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Investigations on Soil Contamination by Toxic Metals within the Vicinities of Bodija Market in Ibadan, Nigeria

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Abstract

This study was carried out to investigate soil contamination with Pb, Cu, Zn, Ni and Cd from Bodija market. Fifty six soil samples were randomly collected from 7 sections of the market, namely: sawmill foodstuff refuse dumpsite slaughterhouse slabs petrol station railway quarters and carpark and 8 samples from a control site making a total of 64 soil samples. The soils were collected at 0 - 15cm and 15 - 30cm depths and the pH, organic matter particle size as well as the metal leaching were determined using standard methods. The metal levels were determined using atomic absorption spectrophotometry. The means values of pH and Organic matter were 6.87 and 3.24% for study area and 4.93 and 2.54±% for the control . The mean particle size analysis (%) in this study with control in bracket showed clay, silt and sand as 6.84(15.8), 7.83(19.6) and 85.3(64.6), respectively. Metal concentration (mg/kg) ranges with median in brackets were: Pb: 3.25 – 154(68.1), Cu: BDL – 478 (13.6), Ni: 7 – 75.8 (19.6), Zn: 0.32 – 128(43.9) and Cd: 0.25 – 4.40 (0.40). The higher pH and Organic matter values suggest influence from cabonaceous and ammonium containing waste in soils from the market. The metal levels for all metals were within the permissible limits set by FAO except Cu (478 mg/kg) and Cd (4.40 mg/kg) in samples collected from railway quarters and slaughterhouse slabs, respectively. The soils pose little or no harm to human health and the environment, but the need for periodic environmental monitoring of soils are important.

Keywords:
Toxic Metals, Soil Contamination, Waste, Bodija market

Introduction

Recently, pollution of the general environment has increasingly attracted interest globally. In this regards, contamination of soil with toxic metals is been considered as a critical challenge within the research community (Faruk *et al*., 2006). Toxic metals are generally present at low levels in soils, except where high concentrations are inherited from the parent material. However, their cumulative behaviour and toxicity, have potential hazardous effects not only on plants growing on metal contaminated soils, but also on human health through direct interaction with the polluted media (soil) or indirect consumption of living organisms (e.g., plants) where the accummulation of these metals in their tissues have occurred (Das *et al*., 1997). Soil pollution results mainly from diverse anthropogenic sources which include polluted effluents, electroplating activities, manufacturing of fertilizers, mine tailings and smelting processes, domestic and municipal wastes (Frost *et al*, 1998).

Wastes are substances or objects discarded as worthless or unwanted, defective or of no further use from related activities mentioned above. They may be classified as general or hazardous in nature. Municipal wastes could be regarded as urban solid waste, as materials for which the primary generator abandoning the materials requires no compensation upon abandonment and it is perceived by the society as within the responsibilities of the municipality to collect and dispose of (Cointreau, 1982). The aforementioned describes the type of waste in this study. Several studies have shown that wastes could be a principal source of toxic metals leading to soil contamination especially, where the metal levels are significant to pose danger to both human health and the environment. The display of food items such as leafy vegetables directly on the soil for sale at the Bodija market could be a direct source of contamination from toxic metals, organic pollutants and dangerous microorganisms.

Once toxic metals get into the environment, whether in small or large quantities, they cannot be completely eliminated. For example, Pb is one of the highly ubiquitous toxic metals in the environment because it is released from diverse sources. The harmful effects that are caused by Pb on humans especially children include intellectual impairment, hyperactivity, hearing loss and behavioural problems (Brigden et al., 2005). The metal also distorts biochemical processes in cells, reducing the activity of some enzymes and it can also stop the biosynthesis of the haemoglobin (Bearer, 1995). It is highly toxic to the foetus as it interfers with proper development (Landrigan et al., 1999). In adults, it can cause elevated blood pressure, kidney and liver damage, as well as infertility (Lanntech , 2006). Extensive doses can cause death (Bachlinski, 2004). Toxic metals can accumulate in tissues and are dangerous even in small doses. Nevertheless a large dose of some metals are required before any obvious symptoms of poisoning develops thus, it is crucial to assess and monitor even minute amounts present in soils, water, atmospheric dusts or plants (Bachlinski, 2004; Abdel-Sabour *et al*, 1998; Jackson *et al*, 1989).

