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Assessment of heavy metals contamination in soil due to leachate migration from open dumpsites in agbor area, delta state. Nigeria

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The concentration of heavy metals was studied in the soil samples collected around the municipal solid waste (MSW) open dumpsites in Agbor Area, to understand the heavy metal contamination due to leachate migration from open dumping site. The dump sites receives approximately 300-400 tonnes of municipal solid waste. Solid waste characterization was carried out for the municipalsolid waste to know the basic composition of solid waste which is dumped in the dumping site. The heavy metals concentration in the soil samples were analysed. The heavy metal concentration in the collected soil sample was found in the following order: Fe>Zn>Ni>Cu>Pb>Cr>Cd. The presence of heavy metals in soil sample indicates that there is appreciable contamination of the soil by leaching migration from an open dumping site. However, these pollutants species will continuously migrate and attenuate through the soil strata and after certain period of time they might contaminate the groundwater system if there is no action to be taken to prevent this phenomenon.
Keywords: heavy metals, soil samples, municipal solid waste (MSW), Agbor Area

Introduction

Solid waste generation by man is inevitable and disposal at dumpsites is a common method of managing these wastes worldwide. In many developing nations like Nigeria, dumpsites are usually not isolated and are located near residential quarters/areas [17]. They are also not designated for specific waste type but rather all forms of wastes. Dumpsites have been reported to release hazardous chemicals through leachate into the groundwater system [1] and these constitute public and environmental health issues in many countries. The leachate problem is worsened by the fact that many dumpsites lack an appropriate bottom liner or collection system; increasing the possibility of dissipation of leachate through the dumpsite layers to contaminate ground water. It can cause serious pollution problems when it gets in contact with the surrounding soil, surface water and ground water leading to detrimental effects on humans. Thus, Leachate formation now is one of the greatest problems that need to be managed properly [18]. The leachate composition varies greatly from dumpsite to dumpsite depending on site specific characteristics. One of the most hazardous components in leachate is heavy metals. There is a growing concern regarding the build-up of heavy metals in soil and ground water. Different kinds of wastes are responsible for the presence of heavy metals in the dumpsite. Sources such as electronic waste, painting waste and used batteries increase heavy metals content in dumpsite [19].

Soil contamination by heavy metals from waste disposal sites is a serious problem in industrial and urban areas [2] Soils are regarded as the ultimate sink for heavy metals discharged into the environment, as many heavy metals are bound to soils [1, 3, 4, 5]. Furthermore, when screening for pollutants in soil and leachate at contaminated sites, the results are often required directly, since classification of the soil is needed before determination of remediation techniques [3, 20, 21]. Hence, this study has been carried out to assess the soil contamination around the local dump area where the municipal solid wastes have been disposed for so many years [22].This study was conducted on the soil samples collected from the various open dumpsites withinAgbor, Delta State. The present study examines basic composition of the waste in the open dumpsite, then the assessment of heavy metal contamination and its concentration level in solid waste. The concentration of heavy metals was determined in the runoff leachate and its potential to the soil nearby the dumpsite area was also investigated [23].

Methodology

Source of Data

The sources of data for this study included secondary and primary sources. The secondary sources are published materials such as books, journals and other categories of internet publications. Data generated from primary sources included water and soil samples collected from different locations within the dumpsite. This comprises of locations

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that are predominantly of asbestos, clinical, metal scraps, biodegradable and sludge wastes [24, 25, 26].

Sampling

Table 1: GPS Coordinates and Elevation Data

S/N	Locations	Latitude	Longitude	Elevation
1	Yoruba Street	060 14' 59.5" N	0060 11' 17.6" E	153m
2	Nzugbe Street	060 14' 56.1" N	0060 11' 20.2" E	150m
3	Oshell by Okoli	060 14' 46.09" N	0060 12' 20.37" E	152m
4	Morka Street	060 14' 57.51" N	0060 12' 19.13" E	166m
5	Boji-Boji, Owa Street	060 14' 56.47" N	0060 12' 1.69" E	162m
6	Along Obi – Ikechukwu	060 15' 12.46" N	0060 10' 49.42" E	148m
7	Queen Street	060 15' 24.37" N	0060 11' 30.92" E	151m
8	Queen Street	060 15' 30.72" N	0060 11' 32.75" E	152m
9	Osuhor Street	060 15' 32.43" N	0060 11' 26.6" E	155m
10	Down Osuhor Street	060 15' 22.9" N	0060 11' 21.4" E	155m

The soil samples were collected randomly from open dumpsites within Agbor area. The GPS was used to take readings of the locations, their coordinates and elevation above sea level. The samples were then taken to the laboratory for analysis within retention time [27, 28].

