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HEAVY METALS POLLUTION INDICES IN TANNERY SLUDGE FERTILIZED FARMS AROUND HAUSAWAN KABA, KANO, NIGERIA

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ABSTRACT

A study was conducted to assess the influence of tannery sludge on heavy metals pollution indices in Hausawan Kaba, Kano, Nigeria. Three farms were randomly selected as sampling stations and named farm 1, farm 2 and farm 3. Soil samples were collected using soil auger, digested using concentrated HCl and analysed using Flame Atomic Absorption Spectrophotometer (FAAS). The highest metal concentration was Pb in Farm 2 with an average value of 130.62 ± 61.12 mg/kg while the lowest was Cadmium in Farm 3 with a concentration of 1.33 ± 2.17 mg/kg. All metal concentrations differed significantly across farms at 0.05 level of significance and they have exceeded World Health Organization (WHO) 1996 maximum permissible limits. The metal with the highest contamination factor was Cadmium (*Cf* = 8.51) in Farm 2 while Iron had the lowest with about 0.001 in Farm 3. Cadmium had the highest enrichment factor value in Farm 2 (*Ef* = 4634.92) while Fe had the lowest *Ef* of 1.00 in all farms. The lowest geoaccumulation index (*Igeo*) was – 8.77 for Pb in Farm 2 while the highest was 15.39 for Cadmium in Farm 3. Igeo >5 showed that all the farms are extremely polluted with heavy metals. Pollution load index (PLI) occurred in the order: Farm 3 (0.43) < Farm 2 (0.88) < Farm 1 (1.13).

Keywords: Flame Atomic Absorption Spectroscopy, Pollution index, Contamination factor, Enrichment factor, Geoaccumulation index, Pollution load index.

INTRODUCTION

Heavy metals are inorganic pollutants of great environmental concern as they are non-biodegradable, toxic and persistent with serious negative ecological complications (Charles *et al*., 2018). Although these metals occur naturally and are found throughout the earth's crust at low quantities, human exposure generally results from anthropogenic activities such as smelting, mining, and agricultural as well as industrial activities (Enegide and Kelechukwu, 2018).

Heavy metal pollution indices are useful and relatively easy ways to assess the composite of overall heavy metal pollution (Al–Hejuje *et al*., 2017). Pollution index is a method of rating that shows the influence of individual heavy metals on the overall quality of the environment. It serves as a monitoring tool and is described as a bridge between professionals and laymen or decision makers. The commonly used pollution indices have been classified into two; the single indices which are indicators for only one metal contamination, e.g. include contamination factor (Cf), ecological risk factor (Er) and enrichment factor (Ef) amongst others while the integrated indices are indicators for more than one metal contamination and are based on the single indices, eg sum of pollution index ($PIsum$), average of pollution index ($PIavg$), Nemerow pollution index (PINemerow) etc. (Gong *et. al*., 2008; Joanna *et a*l., 2018).

Kano is one of the most irrigated States in Nigeria with more than three million hectares of cultivable land which ensure all year round farming (Uduma *et al*., 2016). Due to its high Nitrogen content, tannery sludge is used as manure on farmlands in the cultivation of crops and this sludge was found to be heavily laden with heavy metals (Hongrui, *et al*., 2003) hence this study is aimed at evaluating the pollution indices of Pb, Cd, As, Cr and Fe in the sludge fertilized farms around Hausawan Kaba in Kano, Nigeria.

MATERIALS AND METHODS

The Study Area

Kano State with a population of well over 9.0 million people lies between latitude 12°00' and 09.4°N and longitude 08°31' and 07°29'E in Northern Nigeria (Bernard and Ogunleye, 2015). Majority of the industries in the city are tanneries, textiles, and allied chemicals that generate a large quantity of waste in form of sludge. Three farms were randomly selected as sampling stations and named farm 1, farm 2 and farm 3 respectively.

