Research Article

Assessment of dominant heavy metals in selected solid waste dumpsites in Port Harcourt metropolis, Nigeria

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Abstract

The concentration of heavy metals in different solid waste dumpsites in Port Harcourt metropolis in Rivers State, Nigeria were assessed. The research was conducted at dumpsites with Lat: 4.9046^{o}N, Lon: 6.9630^{o}E and Lat: 4.9046^{o}N and Lon 6.9630^{o}E for dormant and active dumpsites respectively while control site was sampled 100m away from the various dumpsites on Lat: 4.9044^{o}N and Lon: 6.9628^{o}E.The systematic sampling technique was adopted and dominant plant species were harvested alongside soil samples at depth0-10m from the various sites. Results showed increase in concentration of Pb, Cd, were high at the various dumpsites. Highest concentration of soil Pb, Cd, total nitrogen and phosphorus was found at active dump site. Increase in soil potassium and cation exchange capacity was found at the control site. Findings also showed that among the dominant plant species present at the sites, *Cyperusiri a*ccumulated high amount of Cd and Pb at active dumpsite while *Talinum triangulare* showed accumulating affinity for Pb at dormantsite. The results suggest that toxic nature of heavy metals affect plants by altering its growth substrate and *Cyperusiria* is seen as potential hyperaccumulator and should be considered for phytoextraction of Cd and Pb.

Keywords: heavy metals, dumpsites, systematic sampling technique, *Cyperusiria*.

1. Introduction

The process of waste disposal system in Nigeria contribute to increase in the concentration of heavy metals in the environment, poor waste management are among the main factors which triggers environmental perturbation since the traditional way of waste disposal system is still practiced in Nigeria (Huget *et al*., 2009). The

environmental pollution emanating from solid waste land filling (SWL) is now gaining much concern to both environmental scientist and concern citizens. The awareness on waste disposal system gain popularity in recent years due to environmental hazard caused by this process (Igwe *et al*., 2002). The landfill in Nigeria is seen as a potential disposal site, most of which are open and uncontrolled dumpsites. Solid and liquid

waste generated are disposed into a landfill untreated hence exposing the hazardous nature of this pollutant to environment particularly underground water through leaching process (Igwe *et al*., 2002). Although deposition of wastes from heavy metal industries into landfills without special precautions has been reported (Kimani, 2007). The inappropriate dumping of these refuse has led to the introduction of many harmful substances into our environment which poses threat to our society. Improper management of solid waste is one of the main causes of environmental land pollution (Kimani, 2007). Land pollution by component of refuse such as solid wastes has been of great concern in the last decades because of their health hazards to man and other organisms when accumulated within a biological system (Igwe *et al*., 2002). Solid wastes are obtained as a by-product of normal and necessary activities of living. These wastes are generated from areas such as food scraps, ash from fires, excreta from humans and animals, municipal garbage, waste steel from automobiles and mine tailings. The tendency of exposing these pollutant through waterways after rainfall by erosion to surface water system (rivers, stream and ocean) is highly promising. Environmental pollution caused by heavy metals is obvious in streams and lakes and in ground water, which is replenished directly from surface water (Huget *et al*., 2009). Heavy metal which is the most abundant pollutant present in dump site have the ability to pollute the air, water and soil. The most prevalent group of heavy metals found in dumpsite have no essential benefit to human health. Increase in heavy metal concentration in dumpsites especially can be attributed to various point of waste generation and collection point, most of these points of waste collection are not properly segregated and hence they are mixed with industrial effluent and clinical waste with high level of heavy metal content (Rajaram *et al*., 2020). Most plants especially vegetables are found predominantly in the dumpsites, these plants growing around these areas are likely to absorb these metals as mobile ion in solution phase from the soil through their root system and subsequently from the atmosphere through their

leaves (Fifield and Haina, 1997). Close residents tend to harvest some of these vegetables hence making it available to the higher consumers, plant species found in areas with records of high level of heavy metals are unsafe for human consumption noting the negative effects of heavy metal on living organisms (Rajaram *et al*., 2020). Heavy metals are non-biodegradable, as a result, they persist in the environment and their concentrations in soil increase overtime and hence when present in excess they bioaccumulate along food chains (Rajaram *et al*., 2020).

2. Materials and Methods

2.1 Study Locations

In this study within the waste dumpsite located along Rumuosi farmland off Airport Road Port Harcourt, two solid waste dump sites were selected along this sampled area. The dump sites were located on Latitude 4.9046^oN, Longitude 6.9630^oE and 4.9046^oN and Longitude 6.9630^oE for dormant and active dump sites respectively. A control site was located at a distance of 100m away from the dump sites on Latitude 4.9044^oN and Longitude 6.9628^oE.

