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Original Article

Levels and ecological risk assessment of mineral and heavy metals in soils around Nasara Fertilizer Blending Plant, Lafia, Nigeria

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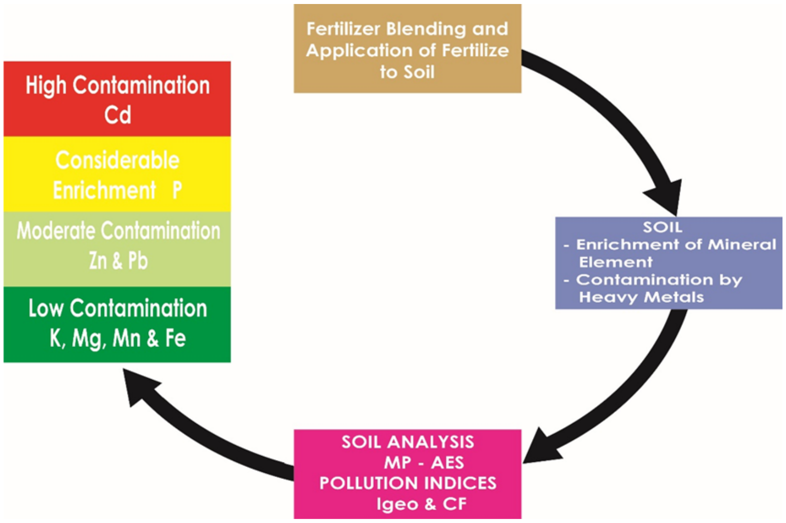
ABSTRACT

Fertilizer introduction in the right elemental proportion based on plants' nutritional needs has contributed positively to crop production. On the other hand, the leakages during fertilizer blending have contributed to excessive mineral nutrients and traces of heavy metals in the environment. These leakages contaminate water bodies or get into the food chain and bio-cumulate in tissues of living organisms with detrimental effects. This study assessed the impact of fertilizer blending on the level of some mineral and heavy metals in soils around the industrial layout using MP-AES, pollution indices in terms of the geo-accumulation index and contamination factor. The results revealed all of the mineral and heavy metals were detected in the soil in the order of abundance: Fe (10560.77±8.00 mg/kg), P (5252.17±36.15 mg/kg), K (1834.53±13.74 mg/kg), Mg (593.99±13.75 mg/kg), Mn (335.18±1.63 mg/kg), Zn (205.96±1.18 mg/kg), Pb (20.08±0.19 mg/kg) and Cd (6.51±0.06 mg/kg). There was a significant difference in soil quality, mineral and heavy metal content between the test and control soil samples ($P < 0.05$). The geo-accumulation index showed moderate contamination by phosphorus and strong to extreme contamination by cadmium. The contamination factor showed the soil is moderately contaminated with zinc and lead, considerably contaminated with phosphorus but highly contaminated with cadmium, a very toxic element that distributes so easily in soil and plant tissues. Hence, consumption of crops, fruits and vegetables from the area may likely be at risk. Regular monitoring and effective clean up are recommended.



HIGHLIGHTS

- The SFP was slightly alkaline, sandy-loam and high in OM and ECEC.
- The concentrations of P, Zn, Pb and Cd in the soil were above background concentration.
- The elements' concentrations in the sample and the control are statistically different.
- P considerably enriched the soil.

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Soil pollution; potentially toxic metals; geo-accumulation index; contamination assessment.

1. Introduction

Introducing modern fertilizer practices based on the chemical concept of plant nutritional need. Has contributed immensely to an increase in agricultural production and has resulted in better food and fodder quality. As a beneficial side-effect, the fertility of soils has been improved, resulting in a more stable yield and better resistance to some diseases and climatic stress. The farmer's economic returns have increased because of more effective production (Spann and Shumann, 2013; Saeed *et al*., 2015). Meeting the nutritional need of a plant is achieved through the processes of fertilizer blending, which is a technical process that offers a customized balance of fertilizer components by adjusting fertilizer inputs to crop requirements (Selassie, 2015).

