STUDY OF WATER AND SOIL CONTAMINATION BY HEAVY METALS FROM INDUSTRIAL EFFLUENTS AT BOMPAI INDUSTRIAL AREA KANO, NIGERIA

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Abstract: The paper aimed at assessing the contamination of soil and water by heavy metals from industrial effluents around Bompai industrial area in Kano metropolis. Soil and water samples were collected from the stream where the industries discharged their effluents. The samples were analyzed for Zn, Ni, Pb, Co and Mn using Atomic Absorption Spectrophotometer (AAS). The results of the analysis in mg/kg for soil show the range of detectable values as Zn (2.78 – 5.55) with Mean value of 3.61; Ni (7.69 – 19.23) with average value of 11.53; Pb (8.69 – 23.91) with mean value of 14.78; Co (5.76 – 15.38) with average value of 9.99; Mn (30 – 112.5) with mean value of 78. The range of detectable values in mg/l for heavy metals in water samples were Zn (0.06 – 0.11) with average value of 0.08; Ni (0.15 – 0.38) with mean value of 0.26; Pb (0.08 – 0.13) with mean value of 0.09; Co (0.03 – 0.11) with average value of 0.07; Mn (0.05 – 0.15) with mean value of 0.1. There was no contamination of soil and water across the study area by the target heavy metals except in water sample 2 where suspected contamination by Pb was observed. Although, the soil and water appeared to be free from contamination by the target heavy metals, the water should not be used for domestic purposes and the soil should not be used for cultivation of food crops until further research on analysis of other chemical and physical parameters on the soil and water across the study area is conducted and ascertain that the water and soil are free from all the toxic chemical and physical parameters. Hence further research on other chemical and physical parameters is recommended.
Keywords: Contamination, heavy metals, industries, effluents, water, soil

Introduction

Environmental contamination is the release of substances (solid, liquid or gaseous) into an environment (water, soil, or atmosphere) in quantities that adversely affects the living conditions of the inhabitants of that environment (Musa *et al.*, 2017). Substances which cause environmental contamination may be biodegradable or non-biodegradable. Usually they are introduced into the environment through man's activities; in rare cases they are introduced by natural processes. Contaminants range from inorganic and organic compounds and they include combustible and putrescible substances, explosives, heavy metals hazardous waste and petroleum products. Of all the inorganic substances, heavy metals constitute the major components and present a different problem than organic substances. Heavy metals are defined as metallic elements that have a relatively high density compared to water. With the assumption that heaviness and toxicity are inter-related, heavy metals are able to induce toxicity at low level of exposure. According to Okpokwasili *et al.* (2013), heavy metals are metals which are of high relative density and may be toxic even at low concentrations. Duruibe *et al.* (2007) defined heavy metal as a collective term, which applies to the group of metals and metalloids with atomic density greater than 4 g/cm^3, or 5 times or more, greater than water.

Industrialization, like other human development activities that have impact on the environment, often results in contamination of environment. It carries inevitable costs and problems in terms of pollution of water resources, soil, air and general degradation of natural environment (Imoobe and Koye, 2010.) Most of the industries are located near source of water because they require large volume of water for processing and discharge of effluents. Industrial effluents are severely disastrous to the environment; they consist of various kinds of contaminants which contaminate the surface and sub-surface water, soil and air (Dan azumi & Bichi, 2010). Heavy metals are the major components of industrial effluent which contaminate the environment severely because of their persistence nature. For instance, in Egypt, El-Mex Bay and Eastern Harbour along the Mediterranean coast are contaminated by industrial effluents, as several industries are located close to the coast and discharge their effluents directly into the bay (Abdallah, 2008; Yabe *et al.*, 2010). The Omoum Drain, which flows directly into El-Mex Bay contributes to Cd, Cu and Zn contamination from phosphate fertilizers industrial effluents (El-Rayis and Abdallah, 2006).
In Tunisian side of the Mediterranean Coast, contamination of El Melah Lagoon sediments with Pb and Cd has been attributed to industrial effluent (Ruiz *et al*., 2006). In Ethiopia., levels of Cd, Cr and Zn in lettuce and spinach exceeding recommended limits was attributed to irrigation of vegetables on soil along Akaki River, which is polluted with untreated sewage and industrial effluent (Prabu, 2009). Contamination of soil and sediments around Iture Estuary in Ghana with Pb and Cd has been attributed to waste carried by the Sorowie and Kakum Rivers, which flow through a rapidly industrialized central region (Fianko *et al*., 2007). In Nigeria, petroleum extraction is one of the major causes of heavy metals contamination around the coastal area. High concentrations of Pb and Cd were recorded in the Warri River following dredging of an oil well access canal (Ohimain *et al*., 2008). Alarming concentrations of Pb, Cd and Cr recorded in tomatoes grown along the Challawa River bank in Nigeria were attributed to untreated effluents from tannery industries located in Challawa Industrial Estate (Abdullahi *et al*., 2007). This paper assessed the environmental contamination by heavy metals (Co, Mn, Ni, Pb and Zn) from industrial effluent around Bompai industrial area, Kano.

