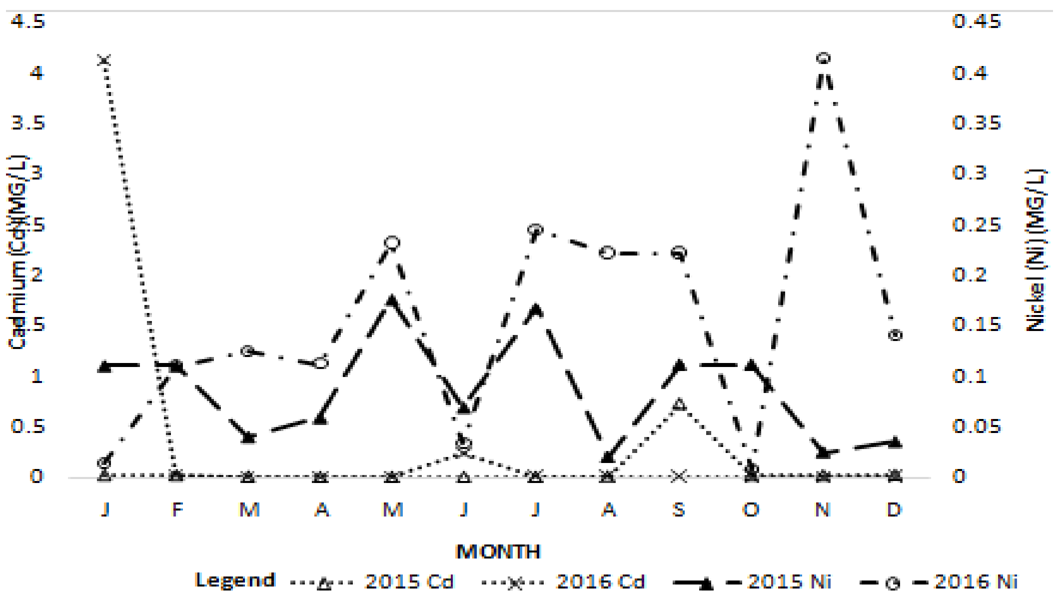

Fig. 5: Monthly concentration of cadmium and Nickel in Romi River, Kadun (2015 – 2016)

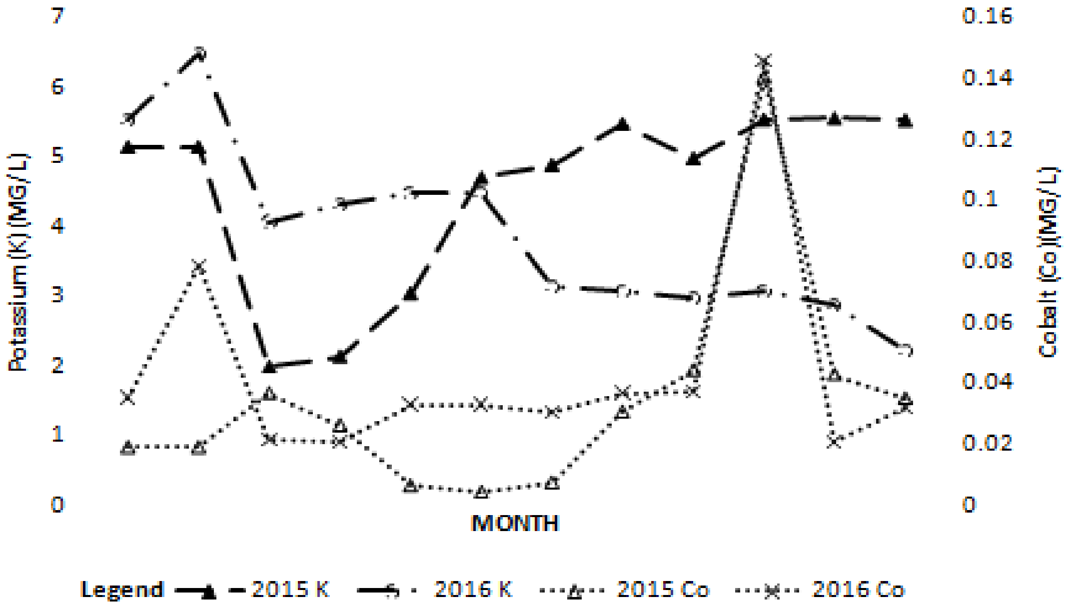

Fig. 6: Monthly concentration of potassium and cobalt in Romi River, Kaduna (2015 – 2016)

