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Assessment of Heavy Metals in Soils and Plant Samples around some Dumpsites in Uyo, Akwa Ibom State, Nigeria

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Abstract

The study examined the concentration of heavy metals (Cr, Cd, Ni, Cu, Pb) in soils and Fluted pumpkin (*Telfairia occidentalis*) growing wildly around some dumpsites in Uyo, Nigeria. Soil (0 – 30cm) and plant samples were collected at distances of 0 – 20m, 20 – 40m, 40 – 60m, 60 – 80m, 80 – 100m for two seasons (wet and dry) and analyzed for metal contents. Cu had the highest mean concentration (17.06mgkg^{-1}), (9.39mgkg^{-1}) in the soil and plant respectively. Mean concentration of soil and plant samples at dumpsite soil were significantly ($p<0.05$) higher than control samples for both wet and dry season. Metal accumulation in soil and plant samples are sequentially arranged as Cu > Pb > Cr > Cd > Ni (0.31) and Cu > Pb > Cd > Cr > Ni respectively for both wet and dry seasons. Value recorded for all metals were higher than the allowable limit for soil and the two most toxic heavy metals (Pb and Cd) were higher in the plant samples than the WHO/FAO recommended values and the transfer factors of these two metals were also high. Indeed, the consumption of vegetables grown on such site; could be dangerous and can poison human and animal health status. Therefore, heavy metal concentrations at dumpsites need to be properly addressed by regulating waste disposal and management processes. Improved remediation techniques such as bio remediation that have shown potentials for their ability to degrade and detoxify certain contaminants should be recommended and practiced by farmers to reduce harmful effects of heavy metal uptake by plants.

Keywords: Dumpsites; heavy metals; solid waste; transfer factor

1.0 Introduction

Solid wastes constitute an environmental and public health nuisance in major cities all over the nation. Waste is generated universally and is a direct consequence of such human activities. Heavy Metals concentrations in soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as agricultural practices, industrial activities and waste disposal methods (Olayinka *et. al.*, 2014). In Uyo metropolis, for instance, leachates from refuse dumpsites constitute a source of heavy metal pollution to both soil and aquatic environments. In some cases, waste is dumped carelessly with no regards to

the environmental health implications, while in some dumpsites, wastes are burnt in the open and ashes abandoned at the sites. The burning of wastes gets rid of the organic materials and oxidized the metal, leaving the ash richer in metal contents (Ebong *et.al.*, 2007). After the processes of oxidation and corrosion, these metals will have dissolved in rain water and leached into soil, and then picked up by growing plants thereby entering the food chain. Wastes on dumpsite generally contain toxic metals, which are of concern and pose dangers to people in contact with the contaminated soil and plants. The chemical compositions of solid waste materials often lead to changes in soil physical and chemical characteristics due to contaminations (Logan 2002).

Most dumpsites in Nigeria have consumable plants grown on the soils such as *Amaranthus spp* and *Telfairia occidentalis*, etc. Fluted Pumpkin (*Telfairia occidentalis*) is a leafy vegetable commonly grown in many parts of Nigeria and is also found growing widely on or around the municipal dumpsites. Heavy metals such as cadmium, lead, nickel, chromium in dumpsite soils are of concern primarily because of their potential to harm soil organisms, plants, animals and human beings (Odukoya *et.al.*, 2000). These metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts (Al-Jassir *et.al.*, 2005).

According to Ebong *et.al.*, (2007) most abandoned waste dumpsites in Uyo metropolis have been used extensively as fertile grounds for cultivating varieties of vegetables, indeed, research works have indicated that some common vegetables are capable of accumulating high level of heavy metals from contaminated and polluted soils (Cobb *et.al.*, 2000). This constitutes dangerous health and environmental concern because of the phytotoxicity of these metals to the plants and the potential health implication to human and animals consuming such vegetables directly or indirectly over a period of time (Pillay *et.al.*, 2003). These findings demonstrate the severity of associated risk with dumpsites soils and vegetable plants grown around the site. Therefore, the main objective is to determine the heavy metal concentrations in soils and plants as influenced by distance, in some dumpsite soil and plant in Uyo, Nigeria.