The following data were obtained in various locations using the aforementioned methods and instruments in the field.

Field Procedure

Soil samples were collected from ten different locations in the study area. Soil samples were collected and analyzed to assess their characteristics and stability All the samples were collected; preserved, unambiguous labels were used to identify all sample bags prior to being properly stored.

The samples were then stored in cooler boxes at temperatures below 5°C, and transported immediately to the laboratory. They were then stored in a refrigerator at 4°C prior to the analyses [29].

The samples were analysed according to the Standard Methods for the Examination of Water and Wastewater at the Tudaka Laboratory. Seven heavy metals [Lead (Pb), Iron (Fe), Nickel (Ni), Copper (Cu), Zinc (Zn), Chromium (Cr) and Cadmium (Cd)] were chosen because of their availability in landfill leachates. Heavy metals were determined using Atomic Absorption Spectrophotometer (ASS) APHA 301 flame system [30].

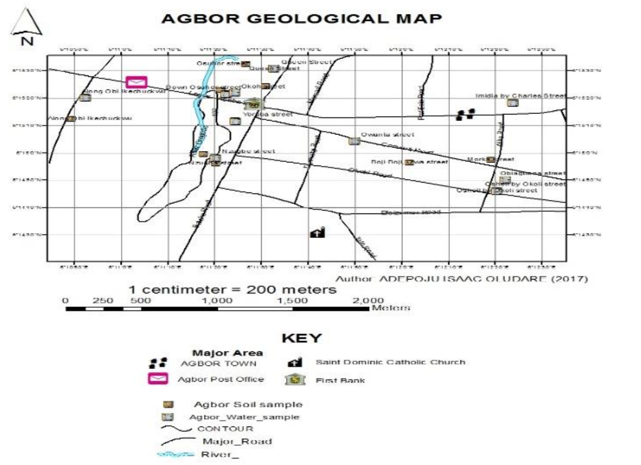

Figure.1: Geological map of the study area showing sample locations.

Laboratory Analysis

The analytical methods used in the determination of the heavy metals are in accordance with the American Standard for Testing Materials [6] and American Public Health [7, 31] Standard procedures. Analyses were carried out as soon as the soil samples arrived at the laboratory.The heavy metal concentration present in the solid waste and soil samples were calculated using the following relation.

$$\mathbf{M = \frac{(C - B)\ 50}{W}}$$

Where,

M = concentration of metal in the solid waste/soil, air dried basis (mg/kg),

C = concentration of metal in the digest (mg/l),

B = concentration of metal in the blank (mg/l),

W = weight of air dried solid waste and soil sample digested (g)

The collected soil were placed on clean plastic sheet, oven dried for three hours and then sieved through a 0.2 mm mesh size to remove stones, plant roots in order to have uniform soil particle size. Following a method developed by Bergdorf Microwave Digestion Application (2011), a soil sample of 500 mg were transferred to digestion vessels with 7.5 ml of HCl and 2.5 ml of concentrated HNO3 (3:1 HCl : HNO3). The vessels were carefully shacked and placed in a fume hood for about 20 min for pre-digestion and to avoid foaming before they were placed on the turntable of the microwave system. Then the pre-digested samples in the digestion vessels were closed and heated on microwave oven. The total concentrations of Cd, Pb, Ni, Cu, Zn,Feand Cr in filtrates were then determined using a Flame Atomic Absorption Spectrometer using air acetylene flame.

Statistical Analysis

Data interpretation is the process of making sense out of numerical data that has been collected, analyzed, and presented.The laboratory analysis showing the quantity of each heavy metal present in the soil is refer to as data. In order to understand the effect of these heavy metals in soil samples,the data must be interpreted. This data is classified as statistics data.