The elimination of toxic metals from the environment was one of the major actions of Agenda 21, endorsed in 1992 at the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro (Bachlinski, 2004). Adequate pollution control can only be guaranteed when the exact sources and concentrations of toxic substances are known. Therefore, this study aims at quantifying the levels of Pb, Cd, Ni, Cu and Zn in soil samples collected from seven different sections of Bodija market engaged in different activities. This study would provide useful data on the sources and levels of toxic metals within the study area.

Materials and Methods

Study area

Bodija market is a major traditional and the largest market in Ibadan, South Western Nigeria. The market is situated along secretariat-University of Ibadan road, Ibadan North Local Government Area of Oyo State and bounded by Agbowo and Orogun in the north and by Bodija Estate in the west (Fig. 1). Bodija market lies between longitude (3° 55' 20" E) and latitude (7° 26' 22" N).

Sampling design and soil sampling

A total of 64 soil samples were collected from seven different sections of the study area (Bodija market) and also from the University of Ibadan botanical garden which served as control site (Table 1). All the samples were collected using a stainless steel soil auger as follows: 4 samples were collected from each section at two soil depths (0-15 cm and 15-30 cm) making a total of 8 samples per section and 56 samples for the 7 sections. In addition, 4 soil samples per depth were collected from the control site. The control samples were composited and a representative sample was taken for the 0 – 15 cm and 15 – 30 cm depths, respectively. All soil samples were transported in well labelled polythene bags to the laboratory for further analyses.

Soil preparation

The soil samples were air-dried at room temperature in the laboratory for two weeks. Followed by handpicking of non soil materials such as wood, stones and dirts. Samples were manually ground to reduce the particle sizes of lumpy components using a porcelain mortar and pestle into fine particles and sieved through a 2 mm mesh size sieve to have soil of fiarly uniform particle size. The mortal and pestle were cleaned after every sample to avoid cross contamination.

Table 1: Description of Sampling Points and Activities around their Neighbourhood

Location	Activities
Sawmill	Timber cutting, loading and selling
Foodstuffs	Buying and selling
Refuse dump	Disposal, open burning of wastes and cattle grazing
Slaughterhouse slabs	Skin processing, selling of meat, cooking of food etc.
Petrol station	Buying and selling of petrol, kerosene and diesel.
Railway quarters	Residential area.
Car park	Parking and boarding of vehicles, and hawking
Background	University of Ibadan botanical garden

Soil analysis

The soil pH was measured in $CaCl_2$ solution with a glass elctrode following the method by Schoefield and Taylor (1955). The soil organic matter (SOM) was determined using Walkey-Black method (Walkey and Black, 1934). Particle size analysis was carried out using the Bouycous hydrometer method (Bouyoucos, 1962). Metal leaching analysis was carried out following the Vackova et al 1990 method as follows: Exactly 1.0g of the sieved soil sample was measured into a 50 mL capacity high density centrifuge tube and 10 mL of 2 M HNO_3 was added and capped. The tube containing the sample was placed in a 1 litre beaker containing boiling water that was heated on a hot plate continually through out the leaching period. Metals were leached from the sample for 2 hours with intermitant opening of the cap to ease pressure and swirling of the tube every 20 minutes to evenly distribute the heat. After leaching, the sample was cooled and filtered with Whatman No 1 filter paper into a 50 mL volumetric flask and diluted to mark with deionized water. The leachate was analyzed for Pb, Cd, Ni, Cu and Zn using a AAnalyst 200 Perkin Elmer Atomic Absorption Spectrophotometer (AAS) (Germany) fitted with appropraite single elemental hollow cathode lamps for each metal. Prior to analysis all plastic and glassware used were washed with teepol detergent and rinsed with tap water before soaking in 1 M nitric acid over night (Onianwa, 2001). These ware were removed from the 1 M nitric acid and rinsed with deionised water before drying. All weighing balances and other instruments were calibrated before use.

