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Relations between soil properties and transfer factor in some plant species at waste-impacted soils within Akwa Ibom State, Niger Delta region of Nigeria

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ABSTRACT

Soil, *Talinum triangulare and Amaranthus hybridus* samples were obtained from six (6) different dumpsite soils namely: Uyo; Ikot Ekpene; Ikot Abasi; Oron; Onna and Ibeno within Akwa Ibom State, Nigeria and analyzed their trace metal contents. Trace metals analyzed for were lead (Pb); cadmium (Cd); nickel (Ni); zinc (Zn); iron (Fe) and copper (Cu). The rate of metal uptake (Transfer factor) by these plant species from soil was evaluated too. Soil pH and organic matter contents of soils were also assessed using standard procedures. Results obtained indicated the following mean concentrations (mg/kg) in soil: 16.31±1.10; 4.21±0.62; 2.13±0.49; 49.95±2.88; 1750.51±125.41 and 10.75±1.28 for Pb; Cd; Ni; Zn; Fe and Cu respectively. *Talinum triangulare* recorded 2.43±0.35; 1.17±0.27; 0.63±0.08; 27.99±2.20; 269±10.46 and 0.86±0.16 while the mean level of metals in *Amaranthus hybridus* were: 2.17±0.39; 1.41±0.26; 0.58±0.11; 29.91±2.71; 250.04±16.12 and 1.21±0.30 for Pb; Cd; Ni; Zn; Fe and Cu respectively. Transfer factors plants showed the trends: Zn> Ni>Cd>Fe>Pb>Cu and Zn>Cd>Ni>Fe>Pb>Cu for *Talinum triangulare* and *Amaranthus hybridus* respectively. Metals assessed in soil and plants were within the safe limits in plants and soil properties however, both plants indicated high potential for zinc. except cadmium in soil. Positive and negative associations were observed between transfer factors.

Introduction

Studies have shown that apart from the natural geological processes of soil formation, the major source of trace metals to soil environment is the anthropogenic sources such as wastes dumpsites, agricultural activities, industrial activities etc [1]; [2]; [3]. Plants especially leafy vegetables grown within the vicinity of these metal loaded environments have the potential of accumulating them to levels higher than what may be required and transferred same into the food chain [4], [5], [6]. However, [7] reported that it is not the pool of metals in soil that are transferred into plants grown on them but only metal in the bioavailable form. Thus, the use of total concentration of metal as a criterion to evaluate the potential effects of soil contamination can be misleading since metal availability and mobility depend greatly on its physical form than its total amount in soil. According to [8] the understanding of metal availability and movement in soil is significant for evaluating its potential environmental and health effects. Transfer factor which is the ratio of metal level in plant to the level in soil is suitable and dependable technique for quantifying the bioavailable metal available for plant uptake [9]. Transfer factor also indicates the potential of plants to absorb metals form soil [10]. Predicting the availability of trace metals in soil for plant uptake has been of great concern for some time now due to the associated health effects of their bioaccumulation in plants and leaching into underground water [11], [12]. *Talinum triangulare* (water leaf) and *Amaranthus hybridus* (green) are plants widely consumed within Akwa Ibom State and they are sometimes obtained at waste dumpsites. Studies have also shown that, dumpsite soils have been used extensively for cultivating varieties of edible vegetables and plant based foodstuff in South-eastern Nigeria [13]. Nevertheless, it has been established that edible plants are the major channels by which metals are taken up by human [14].This study was undertaken to assess the quality of these vegetables, evaluate the amount of metals absorbed from soil and examine the soil properties that may enhance or hinder the transfer of metals into these plant species. Thus, by this work can be used as a baseline study for environmental work on phytoremediation within the study area.

