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Evaluation of Heavy Metals in Roadside Soil of Tumfure Main Market, Gombe State

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Abstract

Heavy metal pollution has been a problem of concern in soil ecology in recent decades. This study evaluated the physico-chemical characteristics and heavy metal contents in roadside soil samples of Tumfure main market, Gombe, Nigeria. The soil samples were collected from six different sampling points with a control sample each by handpicking, this was followed by oven-drying, ground to fine grain, and then sieved using a 2 mm mesh sieve. The pH, electrical conductivity and bulk density were carried out on the soil samples, sieve and sedimentation method were used to determine the soil texture. The soil samples were weighed and digested using mixture of HCl and HNO₃. The contents (mg/kg) of four metals (cadmium, copper, lead and zinc) were estimated using Atomic Absorption Spectrophotometer (AAS). Among the metals analyzed, the contents of Cd, Cu and Pb were not detected while the content of Zn (23.454 - 36.026) was found to be within the desirable permissible limits by the World Health Organization (WHO) and European Regulatory Standards (EURS) whose prevalence is to be considered non-toxic in unpolluted soils.

Keywords: Atomic Absorption Spectrophotometer, Heavy metals, Roadside soil, Pollution, Zinc

Introduction

The amorphous minerals and organic matter that make up soil are found immediately below the surface of the ground and act as a natural medium for the growth of plants and other developmental processes (Chen et al., 2005). Comprising of mineral elements, organic material (humus-rich), water, air, and life forms, soil controls the biological cycles of these elements (Huang et al., 2019a). Naturally occurring heavy metals can be found in soils that are the result of geological processes such as erosion and change of the subsurface rock composition (Al-Jbury and Al-Kasser, 2023). In addition to the originating material, industrial and agricultural contaminants are two of the many sources of pollution in soils (Rehman et al., 2023). It is necessary to find soil erosion processes based on naturally occurring solutions since high rates of runoff and soil losses are the primary factors that propel pollutants into the environment (Luo, 2023).

Therefore, methods for stopping soil erosion that rely on natural remedies must be discovered (Al-Hamad et al., 2023). Because heavy metals, in contrast to certain other pollutants, are not biodegradable, the contamination of the environment by heavy metals has emerged as a global issue in recent years (Smyrnov et al., 2023). As so, instead of being detoxified, they

bioaccumulate in the surroundings. Any metallic element that is hazardous or toxic even at low concentrations and has a relatively high density is referred to as a heavy metal (Abdullahi et al., 2016). Metals and metalloids with densities more than 5 g/cm³ are classified as heavy metals (Moore et al., 2009). Man's industrial, household, and business operations, industrial effluents, pesticides, fungicides, and poultry farm manure all emit heavy metals into the environment (Abdullahi et al., 2016).

Heavy metal contamination of soil has detrimental effects on health, particularly for crops and vegetables cultivated in such soils (Steffan et al., 2018). The majority of these heavy metals—Fe, Zn, Mn, Cu, Co, and Ni—are required in trace amounts for the growth and regular operations of both plants and animals, but excessive concentrations of any one of them can be hazardous in the short- or long-term. Chronic exposure to heavy metals in humans and larger animals can cause central nervous system disorders, renal failure, and mental lapses (Akpoveta et al., 2011). For instance, long-term exposure to Cd can cause lung cancer, bone fractures, kidney failure, and high blood pressure. Lead (Pb) exposure can result in symptoms related to the central nervous system, anemia, nephropathy, intestinal colic, and plumbism (Abdullahi et al., 2016; Huang et al., 2019b).

Due to their significant physiological roles in nature, heavy metals have a unique place in soil chemistry (Akpoveta et al., 2011; Oves et al., 2016). The top soil layer often has the highest concentration of contaminants. The adsorption capabilities of soil matter primarily determine the contaminants concentration in soil. The ability to dissolve by ions of heavy metals in soil was significantly impacted by several parameters such as the pH level, conductivity, and moisture content (Rasulov et al., 2020). As a result of rising anthropogenic activity, heavy metal contamination of water, soil, and air represents a major environmental hazard affecting the quality of food and human health. Because edible plants can absorb heavy metals, these metals may end up in the food chain (Shaapera et al., 2013).