Spike recovery studies

The analytical procedures were validated using the spiked recovery studies. This was carried out by spiking a known concentration of a metal on a previously analyzed soil sample for that metal in duplicate (Stanton, 1966; Valcarcel, 2000).

Statistical analysis

Pearson's correlation coefficient was used to determine the relationship between concentrations of parameters determined using Statistical Package for Social Science (SPSS) version 14.0 (Lindaman, 1992).

Results and Discussion

Soil analysis

The result of soil analysis is presented in Table 2. The pH for all the soil samples ranged from 4.46 - 8.10 with the lowest pH recorded at the petrol station while the highest was observed at the refuse dump site. The mean pH of control soil samples were 4.70 and 5.15 at the 0 - 15 cm and 15 - 30 cm depths, respectively. Soil pH in the study area were more in the alkaline range compared with the acidic pH range measured at the control site. This from common knowledge could be connected with the deposition of waste high in nitrogenous compounds which normally impact a basic pH on soil. The pH of soil samples from the market was within the limit of 6.50 - 8.50 set by Food and Agricultural Organization (FAO, 2000) , except for the foodstuff section with pH of 4.46 in soil at 0-15cm depth and petrol station with pH of 5.70 cm in soil at 15 - 30 cm depth.

The organic matter content ranged from 1.35 - 4.52 %, with the lowest recorded at the foodstuff area and the highest at the saw mill area. The high organic matter in saw mill section is apparently connected with the high carbon content of wood shavings in this area.

The average % clay, silt and sand of soils from study area were 6.28, 7.83, and 85.3, respectively. This shows that the soils in the market were generally sandy in nature and could support high rate of metal leaching. On the other hand, soils from the control site contained 15.8 %, 19.6 % and 64.6 % clay, silt and sand, respectively (Table 2). The higher % clay and lower % sand contents of control soils compared to the study area could be as a result of lower erosion at the control site due to vegetation coverage.

Table 2: Soil Characterization

Sampling Location	Depth	pH	Organic Matter	Pb	Cu	Ni	Zn	Cd
	(cm)		(%)	(mg/kg)				
Car park	0 - 15	6.95	3.69	18.8	15.4	20.3	9.98	0.25
	15 - 30	7.45		154	6.28	18.8	12.6	0.30
Foodstuffs Section	0 - 15	6.28	1.35	9.53	BDL	17.3	0.32	0.33
	15-30	5.70		3.25	BDL	7.00	0.68	0.30
Sawmill Arena	0 - 15	7.44	4.52	4.73	BDL	15.0	45.9	0.35
	15 - 30	7.20		4.05	21.1	11.4	26.9	0.29
Railway Quarters	0 - 15	6.28	1.90	69.5	478	39.0	104	1.13
	15 - 30	6.26		37.1	11.2	23.0	93.2	1.58
Slaughter Slabs	0 - 15	7.63	3.38	142	30.9	26.5	128	4.40
	15 - 30	7.98		66.6	105	41.3	117	2.45
Refuse Dump	0 - 15	8.05	4.14	94.8	11.6	28.8	83.5	1.28
	15 - 30	8.10		105	11.8	75.8	91.0	1.88
Petrol Station	0 - 15	4.46	3.73	105	81.9	13.0	41.8	0.30
	15 - 30	6.33		151	20.5	12.5	35.4	0.45
Control	0 - 15	5.15	2.07	14.0	BDL	9.25	10.3	0.08
	15 - 30	4.70		BDL	BDL	BDL	BDL	BDL
Clay = 6.84[a] (15.8[b])		Silt = 7.83 (19.6)		Sand = 85.33(64.6)				

BDL – Below Detection Limit[a]Study area[b]ControlOrganic matter – for topsoil (0-15 cm)

The ranges of Pb, Cu, Ni, Zn and Cd levels (mg/kg) at 0 - 15 cm depth with 15 - 30 cm depth in bracket in soils from the study area were: Pb - 4.73 – 142 (3.25 - 154), Cu - BDL – 478 (BDL - 105), Ni - 13.0 - 39.0 (7.00 - 75.8), Zn - 0.32 – 128 (0.68 - 117), and Cd - 0.25 - 4.40 (0.29 - 2.45).