Materials and Methods

Plant samples (*Talinum triangulare* and *Amaranthus hybridus*) as well as soil samples used in this study were obtained from six (6) urban dumpsite soils within Akwa Ibom State, Nigeria. These samples were collected between the months of January and March, 2014 from Uyo, Ikot Ekpene, Ikot Abasi, Oron, Eket and Ibeno local government areas (See Table 1 below for coordinates). At each dumpsite soil, top soil (0-15cm) samples were collected using soil auger at four(4) different locations and merged together to obtain a composite sample for that location while the leaves and stems of *Talinum triangulare* and *Amaranthus hybridus* were obtained using stainless steel knife [15], [16]. A total of eighteen (18) composite soil samples and thirty six (36) plant samples were obtained. These samples were sun dried for three (3) days and ground to pass through a 2mm mesh. 1g of each dried soil sample was digested with aqua regia on a hot plate using the procedures of [17] while 1g of each plant sample was digested with a mixture of acids (HNO_3 + $HClO_4$) on hot plate too following the procedures of [18]. Soil pH was measured in 1:2.5 (v/v) ratio of soil and water suspension [19]. Soil organic matter was determined by wet oxidation methods of Walkey and Black demonstrated by [20]. Concentrations of total metals were analyzed for in these samples using Unicam 939/959 atomic absorption spectrophotometer (AAS) [21].

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Table 1. Location and Coordinates

S/N	Location	Longitude (^{0}E)	Latitude (^{0} N)
1	Uyo	007. 55	05.02
2	Ikot Ekpene	007. 43	05.11
3	Ikot Abasi	007.55	04.38
4	Oron	007.56	05.30
5	Onna	007.52	04.39
6	Ibeno	007.98	04.57

Table 2. Concentrations (mg/kg) of trace metals in dumpsite soils

Location	Pb	Cd	Ni	Zn	Fe	Cu
Uyo	17.65	4.86	3.04	54.85	1937.51	12.86
Ikot Ekpene	16.13	3.93	1.78	51.26	1856.27	10.45
Ikot Abasi	14.84	3.72	2.05	46.80	1673.86	9.76
Onna	16.86	3.58	1.65	47.91	1692.05	9.35
Eket	17.12	4.06	2.11	50.22	1598.32	10.49
Ibeno	15.28	5.13	2.16	48.64	1745.07	11.56
Mean	16.31	4.21	2.13	49.95	1750.51	10.75
SD	1.10	0.63	0.49	2.88	125.41	1.28
Range (n = 6)	2.81	1.55	1.39	8.05	339.19	3.51

Table 3. Concentrations (mg/kg) of trace metals in *Talinum triangulare*

Location	Pb	Cd	Ni	Zn	Fe	Cu
Uyo	2.96	1.65	0.79	28.92	294.21	0.81
Ikot Ekpene	2.61	1.09	0.64	34.13	285.18	0.80
Ikot Abasi	2.57	0.91	0.58	31.03	256.36	0.73
Onna	1.98	1.27	0.62	29.47	261.73	1.13
Eket	2.04	1.16	0.53	26.25	275.61	0.94
Ibeno	2.42	0.96	0.65	25.14	266.40	0.72
Mean	2.43	1.17	0.63	27.99	269.92	0.86
SD	0.35	0.27	0.08	2.20	10.46	0.16
Range (n = 6)	0.98	0.74	0.23	5.89	28.82	0.41

Table 4. Concentrations (mg/kg) of trace metals in *Amaranthus hybridus*

Location	Pb	Cd	Ni	Zn	Fe	Cu
Uyo	2.31	1.84	0.65	34.26	275.14	1.37
Ikot Ekpene	2.72	1.12	0.71	29.35	263.47	0.94
Ikot Abasi	2.17	1.23	0.49	31.14	236.08	1.10
Onna	1.57	1.46	0.55	30.17	242.56	1.29
Eket	1.94	1.52	0.42	28.30	234.72	1.67
Ibeno	2.33	1.27	0.63	26.25	248.25	0.88
Mean	2.17	1.41	0.58	29.91	250.04	1.21
SD	0.39	0.26	0.11	2.71	16.12	0.30
Range (n = 6)	0.85	0.72	0.29	8.01	40.42	0.79

Table 5. Transfer factor of trace metals from soil into *Talinum triangulare*

Location	Pb	Cd	Ni	Zn	Fe	Cu
Uyo	0.17	0.32	0.26	0.53	0.15	0.06
Ikot Ekpene	0.16	0.28	0.36	0.67	0.15	0.08
Ikot Abasi	0.17	0.25	0.28	0.66	0.15	0.08
Onna	0.12	0.36	0.38	0.62	0.16	0.12
Eket	0.12	0.29	0.25	0.52	0.17	0.09
Ibeno	0.16	0.20	0.30	0.52	0.15	0.06
Mean	0.15	0.28	0.31	0.59	0.16	0.08
Range (n = 6)	0.05	0.16	0.13	0.15	0.02	0.06

