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REGULAR ARTICLE

Soil quality assessment and phytoaccumulation potentials of selected edible vegetables around Ntigha solid waste dump, Abia State, Nigeria

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Abstract

The present study evaluated the impact of open solid waste dumping on soil physicochemical characteristics, enzyme activities, soil heavy metals and bioavailability of these metals in selected edible vegetables. Twenty-six soil samples were collected from 13 different points. The considered points were center of the dumpsite (DC), 4 meters away east (E_1), west (W_1), north (N_1), and south (S_1) from the center of the dumpsite; and 8 meters away east (E_2), west (W_2), north (N_2) and south (S_2) from the center of the dumpsite. The controls were taken 100 meters away from the dumpsite center east (E3), west (W_3), north (N_3), and south (S_3). Soil samples were collected at the depth of 0-45cm and 46-90cm at each point. Results obtained showed the physicochemical and enzyme activities of the center of the dumpsite (DC) were affected when compared to other points considered in this study. Significant differences between soil depths were also observed. Soil heavy metals also showed significant increase in dumpsite compared to control soils ($P<0.05$). Phytoavailability of the heavy metals studied showed that vegetables grown around Ntigha dumpsite accumulated significant level of the metals compared to their control counterparts ($P<0.05$). This study has revealed that open pit disposal of solid waste increased the phytoaccumulation potentials of edible vegetables grown around the dumpsite. Hence proper waste disposal method is advocated so as to prevent bioaccumulation of these heavy metals in human food chain.

Key words: Ntigha dumpsite; physicochemical characteristics; soil enzymes; heavy metals

Introduction

In soil there is a continuous interaction take place between soil minerals, organic matter and microorganism that influences biogeochemical characteristics of the terrestrial system [1]. The effect of environmental pollution such as open pit dumping to humans, cultivated crops and the ecosystem has been posited [2]. Most solid waste dumpsites in many towns and villages in Nigeria attract people as fertile grounds for cultivation of varieties of edible crops and vegetables [3]. The cultivated plants may take up metals either as mobile ions present in the soil solution through the roots or through foliar absorption. The uptake of these metals by crops and vegetables results in bioaccumulation of these elements in plant tissues which may pose health risk on

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continuous consumption [4]. Increase in human activities due to population growth has resulted in generation of solid wastes that are poorly managed in most developing and under-developed nations [5,6]. Like other developing nations, Nigeria is also facing problem with solid waste management in varying degrees [7,8,9]. Most developing and under-developed nations use the open dump method of solid wastes disposal. For instance, in Nigeria, the open dump is the available method of solid waste disposal in both rural and urban cities [10, 11]. Such method has been defined as the disposal of solid wastes by infilling depressions on land [12,13].

Ntigha dumpsite is located along Umuahia-Aba road and lies on longitude (07°29'28E" and latitude 05°29'42"N). These two cities are the major populated cities in Abia State. Hence most solid waste generated from these cities due to high anthropogenic activities is usually dumped in this site. The need to evaluate the impact of open solid waste dumping on soil quality and phyto-availability of heavy metals in vegetables grown around the dumpsite is evident. These vegetables are the commonly cultivated vegetables around the dump sites. The present study is therefore aimed at assessing the pollution status of Ntigha dumpsite and the phyto-accumulation potentials of edible vegetables grown around the dump in order to assess the health risk that may be associated with consumption of such vegetables.

Materials and method

Soil sample collection

Twenty-six (26) soil samples were used for the analysis. Two soil samples each were collected from 13 different points considered from the studied waste dumpsite`s vicinity. The soil samples were collected using plastic auger at the depths of 0-45cm and 46-90 cm. Collection points were the center of the dumpsite (DC), 4 meters away east (E_1), west (W_1), north (N_1), and south (S_1) from the center of the dumpsite and 8 meters away east (E_2), west (W_2), north (N_2) and south (S_2) from the center of the dumpsite. The controls soil samples were taken at 100 meters away from the dumpsite center east (E_3), west (W_3), north (N_3), and south (S_3). The collected soil samples were placed in covered plastic plates and were properly labelled.

Preparation of soil sample

The soil samples were air-dried, mechanically grounded using a stainless steel roller, mortar and pestle and prepared by following standard method [26].

Physicochemical parameters determination

Temperature of the soil samples and pH were determined *in situ* using the JENWAY multipurpose tester HANNA 1910. Soil moisture was determined using the standard method [14]. Cation exchange capacity [15] and exchangeable acidity [16] were also determined by standard analytical methods.

Soil enzymes

The activity of soil dehydrogenase, acid phosphatase and alkaline phosphatase was determined [17]. Soil hydrogen peroxidase, protease and soil urease were estimated by following standard methods [18, 19, 20].

Heavy metals determination in plant samples

The heavy metals were determined according to the method described previously [14].

Statistical analysis

Data collected were subjected to statistical analysis [21].

Results and discussion

Soil temperature plays an important role in many processes which takes place in soil [22, 23]. Soil temperature values of the present study ranged from 25.8 to 36.4°C. Findings showed that soil temperature of 0-45cm depth was significantly ($p<0.05$) higher than 46-90cm depth in all the sampling points studied. This shows that soil temperature changes with soil depth in this study. The highest values of temperature (Fig. 1) were observed at the center of the dumpsite (DC). The significant increase ($P<0.05$) in temperature of dumpsite (DC) compared to other sampling points in the present study could be attributed to biogeochemical reactions due to degradation large volume of wastes. Temperature rise in soil has been reported to increase metal activity in soil solution as well as absorption rate in plants through higher evaporation and transpiration from plants [1].

