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LATERITE AS A BINDER FOR REMEDIATION OF POLLUTED LANDSITES

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Abstract

The labile fractions of heavy metals in soils are the most important for toxicity to plants and organisms, therefore, it becomes pertinent to decrease this fraction in soils to minimize the negative effect of heavy metals to human, animal health and food security. Several materials have shown promising potentials in remediating environmental pollution with a level of toxicity, environmental impairment or non-cost effective. This research therefore evaluates the potential of laterite as an alternative binder for the remediation of polluted soils and assess the environmental risks of these heavy metals for the soil metal fractions.

Soil samples were collected from an exide battery site in Ibadan, Nigeria. Laterite samples were obtained from Abeokuta in Ogun state and Emuhu in Delta state and characterized. These were pretreated, phytochemical screening was carried out on the soil according to standard. Remediation studies was carried out using standard methods. The geochemical fractions of Pb, Mn, Cr, Ni, and Zn that are present in Lalupon polluted site using the seven steps of Zeinen and Brummer fractionation scheme after two- and three-months incubation periods with proportion of samples from the laterites were determined. Pseudo- total metal concentration in soils were equally determined using aqua-regia digestion.

The sum of the fractions of Pb, Zn, Cr, Mn and Ni for both two- and three-months incubation do not differ widely from that observed for these metals in the pseudo total metal concentrations of the metals determined independently by using aqua-regia digestion. Lead occluded majorly in the exchangeable fraction which makes it more dangerous among the metals of interest. Zn, Cr, Ni, and Mn were all majorly occluded at the residual fractions. Lead accounts for 98% of the pollution on this polluted land, its remediation trend for the two months shows 99.97%, 99.95% and 99.96% for 5, 10 and 20 percent LA-AB. The LA-EM counterpart gives 99.95%, 99.95% and 99.97% for 5, 10 and 20 percent respectively. The three months LA-AB gives an efficiency of 99.95%, 99.97% and 99.96 for 5, 10, and 20% respectively. The three months LA-EM results into 99.95%, 99.96% and 99.95% for the 5, 10, and 20 percent respectively.

The trend showed that both LA-EM and LA-AB have promising potential to remediate a heavy metal polluted site.

Keywords: Heavy metals, Laterites, Binder, Labile fractions, Remediate.

INTRODUCTION

Polluted land sites are among the commonest environmental problems of the world today and their assessment depends heavily on chemical analysis. All anthropogenic activities give rise to some form of pollution and in some places where land has been used and reused, sometimes over many centuries; the problems are particularly acute (Fifield and Haines, 1995, Olu-Owolabi *et al.*,2010). The problems caused by the increase in the total volumes of wastes generated globally are compounded by the presence of an expanding array of pollutants. As a consequence, all waste streams are been viewed as potential threats to the environment, thus necessitating the development of innovative waste disposal strategies (Ijmdiya, 2013; Chikwe, 2019).

Also, much of the waste generated by the chemical industry and at the same time modern life is very much dependent upon the usage of chemicals and their by-products. The public enjoyment of the immediate benefits is now been tampered by the fact that, there may be long-term adverse environmental and human health effects from these chemicals (Erickson, 1993; Bagherifem *et al.,* 2021). The disposal of the majority of domestic and industrial wastes is by burial in landfills sites. Water percolating through these buried wastes leaches out soluble chemicals and also enables a biochemical breakdown of organic materials to form a potential polluting leachate. The polluting potential of leachate is usually greater than the material which has simply been dissolved out of the waste. For wastes to be well attended to, hazardous waste management is necessary. These involve prevention, treatment, disposal and remedial actions (Diplock *et al.*, 2009; Wang *et al.*, 2021).

One aim of any hazardous waste management strategy should be to reduce to a minimum, the quantity of hazardous waste that must be managed. Hazardous waste reduction can be achieved by changing production process conditions, changing chemicals used in the process, separating waste at the source, and maintaining close control over spills and equipment breakdown. Treatment and disposal techniques should render the wastes less hazardous and dispose of them in a manner such that environmental and human health problems do not occur. These techniques include chemical, physical and biological treatment technologies to render the waste less hazardous and land application processes to dispose the wastes and the residues from the treatment processes (Raymond and Felix, 2011; Kuppusamy *et al.*, 2017). Remedial action is required for the hazardous wastes that already have been released to the environment as a result of improper disposal or poor management practices. Abandoned or inactive hazardous waste sites are examples of locations where remedial methods are needed (Adebowale *et al.*, 2008). Treatment and disposal methods and remedial action methods both involve land to a large degree because land application can be economically and technically sound method for hazardous waste and treatment disposal (Marti and Johnson, 1987). Remedial measures also require an understanding of the use of soil to control the pollutants improperly released. Laterite, a geomaterial, has been utilized by research groups in removing priority inorganic pollutants from water. The presence of silica, alumina, and other metal oxides in laterite probably makes it a good adsorbent.

Laterite from Missiones, Argentina was used to remove Arsenic from an arsenic contaminated groundwater in Santiago del Estero, Argentina from an initial concentration of 500µg/L to 10-30µg/L which is a decrease of 94-98%. It was found that the higher the laterite amount, the more the rate of adsorption. (Claesson and Fagerberg, 2003). As well, Anjali *et al*, 2007 studied the adsorption characteristics of arsenic on laterite soil. The studies were conducted by both batch and continuous mode. Laterite soil was found to be very efficient for arsenic removal from the groundwater collected from arsenic affected area. The initial concentration of arsenic in soil was 0.33ppm. Under optimized conditions, laterite soil could remove up to 98% of the arsenic present. The optimal adsorbent dose was 20g/L and the equilibrium time is 30 minutes. The present work is conducted to immobilize a polluted soil which was a former dump site for a defunct lead battery manufacturing company in Lalupon, an outskirt of Ibadan in Lagelu local government area of Oyo State, Nigeria with laterite samples collected from Abeokuta in Ogun State and Emuhu in Delta State, all within Nigeria.