Materials and Methods

The study area

The study area is located in Bompai industrial area of Nasarawa local government area, Kano State. It lies within Latitude 12° 01' 15"to 12° 01'45" N and Longitude 8° 33' 30" to 8° 34'00"E (Fig. 1). The industrial area is within the northern part of Kano metropolis, at an altitude of 472 m. The industries in the area are mostly tannery, textile, fertilizer, chemical, food, plastic, and drug. The main industrial areas of Kano are Bompai, Sharada, and Challawa. The selection of the study area was based on the fact that a lot of studies were conducted in Sharada and Challawa industrial areas while fewer studies were conducted in Bompai; also due to its appreciable size and location among other criteria (Emmanuel & Adepeju, 2015).

Sampling technique

Five soil and water samples were collected from the stream where the industries discharged their effluents. The soil samples were collected at the interval of 200 m between each sampling point. At each sampling point, a 9 m^2 quadrat was placed at 5 m distance from the stream. Five soil samples weighing 0.5 kg from four angles and the center of the quadrat were collected from 0 – 15 cm depth using auger and mixed to obtained one composite soil sample to save time and cost as described by Musa *et al.* (2017). Similarly, five water samples were collected from the surface of the stream at 5 m perpendicular to the soil sampling points. The water samples were collected in a plastic container and tight firmly with the cover and store under temperature of 4^{o}C to prevent the growth of microbes.