2.2 Samples Collection/ Preparation of Soil Samples

Sampling was done systematically. A transact line was laid across a mapped out area of 20m by 20m, and a quadrant of 1m by 1m was placed on the marked point on the line. Sampling was done at 5m interval all the way down the line given a total of four sample plots at each site. Soil samples were obtained at 0 - 15m using soil augur, and the most dominant plant species were also collected. The soil and plant samples were placed in an ice-pack and transported to the laboratory for analysis. The soil samples were air-dried using a bulb for 1 month to constant weights. The samples were grounded after drying and sieved using a 2mm wire mesh sieve and the coarse particles were discarded. The powdered form was then stored for digestion and subsequent analysis of heavy metals and physiochemical characteristics. Plant samples were washed with

distilled water to get rid of all adhering soil and was dried to constant weight. Each dried sample was ground to fine powder using a wearing blender (Model type A 10 Janke and Kunkel GBH). The samples were then stored for digestion and subsequent analysis.

Plate 3.1: Active Dump Site

Plate 3.2: Dormant Dump Site

2.3 Digestion of Samples

2g of 2mm sieved plant sample was placed in a crucible and incinerated in a furnace at $500^{o}C$ for 4h. The ash was then dissolved in 5ml of 20% HCl and filtered using an acid washed filter paper. The volume of the filtrate was increased to 50ml using distilled water and concentrations were read using Atomic Absorption Spectrophotometer. 2g of air-dried soil sample accurately weighed and then transferred into a 250ml conical flask and was placed in the fume hood. A measured volume of well-mixed perchloric acid, nitric acid and sulphuric acid were added into the flask containing sample in the ratio of 1:2:2. The sample was heated for about 15-20mins on a hot plate till a white fume was observed, and was allowed to cool. 20ml of distilled water was added after cooling and transferred into a 100ml volumetric flask after filtering using Whatmann 42 filter paper and diluted to 100ml with distilled water. The extract was then taken for subsequent analysis of heavy metals of cadmium and lead. The concentrations of cadmium (Cd) and lead (Pb) in the digested soil and plant samples were determined using Atomic Absorption Spectrophotometer (PG Instrument AA 500 Spectrophotometer) following the methods described by Ebong *et al.,* (2008).

2.4 Determination of Cation Exchange Capacity (CEC)

A quantity of 30 mL of 1 part of ammonium acetate solution was added to 5g of oven dried sample and stirred for 15 minutes. The supernatant was decanted into 1000 mL capacity flask. After repeating process twice the extracted supernatant was made up to 100 mL by the addition of ammonium acetate solution. The amount of calcium, potassium, sodium and magnesium in samples were determined using Atomic Absorption Spectrophotometer (AAS) (BUCK scientific 200A model).The CEC was obtained and mean soil cation exchange capacity of different location was calculated and expressed in meq/100g of the sample.

2.5 Determination of pH

10g of 2mm sieved, air-dried soil was put into a 50 ml plastic beaker and 25ml of distilled water was added and the mixture was stirred for 10 minutes and allowed to stand for 1hour. The electrode of the pH meter was then immersed into the beaker but it was prevented from touching the bottom of the beaker. The pH reading was taken after 30secs, so as to allow steady reading (Carter, 1993).

2.6 Determination of Total Nitrogen content.

This was determine by spectrophotometry. A blank solution (25ml of sample supernatant only) and sample solution (25ml of supernatant + nitraver-5 nitrate reagent powder) were prepared. The blank solution was placed in spectrophotometer (HACH, DR/890 colorimeter model) cell holder and the reading of the blank solution as displayed by the spectrophotometer was zeroed. The blank solution was substituted with the sample solution, and its nitrate content as displayed by the machine was read and recorded. Mean total nitrogen of treatment was calculated and expressed as percentage (%).

2.7 Determination of Phosphate (APHA 4500)
Soil samples (2g) were added with 40 ml of Olsen's extracting solution was added which was then filtered using whatmann filter paper. Five (5) ml of the filtrate was measured into 25 ml measuring cylinder and 10 ml of distilled water was added along with 4 ml of B-reagent which was added to 25 ml mark with distilled water. This was allowed for 10 mins and the absorbance readings was taking using the T60 UV visible spectrophotometer.

2.8 Determination of Potassium (APHA 4500)

Soil samples (5g) were weighed in 100 ml conical flask containing 25 ml of 1 N NHAOAc solution. The mixture was shake for 5 mins using mechanical shaker then filtered with whatman No 1. Filter paper. Potassium extract was obtained by Flame Industrial Photometer model 410.

2.9 Data Analysis

The data generated were subjected to statistical analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2002) to test the significant.