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Fertilizer blend usually provides in the right proportion the levels of major nutrients, secondary and micronutrients. Aside from these beneficial and essential elements, it has reportedly found toxic ones in fertilizer blend at elevated levels and hence the risk of entering into the food chain (Meng *et al*., 2018). For instance, phosphate fertilizers may contain cadmium alongside other heavy metals when sedimentary rock phosphate is used as raw material for production (Mirlean and Roisenberg, 2006; Mar and Okazaki, 2012). Likewise, the continuous changes in temperature, humidity and the functional stresses, impose on a vessel over time which is common to the process of fertilizer blending, can cause mechanical and chemical changes, like material swelling, cracking, corrosion and degradation (Tiruta-Barna and Barna, 2013). Heavy metals and minerals availability is influenced by factors such as soil pH, soil organic matter and cation exchange capacity. Previous studies have suggested that the soil pH, organic matter content and cation exchange capacity are mostly negatively correlated with the availability of minerals and heavy metals (Zhang *et al*., 2018).

Previous studies reported that concentrations of contaminants are usually higher where significant human activities are recorded (Arowojolu *et al*., 2021). For instance, they have reported elevated heavy metals in plant tissues growing around some industrial layout within the Lafia metropolis in Nigeria (Akomolafe and Lawal, 2019), as well as dumpsites within the same metropolis (Solomon, 2019). Aside from heavy metals contaminations, they have reported fertilizers leakages into the environment to cause serious contamination of soil, freshwater and marine ecosystems. Through enrichment with a nutrient that encourages algae blooms, causing the depletion of oxygen in surface water as well as increasing pathogens and nitrates levels in drinking water, leading to the emission of odours (Selassie, 2015).

Since levels of mineral and potentially toxic metals in soils around Nasara Fertilizer Blending Plant (NFBP), Lafia, Nigeria based on a literature search, this study aims to establish the baseline concentrations of P, K, Mg, Mn, Fe, Zn, Cd and Pb in agricultural soils around the plant. In addition, the study evaluates the impact of the fertilizer plant on the concentrations of the elements in the soil around NFBP.

2. Materials and methods

2.1 Materials and reagents

Microwave digestion system (Milestone connect), Micro Plasma Atomic Emission Spectrophotometer (4210 MP-AES Agilent Technologies), flame photometer (Sherwood 410) and pH meter (Jenway 2000) were employed in the study. All reagents used were of analytical grade. The standard materials of P, K, Mg, Mn, Fe, Zn, Cd and Pb as well as sulfuric acid (98%) hydrochloric acid (35%), nitric acid (70%) and hydrogen peroxide used for digestion were acquired from Zayo-Sigma Chemical Limited, Nigeria.

2.1 Study Area

Nasara Fertilizer Blending Plant, Lafia with the geographical coordinate 8o28’47.82612”N and 8o33’9.20232”E is in Lafia local government area, the administrative capital of Nasarawa State, Nigeria as shown in Figure 1. The facility is situated in the extension of the ministry of agriculture where worn-out tractors, tractors part, worn-out vehicles and heavy agricultural machinery that are no longer in use are being kept. There are farmlands, where maize and beans are annually cultivated, around the blending plant having blending equipment’s parts and others abandoned on them as shown in Figure 2 (A, C and D). NFBP Lafia was established over twenty years back but the production of fertilizer has greatly reduced over the years.

