

Research paper

Levels of Heavy Metals in and Around Scrap Car Dumpsite at Uwelu, Nigeria

ABSTRACT

Soil contaminated with heavy metals can result to very serious environmental hazard. As a result of this problem, this research was carried out to investigate the concentration of heavy metals (Fe, Zn, Pb, Cu and Cr) in and around Uwelu scrap car dumpsite. In carrying out this research, soil samples were collected at various depths at the dumpsite, and at various horizontal distances from the dumpsite including human settlements close to the dumpsite, in order to ascertain the levels of toxic heavy metal concentration on human living habitat around the dumpsite. Di-acid digestion and DTPA extraction methods were used to extract the metals from the soil. The analysis of the heavy metals was then carried out using atomic absorption spectrophotometer (AAS). The results show that Fe had the highest concentration of 515mg/kg, followed by Zn, 236.8mg/kg, Cu, 78.61mg/kg and Cr, 0.5mg/kg at the dumpsite surface, where all the metals recorded their highest concentration. The level of Fe and Zn were above the FEPA minimum acceptable limit. Besides, the concentrations of these heavy metals decreased with increased vertical depth at the dumpsite and with increased horizontal distance from the dumpsite. Similar trends were observed for the various soil pH.

Keywords: Heavy metals, dumpsites, scrap car, soil, horizontal distance, vertical depth

1. INTRODUCTION

Presently, in most cities in Nigeria scrap car dumpsites are located in and around human settlements, very close to motor mechanic workshops and fairly used motor spare parts markets. The absence of metals recycling systems in most cities in Nigeria have resulted to gradual accumulation of scrap motor parts as well as scrap motors (which can either be cars, lorries and motor cycles), which later becomes heaps, known as scrap car dumpsites. The presence of used/worn-out scrap car parts and scrap motor vehicles at the dumpsites causes soils, underground water and surface water contamination. The pollutants are mainly toxic heavy metals such as Fe, Pb, Zn, Cu, Cd etc. The sources include motor vehicle parts, scrap tyres/rubber. After corrosion these metals gets leached into the environment causing serious pollution. Scrap cars pollution from heavy metals is a major environmental concern worldwide [1]. Heavy metals are natural components of the Earth's crust, which cannot be degraded nor destroyed [2]. Their presence in high levels can endanger the ecosystem, plants and animals and cause severe health problems in humans, animals and plants. However, some heavy metals (trace elements) such as copper, selenium and zinc are essential to maintain the metabolism of the human body [3]. Nevertheless, at higher concentrations they can lead to poisoning [4]. Heavy metals are dangerous because they

tend to bioaccumulate, that is, build up within the biological systems over time. Trace elements accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Studies have revealed that various factors such as presence or absence of other ions, pH, temperature and residence time can affect the sorption/desorption process of heavy metals from soils, soil clay fractions, and other soil components [5-7].

The awareness of this fact has led to increased scientific and public attention to level of toxicity exerted by these metals in the environment. This has resulted in governments the world over, funding research in new methods of analytical determination of concentrations of heavy metals in soil at waste dumpsites in particular, and the methods of treating industrial effluents so as to reduce the effect of these metals on the environment. The effects include:

- destruction of eco system,
- destruction of marine biota,
- hindering of fisheries and other aquacultural operations,
- poisoning of sea food, contamination of surface and underground water,
- disturbances of soil function,
- reduction of plants productivity and chance of survival etc.

The aim of the study was to ascertain the concentration of heavy metals, and the extent contamination of human living habitant in and around scrap car dumpsite.

2. MATERIAL AND METHODS

2.1 Sample collection and preparation

Soil samples were collected using polythene bags from in and around Uwelu scrap car dumpsite, Benin City, Nigeria. The samples were collected at various vertical distances (depths) up to 1.6m at the dumpsite and 18m from the dumpsite. Also, at various horizontal distances from the dumpsite up to 15m. The soils were air-dried at laboratory temperature ($30 \pm 2^\circ\text{C}$) for 6 days and then ground and passed through 2 mm sieve to obtain the soil fraction used.

All the reagents were of analytical grade and were obtained from Chemical Engineering laboratory store, University of Benin, Benin City, Nigeria.