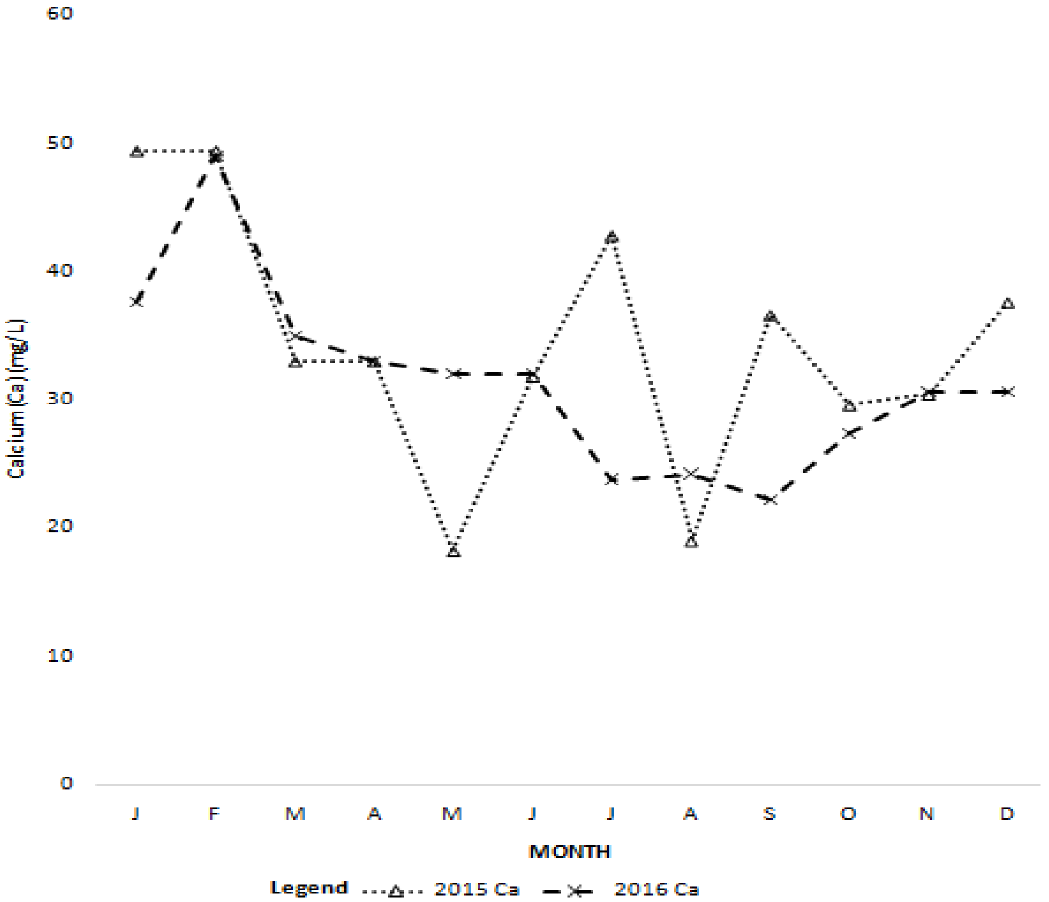

Fig. 7: Monthly concentration of calcium in Romi River, Kaduna (2015 – 2016)

Trace amounts of metals are common in water and these are normally not harmful to our health. Calcium, magnesium and potassium are essential to sustain life while drinking water containing high levels of these essential metals such as arsenic, cadmium, chromium, lead and mercury may be hazardous to our health (Hanaa *et al*., 2000). Iron and copper concentrations are above acceptable limit and other metal concentration is within the acceptable limit. Comprehensive study of the results reveals that out of 5 water quality stations monitored, 24 water samples were collected at each sampling stations of 5 are found to be above the permissible limit for all purposes except station 1. While stations 2 were found to have chromium and Copper concentration are above the acceptable limit proposed in WHO (1993). The contents of Lead metal ions were higher at stations 2 and 5, while Arsenic concentration in station 2 and 3 is high above the acceptable limit. The major source of copper and nickel pollution on rivers is the anthropogenic municipal solid waste and sewage from nearby residential homes, agricultural runoff and native soil erosion. The quality of the rivers is degraded which cause a decline in environmental quality due to the industrial and municipal discharges from the catchments (Figs. 1 –7); similar findings was reported by Ali *et al.* (2004), EPA (2001), Nayyet *et al*. (2012) and WHO (2006).

Conclusion

The introduction of influent into this river greatly impairs the water quality. The consequence is seen as the concentration of heavy metals study at stations 2 - 5 ($NNPC_2$, $NNPC/Rido_3$, $Juji_4$ and $Romi_5$) elevated above WHO permissible limit in drinking water. The increased in the trace metal is also implicative of discharge of effluents by companies, factory, materials and other relevant occupational fields. Thought the level of pollution is more pronounced at sampling station 2 and 3(NNPC & NNPC/Rido). The concentrations of heavy metals decreases as the water flow downstream.

Conflict of Interest

Authors declare that there is no conflict of interest in this study.

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