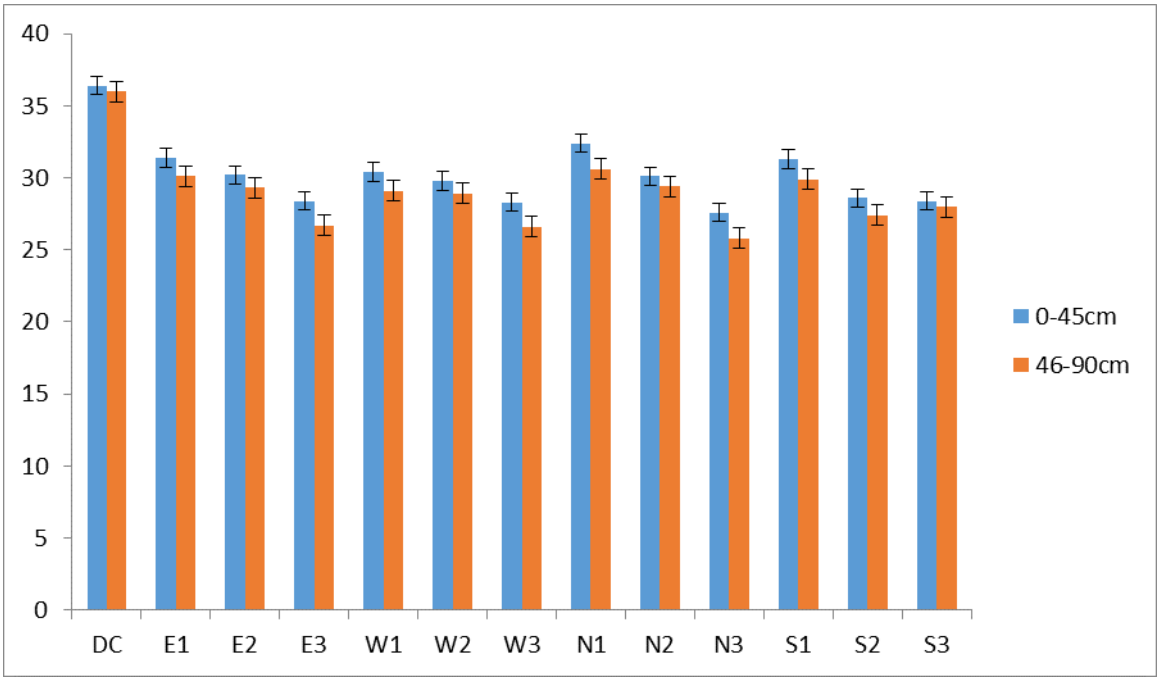

Fig. 1. Soil temperature (°C) of dumpsite and control soils.

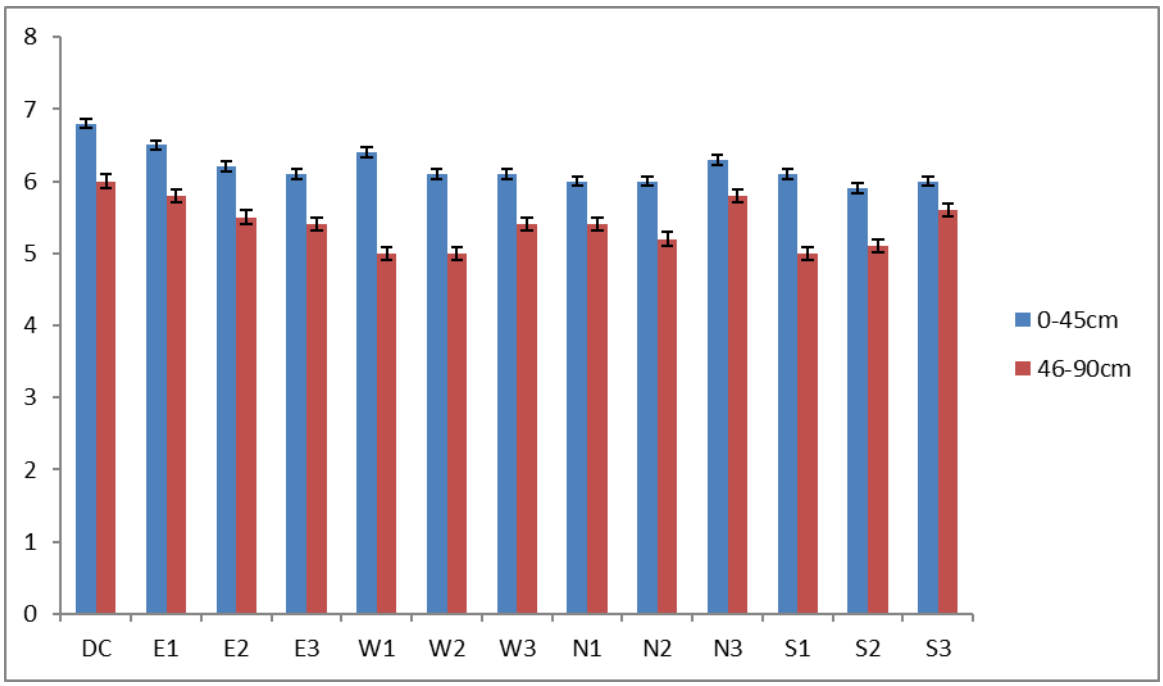

Fig. 2. Soil pH of dumpsite and control soils.