In the research conducted by Shaapera et al., (2013), the concentrations of Cr, Cu, Cd, Pb, Ni and Zn in soils from greenhouse vegetable production area located in northern Jordan was determined. A trend in the heavy metals concentrations of Zn>Pb>Ni>Cu>Cr>Cd was established, they attributed the contamination of this area to agricultural activities derived from the application of agricultural chemicals such as the pesticides, nitrogen and phosphatic fertilizers, chicken droppings in addition to industrial and traffic related emissions.

Heavy metal contamination of roadside soil has not been given much attention in Gombe, north-east, Nigeria. To the best of our knowledge, there are currently no published studies about heavy metal contamination of soils in Tumfure roadside location in Gombe. Therefore, the present study was undertaken to study the physico-chemical characteristics and heavy metals (Cd, Cu, Pb and Zn) contamination in roadside soil of Tumfure main market to check whether the heavy metals exist within the range tolerance or not.

Area of study
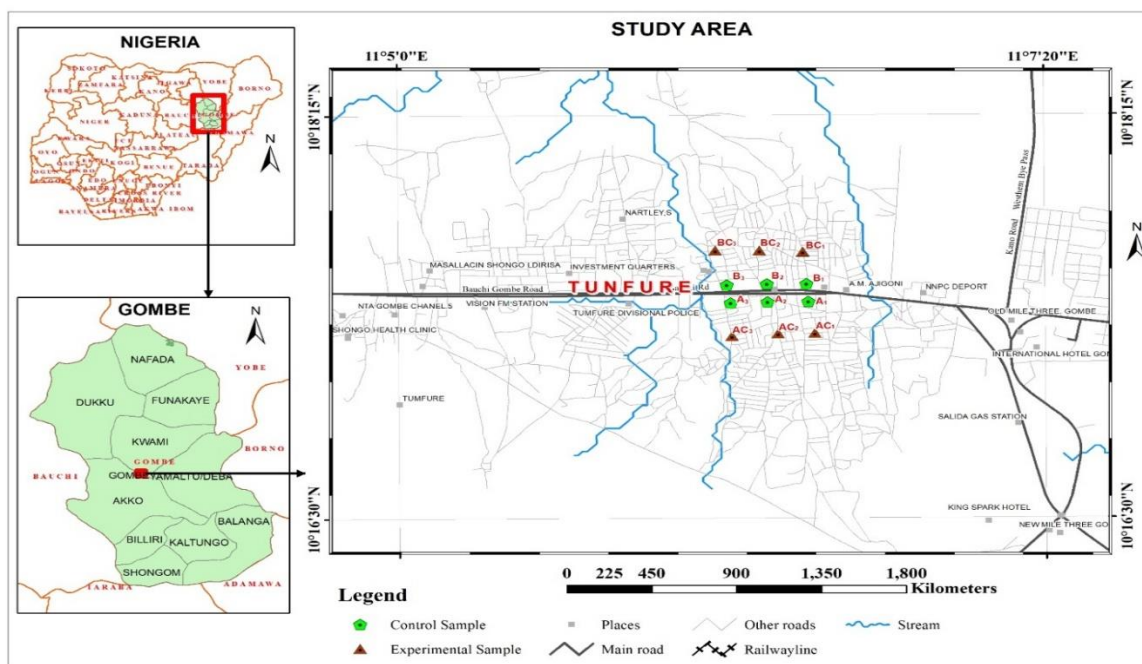This research work was carried out in Tumfure, Akko L.G.A, Gombe State located in the North-eastern part of Nigeria.

Figure 1. Map of Tumfure showing sampling points

Experimental Procedures

Materials
Soil sample, plastic container, polythene bags, distilled water, Whatman No. 1 filter paper, perchloric acid, nitric acid, sulfuric acid, pH meter (model μ-361), electrical conductivity meter (model 307), 250 ml beakers, mechanical shaker, 100 ml measuring cylinder. All chemicals used were of analytical grade and were used without any further purification, obtained from BDH chemicals, Poole, UK.

