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Pollution Status of Selected Agricultural Farmlands in Zaria, Kaduna State, Nigeria

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The pollution status of agricultural farmland soils of Basawa, Galma, Kubanni and Kufena in Zaria, Kaduna state, Nigeria were assessed. The samples were collected in the dry season, digested with aqua regia and analyzed for heavy metals using atomic absorption spectrophotometer (AAS). Physicochemical parameter (pH, soil texture, organic matter, moisture content and electrical conductivity) were also determined. The physicochemical parameters indicated that pH ranged from 6.20 to 6.90, electric conductivity ranged from 0.150 to 0.600dcm. Organic matter contents ranged from 1.19 to 3.29 %, % sand (%) ranged from 42 to 62, % clay ranged from 8 to 20 and % silt ranged 30 to 40 for all the soils obtained from the farmlands. The textural classes of Basawa and Galma are loam and that up Kubanni and Kufaina ware sandy loam. The result were that the concentrations of metals in the soil ranged from 0.05 to 2.03mg/kg for Cd; 3.98 to 43.75mg/kg for Cu; 5.85 to 33.35mg/kg for Pb and 1.95 to 6.55 mg/kg for Cr. The geoaccumulation indices (I_{geo}) showed that of all the metals studied, Cadmium in Basawa farmland soil sample was the major pollutant being moderately to highly polluted (2.1699 mg/Kg).

Keywords: Soil, Heavy metals, Geoaccumulation indices, Pollution, Farmland

1. Introduction

With rapid development in agriculture, industry, commerce, hospital and health-care facilities, many activities are consuming significant quantities of toxic chemicals and generating a large amount of hazardous waste (Blaylock and Huang, 2000). Varieties of environmental problems have emerged in modern times of which potentially toxic metal pollution is a major issue, especially in soils. Heavy metals are found ubiquitously in both polluted and unpolluted soil although these heavy metals occur naturally in the earth crust; they tend to be concentrated in agricultural soil because of irrational application of commercial fertilizers, manure and sewage sludge containing heavy metals (Blaylock and Huang, 2000).

Soil is the preeminent source of most biologically active trace elements such as lead, cadmium, chromium, nickel, silver, and zinc that reach man through plants and animals (Mitchell and Burridge, 1979). It is the dynamic body of natures and complex system in which all the times: chemical, biological, physical, geological, biogeophysico chemical reactions are taking place with characteristics that vary over time and space. Soil is the valuable resource of a nation whose quality determines its capability to function well for many contended uses (Ideriah *et al.,* 2005). Soils may become contaminated by the accumulation of heavy metals through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, land application of fertilizers, animal manures, sewage sludge, pesticides, waste water irrigation and atmospheric deposition (Wuana and Okieimen, 2011).

Heavy metals are defined as elements in the periodic table having densities more than 5g/cm^3. The environmental burden with heavy metal are that they are non-degradable and most of them have toxic effect on living organisms when they exceed a certain concentration level either in water, soil or food substances (Hong *et al*., 2014). Heavy metals are currently of much environmental concern. They are harmful to humans, animals and are susceptible to bioaccumulation in the food chain. Heavy metals may come from many different sources in urban areas. Atmospheric pollution is a major contributor to heavy metal contamination in top soils (Kelly *et al.,* 1996). Heavy metals are important environmental pollutants threatening the health of human population and natural ecosystems. Heavy metals can affect the quality of agricultural soils, including phytotoxicity and transfer of heavy metals to the human diet from crop uptake (Nicholson *et al.,* 2003).

Heavy metal contamination levels in agricultural soil are of major significance because of the potential to accumulate in soil for a long period of time (Iwegbue *et al*., 2013). High concentration of metal ions in soil environment may pose a significant risk to the quality of soils, plants, natural waters and human health (Wu and Zhang, 2010). Excessive accumulation of heavy metals in agricultural soils may result not only in soil contamination but also affect food quality and public health safety issues.The problem of environmental pollution due to toxic metals is a major issue in most urban communities because of their effects on human health. Food chain contamination by heavy metals has become a major issue in recent years because of their potential accumulation in biological systems through contaminated water, soil and air. (Amfo-Out, 2007). Large amount of heavy metals in soil causes environmental degradation and threatens all life forms because its toxicity. As a country develops economically, expansion of industries, the building of new roads and infrastructure, and the increasing population in the cities generates waste that has caused an accumulation of these trace metals in the soil surrounding these sites. It is therefore of the utmost importance to monitor the environment constantly, to prevent disasters arising from the introduction of heavy metals into the soil (Omoniyi *et al.*, 2016).