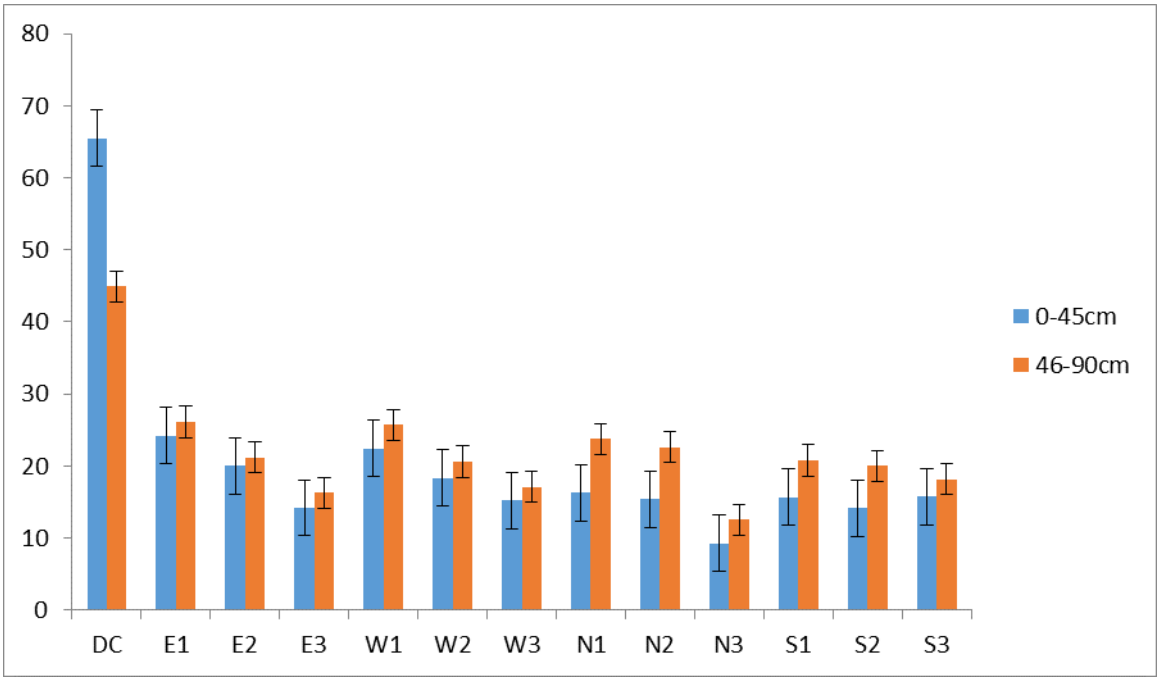

Fig. 3. Moisture content of dumpsite and control soils.

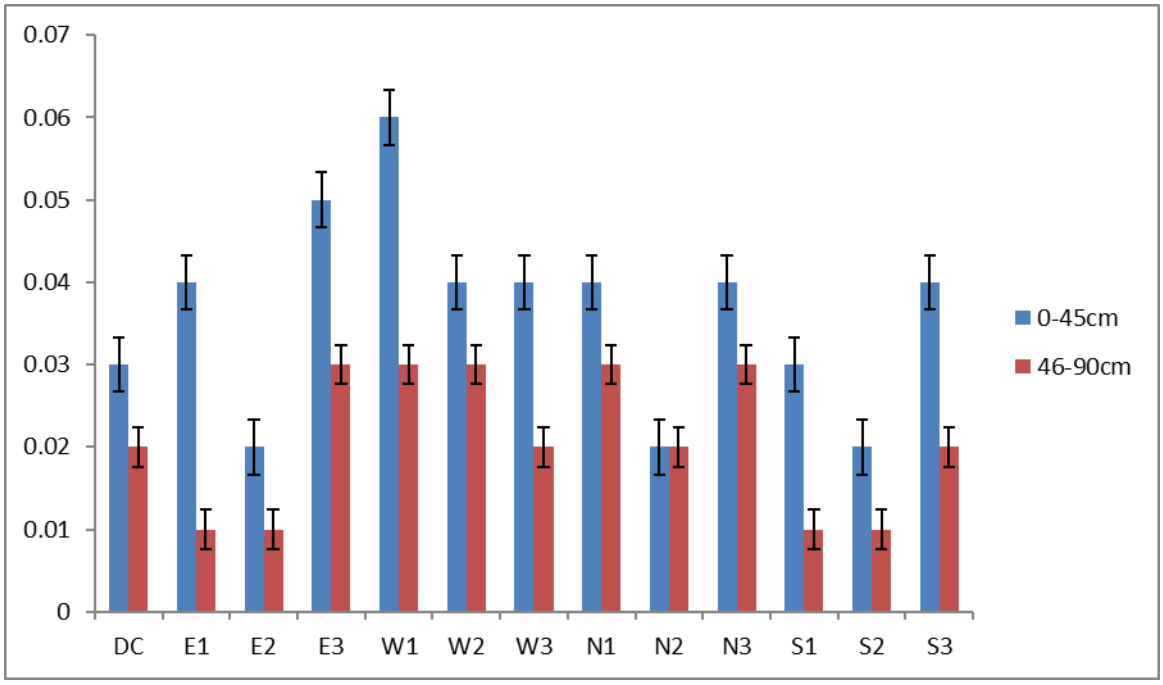

Fig. 4. Exchangeable acidity (Meq.) of dumpsite and control soils.