3. Results

Heavy Metal Content in the Study Locations

Result showed high level of cadmium (Cd) and lead (Pb) content in the study locations (Fig 1 and 2). The highest in Cd soil concentration was found at the active dumpsite closely followed by dormant dumpsite as compared to the reference or control site (Fig 1). Similarly, increase in Pb concentration was observed with active dumpsite site showing the highest Pb concentration as compared to dormant site and control site (Fig 2). There were significant statistical difference in the mean accumulation of Cd and Pb at (P =0.05).

Fig 1: The mean concentration of Cd in the study locations

Fig 2: The mean concentration of Pb in the study locations
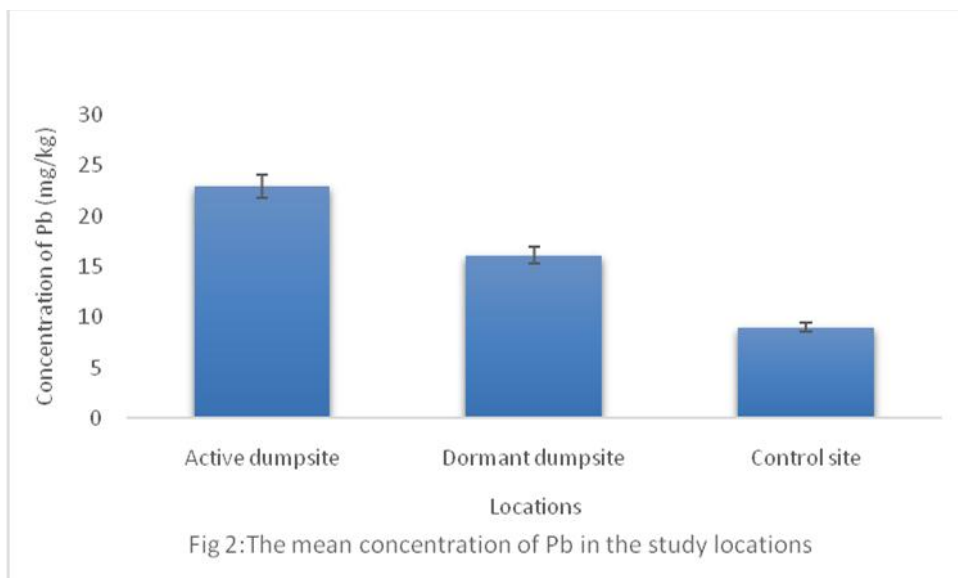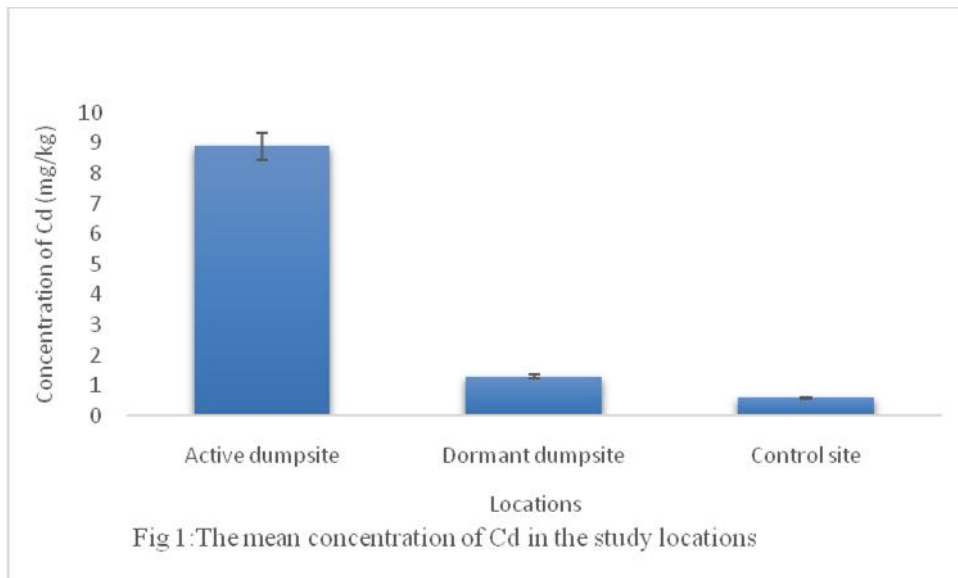
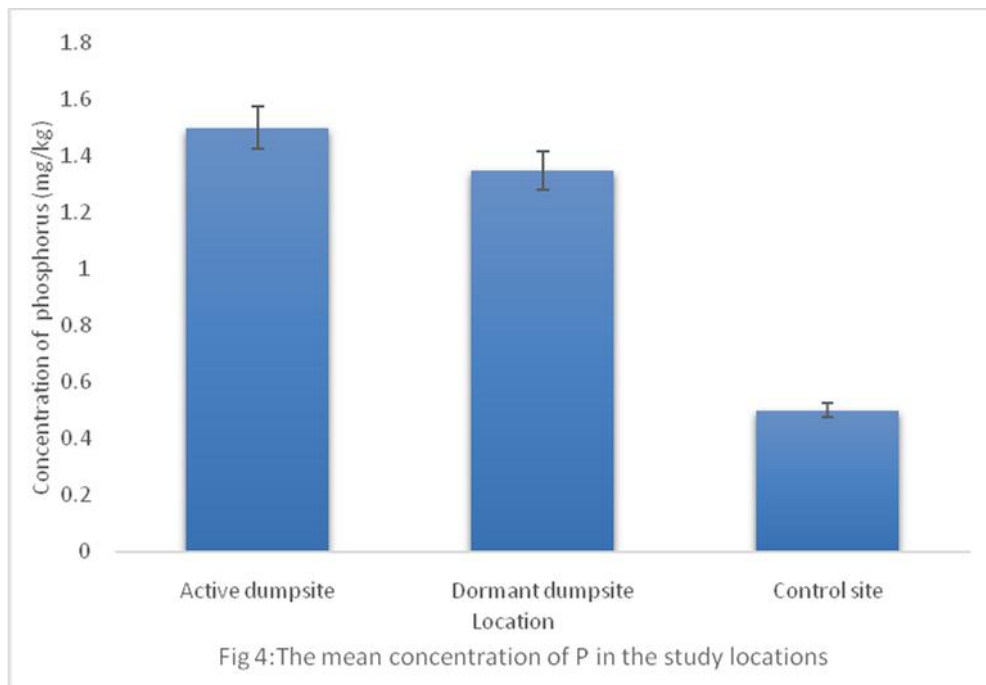**Soil chemical properties.**

