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Assessment of Heavy Metals Level of Soils Around Sacks and Packaging Company, Akwanga Nasarawa State, Nigeria

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Abstract

Increasing industrial activity around the world has left behind large number of contaminants such as heavy metals which can easily get into food chain and bio-cumulate in tissues of living organism with detrimental effect. This study was carried out to assess the impact of activities in a sack production and packaging company on the level of heavy metal on soils around the industrial layout. The results obtained from the soil analysis reveals that the pH, organic carbon and organic matter content of the test and control soils were (8.40 ± 0.20 and 8.51 ± 0.01), (1.76 ± 0.030 and 0.92 ± 0.02%) and (3.03 ± 0.33 and 0.55 ± 0.05%) respectively. While the available phosphorus content, nitrogen and effective cation exchange capacity of the test and control soil samples were (3.62 ± 0.02 and 4.11 ± 0.10%), (0.251 ± 0.01 and 0.078 ± 0.001%) and (65.59 ± 0.05 and 14.78 ± 0.01 Meq/100 g) respectively which were within the limits of normal agronomical soil. The mean ± standard deviation of heavy metal concentrations in the test and control soil were Fe (4625.32 ± 0.252 mg/kg and 3676.44 ± 0.57 mg/kg), Ni (48.20 ± 0.128 mg/kg and 27.50 ± 0.11 mg/kg) Co (36.85 ± 0.046 mg/kg and 37.05 ± 0.044 mg/kg) and Pb (321.45 ± 0.038 mg/kg and 174.23 ± 0.088 mg/kg) respectively where the mean concentrations of the heavy metals in the soil are in the order: Fe>Pb>Ni>Co while Cd and Cr were below detection limit. The impact of the industrial activities determines using indices such as Geo-accumulation index and contamination factor indicates high contamination of the soil with lead, a non-essential element responsible for lead poisoning. Also, the statistical analysis showed a general significant difference between the mean content of heavy metal between the soil around the industry and the soil around the control site suggesting that metal enrichment is likely due to anthropogenic activity since the metal level in the test soil were generally higher with the exception of cobalt.

Keywords: Soil; Heavy metals; Geo accumulation index; Contamination factor

Introduction

Older packaging methods like multi-ply paper sacks, cotton bags, jute bags, had been used to cart away agricultural produce and industrial products. Due to the inadequacy of these packaging methods to withstand various atmospheric conditions, leading produce spoilage and financial losses and frustration to farmers and producers has led to the production of synthetic sacks from polypropylene. Polypropylene sacks are suitable for almost all the products that have used paper sacks, cotton bags, jute bags for packaging. These sacks are better suited for storage due to their strength, durability and ability to withstand water and pests [1].

The use of synthetic sacks is steadily increasing in the agricultural and manufacturing sector, with increasing agricultural yields alongside other industrial products with polypropylene being the major raw material which is said to affect the endocrine system, cause genetic mutations and tumors. Also, unlike the tradition sack, synthetic sack is not easily degradable by nature and steps involve during production as well as the raw materials employed may impart the environment and hence this study seek to evaluate the impact of activities on Nasara Packaging company on some heavy metal concentration which is now a global phenomenon. As a result of the increasing concern on the potential effects of the metallic contaminants on human and environment health, the research on fundamental, applied and health aspects of trace metals in the environment is also increasing [2]. The industrialization of the world has led to a dramatic increase in the overall environmental load of heavy metal. Industrial processes that release a variety of heavy metals into the environment may include mining, smelting, refining and almost all industrial processes that produce waste discharges are potential sources of heavy metals to the environment [3]. Heavy metals can easily get into food chain and bio-cumulate in tissues of living organism resulting in detrimental effect especially when present in elevated concentration hence the need to employ technologies that can remove contaminants in the environment [4]. Nevertheless, the aim of this work is to assess the impact of activities in the sack production and packaging industry on the concentration of heavy metals on surrounding soils.

Study area

Nasara sacks and packaging company, Akwanga with the geographical coordinates 55'20.964" N (latitude) and 21'25.74612" E (longitude), is situated along Akwanga - Abuja road in Akwanga about 58.4 km from Lafia the capital of Nasarawa State located in the North-Central geopolitical zone of Nigeria. The industry was established in the year 2010.