2.2 Heavy metals extraction and determination

Di-acid (Concentrated HNO_3 : 70% HClO_4 , 5:1) digestion method and DTPA (0.005 M DTPA-0.01 M TEA, 1:2) extraction methods were used to extract the heavy metals (Fe, Zn, Pb, Cu and Cr) from the soil [8]. The metal contents were measured using atomic absorption spectrophotometer (AAS).

3. RESULTS AND DISCUSSION

Figure 1 shows the variation of pH with vertical distance at the dumpsite and at 18m from the dumpsite. It can be seen that the pH values decreased with increased vertical distance. This might be as a result of the fact that soil acidity was produced by mineral leaching from the corroded metal parts, industrial wastes, acid rain and certain forms of micro-biological activity as previously reported by Xin, [9]. In addition, the decreases in heavy metal concentrations with vertical distance give a very good clue to the decreasing value of pH with increasing vertical distance.

Figure 2 shows the variation of pH with horizontal distance from the dumpsite. The pH was 5.9 at the dumpsite and 4.7 at 15m from the dumpsite. The decrease in pH might be as a result of decrease in alkalinity due to the decreasing concentration of heavy metals with horizontal distance. However, at the dumpsite, there was an increase in pH from 4.9 at a depth of 0.8m to 5.1 at a depth of 1.2m. This occurrence might be as a result of non-uniformity in the mobility of minerals down the soil profile. This phenomenon was also

observed in pH values at horizontal distance between 12m and 15m from dumpsite. Comparing the pH values at the dumpsite with pH values at 18m from the dumpsite (in and around human settlement), it was found that at a depth of 1.2m the pH values have the same value of 5.1. Federal environmental protection agency FEPA, [10] reported that Nigeria soil pH is usually between 5 and 8. This implies that the soils at the dumpsite and in the neighborhood (within 18m from the dumpsite) were within the acceptable soil pH limit.