2.0 Materials and Methods

2.1 Description of Study Area

The study was conducted in Uyo metropolis, the capital city of Akwa Ibom State, Nigeria, which has a population of 305,961 (TWG, 2007). It is situated between latitudes 7° 50' E and 8° 00' E, and Longitudes 4° 59' N and 5° 05'N (Fig. 1) at an altitude of 60.0m above sea level with a mean annual rainfall of 3000mm and temperature range between 27 to 34°C. The relative humidity varies through the year from 70 to 80% (AKSEPA, 1999). The city has two distinct seasons, namely; dry and wet seasons. The dry season usually starts in November and ends in March while the wet season usually starts in April and ends in October. Uyo is within the modified rainforest zone now called oil palm bush. The type of vegetation is however disappearing due to urban development. The topography of the area is generally undulating, except in some parts that are occupied by valley. Parts of the valley are so steep that they are described as ravines. This topography poses a major limitation to physical development of the city. The waste dumpsites and control site under study are Mbak Itam, Old Stadium Road, Ekom Iman and Uyo Village Road. Farmlands (200m) far away from each dumpsite were served as control site.

2.2 Study Design

A Randomized complete block design with three replications was used for this study. Four waste dumpsites were randomly selected to represent the North, East, South and West of Uyo Metropolis as follows; Uyo Village Road, Mbak Itam III, Ekom Iman, and old stadium road. Farmland of about 200 meters away from each dumpsites location was used as control site. Within each site, soils (0 - 30 depth) and plants were sampled at a distance interval of 0 - 20 meters, 20 - 40 meters, 40 - 60 meters, 60 - 80 meters and 80 - 100 meters to represent each distance interval. Soil and plant sampling were done twice in September 2020 and February 2021 to represent the wet and dry seasons.