Farming in Basawa, Galma, Kubanni and Kufena, farmlands provide vegetable crops for the people of Zaria and the environs during the dry season and early part of the rainy season. It is worthy of note that domestic, industrial, metallurgical and agricultural activities take place around the farmlands, these activities contribute to the heavy metal loading of the soil. Therefore the determination of the heavy metal levels of the soils becomes imperative since these metals are taken up by plants and thereby enter into the food chain where they may cause health hazards. The pollution indices of the soil will help to determine the level of pollution loading (Omoniyi *et. al*, 2016)**.**

The aim of this work was to analyse the heavy metal content (Cr, Cu, Cd, and Pb) in agricultural soils obtained from Basawa, Galma, Kubanni and Kufaina farmlands in Zaria, Nigeria and to evaluate the degree of contamination of soils by heavy metals using various integrated pollution indices methods, with a view the study would provide a baseline data regarding the distribution and accumulation of the selected metals in the soil and would help reduce the contamination in the Soils by identifying the major pollution sources. Furthermore, for the best management and utilization of the soil resources, it is very important to have information about the pollution hazards and heavy metals concentration of the study area.

2. Materials and Methods

2.1 Description of the Study Area and Sampling Sites

The sample locations are in Zaria, a major city in Kaduna State in Northern Nigeria located within latitudes 11°7, 11°12 N and longitudes 07°41 E. It has an estimated population of 547,000 and a growth rate of 3.5% per annum (Yakubu, 2009). Zaria is characterized by a tropical climate, a monthly mean temperature ranging from 13.8 to 36.7°C and an annual rainfall of 1092.8 mm. It is approximated that about 40 to 75% of its working population derive their principal means of livelihood from agriculture (Yakubu, 2009). Agricultural activity in Zaria can be divided into two types: rain-fed (from May to October) and irrigation farming in the dry season (from November to April).

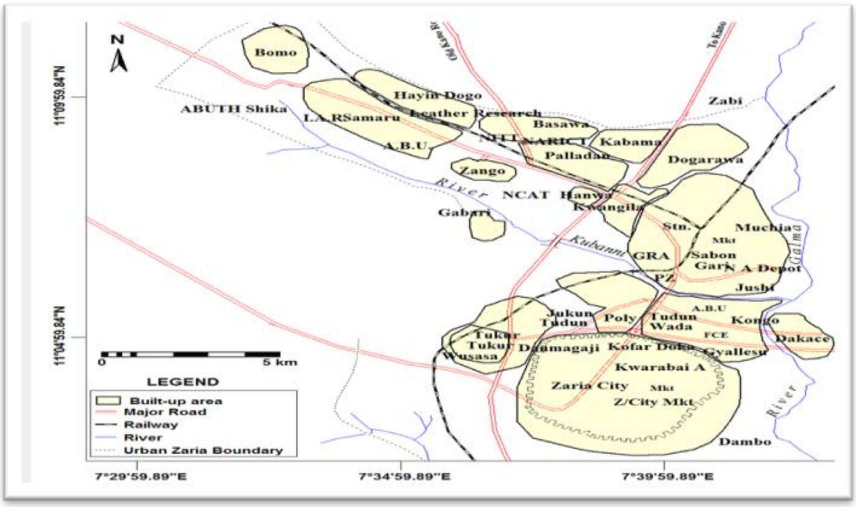

Figure 1. Map of Zaria showing the sampling locations

2.2 Sample Collection

The soil samples were randomly collected from Basawa, Galma, Kubanni and Kufaina farms in duplicates, at 10cm depth and 50m apart. The collected soil samples from each site were mixed to give a composite sample and were placed and labeled in polythene bags then taken to the laboratory for treatment and analysis (Krishna and Govil, 2007).