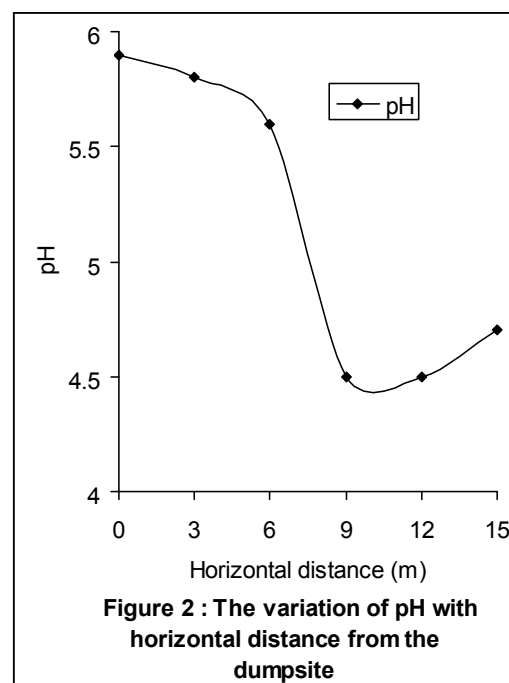
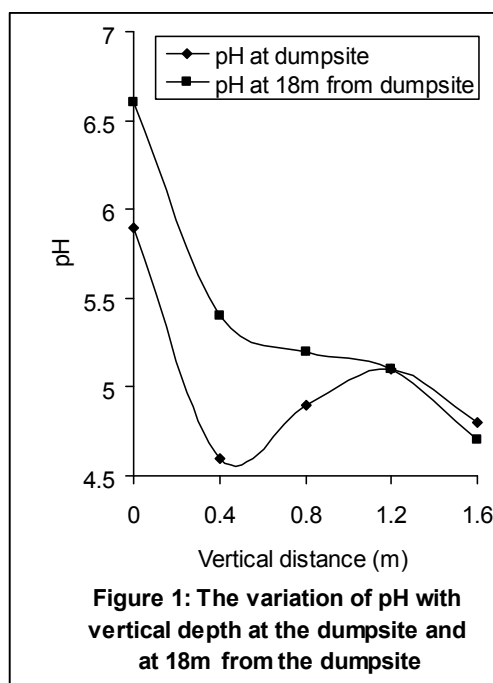
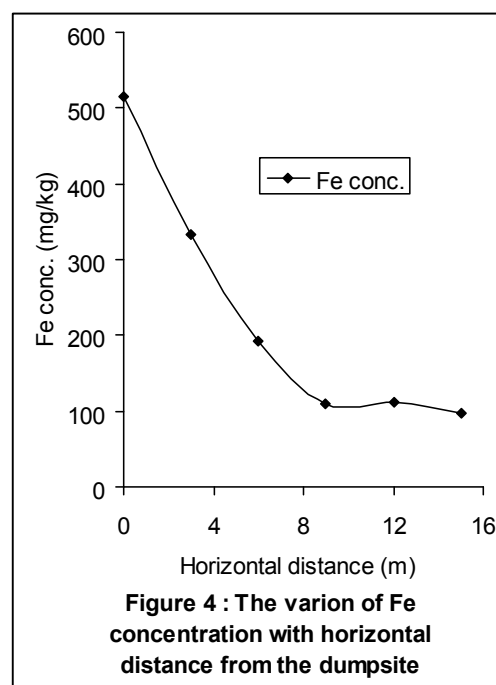
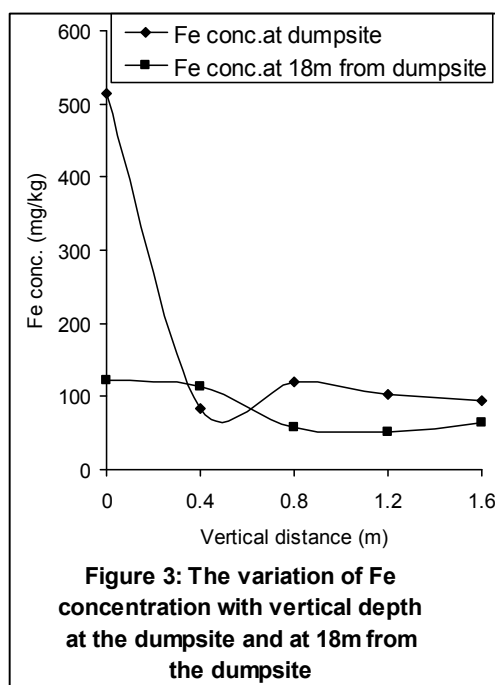


Figure 3 shows the variation of Fe concentration with horizontal distance from the dumpsite. The Fe concentration was highest (515mg/kg) at the dumpsite surface. This was above the FEPA maximum acceptable limit [10]. This might be due to the fact that most motor vehicle parts, and scrap vehicles dumped at the dumpsite are mainly made of iron, which corrode very fast when exposed to environment conditions. The results also show that there was a sharp decrease in Fe concentration from 515mg/kg at the surface of the dumpsite to a value of 84.9mg/kg within 0.4m depth. This is because iron is strongly adsorbed and retained by soil [9,11]. Thus, with this high retention and adsorption, Fe could not be effectively leached down the soil profile, hence the low Fe concentration at depths below the surface. Some researchers have reported that soil with coarse texture has a higher infiltration rate than soil with fine texture [12]. The visual inspection of the soil around the dumpsite shows that the soil has fine texture. This can also explain the low concentration of Fe down the surface of the dumpsite. Also, the concentration of Fe on the surface at 18m from the dumpsite (neighbourhood) was found to be 122.5mg/kg, which was higher than the concentration at 0.4m depth at the dumpsite. This might be as result of the fact that the mobility of Fe was by soil erosion rather than leaching. The variation of Fe concentration with increased depth at 18m from the dumpsite was similar to that at the dumpsite. Between the depths of 0.8m to 1.6m, the concentration of Fe was found to be almost constant at both the dumpsite and at 18m from the dumpsite. This might be as a result of very little or no leaching process taking place between this depths. However, the Fe concentration was within FEPA acceptable limit [10].

