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Ecological Risk Assessment of Mineral and Heavy Metals Levels of Soil Around Auto Mechanic Village Wukari, Nigeria

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Abstract

Environmental contamination is one of the serious challenge facing humanity and other life forms on our planet today. contamination occurs when contaminating substances exceeds their natural levels or when natural resources are use at a rate higher than nature's capacity to restore itself. This study determines the levels of mineral element and potential toxic metals namely: P, K, Mg, Mn, Si, Fe, Zn, Cd, Pb and Al in agricultural soil around mechanic village Wukari-Nigeria. by means of MP-AES (4210 MP-AES Agilent technologies) while their pollution indices by means of geo-accumulation index and contamination factor. The results reveals that the mean ± standard deviation abundance of mineral and heavy metals in the soil was: Fe (20723.64±153.71), Al (3753.80±30.54) K (368.13±2.17), Mg (298.05±3.88), Mn (231.97±0.74), P (221.22±5.47), Zn (184.83±0.47), Pb (86.29±0.31), Si (64.27±0.43) and Cd (1.33±0.06). There was generally a significant difference between the concentration in the test and control sample ($P < 0.05$). While pollution indices show moderate to very high contamination of the soil by zinc, lead and cadmium signalling higher potential risk in terms of mobility on acidification since the organic content is moderate and soil texture being sandy-loam usually characterise with moderate capacity to immobilize heavy metals. Lead contamination can result in neurological and hematological dysfunctions, renal and hepatic damages as well as reproductive disorders in the humans while cadmium is known to have effect on kidney.

Keywords: Mineral; Heavy metal; Concentration and contamination.

1. Introduction

Ecological contamination is one of the most serious problems facing humanity and other life forms on our planet today. It has been defined as the alteration of the physical and biological components of the earth/atmosphere system to such an extent that normal ecological processes are adversely affected. Pollutants can be naturally occurring substances but are considered contaminants when in excess of natural levels. Any use of natural resources at a rate higher than nature's capacity to restore itself can result in pollution of the environment [1].

The decline in environmental quality as a result of pollution is evidenced by loss of vegetation since they are capable of decreasing crop production due to the risk of bioaccumulation and biomagnification in the food chain, loss of biological diversity, excessive amounts of harmful chemicals in the ambient atmosphere, food stuffs and growing risks of environmental accidents and threats to life support systems. There's also the risk of superficial and groundwater contamination. Pollution is viewed from different angles by different people but is commonly agreed to be the outcome of urban-industrial and technological revolution due to rapid and speedy exploitation of natural resources, increased rate of exchange of matter and energy as well as the ever-increasing industrial wastes, urban effluents and consumer goods [2].

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, use of leaded gasoline, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals and atmospheric deposition [3, 4]. While mineral element such as P, K and Mg are usually required by living systems in relatively large amount for the normal physiological processes of living organism due to the role they play in building up and proper functioning of living tissues, elements like Mn, Zn and Fe are needed in very minute quantities for the proper growth, development and physiology of the organism. Silicon is termed beneficial element yet not essential as it aid plants ability to resist infection. Heavy metals constitute an ill-defined group of inorganic chemical hazards and those commonly found at contaminated sites include: lead, chromium, arsenic, cadmium, mercury as well as zinc and copper at elevated concentration. Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and most metals do not undergo microbial or chemical degradation hence their total concentration in soils may persists for a long time after their introduction likewise changes in their chemical forms (speciation) and bioavailability are, however, possible. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants as well as pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain, drinking of contaminated ground water, reduction in food quality, reduction in land usability for agricultural production causing food insecurity [5].

To adequately know contaminated of soil in the ecosystem by metals requires soil characterization to provide an insight into heavy metal speciation before remediation. Remediation of soils contaminated by heavy metals have been reportedly achieved via: Physical remediation (soil replacement, soil isolation, vitrification, electrokinetic remediation [6] Chemical remediation (immobilization techniques, encapsulation, soil washing) and Biological remediation [7-9]. Hence the aim of this study is to determine the levels of P, K, Mg, Mn, Si, Fe, Zn, Cd, Pb and Al and their pollution indices in agricultural soil around mechanic village Wukari-Nigeria.

2. Materials and Methods

2.1. Study Area and Sample Collection

Mechanic village Wukari with the geographical coordinate 7^{o}51’17.208’’N and 9^{o}47’40.374’’E is situated in Wukari local government area of Taraba state, Nigeria. The facility has been in existence for about two decades now where activities such as car repairs, car spraying, car electrical components fittings, car battery repairs and others are carried out on daily basis thereby generating a lot of waste where in most cases such waste are done away by means of incineration while other are dumped in open field around the facility as shown in Plate 1.