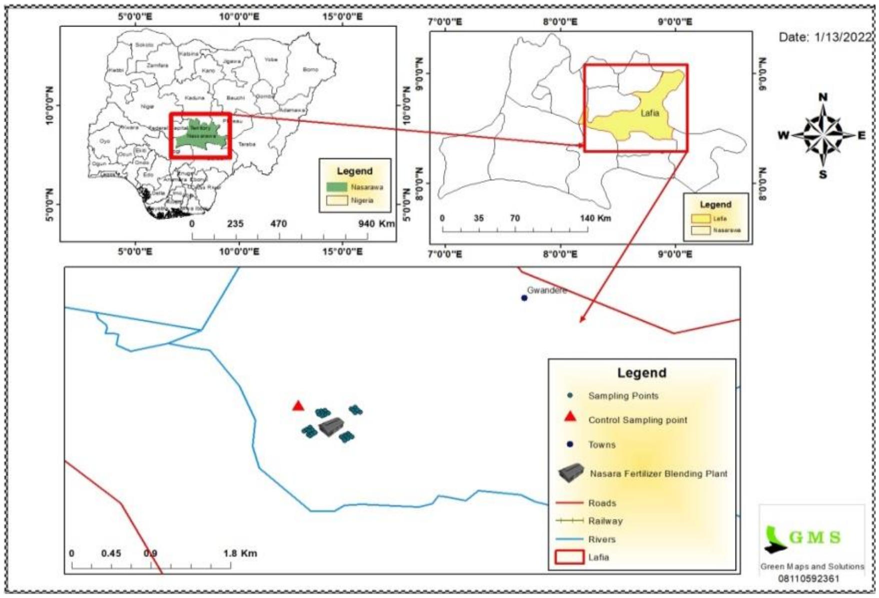

Figure 1. GPS Map of Lafia Local Government and Nasara Fertilizer Blending Plant.

Figure 2. Nasara Fertilizer Blending Plant Lafia (A) surrounding farmlands, (B) some equipment of the plant, (C) abandoned blending equipment around the plant and (D) some abandoned vehicle on-site.

2.2 Sample Collection

This study adopted a stratified sampling technique. The sampling site (SFP) was broken into four (4) strata. Each stratum was further broken into four quadrants of equal sizes before five (5) samples were taken randomly at the depth of 0–15 cm, totalling eighty (80) samples. A control sample, labelled C-SFP, was collected within a 1.3 km radius from the SFP (Xue and Cheng, 2001; Yerima *et al*., 2020).

2.3 Sample Preparation

Prior to sample digestion and analysis, the soil sample was air-dried at room temperature over two weeks. The air-dried samples were sieved through a nonmetallic sieve of 2 mm diameter mesh hole to remove stones, pebbles and larger aggregates. The same procedure was carried out on the control soil sample.

2.4 Soil Quality Analysis

The pH value was obtained by shaking 1.0 g of the soil sample in 10 mL of distilled water, the mixtures were then allowed to settle for 30 min. A pH meter was used to read the pH value after calibration with buffer solutions of pH values 5.5, 7.0 and 8.0 respectively (Motsara and Roy, 2008).

Soil organic carbon was determined employing wet dichromate oxidation by the addition of 50 mL potassium dichromate (0.5 M $K_2Cr_2O_7$) and 2.5 mL concentrated sulphuric acid in 5 % $FeSO_4$. Since the mean content of carbon in soil organic matter is equal to 58 % the conversion factor of 1.724 was used to calculate the percentage of organic matter from the content of organic carbon (Walkley and Black, 1934; Yerima *et al*., 2020). Nitrogen in the soil was estimated using the distillation and titrimetric method described by Kjeldahl after digestion with concentrated sulphuric acid. Available phosphorus composition was estimated by ultraviolet spectrophotometry at the wavelength of 660 nm (Bray and Kurtz, 1945; Yerima *et al*., 2020).

The textural classification of the soils using the hydrometer method is described elsewhere (Motsara and Roy, 2008). The exchangeable acidity (H^+ and Al^{3+}) of the soils was determined by titrimetric analysis, available Na and K content by flame photometry (Sherwood 410) while Ca and Mg using complex metric titration (Rathore *et al*., 1993).

2.5 Sample Digestion

Digestion of soil samples was carried out by adding 10 mL of 1:1 HNO3 to 1.0 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 utilizing a microwave digestion system (Milestone connect). After cooling, 5 mL of the HNO3 was added and the 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% H2O2 was added and heated to 95 ± 5 °C. After the digests were cooled again, another 1 mL of 30% H2O2 was added while heating continued until the sample volumes were reduced to approximately 5 mL. The digests were then allowed to cool and filtered before being diluted again to 50 mL with deionized water (Yerima *et al*., 2020).

2.6 Determination of Total Heavy Metal and Mineral Content

After soil samples digestion, the concentrations of P, K, Mg, Mn, Zn, Fe, Pb and Cd in the soil samples were determined using Micro Plasma Atomic Emission Spectrophotometer (4210 MP-AES Agilent technologies). With a calibration coefficient limit of 0.999, four replicates. Sample introduction using Agilent SPS 4, pump speed 15 rpm, sample uptake time of 25 s and rinse time of 25 s, stabilization time of 5 s and total run time of 55 s

2.7 Data Processing and Statistical Analysis

Data were compared using t-test on Statistical Package (IBM SPSS Statistics 20) at 95% confidence limit. The concentrations of mineral and heavy metal obtained were further subjected to the Index of geo-accumulation (I_{geo}) with Contamination factor (C_f) models to assess the pollution impact of the industry on the SFP.