EXPERIMENTAL Study Site

The study site is located at Lalupon in Lagelu local government of area of Ibadan, Oyo State, Nigeria. Lalupon is between longitude 7^o 28’N and Latitude 4^o 04’E. It is about 4-6km from Ibadan city and serves as one of the dump sites that was used by the defunct Exide battery limited. The dumpsite is an approved landfill given to the company by the then Oyo State environmental Protection Agency (OYSEPA), now federal ministry of environment, to stop illegal unauthorized dumping of hazardous waste into people’s farmland at Olodo village in Ibadan, Oyo state, Nigeria. This land was an abandoned quarry near the village and the company had to construct the dumpsite in 1996. The land space covers about 1.0 acre. The slag has been shown to contain a significant level of Lead (Pb) and other metals such as Cadmium (Cd), Nickel (Ni), Iron (Fe) Zinc (Zn), Cobalt (Co), Chromium (Cr), Manganese (Mn) and so on which may be associated in small amount as impurities in the alloy of lead used, or as trace additives in the molding and casting process of the company.

Due to the magnitude of the pollution of the dumpsite, it does not accommodate any vegetation but as the distance increases, vegetation density increases too. There is a control well and a leachate pond that was constructed by the company as control measures to check the level of pollutants migration in the soil. During rainy season, the leachate pond does get filled and overflow into adjacent stream.

Soil Sampling and Sample Pretreatment

Laterite was collected from the non-vegetative layer of the sampling sites. The sites are Imosan in Abeokuta, Ogun State, Nigeria and Emuhu in Agbor, Ika South) local government of Delta State, Nigeria. The polluted soil sample was collected from Lalupon (longitude 7^o 28’N and Latitude 4^{o}04’E) in Lagelu local government of Oyo State. Samples were collected with soil auger and stored in polyethylene bags which were well labelled for easy identification. The samples were carefully air dried, grinded and sieved to remove stones, leaves and other debris through 1.0mm mesh size sieve and stored for analysis.

Physicochemical analysis

Routine physicochemical analysis was carried out as follows. The soil pH was measured with a glass-electrode pH meter in 1:1 soil to water and soil to 1M KCl (Diagboya, 2009). The organic carbon and organic matter were determined by the wet oxidation method of Walkley and Black 1934, and Jackson 1958. Particle size distribution was measured by the hydrometer (Day, 1965). The exchangeable bases were extracted with 1M NH_4OAc (pH 7) (Ugochukwu et al., 2016) and the exchangeable aluminum (AL_k) extracted with 1M NH_4OAc (Barnhisel and Bersch, 1982). The effective capacity of the exchange complex (ECEC) was calculated as the sum of AL_k and the amount of Ca, Mg, Na, and K extracted by 1M NH_4OAc at pH 7 (Shuman, 1990). The Ca, Mg, and Al contents were determined by atomic absorption spectrometer (AAS).

Remediation Studies

Polluted soil samples were incubated with variable amounts of laterite samples (5%, 10% and 20%) from Abeokuta, Ogun state and Emuhu in Ika local government of Delta state separately in triplicate and in different containers for three months. Each of the laterite amounts were weighed into three different containers and the corresponding Lalupon polluted soil was added to make 5%, 10% and 20% respectively. These soils were continually moistened for the incubated period. Pseudo-total metal concentration and metal separation of the incubated soils were investigated at the end of the second and third month using the method of Zein and Brummer (1989).

Determination of Pseudo- total Metal concentration in Soils

Pseudo-total (meaning aqua- regia extractible) metal concentrations were determined by digestion in Pyrex digestion flask on electric hot plate for 2 hours. 1.0g of air-dried soil was separately digested with 20ml of aqua regia independently and then cooled. After cooling, the solution was filtered using whatman filter paper. The filtrate was made up to 50ml mark using de-ionized water. This was analyzed for the five metals (Pb, Cr, Zn, Mn and Ni) in each digester using Buck Scientific 210/211 VGP Model Atomic Absorption spectrometer (AAS).

Fractionation of Soils

This was carried out using the method adopted by Zein and Brummer (1989). 1.0g of the pretreated soil sample was weighed into different pair of conical flasks. The following steps were followed for the metal fractionation.

Mobile fraction

The mobile metal fraction was extracted from 1.0g air dried soil samples by shaking in a mechanical shaker for 24 hours at 27 ± 2^{O}C with 50mL 1M NH_4NO_3 (80.04g/L). Shaking was done in 100mL polyethylene bottles. The supernatant was filtered (using Whatman type 45 filter paper) into another precleaned 100mL polyethylene bottle and was stabilized with 0.5mL concentrated HNO_3.

Easily mobilized fraction

The residue from step 1 was placed in a mechanical shaker and was shaken for 24 hours with 50mL 1M NH_4NO_3(77.08g/L) at pH 6.0. After shaking, the supernatant was filtered (using Whatman type 45 filter paper). The residue was washed with 25ml 1M NH_4NO_3 for10 minutes, centrifuged and thereafter filtered. The filtrate was pooled together and was preserved with 0.5mL concentrated HNO_3 until analysis.

Bound in Manganese oxides fraction

The residue from step 2 was extracted with 50mL **0.**1M NH_4OH* HCl (6.949g/L) + 1M NH_4OAc (77.08g/L) at pH 6.0 and was shaken in a mechanical shaker for 30 minutes at 27 ± 2^{O}C. The supernatant was filtered. The residue was washed twice with 25mL 1M NH_4OAc (pH 6.0) for 10 minutes each time and was thereafter filtered. The filtrates were collected together in a 100mL polyethylene bottle and was preserved with 0.5mL concentrated HCl until analysis.

Organically bound fraction

The residue from step 3 was shaken for 90 minutes at 27 ± 2^{O}C with 50mL 0.025M NH_4EDTA (971.164g NH_4Cl + 9.306g EDTA) at (stabilized with ammonia) pH 4.6 and the clear solution was filtered. The residue was washed by shaking for 10 minutes with 25mL NH_4Ac (77.08g/L; adjusted to pH4.6 with 100% acid), and filtered. The filtrate was pooled together and kept for metal analysis.

Bound in Poorly Crystalline iron oxides fraction

The residue from step 4 was subjected to extraction with 50mL 0.2M NH_4 oxalate buffer (0.2M Di-ammonium monohydrate, 28.422g/L) at pH 3.25 (stabilized with ammonia solution). This was shaken for 4 hours in the dark and was thereafter filtered. The residue was washed in the dark by shaking for 10 minutes with 25mL 0.2M NH_4 oxalate (pH 3.25) and was filtered. The filtrates were pooled together and kept in the dark till analysis.