2.3 Pre-Treatment of the Soil Sample

The samples were air-dried in the oven at 30^{0}C overnight and homogenized using a clean acid washed porcelain mortar and pestle, and passed through a 2mm sieve to obtain fine fractions. The fine fractions (less than 2mm) were retained for analysis. The fine ground samples obtained were then stored in sterilized polythene bottles and placed in desiccators to attain constant weights pending analysis (Inuwa *et al.,* 2007).

2.4 Soil Texture

Soil texture refers to the relative amounts of differently sized soil particles, or the fineness/coarseness of the mineral particles in the soil. It indicates the relative content of particles of various sizes such as sand, silt and clay in the soil (Kaihua *et al.,* 2013).

2.5 Particle Size Analysis

Particle size analysis was determined according to the method of Bouyoucos (1962). 50g of the soil sample was soaked overnight with 50 ml of cagon solution. The mixture was then transferred into a 1000 ml measuring cylinder and was made up to mark. The mixture was shaken and left for 40 secs. before dipping the hydrometer into it to determine the sandy content while the clay and silt was determined after 3 hours interval (for the mixture to settle down) through the same process. The temperatures were then recorded simultaneously. % sand, % clay and % silt were calculated as follows where H1 and H2 are hydrometer readings at 40 secs and 3 hours respectively at corresponding temperature readings T_1 and T_2 (Bouyoucos, 1962).

2.6 Determination of the Soil Physico-Chemical Properties

The soil pH in the suspension was determined using the method of Black (1965), textural class as adopted by Ogunfowakan (2009); organic carbon, organic matter and moisture contents were determined using the standard method adopted by Walkley and Black (1997).

2.7 Digestion of Soil Samples

Two grammes (2g) of the soil sample were transferred into pre washed100ml glass beakers. To the samples in the dry beakers 15ml concentrated. HCl and 5ml concentrated. HNO_3 (aqua regia) were added (Jeng and Bergseth, 1992). The samples were swirled gently and left to stand overnight. The beakers were placed on a hot plate and heated at 90-100˚C under reflux conditions for two hours. Refluxing was stopped but boiling continued until the formation of white fumes. The solutions were cooled and the residues dissolved in 5ml concentrated HNO_3. The digested samples were filterd through Whatman No. 2 filter paper into 50-ml volumetric flasks and deionized water added to volume. The 50-ml mark,then transferred to 100ml polypropylene bottles. Heavy metals in the digests were determined using Atomic Absorption Spectrophotometry (AAS), with appropriate standards prepared in a similar matrix (i.e. 10% HNO_3) in duplicate.

2.8 Quality Control

All glassware, crucibles and plastic containers used for the experiments were washed with liquid soap rinsed with distilled water and soaked in 10% HNO_3 for 24 hrs and rinsed thoroughly with deionized water and dried in the oven at low temperature.

2.9 Geoaccumulation Index (I-geo)

The Geoaccumulation Index (Igeo) was originally defined by (Müller, 1969, 1981] for metal concentrations in the 2-micron fraction and was developed for global standard shale values. The geoaccumulation index (I-geo) as proposed by (Taylor and Mclennan, 1995), was calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the mathematical relation (Muller, 1969).

$$I - geo = log2\left(\frac{C_n}{1.5B_n}\right)$$

The index of geoaccumulation (Igeo) actually enables the assessment of soil contamination. The method assesses the degree of metal pollution in terms of seven enrichment classes (Table 1) based on the increasing numerical values of the index.

Where Cn is the concentration of metal n in the soil, Bn is the soil background concentration of heavy metal n and 1.5 is a factor compensating the background data (correction factor) due to lithogenic effects. According to Bradl (2005). The reference samples were Cd: 0.3, Cr: 100, Pb: 20 and Cu: 50 µg/g. Muller (1981) report distinguished the following seven classes or grades of the geoaccumulation index:

Table 1: Index of geoaccumulation (Igeo) for contamination levels in soil (Barbieri, 2016).

