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Assessment of Heavy Metals Contamination in Soils from Open Dumpsite in Sagamu, Southwest Nigeria

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Abstract

Concerns over the possible health and ecological effects of accumulation of heavy metals contaminants in the soil have prompted numerous researches in recent times. This study assessed the environmental quality of soils from an open dumpsite in Sagamu to investigate the ecological risk of heavy metals. A total of 13 soil samples were collected and air-dried at 30°C. Heavy metal concentrations were determined using atomic absorption spectrophotometer. Mean heavy metal concentration in the soil were of the order Cu >Pb> Zn > Cd, which were higher than their control concentrations. It was revealed that Copper had the highest concentration (2214.25 mg/kg); based on Nemerow's Synthetical Pollution Index (NSPI), the soils were polluted by Cu and Cd, while Pb and Zn were within the safety domain. The correlation coefficient of the heavy metals showed that Cu correlated positively with Cd and Zn (0.53 and 0.17 correlation coefficient respectively), while Pb correlated positively with Cd (correlation coefficient of 0.17). The lack of a significant correlation between Pb and other heavy metals shows that its sources were quite different from those of the others. The study further shows that Cu and Cd had high ecological risk factor than Pb and Zn. It was concluded that open dumpsite in Sagamu poses great environmental risk to water and land resources. While it was recommended that Open dumpsites should not be only sited far from residential areas but integrated waste management should be encouraged to reduce soil pollution.

Évaluation De La Contamination De Métaux Lourds Dans Les Sols De D'une Decharge Ouvert À Sagamu, Dans Le Sud-ouest Du Nigeria

Résumé

Les préoccupations concernant les effets sanitaires et écologiques possibles de l'accumulation de métaux lourds contaminants dans le sol ont suscité de nombreuses recherches ces derniers temps. Cette étude a évalué la qualité environnementale des sols d'une décharge à Sagamu afin d'étudier le risque écologique des métaux lourds. Un total de 13 échantillons de sol a été recueillis et séchés à l'air à 30oC. Les concentrations de métaux lourds ont été déterminées en utilisant un spectrophotomètre d'absorption

atomique. La concentration moyenne de métaux lourds dans le sol était de l'ordre Cu> Pb> Zn> Cd, qui étaient supérieures à leurs concentrations témoins. Il a été révélé que le cuivre avait la concentration la plus élevée (2214,25 mg / kg); D'après l'indice synthétique de pollution de Nemerow (NSPI), les sols étaient pollués par le cuivre et le cadmium, tandis que le plomb et le zinc se trouvaient dans le domaine de la sécurité. Le coefficient de corrélation des métaux lourds montre que le Cu est corrélé positivement avec Cd et Zn (coefficient de corrélation de 0,53 et 0,17 respectivement), alors que Pb est corrélé positivement avec Cd (coefficient de corrélation de 0,17). L'absence d'une corrélation significative entre le Pb et les autres métaux lourds montre que ses sources étaient très différentes de celles des autres. L'étude montre en outre que le Cu et le Cd ont un facteur de risque écologique élevé par rapport au Pb et au Zn. Il a été conclu que la décharge à ciel ouvert à Sagamu présente un grand risque environnemental pour l'eau et les ressources terrestres. Bien qu'il ait été recommandé que les décharges ouvertes ne soient pas situées loin des zones résidentielles, la gestion intégrée des déchets devrait être encouragée pour réduire la pollution des sols.

Introduction

Environmental pollution problems have recently been aggravated as a result of urbanization. Heavy metals are defined as elements in the periodic table having atomic number more than 20 or having densities more than 5g/cm3 (Hong *et al.,* 2014); and low solubility properties (Hefni *et al.,* 2016). The major environmental burden of heavy metals is their inability to degrade and most of them have toxic effect on living organisms when they exceed a certain concentration level either in water, soil or food substances (Hong *et al.,* 2014). High concentration of metal ions in soil environment may pose a significant risk to the quality of soils, plants, natural waters and human health (Wu and Zhang, 2010).

Dumpsite is a classical method of waste disposal (Odukoya and Abimbola, 2010). In developed countries, they are often established in derelict quarries, mining or excavated pits far away from residential areas with modern landfill facilities, where designated government agencies, corporate bodies and some individuals saddled with the responsibilities of waste management, usually deposit wastes (Ideriah *et al.,* 2007). In contrast, dumpsites in developing countries are often located close to residential areas; therefore, it is expedient to monitor ecological risks of heavy metals emanating from such dumpsites.