Bound in well crystalline iron oxides fraction

The residue from step 5 was shaken with 50mL 0.1M Ascorbic acid (17.613g/L) + 0.2M NH_4 oxalate (pH 3.25). It was heated at 95 ± 3^{O}C in a water bath for 30 minutes (Shuman and Hargrove, 1985) and filtered. The residue was washed by shaking in the dark with 25mL NH_4 oxalate for 10 minutes and filtered. The filtrate was collected in a 100ml polyethylene bottle and kept in the dark till analysis.

Residual fraction

The residue was quantitively transferred into a 250mL digestion flask and digested with 9mL concentrated HCl and 3mL concentrated HNO_3 for 2 hours. It was then cooled and filtered (whatman type 45 filter paper). The digest and digestion tube were rinsed with de-ionized water and poured in the filter paper. The filtrate was made up to 50mL in a 50mL volumetric flask and poured into a 100mL polyethylene bottle ready for analysis.

Metal Analysis

The extracts from the seven fractions before and after incubation were analyzed for Cr, Zn, Mn, Pb and Ni using Buck Scientific 210/ 211 VGP model atomic absorption spectrometer (AAS). The AAS was first calibrated by running standard solutions for each metal before the samples were analyzed.

Statistical Analysis

The mean and standard deviation of replicate values (expressed in mg/Kg) were determined. The percentage of each fraction present in the total metal of each metal was estimated.

Quality Control and quality Assurance

All the glass wares and polyethylene bottles/ containers used were properly washed with liquid soap and rinsed with tap water. They were soaked in 2M HNO_3 and rinsed with distilled de-ionized water before use. Immediately after use, they were subjected to the same treatment to avoid cross contamination. Analar grade reagents were used to prepare extractant solutions so as to reduce contamination and ensure accuracy of results. Distilled de-ionized water was utilized in the preparation of reagents, metal solutions as well as in the rinsing of Apparatus and plastic bottles. The use of distilled deionized water is aimed at minimizing the introduction of metals from external sources. Operational blanks for all extractant were analyzed for the five metals and their values deducted before further calculations were made. Extractants were prepared when needed to ensure they are fresh during the time of extraction and the adjusted pH intact. Moreover, ascorbic acid decomposes with time and so was used when it is freshly prepared. Duplicate incubation and extractions were carried out to ensure that the results obtained were reproduced.

RESULTS AND DISCUSSION

Table 1.1 (A): **Physiochemical parameters of the laterite soil sample studied.**

Sample	pH		Organic (%) Carbon	N	Total Exchangeable Bases mg/100g				Ex. Acidity Me/100g	CEC Me/ 100g	Base sat
	KCl	H_2O	(%)	(%)	Ca	Mg	Na	K			
LA AB	3.80	4.50	0.60	0.15	1.06	0.57	0.75	0.04	1.40	3.82	63.35
LA EM	4.60	5.30	0.09	0.02	1.24	0.54	0.87	0.07	1.40	4.12	66.02

Table 1.1 (B)physiochemical parameters of the laterite soil sample studied (contd.)

Samples Distribution	Particle Size			Exchangeable micronutrients				Chemical Composition of the Sample									
	Sand	Silt	Clay	Cu	Zn	Mg	Fe	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	AR	$CaCO_3$
LA AB	71.20	6.00	22.80	0.60	1.19	1.60	11.20	70.33	17.58	5.91	2.46	1.37	0.02	0.29	0.04	2.98	4.40
LA EM	55.20	6.00	38.80	0.95	1.37	2.30	20.20	67.70	17.20	6.10	1.75	1.23	0.02	0.35	0.03	2.82	3.12

Key: LA-AB = Laterite Abeokuta. LA-EM = Laterite Emuhu. Ex. Acidity = Exchangeable Acidity
CEC = Cation Exchangeable Capacity. Base sat. = Base saturation. AR = Ratio of the Oxide to Sesquioxide $\{SiO_2/(Fe_2O_3+Al_2O_3)\}$.

The chemical compositions of the two laterite samples studied (Tables 1A and 1B) showed high contents for the combined silica content (SiO_2), Alumina (Al_2O_3) and the iron bearing mineral (Fe_2O_3). This shows that laterites are formed through the weathering processes that favour the formation of iron and aluminium oxides. This process breaks down the high silicate minerals into clay minerals like kaolinite and illite (Elueze and Kehinde-Philips, 1993). The iron and the aluminum oxides are involved in the formation of reddish brown colour associated with the laterite samples. However, an examination of table 1B gives a smaller percentage to the iron bearing minerals (Fe_2O_3) when compared to the silica content (SiO_2) and Alumina (Al_2O_3) and this is similar to the findings of Elueze and Kehinde-Philips in their analysis on laterite formation (1993).

This could give an erroneous impression that the iron bearing minerals in the parent rock have probably not been affected by chemical weathering to release iron oxide or its hydroxide into the weathering solution because of the depletion of Fe_2O_3 in the weathering horizons. This cannot be the case here because usually even at the base of the profile (an environment with high pH and low Eh values under humid tropical well drained conditions), parent minerals weather into kaolinite and amorphous or crystallized ferruginous oxyhydroxides. Therefore, the depletion of Fe_2O_3 can be explained by the congruent dissolution of iron bearing minerals and subsequently leaching and transportation of the oxyhydroxides from the weakly acidic surface layers down the lateritic profile and subsequent deposition further down the profile possibly as iron concretion or complete loss from the system through drainage by groundwater (Elueze and Kehinde-Philips, 1993; Sandipan et al., 2020).

The degree of laterization (formation of laterite) is estimated by the Silica –Sesquioxide (S-S) ratio [SiO2/ (Fe_2O_3+Al_2O_3]. Soils are classified by the S-S ratios. Therefore, an S-S ratio of 1.33 or below = laterite.
S-S ratio of 1.33–20 = lateritic soil.
An S-S ratio of 20 and above = non-lateritic i.e. tropical soil.