Plate-1. Auto Mechanic Village Wukari and Waste Generated

Stratified sampling technique was used for soil sample collection where the sampling site was broken into four (4) stratums (small areas) north, south, east and west with respect to Mechanic village Wukari. Each stratum was further subdivided into four quadrants of equal size before five (5) samples were taken randomly by grab method within the depth of 0–15 cm in the individual quadrant (smaller area) making a total of twenty (20) samples per strata (small area) and a total of eighty (80) samples from the four stratums situated at the north, south, east and west of the industry to enable detailed representation of variability within the study area [10, 11].

The 80 sample units of approximately equal size were pooled together to form the composite and a representative sample for the entire area labeled ‘SMV’. The control soil sample was collected in a farmland within 1.2 km radius from the industry remote to any possible source of contamination associated with the mechanic village and was labeled ‘C-SMV’.

The representative soil sample obtained was sorted to eliminate pebbles and coarse materials and then air-dried at room temperature over three days with occasional breaking of aggregated materials with wooden roller; followed by sieving through a nonmetallic sieve with mesh hole of 2 mm diameter to remove stones, plants and animal’s debris. The pH and soil textural class were determined by standard methods [12] while the soil organic carbon was determined by using potassium dichromate and concentrated sulphuric acid oxidation. since the average content of carbon in soil organic matter is equal to 58 % the conversion factor 1.724 was used to calculate the percentage of organic matter from the content of organic carbon [13, 14].

2.2. Determination of Soil Physiochemical Parameters

The pH value was determined by homogenizing 10 g of the less than 2 mm air dried soil sample in 25 cm^3 distilled water and stirred gently to enhance H^+ (Hydrogen ions) release from soil, the mixtures was allowed to stand for 30 min. pH meter was used to read the pH value of the supernatant after calibration with buffer solutions of pH values 5.5, 7.0 and 8.0.

Soil organic carbon was determined titrimetrically after subjecting soil sample to rapid oxidation by means of potassium dichromate and concentrated sulphuric acid in 5 % $FeSO_4$. The resulting solution was treated with phosphoric acid (H_3PO_4) when cooled to eliminate interference from Fe^{3+} that may be present. Considering that the average content of carbon in soil organic matter is equal to 58 % the conversion factor 1.724 was used to calculate the percentage of organic matter from the content of organic carbon using equation 1 [14, 15].

$$\%\,\mathrm{OM} = \%\mathrm{OC}\ \times 1.724 \qquad (1)$$

Exchangeable acidity (H^+ and Al^{3+}) of the soils was determine by leaching 5.0 g of the less than 2 mm air dried soil sample via filter paper place on a funnel fitted on a 250 mL conical flask with 50 mL potassium chloride (1M).

To the leachate, 3 drops of phenolphthalein indicator was added and was titrated with 0.1 M sodium hydroxide solution to pink color to indicate the end point. The exchangeable acidity was calculated using equation (2). Where: T = sample titre value, B = blank titre value, Ev = extracted volume (leachate), M = molarity of base, A = aliquot or leachate used (mL), Wt = weight of sample used.

$$\mathrm{EA\ (c\ mol/kg)} = \frac{(\mathrm{T}-\mathrm{B}) \times \mathrm{Ev} \times \mathrm{N}\ \times 100}{\mathrm{Wt}\ \times \mathrm{A}} \qquad (2)$$

The exchangeable cations (bases): Na and K were estimated by means of flame photometer (Sherwood 410) while Ca and Mg were by titrimetric analysis in the soil leachate after draining with ammonium acetate (Ross, 2009).

ECECsum(meq/100g) = (ppm Ca /200) + (ppm Mg /120) + (ppm K/391) + (ppm Na/229.9) + EA (3)

The percentages of sand, silt and clay in the soil sample were determined using the Hydrometer method. The textural class of the soil was determined using the soil textural triangle adopted by the United State Department of Agriculture [12, 16].

Nitrogen content of the soil was estimated using distillation and titrimetric method describe by Kjeldahl, while the available phosphorus content was determined using a spectrophotometer (Unicam UV-500) at a wavelength of 660 nm after extracting the available phosphorus in the soil into solution by means of Bray's extractant (0.03 M NH_4F in 0.025M HCl) and coloured by means of molybdate reagent [12, 17].