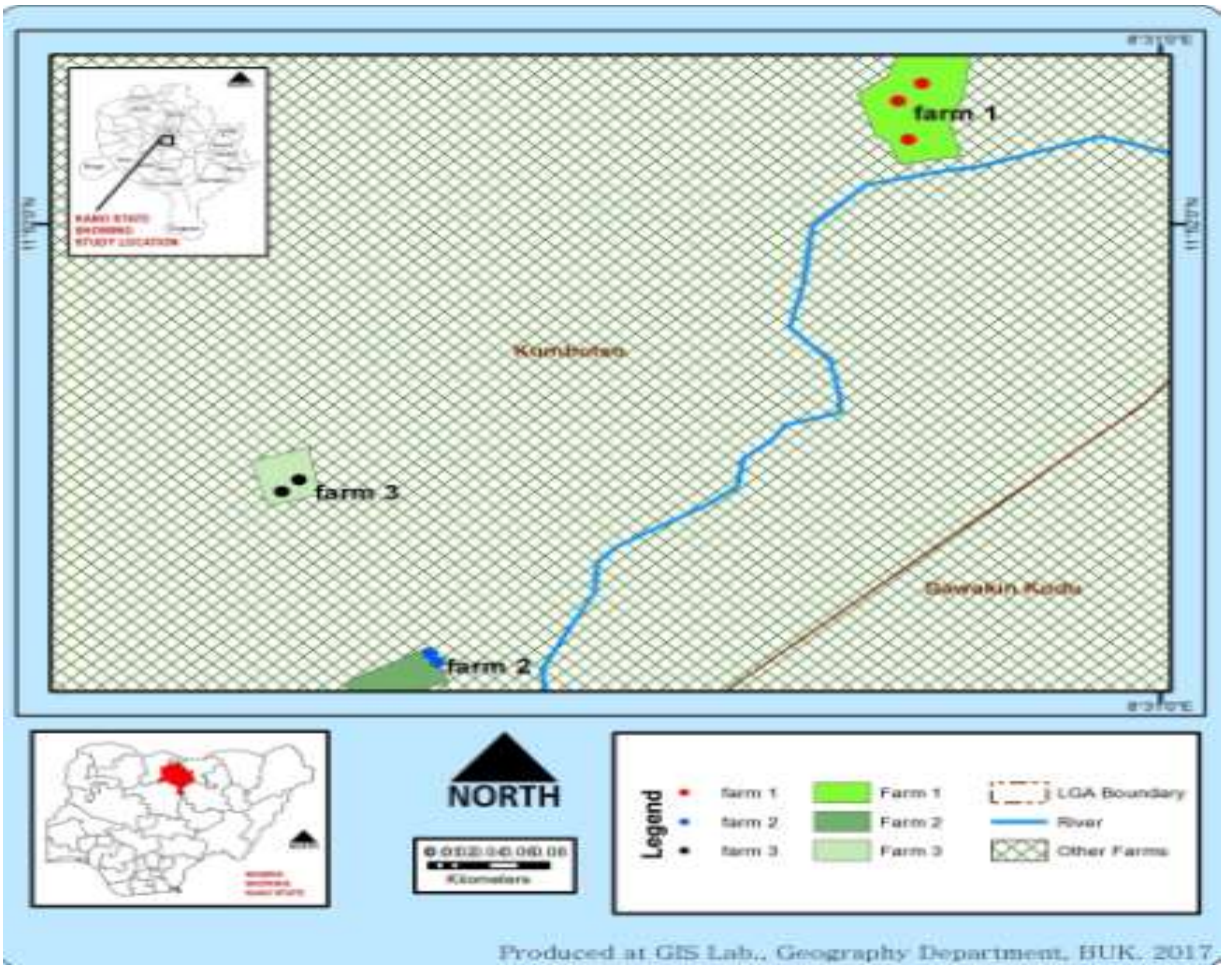

Fig. 1: Map of the Study Area showing the Location of Sampling Stations

Sample Collection and Analysis

The sample locations were carefully chosen after a pre–sampling survey of the sites. Sampling spots were cleaned of debris and composite top soil with depth from zero to 15 centimeters were collected from different selected points to provide a representative coverage of the study area using soil auger and transferred into clean acid–washed polythene bags and then transported to the laboratory.

The samples were passed through a two millimetre sieve, one gramme of each sample was put in 100 ml beaker and 15 ml of 30% H_2O_2 was added to it. This was allowed to stand for an hour until the vigorous reaction ceases then 15 ml of concentrated HCl was added and the content was heated slowly on a hot plate for about two hours according to Tsafe *et al.* (2012). The digest was then filtered into 50 ml standard flask and the analysis was conducted using Flame Atomic Absorption Spectrophotometer (FAAS). This procedure originated with the work of Kirchoff and Bunsen in 1860 which is based on absorption of light by metallic ions. It was found out that atoms of different elements absorb characteristic wavelengths of light hence a beam of electromagnetic radiation is passed through a vaporized sample and the greater the number of atoms there is in the vapour, the more radiation is absorbed (Asha, 2017). The whole procedure was replicated six times over a period of six months.

Pollution Indices

The following pollution assessment models were employed in this study: Contamination factor, Enrichment factor, Geoaccumulation factor and Pollution load index.

Contamination factor (Cf): This index is the assessment of soil contamination by heavy metals against the pre–anthropogenic activities reference levels as given by Hakanson (1980), (Tesleem *et al*., 2018):

$$Cf = \frac{Cn}{Bn} \qquad 1$$

Where Cn is the metal concentration from the mining area and Bn is the background concentration which is the DPR target value in this study. In order to evaluate the degree of contamination in sediments, the following gradations are proposed: CF < 1, no/low contamination; 1 ≤ CF < 3, moderate; 3 ≤ CF < 6, considerable; 6 ≤ CF – very high contamination (Nijole *et al*., 2018).