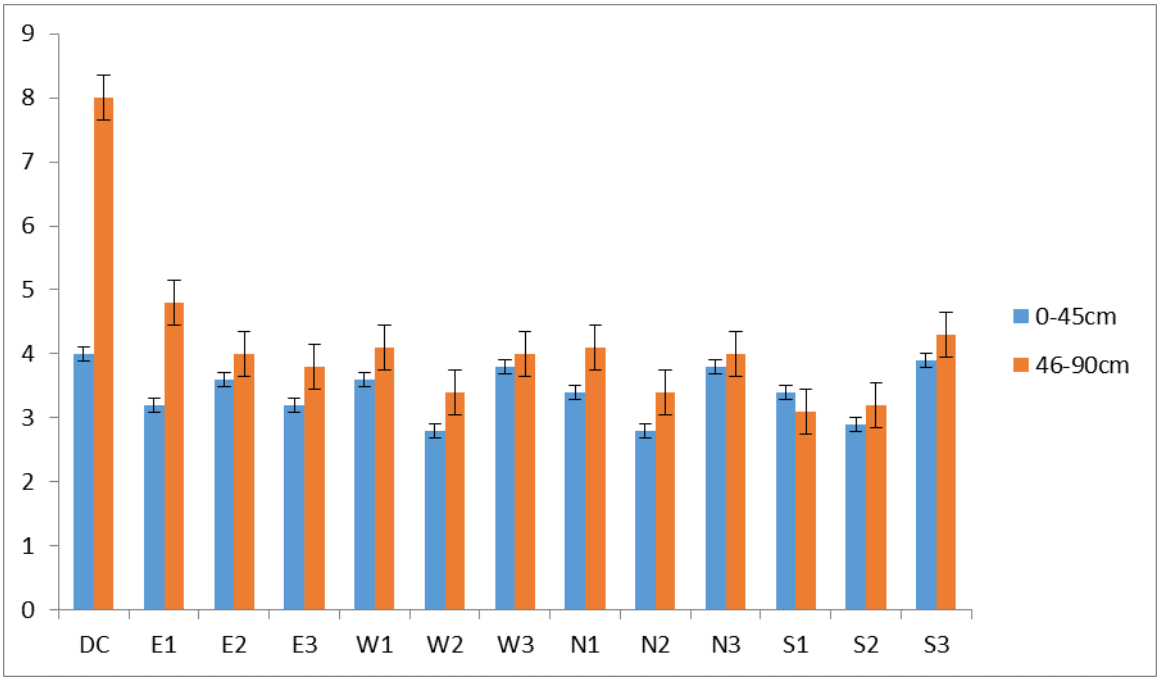

Fig. 5. Cation exchange capacity (mg/kg) of dumpsite and control soils.

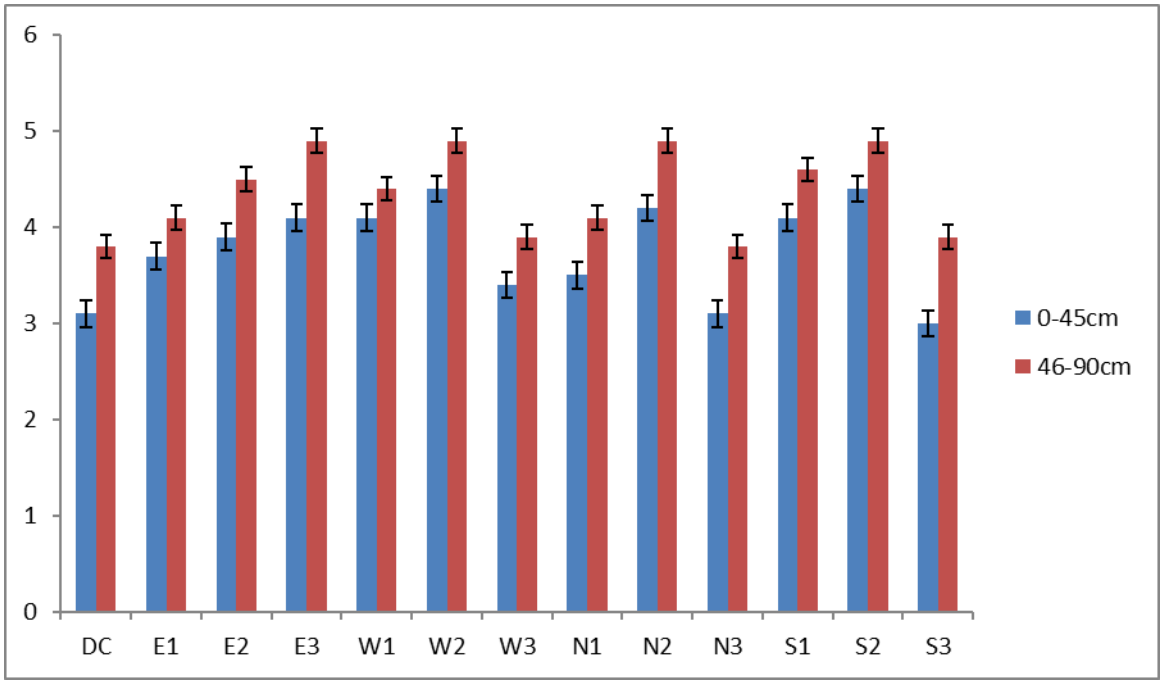

Fig. 6. Acid phosphatase activities (µmol-p-ntrophenol) of dumpsite and control soils.

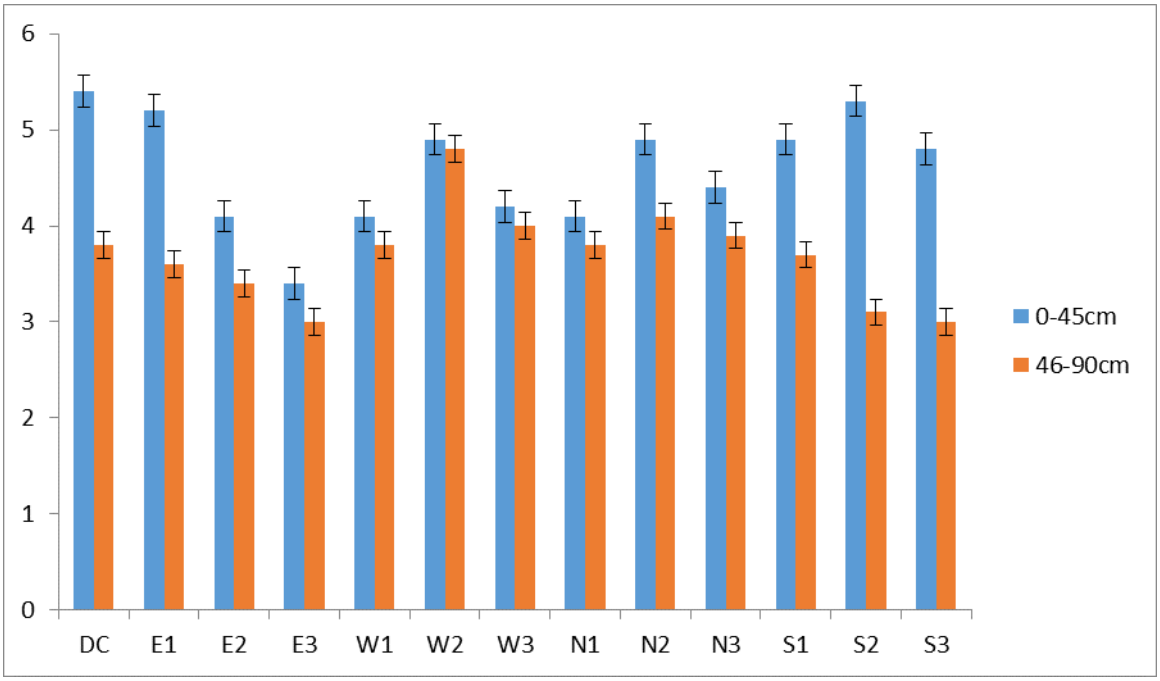

Fig. 7. Alkaline phosphatase activities (µmol-p-ntrophenol) of dumpsite and control soils.