2.3. Determination of Total Heavy Metal and Mineral Concentration

Mineralization of soil was carried out using 10 mL of 1:1 HNO_3 added to 1.00 g of the air dried sieved sample in a 25 x 150 mm glass digestion tube. The samples were then heated to 95 ± 10 °C for about 15 minutes by means of microwave digestion system. When cool, 5 mL of the HNO_3 was added and heat was applied for another 30 minutes. The digests were again allowed to cool, before 2 mL of deionized water and 3 mL of 30% H_2O_2 was added and heated to 95 ± 5 °C. After the digests were cooled again, another 1 mL of 30% H_2O_2 was added while heating continued until the sample volumes reduced to approximately 5 mL.

The digests were then allowed to cool and filtered before being diluted again to 50 mL with deionized water. Total P, K, Mg, Mn, Al, Si, Zn, Fe, Pb and Cd content in the soil samples were determined using MP-AES (4210 MP-AES Agilent technologies).

2.4. Determination of Pollution Indices

Geo accumulation Factor (Igeo) was used to compare the status of heavy metal concentration with the background values. The Geo-accumulation index was calculated using the equation (4).

$$\mathrm{Igeo} = \log_2\left[\frac{\mathrm{Cn}}{1.5\mathrm{Bn}}\right] \qquad (4)$$

where Cn is the measured concentration of the element in soil or sediment and Bn is the estimated geochemical or background values [18, 19]. The constant value, 1.5, is back-ground matrix correction factor due to the lithological variations. Where Igeo value of (0) is classified as Uncontaminated; (0 - 1) Uncontaminated to moderately contaminated; (1 - 2) Moderately contaminated; (2 - 3) Moderately to strongly contaminated; (3 - 4) Strongly contaminated; (4 - 5) Strongly to extremely strongly contaminated while (>5) Extremely contaminated [20].

The contamination factor (CF) ratio was estimated by dividing the concentration of each metal in the soil by the background/control value as shown in equation (5); where the different levels of degree of contamination include: low contamination for C_f value < 1; moderate contamination for $C_f \geq 1$ to < 3; considerable contamination for C_f value ≥ 3 to < 6 and very high contamination for C_f value ≥ 6 as describe by Rahman, *et al.* [21].

$$\mathrm{CF} = \frac{\mathrm{C\ heavy\ metals}}{\mathrm{C\ back\ groud}} \qquad (5)$$

Table-1. Physiochemical Properties of Test and Control Soil Samples

S/no	Parameter	Test soil	Control soil
1	pH	8.20±0.41	8.51±0.01
2	Organic carbon (%)	1.215±0.049	0.92±0.02
3	Organic matter (%)	2.09±0.08	1.29±0.02
4	Nitrogen (%)	0.16±0.01	0.078±0.001
5	Avail P(mg/kg)	18.95±5.93	4.11±0.10
6	K (Meq/100g)	0.19±0.084	0.20
7	Na (Meq/100g)	14.18±0.04	2.26
8	Ca (Meq/100g)	12.25±0.47	9.40
9	Mg (Meq/100g)	3.03±1.60	2.92
10	AE (H^++Al^{3+}) (Meq/100g)	0.55±0.08	0.05
11	ECEC (Meq/100g)	30.20±0.45	13.78±0.01
12	Textural class base on USDA standard	Sandy Loam	Sandy Loam

Table-2. Mineral and Heavy Metal Concentration with their Pollution Indices

	Sample	Mean ± S.D.	Bn	Igeo	Remark	CF	Remark
Phosphorus Content (mg/kg)	SMV	221.22±5.47	1,000	-2.761	Uncont.	0.221	Low cont.
	C-SMV	214.30±5.80	1,000	-2.807	Uncont.	0.214	Low cont.
Potassium Content (mg/kg)	SMV	368.13±2.17	21000	-6.418	Uncont.	0.0175	Low cont.
	C-SMV	153.40±1.74	21000	-7.681	Uncont.	0.0073	Low cont.
Magnesium Content (mg/kg)	SMV	298.05±3.88	19000	-6.579	Uncont.	0.016	Low cont.
	C-SMV	224.12±1.75	19000	-6.990	Uncont.	0.012	Low cont.
Manganese Content (mg/kg)	SMV	231.97±0.74	950	-2.618	Uncont.	0.244	Low cont.
	C-SMV	214.12±1.75	950	-2.734	Uncont.	0.225	Low cont.
Zinc Content (mg/kg)	SMV	184.83±0.47	75.00	0.716	Uncont.	2.464	Moderate cont.
	C-SMV	134.65±0.45	75.00	0.259	Uncont.	1.795	Moderate cont.
Silicon Content (mg/kg)	SMV	64.27±0.43	277,100	-12.65	Uncont.	2.32×10^{-4}	Low cont.
	C-SMV	44.15±0.23	277,100	-13.20	Uncont.	1.59×10^{-4}	Low cont.
Lead Content (mg/kg)	SMV	86.29±0.31	14.00	2.038	Moderate cont.	6.164	Very high cont.
	C-SMV	6.87±0.08	14.00	-1.612	Uncont.	0.491	Low cont.
Cadmium Content (mg/kg)	SMV	1.33±0.06	0.110	3.011	Moderate cont.	12.09	Very high cont.
	C-SMV	0.20±0.03	0.110	0.278	Uncont.	1.818	Moderate cont.
Iron Content (mg/kg)	SMV	20723.64±153.71	41000	-1.57	Uncont.	0.505	Low cont.
	C-SMV	4940.98±25.61	41000	-3.63	Uncont.	0.121	Low cont.
Aluminium Content (mg/kg)	SMV	3753.80±30.54	82000	-5.03	Uncont.	0.046	Low cont.
	C-SMV	2940.98±25.61	82000	-5.38	Uncont.	0.036	Low cont.