Result showed decrease in concentration of potassium in active and dormant dumpsite when compared to the control site. The least decrease in soil potassium was recorded in active dumpsite while the control or reference site has the highest soil potassium concentration (Fig 3). There were significant statistical difference in the mean concentration of potassium at (P =0.05)

Fig 3:The mean concentration of K in the study locations
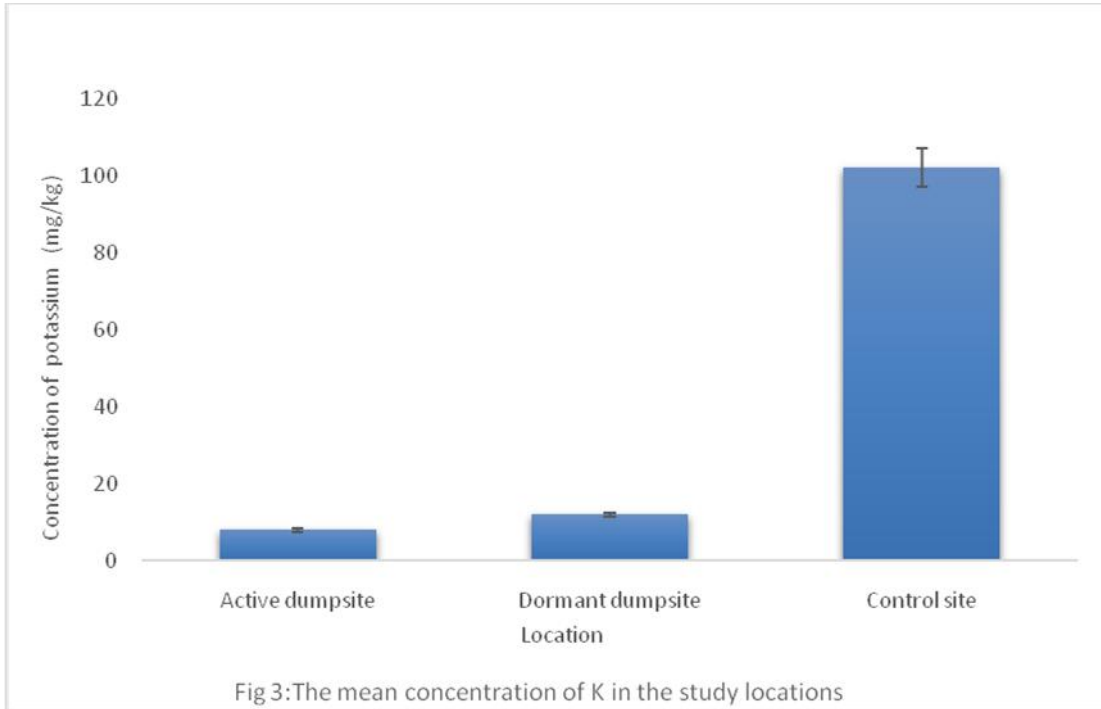
In Figure 4. Result showed increase in concentration of phosphorus in active and dormant dumpsite when compared to the control site. The least decrease in soil phosphorus was recorded in control site while the active dumpsite showed the highest concentration of phosphorus. There were significant statistical difference in the mean concentration of phosphorus at (P =0.05)