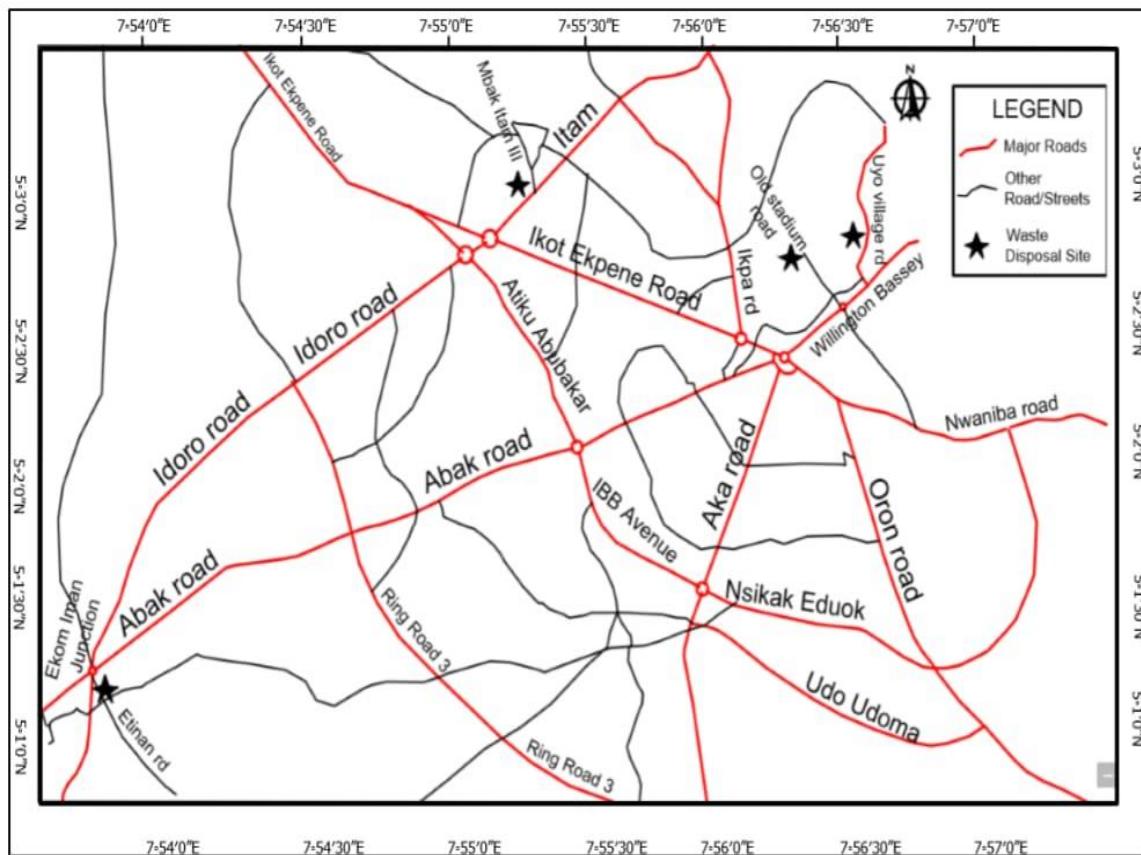


Figure 2.1: Location of waste dumpsite on the map of study area, Uyo metropolis.

2.3 Sample Collection and Preparation

Five sampling points were randomly made within each dumpsite from a marked out distance interval of 0 - 20 meters, 20 - 40 meters, 40 - 60 meters, 60 - 80 meters and 80 -100 meters apart to cover the total dumpsites area. Composite soil samples (0-30cm depth) were collected at the dumpsites and *Telfairia occidentalis* plants were also collected from farmland further away from the dumpsites. Soil sample was collected using Dutch auger while knife was used to cut the *Telfairia occidentalis* plants. Samples of soil and plant from the waste dumpsites and control site were transferred into appropriately labeled polyethylene bags and taken to the laboratory for analysis.

2.4 Laboratory Analysis

The soil samples were air-dried, grinded and sieved through a 2.00mm mesh sieve. Plant samples were dried in oven at 80°C for 24 hours, and were ground with blender to a powder form prior to analysis. 1g of each sample of soil and plant was weighed into a digestion flask,

followed by addition of analytical grade acid (analar (R)), concentrated trioxonitrate (v) acid and perchloric acid, (HNO_3 and HClO_4), in the ratio of 2:1, respectively (10ml and 5ml). The HNO_3 acid was added to the sample before HClO_4 acid to avoid any explosive reaction of HClO_4 with untreated organic materials. This was covered with watch glass. The flasks and the contents were placed in a standing position on an electric hot plate in a fume cupboard and gently heated to evaporate until 1 – 2 min of the acid were left (near dryness), the colour changes to white. This was allowed to cool before leaching the residue with 5ml of 20% HNO_3 . The filtration was done using an acid filter paper (whatman no. 1), finally made up to 50cm with de-ionized water. A blank determination that serves as the control was also carried out with all the reagents used for digestion except that it contained no sample of interest. The aliquots were used for the determination of cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr) and copper (Cu), using a Unicam atomic absorption spectrophotometer (AAS) MODEL 939. (Udoh *et.al.*, 2009).

2.5 Method of Calculating Pollutant Indices:

Geoaccumulation Index (Igeo): This index (Igeo) of heavy metal accumulation was calculated by computing the base 2 logarithm of the measured total concentration of heavy metals using the equation below by Muller, (1979).

$$\text{Igeo} = \text{Log}_2 \left(\frac{C_n}{1.5 B_n} \right) \quad (i)$$

Where; C_n is the measure of total concentration of the element,

B_n is the geochemical concentration of the element in soil while 1.5 is the constant.

2.6 Statistical analysis

Data generated from the laboratory studies were subjected to analysis of variance and means compared using least significant difference at $P < 0.05$. In order to qualify the relative differences in bioavailability of metals to plant, Transfer Factor (TF) and Geo-accumulation Index were also analysed (Gomez and Gomez, 1984)

3.0 Results and Discussion

3.1 Heavy Metal Concentration in Soils

In this study there are significant differences ($P \leq 0.05$) in the concentrations of heavy metals in soils collected from the dumpsite relative to the control site. The distance away from dumpsite (0 – 20m, 20 – 40m, 40 – 60m, 60 – 80m, 80 – 100m), heavy metal levels in the soil samples ranged from 2.62mgkg^{-1} – 3.96mgkg^{-1} , 2.15 – 2.93mgkg^{-1} , 1.20 – 1.72mgkg^{-1} , 14.39