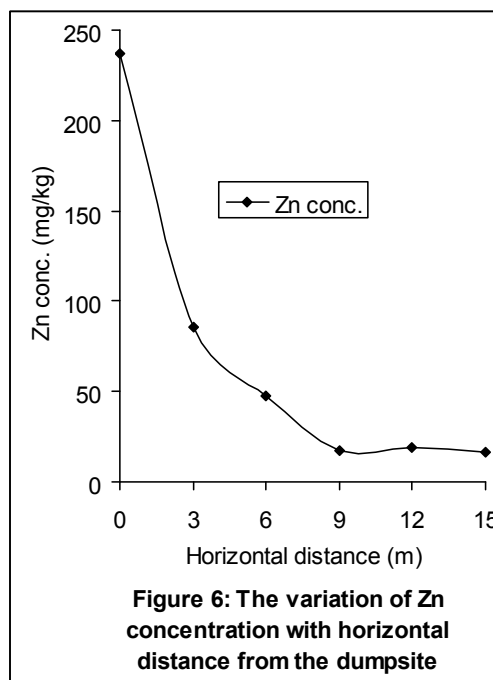
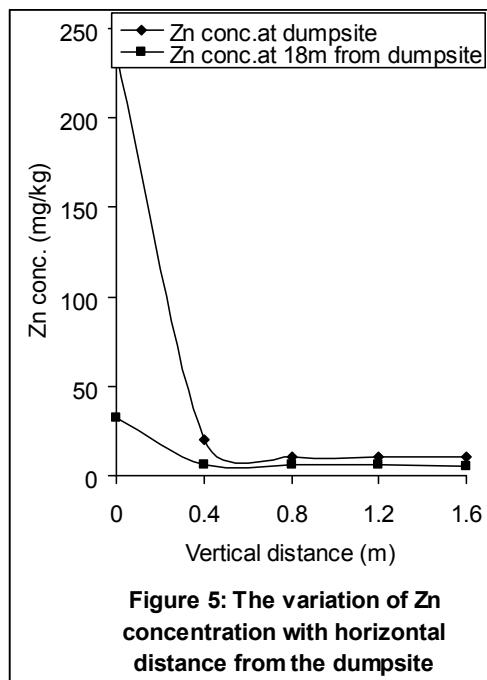
Figure 4 shows the variation of Fe concentration with horizontal distance from the dumpsite. The Fe concentration decreased with increasing horizontal distance from the dumpsite.

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Figure 5 shows that the concentration of Zn at the surface of the dumpsite was 236.8mg/kg and this value decreased to 9.89mg/kg at a depth of 0.4m. The concentration of Zn was significantly high at the surface of the dumpsite and was above FEPA maximum acceptable limit [10]. However, it decreased drastically to almost a constant value of 9.89mg/kg at a depth of 0.4m. This concentration was within the FEPA acceptable limit. This simply implies that soil toxicity decreased with depth. Similar trend was observed at 18m from the dumpsite, around the neighbourhood. The high concentration of Zn at the surface of the dumpsite might have resulted from the corroded Zn plated materials, from car scrap dumped at the dumpsite. Förstner and Wittmann, [2] reported that Zn is an adsorbing metal, whose mobility depends strongly on the pH value and the concentration of humid substance. Also, Zn has a high affinity to clay materials. Besides, Xin, [9] reported that metal adsorption increases with the concentration of dissolved heavy metals as long as the corresponding surface sites are available. The studies reported by Fic and Schroter, [13] indicated that there were significant differences in mobility among heavy metals. They classified Zn and Cd as relatively mobile and Cu and Cr as relatively immobile. Thus, the high retention nature of Zn to the surface soil with little leached down the subsurface could be explain. This is the reason for the sharp decline seen in Figure 5.