Fig 4:The mean concentration of P in the study locations

In Figure 5. Result showed decrease in concentration of cation exchange capacity (CEC) in active and dormant dumpsite when compared to the control site. The least decrease in soil CEC was recorded in active dumpsite while the highest increase was recorded for the reference site. There were significant statistical difference in the mean concentration of CEC at (P =0.05).

Fig 5:The mean concentration of P in the study locations
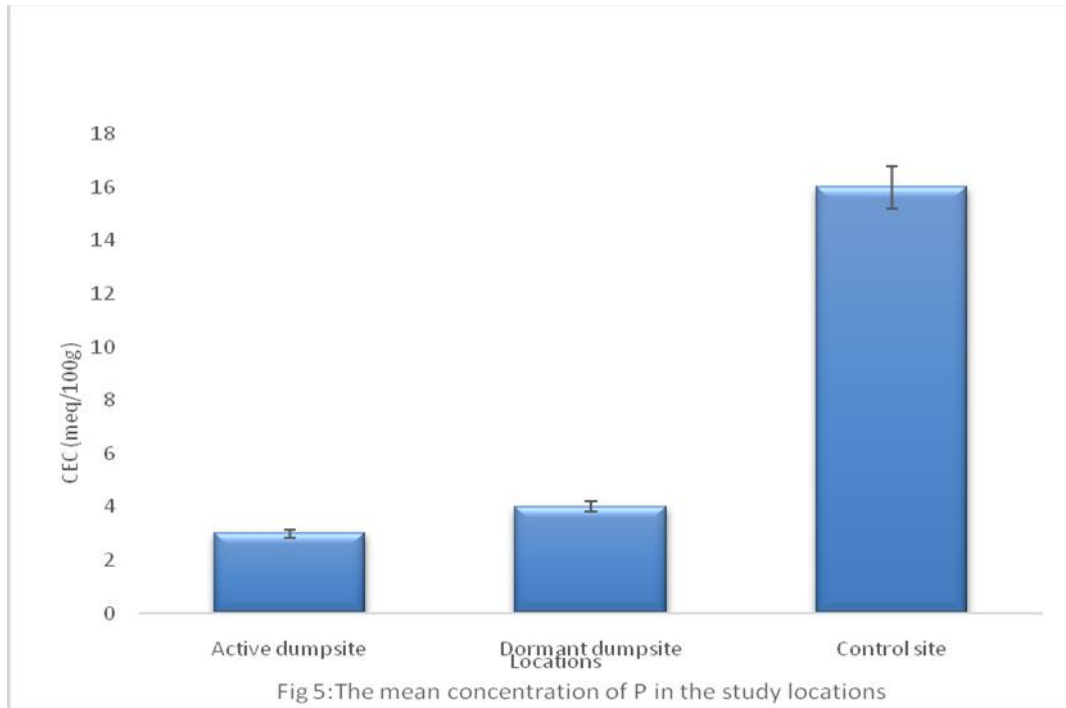
Result showed the level of soil pH in the study sites. The pH level in all locations was slightly above neutral. Higher pH level was observed in the dumpsite as compared with the reference soil. The highest in pH level was recorded in active dumpsite while the least decrease in soil pH was recorded in control (Fig 6). There were significant statistical difference in the mean concentration of pH at (P =0.05)