Sample collection

The stratified sampling technique was applied for soil sample collection with little modification [5]. Under this sampling technique, the sampling site was broken into four (4) stratums (small areas) north,

south, east and west with respect to Nasara sacks and packaging company. Each strata were 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 were pooled together to form the composite sample labeled to enable detailed representation of variability within the study area. The control soil sample for the industry was collected in a farmland within 1.4 km radius from the industry from site remote to possible sources of contamination associated with the industry.

Sample preparation

The composite and the control sample were each sorted, pebbles and coarse materials removed 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, plant and animal's debris. The air dried and sieved soil was employed as soil sample for extraction and analysis.

Determination of soil physiochemical parameters

The pH was determined by homogenizing of the sample in 10 c distilled water and stirred gently to enhance H^+ (Hydrogen ions) release from soil, the mixtures was then be allowed to stand for 30 min. pH meter (JENWAY 2000) was used to read the pH value after calibration with buffer solutions of pH values 5.5, 7.0 and 8.0 respectively [6].

Soil organic carbon was determined by means of wet dichromate oxidation by the addition of 50 mL potassium dichromate (0.5 M K) and 2.5 mL concentrated sulphuric acid in 5% FeS. 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 [7,8]. Nitrogen in the soil was estimated using distillation and titrimetric method describe by Kjeldahl while the phosphorus content using molybdate reagent on the spectrophotometer at a wavelength of 660 nm [9,10].

Cation exchange capacity was determined by weighing 5.0 g of the dried soil was extracted with 25 mL of 1 M NHAc solution four consecutive times. The leachate was used for atomic absorption spectrophotometric determination of Ca and Mg while flame photometer was used for the determination of K and Na [11,12]. While the textural property of the soil was determined using the Hydrometer method [10].

Determination of Heavy Metals: The concentration of the heavy metal was determined using Atomic Absorption Spectrophotometer equipped with Zeeman's background correction. Prior to sample analysis, the flame condition was optimized for maximum absorbency and linear response while aspirating known standards.

Impact assessment

The index of geo accumulation (I_{geo}) actually enables the assessment of contamination by comparing the current status and pre-industrial concentrations originally bottom sediments [13,14]; it has also been applied in the assessment of soil contamination. The method assesses the degree of metal pollution in terms of seven enrichment classes based on the increasing numerical values of the index (Table 1). The index of geo accumulation was calculated using the Equation (1).

$$I_{geo}=I_o[Cn/1.5\ Bn] \qquad (1)$$

where, Cn is the measured concentration of the element in soil or sediment and Bn is the geochemical background value. The constant value, 1.5, is back-ground matrix correction factor due to the lithological variations. Table 1: presents a descriptive classification for the I_{geo} values [15].

I_{geo}	I_{geo} class	Description of soil quality
0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately to strongly contaminated
3-4	4	Strongly contaminated
4-5	5	Strongly to extremely strongly contaminated
5-6	6	Extremely contaminated

Table 1: Classification of geo-accumulation index.

Contamination factor

The assessment of soil contamination was also carried out using the contamination factor (CF) which is a single element index as well as the degree of contamination Cd which is the sum of contamination factors (CF) for all elements examined in the environment; the contamination factor was calculated using Equation (2).

$$C_F \equiv [M]/[M]_b$$

Where [M]=Concentration of heavy metal in the studied area; $[M]_b$=Background concentration levels of metals in soil. Background value of the metal is equal to the world surface rock average given by Barbalace [16]. The C_F values between 0.5 and 1.5 indicates 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 [17]. The different levels of degree of contamination include: low contamination for CF value<1; moderate contamination for CF ≥ 1 to<3; considerable contamination for CF value ≥ 3 to<6 and very high contamination for CF value ≥ 6 as describe by Rahman et al. [18].

Results and Discussion

As presented in Table 2, the pH, organic carbon and organic matter content of the test and control soils were (8.40 ± 0.20 and 8.51 ± 0.01), (1.76 ± 0.030 and 0.92 ± 0.02%) and (3.03 ± 0.33 and 0.55 ± 0.05%) respectively. With the exception of pH, there is generally a significant difference between the test and control soil at 95% confidence limit suggesting that activities around the industry may be responsible for the variation. The pH values were moderately alkaline and are generally within the acceptable status of agronomical soil. The organic carbon content of the test soil was about twice the content of the control soil while the organic matter content was more than five times the content in the control sample suggesting enrichment in carbon content due to the industrial activity on the soil. 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 [14].