The ratio of the sample used for classifying the samples is in Table 1 and is denoted as AR. The slight deviation in the ratio obtained for the laterite samples from 1.33 could be a factor that depends on the parent rock composition and the formation conditions (Schellman, 2007). This also classifies the laterite samples as lateritic soil. The Silica– Sesquioxide of LA-EM which is 2.91 is closer to the pure laterite than LA-AB with a value of 3.14 for Silica –Sesquioxide. The pHs of the laterite samples are acidic. The two samples showed appreciable exchangeable bases in the order of Ca > Na > Mg > K (table 1). This order can be as a result of the appreciable carbonate that is present in each sample. A similar order of the exchangeable bases as shown in Table 1 above was obtained by Banjoko *et al.*, 1983 on some soils in Northern Nigeria. LA-EM has higher base saturation than LA-AB which suggested that cation exchange processes may provide a stronger capacity to buffer incoming proton additions in LA-EM than LAAB (Gong and Donahoe, 1996).

Analysis on heavy metal fractionation

Table 2: Fractionation of Mn (mean in mg/kg) in LA-AB

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**
1	0.37±0.04	0.57±0.57	0.59±0.03	0.54±0.17	0.94±0.04	0.45±0.18	0.49±0.05
2	1.11±0.10	1.14±0.02	2.08±0.05	1.11±0.25	2.09±0.23	0.90±0.19	1.70±0.01
3	5.90±0.58	5.78±0.08	4.37±0.13	4.81±0.04	4.23±0.03	5.21±0.41	4.83±0.21
4	2.06±0.13	1.96±0.05	3.92±0.12	2.10±0.38	3.55±0.17	1.83±0.43	3.73±0.55
5	2.56±0.43	2.75±0.08	5.30±0.02	2.90±0.71	5.99±0.13	2.27±0.22	5.88±0.19
6	1.98±0.61	1.59±0.74	2.00±0.21	1.65±0.59	1.72±0.12	1.78±0.31	2.55±0.11
7	20.78±0.46	9.06±10.25	6.03±0.26	15.85±o.57	6.87±0.10	14.30±1.41	8.00±0.76
Total	34.75±24.58	22.83±16.16	24.26±24.29	28.95±20.48	25.39±17.95	26.73±18.91	27.17±19.22

Table 3:Fractionation of Cr (mean in mg/kg) in LA-AB

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**
1	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	0.05±0.07	0.30±0.04	0.00±0.00	0.02±0.03	0.00±0.00	0.02±0.02	0.00±0.00
7	6.28±0.70	8.58±1.58	25.08±3.57	4.20±4.63	34.12±6.43	11.30±2.52	51.62±3.76
Total	6.33±4.48	8.88±6.26	25.08±17.73	4.22±2.63	34.12±24.13	11.32±8.00	51.62±26.86

Key: F1 (fraction 1) = Mobile fraction. F2 (fraction 2) = Easily mobilizable fraction. F3 (fraction 3) = Metal forms bound to manganese oxide. F4 (fraction 4) = Metal forms bound to organic matter. F5 (fraction 5) = Metal forms bound to amorphous iron oxide. F6 (fraction 6) = Metal forms bound to crystalline iron oxide. F7 (fraction 7) = Residual fraction forms. ∑F1-7= sum of fraction 1-7 SD = Standard deviation.

Fractionation of the Mn, Cr, Zn, Pb and Ni present in LA-AB

The movement of metals from soil to different environmental compartments is strongly dependent on the concentration of their geochemical fractions in soils. Table 2 showed the distribution of manganese in the polluted soil and the incubation results for LA-AB. Lalupon bounded majorly to the residual fraction with a mean value of 20.78mg/kg. This is equivalent to 59.80% of the total manganese present in the polluted sample, organic matter is 7.37% and the crystalline iron oxide is 5.70%. The various speciation results in the table above were as well majorly bounded to the residual fractions. A close look at table 2 showed that the major bond of manganese to the residual fraction and the oxides of iron suggest that the metal under consideration may have long time availability if changes in soil chemistry and microbiology permit. The high residual fraction suggests stability (Agbeni, 2010). The organic matters contain higher concentration with three months than two months. The adsorptive layers of iron oxide immobilized better with the various three months than the corresponding two months but residual fraction was more consistent with the two months than the corresponding three months. The various occlusions at the oxide of irons can result from the pore sizes affecting the solid-state diffusion of the metals (Jakubus and Czekala, 2010). The 5% incubation showed an improved efficiency over the 10% and 20% respectively. The metal was more effectively occluded in the two months processes than what was observed in the three months results.

In the Lalupon soil and the results from the two months incubation, chromium majorly bounded to the residual fraction (Table 3). A small percentage was associated with the crystalline fractions. There were no adsorptions in the first five fractions. In the three months incubation results from the metal fractionation, Chromium bounded mainly to the residual fraction as well. Similar report was made by Jakubus and Czekala, 2010 that this could be due to the fact that the mobility of chromium in the environment was limited by the dominating (+3) oxidation state and gave the formed compound a low solubility especially with iron oxide and hydroxide. Also, Imai and Gloyna, (1990) reported that irrespective of the oxidation degree, the dominant part of chromium does bond firmly and was always difficult to dissolve. This majorly accounted for the dominance of chromium at residual fraction (Table 3).

Table 4 showed that zinc was majorly adsorbed in the residual fraction with a mean value of 19.98mg/kg which is equivalent to 62.30%, amorphous oxide contains 18.90%, organic matter has 8.70% and the easily mobilizable fraction is 5.27% . This suggested both lithogenic and anthropogenic source for the metal in the polluted site. Zinc was also found in the other fractions in relatively lesser percentages. Their fair distribution across the seven fractions suggested that it was one of the most mobile elements in soils and had displayed a similar trend in the samples under consideration (Jakubus and Czekala, 2001). Zinc was generally considered to be of low toxicity due to the wide margin between the usual environmental concentrations and toxic levels (Lisbeth *et al*., 2009). Zinc gave a total mean value of 32.07mg/kg but an unusual trend was noticed in the residual fraction of Table 4 (5%) which did not agree to every other result that were obtained for both LA-AB and LA-EM. Apart from this, Zinc showed a normal expected trend in all the results. The distribution cut across all fractions and this could result from the fact that it is one of the most mobile elements in soil. The mobile fraction was the least of all the seven –fractions steps for the Lalupon soil, two months and the three months incubation results. The exchangeable fraction was higher in the three months than the two months though not too wide for 5%, 10% and 20%. The two months bounded with higher mean values in manganese oxide than what was noticed in the results for the various three months. The two months bound better in the amorphous oxide than the two months.