Fig 6:The mean concentration of pH in the study locations
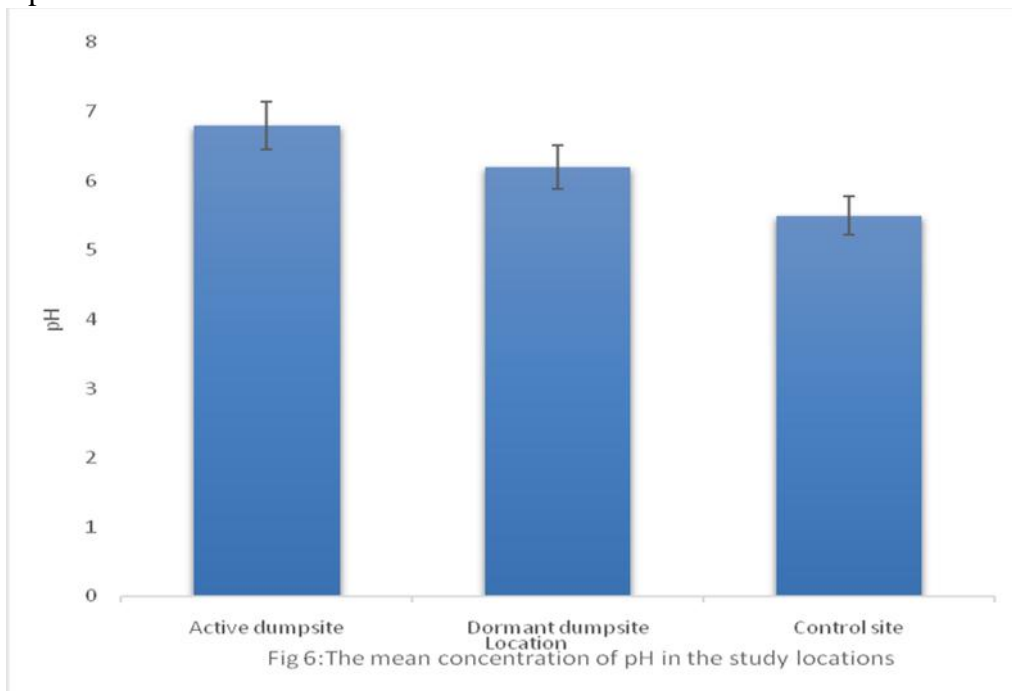
Result showed the level of soil total nitrogen content in the study sites. Higher total nitrogen content level was observed in the active and dormant dumpsites as compared with the reference soil. The highest in total nitrogen content level was recorded in dormant dumpsite while the least decrease was recorded in control (Fig 7). There were significant statistical difference in the mean concentration of TN at ($P = 0.05$).
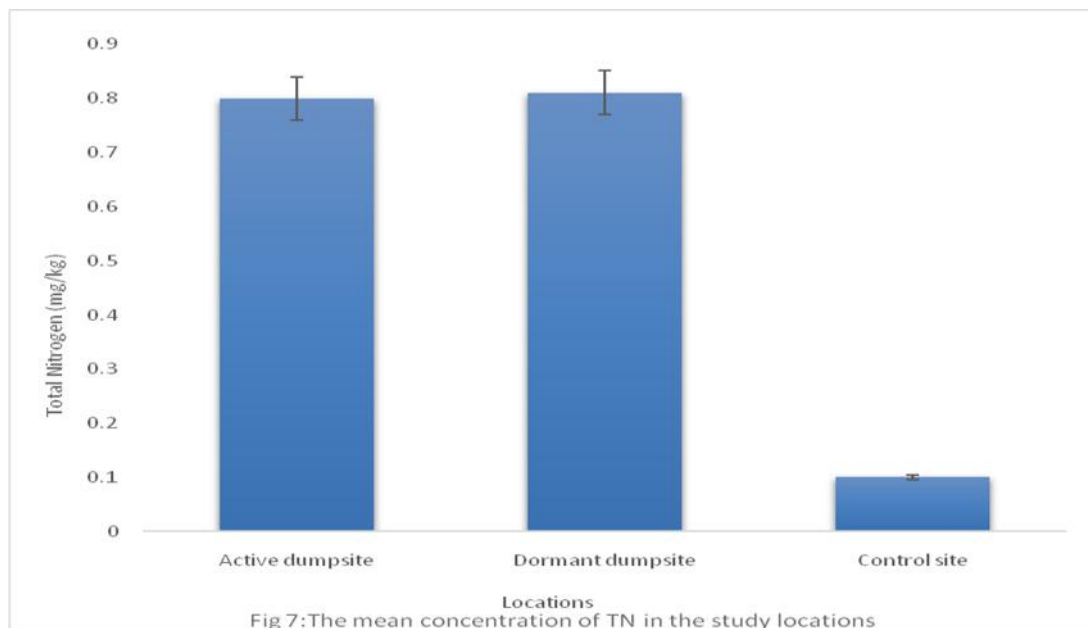