S/No	Parameter	Test soil	Control soil	USDA standard
1	pH	8.4 ± 0.20	8.51 ± 0.01	6.1-8.5
2	Organic carbon (%)	1.76 ± 0.03	0.92 ± 0.02	-
3	Organic matter (%)	3.03 ± 0.33	0.55 ± 0.05	0.4-1.5
4	Nitrogen (%)	0.251 ± 0.01	0.078 ± 0.001	0.1-0.2
5	Avail P(mg/kg)	3.62 ± 0.02	4.11 ± 0.10	1.0-10
6	K (Meq/10)	1.02	0.20	0.2-1.0
7	Na (Meq/100 g)	1.04	2.26	0.1-2
8	Ca (Meq/100 g)	47.20	9.40	2.0-20
9	Mg (Meq/100 g)	16.33	2.92	0.3-8.0
10	AE (H$^+$+A$^+$) (Meq/10)	0.05	0.05	0.05-2.5
11	ECEC (Meq/100 g)	65.59 ± 0.05	13.78 ± 0.01	-
12	Sand (%)	46	53	-
13	Silt (%)	49	40	-
14	Clay (%)	5	7	-
15	Textural class base on USDA standard	Sandy Loam	Sandy Loam	-

Table 2: Physicochemical parameters of soil samples around sack and packaging company.

The available phosphorus content, nitrogen and effective cation exchange capacity of the test and control soil samples were (3.62 ± 0.02 and 4.11 ± 0.10%), (0.251 ± 0.01 and 0.078 ± 0.001%) and (65.59 ± 0.05 and 14.78 ± 0.01 Meq/100 g) respectively as shown in Table 2, where the available phosphorus were approximately same between the test soil and the control soil; the nitrogen content of the test soil is more than 3 fold the content in the control soil while the effective cation exchange capacity of the test soil is more than 3 times the capacity of the control soil which is traceable to the to the elevated organic matter content in the test soil compare to the control soil [19]. Cation exchange capacity (CEC) of a soil is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions especially when the soil is rich in clay and organic matter at pH near neutral [12]. The available phosphorus and nitrogen were generally within the limits of normal agronomical soil stipulated by USDA except the nitrogen content that is slightly higher.

Determination of iron concentration

The mean concentrations of iron in the test and control soil were 4625.32 ± 0.252 and 3676.44 ± 0.57 mg/kg respectively as presented in Table 3 and Figure 1, there is a significant difference between the iron content of the test and control soil at 95% confidence limit which may be traceable to industrial activities. The mean concentrations of iron recorded are generally far below the average crustal value (background concentration) 41000 mg/kg of Iron reported by Barbalace [16]. Likewise, the I_{geo} and C_F pollution indices indicate non-contamination on soils around both the industry and the control site as describe in Table 1.

	Parameter	Fe	Ni	Co	Pb	Cd	Cr
Test Soil	Mean (mg/kg)	4625.32 ± 0.252	48.20 ± 0.128	36.85 ± 0.046	321.45 ± 0.038	ND	ND
	average shale (mg/kg)	41000	80	20	14	0.11	90
	I_{geo} value	<0	<0	0.30	3.9	<0	<0
	I_{geo} class	Uncont.	Uncont.	Uncont.	Moderately cont.	Uncont.	Uncont.
	CF	0.113	0.603	1.842	22.96	<0	<0
	CF remark	Uncont.	Uncont.	Cont.	Cont.	Uncont.	Uncont.
Control Soil	Mean (mg/kg)	3675.44 ± 1.14	27.49 ± 0.22	37.05 ± 0.044	174.23 ± 0.088	ND	ND
	average shale (mg/kg)	41000	80	20	14	0.11	90
	I_{geo} value	0	0	0.31	3.1	<0	<0
	I_{geo} class	Uncont.	Uncont.	Uncont.	Strongly cont.	Uncont.	Uncont.
	C_F	0.089	0.343	1.852	12.445	<0	<0
	C_F remark	Uncont.	Uncont.	Cont.	Cont.	Uncont.	Uncont.

Table 3: Mean concentration (mg/kg) average shale (mg/kg), geo-accumulation index (Igeo) values and enrichment factor of heavy metals in soils.

Determination of nickel concentration

The mean concentrations of Ni in the test and control soil were 48.20 ± 0.128 and 27.50 ± 0.11 mg/kg respectively as presented in Table 3, there is a significant difference between the nickel content of the test and control soil at 95% confidence limit where the content in the test soil is about double the content in the control soil. Nevertheless, these concentrations are generally lower than the 80 mg/kg concentration of Ni in the background as reported by Barbalace [16] and as well as the 75 mg/kg maximum limit set by the European Union [20,21]. Likewise, the I_{geo} and CF pollution indices indicate uncontamination with respect to Ni on soils around both the industry and the control site as describe in Table 1.