Igeo Class	IgeoValue	Contamination Level
0	Igeo≤ 0	Uncontaminated
1	0 < Igeo < 1	Uncontaminated/moderately contaminated
2	1 < Igeo < 2	Moderately contaminated
3	2 < Igeo < 3	Moderately/strongly contaminated
4	3 < Igeo < 4	Strongly contaminated
5	4 < Igeo < 5	Strongly/extremely contaminated
6	5 < Igeo < 6	Extremely contaminated

2.10 Statistical Analysis

Statistical analyses were performed using Excel and SAS statistical package version 16. Analysis of Variance (ANOVA) was carried out to compare the difference of means from various sampling sites, and the means were separated by Duncan Multiple Range Test (DMRT) when difference was significant. P-values < 0.05 was taken for significant difference. Correlation analysis was carried out to determine relationship between heavy metals in soil and soil physicochemical and biological properties.

3. Results and Discussion

Results from this studies indicated differences in the physicochemical properties and the heavy metals contents of the soil in Basawa, Galma, Kubanni and Kufaina as shown in table 2 and figure 1 below. The physicochemical parameters indicated that pH ranged from of 6.20 to 6.90, electric conductivity ranged from 0.150 to 0.600dcm. Organic matter contents ranged from 1.19 to 3.29 %, % sand ranged from 42 to 62, % clay ranged 8 to 20 and % silt ranged 30 to 40 for all the soils obtained from the farmlands. The textural class of Basawa and Galma ware loam and that up Kubanni and Kufaina ware sandy loam. The results shows that the concentrations of metals in the soil ranged from 0.05 to 2.03 for Cd; 3.98 to 43.75 for Cu; 5.85 to 33.35 for Pb and 1.95 to 6.55 mg/kg for Cr.

The Geo-accumulation Index (I_{geo}) of metals in the soil as shown in table 3a, 3b, 3c and 3d below ranged from -2.3585 to -0.2258 for Pb; -3.1701 to 2.1699 for Cd; -6.2653 to -4.5162 for Cr and -4.2379 to -0.7778 mg/kg for Cu, The result shows that the geo-accumulation indices (I_{geo}) of Cd, Cu, Cr and Pb in the soils samples are in Class 0; Igeo < 0 = unpolluted, except that of Cadmium in Basawa farmland soil sample which was found to be moderately to highly polluted (2.1699 mg/kg).

Table 2: Physicochemical Parameters of Farmland Soils of Basawa, Galma, Kubanni and Kufaina in Zaria

Soil property	BSW	GLM	KBN	KFN
pH (H_2O)	6.40	6.20	6.90	6.60
pH($CaCl_2$)	5.70	5.90	5.80	5.40
% sand	48	42	62	54
% clay	12	20	8	10
%silt	40	38	30	36
Textural Class	Loam	Loam	Sandy loam	Sandy loam
Organic Matter (%)	1.19	1.91	3.29	1.48
Moisture Content (%)	1.42	1.68	2.60	1.91
Electrical conductivity(dcm)	0.250	0.150	0.600	0.160

Table 3a: Geo-accumulation Index of Lead (Pb) in Farmland Soils of Basawa, Galma, Kubanni and Kufaina in Zaria

Locations	Geo-accumulation(I_{geo})	Degree of (I_{geo}).
BSW	-0.2258	Unpolluted
GLM	-2.0941	Unpolluted
KBN	-1.1736	Unpolluted
KFN	-23585	Unpolluted

Table 3b: Geo-accumulation Index of Cadmium (Cd) in Farmland Soils of Basawa, Galma, Kubanni and Kufaina in Zaria

Locations	Geo-accumulation(I_{geo})	Degree of (I_{geo})
BSW	2.1699	Moderately to highly polluted
GLM	-1.3625	Unpolluted
KBN	-2.1701	Unpolluted
KFN	-3.1701	Unpolluted

Table 3c: Geo-accumulation Index of Chromium (Cr) in Farmland Soils of Basawa, Galma, Kubanni and Kufaina in Zaria

Locations	Geo-accumulation(I_{geo})	Degree of (I_{geo})
BSW	-4.5162	Unpolluted
GLM	-4.7890	Unpolluted
KBN	-4.9748	Unpolluted
KFN	-6.2653	Unpolluted

Table 3d: Geo-accumulation Index of Copper (Cu) in Farmland Soils of Basawa, Galma, Kubanni and Kufaina in Zaria