2.7.1 Index of geo-accumulation (Igeo)

Index of geo-accumulation was used to assess the degree of mineral and heavy metal pollution and was calculated using Equation 1. Factor 1.5 is introduced to accommodate the effect of variability in background values that may be attributed to lithological variations imparted in the soils (Guan *et al*., 2014; Edith-Etakah *et al*., 2017). Levels of contamination described by Muller (1969) was adopted where the geo-accumulation value of (0) is considered 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.

$$I_{geo} = \log_2 \left[\frac{C_n}{1.5B_n}\right] \quad (1)$$

Where C_n is the metal concentration in the soil samples and B_n is the background concentrations in soils derived from rocks of average shale composition.

2.7.2 Contamination Factor

The assessment of soil contamination by P, K, Mg, Mn, Si, Zn, Fe, Pb and Cd were also carried out in terms of contamination factor (C_f) using Equation 2. The background concentration of the metal is equal to the world surface rock average given by Barbalace (2007). The C_f values between 0.5 and 1.5 indicate that the metals are entirely from the coastal materials whereas C_f values greater than 1.5 indicates that the sources are most likely to be anthropogenic activities (Zhang and Liu, 2002). The different levels of degree of contamination include low contamination for C_f value 0 to < 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 described by Moore *et al.* (2009).

$$C_f = \left[\frac{[C]}{[C]_b}\right] \quad (2)$$

Where [C] is the concentration of heavy metal in the studied area and $[C]_b$ is the background concentration levels of metals in soil.

3. Results and discussion

3.1 Soil Quality

The mean soil pH of the soils obtained from Nasara fertilizer blending plant Lafia was 7.69±0.32 while of the control soil sample was 7.80±0.16 as displayed in Table 1. There is no significant variation in pH value between the test and control soil samples ($P > 0.05$). Both soils were slightly alkaline (7.5 – 7.8) based on the United State Department of Agriculture (USDA) classification (Motsara and Roy, 2008). Soil alkalinity is known to lower the availability of minerals for plant uptake pH and soil's interaction does regulate the movement of mineral and potentially toxic metals in soil (Pam *et al*., 2013).

3.1.1 Organic matter

The mean percentage organic carbon content of the soils obtained from farmlands around Nasara Fertilizer Blending Plant Lafia and the control soil sample was 2.04±0.14% and 0.71±0.07, respectively, as shown in Table 1. The 2.04% carbon content of the SFP falls within the high carbon content (> 1.5%) USDA classification while the content in the control sample is within the range of low organic carbon content (0.4-1.0%). The mean percentage organic matter content of the test and control soils was 3.52±0.11% and 1.23±0.01% respectively. There is significant variation in organic matter content between the test and control soil samples ($P < 0.05$). Organic matter has been shown to influence physical, chemical and biological processes in the soil such decrease in heavy metal availability through immobilization of the metals (Johnston *et al*., 2009).

Table 1. Physiochemical properties of the test and control soil.

Parameter	SFP	C-SFP
pH	7.69±0.32	7.80±0.16
Organic carbon (%)	2.04±0.14	0.71±0.07
Organic matter (%)	3.52±0.11	1.23±0.01
Nitrogen (%)	0.29±0.03	0.09±0.00
Avail P(mg/kg)	127.37±6.41	28.86±1.37
K (cmol/kg)	0.60±0.09	0.15±0.04
Na (cmol/kg)	16.8±0.02	9.41±0.56
Ca (cmol/kg)	12.16±1.91	5.41±1.54
Mg (cmol/kg)	7.81±0.51	2.07±0.72
AE (H^++Al^{3+}) (cmol/kg)	1.75±0.33	1.40±0.84
ECEC (cmol/kg)	39.12±0.572	18.45±01.87
Textural class based on USDA standard	Sandy Loam	Sandy Loam

SFP = Test soil sample, C-SFP = Control soil sample

3.1.2 Nitrogen content

The mean percentage nitrogen content of the test and control soils was 0.29±0.03% and 0.09±0.00 respectively, as shown in Table 1. There is a significant difference in nitrogen content between the test and control soil samples ($P < 0.05$). The nitrogen content of the SFP (0.29%) is within the USDA > 0.20 threshold classification for soil with high nitrogen content while the content of the control soils (0.09%) falls within the (< 0.10%) nitrogen content classified as low. The enrichment of nitrogen content in farmland soils around the fertilizer blending plant is because of the anthropogenic activities in the plant, making use of nitrogenous compounds as raw material.