SMV= Test soil sample, C-SMV= Control soil sample, Igeo = Geo-accumulation Index, CF = Contamination, Bn = Background concentration [18, 19], Uncont.= Uncontamination, cont. = Contamination

2.5. Soil pH

The mean soil pH of the soils obtained from farms around Mechanic village Wukari was 8.20±0.41 and 8.51±0.01 for the control soil sample (C-SMV) as displayed in Table 1. The soils pH around mechanic village were moderately alkaline (7.9 – 8.4) based on USDA classification [12]. The high soil pH values suggest that heavy metals as well as plant nutrient such as phosphate, iron, zinc, copper and manganese availability for plant uptake is low in the soil samples. High soil pH may result due to calcium carbonate-rich parent material weathering or irrigation with alkaline water and can be corrected by addition of acidifying fertilizers, such as ammonium sulfate and organic matter [22].

2.6. Organic Matter

The mean percentage organic carbon content of the soils obtained from farm lands around Mechanic village Wukari and the control sample were 1.215±0.049% and 0.92±0.02% respectively as shown in Table 1.

Based on USDA classification where < 0.4% carbon content (very low); 0.4-1.0% carbon content (low); 1.0-1.5% carbon content (moderate) and > 1.5% carbon content (high) indicates that the 2.04% carbon content of soils obtained in farms Mechanic village 1.215% was within the moderate level (1.0-1.5%). The mean percentage organic matter content of the soils was 2.09±0.08% and 1.29±0.02% for the control sample respectively as displayed in Table 1. The organic matter content of the soils correlates positively with the organic carbon content. Organic matter consists of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms as well as substances synthesized by soil organisms which help in improving the soil structure, enhanced cation exchange capacity and minimize erosion [23]. Organic matter has been shown to decrease heavy metal availability through immobilization of the metals [24]. Continues agricultural production without amendment and the incorporation of natural areas for agricultural activities has resulted in the loss of soil organic matter and consequent emission of greenhouse gases [25].

2.7. Nitrogen Content

The mean percentage nitrogen content of soils obtained from the farm land was 0.16±0.01% and 0.078±0.001% for the control soil sample respectively as shown in Table 1. The nitrogen content recorded in the test soil falls within the (0.10 – 0.20%) U.S.D.A classified as moderate while the nitrogen content of the control soil was twofold less than that of the test soil. The moderate nitrogen content in farmland is due to the application of nitrogenous fertilizer during farming season. Nitrogen (N) is a major fertilizer for agriculture and food production. About 67.84 million tons of N are annually applied to agricultural fields [26].

2.8. Available Phosphorus Content

The mean content of available phosphorus in soils obtained from farm lands 18.95±3.60 mg/kg and 4.11±0.10 mg/kg respectively as displayed in Table 1. Indicating that the available phosphorus content of the test soil was more than five times the content in the control soil. Based on united states department of agriculture (USDA) and natural resources conservation service (NRCS) classification. Available phosphorus content of ≤ 5 mg/kg (very low), 6 - 15 mg/kg (low), 16 – 24 mg/kg (medium), 25 – 30 mg/kg (high) while > 30 mg/kg (very high)

The available phosphorus recorded in the test soils falls within medium range (16 – 24 mg/kg) while the content of the control soil falls within the very low category (≤ 5 mg/kg). After nitrogen, phosphorus is the second most widely used fertilizer throughout the world [27].

When phosphorus is applied to soil, there is generally an increase in the available phosphorus content. The magnitude of the increase is a function of soil properties such as clay content, organic carbon, iron, aluminum, and calcium carbonate ($CaCO_3$) content. Applied phosphorus can be taken up by the crop or converted to the tissue component of soil microflora and micro-fauna [28].