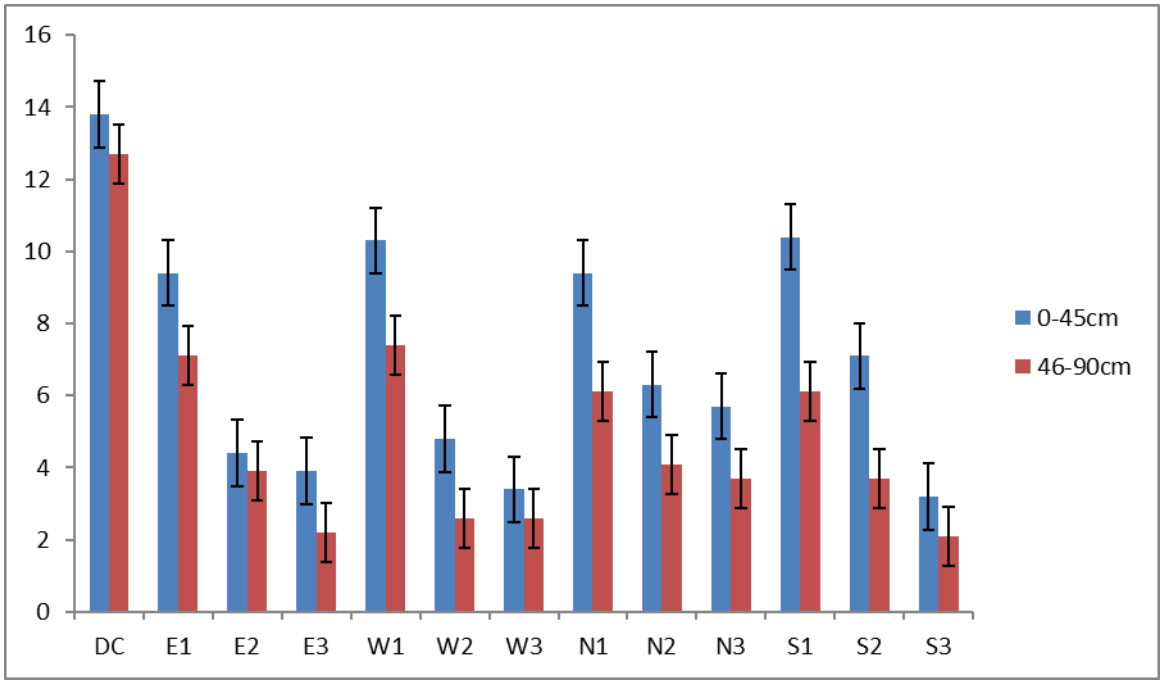

Fig. 8. Dehydrogenase activities (mg TPFg^{-1} 6h $^{-1}$) of dumpsite and control soils.

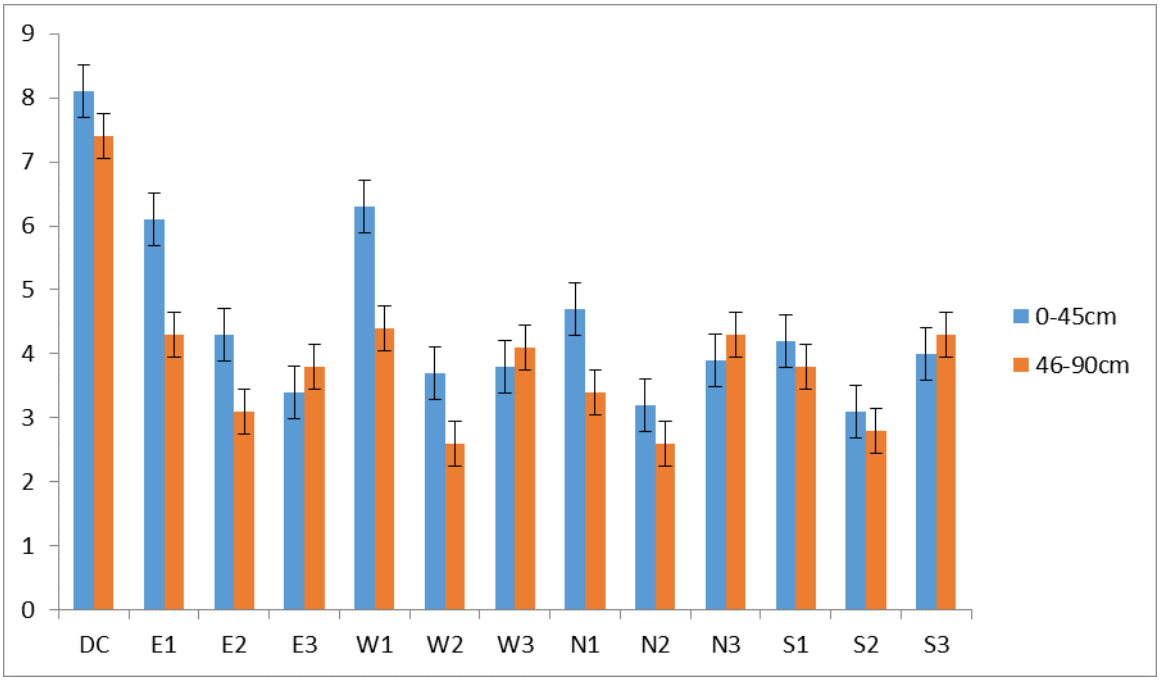

Fig. 9. Hydrogen peroxidase ($mlg^{-1}1h^{-1}$) activities of dumpsite and control soils.