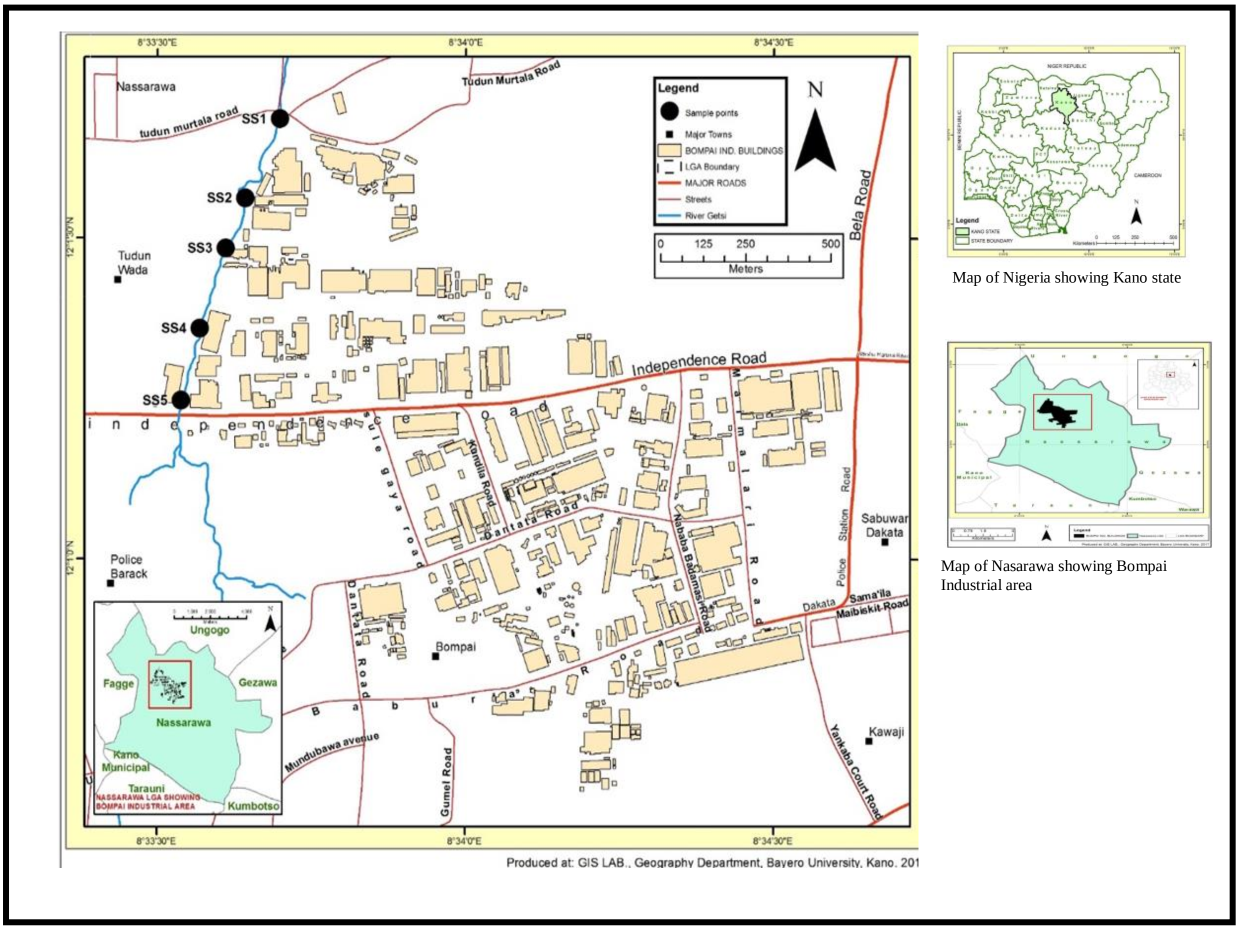

Fig. 1: The study area showing sampling points

Treatment of soil samples

The collected soil samples were air dried and sieved in a 2 mm mesh. 5 g of the sieved soil samples were put in a 50 ml washed plastic container. 25 ml of extractant (0.5 m HCl and 0.0125 m H_2SO_4) were added to the sample in the plastic container and shake for about 15 minutes in a reciprocating shaker and the suspension was filtered through Whatman filter paper. The filtrates were analyzed for heavy metals using Oluwaofor *et al.* (1990) method.

Treatment of water sample

2.5 ml of concentrated HNO_3 was added to 50 ml of the water sample, transferred to an evaporating dish and evaporated on a steam bath to about 20 ml. 10 ml of HNO_3 of about 98% purity was added and evaporated on a hot plate to near dryness. The residue was quantitatively transferred using two aliquot of 10 and 15 ml of concentrated HNO_3 into a 250 ml flask. 20 ml of $HClO_4$ was added and boiled until the solution became clear and white fumes of $HClO_4$ appeared. It was then cooled and deionized distilled water (about 50 ml) was added and the solution filtered. The filtrate was quantitatively transferred to a 100 ml volumetric flask with two portions of 5 ml of deionized distilled water. The solution was diluted to mark and mixed thoroughly by shaking as described by Chiroma *et al*. (2014).

The digested samples were analyzed for heavy metals (Co, Mn, Ni, Pb and Zn) using Atomic Absorption Spectrophotometer (AAS Buck Scientific VGP 210 Model) at the department of Geography, Bayero University Kano, Nigeria. The instrument setting and operational conditions were done in accordance with the manufacturer's specifications

Data analysis

The data were subjected to descriptive statistical analysis (minimum, maximum and mean) in order to identified areas with significant different. Data were also subjected to Contamination Factor (CF) which is used to determine the degree of contamination of the heavy metals in the study area. It is calculated as the ratio of heavy metal concentration at each sampling point to metal evaluation criteria. A metal evaluation criterion is the permissible limit of the metal. Thus,

$$Contamination\ Factor\ CF = \frac{C_i}{C_{ref}} \quad (1)$$

Where:
C_i is the metal concentrations at each sampling point.
C_{ref} is the evaluation criterion of the metal.