2.8.1. Effective Cation Exchange Capacity (ECEC)

The mean effective cation exchange capacity (ECEC) of soils obtained from farm lands around Mechanic village Wukari and control sample were 30.20±0.45 Meq/100g and 13.78±0.01 Meq/100g respectively as shown in Table 1. The mean effective cation exchange capacity (ECEC) of the soils around mechanic village (30.20 Meq/100g) falls within the range of high effective cation exchange capacity (> 25.0 Meq/100g). implying that the test soil has a reasonable measure of negatively charged sites on soil surfaces that can retain positively charged ions. Cation exchange capacity is most pronounce when the soil is rich in clay and organic matter at pH near neutral [29].

2.8.2. Soil Textural Class

Results obtained from particles size analysis revealed that the mean percentage clay content of the soils obtained from farm lands around Mechanic village Wukari and the control soil sample were: 8.40±1.67% and 9.00±1.73% while the percentage silt content were: 35.6±1.51% and 31.2±7.19%. The percentage sand content was: 56.0±1.87% and 59.8±8.87% respectively for the test and control soil samples while the textural class were generally sandy loam. Soil texture indicates the relative content of particles of various sizes, such as sand, silt and clay in a mass of soil. Texture influences the ease with which soil can be worked on, the amount of water and air it holds and the rate at which water can enter and move through soil. Texture has a major effect on soil's: fertility levels, infiltration and drainage rate, water holding capacity, bearing strength, ease of cultivation, shrink and swell potential, ability to crack on drying and susceptibility to erosion while soil structure is affected by texture, chemical interaction and mechanical actions such as compaction from agricultural machinery [16, 30].

3. Mineral and Heavy Metal Content of the Soil

3.1. Phosphorus Content

The mean content of total phosphorus in soils obtained from farm lands around Mechanic village Wukari: 221.22±5.47 mg/kg and 214.30±5.80 for the control sample respectively as shown in Table 2 and Figure 1. The phosphorus content was more than four times below the 1000 mg/kg geochemical background value concentration of phosphorus in the soil which is the average concentration in the shale [18]. The relatively higher level of phosphorus in the test soil compared to the control is traceable to the wide utilization of the element as component of fertilizer throughout the world [27].

3.1.1. Potassium Content

The mean content of total potassium in soils obtained from farm lands around Mechanic village Wukari and was 368.13±2.17 mg/kg and153.40±1.74 for the control sample respectively. The potassium content of the test soil was more than two fold the content of the control soil sample which is traceable to its utilization as fertilizer component in farms but the content was far less than the 21,000 mg/kg to 23, 000 mg/kg geochemical background value of potassium on the earth crust [18, 19].

Pollution indices of -6.418 and 0.0175 for the geo-accumulation index and the contamination factor indicates uncontamination and low contamination with respect to potassium in agricultural soil around Mechanic village Wukari.

3.1.2. Magnesium Content

The mean content of total magnesium in soils obtained from farm lands around Mechanic village Wukari and control sample were: 298.05±3.88 mg/kg and 224.12±1.75 mg/kg respectively.

The slightly higher level of magnesium in soil around the farmland is traceable to application of fertilizer annually during cropping since Mg is a macro element required by plant in relatively large amount [31] Pollution indices of -6.579 and 0.016 for the geo-accumulation index and the contamination factor indicates uncontamination and low contamination with respect to Mg in the test soil.

3.1.3. Manganese Content

The mean content of total manganese in soils obtained from farm lands around Mechanic village Wukari and control sample were: mg/kg, 231.97±0.74 mg/kg and 214.12±1.75 mg/kg respectively. The value was four times less than the 950 mg/kg geochemical background value concentration of Mn in the soil which is the average concentration in the shale [18]. The -2.618 geo-accumulation index of the test soil samples was less than zero thereby indicating uncontamination with respect to manganese. Likewise, the contamination factor was 0.244 which was also less than one, indicating low contamination with respect to manganese in agricultural soil around the industry.

3.1.4. Silicon Content

The mean content of total silicon in soils obtained from farm lands around Mechanic village Wukari and control sample was 64.27±0.43 mg/kg and 44.15±0.23 mg/kg respectively. The value was four times less than the 277,100 mg/kg geochemical background value concentration of Si in the soil which is the average concentration in the shale [18]. The -12.65 geo-accumulation index of the agricultural soil samples around the mechanic village which was less than zero indicates uncontamination with respect to silicon. Likewise, the contamination factor of 2.32×10^{-4} recorded was less than one, indicating low contamination. Silicon is not considered an essential nutrient but beneficial element, it is typically abundant in soils and can be taken up in large amounts by plants. Silicon is known to have beneficial effects when added to several plants. These effects include disease and insect resistance, structural fortification, increase biomass and regulation of the uptake of other ions [32].