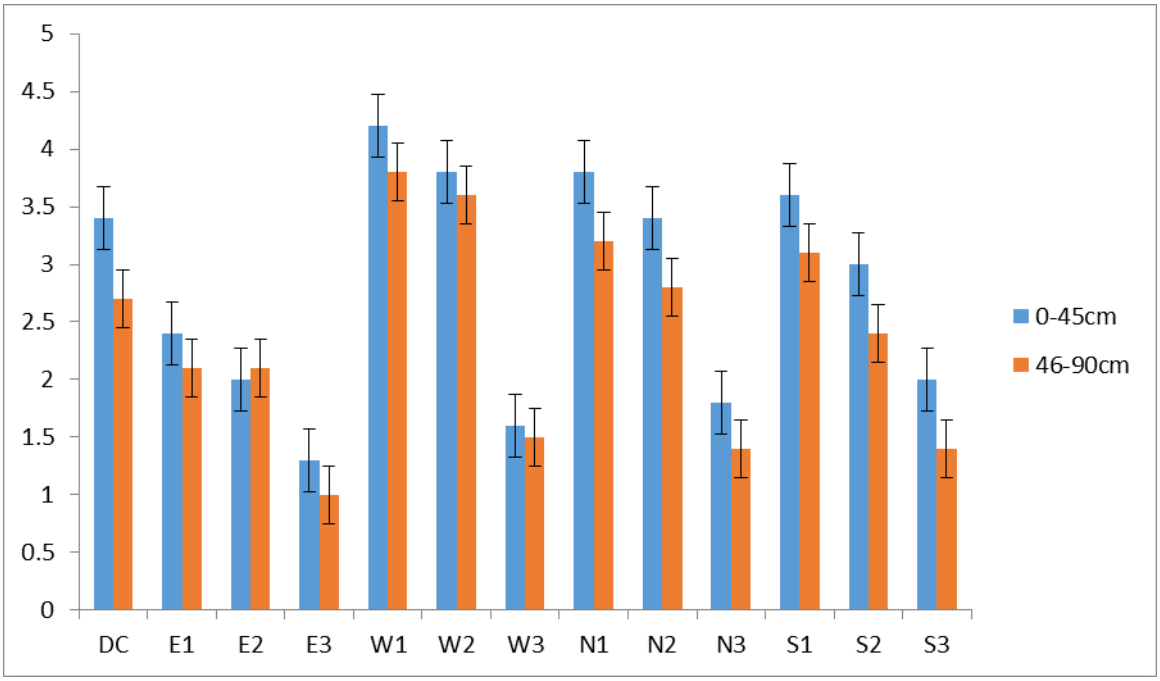

Fig. 10. Urease ($mgNH_3\text{-}Ng^{-1}2h^{-1}$) activities of dumpsite and control soils.

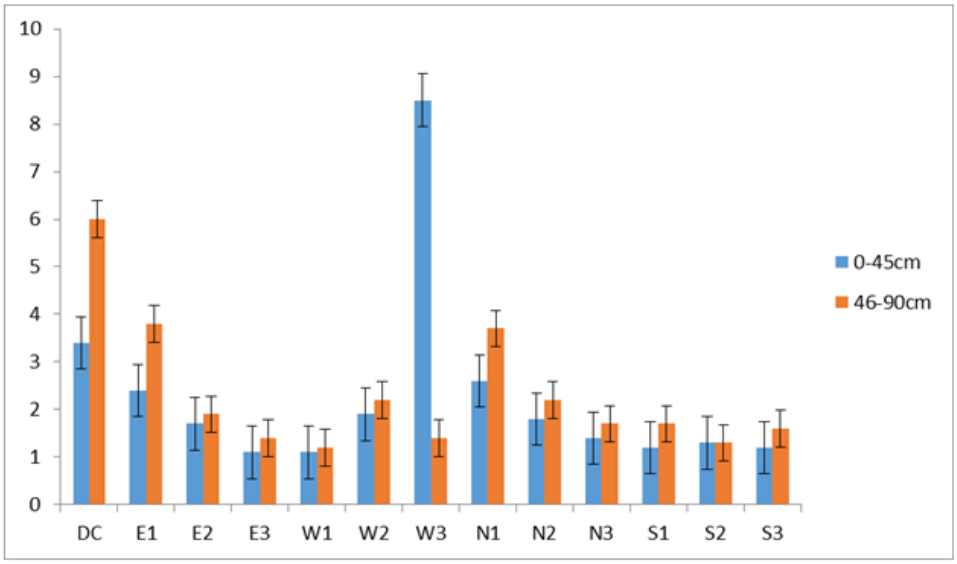

Fig. 11. Protease × 10^4 (µtyrosine g-1dwt-1) activities of dumpsite and control soils

Table 1. level of heavy metals (mg/kg) in Ntigha dumpsite soil at 0-45cm soil depth

Location	Lead	Cadmium	Chromium	Nickel	Manganese
Control	1.93±0.00^{a}	1.02±0.00^{a}	0.73±0.00^{a}	2.67±0.00^{a}	1.49±0.00^{a}
DC	4.78±0.51^{j}	3.63±0.57^{j}	3.13±0.02^{h}	7.09±0.16^{h}	5.50±0.15^{h}
E_1	3.75±0.15^{f}	2.25±0.20^{c}	2.03±0.15^{c}	5.92±0.16^{g}	3.48±0.02^{h}
E_2	2.71±0.10^{e}	2.08±0.10^{b}	3.10±0.71^{g}	4.93±0.52^{g}	2.39±0.10^{g}
W_1	4.02±0.55^{i}	2.30±0.17^{f}	2.45±0.15^{e}	5.48±0.55^{f}	3.78±0.32^{i}
W_2	3.93±0.71^{g}	2.27±0.25^{e}	2.30±0.21^{e}	4.26±0.22^{e}	0.34±0.21^{f}
N_1	2.92±0.53^{e}	2.26±0.15^{d}	2.07±0.64^{d}	5.21±0.20^{e}	4.99±0.10^{d}
N_2	3.95±0.08^{h}	2.82±0.01^{i}	2.02±0.05^{c}	4.93±0.33^{d}	3.07±0.58^{e}
S_1	2.88±0.21^{d}	2.66±0.26^{h}	2.94±0.06^{f}	4.08±0.16^{c}	3.93±0.21^{c}
S_2	2.57±0.20^{b}	2.37±0.06^{g}	1.83±0.50^{b}	2.88±0.15^{b}	2.54±0.10^{b}