Pb was majorly bounded to the easily mobilizable fraction, residual fraction and organic matter with mean values of 2770mgkg^{-1}, 2392mgkg^{-1} and2210mgkg^{-1} respectively on soil (Table 5). It was the most abundant element of all the metals of interest that polluted the site accounting for 98.89%. Lead was highest with easily mobilizable fraction, this suggests that it must have been redistributed between the soil's liquid and solid phase over time and had been readily transferred into the easily mobilizable fraction over a time scale of months or years (Nowack *et al*., 2010). This is possible because of its ability to exhibit variable states of +2 and +4. However, the crystalline metal phases are low (F5 and F6). This must have resulted from the fluctuations of the soil pH over a period of time because Nowack *et al*, 2010, suggests that the formation of these crystalline metal phases occurred within few months in soils with a neutral or alkali pH. Pb showed more redistribution pattern in the exchangeable fraction of the two months than found in the 3 months of the 5%. With the 10% and 20% (Table 5), the three months showed an improved distribution trend. The iron oxide fractions were the least among the seven fractions. A comparison of Lalupon soil with the results of oxides of iron in the two months of 10% and that of 20% showed that adsorption had occurred to a certain extent. However, lead was distributed more since a lot were found in the easily exchangeable fractions. The mobile phase was relatively low as noticed in other metals. Fractionation of the Ni that is present in LA-AB

The total concentration of Ni in the polluted sample was small compared to Zn, Pb and Mn (Table 6). It bounded majorly to the residual fraction (94.18%) and amorphous iron oxide (2.82%) (Table13). This according to Usman *et al*., (2005) resulted from the ability of iron hydroxide especially at neutral pH in lowering the nickel content in the solution. Kobya, (2004) suggested that nickel ends up in the soil where they were strongly attached to particles containing iron or manganese. Under acidic conditions, nickel was more mobile in soil and may seep into groundwater. From the Lalupon soil to the various results for incubations, Ni did not bound any of the mobile fractions. Similar trend occurs with the manganese oxide. There was good immobilization strength for the binding agents as we transverse from the two months to the three months speciation. This was noticed in the two fractions of the oxides of iron from 5, 10 and 20 percentages. The redistribution trend was low compared to what was obtainable in the metals considered so far. This signified that the metal was not as distributed as the trend observed in Pb, Mn and Zinc (Nowack et al., 2010). The mean contents of the various fractions for the 5% signified that LA-AB at 2 months immobilized better than LA-AB at three months, the 10% showed that the two months had a better immobilization efficiency considering the oxides of iron in particular.

Table 4: Fractionation of Zn (mean in mg/kg) in LA-AB

Fraction	**Mean±SD**	**2 months Mean±SD**	**3 months mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**
1	0.20±0.02	0.30±0.01	0.36±0.07	0.26±0.06	0.27±0.06	0.29±0.08	0.38±0.09

2	1.69±0.32	2.11±0.05	1.62±0.05	2.13±0.25	1.44±0.23	1.98±0.23	1.79±0.31
3	0.38±0.01	0.59±0.02	0.25±0.07	0.43±0.02	0.33±0.07	0.43±0.04	0.25±0.07
4	2.79±0.13	3.22±0.20	39.35±8.20	3.02±0.38	5.57±2.60	2.71±0.30	3.23±0.35
5	6.06±0.03	5.99±0.40	25.29±4.22	6.26±0.71	18.12±1.23	5.60±0.59	10.60±2.08
6	0.97±0.09	1.08±0.09	0.45±0.12	0.83±0.59	0.72±0.08	0.65±0.23	0.31±0.02
7	19.98±0.24	3024.09±.00	14.34±1.50	16.57±0.57	12.54±0.74	14.45±1.04	13.19±1.16
Total	32.07±22.06	3037.36± 0.77	81.65±57.75	29.49±20.85	38.99±27.57	25.60±18.11	29.74±21.03

Table 5 Fractionation of Pb (mean in mg/kg) in LA-AB

	Lalupon	5% Incubation		10% Incubation		20% incubation	
Fraction	Mean±SD	2 months	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD
1	48.05±22.98	60.10±29.84	114.50±6.79	60.55±17.32	111.75±0.64	47.50±1.84	121.66±2.76
2	2770.25±245.91	2747.50±590.43	4964.60±99.56	2515.00±770.75	4547.95±120.84	2597.50±	4328.70±153.87
3	336.30±41.41	341.25±73.89	45.16±1.47	251.50±22.63	24.86±1.94	223.50±159.97	16.64±2.09
4	2210.75±149.55	2167.50±109.60	2015.90±23.48	2005.00±106.07	1741.70±135.48	1625.00±56.57	1970.30±46.39
5	107.50±9.91	111.50±26.87	484.75±39.24	94.60±18.67	201.15±1.23	80.40±12.45	271.25±12.50
6	14.19±2.21	17.54±4.06	31.55±5.44	10.86±0.95	58.36±58.36	8.26±0.93	17.04±1.65
7	2392.70±173.52	1897.50±823.78	1256.63±80.08	2122.50±236.88	1042.25±84.50	2137.50±342.95	1305.75±29.34
Total	7879.74±5571.82	7342.89±5195.39	8913.09±6302.51	7060.01±4992.18	7728.01±5464.54	6719.66±745.86	8031.33±5679.022

Table 6 Fractionation of Ni (mean in mg/kg) in LA-AB

	Lalupon	5% Incubation		10% Incubation		20% Incubation	
Fraction	Mean±SD	2 months Mean±SD	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD
1	0.00±0.00	0.00±0.00	0.00±0.00	0.000.00	0.00±0.00	0.00±0.00	0.00±0.00
2	0.22±0.01	0.21±0.02	0.30±0.06	0.27±0.05	0.18±0.04	0.26±0.01	0.25±0.00
3	0.14±0.05	0.07±0.10	0.00±0.00	0.04±0.04	0.00±0.00	0.05±0.07	0.00±0.00
4	0.31±0.06	0.26±0.07	0.38±0.06	0.27±0.06	1.14±0.26	0.27±0.01	0.46±0.11
5	1.21±0.08	1.23±0.00	1.73±0.21	1.16±0.03	1.71±0.05	0.90±0.09	2.71±0.43
6	0.61±0.07	0.29±0.02	0.49±0.06	0.28±0.04	0.44±0.01	0.38±0.04	0.43±0.04
7	40.48±0.39	3.59±0.52	24.75±0.52	3.96±1.94	30.12±0.23	8.06±7.21	45.91±0.80
Total	42.98±28.62	5.65±4.00	27.64±19.55	5.98±4.23	33.59±23.75	9.93±7.01	49.76±35.19