– 17.06mgkg⁻¹ and 5.89 – 9.29mgkg⁻¹ for chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu) and lead (Pd) respectively (Table 3.1). The mean values of all heavy metals in dumpsite soils decreases with increased in distance away from the dumpsite, and were significantly ($P < 0.05$) higher than that of the control (Table 3.1). Of all the metals, Cu had the highest mean value (17.06mgkg⁻¹) in the soil sampled followed by Pb, which is 9.29mgkg⁻¹, and is sequentially arranged as Cu > Pb > Cr > Cd > Ni for both wet and dry season. However, Cu, Pb and Cr had the highest mean concentration in wet season than dry season while Cd and Ni had the highest mean concentration values in dry season than wet season (Table 3.1). The concentration of heavy metals in the soils for this study is considerably lower compared to the work reported by Nduka *et.al.*, (2006) in a study of soil samples from refuse dumps in Awka (Anambra State, Nigeria).

The values recorded for all metals were high than the allowable limits for soil as proposed by WHO/FAO, (1996). Indeed, Pb and Cd normally do not accumulate in the topsoil but, anthropogenic activities such as dumping of wastes can increase their concentration in the soil (Al-Turki, 2004). Anthropogenic contribution to heavy metals contamination of the environment can therefore be significantly more than natural input (Olayinka *et.al.*, 2014). Therefore, cadmium, lead, chromium are not considered as an essential for human beings, its toxic effects are recognized and when they gain entry through food chain they causes damage to vital organs such as the liver, lungs and kidneys. The natural range of concentration of Cu in soil is 2-100mgkg⁻¹ (Ebong *et.al.*, 2008), the concentration in this study ranged between 14.39 – 17.06mgkg⁻¹ and 1.68mgkg⁻¹ for dumpsite soil and control site (Table 3.1). These values are however within the soil critical range (50 – 250mgkg⁻¹) as given by Kabata Pendias and Pendias, (1992). Although, Cu is an essential element that plays important roles in iron and catacholamine metabolism, free radical scavenging, and in the synthesis of hemoglobin, elastin and collagen, but when present in high quantity in the dumpsite soil may lead to increase uptake by plants, and when ingested in large dose by human and animals could result in severe diarrhea, intestinal cramps, hepatic and renal damage (Goyer, 1991).

Table 3.1: Mean concentration of heavy metals (Cr, Cd, Ni, Cu and Pb) in the soil as affected by season and distance from dumpsite

	Cr	Cd	Ni	Cu	Pb
mg kg⁻¹					
					Season
Wet	3.26	2.23	1.24	14.42	6.92
Dry	2.39	2.25	1.30	12.31	5.61
LSD _(0.05)	0.42*	0.28*	0.20*	1.27*	0.71*
Fcal	28.01	30.32	17.33	60.09	50.07
Ftab	2.53	2.53	2.53	2.53	2.53
Distance Away from Dumpsite					
0 – 20m	3.96	2.93	1.72	17.06	9.29
20 – 40m	3.92	2.85	1.58	16.38	8.17
40 – 60m	3.26	2.63	1.38	15.99	7.13
60 – 80m	2.78	2.40	1.41	14.71	6.40
80 – 100m	2.62	2.15	1.20	14.39	5.89
Control	0.41	0.49	0.33	1.68	0.73
LSD _(0.05)	0.72*	0.48*	0.35*	2.20*	1.23*
Fcal	28.01	30.32	17.33	60.09	50.07
Ftab	2.53	2.53	2.53	2.53	2.53

*LSD is significant at 5% level of probability, ns -LSD is not significant at 5% level of probability

3.2 Heavy Metal concentration in Plant (Fluted Pumpkin)

Concentration of Cr and Cd in fluted pumpkin plant samples taken from the dumpsites ranged from 0.63 – 1.22mgkg⁻¹ and 0.64 – 1.47mgkg⁻¹, respectively (Table 2). Cadmium is a highly mobile metal, easily absorbed by the plants through root surfaces and moves to wood tissue and transfers to upper parts of plants growing on dumpsites (Olayinka, *et.al.*, 2014). Metal accumulation in plant samples, taken from the study area varies significantly from one element to the other with the sequence of Cu > Pb > Cd > Cr > Ni (Table 3.2).