Fig 7: The mean concentration of TN in the study locations

Concentration of Heavy Metal in Plant

The variation of the abundant plant species in the study locations in term of heavy metal accumulation rate was observed. *Phylathus amarus* showed the highest increase in the accumulation of cadmium (Cd) in all study locations with an overall increase in Cd concentration at the active dumpsite. The least in Cd plant accumulation was recorded for *panicum* sp at active dumpsite and *Talinum triangulare* at dormant dumpsite. The least in Cd plant accumulation was found in *Calapogonium* sp in the control site and slight decrease was recorded in dormant site as shown in Figure 8. There were significant statistical difference in the mean concentration of cadmium in plants at ($P = 0.05$).
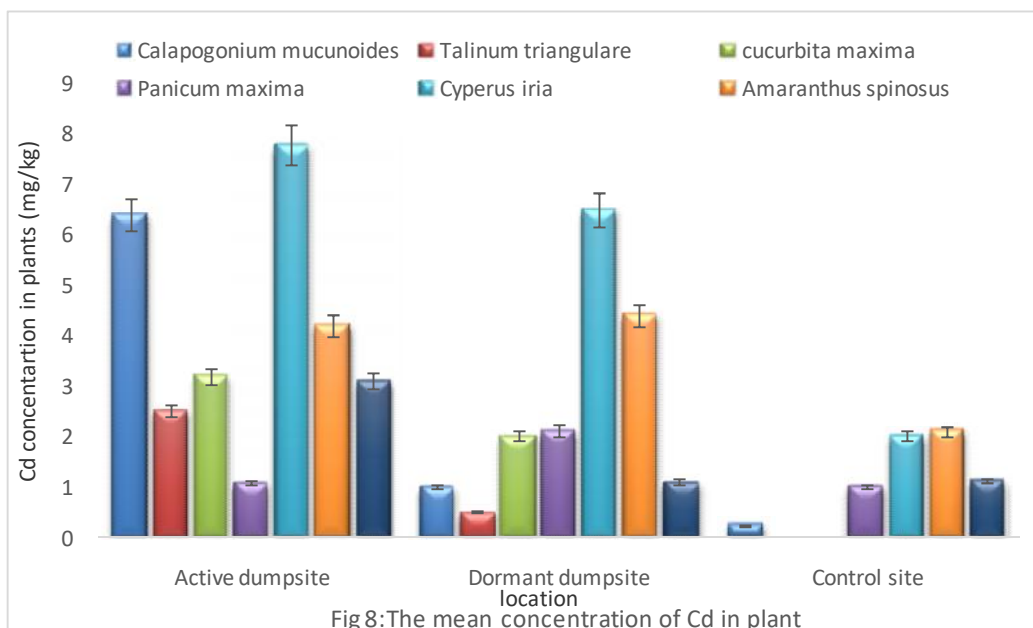

Fig 8: The mean concentration of Cd in plant

The variation of the abundant plant species in the study locations in term of heavy metal accumulation rate was observed. *Cyperus iria* showed the highest increase in the accumulation of lead (Pb) at active dumpsite and dormant dumpsites. *Talinum triangulare* showed an increase in Pb accumulation at dormant dumpsite.

The least in Pb plant accumulation was recorded for *Phylathus* sp at active and dormant dumpsite. The least in Pb plant accumulation was found in *cucurbita* sp in the control as shown in Figure 9. There were significant statistical difference in the mean concentration of Pb in plants at (P =0.05).

Fig 9:The mean concentration of Cd in plant
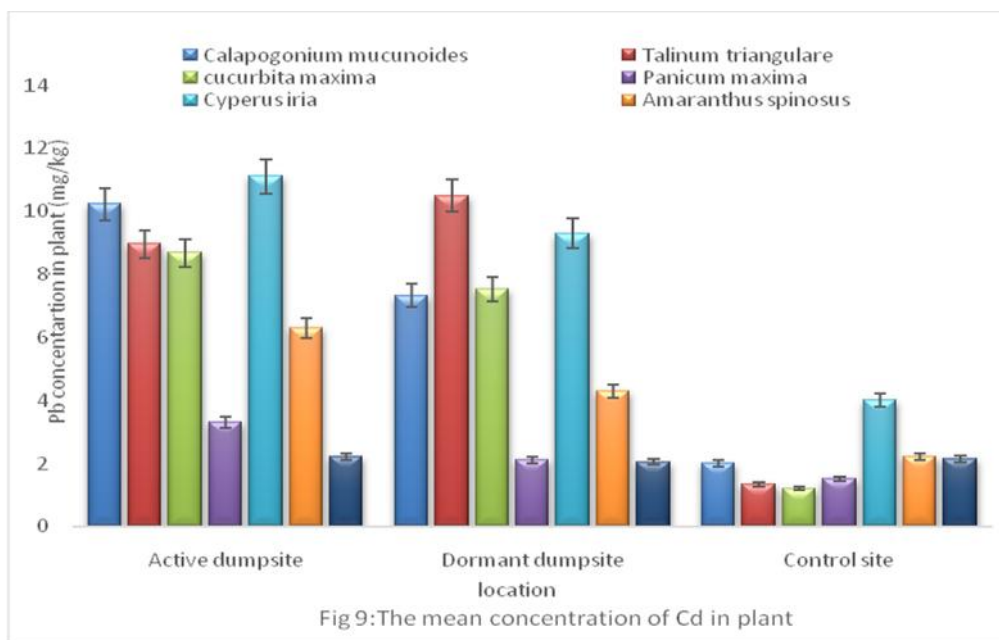
4. Discussion