Method

Sample collection
Samples were obtained in the dry season of year 2021, at Tumfure main market, Gombe metropolis. At each sampling point, about 10 g of the roadside soil samples were collected randomly and homogenized to obtain a composite sample from the surface of the roadside at a distance of 20 m away from each point on the road and labelled as $A_1, A_2, A_3, B_1, B_2, B_3$ as well as a control sample 50 m away from the roadside, represented as; AC_1, AC_2, AC_3, BC_1, BC_2, and BC_3 respectively.

Sample preparation
Five samples were collected at each point, thoroughly mixed in a clean plastic container to obtain a representative sample, stored in a labeled polythene bags prior to analysis.

Physicochemical analysis of the soil samples
For the analysis of the physico-chemical parameters, the soil extract (1:5 *w/v*) was prepared. A total of 20 g of the collected soil sample was added in 100 mL of distilled water. This solution was maintained at room temperature in a mechanical shaker for 12 h before being filtered through Whatman No. 1 filter paper. The filtrate was called soil extract and was used to determine the different physico-chemical parameters, such as, pH and electrical conductivity

(EC). The dry combustion method was used to determine the soil organic matter in the soil (Nelson and Sommer, 1982). For the bulk density (BD) estimation, a core measuring cylinder (100 mL) was utilized (Jacob and Clarke, 2002). The sieve and sedimentation method were used to determine the soil texture (ISO, 2009). Different sizes of the soil particles are classified as follows: sand, 0.5-2.00 mm; silt, 0.002-0.5 mm and clay, 0.002 mm.

Digestion of the soil samples

For the heavy metal investigation, each sample weighed five grams, which were then put into 250 ml beakers and digested with 10 ml of perchloric acid, 50 ml of nitric acid, and 10 ml of sulfuric acid (Abdullahi et al., 2016). After heating the mixture for roughly an hour, it was let to cool down to room temperature. After that, it was brought up to the appropriate level with deionized water and filtered through acid-washed filter paper (Whatman 24) into a 50 ml volumetric flask. The digested sample was stored in a clean sample container for analysis. The elemental analysis of the samples was carried out using atomic absorption spectrophotometer (AAS).

Instrumentation

The atomic absorption spectrophotometer (AAS) Buck Scientific, model VGP, was used to analyze the elements in the samples and determine the blank values for the concentration of heavy metals. Every determination was made in three replicates.

Results and Discussion

The results of the various physico-chemical characteristics analyzed for the soil samples collected from roadside of Tumfure main market are presented in Table 1. The pH is an important parameter that measures hydrogen ion concentration (indicates the acidic or alkaline nature of the soil). The pH of the soil samples was found to be slightly acidic and slightly alkaline (6.8 – 8.2). These findings are similar to the results (6.5 – 8.5) reported by Ramachandra et al., (2012). The content of EC (mS/cm) for the soil samples ranged from 0.18 – 2.80. The EC of all the samples was found to be less than the salt concentration limit for the non-saline soil extract, i.e., 4.5 mS/cm. this indicated that the soil samples are not saline in nature (Brouwer et al., 1985). Our findings are in agreement with the work of Kaur et al., (2014) where they found that the roadway soil in Sakarya city, Turkey is non-saline and attributed it to a lack of various ions in the soil mixture. The bulk density (BD) values for the roadside soils collected at Tumfure main market ranged from 0.9 to 1.32 g/cc. Soil texture is one of the important parameters, which is defined as the stable aggregates formed by the arrangement of soil particles of varying sizes, such as silt, clay and sand. The content of sand dominated all the roadside soil samples studied (Table 1). Clay particles hold cations over their surface due to being negatively charged. Therefore, these soils are chemically not active because the absorbed fractions do not offer an incessant source of cations to the soil and the roots of plants. Soil organic matter (SOM) is an important parameter of the soil that affects nutrient retention and heavy metals in the soil, as well as helps in the growth of plants (Bhatti et al., 2018). The values of SOM ranged from 1.58 to 9.84% in the roadside soil samples.