The metal levels (mg/kg) in the top soil from control site were Pb – 14.0, Ni – 9.25, Zn – 10.3 and Cd – 0.08. Copper was BDL both in top and sub soil with other metals investigated BDL in subsoil. The soils in Bodija market were generally not contaminated with the metals investigated, when compared with levels within the ranges of unpolluted soils (Vecera et al., 1999). Also, when compared with international standards (Table 3), they fell below the maximum allowable concentrations (Kabata-Pendias, 2002), except Cu (478 mg/kg) in soils collected from railway quarters and and Cd (4.40 mg/kg) in soils from slaughters slab which showed elevated levels. The elevated Cu level could be associated with materials used during the recent refurbishment of the rail lines. The elevated Cd level in slaughters slab is not clearly understood, however there should be a follow-up on this to circumvent any contamination of meat products if non has occurred.

Correlation studies

Table 4 shows the correlation between all the parameters determined. The correlation of Zn/Ni (0.74) and Zn/Cd (0.89) were strong suggesting that metals correlated could be from the same source. Zinc and cadmium have been reported to have a strong geochemical association and found together in natural ore deposits (Kabata-Pendias, 2002).

Table 3: Comparison of Metals Level in Present Study with Permissible Limits of Various Countries

Country	Pb	Cd	Zn	Ni	Cu
Austria[a]	100	5.00	300	100	100
Poland[a]	70 -150	-	100 - 300	30 - 75	30 – 70
Germany[a]	100	3	300	50	100
Russia[a]	20	-	110	35	23
UK[a]	500 - 2000	3 – 15	130	20	50
US[a]	60	1.60	220	32	100
EU[a]	50 – 300	1.30	150 - 300	30 - 75	50 – 140
Present study (Mean)	69.0 ±57.0	1.09 ±1.19	56.4 ±45.0	25.0 ±17.7	56.7 ±125
Present study (Range)	3.25 - 154	0.25 - 4.40	0.32 - 128	7.00 - 75.8	BDL – 478

[a]*Kabata-Pendias, 2002*

Table 4: Correlation Studies between Physico-chemical Parameters

Parameters	Organic Matter	pH	Nickel	Cadmium	Lead	Copper	Zinc
Organic Matter	1.0000						
pH	0.5249	1.0000					
Nickel	0.4073	0.2036	1.0000				
Cadmium	-0.2018	0.0137	0.6494	1.0000			
Lead	0.3174	0.4492	-0.4320	-0.1815	1.0000		
Copper	0.3154	0.5926	0.1616	0.1682	0.5192	1.0000	
Zinc	0.1860	0.4238	0.7436	0.8880	0.0571	0.4703	1.0000

Spike recovery studies

The percentage recoveries for the metals ranged as follows: Pb – 86.0 - 90.4 %, Cu - 77.1 - 102 %, Cd - 80.6 - 90.0 % and Ni - 90.4 - 105 %. These recoveries were within the same ranges as in some previous studies (Shan, 1988; Liu *et al.* 1989,).

Conclusion

The levels of Pb, Cu, Ni, Zn and Cd in soil samples collected from various sections of Bodija market were assessed. The levels of all metals except Cd and Cu at some locations were within the permissible limits set by FAO. Metal levels from study area were higher compared with control site levels, suggesting anthropogenic influence. Generally, all the metal levels were within the ranges reported for unpolluted soils. However, the need for periodic environmental monitoring is important. This study provided useful data on some toxic metal levels in soils within the vicinity of Bodija market and also provided the basis for periodic environmental monitoring of various environmental media directly in contact with humans.

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