However, plant sample concentration is significantly higher in wet season than in dry season except for lead (Pb) which is higher in dry season (1.03mgkg^{-1}) than wet season (0.76mgkg^{-1}) (Table 3.2). The mean concentration for Ni and Cu plant samples ranged from $0.18 - 0.63\text{mgkg}^{-1}$ and $7.91 - 9.39\text{mgkg}^{-1}$ respectively (Table 3.2). Though Cu Concentration is higher in the study area, this may be attributed to the fact that copper is known to occur naturally in soils as plant micro nutrient, because it is an essential element for plants and animals. The uptake and bioaccumulation of heavy metals in vegetables (*Telfairia occidentalis*) is influenced by many factors such as atmospheric depositions, climate, the concentrations of metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Suruchi and Panka, 2001).

The result revealed that Pb concentration in plant samples is higher than the WHO limit. The levels of the two most toxic heavy metals (Pb and Cd) were higher in the plant samples than the WHO/FAO (1996) recommended values and the transfer factors of these two metals were also high. Indeed, the consumption of vegetables grown on such sites could be dangerous and can poison humans and animals that consume the vegetables leading to alteration of human and animal healthiness state. However, considering the distance away from dumpsite, heavy metal concentration at dumpsite need to be properly addressed by regulating waste disposal and management processes, and improve remediation techniques such as bio remediation that have shown potentials for their ability to degrade and detoxify certain contaminants should be recommended and practice by farmers to reduce harmful effect of heavy metal uptake by plants.

Table 3.2: Mean concentration of heavy metals (Cr, Cd, Ni, Cu and Pb) in plant as affected by season and distance from dumpsite

	Cr (Plant)	Cd (Plant)	Ni (Plant)	Cu (Plant)	Pb (Plant)
	mg kg ⁻¹				
	Season				
Wet	0.85	0.99	0.31	8.73	0.76
Dry	0.63	0.79	0.27	6.19	1.03
LSD _(0.05)	0.20*	0.26*	0.18*	0.94*	0.26*
Fcal	10.00	7.76	3.72	30.51	7.54
Ftab	2.53	2.53	2.53	2.53	2.53
	Distance Away from Dumpsite				
0 – 20m	1.22	1.47	0.63	9.39	1.57
20 – 40m	1.04	1.16	0.35	8.90	1.08
40 – 60m	0.76	1.01	0.28	8.69	0.87
60 – 80m	0.64	0.83	0.24	8.61	0.80
80 – 100m	0.63	0.64	0.18	7.91	0.80
Control	0.12	0.21	0.03	1.27	0.25
LSD _(0.05)	0.35*	0.46*	0.31*	1.63*	0.46*
Fcal	10.00	7.76	3.72	30.51	7.54
Ftab	2.53	2.53	2.53	2.53	2.53

*LSD is significant at 5% level of probability, ns -LSD is not significant at 5% level of probability

3.3 Transfer Factor

The transfer factors (TF) were based on the root uptake of the metals and the foliar absorption of atmospheric metal deposits. The transfer factors for heavy metals from soils to test plant in the study area are presented in Table 3.3. Highest TF values were obtained for Cu, Pb, Cd, Cr and Ni in that order. Transfer factors for Cu, Cd, Ni were higher in wet season than dry season while Pb and Cr were higher in dry season than wet season. The value of transfer factor of Pb (0.58), Cd (0.46) and Cr (0.30) were above the range limit in plants, as recommended by WHO/FAO (1996). Indeed, more concern is needed since Pb, Cd, and Cr are non-essential toxic elements for plants, animals and humans. The effect of distance from dumpsite on the transfer factor of studied heavy metals in the soils shows that there were no significant ($P < 0.05$) difference among the metal (Table 3.3).

Table 3.3: Transfer factors of heavy metals in the study area as affected by season and distance from dumpsite.