Table 1. Physico-chemical characteristics of Roadside Soil of Tumfure Main Market, Gombe, Nigeria

Sampling points	pH	EC (mS/cm)	BD (g/cc)	Silt (%)	Clay (%)	Sand (%)	SOM (%)
A_1	6.82	0.18	1.12	16.97	15.47	67.56	3.96
A_2	7.02	0.27	1.04	16.17	15.92	67.91	1.58
A_3	6.98	0.16	0.98	23.49	10.41	66.10	2.46
B_1	7.45	1.77	0.84	14.99	8.58	76.43	4.64
B_2	7.04	2.80	1.28	1.66	13.75	84.59	9.84
B_3	8.20	1.98	1.32	9.97	10.84	79.20	8.65

AC$_1$	7.28	0.94	1.22	3.61	29.09	67.31	4.79
AC$_2$	7.64	0.65	1.08	12.73	32.10	55.17	4.38
AC$_3$	7.08	2.66	1.13	22.12	29.68	48.20	5.89
BC$_1$	7.13	0.65	1.17	14.97	17.26	68.39	4.86
BC$_2$	7.78	2.74	0.90	7.46	39.05	53.50	8.26
BC$_3$	7.50	2.24	1.23	29.58	22.31	48.11	7.92
Limits	**6.5 – 8.5**[a]	**4.5**[b]					

Key: EC: electrical conductivity, BD: bulk density, SOM: soil organic matter; [a] Ramachandra et al., 2012 [b] Brouwer et al., 1985.

The heavy metal contents revealed that concentrations of Cu, Cd, and Pb were not detected and as such, there was no contamination of the soils within the vicinity by these heavy metals (Table 2). The absence of their contamination could be attributed to seasonal variations and could have impacted on the soil when their concentrations were invariably low. It can also be attributed to fact that the soil could have had very low ability to retain or adsorb these heavy metals or the study area was not too exposed to pollution sources such as factories or heavily trafficked roads.

Table 2. Heavy Metals Concentrations of Roadside Soil of Tumfure Main Market

Sampling points	Zn (mg/Kg)	Cu (mg/Kg)	Cd (mg/Kg)	Pb (mg/Kg)
A$_1$	Nd	Nd	Nd	Nd
A$_2$	Nd	Nd	Nd	Nd
A$_3$	23.45	Nd	Nd	Nd
B$_1$	27.45	Nd	Nd	Nd
B$_2$	36.03	Nd	Nd	Nd
B$_3$	35.48	Nd	Nd	Nd
AC$_1$	Nd	Nd	Nd	Nd
AC$_2$	Nd	Nd	Nd	Nd
AC$_3$	Nd	Nd	Nd	Nd
BC$_1$	24.42	Nd	Nd	Nd
BC$_2$	Nd	Nd	Nd	Nd
BC$_3$	Nd	Nd	Nd	Nd

Key: Nd = not detected

The prevalence of Zn was observed along the roadside at 20 m (A$_3$, B$_1$, B$_2$ and B$_3$ respectively) with concentrations 23.45, 27.45, 36.03 and 35.48 mg/kg while, a control at BC$_1$, located 50 m away from the roadside had a Zn concentration of 24.42 mg/kg as shown in Table 2. These concentrations were found to be higher when compared to the investigation by (Abdullahi et al., 2016) (soil from the vicinity of a kaolin milling plant); (Chanda and Gupta.,2021) (soil from an industrial area of Gida) whose Zn concentrations were in the range 0.42 to 6.37 mg/kg and 0.52 to 4.00 mg/kg respectively. This could be attributed to anthropogenic activities, atmospheric depositions and urbanization (Abdullahi et al., 2016; Govil et al., 2001; Parvez et al., 2023). However, the concentrations of Zn derived from this research were found to be lesser when compared to investigation by (Tüzen, 2003) for heavy metals in soils collected at Tokat, Turkey, near high-density traffic and textile plant roads whose concentrations were 60±5 and 74±6 (mg/kg) respectively.

