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Assessment of Physicochemical and Selected Heavy Metal of Soil around Dana Steel Industry Limited Katsina, Katsina State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SAZ and AM designed the study, performed the laboratory experiment and wrote the first draft of manuscript. Authors KJU, AAI and KB designed the experiment and carried out the statistical analysis. Authors IA and YMS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The physicochemical parameters and levels of selected heavy metals (Cd, Cr, Mn, Zn and Pb) in soil around Dana Steel Rolling Limted Katsina were investigated in this research. The sample area was divided into four units; East, West, North and South and label as A, B, C and D respectively using stratified random sampling method. The soil was digested using H_2SO_4, $HClO_4$ and HNO_3 for 15 minutes and filtered. The filtrate was used for the analysis using Atomic Absorption

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Spectrophotometer. The results obtained showed that the sampling area is mildly alkaline with pH >7.0. Low moisture and organic matter was also observed in the entire sampling site. For the heavy metals contents, the results indicated that the area under investigation was not polluted with respect to heavy metals content. As the metals content investigated were all below the US EPA standard of heavy metals in soils that requires clean up.

Keywords: Soil; heavy metals; Dana steel; environment; physicochemical.

1. INTRODUCTION

One of the most serious problems facing humanity and other forms of life on earth now is environmental pollution [1]. Understanding soil pollutants and their dependence on its physicochemical properties has provides a basis for careful soil management that limits as far as possible the negative impact of the pollutants on the ecosystem. Soil contaminated with heavy metals is poor in nutrients and contribute to sub-optimal plant biomass accumulation [2].

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; Raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individual [3]. Heavy metals exist in colloidal, ionic, particulate, and dissolved phases. They are present in soil as free metal ions, soluble metal complexes, exchangeable metal ions, and organically bound metals, precipitated or insoluble compounds like oxides, carbonates, and hydroxides, silicate materials [4]. Metals are natural constituents of soil. They persist in soils and have a very slow leaching rate; hence they tend to accumulate in soils. Trace amount of some heavy metals are required by living organisms but in excess they are detrimental. The eco-toxicological risks of metal contamination bear potential harm for plants, animals and human. Heavy metals pollution can suppress or even kill sensitive parts of plant and soil microbial communities and lead to a shift in their functional diversity and structure. The release of metals into the soil is a concern to the environment. Since these metals might be release from soil solid phase to soil solution particularly under different conditions and eventually transferred to the human via food chain, thereby posing a hazard to environment and human health [5].

Once they are accumulated in the food chain, their effect gets adverse with tropic levels due to biomagnification. On the other hand, heavy metals like Cu, Fe, Mn, Ni, and Zn are essential for plant growth and are important constituents of many enzymes. In addition, metals like Al, As, Cd, Cr, Hg, Pb, Sb, Se, among others are nonessential and toxic above certain threshold levels [6].

Soils vary across the landscape, therefore each soil contains unique trace element concentrations based on its parent material and other soil-forming factors that may have added or removed these elements from the soil. High background concentrations of trace elements, whether natural or anthropogenic, could result in mobilization and release into surface and subsurface waters and subsequent incorporation into the food chain. Soil factors such as organic matter, type and amount of clay, pH and cation exchange capacity (CEC) influence the quantity of trace elements available for mobilization and release or sorption in a soil. The extent of soil pollution by heavy metals and base metal ions some of which are soil micronutrients is very alarming [7].

In Nigeria today, numerous studies indicated that industrial activities release heavy metals either as solid, gas and most especially liquids in the form of waste water or effluents allowed draining into water ways or bodies. Small scale road side activities are also significantly contributing to the transmission of these toxic species [8]. Joel and Amajuoyi [9], investigated the physicochemical parameters and heavy metals contents of a Drilling Cutting Dump Site at Ezeogwu–Owaza, Nigeria and reported that some of the metal like Cu, Fe and Ca showed high level of contamination.

Tijjani et al. [10], studied the heavy metal contents in soil of Rimi local government in Katsina state using AAS and reported that the levels of the metals (Cr, Fe, K, Mg, Na, Pb and Zn) investigated were generally below the maximum permissible level for normal agricultural land practices.

Based on the available literature, little or no work has been done to ascertain the extent of pollution in terms of heavy metals content in soil around Dana Steel Limited Katsina, Katsina State, Nigeria despite the fact that the area is an Industrial layout. Hence, we attempt to bridge that gap.

2. MATERIALS AND METHODS

2.1 Materials

All the reagents used were of analytical grade (Analar) and all the glassware and containers used were washed with liquid detergent first, rinsed with 20% (v/v) nitric acid and finally rinsed with deionised water. The containers and glassware were kept in an oven at 105°C until needed. Deionised water was used throughout the work.