The following techniques are adopted from statistic to analyze and interpret this data:

1. **Bar Charts**

   The Bar Chart (or Bar Graph) is one of the most common ways of displaying qualitative data. Bar Graphs consist of 2 variables, one response (sometimes called "dependent") and one predictor (sometimes called "independent"), arranged on the horizontal and vertical axis of a graph. This allows the inspection of the data for its underlying distribution e.g., normal distribution, outliers, skewness, etc. The data was used to plot a histogram that shows the distribution of heavy metals across the study area.

2. **Principal Component Analysis**

   Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components (or sometimes, principal modes of variation). PCA is mostly used as a tool in exploratory data analysis and for making predictive models [32, 33, 34]. Factor analysis was used to group the soil properties into statistical factors.

   Factor loadings are the simple correlation between properties and each factor. Eigenvalues are the amount of variance explained by each factor. The PCA was used to interpret the heavy metals data in order to visualize genetic distance and relatedness between its distributions.Also, PCA helps to show the risk management of the heavy metals distribution in the study area [9, 10, 11].

(Iii) Result And Discussion

Table 1: AAS analysis result for heavy metals in soil samples

Table 2: AAS analysis result for heavy metals in soil samples (continued)

NB: AGBSL means Agbor Sample Location

Sample	Iron (mg/kg)	Zinc (mg/kg)	Lead(mg /kg)	Cadmi um (mg/kg)	Chromium (mg/kg)
AGBSL1	384.93	3.761	0.242	0.183	0.194
AGBSL2	390.434	3.846	0.249	0.194	0.206
AGBSL3	420.224	5.466	0.568	0.314	0.498
AGBSL4	486.11	6.954	0.685	0.386	0.522
AGBSL5	450.684	5.622	0.458	0.21	0.438
AGBSL6	301.243	2.781	0.193	0.133	0.162
AGBSL7	436.481	5.27	0.422	0.275	0.429
AGBSL8	400.658	4.112	0.398	0.225	0.414
AGBSL9	390.662	4.624	0.306	0.211	0.316
AGBSL10	399.261	4.843	0.318	0.214	0.336
Min.	301.243	2.781	0.193	0.133	0.162
Max.	486.11	6.954	0.685	0.386	0.522
Mean	406.0691	4.7279	0.3839	0.2345	0.3515
Median	399.9595	4.7335	0.358	0.2125	0.375
S.D.	48.89325	1.1785 13	0.15523 6	0.0723 96	0.129664
Skewness	-0.63778	0.2634 68	0.77873 5	1.0103 73	-0.27925

Sample	Copper (mg/kg)	Nickel (mg/kg)
AGBSL1	1.126	1.341
AGBSL2	1.511	1.648
AGBSL3	2.189	2.148
AGBSL4	2.245	1.933
AGBSL5	2.098	1.736
AGBSL6	1.097	1.29
AGBSL7	2.089	1.885
AGBSL8	2.148	1.668
AGBSL9	1.268	1.786
AGBSL10	1.204	1.68
Min.	1.097	1.29
Max.	2.245	2.148
Mean	1.6975	1.7115
Median	1.8	1.708
S.D.	0.495307	0.257703
Skewness	-0.12639	-0.21447

Table 3: Pearson's Correlation Matrix of Heavy Metals.

	Fe	**Zn**	**Pb**	**Cd**	**Cr**	**Cu**	**Ni**
Fe	1						
Zn	0.94	1					
Pb	0.847	0.918	1				
Cd	0.825	0.892	0.941	1			
Cr	0.836	0.887	0.941	0.855	1		
Cu	0.761	0.713	0.857	0.749	0.886	1	
Ni	0.728	0.798	0.813	0.824	0.864	0.743	1

Table 4: Factor loadings (pattern Matrix) and unique variances

Variabl e	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Uniquene ss
Fe	0.9123	-0.230	0.2657	0.051	0.0743	0.0359
Zn	0.9491	-0.285	0.0275	0.0352	-0.083	0.009
Pb	0.9746	0.0313	-0.059	-0.183	-0.072	0.0067
Cd	0.9322	-0.097	-0.189	-0.133	0.1081	0.0561
Cr	0.961	0.1411	-0.010	0.0796	-0.104	0.0392
Cu	0.8726	0.3843	0.1856	-0.034	0.0441	0.0533