Table 6. Transfer factor of trace metals from soil into *Amaranthus hybridus*

Location	Pb	Cd	Ni	Zn	Fe	Cu
Uyo	0.13	0.36	0.21	0.63	0.14	0.11
Ikot Ekpene	0.17	0.29	0.40	0.57	0.14	0.09
Ikot Abasi	0.15	0.33	0.24	0.67	0.14	0.11
Onna	0.09	0.41	0.33	0.63	0.14	0.14
Eket	0.11	0.37	0.20	0.56	0.15	0.16
Ibeno	0.15	0.26	0.29	0.54	0.14	0.08
Mean	0.13	0.34	0.28	0.60	0.14	0.11
Range (n = 6)	0.08	0.15	0.20	0.13	0.01	0.08

Transfer ratio of metals into was computed based on the methods of [10]. The relationship between transfer factor of metals and soil properties was ascertained using Pearson's correlation coefficient procedures.

Results and Discussion

Total metal concentration in soil and plant species studied

Total metals concentrations in Table 2 show the following ranges (mg/kg) in dumpsite soils assessed: Pb (14.84 - 17.65); Cd (3.58 – 5.13); Ni (1.65 – 3.04); Zn (46.80 – 54.85); Fe (1598.32 – 1937.51) and Cu (9.35 – 12.86). Ranges recorded for Pb; Cd and Ni in soil are lower than 3.0- 117.5; 0.91-51.6 and 1.5- 54.8 $mgkg^{-1}$ reported in waste dumpsite soil by [22]. However, the range obtained in this study for Fe is higher than 17.7- 563.3 $mgkg^{-1}$ recorded by [22]. Concentrations ($mgkg^{-1}$) of Zn and Cu obtained are lower than 827-1836 and 597-1468 $mgkg^{-1}$ respectively reported in waste-impacted soil by [23]. All the ranges recorded for trace metals in soil were within their normal ranges in soil except Cd which is above 0.01 – 2.00µg/g recommended by [24]. Cadmium and its attendant health implications may therefore be introduced into the food chain from soil if the situation is not properly managed.

Plants studied indicated the following ranges for trace metals as indicated in Table 3 and 4 respectively: (*Talinum triangulare*): Pb (1.98 – 2.96); Cd (0.91 – 1.65); Ni (0.53 – 0.79); Zn (25.14 – 34.13); Fe (256.36 – 294.21) and Cu (0.72 – 1.13) while *Amaranthus hybridus* recorded Pb (1.57 - 2.72); Cd (1.12 – 1.84); Ni (0.42 – 0.71); Zn (26.25 -34.26); Fe (234.72 – 275.14) and Cu (0.88 -1.67). Results obtained also indicated that ranges of Ni; Zn; Fe and Cu recorded in both plants species are lower than 1.20 – 8.10µg/g; 35.40 – 392.90µg/g; 250.00 – 710.00µg/g and 3.60 – 10.80µg/g reported by [25] in *Elusine indica*. Nevertheless, ranges of lead and cadmium reported in this study are higher than 0.31 – 1.00µg/g and 0.05 – 0.15µg/g respectively obtained by [25]. However, the level of metal accumulation by these plants may not pose any health problem within the area as all the ranges obtained in both plant species were within the recommended limits in plants [24]. Though, future examination should be carried out to avoid bioaccumulation of these metals with time.

Transfer factor (TF) of metals into plant species studied

The transfer factors for the trace metals in *Talinum triangalare* as Indicated in Table 5 below showed the following mean values : (0.15)Pb; (0.28)Cd; (0.31)Ni; (0.59)Zn; (0.16)Fe and (0.08)Cu while *Amaranthus hybridus* recorded the following: (0.13)Pb; (0.34)Cd; (0.28)Ni; (0.60)Zn; (0.14)Fe and (0.12)Cu (Table 6). The mean transfer factors obtained for Cd; Pb and Ni in both plant species are higher than their corresponding TF values reported by [1] *Talinum triangalare* . However, the TF values for Zn and Fe were lower 0.607 and 1.142 obtained by [1] while the mean TF value for copper in this study is lower than 0.40 reported by [25] in *Elusine indica*. TF values obtained for trace metals in *Talinum triangalare* and *Amaranthus hybridus* indicated the following trends: Zn> Ni>Cd>Fe>Pb>Cu and Zn>Cd>Ni>Fe>Pb>Cu respectively. This study therefore revealed that, zinc was highly absorbed by both plant species while the least absorbed plant was copper. The low TF of copper obtained may be attributed to the antagonistic effects of zinc as reported by [26]. The high TF value recorded in this study by zinc is similar to that reported by [27] (2010) in Tunisia. The high TF value for zinc may also be attributed to the high utilization of the metal for various enzymatic activities by plants [28]. The obtained results also indicated that, both plants may not be used for phyto-extraction and phytoremediation since TF values of these metals are not $\geq$1, however they are suitable for consumption [29]. This study has also shown that, both plants have the potentials of accumulating very high concentrations of zinc and low levels of copper.