Values are mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are significantly different (P<0.05).
DC= Dumpsite center; E_1= 4 meters away east; W_1= 4 meters away west; N_1= 4 meters away north; S_1 = 4 meters away south; E_2= 8 meters away east; W_2=8meters away west; N_2= 8 meters away north; S_2= 8 meters away south

Table 2. level of heavy metals (mg/kg) in Ntigha dumpsite soil at 46-90cm soil depth

Location	Lead	Cadmium	Chromium	Nickel	Manganese
Control	2.79±0.00^{a}	1.0±0.00^{a}	2.54±0.00^{a}	0.52±0.00^{a}	1.32±0.00^{b}
DC	7.86±0.21^{j}	13.2±7.27^{j}	8.89±2.51^{h}	1.44±0.17^{i}	2.16±0.06^{g}
E_1	7.16±0.31^{i}	7.11±5.31^{i}	1.93±3.15^{f}	1.32±0.11^{i}	1.95±0.17^{e}
E_2	6.33±0.06^{h}	3.23±4.34^{d}	3.07±3.14^{e}	1.25±0.15^{h}	1.82±0.11^{c}
W_1	5.97±0.02^{f}	3.30±2.52^{g}	4.42±5.16^{j}	0.93±0.01^{e}	2.32±0.15^{h}
W_2	6.23±0.91^{g}	3.0±5.35^{b}	3.39±3.78^{i}	1.00±0.01^{f}	2.06±0.55^{f}
N_1	4.06±0.23^{e}	3.14±2.53^{c}	5.71±2.16^{g}	0.84±0.15^{b}	2.33±0.22^{h}
N_2	3.58±0.298^{d}	4.25±2.65^{h}	4.32±2.46^{c}	1.05±0.26^{g}	1.87±0.52^{d}
S_1	3.46±0.35^{c}	3.61±1.00^{f}	3.96±2.17^{d}	0.89±0.06^{c}	1.98±0.73^{e}
S_2	2.95±0.17^{b}	3.27±3.33^{e}	1.53±2.09^{b}	0.87±0.20^{d}	1.02±0.89^{a}

Values are mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are significantly different (P<0.05)
DC= Dumpsite center; E_1= 4 meters away east; W_1= 4 meters away west; N_1= 4 meters away north; S_1 = 4 meters away south; E_2= 8 meters away east; W_2=8meters away west; N_2= 8 meters away north; S_2= 8 meters away south

Table 3. Level of heavy metals (mg/kg) in root and leaves of *Gongronema latifolium*.

location	Lead Root	Cadmium Root	Chromium Root	Nickel Root	Manganese Root	Lead Leaves	Cadmium Leaves	Chromium Leaves	Nickel Leaves	Manganese Leaves
Control	0.04±0.00^{a}	0.03±0.00^{a}	0.11±0.00^{a}	0.04±0.00^{a}	0.16±0.00^{a}	0.08±0.00^{a}	0.09±0.00^{a}	0.15±0.00^{a}	0.09±0.00^{a}	0.06±0.00^{a}
N	2.16±0.12^{b}	3.07±0.06^{c}	3.20±0.10^{b}	4.42±0.15^{e}	3.19±0.10^{d}	1.97±0.06^{e}	1.76±0.00^{e}	2.85±0.14^{e}	2.99±0.12^{e}	1.65±0.17^{c}
W	2.82±0.25^{e}	4.19±0.12^{e}	3.50±0.07^{c}	4.32±0.06^{d}	3.53±0.05^{e}	1.07±0.47^{c}	1.64±0.07^{d}	1.90±0.06^{d}	1.79±0.06^{b}	1.82±0.07^{e}
E	2.44±0.26^{c}	3.25±0.15^{d}	4.39±0.15^{d}	3.20±0.006^{b}	1.05±0.17^{b}	1.88±0.11^{d}	1.49±0.05^{c}	1.85±0.19^{c}	2.75±0.03^{d}	1.76±0.34^{d}
S	2.61±0.07^{d}	2.01±0.90^{b}	5.12±8.05^{e}	3.06±6.05^{c}	2.19±0.67^{c}	1.04±6.20^{b}	1.00±0.71^{b}	1.02±3.30^{b}	2.24±0.02^{c}	1.03±6.30^{b}

Values are mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are significantly different (P<0.05)
N= North, W=West, E=East, S=South of the dumpsite center.

Table 4. Level of heavy metals (mg/kg) in roots and leaves of *Taliferia occidentalis*.

location	Lead Root	Cadmium Root	Chromium Root	Nickel Root	Manganese Root	Lead Leaves	Cadmium Leaves	Chromium Leaves	Nickel Leave	Manganese Leaves
Control	0.04±0.0^{a}	0.03±0.01^{a}	0.11±0.0^{a}	0.04a±0.03^{a}	0.16±0.00^{a}	0.08±0.00^{a}	0.09.±0.00^{a}	0.15±0.00^{a}	0.09±0.00^{a}	0.06±0.00^{a}
N	3.67±0.12^{e}	2.07±0.06^{b}	2.20±0.10^{b}	3.42±0.15^{d}	3.19±0.10^{d}	1.97±0.06^{e}	1.76±0.00^{d}	1.85±0.14^{d}	1.99±0.12^{e}	2.65±0.017^{e}
W	2.82±0.5^{d}	3.19±0.12^{e}	3.50±0.07^{e}	2.32±0.06^{c}	3.53±0.05^{e}	1.07±0.47^{c}	1.64±0.07^{c}	2.902±0.06^{e}	0.796±0.06^{b}	0.827±0.07^{b}
E	2.44±0.6^{c}	2.57±0.15^{d}	2.39±0.15^{c}	1.20±0.06^{b}	1.05±0.17^{b}	1.88±0.11^{d}	1.49±0.05^{b}	0.85±0.19^{b}	1.75±0.03^{d}	1.76±0.34^{d}
S	1.19±2.2^{b}	2.53±0.1^{c}	2.54±4.4^{d}	3.18±0.09^{e}	2.67±007^{c}	0.98±3.50^{b}	1.92±2.1^{e}	1.05±1.3^{c}	1.01±0.41^{c}	1.3±0.74^{c}