Nitrogen (N) and its compound is the most utilised fertilizer for agriculture and food production. Mineralization does promote the uptake of nitrogen by crops as well as increases the risk of nitrogen loss. Nitrogen loss during mineralization can be reduced by the use of an immobilizer (Sharpley *et al*., 2018).

3.1.3 Available phosphorus content

The mean content of available phosphorus in soils (test and control) was 127.6±6.41 mg/kg and 28.86±1.37 mg/kg respectively, as displayed in Table 1. There is significant variation in available phosphorus content between the test and control soil samples ($P < 0.05$). The concentration of available phosphorus recorded in the SFP was (127.37 mg/kg) falls within the very high levels (> 30 mg/kg) while the control soil falls within moderate USDA range for available

Table 2. Mineral and Heavy Metal Concentration in mg/kg.

Sample	Phosphorus	Potassium	Magnesium	Manganese	Zinc	Lead	Cadmium	Iron
SFP	5252.17±36.15	1834.53±13.74	593.99±13.75	335.18±1.63	205.96±1.18	20.08±0.19	6.51±0.1	10560.77±8.00
C-SFP	249.59±5.92	207.52±1.48	1.24±0.27	0.11±0.03	40.62±0.38	6.63±0.20	ND	3940.98±25.61
BC	1,000	21000	19000	950	75	14	0.11	41000

SFP = Test soil sample, C-SFP = Control soil sample; BC = Background concentration (Barbalace, 2007; Sharma *et al*., 2016)

phosphorus (25–30 mg/kg) stipulations of United States Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS) classification. Phosphorus compounds are widely used as fertilizers throughout the world. The use of phosphorus as fertilizer has increased yield and improved the nutritional status of food for humans (Sharpley *et al*., 2018). While mismanagement and excessive application of the product in the environment can result in serious environmental pollution, especially available phosphorus whose presence in water leads to eutrophication. This decreases water quality for aquatic lives and humans using such water as a source of drinking and recreation (Joseph and Ganga, 2019).

3.1.4 Effective cation exchange capacity (ECEC)

The mean effective cation exchange capacity (ECEC) of the test and control soils sample obtained from farmlands around Nasara fertilizer blending plant Lafia was 39.12±0.57 cmol/kg and 18.45±01.87 cmol/kg respectively as shown in Table 1. There is a significant variation in mean ECEC between the test and control soil samples ($P < 0.05$). High ECEC enhances mineral and heavy metals retention in the soil. The textural class of the test and control soils was sandy loam suggesting good aeration and less water retention capacity. Soil texture indicates the summation of sand, silt and clay content proportion in a given soil sample. Texture affects the biophysical properties of the soil as well as interrelates with soil fertility and quality in the long run (Al-Saedi *et al*., 2016; Upadhyay and Raghubanshi, 2020).

3.2 Levels of Mineral and Heavy Metal in Nasara Soil

3.2.1 Phosphorus content

The mean content of total phosphorus of the test and control soils sample obtained from farmlands around Nasara fertilizer blending plant Lafia was mg/kg, 5252.17±36.15 mg/kg and 249.59±5.92 mg/kg respectively as presented in Table 2. There is a significant difference in phosphorus content between the test and control soil samples ($P < 0.05$). The phosphorus content of the SFP was higher than the 1252 mg/kg phosphorus composition of soils derived from Ajata's clay shale Abia, Nigeria reported by Ohaeri and Eshett (2011) as well as the 1000 mg/kg geochemical background value concentration of phosphorus in the soil which is the average concentration in the shale (Barbalace, 2007).

The concentration of total phosphorus found in soil correlates with the available phosphorus content. The high level of phosphorus in the soil around the fertilizer plant is traceable to the utilization of the element as raw material in the blending plant. Phosphorus is an essential macro-element widely used as fertilizer throughout the world (Ohaeri and Eshett, 2011).