Heavy metal contamination levels in soil are of major significance because of the potential to compile for a long period of time (Iwegbue *et al.* 2013). High concentration of metal ions in soil environment may pose a significant risk to the quality of soils, plants, natural waters and human health (Wu and Zhang, 2010). It has also been reported that excessive accumulation of heavy metals in soils may result in soil contamination, which diminishes food quality and may result to public health safety issues (Hong *et al.,* 2014). As a result, the importance of assessing heavy metal contamination cannot be over emphasized.

In Sagamu metropolis, engineered landfill facilities are unavailable. As a result, wastes are deposited at open dumpsites. Consequently, poor management of these sites could create many adverse environmental impacts including leachate, which could pollute underground soil bed (Ideriah *et al.,* 2007). Leachate from dumpsites is said to be of interest when it contains potentially toxic heavy metals (Odukoya and Abimbola 2010). It is against this background that the present study seeks to assess the environmental risk of heavy metal pollution in soils around an open dumpsite.

Description of Study Area

The study location is situated in the southwestern part of Nigeria. Sagamu is located proximately within latitude 6°50' and 7°00' N and longitude 3°45' and 4°00' E (Gbadebo and Bankole, 2007*)* (Figure 1). It is about 63 km southeast of Abeokuta, 72 km southeast of Ibadan, 67 km northwest of Lagos and 32 km west of Ijebu-ode, all in South-west Nigeria. The area stands on a low-lying gently undulating terrain with altitude ranging between 30 and 61 m above sea level. The area is characterized by high annual temperature, high rainfall, high evapo-transpiration and high relative humidity (Akanni, 1992).

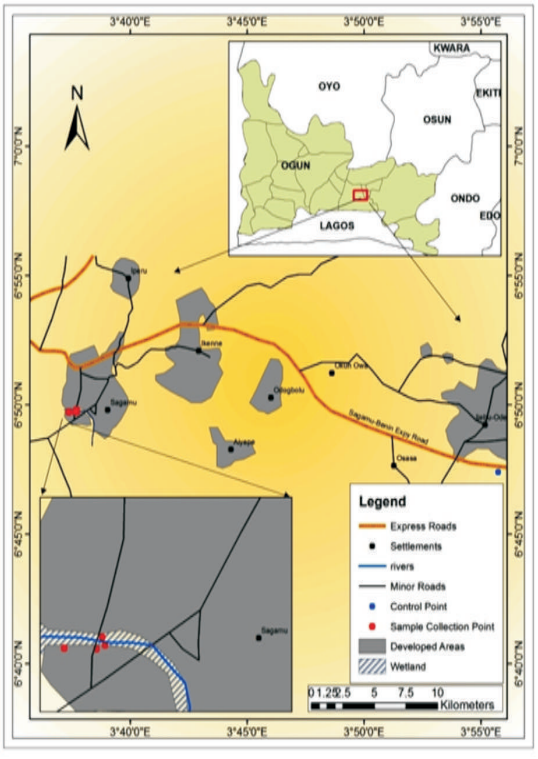

Figure 1: Map of the Study Area

Methodology

Sample Collection

Twelve (12) soil samples were collected from different points around the site from the depth of 0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm respectively after which were mixed together in a clean plastic bucket, in order to have representative samples of the soil specimen. A control sample was taken from a farmland at the outskirts of Ijebu-Ode near Sagamu-Benin express road. All samples were collected the same day and kept in a labeled polythene bag, air dried for two weeks at room temperature and ground with mortar and pestle. The ground soil sample was sieved using mesh size, preserved and then bottled in a polyethylene bottle for further treatment.

Chemical Analysis

The chemicals used for the study include lead nitrate, copper nitrate and calcium chloride. while apparatus such as glassware, weighing balance (Gallenkamp 80), pH meter (Fisher Hydrus 300 model), mechanical shaker (Model TT 12F, Techmel and Techmel, Texas, US), electric heater, centrifuge (Model TGL-16G, Shanghai, China), atomic absorption spectrophotometer (Buck Scientific Model 210A, Norwalk, Connecticut, US) were used. All reagents and acids used were of analytical grade. De-ionized water was used for the preparation of reagents. Tessier *et al.* (1979) have described the conventional sequential extraction procedure adapted in this study for analysis of heavy metals in the soil samples.