Ni	0.8672	0.0807	-0.213	0.2036	0.0497	0.1518

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	5.989	5.67012	0.9074	0.9074
Factor2	0.31889	0.12777	0.0483	0.9557
Factor3	0.19112	0.08689	0.029	0.9847
Factor4	0.10423	0.05949	0.0158	1.0005
Factor5	0.04474	0.06408	0.0068	1.0073
Factor6	-0.01935	0.00926	-0.0029	1.0043
Factor7	-0.02861	.	-0.0043	1

Figure 3: Bar Chart Showing the Concentration of Zinc across Sample locations. LEAD (Pb)

Lead concentration in the study areas ranges from 0.193 – 0.685 mg/kg with a mean value of 0.384 mg/kg.The WHO (1993) standard for this parameter range from 0.1 - 6 mg/kg therefore, the concentration of lead is lower than the permissible limit of the stipulated standards but also has significant health impact.The lead present in the soil sample at Morka Street (AGBSL4) shows maximum concentration (0.685mg/kg). Lead in the soils of the study area could be

Table 2: Eigenvalues with factors unrotated

	Iron (mg/kg)	Zinc (mg/kg)	Lead(mg/kg)	Cadmium(mg/kg)	Chromium(mg/kg)	Copper(mg/kg)	Nickel (mg/kg)
AGBSL1	-0.43227	-0.82044	-0.91409	-0.71137	-1.21468	-1.15383	-1.4377
AGBSL2	-0.31978	-0.74832	-0.869	-0.55942	-1.12213	-0.37653	-0.24641
AGBSL3	0.289506	0.626298	1.185939	1.098128	1.129844	0.992314	1.693812
AGBSL4	1.637054	1.888906	1.939632	2.09266	1.314938	1.105376	0.859517
AGBSL5	0.912496	0.758668	0.477339	-0.33842	0.667109	0.80859	0.095071
AGBSL6	-2.14398	-1.652	-1.22974	-1.40201	-1.46147	-1.21238	-1.63561
AGBSL7	0.622006	0.459986	0.245433	0.559424	0.597699	0.790419	0.673256
AGBSL8	-0.11067	-0.52261	0.09083	-0.13122	0.482015	0.909537	-0.1688
AGBSL9	-0.31512	-0.08816	-0.50182	-0.3246	-0.27378	-0.86714	0.289093
AGBSL10	-0.13924	0.097665	-0.42452	-0.28317	-0.11954	-0.99635	-0.12223

*Ta*ble 3: Score Variables (Factor) That Showed Variance of Heavy Metals Distribution within Study Area.

(Iv) Discussion And Interpretation

Heavy metals in soil

Seven (7) heavy metals were tested for each sample collected includes: Fe, Zn, Pb, Cd, Cr, Cu and Ni

IRON (Fe)

Iron concentration in the study areas ranges from 301.243 – 486.110mg/kg with a mean value of 406.064mg/kg. The permissible limit of the stipulated standards for iron is not applicable and also has no significant health impact. The iron present in the soil sample at Morka Street (AGBSL4) shows maximum concentration (486.110mg/kg). The introduction of the iron into the soil could be as a result the leachate contamination based on the iron materials dumped at the site.

ZINC (Zn)

Zinc concentration in the study areas ranges from 2.781 – 6.954 mg/kg with a mean value of 4.728 mg/kg. The ((WHO), 2010)for this parameter range from 10- 500 mg/kg therefore, the concentration of zinc is lower than the permissible limit of the stipulated standards but also has significant health impact because zinc increase acidity of water.The zinc present in the soil sample at Morka Street (AGBSL4) shows maximum concentration (6.954mg/kg). The main sources of pollution are industries such as mining coal combustion, steel processing and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture (Gowd et al., 2010).

from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions.

CADMIUM (Cd)

Cadmium concentration in the study areas ranges from 0.133 – 0.386 mg/kg with a mean value of 0.2345 mg/kg. These are within the natural limits of 0.01- 0.8 mg/kg in soil as given by EC (1986) and MAFF (1992) [11, 12, 13].The WHO (1993) standard for this parameter is 0.3 mg/kg therefore, the concentration of cadmium(0.386 mg/kg)in Morka Street (AGBSL4) is higher than the permissible limit of the stipulated standards. The major threat of cadmium to human health is chronic accumulation in the kidneys leading to kidney dysfunction. Cadmium in the soils of the study area could be from aerial deposition and sewage sludge, manure and phosphate fertilizer.