Phosphorus occurs in the organic form in the soil as nucleic acids, phospholipids, inositols, and fulvic acids, or in less soluble humic acids. While in the inorganic form, in the parent materials, both organic and inorganic sources contribute to the phosphorus content of the soil (Requejo and Eichler-Löbermann, 2014).

Excessive phosphorus in the soil may impede plants' ability to take up required micronutrients as well as leached into nearby water bodies resulting in eutrophication, a situation where increased production of aquatic plants and algae makes water body unhealthy because of significant lowering of its oxygen content resulting in decay and release of unpleasant odour (Selassie, 2015). The alkaline pH (7.69±0.32) and the relatively high organic matter content (3.52±0.11%) recorded in the SFP may increase the immobilization of phosphorus in the soil (Pam *et al*., 2013; Requejo and Eichler-Löbermann, 2014).

3.2.2 Potassium content

The mean content of total potassium in the test and control soil was 1834.53±13.74 mg/kg and 207.52±1.48 mg/kg respectively as presented in Table 2. There is a significant variation in mean potassium content between the test and control soil samples ($P < 0.05$). The relatively high level of potassium in the soil around the fertilizer plant in comparison with the control sample is traceable to the utilization of the element as a composite material in fertilizer blending (Finch *et al*., 2014). The 1834.53 mg/kg potassium content recorded in soils around the fertilizer plant is about 12 times less than the 21,000 mg/kg average concentrations of potassium in the background shale (Barbalace, 2007) as well as the 23,000 mg/kg background concentration on the earth-crust recorded by Sharma *et al*. (2016).

3.2.3 Magnesium content

The mean content of total magnesium recorded in the test and control soils was 593.99±13.75 mg/kg and 1.24±0.27 mg/kg respectively. There is a significant variation in mean magnesium content between the test and control soil samples ($P < 0.05$). The relatively high level of magnesium in the soil around the fertilizer plant compared to the C-SFP is traceable to the utilization of the element as raw material in the fertilizer blending process since magnesium is a macro-element required by the plant in relatively large amounts (Finch *et al*., 2014). However, the 593.99±13.75 mg/kg Mg content in the SFP is far less than the 19000 mg/kg recorded as background value (Sharma *et al*., 2016).

3.2.4 Manganese content

The mean content of total manganese in test and control soils was 335.18±1.63 mg/kg and 0.11±0.03 mg/kg respectively, as shown in Table 2. There is a significant variation in mean manganese content between the test and control soil samples ($P < 0.05$). However, the 335.18±1.63 mg/kg manganese content of the test soil was about three times less than the 950 mg/kg in the background soil implying insignificant enrichment of Manganese because of activities around the facility (Barbalace, 2007).

3.2.5 Zinc content

The mean content of total zinc in the test and control soil sample was 205.96±1.18 mg/kg and 40.62±0.38 mg/kg respectively. There is significant variation in zinc content between the test and control soil samples ($P < 0.05$). The zinc content of the SFP (205.96 mg/kg) was slightly lower than the average concentration of 222.46 mg/kg reported in the soil around a mechanic workshop but higher, twofold, than the maximum concentration of 75.59 mg/kg found in agricultural fields in Puducherry, India (Khan and Kathi, 2014). Zinc is an essential plant nutrient; nevertheless, high zinc levels harms soil microorganisms and slows down the metabolism of organic matter that provides basic nutrition to plant roots. Excessive zinc also stunts plant growth, bringing about yellowing of plant leave and eventually causing death in sensitive plants, especially broad-leaf as grasses are more tolerant to high zinc levels in soil (Kaur and Garg, 2021).

3.2.6 Lead content

The mean content of total lead in the test and control soils was 20.08±0.19 mg/kg and 6.63±0.20 mg/kg respectively. There is significant variation in lead content between the test and control soil samples ($P < 0.05$). The average level of lead in the SFP was higher than its 14.00 mg/kg background (geochemical) concentration on the earth's crust (Barbalace, 2007; Sharma *et al*., 2016) and similar to the 20.02 mg/kg recorded in some farmlands in Kaduna State, Nigeria (Agbaji *et al*., 2015). Although, it was two times less than the 50 mg/kg benchmark of the European legislation. Elevated lead content may bring about renal and hepatic damage, reproductive disorders, neurologic and haematological dysfunctions in humans. In plants, excessive lead is associated with stunted growth, chlorosis and inhibition of photosynthesis (Sharma and Dubey, 2005). Since the SFP is slightly alkaline with pH (7.69±0.32) and a relatively high organic matter content (3.52±0.11%), mobility of lead may be lower (Agbaji *et al*., 2015).