2.2 Description of the Study Area

The study was conducted in katsina, North-western region of Nigeria in April, 2015. Katsina town is bordered to the north-east by Kaita, Jibia and Batsari to the North-west, Batagarawa to south and Mani local Government Areas to the east [11]. It is located at 12.59° N and 7.36° E at an elevation of 464 meters above sea level. The mean annual maximum and minimum temperatures are 33.2°C and 18.7°C respectively and the average relative humidity is 60% with mean annual rainfall of 600 mm [12].

2.3 Sampling and Sample Treatment

2.3.1 Soil sampling

Stratified random sampling method was used as follows; each sampling area (the four cardinal points) was divided into seven smaller units and from each unit; seven (7) samples were collected randomly at a depth of 15 cm, mixed and homogenized. The representative samples were obtained using cone and quartered method. The samples were transported to the laboratory for analysis in clean polythene bags [13]. The sampling areas were labeled as follows:

A = East, B= West C= North and D = South.

2.3.2 Sample treatment and analysis

Soil was air dried for 5 days. Foreign and non-soil materials were removed and the soil was crushed using pestle and mortar, sieved via 1.5 mm mesh sieve. One gram of each soil sieved soil was put in a digestion tube. 5 cm^3 of conc. H_2SO_4, 1 cm^3 of 60% $HClO_4$ and 0.5 cm^3 HNO_3 were added to the sample. The digestion tube were placed in a block digester, heated to 105 ^0C until a clear fumes was obtained. The digest was then splashed with distilled water and allowed to cool. After cooling it was filtered into a 50 cm^3 volumetric flask and diluted to the mark with distilled water [14]. The filtrate was used for metals analysis using flame Atomic Absorption Spectrophotometer. Physico-chemical parameters (pH, Organic matter, moisture and cation exchange capacity) and mineral elements (nitrogen, potassium and phosphorus) were determined according to Radojevic and Bashkin [14].

2.4 Statistical Analysis

Data obtained were statistically analyzed using one-way analysis of variance (ANOVA) with SPSS version 10.0 statistical packages and reported as mean ± standard error of mean of three replicate analyses.

3. RESULTS AND DISCUSSION

The results for physicochemical parameters and mineral elements in the soil are determined and presented in Table 1. Results are expressed as mean±standard error of mean of triplicate analysis.

3.1 pH

The pH value of the soil (Table 1) indicated that the soil in the entire samples site were mildly basic in nature. pH is one of the most important parameter that serve as an index for pollution. Its a term used universally to describe the intensity of acidic or alkaline nature of the substances. All the soil samples investigated in the present study are alkaline. The pH value of soil samples varied between 7.11-7.22 which is an indication of the alkalinity of the soil.

3.2 %CEC

The total number of cations a soil can hold or its total negative charge is the soil's cation exchange capacity. The percentage cation exchange capacity (CEC) represents the total exchangeable cation held within the soil. In the present study, the CEC ranges between 4.46 to 5.84 which are lower when compared to the 19.2% and 27.22% reported by Zauro et al. [15] and Nigussie et al. [16] respectively.

3.3 Organic Matter (OM)

Soil organic matter is a principal factor that affects the heavy metal distribution in soil [17]. Increase in soil organic matter content lead to elevation of soil adsorption capacity hence enhancing the accumulation of trace metals. Organic matters can therefore be considered as one of the medium through which heavy metals are incorporated into the soil. Soil in all the sampling points generally contained low organic matter content with the highest being at sampling point A (0.798±0.00%) with the least value (0.080±0.01) observed in sample C. The percentage OM of the soil showed that it falls within the range of low fertility class. This low OM value could be due to low humus content of the soil [18]. The obtained OM values were lower than the reported value by Inobeme et al. [17] in similar work.

3.4 Moisture

The percentage moisture content in all the samples is low. This could be attributed to the time of sampling (April) which is dry season. The moisture content value ranges from 2.0% to 6.0%. It is clear from the result that sample D have highest moisture content than samples A, B and C. The obtained results in this study are low when compared with the reported moisture content in soil of Katol Taluka District Nagpur in India [19].

3.5 Mineral Elements

The exchangeable Na, K, Ca and Mg were low in all the samples. This is due to the low values of CEC in all the samples. The only element that affects sodium levels in the soil is potassium. When sodium percentage is higher than potassium then there is often trouble on the horizon from soil health and crop productivity point of view [20]. The highest content of K of 11.80 mg/kg was found in sample D compared with the 2.20 mg/kg found in sample C. Table 1 showed that the Na concentration of 0.24 mg/kg was obtained in the sample (D) with highest value of K. Ca and Mg analysed in the present study are shown in Table 1. The no difference was observed in the amount of Ca between samples A, B and D. For Mg the concentration varies with in the samples. Even though, all the samples showed low concentration compared to what was reported by Joel and Amajuoyi [9] in similar work.