Effects of soil properties on the uptake of trace metals by *Talinum triangulare*.

The relationship between pH and transfer factors of trace metals into *Talinum triangulare* indicated the following values for correlation coefficient (r) at $P < 0.20$: Pb (0.012); Cd (0.526); Ni (0.434); Zn (0.814); Fe (-0.066) and Cu (0.439). This study revealed that, pH may have accelerated strongly the transfer of cadmium, very strongly zinc and moderately nickel and copper into *Talinum triangulare* in the areas studied at 80% confidence. Nevertheless, pH showed a very weak positive relationship with the transfer of lead into *Talinum triangulare*. Consequently, this soil property may have influence the transfer of lead from soil into the plant inconsequentially thereby leading to the low level (15%) of lead transferred from the total lead into plant. pH showed a very weak negative relationship with the transfer of iron into *Talinum triangulare* at $P < 0.20$. This negative relationship between pH and transfer factor of iron may have resulted in the low proportion of Fe (8.0%) being transferred despite the high mean total iron in soil. the negative relationships between pH and some trace metals recorded in this study is similar to results obtained by [30] and [31].

The relationship between organic matter contents of areas studied and transfer factors of trace metals in *Talinum triangulare* recorded the following r values: -0.778; 0.667, -0.215; -0.543; 0.846 and 0.447 for Pb; Cd; Ni; Zn; Fe and Cu respectively. Organic matter (OM) showed significant positive relationships with the transfer of Cd and Fe into *Talinum triangulare*. Thus, organic matter may have formed soluble metal-organic complexes with Cd and Fe that rendered them more available for plant uptake. However; the high pH range obtained may have inhibited the availability of Fe as reported by [32] that, the rate of iron uptake by plants is significantly reduced at high soil pH. The relationship recorded for OM and Cd may have given rise to a fair mean transfer factor (28) reported in this study. The relationship between OM and copper uptake was positive but a moderate and insignificant one at 80% confidence. This divulged that the low mean OM recorded may have supported the uptake of copper moderately. Nonetheless, the high total iron and zinc in areas investigated may have antagonized the availability of copper as its deficiency is directly proportional to the high levels of these metals in soil couple with the high mean pH recorded [26], [33]. The transfer factor of lead indicated a significant negative relationship with organic matter content in soil at 80% confidence level. This may have been a strong reason behind the low mean transfer rate of Pb (15) into *Talinum triangulare* in this study since an increment in OM contents may result in a reduction of transfer factor of the metal. Organic matter also indicated a negative but moderate and significant association with zinc at $P < 0.20$. Thus, the transfer factor of Zn was inversely proportional to the organic matter contents in the study area.

Effects of soil properties on the uptake of trace metals by *Amaranthus hybridus*.

The relationship between pH and the transfer of trace metals into *Amaranthus hybridus* recorded the following correlation coefficients (r) for Pb; Cd; Ni; Zn; Fe and Cu: 0.090; 0.335; 0.416; 0.502; -0.173 and 0.152 respectively at $P < 0.20$. These correlation coefficients indicate that, pH correlated positively but moderately with the absorption of nickel and zinc from soil. Thus, this relationship may have contributed to the fair and high proportion (27% and 60%) of Ni and Zn respectively transferred from their total contents in soil. pH indicated a positive but weak correlation with the transfer of cadmium into *Amaranthus hybridus* however, a fair mean transfer factor (34) was recorded for cadmium. Thus, the level of soil pH recorded may have supported the uptake of Cd by *Amaranthus hybridus* fairly. Correlation analysis between soil pH and transfer factors of lead and copper, revealed very weak positive and very weak negative relationships respectively. Accordingly, the high soil pH recorded in this study may have aided the absorption of lead by *Amaranthus hybridus* insignificantly while reducing the rate of iron uptake though weakly too.