Determination of cobalt concentration

The mean concentrations of cobalt in the test and control soil were 36.85 ± 0.046 and 37.05 ± 0.044 mg/kg respectively as presented in Table 3 and Figure 1, These concentrations are generally higher than the 20 mg/kg concentration of Co in the background as reported by Barbalace [16] but are generally below the 50 mg/kg maximum limit of Australian standard for soils [21]. Likewise, the I_{geo} and CF pollution indices of (0.30 and 0.31) and (1.842 and 1.852) respectively indicates un-contamination as describe in Table 1.

Determination of lead concentration

The mean concentrations of lead in the test and control soil were 321.45 ± 0.038 and 174.23 ± 0.088 mg/kg respectively as presented in Table 3 and Figure 1, there is a significant difference between the lead content of the test and control soil at 95% confidence limit. Also, these concentrations are generally much higher than the 14 mg/kg concentration of Pb in the background as reported by Barbalace [16] and are also above the 100 mg/kg maximum limit of Australian standard [21]; as well as the 210 mg/kg intervention values set by the Department of Petroleum Resources except the control soil which is below the intervention level [22,23]. Likewise, the I_{geo} and CF pollution indices of (3.9 and 3.1) and (22.96 and 12.445) respectively indicating strong contamination. High lead in the soil can be transfer into biota resulting in health challenge associated with brain damage in children and other symptoms may include abdominal pain, constipation, headaches, irritability, memory problems, inability to have children, and tingling in the hands and feet [24].
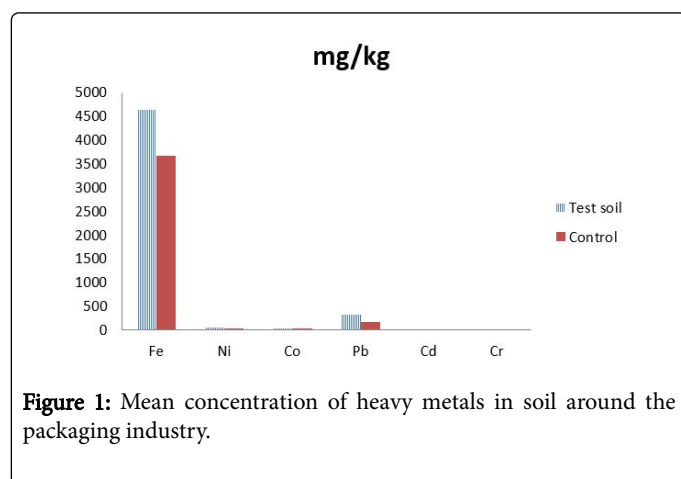

Figure 1: Mean concentration of heavy metals in soil around the packaging industry.

Statistical analysis

Comparing mean using IBM SPSS Statistics 20 reveals that there is significance difference in organic carbon, organic matter, nitrogen, available phosphorus and the cation exchange capacity except pH, likewise the mean concentration of metals in soils around the packaging company significantly different with that in the control soil ($P<0.05$) suggesting that anthropogenic activity may have brought about the variation. Correlation analysis of the physiochemical properties and metal content of the test soil reveals a strong positive relationship between cation exchange capacity versus organic carbon and organic matter content ($P \leq 0.01$) implying that their presence in the soil enhances the capacity of the soil to hold and retain cations. A significant correlation was equally obtaining among nickel, available phosphorus and nitrogen ($P \leq 0.01$) suggesting that they might have emanate from the same source.

Conclusion

The results obtained from the analysis of soils around packaging company, Akwanga in order to assess the impact of the industry on the metal levels of surrounding soil reveals that the dominant metal concentrations were in the order: Fe>Pb>Ni>Co while Cd and Cr were below detection limit. The Geo-accumulation index and contamination factor indicates high contamination of the soil with lead which a non-essential element responsible for lead poisoning. Also, the statistical analysis reveals a significant difference between the mean content of heavy metal between the soil around the industry and the soil around the control site cobalt suggest metal enrichment is due to anthropogenic activity since the metal level in the test soil were generally higher with exception of cobalt.

Competing Interests

Authors have declared that no competing interests exist.

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