Table 1. Physicochemical parameters (CEC, moisture, pH and organic matter) and mineral elements of the soil

Parameters	Samples			
	A	B	C	D
pH	7.20±0.02	7.12±0.10	7.14±0.04	7.11±0.40
Moisture (%)	2.0±0.10	1.5±0.2	1.5±0.0	6.0±0.6
CEC (%)	5.34±0.50	5.36±0.42	5.20±0.01	5.06±0.60
Organic Matter (%)	0.798±0.00	0.140±0.70	0.080±0.01	0.120±0.20
Na (mg/kg)	1.56±0.03	0.86±0.00	0.16±0.10	0.24±0.02
K (mg/kg)	3.94±0.05	4.42±0.20	2.20±0.00	11.80±0.60
Ca (mg/kg)	1.35±0.01	1.35±0.30	1.15±0.04	1.35±0.10
Mg (mg/Kg)	0.95±0.20	1.25±0.03	0.70±0.10	1.05±0.01

Table 2. Concentration of metals analyzed in (mg/kg) in the soil

Samples	Metal concentration (mg/kg)				
	Cd	Cr	Mn	Zn	Pb
A	0.412±0.030	3.250±0.01	1.931±0.00	1.186±0.002	ND
B	0.929±0.040	4.187±0.002	2.289±0.100	0.914±0.001	ND
C	0.853±0.010	0.642±0.050	ND	1.530±0.002	ND
D	ND	ND	ND	1.450±0.005	ND
US EPA	70	230	NA	23,600	400

Key: ND= Not detected
US EPA= United State Environmental Protection Agency

The results of the heavy metals (Cd, Cr, Mn, Zn and Pb) concentration (mg/kg) analysed in the present study is presented in Table 2.

Cadmium is naturally non-essential toxic element and it interferes with the metabolism of some essential elements such as zinc, calcium and iron. The concentration of Cd was found in the range of 0.382-0.969 mg/kg with the highest value of 0.929±0.040 mg/kg observed in sample B. The Cd was not detected in sample D. The result in this work is higher than the ranges of 0.00-0.07 mg/kg reported in soil around paint industries in Kaduna [16] and far below the 70 mg/kg recommended for clean up by US EPA [21].

The concentration of Chromium in the study area ranged from 0.642±0.050 to 4.187±0.002 mg/kg (Table 2) and in sample D the Cr was not detected. Despite the low concentration of Cr recorded in the present study in all the samples compared to the 230 mg/kg and 154.8 mg/kg recommended by US EPA for soil that requires clean up and reported by Krishna and Govil, [22] respectively in soil around Pali Industrial Area, India. The presence of this metal is attributed to the use of fossil fuel and emission from the vehicular movement. Other factor considered for the present of Cr is smelting process [23] near the sampling area (Dana Steel Company).

Mn is one of the commonly found elements in the lithosphere. The concentration of Mn found in the present study ranges from 1.931 to 2.389 mg/kg (Table 2). The Mn was not detected in samples C and D and this could be due to the fact that the amount of targeted element is below the detection limit of the machine or completely absent. The Mn content found in the present work is far below the 339 mg/kg reported in the literature [24].

Zinc is a metal whose sources in industrial locations are usually anthropogenic [23]. The main anthropogenic sources of Zn are related to the non-ferric metal industry and agricultural practice. Zinc is a very readily mobile element. Though relatively non toxic, high doses of Zn show toxic and carcinogenic effects and result in neurologic and hematological complications, hypertension, and kidney and liver function disorders. The concentration of Zn in all the samples area is very negligible when compared with the 23,600 mg/kg suggested by US EPA for soil requiring clean up [21].

Lead was not detected in all the samples despite the fact that the sampling areas lie near the major road. Another reason could be that the concentration is below the detection limit of the AAS.

4. CONCLUSION

In this work we investigated physicochemical parameters and some heavy metal contents in soil around Dana Steel Company Katsina. The results obtained showed that the soil of the study area is mildly basic/alkaline and of low fertility. Other parameters such as CEC, Na, K, Ca and Mg ions were all low in the soil. Similarly, the results also showed that all the metals analysed were present in samples A, B and C, but only Zn were detected in sample D. The Pb was not detected in all the samples. The amount of metals obtained in this work showed that the area was not polluted as they metals contents were all below the value recommended by US EPA for soil that require clean up. Furthermore, there is need for further study to ascertain the level of contamination by other pollutants and the biological sustainability of the soils in the near future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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