Table 7 Fractionation of Mn (mean in mg/kg) in LA-EM

Fraction	Lalupon	5% Incubation		10% Incubation		20% Incubation	
	Mean±SDs	2 Months Mean±SD	3 Months Mean±SD	2 Months Mean±SD	3 Months Mean±SD	2 Months Mean±SD	3 Months Mean±SD
1	0.37±0.04	0.56±0.18	2.43±0.47	0.56±0.15	1.91±0.14	0.59±0.16	0.98±0.05
2	1.11±0.10	1.11±0.03	2.43±0.47	0.96±0.01	1.91±0.14	1.16±0.32	2.12±0.28
3	5.90±0.58	5.06±0.62	4.72±0.57	4.17±0.11	6.16±0.38	5.19±0.12	5.34±0.02
4	2.06±0.13	2.35±0.28	4.21±0.16	1.94±0.09	4.24±0.43	1.85±0.38	3.54±0.47
5	2.56±0.43	2.69±0.40	5.38±0.03	2.46±0.16	5.50±0.31	2.88±0.14	8.08±0.14
6	1.98±0.61	1.88±0.45	10.69±0.09	1.17±0.51	1.52±0.70	1.61±0.98	3.87±0.48
7	20.78±0.46	15.05±0.35	3.07±0.21	1.67±0.06	10.11±0.33	18.15±3.89	8.70±0.44
Total	34.75±24.58	28.69±20.29	32.92±23.29	12.91±9.14	31.33±22.17	31.42±22.22	32.62±23.07

Table 8: Fractionation of Cr (mean in mg/kg) in LA-EM

	Lalupon	5% Incubation		10% incubation		20% incubation	
Fraction	Mean±SD	2 Months Mean±SD	3 Months Mean±SD	2 Months Mean±SD	3 Months Mean±SD	2 Months Mean±SD	3 Months Mean±SD
1	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	0.05±0.07	0.00±0.00	0.00±0.00	0.08±0.02	0.00±0.00	0.05±0.07	0.00±0.00
7	6.28±0.70	9.80±4.64	37.64±3.55	7.12±1.17	37.98±1.80	7.79±0.13	6.49±2.73
Total	6.33±4.48	9.80±6.57	37.64±26.62	7.19±5.09	37.98±26.86	7.84±5.54	6.49±4.59

Table 9: Fractionation of Zn (mean in mg/kg) in LA-EM

	Lalupon	5% Incubation		10% Incubation		20% Incubation	
Fraction	Mean±SD	2 months Mean±SD	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD	2 months Mean±SD	3 months Mean±SD
1	0.20±0.02	0.28±0.02	0.45±0.09	0.30±0.08	0.52±0.08	0.33±0.07	0.40±0.06
2	1.69±0.32	2.25±0.14	1.88±0.21	2.44±0.62	1.60±0.09	2.01±0.95	1.74±0.23

3	0.38±0.01	0.49±0.05	0.59±0.17	0.43±0.12	0.41±0.14	0.48±0.07	0.32±0.02
4	2.79±0.13	2.74±0.33	13.05±2.57	2.38±0.38	5.56±1.92	2.39±0.48	4.01±0.21
5	6.06±0.03	5.90±0.59	33.91±0.27	5.70±0.70	35.33±5.06	6.40±0.04	24.61±2.41
6	0.97±0.09	0.70±0.12	0.26±0.07	0.81±0.15	0.70±0.19	1.00±0.21	0.32±00
7	19.98±0.24	15.67±0.67	10.15±0.38	18.00±o.74	14.02±0.83	17.62±2.03	12.27±0.87
Total	32.05±22.60	28.02±19.82	60.29±42.64	30.06±21.32	58.14±41.11	30.21±21.39	43.66±30.88

Table 10: Fractionation of Pb (mean in mg/kg) in LA-EM

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**
1	48.05±22.98	43.70±11.60	75.70±5.10	47.60±2.12	133.36±5.56	73.50±11.38	171.05±9.97
2	2770.25±245.91	3177.50±399.52	3910.55±50.28	2667.50±31.82	3658.20±89.38	2720.00±410.12	3519.90±130.67
3	336.30±41.41	240.50±49.50	204.90±20.93	229.25±46.32	33.31±16.67	289.50±36.06	28.54±0.74
4	2210.75±149.55	2017.50±81.32	2803.25±124.80	2397.50±781.35	2314.25±122.68	2510.00±926.31	2223.05±34.58
5	107.50±9.91	116.15±48.58	829.50±108.89	81.95±3.61	412.15±38.68	139.40±17.25	360.55±66.54
6	14.19±2.21	11.55±4.00	5.28±1.04	24.69±9.34	56.80±7.78	30.76±12.92	21.67±2.52
7	2392.70±173.52	2390.00±14.14	967.25±64.70	2117.50±24.75	1003.80±15.84	2740.00±1025.30	769.62±59.57
Total	7879.74±5571.82	7996.90±5654.66	8796.44±6220.03	7566.00±5349.97	7611.88±5382.36	8503.17±6012.53	7094.39±4996.31

Table 11: Fractionation of Ni (mean in mg/kg) in LA-EM

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**
1	0.00±0.00	0.00±0.00	0.15±0.01	0.00±0.00	0.19±0.03	0.00±0.00	0.00±0.00
2	0.22±0.01	0.26±0.03	0.25±0.00	0.26±0.06	0.26±0.07	0.30±0.02	0.53±0.05
3	0.14±0.05	0.00±00	0.19±0.03	0.00±0.00	0.18±0.02	0.00±0.00	0.09±0.01
4	0.31±0.06	0.34±0.11	0.57±0.11	0.31±0.08	0.41±0.07	0.31±0.08	0.46±0.01
5	1.21±0.08	1.14±0.15	1.91±0.11	1.02±0.05	2.28±0.19	1.20±0.02	1.65±0.10