	Cr	Cd	Ni	Cu	Pb
Season					
Wet	0.29	0.46	0.23	0.64	0.13
Dry	0.30	0.38	0.21	0.56	0.58
LSD _(0.05)	0.08 ns	0.13 ns	0.12 ns	0.15 ns	0.83 ns
Fcal	1.62	2.42	1.21	1.45	1.17
Ftab	2.53	2.53	2.53	2.53	2.53
Distance Away from Dumpsite					
0 – 20m	0.30	0.48	0.37	0.55	0.18
20 – 40m	0.28	0.40	0.19	0.54	0.13
40 – 60m	0.23	0.37	0.22	0.55	0.12
60 – 80m	0.26	0.34	0.18	0.59	0.12
80 – 100m	0.29	0.31	0.15	0.56	0.13
Control	0.42	0.64	0.20	0.81	1.43
LSD _(0.05)	0.15 ns	0.23 ns	0.21 ns	0.26 ns	1.43 ns
Fcal	1.62	2.42	1.21	1.45	1.17
Ftab	2.53	2.53	2.53	2.53	2.53

*LSD is significant at 5% level of probability, ns -LSD is not significant at 5% level of probability

3.4 Geo-accumulation Index of Heavy Metals in Soil

Geo-accumulation index (I_{geo}) has extensively been used to evaluate the degree of metal contamination/pollution in soil all over the world (Alshahri and El-Taher, 2018). It is used to quantify the degree of anthropogenic contamination and compare different metals that appear in different ranges of concentration in the study areas as (geo-accumulation, [I_{geo}]) proposed by Muller and Suess, (1979). The distribution of geo-accumulation index (I_{geo}) of heavy metals in soil is depicted in figure 2. The geo-accumulation Index (I_{geo}) values of Cr, Cd, Ni, Cu and Pb ranged from 2.00 – 3.00, 2.00 – 2.70, 1.00 – 3.00, 2.50 – 3.00; and 3.00 – 4.00 respectively for both wet and dry seasons. The I_{geo} values indicated that Cd, Ni and Cu were moderately to strongly contaminating the soil of the study area by anthropogenic activities, while Pb and Cr indicates strong contamination in the soil of the study area. However, when compared I_{geo} of different metals in the study area, it appeared in different ranges of

concentration for both seasons and distances from dumpsites as indicated in Figure 2 showing the sequential trend and index rating as follows; Lead (Pb) ranged from 2.50 to 300; 3.50 to 400 for wet (moderately to strongly contaminated) and dry (strongly contaminated) respectively. Chromium (Cr) ranged from 2.00 to 3.00; 3.00 to 3.50 for wet (moderately to strongly contaminated) and dry (strongly contaminated) respectively. Copper (Cu) ranged from 2.50 to 2.70; 2.80 to 3.00 for wet (moderately contaminated) respectively. Cadmium (Cd) ranged from 2.00 to 2.50; 2.50 to 2.70 for wet (moderately to strongly contaminated, and dry (moderately to strongly contaminated) respectively. Nickel (Ni) ranged from 1.00 to 2.00; 2.50 to 2.80 for wet (moderately contaminated) and dry (moderately to strongly contaminated) respectively. Also the interactive effect of season and distance from dumpsites on the Geo-accumulation indices of concentration of heavy metal decreased with increasing distance interval away from dumpsite and the geo-accumulation indices shows that there is degree of metal contamination in soil of the study area.