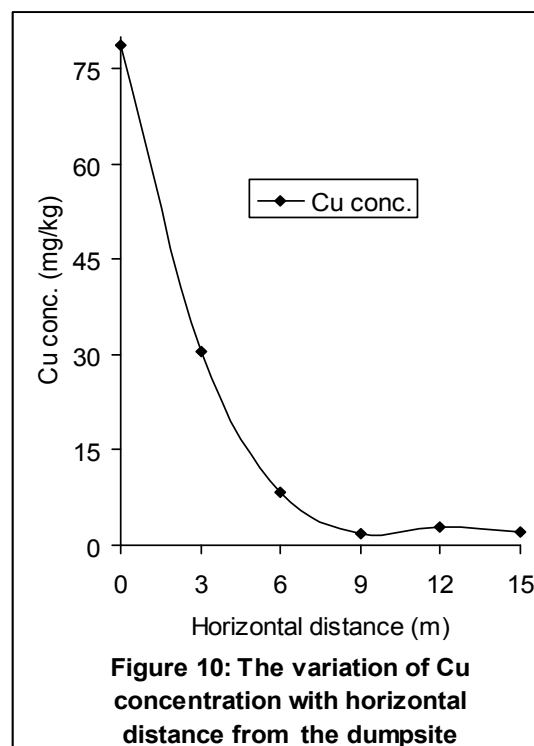
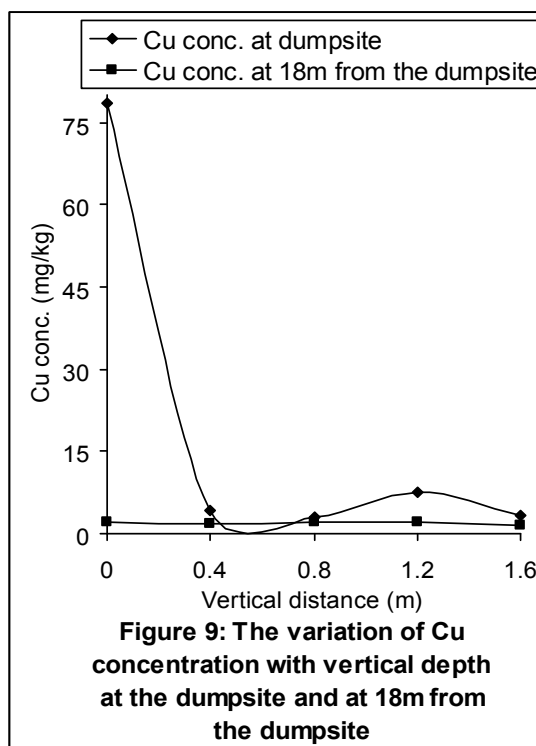
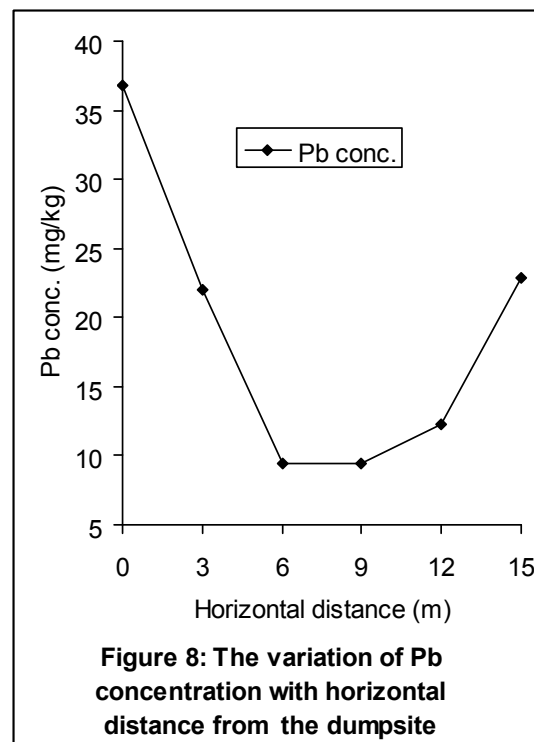
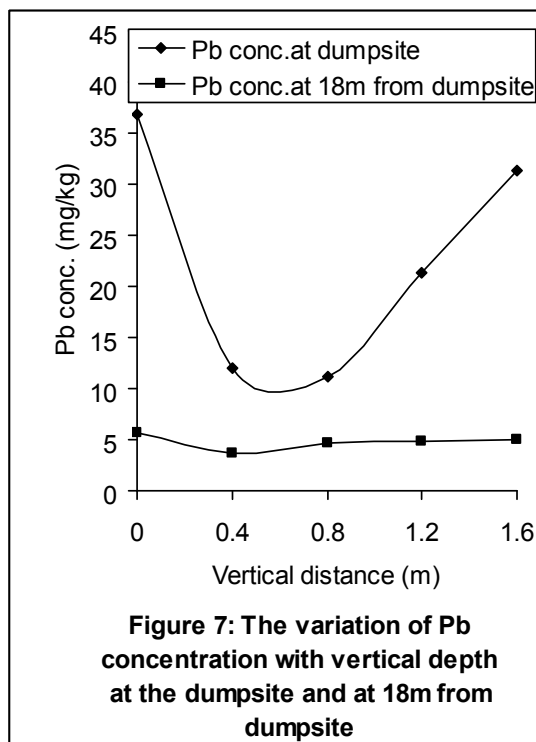