Fractionation of the Mn that is present in LA-EM

Table 7 showed the mean and standard deviation of Lalupon soil sample, 5%, 10% and 20% **i**ncubation result for Mn. The mobile fraction was the least with mean values ranging from 0.37-1.19 mg/kg for the Lalupon soil sample and the incubated results. The exchangeable fraction was not so significant for the two and three months although some were more than the other. The three months of the 5, 10 and 20 percent were slightly higher than the corresponding two months. This implies that as the duration of incubation increases, the metal becomes more redistributed. A close look at the table above showed that the major bond of manganese to the residual fraction, the oxides of iron suggests that the metal under consideration may have a long-time availability if changes in soil chemistry and microbiology permits. The high value at the residual fraction suggests stability. The 5%, 10% and 20% all have low values for the easily available fractions (the mobile fraction and the exchangeable fraction), the manganese oxide, amorphous iron oxide and crystalline iron oxide have high mean values for all the percentages under consideration. The residual fraction is only low with 3 months 5% and 2 months 10%. The redistribution trend of this metal showed that some of the results of the speciation for the various incubation are higher than the mean content of the polluted site. This implies that the laterite samples contained this metal in a small amount as well. The three months result showed higher mean values (mg/kg) for the various mobile fractions and the exchangeable fractions while others are higher for the two months.

Fractionation of the Cr that is present in LA-EM

There was no adsorption in the mobile fraction, exchangeable fraction**,** manganese oxide fraction, organic matter, amorphous oxide. However, chromium adsorbed at the crystalline iron oxide fraction and the residual fraction in the two months while it only occluded at the residual fraction in the three months this further strengthened the ideal of Imai and Gloyna, (1990) that it was difficult to remove chromium from its concentrated fraction. The bound fraction of chromium to the residual fraction enhances its stability. The three months had higher amount in their residual fraction than the corresponding two months. Table 8 showed that the mean content for the polluted soil was 6.33mg/kg at the residual fraction while each of the result adsorbed higher, this suggested that the laterite samples used as binding agents contained this metal as well.

Table 10: Fractionation of Pb (mean in mg/kg) in LA-EM

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**	**2 months Mean±SD**	**3 months Mean±SD**
1	48.05±22.98	43.70±11.60	75.70±5.10	47.60±2.12	133.36±5.56	73.50±11.38	171.05±9.97
2	2770.25±245.91	3177.50±399.52	3910.55±50.28	2667.50±31.82	3658.20±89.38	2720.00±410.12	3519.90±130.67

3	336.30±41.41	240.50±49.50	204.90±20.93	229.25±46.32	33.31±16.67	289.50±36.06	28.54±0.74
4	2210.75±149.55	2017.50±81.32	2803.25±124.80	2397.50±781.35	2314.25±122.68	2510.00±926.31	2223.05±34.58
5	107.50±9.91	116.15±48.58	829.50±108.89	81.95±3.61	412.15±38.68	139.40±17.25	360.55±66.54
6	14.19±2.21	11.55±4.00	5.28±1.04	24.69±9.34	56.80±7.78	30.76±12.92	21.67±2.52
7	2392.70±173.52	2390.00±14.14	967.25±64.70	2117.50±24.75	1003.80±15.84	2740.00±1025.30	769.62±59.57
Total	7879.74±5571.82	7996.90±5654.66	8796.44±6220.03	7566.00±5349.97	7611.88±5382.36	8503.17±6012.53	7094.39±4996.31

Table 11: Fractionation of Ni (mean in mg/kg) in LA-EM

	Lalupon	**5% Incubation**		**10% Incubation**		**20% Incubation**	
Fraction	**Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**	**2 Months Mean±SD**	**3 Months Mean±SD**
1	0.00±0.00	0.00±0.00	0.15±0.01	0.00±0.00	0.19±0.03	0.00±0.00	0.00±0.00
2	0.22±0.01	0.26±0.03	0.25±0.00	0.26±0.06	0.26±0.07	0.30±0.02	0.53±0.05
3	0.14±0.05	0.00±00	0.19±0.03	0.00±0.00	0.18±0.02	0.00±0.00	0.09±0.01
4	0.31±0.06	0.34±0.11	0.57±0.11	0.31±0.08	0.41±0.07	0.31±0.08	0.46±0.01
5	1.21±0.08	1.14±0.15	1.91±0.11	1.02±0.05	2.28±0.19	1.20±0.02	1.65±0.10
6	0.61±0.07	0.26±0.01	0.34±0.07	0.32±0.06	0.22±0.02	0.43±0.04	0.31±0.04
7	40.48±0.39	4.71±2.71	40.23±1.27	2.98±0.44	33.34±1.83	3.63±0.09	6.11±0.32
Total	42.98±28.62	6.71±4.74	43.63±30.86	4.89±3.46	36.87±26.08	5.87±4.15	9.14±6.47

Fractionation of the Zn that is present in LA-EM

The mobile fractions were negligible in terms of mean concentration in the seven fractions; this was strictly followed by the exchangeable fraction. This denoted that the metal was not easily accessible to plants, Animals and so on. The Lalupon soil was majorly available at residual fraction and the amorphous iron oxide. A good proportion was present in the organic matter and the crystalline iron oxide. The laterites showed good adsorption strength in the 2 months of the 5% and the 2 months of the 20% (F5 and F6). The bonding of this metal to fraction 3-7 much more than the other two fractions was a positive development as against its presence in the exchangeable fraction. This implied that the metal would not be easily available to be redistributed in the water solution of the soil. Zn bounded the carbonate specie and therefore exhibited amphoteric nature which implies that it reacted with the carbonates in the soil as an acid and exists as carbonate bound species. However, a reduction in the acidity of the soil can lead to the release of this metal. The manganese oxide and oxides of iron were significant meaning that Zn was in a reducible form and only the microorganisms that are capable of reducing the Fe (III) to Fe (II) will cause the release of this metal. If this happened, Zn becomes mobile and bioavailable. The principle behind this speciation trend and preference for Fe/Mn bound specie are low polarization and high stability of Fe^{3+}.The 2 months of 5% showed that that laterite adsorbed better than the corresponding 3 months (F5 and F6). This similar trend was observed in the 10% as well. The crystalline iron oxide fraction of the 2 and 3 months showed that the metal was adsorbed on the iron and manganese hydroxide fractions.