3.1.5. Zinc Content

The mean content of total zinc in soils obtained from farm lands around Mechanic village Wukari and control sample Wukari were: 184.83±0.47 mg/kg and 134.65±0.45 mg/kg respectively. The Zn content in the test soil was more two fold the 75 mg/kg geochemical background value concentration of Zn in the soil which is the average concentration in the shale [18].

The higher level of zinc content in the soil is traceable to the use of zinc and its compound in galvanization of iron in order to prevent rusting in the industry.

Nevertheless, the value was less than the threshold value of 200 mg/kg of the United Nation Environmental Protection which indicates the need for further assessment of the area as well as the 250 mg/kg guideline, to indicate that the area has its contamination level to an extend presenting ecological risk [33, 34]. The pollution indices of the soil by zinc base on the geo-accumulation index was 0.716 which was within 0 to 1.00 implying uncontamination to moderate contamination. Likewise, the contamination factor was 2.464 which falls within (≥ 1 to < 3) and indicates moderate contamination with respect to zinc.

Zinc is an essential nutrient with over 200 zinc-dependent enzymes in major biochemical pathways in the body and plays a key role in the development of immune system. The element is an essential component of both DNA and RNA polymerase enzyme and is vital to the activity of a variety of hormones such as insulin, growth and sex hormones [35].

High zinc levels can interrupt the metabolic activity in soils, as excessive zinc negatively harms microorganisms and earthworms, slowing down breakdown of organic matter that provides basic nutrition to plant roots. Excessive zinc also stunts plant growth, bringing about yellowing of plant leave and eventual death of the plant that are sensitive which are mostly broad-leaf while grasses are more tolerant of high zinc levels in soils. Likewise, in animal at low pH in the stomach causes the release of free zinc, which then forms soluble caustic zinc salts. These salts are absorbed from the duodenum and rapidly distributed to the liver, kidneys, prostate, muscles, bones, and pancreas [36].

3.1.6. Lead Content

The mean content of total lead in soils obtained from farm lands Mechanic village Wukari and control sample were 86.29±0.31 mg/kg and 6.87±0.08 mg/kg respectively. The Pb content was more than four times the 20.02 mg/kg Pb content recorded in soil from irrigated farmlands in Kaduna metropolis as well as the 50 mg/kg limit of the European standard but less than the 321.45 mg/kg content of the top soil around sack and packaging company akwanga [15], as well as the 210 mg/kg intervention value by the Department of Petroleum Resources [22].

The pollution indices of lead based on geo-accumulation index of the soil samples around industries was 2.038 which falls within 2.00 to 3.00 implying moderate to strong contamination with respect to lead. Likewise, the contamination factor of 6.164 being ≥ 6, indicates very high contamination with respect to lead. The high level of lead content in the soil may be traceable to the use of lead compound such as lead oxide, which are very stable and suitable as ingredients in corrosion-resistance coating for iron and steel as well as in car battery.

Excess Pb may be evident with toxicity symptoms such as stunted growth, chlorosis and blackening of root system in plants. Pb has also been reported to inhibits photosynthesis, upsets mineral nutrition and water balance, changes hormonal status, affects membrane structure and permeability [37]. While in animals Pb exposure has been reported to induce neurologic and haematological dysfunctions, renal and hepatic damage as well as reproductive disorders in the human body. Children are especially at greater risk because they have higher intestinal Pb absorption and more vulnerable nervous systems which are still under development [38].

3.1.7. Cadmium Content

The mean content of total cadmium in soils obtained from farm lands around Mechanic village Wukari and control were: 1.33±0.06 mg/kg and 0.20±0.03 mg/kg respectively.