Below 0.4m depth, the concentration of Zn was found to be almost constant. This might be as a result of very little or no leaching process taking place below this depth. Along horizontal distance, the variation of Zn concentration with distance from the dumpsite gave a similar trend as shown in Figure 6.

Figure 7 shows that the concentration of Pb at the surface of the dumpsite was 36.85mg/kg. It decreased to 11.17mg/kg at a depth of 0.4m and then increased to 31.36mg/kg at a depth of 1.6m. The entire Pb concentration was above FEPA maximum acceptable limit [10]. This implies that there was Pb toxicity in soil in and around the dumpsite. Also, the reason for this non uniform distribution of Pb is because metallic Pb is only stable in a very low redox potential condition [14]. The rate of Pb oxidation and the resulting corrosion products are highly variable and site specific. In general, Pb is much more soluble under acidic (low pH) conditions than at neutral or alkaline (high pH) conditions [9].

Pb sorption in clay usually increases with increasing pH, decreasing soil/solution ratio, and decreasing ionic strength [15]. It can be seen from the soil pH results in Figure 1 that as the soil depth increases, the soil becomes more acidic hence, the increasing solubility of Pb. Similar trend was observed in the variation of Pb concentration with horizontal distance from the dumpsite as shown in Figure 8.

Figure 9 shows that the concentration of Cu at the surface of the dumpsite was 78.61mg/kg and this value decreased to 4.26mg/kg at a depth of 0.4m. The concentration of Cu was quite high at the surface of the dumpsite and was above FEPA maximum acceptable limit [10]. This could have been as a result of corrosion and leaching of Cu metal from the scrap car and vehicle parts at the dumpsite. Besides, the concentration of Cu decreased sharply within a depth of 0.4m at the dumpsite. This concentration was within the FEPA acceptable limit. This indicates that soil toxicity decreased with depth, because Cu mobility was low.



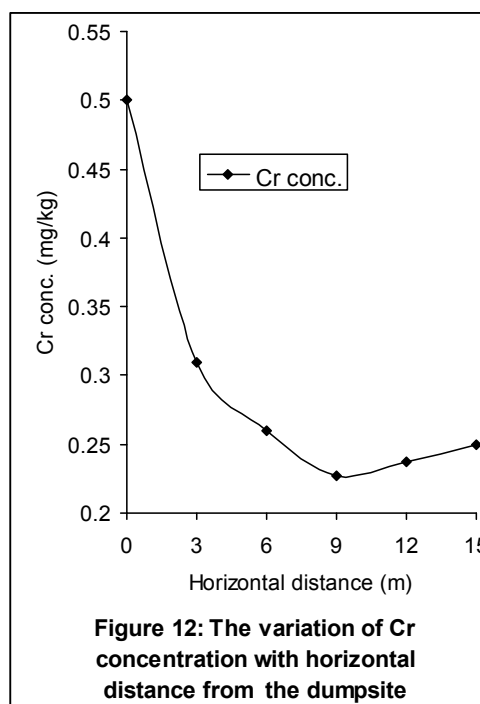
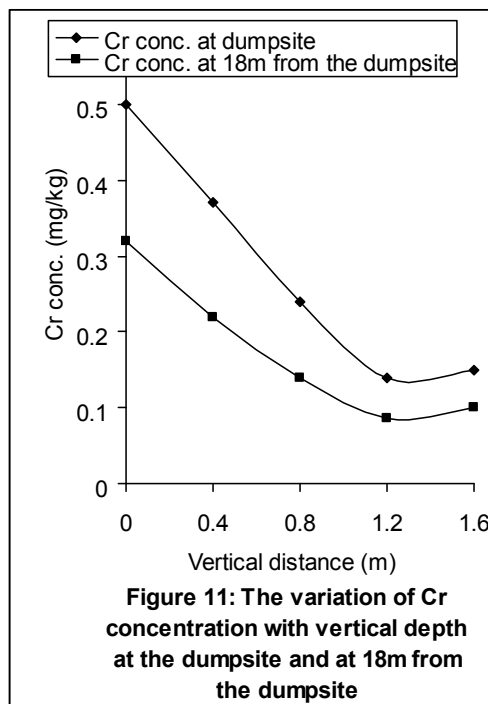
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173 The results also show that Cu concentration at the dumpsite was much lower than that of Fe
174 and Zn. This might be due to its relatively low corrosion rate. [Borg and Johansson](#) [16]