Fractionation of the Pb that is present in LA-EM

The mobile fraction and the easily mobilizable fractions were high for the Lalupon soil but the exchangeable fraction was much more significant. The trend also cut across each incubation period. The organic matter content was very high for both Lalupon and all the speciation results. The iron oxide fractions and the manganese bound specie were low and the residual fraction was also very high for both Lalupon and the various results for incubation. This implies that at the polluted site the metal was in a redistribution trend. The low values observed for both Lalupon soil sample and the various speciation results for incubation suggest that this metal was available to metals probably as a result of the action of microorganisms (microbial decomposition, conversion of Fe^{3+} to Fe^{2+}, redox potential and so on) and the various management practices. This leads to the redistribution of the metal which is found in the exchangeable fraction than by the laterite sample. However, the higher value at the various residual fractions showed that stability since it was part of the silicate that was quite stable over time.

Fractionation of the Ni that is present in LA-EM

The distribution of Ni among the geochemical fractions was dominated by the residual fractions. The Lalupon soil had a total mean value of 42.98mg/kg. The 5% of the 2 months showed a total mean content of 6.33mg/kg and the three months contained a mean value (mg/kg) of 43.63. The 10% showed a total mean content of 4.89mg/kg for the 2 months and 36.87mg/kg for the 3 months. The 20% contained a total mean value of 5.87mg/kg for its 2 months and 9.14mg/kg for the three months. This showed that there were more Ni contents at each three months the respective two months. The mobile fractions of the 3 months of 5% and 10 % contained very little amount whereas there were no adsorptions in the other fractions. The exchangeable fractions were very low in all the speciation studies. The major contents were in the residual fractions and oxides of iron. The higher and quicker release of Ni at the residual fraction can be attributed to the metal complexation by soluble organic compounds (Gong and Donahoe, 1996).

Total metal concentration of the soil

The total metal concentrations of Zn, Pb, Ni, Mn and Cr in the polluted soil as well as the two laterite samples were determined by aqua regia and these cations were analyzed with AAS (Atomic Absorption spectrophotometry). The pseudo total metal concentration of the 5%, 10% and 20% incubation were calculated and the results were compared with the speciation results in table 12 (A) and 12 B above. The result obtained for the pseudo total metal was close to that obtained for the speciation result. The potential of laterite soils as an alternative binder was studied on a heavy metal polluted soil. This was done using variable proportions (5%, 10% and 20%) of the laterite for two and three months under incubation study with the polluted soil. The Zeinen and Brummer fractionation scheme was used in the environmental assessment of Pb, Zn, Cr, Mn and Ni in incubation analysis. The results obtained showed that manganese and Zinc bounded majorly to the residual fraction, iron oxide, amorphous oxide and manganese oxide fractions and they had the least mean content in the residual fraction. This signifies that the metal may have long term availability if changes in the soil chemistry and microbiology permit. The chromium and Nickel were bounded majorly to their residual fractions. This implies stability for them because they are part of the silicate that is quite stable over time. The lead (Pb) occurred more in the easily mobilizatible fraction than other fractions. This implies that the metal is in the redistributive phase and can penetrate the groundwater and find its way into the soil solution. The manganese and zinc held much more to the adsorptive phases of the laterite samples than Pb, Ni, and Cr.

Conclusion

The potential of laterite soils as an alternative binder was studied on a heavy metal polluted soils . this was done using variaable proportions (5%, 10% and 20%) of the laterite for two and three months under incubation study with the polluted soil. The Zeinen and Brummer fractionation scheme was used in the environmental assessment of Pb, Zn, Cr, Mn and Ni in incubation analysis. The results obtained showed that manganese and Zinc bounded majorly to the residual fraction, iron oxide, amorphous oxide and manganese oxide fractions. They had the least mean content in the residual fraction. This signifies that the metal may have long term availability if changes in the soil chemistry and microbiology permit. The chromium and Nickel were bounded majorly to the residual fractions. This implies stability for them because they are part of the silicate that is quite stable over time. The lead (Pb) occurred more in the easily mobilizable fraction than other fractions. This implies that the metal is in the redistribution phase and can penetrate the groundwater and find its way to the soil solution. The manganese and zinc held much more to the adsorptive phases of the laterite sample than Pb, Ni and Cr.

Table 12: Total metal concentration in incubated results: **Comparison of total metal concentration and the sum of metal fractions as determined by Zein and Brummer (1989) for 3 months speciation scheme for the polluted site.**

	5% LA-EM		5% LA-AB		10% LA-EM		10% LA-AB		20% LA-EM		20% LA-AB	
Heavy metal	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg))	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)
Mn	26.83	28.70	22.06	22.85	11.66	12.93	28.17	28.96	29.56	31.43	25.95	26.74
Cr	8.69	9.81	8.07	8.88	6.08	7.20	3.41	4.22	7.72	7.84	10.51	11.32
Zn	27.76	28.03	3037.01	3037.37	29.88	30.15	29.13	29.49	29.76	30.23	25.26	25.62
Pb	7996.45	7996.90	7346.58	7347.39	7565.55	7566.00	7059.20	7060.01	8501.34	8503.17	6710.65	6711.66
Ni	6.71	6.71	5.65	5.65	4.89	4.89	5.98	5.98	5.87	5.87	9.92	9.92

Table 12: Comparison of total metal concentration and the sum of metal fractions as determined by Zein and Brummer (1989) for 2 months speciation scheme for the polluted site

	5% LA-EM		5% LA-AB		10% LA-EM		10% LA-AB		20% LA-EM		20% LA-AB	
Heavy metal	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg))	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)	Total (mg/kg)	∑Fraction (mg/kg)
Mn	31.06	32.93	23.53	24.29	29.48	31.35	24.60	25.39	30.76	32.63	25.95	27.18
Cr	36.52	37.64	24.27	25.08	36.80	37.98	33.31	34.12	5.87	6.49	50.81	51.62
Zn	60.03	60.30	81.31	81.67	57.87	58.14	38.63	38.99	43.40	43.67	29.38	29.76
Pb	8796.00	8796.45	8912.64	8913.09	7611.43	7611.80	7727.25	7728.01	7085.40	7085.85	8030.53	8031.74
Ni	43.04	43.64	27.65	27.65	36.88	36.88	33.59	33.59	9.15	9.15	49.76	49.76

Pseudo- total metal was calculated as (∑fractions- total)

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