Statistical Distribution Diagram

Factor loadings and score variables (factor) statistical distribution diagrams among others are used in this work to gain better insight into the processes operating during leaching of heavy metals into the groundwater system(Lawley & Maxwell, 1962) [14, 15, 16].

Seven (7) factors was considered in relations to soil properties, the factors represent the following:

Factor 1 represent Water transmission
Factor 2 represent Soil aeration
Factor 3 represent Soil pore connection 1
Factor 4 represent Soil texture
Factor 5 represent Moisture status
Factor 6 represent Soil aggregation

Factor 7 represent Soil pore connection 2

Among five factors, only two factors (factor 1 and factor 2) are important properties considered in this work.Water transmission (factor 1) explains the rate at which water infiltrate through the soil into the groundwater system. Soil aeration (factor 2) explains the rate at which the heavy metals dissolved in the soil.

1. **Factor Loadings Diagram**
2. Factor loading diagram is basically the correlation coefficient for the variable (heavy metals) and factors (soil properties). Factor loading diagram shows the variance explained by the variable based on factor 1 and factor 2. Within the study area, it can be deduce that copper (Cu) have the highest rate at which its dissolved in the soil, while zinc (Zn) have the lowest rate at which its dissolved in the soil (Figure 6). **Score variables (factor) Diagram**

The factor score is also called the component score. This score is of all row and columns, which can be used as an index of all variables and can be used for further analysis. The score variables plot is used graphically to illustrate the rate at which water transmits through the soil (factor 1) and the rate at which the heavy metals were being dissolves in the soil (factor 2) in each location of the study area. From the graph, it can be deduce that Oshell by Okoli Street (AGBSL3) have the highest rate at which heavy metals dissolved and water transmitted into the soil, while Down Osuhor Street(AGBSL10) have the lowest rate at which heavy metals dissolved and water transmitted into the soil (Figure 7).

1. **Eigen values Diagram**

Eigen values is also called characteristic roots. The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. The eigenvalue of structure of the soil properties are shown in Table 8. The Cattell scree test plots the factors as the X axis and the corresponding eigenvalues as the Y-axis. As one moves to the right, toward later components, the eigenvalues drop. According to the Kaiser Criterion, Eigenvalues is a good criteria for determining a factor. If Eigenvalues is greater than one, we should consider that a factor and if Eigenvalues is less than one, then we should not consider that a factor. According to the variance extraction rule, it should be more than 0.7. If variance is less than 0.7, then we should not consider that a factor. Based on Kaiser Criterion and variance extraction rule, only factor 1 (water transmission) in the table was retained. This implies that only the rate at which water transmits through the soil into the groundwater system was most considered important properties.

Conclusion

The study on the assessment of heavy metal contamination in soil due to leachate migration has been carried out. The results of the analysis indicate that Iron, Zinc, Lead, Cadmium, Chromium, Copper and Nickel have a serious impact, thus deteriorating and polluting the soil quality and microorganisms in the area. The study observed that waste management strategies are not practiced at all in the area and this constitutes a serious pollution problem with the soil quality. Earlier attempts in the solution of this soil pollution problem did not focus on locational variations of individual soil chemical pollutants. This would have aided the advancement of solutions to soil pollution management.

The indiscriminate disposal of MSW without covering is considered a dangerous practice in integrated waste management at the global level. The characterization of leachate confirms the methanogenic condition of the dumpsite. Based on the average concentration, the heavy metal components in the leachate and soil were found in the following orders: Fe> Zn>Ni > Cu >Pb> Cr > Cd. The presence of heavy metals Fe, Zn, Pb, Cd, Cr, Cu and Ni) in soil sample indicates that there is appreciable contamination of the soil by leachate migration. This is indicative that the migration and distribution of the contaminants species are still localized and not diffused with a wide area. However, these pollutant species continuously migrate and percolate through the soil strata and after certain period of time might contaminate the groundwater system if no action is taken to prevent this phenomenon.

This study recognized Iron, Zinc, Lead, Cadmium, Chromium, Copper and Nickel as grave soil pollutants in the study area. The pollution levels of these heavy metals vary significantly with the type of solid waste that predominates in the study locations within the dumpsite. These innumerable problems call for stringent adherence to the recommended management strategies. It also serves as a clarion call for the prompt implementation of policy on waste management as established by this study.

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