175 reported that copper is largely retained in the soil. They noticed that the mobility increased
 176 with decreased pH. They suggested that the mobility of Cu was associated with the transport
 177 of organic material since the Cu was highly adsorbed by them. Cu is a strongly adsorbing
 178 metal, it can bound very strongly to humus substances, Fe/Al-oxides and other variable-
 179 charge particle surfaces due to its large tendency to form complexes, so theoretically it
 180 should be well retarded in most type of soils and thus being prevented from leaching to
 181 further soil profiles. [Xin](#), [9] and [Igloria et al.](#), [12] reported that the possibility of formation of
 182 complexes between heavy metals and organic matter colloids in solutions, as well as those
 183 attached to soil surfaces. [Sposito](#) [17], on the other hand, claimed that the effect of these
 184 colloids might retard metals transport. [Ma et al.](#) [18] suggested that the chemical speciation
 185 of the metals determined metal behaviour and mobility in the environment. [Howell and](#)
 186 [Gawthorne](#) [3] discussed the important role of organic matter in the retention and behaviour
 187 of Cu. These reasons explained the sharp decreased in Cu concentration. At 18m from
 188 dumpsite, the concentration of Cu was very low and it has an approximate constant value of
 189 1.98mg/kg irrespective of the depth. The concentration of Cu also decreased with horizontal
 190 distance from the dumpsite as shown in Figure 10.

191 Figure 11 shows that the concentration of Cr at the surface of the dumpsites was 0.5mg/kg
 192 and this value decreased 0.15mg/kg at a depth 1.6m. The concentration of Cr was relatively
 193 low at the dumpsite when compared with other heavy metals. Also, it was within the FEPA
 194 acceptable limit [\[10\]](#). The low concentration of Cr might be as a result of Cr strong resistant
 195 to corrosion couple and also because it is only few car parts actually contain Cr. This
 196 explanation was supported [Xin](#), [9] report that low concentration of Cr was as a result of the
 197 ability of Cr to resist corrosion; hence the leaching process is very limited. At 18m from the
 198 dumpsite, the concentration was 0.14mg/kg at the surface as shown in Figure 11. Cr the
 199 mostly naturally occurs as chromium (VI) which is toxic at low concentration. However, the
 200 toxicity associated with Cr in soil might be very low, since the dumpsite has a large Fe
 201 concentration, which according to some researchers, will largely reduce chromium (VI) to
 202 chromium (III) [19,20]. The Cr present in the dumpsite will most likely be the less toxic form
 203 (chromium (III)).



4. CONCLUSION

In this work, the variables that could influence citric acid production from hydrolysed corn starch were optimised. They include substrate concentration, broth pH and fermentation. The conclusions made from this research study are as follows:

- The soil in and around the scrap car dumpsite was contaminated with toxic heavy metals such as; Fe, Pb, Cu, Zn, and Cr.
- At the dumpsites, the FEPA limit for metals concentration in soil was exceeded by Fe, Zn, Cu and Pb, hence the soil was polluted with heavy metals.
- Around the neighbourhood of the dumpsite (10m to 18m from the dumpsite) the soil was mainly polluted with Pb.
- The risk for heavy metals been transported through soil profiles originates from two aspects: the metal corrosion capacity and the soil retention capacity.
- It was found that for all the heavy metals, the concentrations were highest at the surface of the dumpsite. Fe had the highest concentration of 515mg/kg, the order was Fe > Zn > Cu > Pb > Cr.
- The metals concentration and pH values decreased with increased vertical depth and with increased horizontal distance from the dumpsite.
- The concentration of heavy metals on soil depends on its corroding tendency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

Author FAA, in collaboration with author IGO, designed the study. Author IGO performed the experiments, and wrote the first draft of the manuscript. Authors FAA and IGO managed the

literature searches while author ETA provided analytical advise and manuscript correction.
All authors read and approved the final manuscript.