Nemerow's Synthetical Pollution Index

Nemerow's synthetical pollution index was applied to assess soil environmental quality (Cheng *et al.,* 2007).

$$Pn \geq \sqrt{(maxp_i^2 + avep_i^2)/2}$$

$$P_i \geq C_i/S_i$$

Where *Pn is the Nemerow's synthetical pollution index,*

P_i is the pollution index of the *ith heavy metal,*
C_i *is the* measured concentration of the *ith heavy metal,*

Si is the required standard of the *ith heavy metal,* $aveP_i$ *and* $maxP_i$ is the average and the maximum value of the pollution indices of all heavy metals respectively.

Table 1: Classification for polluted index of soil environmental quality (Adapted from Cheng *et al.,* 2007)

Grade	Synthetical Index	Appraisal Result
1	$P_n \geq 0.7$	Safety domain
2	$0.7 < P_n \geq 1.0$	Precaution domain
3	$1.0 < P_n \geq 2.0$	Slightly polluted domain
4	$2.0 < P_n \geq 3.0$	Moderately polluted domain
5	$P_n > 3.0$	Seriously polluted domain

Ecological Risk Index (RI)

The potential ecological risk of heavy metal pollutants in the surface was evaluated using the ecological risk index (RI) (Hu *et al.,* 2013).

The RI was calculated as the sum of risk factors of the heavy metals:

$$RI \geq \sum E_i$$

Where Ei is the single risk factor for heavy metal i, and is defined as:

$$E_i s = T_i f_i = T_i \frac{C_i}{Bi}$$

where Ti is the toxic-response factor for heavy metal I.

According to Xu *et al.* (2008), the Ti values for Cd, Cu, Pb, and Zn are 30, 5, 5, and 1, respectively.

$B_i \geq$ concentration at control points

Metal Pollution Index (MPI)

The quantification of metal contamination/ pollution index as defined by Lacatusu (2000) was adopted for this study; being represented:

$$MPI \geq \frac{Concentration\ of\ Metal\ in\ Soil}{Reference\ soil\ (control)}$$

Table 1: Classification for polluted index of soil environmental quality (Adapted from Cheng *et al.,* 2007)

MPI	Significance
< 0.1	Very Slightly Contamination
0.10-0.25	Slight Contamination
0.26-0.5	Moderate Contamination
0.5-0.75	Severe Contamination
0.76-1.00	Very severe contamination
1.1-2.0	Slightly polluted
2.1-4.0	Moderate pollution
4.1-8.0	Severe pollution
8.1-16.0	Very severe pollution
> 16.0	Excessive pollution

Adapted from Lactusu (2000)

Results and Discussion

The result of the analysis of the soil samples is presented in table 3. Table 3 shows that the concentration of heavy metals in the soilsamples around the GRA dumpsite between the depth of 0 and 20 cm was higher than both the concentration of heavy metals in soils from the control and the standard permissible limit of WHO and United Kingdom. As depicted in Figure 2, the soil of the study site was more polluted with Cu, which could have been as a result of the high content organic matter that had been deposited at the dumpsite. Cadmium was the least of the heavy metals in the soil samples; this corroborates Tessier *et al.* (1979) assertion that the total concentration of Cd in was 50:1 mg kg^{-1}.

Table 3: Concentration of Heavy Metals in Soil Sample at Depth of 0 – 20 cm

Sample (mg/kg)	Cu	Zn	Pb	Cd
1	2151.0	49.2	44.8	51.1
2	2141.0	48	41.1	50.5
3	2161.0	50.4	48.5	51.7
4	2137.0	43.9	64.1	52.4
5	2119.0	43.1	63.35	51.98
6	2137.0	44.7	64.85	52.82
7	2337.0	46.6	44.3	54.5
8	2319.4	45.74	43.53	53.84
9	2354.6	47.46	45.07	55.16
10	2238.0	47.5	44.1	50
11	2211.0	46.7	43.44	49.58
12	2265.0	48.3	44.76	50.42
Control	94.9	46.7	38.9	19.08
Mean	2214.25	46.8	49.325	52
WHO Standard	86.4	2.15	9.07	0.02
Uk STD	270	200	63	1.4