Enrichment factor (Ef): Is a common approach to estimate how much the soil is impacted (naturally or anthropogenically) with heavy metal above uncontaminated background or reference levels (Huu *et al*., 2010). The enrichment factor was calculated using the formula originally introduced by Buat-Menard and Chesselet (1979) and used by Alfred *et al*. (2013):

$$Ef = \frac{\left(\frac{Cn}{Cref}\right)}{\left(\frac{Bn}{Bref}\right)} sample \qquad 2$$

Where $Cn(sample)$ is the concentration of the examined chemical element in the examined environment, $Cref(sample)$ is the concentration of the examined chemical element in the reference environment, Bn is the concentration of the reference chemical element in the examined environment and $Bref$ is the concentration of the reference element in the reference environment. In this study, Iron (Fe) was used as the reference element with a DPR target value of 38000 mg/kg. Ef < 2 means deficiently to minimal enrichment, 2 ≤ Ef < 5 means moderate enrichment, 5 ≤ Ef < 20 means significant enrichment, 20 ≤ Ef < 40 means very high enrichment and Ef ≥ 40 means extremely high enrichment (Alfred *et al*., 2013).

Geoaccumulation index (*Igeo*): It is quantitative measure of the extent of metal pollution in the studied soil and is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the following mathematical relation (Odat, 2015):

$$\boldsymbol{Igeo = log2\left(\frac{Cn}{1.5Bn}\right)} \qquad \mathbf{3}$$

where, *Cn* is the measured total concentration of the element *n* in the soil, *Bn* is the average (crustal) concentration of element n in shale (background), i.e. the DPR target value and 1.5 is the correction factor due to lithogenic effects.
Odat (2015) gave the following interpretation for geoaccumulation index: Igeo<0 = practically unpolluted, 0<Igeo<1 = unpolluted to moderately polluted, 1<Igeo<2 = moderately polluted, 2<Igeo<3 = moderately to strongly polluted, 3<Igeo<4=strongly polluted, 4< Igeo<5= strongly to extremely polluted and Igeo >5 = extremely polluted.

Pollution load index (PLI): Is a measure of pollution severity and its variation along sites. It is a quick tool for comparing the pollution status of different places. It is calculated as follows:

$$PLI = \sqrt[n]{Cf1 \times Cf2 \times\ Cf3 \ldots\ldots \times Cfn} \qquad 4$$

Where: Cf is the contamination factor of metals and *n* is the number of metals assessed.
The *PLI* value of >1 is polluted, whereas <1 indicates no pollution (Adel *et al*., 2011).

RESULTS

Heavy Metals Concentration in Soils

The highest metal concentration was Pb in Farm 2 with an average value of 130.62 ± 61.12 mg/kg while the lowest was Cadmium in Farm 3 with a concentration of 1.33 ± 2.17 mg/kg. All the metals differed significantly across farms at 0.05 level of significance and they have exceeded World Health Organization (WHO) 1996 maximum permissible limits. The mean metal concentrations and their comparison against WHO standards are shown in table 1.

Heavy Metals Pollution Indices

Cadmium had the highest contamination factor (*Cf*) of 8.51 in Farm 2 while Iron had the lowest with about 0.001 in Farm 3. Fe had the lowest enrichment factor (*Ef*) of 1.00 and the highest was Cadmium in Farm 2 with a value of 4634.92. The lowest geoaccumulation index (*Igeo*) was – 8.77 for Pb in Farm 2 while the highest was 15.39 for Cadmium in Farm 3. Pollution load index (PLI) was highest (1.13) in Farm 1 and lowest (0.43) in Farm 3. Table two shows the heavy metals pollution indices from the tannery sludge fed farms in Hausawan Kaba, Kano during the period of this study.

Table 1: Mean ± Standard Deviations (mg/kg) of Heavy Metals from the Three Sampling staions, their Test of Difference and Comparison against WHO Standards

Metals	Farm 1	Farm 2	Farm 3	F–value	Sig. value	P–test	Inference	WHO limit	DPR Target Values
Pb	110.32 ± 71.73	130.62 ± 61.12	28.16 ± 17.62	5.13	0.02	P < 0.05	Diff. sig.	0.01	85.00
Cd	5.67 ± 5.19	6.81 ± 11.21	1.33 ± 2.17	0.87	0.04	P < 0.05	Diff. sig.	0.003	0.80
As	4.95 ± 4.24	1.94 ± 1.33	1.37 ± 2.68	3.21	0.04	P < 0.05	Diff. sig.	0.001	1.00
Cr	4.37 ± 4.04	2.08 ± 1.99	1.61 ± 199	1.25	0.02	P < 0.05	Diff. sig.	2.00	100.00
Fe	117.62 ± 62.09	69.79 ± 32.79	37.45 ± 27.53	3.74	0.02	P <0.05	Diff. Sig.	0.30	38000.00