Pearson's correlation analysis between OM and transfer factors of metals into *Amaranthus hybridus* indicated significant positive relationships with the uptake of Cd, Fe and Cu (r = 0.778; 0.677 and 0.867 respectively at $P < 0.20$). Consequently, the uptake of these metals by green was directly proportional to the organic matter contents of the areas studied. However, the high mean pH may have resulted in low mean transfer factor reported for Fe as confirmed by the negative relationship between the two. The low mean transfer factor also recorded by copper may be attributed to the high pH, high total Zn and Fe contents in soils studied. Cadmium indicated a high transfer factor since high soil pH may not reduce its uptake by plants [34], [35]. The relationship between lead uptake by *Amaranthus hybridus* and organic matter contents in soil indicated a significant positive one with r value = -0.871 at 80% confidence. Invariably, the range of organic matter contents in soil studied may have strongly inhibited the uptake of lead by *Amaranthus hybridus* thereby resulting in the low mean transfer factor reported. Relationship between Ni uptake by *Amaranthus hybridus* and organic matter showed a moderate positive but insignificant one with r = -0.453 at $P < 0.20$. It could be inferred from this result that, the rate of Ni uptake by the plant may have been impaired by organic matter contents in soil. This finding is in agreement with the report by [36] that, OM can reduce nickel availability in soil. The absorption of zinc by *Amaranthus hybridus* showed a very weak negative relationship with organic matter content in soil with r value of -0.089 at $P < 0.20$. Consequently, a variation in organic matter contents in soil studied may not influence the availability of zinc in the area substantially. The high mean transfer factor of Zn (60) obtained in this study may be attributed to low OM contents and a corresponding reduction in the number of available sites for the binding of zinc ions [37].

Distribution of soil properties in the area of study

The pH of areas studied ranged between 6.79 at Onna dumpsite soil and 7.43 in Ikono dumpsite soil with mean of 7.17±0.22 (Fig.1). The pH range obtained in this study is peculiar to the pH range in the tropics which usually range between acidic to slightly neutral according to [38]. This pH range is lower than 11.05±1.09 – 8.72±0.72 obtained in dumpsite soils by [39] but higher than 6.61 – 7.13 reported by [40]. The pH range obtained in this study is favourable for most plants and optimal mineral elements availability for most crops which is 6.0 - 7.5 [41], [42]. The pH of dumpsite soils varied from one location to the other with all the locations being slightly alkaline except at Onna dumpsite soil where acidic pH was recorded. Organic matter contents in dumpsite soils studied as shown in Fig. 1 below varied between 4.60% obtained in Abak dumpsite soil and 9.89% at Eket dumpsite soil with a mean value of 6.85±2.20. This range is higher than 1.03 – 4.71% reported by [41] but lower than 4.3 – 21.8% obtained by [39]. The low organic matter obtained in this study may be attributed to the low level of biodegradable waste materials at these dumpsites.

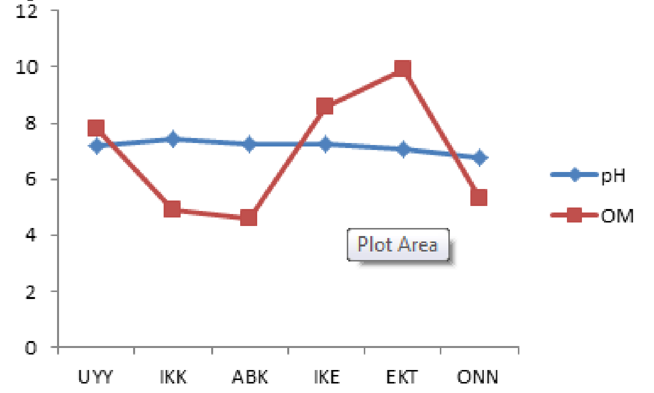

Fig 1. Distribution of soil pH and organic matter within the study area

Conclusion

This work has confirmed that, the absorption of trace metals in soil is a function of soil properties and plant species as opined by [44]. It has also corroborated the findings by [45] that accumulation of Pb and Ni is comparatively less than that of Cd in plants. it has been established in this study that, organic matter content of the areas studied can inhibit the availability of lead for plant uptake. This is in agreement with the report by [46] that, organic matter forms insoluble compounds with lead in soil.

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