Table 1: The evaluation criteria of metals in soil and Water by WHO

Metals	Soil (Mg/kg)	Water[#] (Mg/l)
Zn	50**	25
Ni	140*	1
Pb	35*	0.10
Co	20****	0.05
Mn	850 ***	20

Source: (#Lindsay, 1979; #Parth *et al*, 2011; *Wuana & Okieimen, 2011; **Sanusi *et al*., 2017; ***Iwegbue *et al*., 2013; ****Cappuyns & Mallaerts, 2014).
CF<1 indicates no contamination, *CF*=1–2 suspected contamination, *CF*=2–3.5 slight contamination, *CF*=3.5–8 moderate contamination, *CF*=8–27 severe contamination, *CF*>27 extreme contaminations (Gonzalez–Miqueo *et al*., 2010 and Ogunkunle and Fatoba, 2014).

Results and Discussion

Heavy metal concentrations in soil across the study area

Heavy metal concentration levels in soil samples across the study area are presented in Table 2. The concentration level of Zn in soil samples ranged from 2.78 – 5.55 mg/kg with mean concentration of 3.61 mg/kg. The distribution of Zn in the soil samples shows that Zn concentration is within the permissible limit in all the soil samples. In a similar study by El-Rayis and Abdallah (2006), Zn was reported to be high in the Omoum Drain, which flows directly into El-Mex Bay in Egypt, and attributed to effluents from phosphate fertilizers industries. The distribution of Ni in the soil samples ranged from 7.69 – 19.23 mg/kg with average concentration level of 11.53 mg/kg. Ni concentration in the soil samples across the study is within the permissible limit. The concentration of Pb in soil across the study area ranged from 8.69 – 23.9 mg/kg with mean concentration of 14.78 mg/kg. The concentration level of Pb in the soil of the study area is also within the permissible limit. Similar result has been reported by Ruiz *et al*. (2006) on the sediment of El Melah Lagoon in Tunisia which was attributed to industrial effluents. However, in contrast, high concentration of Pb upto 297 mg/kg has been reported by Bloundi *et al*. (2009) in Nardo Lagoon sediment in Moroco, which was also attributed to industrial effluents. The concentration level of Co in the soil of the study area ranged from 5.76 – 15.38 mg/kg with averaged concentration value of 9.99 mg/. The distribution of Co across the study area is within the permissible limit. Howver, in a similar study conducted by Pettersson and Ingri, (2001), extremely high level of Co (1,030) was recorded in sediments from the Kafue River, which was atrributed to effluents from Co mining industries in the Cobalt belt Province of Zambia. Mn in soil across the study area ranged from 30 – 112.5 mg/kg with mean value of 78 mg/kg. The concentration level of Mn across the study area is within the permissible limit. Iwegbue *et al*. (2013) reported similar result for Mn in soil around cassava processing industries in Delta State, Nigeria. The result in Table 2 indicates that heavy metals in soil across the study area are within the permissible limit.

Table 2: Concentration of heavy metals in soil samples

Sample	Zn	Ni	Pb	Co	Mn
SS1	2.78	11.53	17.39	15.38	87.5
SS2	2.78	19.23	8.69	9.61	112.5
SS3	5.55	11.53	23.91	11.53	77.5
SS4	4.16	7.69	10.86	7.69	82.5
SS5	2.78	7.69	13.04	5.76	30
Min	2.78	7.69	8.69	5.76	30
Max	5.55	19.23	23.91	15.38	112.5
Mean	3.61	11.53	14.78	9.99	78

Table 3: Concentration of heavy metals in water samples

Sample	Zn	Ni	Pb	Co	Mn
WS1	0.06	0.15	0.08	0.07	0.15
WS2	0.11	0.31	0.13	0.03	0.05
WS3	0.06	0.38	0.08	0.07	0.1
WS4	0.08	0.23	0.08	0.07	0.1
WS5	0.11	0.23	0.08	0.11	0.1
Min	0.06	0.15	0.08	0.03	0.05
Max	0.11	0.38	0.13	0.11	0.15
Mean	0.08	0.26	0.09	0.07	0.1