Locations	Geo-accumulation(I_{geo})	Degree of (I_{geo})
BSW	-0.7778	Unpolluted
GLM	-0.8547	Unpolluted
KBN	-4.2379	Unpolluted
KFN	-3.5395	Unpolluted

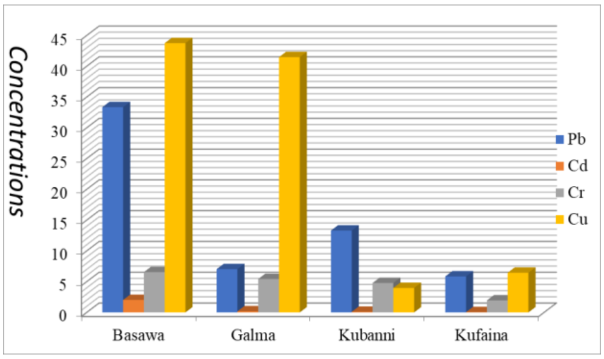

Figure 2: Concentrations (mg/Kg) of Pb, Cd, Cr and Cu in Farmland Soils of Basawa, Galma, Kubanni and Kufena in Zaria.

The statistical analysis using Analysis of Variance (ANOVA) of Pb, Cd, Cr and Cu shows that there was no remarkable difference in the mean values of most parameters across the agricultural fields, with p-value greater than the significance level (α) of 0.05 and also using the Student t-test showed that there was no significant difference (95% level of confidence) in the concentrations of Cu, Cd, Cr and Pb of the soil samples obtained.

4. Conclusion

From the present study, it can be concluded that in the agricultural fields of Galma, Kubanni and Kufaina, the concentration of Cu, Cr, Cd and Pb are within the normal soil value and were below World Health Organization (WHO) permissible limit which is lower than (0.07ppm) as reported by Igwilo *et al*., 2006; Waziri *et al*., 2013, as reflected by geoaccumulation indices indicating that the farmland soils are in Class 1; 0 < Igeo < 1 = unpolluted to moderately polluted, while Basawa farmland soils has the highest concentration of all the metals studied but the level is still within limit except Cd which is moderately to highly polluted in the farmland, this may be attributed to the use of phosphatic fertilizers, irrigation with untreated water and Lead is usually deposited from anthropogenic sources (metallurgical industry, traffic, paint and from mining of lead), does not biodegrade or decay and is not rapidly absorbed by plants, so it remains in the soils at elevated level. The remaining metals concentration are lower due to decrease in industrial, mining and metallurgical activities in Zaria, continuous removal of heavy metals by the food crops grown on this area and also due to leaching of heavy metals into the deeper layer of the soil and to the ground water.

Heavy metals exposure happens over life time, depending on where you live, and your exposure. The toxicity of the metals is a growing concern and often an unknown root cause of number of serious health issues. Similarly owing to the loud cries of pollution from environmentalist and that care for natural balance of substances in the globe as such the following recommendations can be looked into:

It is recommended that research be carried out regularly to ascertain the level of pollution of heavy metals in the farmland soils. Heavy metals and their causative effects should be taught in secondary, primary schools and tertiary institutions. Furthermore, an irrigation management system that encourages other water source such as underground water may also be recommended to reduce the rate of introduction of pollutant into the soil through waste water. Government should set team of expert to give proper orientation/awareness on regular basis to the community in both affected and unaffected area on how to conduct their agricultural activities in the area.

Government should encourage tertiary and research institutions by way of funding to embark on regular monitoring of industrial effluents in other to ascertain the level of compliance to the use of treatment plant.

The National Agency for Food and Drug Administration Commission (NAFDAC) and Standard Organization of Nigeria (SON) and other relevant agencies should be well funded to up-date their research laboratories in order to meet the present day challenges. Assess the various action plans for the sustainable development of the area by governments and their level of implementation and legal frameworks for environmental decision making in the region. Government at local, state and national levels should set up a team of medical personals to conduct a free regular medical check up to the people of the affected areas and those that are not, as such to ascertain the health status of the peoples living in the areas.

Conflict of interest

The authors declare no conflict of interest.

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