Values are mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are significantly different (P<0.05)
N= North, W=West, E=East, S=South of the dumpsite center

The pH range obtained from this study is not in line with that reported previously [24] along Enugu-Portharcult express way. The pH range difference could be from the nature of wastes in Ntigha dump site. It has been noted that biodegradation of wastes generate compound, which dissolves in soil moisture to affect the soil pH [25]. The pH of 0-45cm soil depth was significantly (p<0.05) higher than the pH of 46-90cm soil depth in all the sampling points of this study. Previous study [1] noted that soil pH is the master variable that affects virtually all soil properties. Decrease in pH results in increase in the availability of some metals which may build to toxic levels in soil and increase heavy metal phytoavailability [3]. Soil moisture (Fig. 3) also followed the same trend observed in soil temperature and pH in this study. 0-45cm depth was significantly (p<0.05) higher in soil moisture than 46-90cm at dumpsite (DC) in the present study. This could be due to insufficient aeration, which may have risen from poor displacement of air in the soil at dumpsite (DC). Also binding of the soil by wastes at dumpsite (DC), which reduced pore spaces, may have aided the insufficient aeration of the soil. Increased soil moisture content in mining effluent discharge points have also been reported [1]. Exchangeable acidity of soils presented in (Fig. 4) ranged from 0.01- 0.06 meq., while cation exchange capacity presented in (Fig. 5) ranged from 2.9-8.00 mg/kg. The observed exchangeable acidity values of dumpsite (DC) in the present study were lower than those of the controls and the values also increase from 0-45cm to 46-90cm depth. The level of exchangeable cations increased with increase in pollution. The cation exchange capacity of the present study was highest at the dumpsite compared to control (P<0.05). Findings from this study showed that 46-90cm depth has more cation exchange capacity than 46-90cm depth. The dumpsite samples were high than their controls with the exception of S_1 in this study. Similar increase has been reported previously [26,27]. It has been noted that cation exchange capacity gives the soil a buffering capacity. Buffering capacity may slow leaching of nutrient cations and positively charged pollutants. This may be related to the observed higher values of cation exchange capacity of the 46-90cm against those of 0-45cm (Fig. 5) in this study.

Soil enzymes activity influences functional processes occurring in soil and plays important role in catalysing chemical and biological processes necessary for soil microbes [3]. The acid phosphatase activity (Fig. 6) was lowest at the dumpsite (DC) compared to other points of the in the present study. There was significant increased (p<0.05) in 46-90cm depth than 0-45cm soil depth. Alkaline phosphatase activity presented in (Fig. 7) was more on the dumpsite (DC) than other points studied in the present

study. The activity of the enzyme increased in 0-45cm soil depth than 46-90cm soil depth. Dehydrogenase are produced by all organisms and are intracellular [28,29]. They serve as good measure of microbial oxidative activities in the soil [17]. Dehydrogenase (Fig. 8) had high activities in the soil samples analysed in this study. The dumpsite (DC) has the highest activities when compared to other sampling points of the present study. Dehydrogenase activities increased in 0-45cm depth against 46-90cm depth. The observation made on dehydrogenase in this study is in line with previous works [30,31] on polluted soil. The dumpsite C) had the highest hydrogen peroxidase activities (Fig.9) than other points considered in the present study. This could explain its higher activities in 0-45cm depth than 46-90cm depth in the present study (Fig.9). It has been noted that the activity of hydrogen peroxidase is high in acidic environment [32]. This is in line with the observation made on hydrogen peroxidase in this study. Urease activities in soil have received a lot of attention due to its role in the regulation of nitrogen supply to plants after urea fertilization [33, 34]. A significant fraction of ureolytic activity in the soil is carried out by extracellular urease [35]. According to earlier reports [36,18], factors such as cropping history, organic matter content, soil depth, soil amendments, heavy metals temperatures, etc, are among the factors that influence that urease activity in soil. The observed urease activity of dumpsite (DC) in this study was lower than those of control points S1 and S2 but increased significantly ($p<0.05$) in 0-45cm depth against 46-90cm depth. It has been suggested that the activity coefficient of urease increases with increase in temperature. The low urease activity of urease activity at dumpsite (DC) may correlate with observed temperature of the dumpsite (Fig.1) in the present study. According to [29]. protease enzyme in the soil is generally associated with organic colloids Protease activity (Fig. 11) was highest in dumpsite (DC). This could mean that the dumpsite (DC) has more organic colloids than other points in this study. The numerous leather materials at the dumpsite (DC) may have enhanced the protease activity. Earlier studies [1] reported that enzyme activities can be influenced by changes in pH value, increasing water content and nutrient addition on soil.

The soil heavy metals presented in (Table 1 and 2) also showed that Ntigha dumpsite is polluted with toxic metals compared to control samples ($P<0.05$). This could be due to increased dumping of scarabs in the dump which tend to increase the metals load. Phytoaccumulation studies presented in (Tables 3 and 4) showed that vegetables grown around Ntigha dumpsite also accumulated high level of these metals. This could be due to seepage from the dumpsite. Findings from this study shows that the level of impaction in soil decreased with increasing distance from the dumpsite centre. Similar finding has also been reported [1] who evaluated influence of mining effluent discharge on soil quality. These values were however higher than the WHO standard.

Conclusion

This study has revealed that open pit disposal of solid waste increased the phytoaccumulation potentials of edible vegetables grown around Ntigha dumpsite. Hence proper waste disposal method is advocated so as to prevent bioaccumulation of these heavy metals in human food chain due to seepage from the dumpsite.

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