Heavy metal concentrations in water across the study area

The distribution of heavy metals in water samples across the study area is presented in Table 3. The concentration level of Zn in water samples across the study area ranged from 0.06 – 0.11 mg/l with average concentration value of 0.08 mg/l. the concentration of Zn in the water across the study area is within the WHO threshold. The concentration level of Ni in the water samples ranged from 0.15 – 0.38 mg/l with mean concentration value of 0.26 mg/l. This also shows that the Ni concentration in the water across the study area is within the standard permissible limit of WHO. Pb depicts similar pattern of concentration with other elements in the water across the study area. It ranged from 0.08 – 0.13 mg/l with the mean concentration value of 0.09 mg/l. However, water sample 3 is beyond the standard threshold of WHO. The distribution of concentration level for Co in water across the study area ranged from 0.03 – 0.11 mg/l with average concentration value of 0.07 mg/l. The concentration of Co in water across the study area is beyond the standard permissible limit except in water sample 2. This shows that the industries that discharged their effluents to the study area are mostly ternary industries. The concentration of Mn in the water of the study area ranged from 0.05 – 0.15 mg/l with mean concentration value of 0.1 mg/l. The Concentration of Mn in the water across the study area is within the standard permissible limit of the WHO. The result of the water samples across the study area is free from Zn, Ni, Pb and Mn. However, further treatment is required for Co and further assessment of other chemical and physical parameters is required for the water to be safer for domestic and other uses.

Contamination levels of heavy metals in soil across the study area

Contamination level of heavy metals in soil across the study area is presented in Table 4. The contamination level of Zn in soil across the study area ranged from 0.06 – 0.11 mg/kg. Ni has the range of contamination factor from 0.05 – 0.14 mg/kg in the sampled soil. The range of contamination factor for Pb in soil across the study area is between 0.25 – 0.68 mg/kg. While the range of contamination factor for Co and Mn are 0.29 – 0.77 mg/kg and 0.04 – 0.13 mg/kg, respectively. The result suggested that the soil across the study area is not contaminated by either of Zn, Ni, Pb, Co nor Mn.

Table 4: Contamination factor of heavy metals in soil samples

Sample	Zn	Ni	Pb	Co	Mn
SS1	0.06	0.08	0.5	0.77	0.103
SS2	0.06	0.14	0.25	0.48	0.132
SS3	0.11	0.08	0.68	0.58	0.091
SS4	0.08	0.05	0.31	0.38	0.097
SS5	0.06	0.05	0.37	0.29	0.035

Table 5: Contamination factor of heavy metals in water samples

Sample	Zn	Ni	Pb	Co	Mn
WS1	0.002	0.15	0.8	0.14	0.008
WS2	0.004	0.307	1.3	0.06	0.003
WS3	0.002	0.38	0.8	0.14	0.005
WS4	0.003	0.23	0.8	0.14	0.005
WS5	0.004	0.23	0.8	0.22	0.005

Contamination levels of heavy metals in water across the study area

Contamination factor of heavy metals in water across the study area is presented in Table 5. The contamination factor of Zn in water across the study area ranged from 0.002 – 0.004 mg/l. While the concentration factor of Ni in the sampled water ranged from 0.15 – 0.38 mg/l. Pb has the range of contamination factor between 0.8 – 1.3 mg/l. The contamination factor of Co in the sampled water across the study area ranged from 0.06 – 0.22 mg/l. While the range of contamination factor of Mn in the water across the study area is between 0.003 – 0.008 mg/l. This result generally, signifies that the sampled water from the study area is not contaminated by the target heavy metals except in water sample 2 where suspected contamination is observed for Pb.

Conclusion

This paper aimed to evaluate heavy metal contamination of soil and water by the industrial effluents around Bompai industrial area in metropolitan Kano. The results obtained were supportive with the conclusion that; the heavy metals (Zn, Ni, Pb, Co and Mn) in soil across the study area were within the permissible limit. The result of the water samples across the study area was free from Zn, Ni, Pb and Mn except Co. The result also suggested that the soil across the study area was not contaminated by either of Zn, Ni, Pb, Co nor Mn. Furthermore, the result signified that the sampled water from the study area was not contaminated by the target heavy metals except in water sample 2 where suspected contamination was observed for Pb. Generally, the results indicated that the effluents discharged by the industries across the study area were being treated before discharged to the environment. Additionally, most of the industries across the study area were not working for quite a long time and therefore, discharged of effluent from the industries will be very minimal. Hence, contamination of soil and water around Bompai industrial area is insignificant.

Although, the soil and water across the study area appeared to be free from contamination by the target heavy metals, the water should not be used for domestic purposes also the soil should not be used for cultivation of food crops until further research on analysis of other chemical and physical parameters on the soil and water across the study area is conducted and ascertain that the water and soil are free from all the chemical and physical parameters. Hence further research on other chemical and physical parameters is recommended.

Competing Interests

Author has declared that no competing interests exist.

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