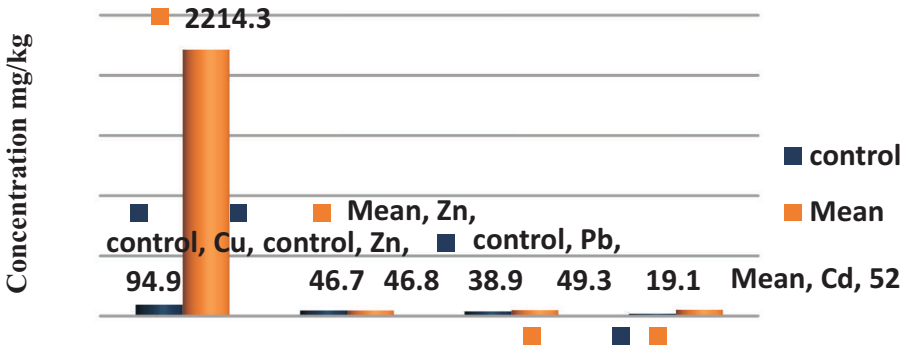

Figure 2: Comparison between Contaminated and Control Soil

The ecological risk of the heavy metals is presented in table 4. It could be observed that based on NSPI, the soils around the study site were seriously polluted by Cu and Cd (8.46 and 32.39 respectively), while Zn and Pb were within the safety domain. Based on the EI, only Cu with a value of 116.66 had moderate potential risk on the soil sample while it causes excessive pollution based on the MPI value of 23.3. This indicates that despite being higher

Table 4: Summary of Ecological Risk Assessment of Heavy Metal Pollution

Metals	NSPI	Remark	EI	Remark	MPI	Remark
Cu	8.46	Seriously Polluted	116.66	Moderate Potential Risk	23.3	Excessive Pollution
Zn	0.24	Safety Domain	1.00	Low Potential Risk	1.00	Slight Pollution
Pb	0.91	Safety Domain	6.34	Low Potential Risk	1.30	Moderate Pollution
Cd	38.29	Seriously Polluted	81.76	Low Potential Risk	2.70	Moderate Pollution

Table 5: Correlation Matrix of Heavy Metals

		Cu	Zn	Pb	Cd
Cu	Pearson Correlation	1	0.174	-0.569	0.532
	Sig. (2-tailed)		0.588	0.054	0.075
	N	12	12	12	12
Zn	Pearson Correlation	0.174	1	-0.729**	-0.274
	Sig. (2-tailed)	0.588		0.007	0.389
	N	12	12	12	12
Pb	Pearson Correlation	-0.569	-0.729**	1	0.168
	Sig. (2-tailed)	0.054	0.007		0.602
	N	12	12	12	12
Cd	Pearson Correlation	0.532	-0.274	0.168	1
	Sig. (2-tailed)	0.075	0.389	0.602	
	N	12	12	12	12

**Correlation is significant at the 0.01 level (2-tailed).

than the permissible level and control points, only Cu of the all the metals considered has high ecological risk on the environment. Table 5 further shows the correlation matrix between the metals. The table shows that there was a significant correlation between Cu and Zn and between Cu and Cd, although not significant ($P>0.05$). In contrast, Cu had a significant negative correlation with Pb ($P<0.05$) which correlated with Cd, which implies that the Pb would have been introduced to the soil from a different source as Cu and Zn.

The high values of the heavy metals obtained in the present study may be attributed to dumping of numerous metal containing wastes such as cadmium and lead acid batteries and metal scraps on the sites. The cadmium levels in the dumpsites were above the critical permissible concentration, which makes it potentially more bioavailable for plants uptake. This result was similar to the findings of Uba *et al*. (2008). Copper concentrations in the dumpsites were all above the toxic limit of 270 mg kg^{-1}. The results indicated that Cu was mostly found in the residual phase (i.e. bound to silicates and detrital materials) which is similar to the reports of Uba *et al.* (2008). Consequently, metals such as Cu and Cd shows possibility of detrimental effect on the environment of the study site.

Conclusion

The study has been able to unravel the fact that open dumpsites pose great environmental risk to water and land resources. As a result, dumpsites should be managed effectively to reduce heavy metal contaminates leaching into the environment of the study area. More so, it can be concluded that open dumpsites in Sagamu pose great environmental risk to water and land resources as a result of high concentration of Cu and Cu found in the soils around the study site. As such, open dumpsites should not be only sited far from residential areas but integrated waste management should be encouraged to reduce soil pollution.

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