REFERENCES

1. Alloway BJ. Heavy Metals in Soils, 1995; Blackie Academic and Professional.
2. Förstner U, Wittmann GT. Metal pollution in the Aquatic Environment, 1981; Springer-Verlag (Berlin), 197-270.
3. Howell JM, Gawthorne JM. Copper in Animals and Man. Vol II. 1987; CRC Press, Inc. Boca Raton, Florida.
4. Lennetech, M. Water treatment and air purification Holding B.V. Rotterdamseweg. 1998; 402.
5. McBride MB, Fraser AR, McHardy WJ. Cu²⁺ interactions with microcrystalline gibbsite. Evidence for oriented chemisorbed copper ions. Clays Minerology. 1984; 32: 12-18.
6. Martinez CE, Sebastien S, Jacobson A, McBride, MB. Thermally induced release of adsorbed Pb upon aging ferrihydrite and soil oxides. Environmental Science and Technology. 1999; 33:2016-2020.
7. Eick MJ, Peak JD, Brady PV, Pesek, JD. Kinetics of sorption/desorption on goethite: Residence time effects. Soil Science. 1999; 164:28-39.
8. Page AL, Miller RH, Keeney DR. Methods of soil Analysis. Part 2. Chemical and Microbiological Properties, 2nd ed., 1982; American Society of Agronomy Inc. U.S.A.
9. Xin L. TRITA-LWR Master Thesis, 2005; ISSN 1651-064X LWR-EX-05-6
10. FEPA. Guidelines and standard for environmental impact assessment in Nigeria. 1997; 87– 95.
11. Kumpiene J. Role of soil organic matter for immobilization of metals: treatment of leachate from MSWI bottom ashes".LicentiateThesis/ Luleå University of Technology, 2003; 62.
12. Igloria RV, Hathhorn WE, Yonge DR. Trace metal attenuation during Storm-Water Infiltration".Journal of Hydrologic Engineering. 1997; 2(3): 120-127.
13. Fic M, Schroter MI. Batch studies for the investigation of the mobility of the heavy metals Cd, Cr, Cu and Zn. Journal of contaminated hydrology.1989; 4: 69-78.
14. Bereket G, Aroguz AZ, Ozel MZ. Removal of Pb(II), Cd(II), Cu(II), and Zn(II) from aqueous solutions by adsorption on bentonite. Journal Colloid Interface Science. 1997; 187: 338-343.
15. Pulse R, Powell RM, Clark D, Eldred CJ. Effects of pH, solid/solution ratio, ionic strength, and organic acids on Pb and Cd sorption on kaolinite". Water Air and Soil Pollution. 1991; 57-58: 423-430.
16. Borg H, Johansson K. Metal Fluxes Swedish Forest Lakes. Water, Air and Soil Pollution, 1989; 47: 427-440.
17. Sposito, G. Sorption of Trace Metals by Humic Materials in Soils and Natural Water.Critical Review in Environmental Control. 1986; 6(2):193-229.
18. Ma Q, Lena A, Rao GN. Chemical Fractionation of Cadmium, Copper, Nickel and Zinc in Contaminated Soils. Journal Environmental Quality 1997; 26: 259-264.
19. Anderson S, Rasmussen G, Snilsberg P, Amundsen CE, Westby T. Assessing Toxicity and Mobilization of Impregnation Salts at a Contaminated Site. Fresenius Journal Analytical Chemistry. 1996; 354: 676-680.
20. Kent DB, Davis JA, Anderson LCD, Rea BA, Waite TD. Transport of chromium and selenium in the suboxic zone of a shallow aquifer: influence of redox and adsorption reactions. Water Resource Research. 1994; 30: 1099-1114.