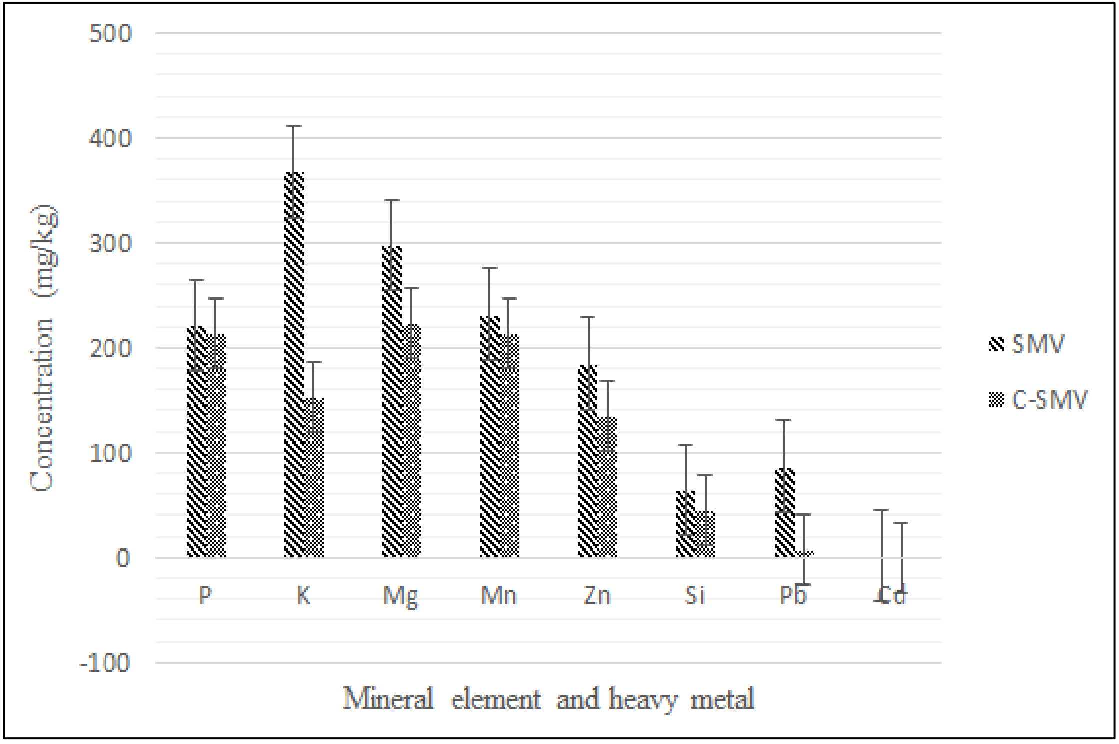
The Cd levels recorded in the present study was generally higher than the 0.73 mg/kg reported for dumpsite in Ghana [39] but were generally less than the 9.05 mg/kg observed in dumpsite soil from Uyo, Nigeria [40].

The geo-accumulation index value of SMV (3.011) falls within 3.00 to 4.00 implying strong contamination Likewise, the contamination factor of 12.09 recorded in the soil was greater than 6, indicating very high contamination with respect to cadmium in soils across the industrial layouts.

Cadmium is a non-essential metal classified as a group I human carcinogen by the International Agency for Research on Cancer [38]. The element is frequently discharged from anthropogenic sources since the element is use as an anti-corrosion coating in electroplating and stabilizer in plastics. It is a component of nickel-cadmium batteries and alloying metal in solders. Cadmium also occurs in varying degree in phosphorus fertilizer and biosolids [41, 42].

Cadmium persistence in the environment and its uptake and accumulation in the food make it a public concern. The effect of Cd toxicity on plants has been largely explored regarding inhibition of growth processes and decrease of photosynthetic activity [43] while the main effect of cadmium on health have been reported as kidney disease, other adverse effect has been documented on pulmonary cardiovascular and musculoskeletal system [42].

Figure-1. Mineral and heavy metal levels



SMV= Test soil, C-SMV = Control soil

3.1.8. Iron Content

The mean content of total iron in soils obtained from farm lands Mechanic village Wukari and the control sample was 20,723.64±153.71 mg/kg and 4,940.98±25.61 mg/kg respectively as displayed in Table 2 and Figure 2. The iron level in soil across the industrial layout was generally greater than the 1771 mg/kg recorded in soils around Illela Garage in Sokoto [44].

The high concentration of total iron (20,723.64 mg/kg) in soil around the industry is traceable to the utilization of the element as composite material in metal work as well as commercial activities of automobile mechanics and iron/metal works artisans, and carcasses of abandoned and unserviceable cars scattered around the vicinity [45].

Nevertheless, the 20,723.64 mg/kg recorded in soils around the mechanic village Wukari is about 2 times less than the 39,000 mg/kg to 41, 000 mg/kg geochemical background value of iron on the earth crust [18, 19].

The -1.57 geo-accumulation index of the soil samples around the industry was below zero thereby indicating uncontamination with respect to iron. Likewise, the contamination factor of 0.505 was less than one, indicating low contamination with respect to iron across the industries.