The indiscriminate disposal of unsegregated and untreated waste into a land-fill is responsible to the current environmental challenges faced by man. Presently, it has been reported that untreated and unscientific waste disposal practices contribute to warming of the environment (global warming). The untreated waste discarded into the environment contain considerable amount of heavy metal, and it has also seen as a known source of heavy metal contamination, which also pose serious threat to soil and groundwater since they cannot be degraded (Amusan *et al.* 2005). The highest increase in cadmium and lead found in the active dumpsite than dormant site could be associated with the on-going waste discharge. This resolution is considerable, since the untreated collected waste from different areas are transported directly to the dumpsite. This result corroborate with the findings of Amusan *et al.* (2005) who conducted an experiment on the

sources of discharge of heavy metals in the environment and reported most heavy metals pollution in the soil was associated with the massive dumping of solid waste. This proposition also agrees with the findings of Dara (2010) who reported that the major source of lead and cadmium accumulation at dump sites is the waste source from industries. In addition, any nearby industry that disposes lead and cadmium as part of its wastes can also influence their concentration in the dumpsite. Least decrease in heavy metals in control or reference soil could be attributed to decrease in anthropogenic activities through soil waste disposal which was not experienced around this area hence the decrease in heavy metal content. This assertion is in agreement with Amusan *et al.* (2005) who reported a decrease in heavy metal content in areas with less human activities, increase in anthropogenic interference always result to increasing heavy metal concentration in the environment.

In this study it was found that the soil potassium content and cation exchange capacity were highest in the control site with no knowledge of soil waste than the actual dump sites (dormant and active). An increase in k content could be attributed to the presence of high leaf litter debris found on the soil which is seen as a group of low molecular weight organic acid which are easily degradable by microorganisms and hence increase soil k content. In addition, potassium is a cation which is generally known with its affinity in soil. Decrease in pH which gives rise to an increase in hydrogen ions (H+) increased mobility of positively elements into solution phase. This discovery could be true because, it have been accounted that decrease in pH of soil increase the availability of cationic element (Jarrod, 2016). The highest increase in soil phosphorus and total nitrogen content in the dumpsites is understood to originate from the composition of wastes since most of the wastes are generated from household having increase in organic matter content. Studies by Ideriah *et al*. (2010); Amos-Tautua *et al*., (2014) also explained that solid waste dumpsite is rich in organic matter which appear as the source of most soil nutrient, and also, the activities of microorganisms in decomposing these waste further put the nutrient in solution phase hence their increase availability. In this study it was also found that higher pH value was recorded in the dumpsite that the control site. Similar observation has been recorded by Ideriah *et al*., (2006), who reported liming materials found in the disposal waste and the activities of microorganisms are responsible for the increase in pH levels of soil found in dumpsite. *Cyperus iria* shown an increase in the accumulation of cadmium and lead content in their biomass and the highest in cd and pb accumulation rate was found in the active site. The possible explanation to this variation could be attributed to inherent ability of the plant species to survive in such area since they showed a high species richness and evenness and the increase in heavy metal accumulation in the active dumpsite could be attributed to the concentration and the availability of these metals to plant since it was also observed solubility of soil nutrients and metals content correlate with pH level (Ideriah *et al*., 2006). This assertion also agrees with Amadi

et al. (2018) who reported that plants has inherent ability to accumulate a wide range of metals from soil and the metal uptake of mechanism from the soil is a function of the metal concentration and availability in the soil also accepting that the rate of absorption and uptake is influenced by the bioavailability of the metals which is in turn determined by both external (soil associated) and internal (plant-associated) factors.

5. Conclusion

The result of this investigation showed that the presence of heavy metal concentration is proportional to the nature and volume of waste present in the dumps. It is worth mentioning here that huge heavy metals present in the dormant and active sites can be reduced if solid waste can be properly segregated from the point of collection to decrease the amount of metal prone materials such as galvanized scraps, used refrigerators, computers, cables, printers, photocopy machines, automobile tyres, batteries, air condition from reaching the dumps while liquid waste should be treated before discharge to avoid contaminating ground water and surface water through leaching and erosion respectively. Furthermore, the dormant dumps seem to be a good breeding ground for the identification and selection of plant species with high phytoremediation potential.

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