3.2.7 Cadmium content

The mean concentration of6.51±0.06 mg/kg of total cadmium was found in the SFP and below the detection limit C-SFP. The total cadmium in the SFP was higher than the 1.33±0.06 mg/kg reported in farmlands around the Mechanic Village of Wukari, Nigeria (Yerima *et al*., 2020), higher than the 1.04–1.58 mg/kg recorded in agricultural field in Nepal, India (Raj and Ram, 2013). Conversely, it was lower than the 11.4 mg/kg found in agricultural soil around Dhaka Export Processing Zone (DEPZ), Bangladesh (Rahman *et al*., 2012). Besides mercury and lead, cadmium has been reported as a major contaminant that poses health risks to both humans and animals (Ismael *et al*., 2019). Cadmium levels in agricultural soils are on the increase because of continuous disposal and circulation of sewage, industrial and municipal wastes to agricultural soils as well as the utilization of phosphatic fertilizers (Singh and Kumar, 2014). The element is highly soluble in water, toxic, distributes so easily in soil and plant tissues. Excessive cadmium in soil and plant tissue is synonymous with symptoms such as stunted growth and chlorosis (Turgut *et al*., 2004).

3.2.8 Iron content

The mean concentration of total iron in the test and control soils was 10,560.77±8.00 mg/kg and 3,940.98±25.61 mg/kg, respectively. Similar to other parameters, except pH, the concentration of Fe in SFP is significantly different from that obtained at C-SFP (Table 3, $P < 0.05$) due to input from the plant. The iron level in the SFP was greater than the 1746.4 to 2839.4 mg/kg found in soils around Cassava Processing Mills in Sub-Urban Areas of Delta State, Southern Nigeria (Iwegbue *et al*., 2013) but about 4 times lesser than the 39,000 mg/kg to 41,000 mg/kg in the background shale (Barbalace, 2007; Sharma *et al*., 2016). There is no ecological risk because of iron levels in the soil around NFBP. The relatively high level of iron in the SFP, when compared with the control sample, is traceable to abandoned metal scraps of corroded vehicles, tractors and heavy-duty machine parts littered around the vicinity.

3.3 Index of Geo-accumulation of Mineral and Heavy Metals in Nasara Soil

The geo-accumulation index as shown in Figure 3, for K (-4.10), Mg (-5.58), Mn (-2.09), Pb (-0.06) and Fe (-2.54) were less than zero, while that of Zn (0.87) was less than one suggesting un-contamination. However, the geo-accumulation of P in the soil was 1.808 which implies moderate contamination by P. While the 5.30 geo-accumulation index for Cd falls within 4.00 to < 6.00 implying strong to extreme contamination concerning cadmium because of activities in the fertilizer plant (Muller, 1969; Edith-Etakah *et al*., 2017). The positive correlation in the geo-accumulation index of phosphorus and cadmium suggested the use of sedimentary rock phosphate-rich cadmium as raw material for production (Mirlean and Roisenberg, 2006; Mar and Okazaki, 2012).

3.4 Enrichment factor of mineral and contamination factor heavy metals in Nasara soil

As presented in Figure 4, the contamination factor of K (0.0873), Mg (0.031), Mn (0.353) and Fe (0.257) were generally less than one, indicating low contamination. While

Table 3. Student's t-test inferential of elements and physicochemical parameters of SFp and C-SFP.