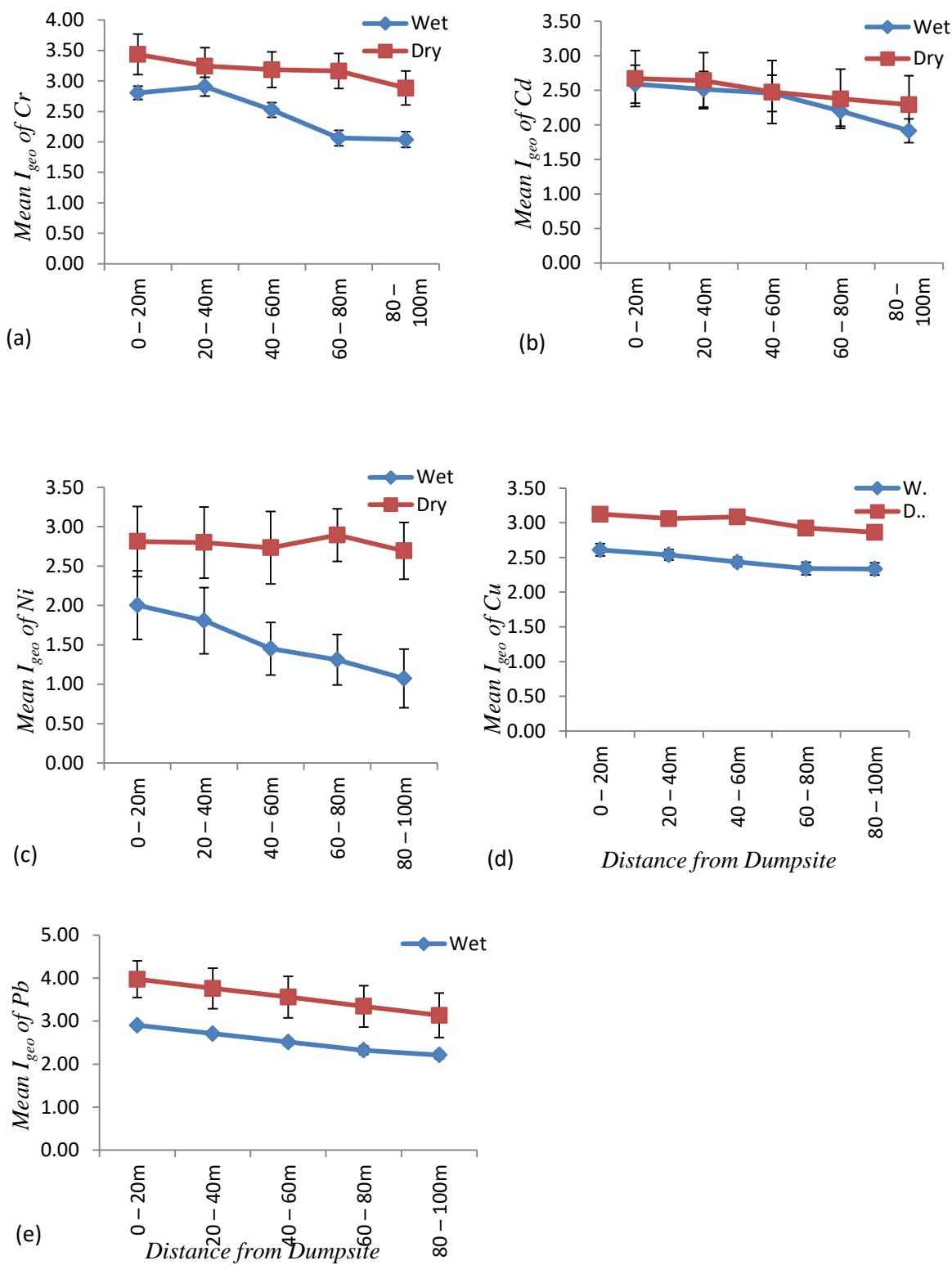


Figure 3.1: Interactive effect of season and distance from dumpsite on the mean geo-accumulation (I_{geo}) indices of (a) Chromium (b) Cadmium (c) Nickel (d) Copper and (e) Lead

4.0 Conclusion and Recommendations

Concentration of studied heavy metals in the dumpsites soils were higher than the allowable limit, and all heavy metals investigated in dumpsite soil were found in concentration higher than the control site, and the concentration of heavy metals decreased with increased distance away from the dumpsites. Metals accumulation in the plant samples taken from the study area varies significantly from one another. Cu is the most abundant element in the vegetable test crop with mean value of 9.39mgkg^{-1} followed by Pb (1.57mgkg^{-1}). High concentrations of heavy metal in the test crop are attributed to the composition of waste in the dumpsite due to increasing population and consumption pattern. The transfer factor (TF) of the metals showed significant accumulation of Cu, Pb, and Cd in the test crop. This suggested that consumption of vegetables grown on such sites could be dangerous to human health. Therefore, to manage heavy metal contamination and decrease their dietary toxicity, waste recycling and bioremediation techniques that have shown potential for their ability to degrade and detoxify certain contaminants should be adopted. Indeed, heavy metal concentrations at dumpsite need to be properly addressed by regulating waste disposal and management processes and discourage farmer from cultivating on dumpsites soil.

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