Table 2: Pollution Indices of Heavy Metals from Tannery Sludge Fertilized Farms in Hausawan Kaba, Kano during the Study Period

	Pb			**Cd**			**As**			**Cr**			**Fe**			***PLI***
Farms	***Cf***	***Ef***	***Igeo***	***Cf***	***Ef***	***Igeo***	***Cf***	***Ef***	***Igeo***	***Cf***	***Ef***	***Igeo***	***Cf***	***Ef***	***Igeo***	
Farm 1	1.30	419.31	– 9.01	7.09	2289.76	– 13.29	4.95	1599.19	– 13.49	0.04	14.12	– 13.67	0.003	1.00	– 8.92	1.13
Farm 2	1.54	836.71	– 8.77	8.51	4634.92	– 13.03	1.94	1056.29	– 14.84	0.02	11.33	– 14.74	0.002	1.00	– 9.67	0.88
Farm 3	0.33	336.17	– 10.98	1.66	1686.96	– 15.39	1.37	1390.16	– 15.35	0.02	16.34	– 15.11	0.001	1.00	– 10.57	0.43

DISCUSSION

Heavy Metals Concentration in Farmland Soils

All mean metal concentrations during the period of this study exceeded the World Health Organization's maximum permissible limits except for Chromium in Farm 3. This portrays a great risk to the farmers as they work there almost all day for so many years. Pb, the metal with the highest concentration 130.62 ± 61.12 mg/kg, has been described as the most immobile of all the common heavy metals and is strongly absorbed by soils under neutral to basic conditions. It accumulates in bones and teeth, where it has a biological half-life of about 20 years during which it is released into the bloodstream where it then travels to target organs such as the brain, kidney, etc. (WHO, 1995). In their study on the effects of small scale mining and metals pollution of agricultural soils in Ishiagu mining district, South Eastern Nigeria, Ezeh and Chukwu (2011) found the highest concentrations of Pb to be 13671 mg/kg and Cd 10 mg/kg while close relationship was found between the polluted areas and areas with history of mining and industrial activities. Yang *et al*. (2014) also identified industrial, agricultural and mining activities as the major sources of soil heavy metal contamination.

Contamination Factor (*Cf*)

This compares the levels of heavy metals against the pre–anthropogenic activities background level. Fe and Cr showed negligible or no contamination at all ($Cf < 1$) in all the farms while Cd had generally very high contamination ($Cf > 6$) except in Farm 3 where it's moderate ($1 \leq Cf < 3$). Arsenic had a considerable to high contamination in Farm 1 ($3 \leq Cf < 6$) and there was low Pb contamination in all the farms.

Contamination factor is affected by the background or reference concentration which means some metal concentrations may be very high but with a low contamination factor. Lower contamination factor values therefore do not imply low pollution or minimum hazards.

Enrichment Factor (*Ef*)

Enrichment factor combines the natural and anthropogenic impacts on levels of heavy metals against the background or reference level. There was extremely high enrichment ($Ef \geq 40$) of Pb, Cd and As in all thefarms, significant enrichment of Cr ($5 \leq Ef < 20$) and deficient enrichment ($Ef < 2$) of Fe. Enrichment factor is also influenced by the background or reference concentration. Ayodele *et al.* (2019) in their study on heavy metals concentration of beach sediments in Lagos, Southwestern Nigeria, found a similar result with Pb having the highest enrichment factor of 2059.62 while Cd had enrichment factor of 1.00.

Geoaccumulation Index (*Igeo*)

It is a quantitative measure of the extent of metal pollution in the studied soil. Geoaccumulation index is also measured against the background or reference level but unlike the other indices, it has a correction factor that takes care of errors due to lithogenic effects. Igeo >5 showed that all the farms are extremely polluted for all the metals in this study.

Pollution Load Index (PLI)

This sums up and summarizes the total heavy metal pollution in an area. It is a pollution status comparative tool between or among different areas. The pollution load indices of the farms in this study occurred in the following order: Farm 3 (0.43) < Farm 2 (0.88) < Farm 1 (1.13).

CONCLUSION

Heavy metals concentration in tannery sludge fertilized farms were found to be above the WHO maximum permissible limits during this study while pollution indices range from low to extremely high. It should however be noted that lower indices do not imply low pollution or minimum hazards but rather a measure of deviations from the background levels of metals in the soil as a result of natural and/or anthropogenic activities.

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