SFP versus C-SFP	95% Confidence Interval of the Difference		t	p
	Lower	Upper		
pH	-.32	.096	-1.73	0.18
N	0.16	.24	17.32	0.00*
AP	87.86	108.11	30.80	0.00*
OM	2.24	2.32	197.45	0.00*
ECEC	18.30	23.06	27.72	0.00*
P	4937	5068.15	242.79	0.00*
K	1606.15	1647.86	248.27	0.00*
Mg	570.67	614.83	85.43	0.00*
Mn	332.48	337.65	412.53	0.00*
Zn	-166.89	-163.78	-338.95	0.00*
Pb	12.93	13.96	82.91	0.00*
Cd	6.42	6.60	234.03	0.00*
Fe	6346.65	6893.01	77.12	0.00*

SFP = Test soil sample, C-SFP = Control soil sample; *Statistically different at $p < 0.05$.

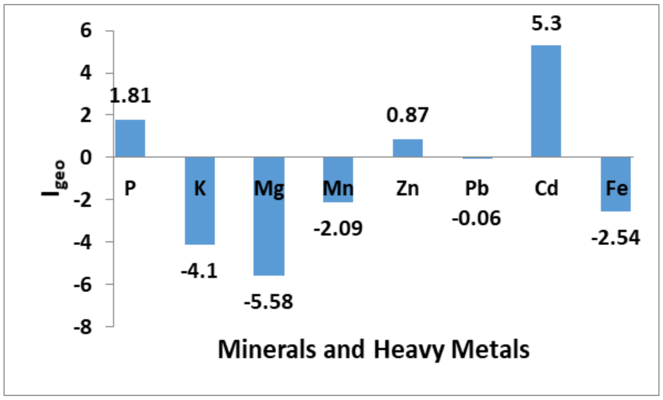

Figure 3. Index of geo-accumulation of mineral and heavy metals in Nasara soil.

that of Zn (2.746) and Pb (1.434) falls within (≥1 to < 3), indicating moderate contamination. The enrichment factor of P (5.252) was within (≥3 to < 6) indicating considerable enrichment while that of Cd (59.18) was much greater than 6, indicating remarkably high contamination of the soil due to anthropogenic activities across the industrial layout. Contamination of soil with cadmium can easily get into the food chain and its toxic effect exerted on the exposed population (Moore *et al.*, 2009; Zhang and Liu, 2002).

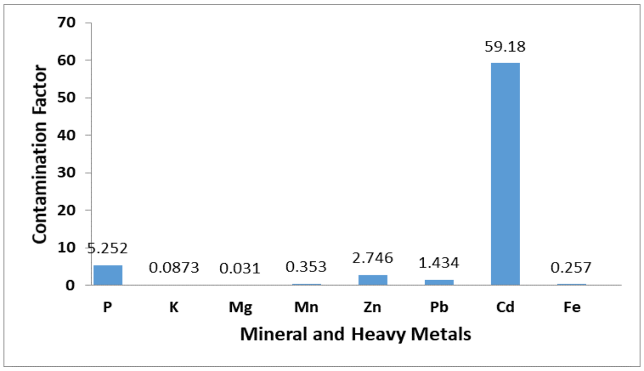

Figure 4. Enrichment factor of mineral and contamination factor of heavy metals in Nasara soil.

4. Conclusion

The results obtained, established the presence of all the mineral and heavy metals in the NFBP are in order of abundance: Fe > P > K > Mg > Mn > Zn > Pb > Cd. The sample was slightly alkaline with very high effective cation exchange capacity and organic matter content which may lower the mobility of the mineral and heavy metals. Pollution indices based on the geo-accumulation index indicates moderate contamination by zinc and phosphorus with extreme contamination by cadmium. While the contamination factor indicates moderate contamination by zinc and lead, considerable enrichment by phosphorus and remarkably high contamination by cadmium, a very toxic element with ecological effect, are evident. Likewise, the remarkably high levels of nitrogen and phosphorus being components of fertilizer confirm activities of the industry and utilization of the industries' products impacted the soil's mineral and heavy metals content. If the contaminated soils are not cleaned off the contaminants by the concerned authorities, eutrophication of water bodies around the plant is likely. Clean up techniques such as phytoremediation and strict implementation of the legislation guiding the activities of the plant, as well as protecting the exposed organisms and environment, are recommended. Also, studies on how nitrogen and phosphorus are released from the plant into the environment are necessary.

CRediT authorship contribution statement

EAY: Conceptualization, Methodology, Writing - original draft, Software, data. AUI: Methodology, Writing - original draft, Writing – review, editing & supervising. RS: Writing – review, editing & supervising. RAW: Writing – review, editing & supervising.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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