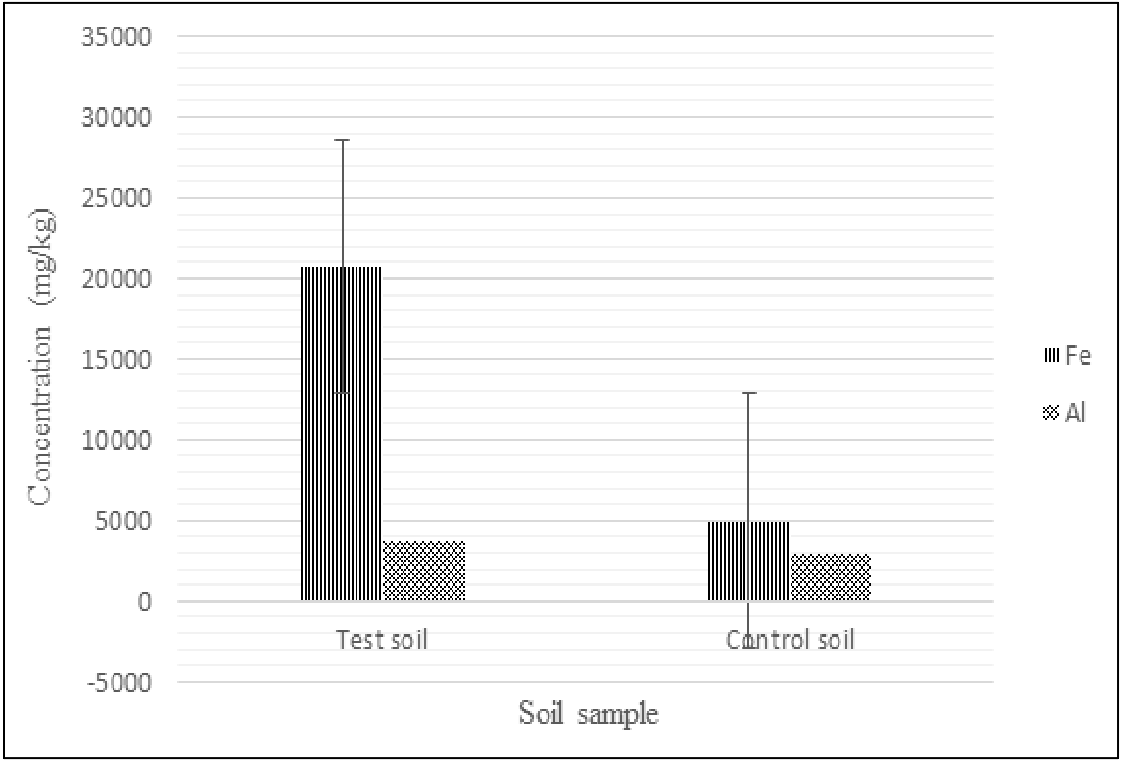
3.2. Aluminium Content

The mean content of total aluminium in soils obtained from farm lands around Mechanic village Wukari and control sample were: 3,753.80±30.54 mg/kg and 2,940.98±25.61 mg/kg respectively as shown in Table 2 and Figure 2.

Nevertheless, the 3,753.80 mg/kg recorded in soils around the Mechanic village Wukari is about 25 times less than the 82,000 mg/kg geochemical background value of aluminium on the earth crust [18, 19]. Aluminium and its compounds comprise about 8% of the Earth's surface; aluminium occurs naturally in silicates, cryolite, and bauxite rock. Natural processes account for most of the redistribution of aluminium in the environment. Acidic precipitation mobilizes aluminium from natural sources, and direct anthropogenic releases of aluminium compounds associated with industrial processes occur mainly to air [46].

The -5.03 geo-accumulation index value of the soil sample around the industry was below zero thereby indicating uncontamination with respect to aluminium. Hence the aluminium content in the soil is likely from the lithogenic source such as aluminium silicate a clay mineral. Likewise, the contamination factor of 0.046 was generally less than one, indicating low contamination with respect to aluminium around the industry.

Figure-2. Concentration of Iron and Aluminium in the Control and Test Soil



3. Conclusion

The abundance of mineral and heavy metals in the soil is in the order: Fe > Al > K > Mg > Mn > P > Zn > Pb > Si > Cd with the concentration in the test soil been generally above that in the control sample indicating enrichment due to activities within the facility where the concentrations of Zn, Pb and Cd were above that at the background with pollution indices base on geo-accumulation index and contamination factor indicating moderate contamination to a very high contamination of the soil by zinc, lead and cadmium respectively.

Competing Interests

Authors have declared that no competing interests exist.

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