This investigation also revealed that the impact of Zn in this current study area was of less significant concentration when compared with results derived near the impact zone of the Miasteczko zinc smelter in Poland. It was recorded that Zn concentrations were as high as 614.50±46.96, 368.50±39.47, 4832.0±517.48, 246.0±31.10, 649.0±88.56, 202.0±7.62, 240.0±31.42 (mg/kg) at the different seven sampling sites studied which resulted to an average mean of 1062.98±124.22 mg/kg Zn concentration. It was also recorded that Zn concentrations in soils

collected at the vicinity of an Aluminium plant in Tajikistan, Slovakia, and Hungary; separate farmlands located in the western part of Nasarawa State, Nigeria was in the range 34.14 to 89.25 mg/kg and 10.51 to 27.40 mg/kg (Mohammad et al., 2023; Rasulov et al., 2020) were comparable to the Zn concentrations in this study. The findings by (Wei et al., 2011) and (Parvez et al., 2023) revealed that Zn concentrations in soils collected from the vicinity of a mining area located in China and Rampal Power Station in Bangladesh were higher and in the range 42.3 to 148.4 mg/kg and 6.7 to 74.6 mg/kg respectively. The investigation carried out by (Magaji et al., 2020) revealed similar characteristics for the concentration of Zn. It was established that the concentration of Zn was found to be greater than that of Pb for soil samples derived from soils at the vicinity of major motor parks located in Gombe Metropolis, Nigeria. The findings revealed a range of 18.41 to 27.37 mg/kg for Zn and 10.29 to 14.67 mg/kg for Pb, these results were however found to be however, lower than that of the European Union regulatory standard for heavy metals in soils (Magaji et al., 2020).

European Regulatory Standards, EU 2002 have set distinctive most extreme contaminant limits for overwhelming metals. The greatest suggested by EURS for soil tests are cadmium 3 mg/kg; chromium 100 mg/kg; copper 30 mg/kg; lead 150mg/kg, iron 1500mg/kg and zinc 300 mg/kg (Chanda and Gupta., 2021).

Zinc as such, was the only heavy metal detected in this study, the site control sample at BC_1 revealed an expected concentration which was collected at 50 m away from the roadside, it was found to be lesser when compared to concentrations detected at B_1, B_2 and B_3 respectively but, varied insignificantly with the Zn concentrations detected at the A_3 sampling point. Zinc is an essential element that partakes in the metabolism of plants, at extreme levels of concentration could impair the metabolic pathway of microorganisms and plants (Diatta et al., 2008). It could be concluded that the depletion or absence of Pb, Cu and Cd in the soils of the study area could have been as a direct result of the high reactivity of zinc and ease to compete with Pb, Cu and Cd in binding with the soil organic matter.

It has been suggested that Zn is added during industrial activities, such as mining, coal, waste combustion and steel processing. Many foodstuffs contain certain concentrations of Zn (Wuana and Okieimen, 2011). According to WHO standards, the permissible limit is 0.6 mg/kg and the target value in soil (desirable maximum levels in unpolluted soils) is 50 mg/kg (Wuana and Okieimen, 2011). It can be justified that the pollution of Zn in the area of study is within the acceptable limits set by WHO and EURS for zinc contamination in soils.

Conclusion
The roadside soil of Tumfure main market, Gombe was investigated for heavy metal contents and physico-chemical characteristics. The soils pH was found to be slightly acidic and slightly alkaline. The electrical conductivity revealed that the soil samples are not saline in nature with sand content forming the larger portion of all the soil samples. For the heavy metal contents, zinc was the only detected heavy metal observed in the study area with a concentration range of 23.45 to 36.03 mg/kg whilst, lead, copper and cadmium were not detected in the soil samples. The highest concentration of zinc was detected and recorded in samples collected from B_2 and B_3 with concentrations 36.03 and 35.48 mg/kg respectively whilst, least values were obtained at A_3 and B_1 with concentrations 23.45 and 27.45 mg/kg respectively from the roadside. However, the concentration of the only detected heavy metal (Zn) was found to be in the desirable maximum levels established by the WHO and EURS as such, the area of study is to be considered unpolluted.

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