

Transfer Characteristics of Trace Metals from Soil to the Edible Parts of Some Vegetable Species Grown in Ibeno, South-South Nigeria

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ABSTRACT

The aim of this study was to assess the levels of trace metal in soils and leafy vegetables at Ibeno, as a result of crude oil exploration activities in the area. The study areas were Mkpanak, Iwuoachang and Ukpenekang all in Ibeno Local Government Area of Akwa Ibom State, Nigeria. Soil and vegetable samples (*Telfaria occidentalis*, *Spinacia oleracea* and *Talinum triangulare*) were collected randomly from sampling sites and analyzed for trace metals (Pb, Zn, Cu, Co and Cd) using atomic absorption spectrophotometric technique. Bioaccumulation of trace metals in plant parts were estimated as transfer factors (TF). Metal concentrations in the soil ranged from 85.56 mg/kg to 143.84 mg/kg for Zn, 39.24 mg/kg to 52.55 mg/kg for Co, 2.66 mg/kg to 4.50 mg/kg for Cu and 0.01 mg/kg for Pb and Cd in the soil. Trace metal levels in soils were below Federal Environmental Protection Agency (FEPA), Nigeria limits for agricultural soils except for Co. Higher levels ($P < 0.05$) of metals were measured in soils at the various locations compared to the control soils. At levels of trace metals in vegetables varied in the order, *Telfaria occidentalis* > *Spinacia oleracea* > *Talinum triangulare* and the concentrations were higher than WHO/FAO limits. TF values showed higher accumulation of Pb with a Pb > Cd > Cu > Zn > Co gradient. The results showed that *Telfaria occidentalis* exhibited the most ability to accumulate trace metals followed by *Spinacia oleracea* and *Talinum triangulare*. This showed the potential of using *Telfaria occidentalis* as an indicator of trace metal pollution in soils. The high TFs observed in this study indicated bioaccumulation of the metals in plants and a possibility of systemic toxicity when these plants are consumed by either humans or animals.

Keywords: Trace metals; soils; vegetables; transfer factor; Ibeno.

1. INTRODUCTION

Excessive intake of metals through consumption of contaminated vegetables and plants is associated with human health risk [1, 2, 3]. Trace metals are toxic as a result of their ability to accumulate in different body parts of the human system even at low concentrations [4]. Since they are persistent in nature [5], many food plants accumulate trace metals, resulting in the rise of the metal content of farms produce [6]. The ingestion of trace metals can cause depletion of some essential nutrients in the body, which in turn causes a decrease in immunological defenses, intrauterine growth retardation,

psychological dysfunctions, disabilities associated with malnutrition and a high prevalence of upper gastro intestinal cancer [2].

Studies have been conducted to measure trace metals in soils with differing levels of anthropogenic influences such as in urban cities and industrial areas [7], automobiles traffic [8] and mining activities [7]. Generally, both natural and anthropogenic sources are responsible for soil enrichment or contamination with trace metals and their contamination level varies from one place to another [9, 10, 11]. Previous research works have shown the levels of trace

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metal enrichment of soil ecosystems and the plants grown on them [12 - 14].

Please mention ref [9] inside the text

Ibeno, Nigeria lies along the Nigerian coast, it is therefore prone to the pollution of its soils and plants due to the presence of trace metals owing to oil exploration, fishing, farming recreational activities, and discharges from automobile exhaust [15]. Due to the activities going on daily in this area, farmlands and plants need to be assessed regularly to determine their extent of contamination with trace metals. For this reason *Talinum triangulare*, *Telfaria occidentalis* and *Spinacia oleracea* were selected and used in estimating the level of bioaccumulation of the trace metals in this study. These vegetables are cultivated widely around Ibeno and are majorly used in local cuisines of the area.

The aim of this study was to assess the levels of trace metal in soils and leafy vegetables, and determine the plant to soil transfer factors of trace metals for edible vegetables at Ibeno, an area in the Niger Delta zone of Nigeria known for crude oil exploration activities. This was with a view to determining the bioaccumulation of the trace metals by the plants from the soils.

2. METHODOLOGY

2.1 Study Area

The study areas included three villages of Mkpanak, Iwuoachang and Ukpenekeang all in Ibeno Local Government Area of Akwa Ibom State, Nigeria, and a control site at Ekpri Nsukara, in Uyo 67 km from the Ibeno. Mkpanak is located between latitude $4^{\circ}33'11''\text{N}$ and longitude $7^{\circ}59'50.94''\text{E}$, Iwuoachang is located between latitude $4^{\circ}34'12.78''\text{N}$ and longitude $7^{\circ}58'03.14''\text{E}$, Ukpenekeang is located between latitude $4^{\circ}34'27.94''\text{N}$ and longitude $7^{\circ}58'32.32''\text{E}$. The control site, Ekpri Nsukara is located between latitude $5^{\circ}2'59.946''\text{N}$ and longitude $7^{\circ}55'59.9226''\text{E}$. Ibeno Local Government of Akwa Ibom State is located in a typical climatic zone characterized by distinct dry and wet seasons. The geology of the area consist of unconsolidated sand formation ranging from coarse to fine sand [16].

2.2 Samples and Sampling

2.2.1 Soil sampling

Soil samples were collected randomly from sampling sites as described by [17]. Nine soil

samples were collected from each of the four sampling sites (making a total of 36 samples) at a depth of 0-15cm with stainless steel auger as described by [18]. Each of the nine samples were collected in the form of sub-samples at a distance of about 20m each from the first sub-sample. Four sub-samples were thoroughly mixed to a composite sample [18]. Soil were also collected from the control site at Ekpri Nsukara, a farming community devoid of oil exploration activities. The soil samples were collected in their natural form in clean polythene bags, properly labeled and taken to the laboratory for treatment and analyses. Sampling was carried out in the dry season.

2.2.2 Vegetable sampling

Fresh samples of three edible vegetables namely *Telfaria occidentalis*, *Spinacia oleracea* and *Talinum triangulare* were picked from the same site as the soil samples. The vegetables were carefully uprooted from the soil and were subsequently separated into leaves, stems and roots in the laboratory. The vegetable were placed in black clean polythene bags, properly labeled and taken to the laboratory in fresh form to avoid deterioration and contamination from further elemental reactions. Vegetables were also collected from the control sites and similarly treated.

2.3 Soil Sample Treatment

Freshly sampled soils were spread in drying trays and air dried for 48 hours in the laboratory. After drying, the samples were mechanically crushed using a pestle and mortar and passed through a 2mm mesh sieve [18].

2.3.1 Vegetable sample treatment

At the laboratory, the vegetable samples were washed with de-ionised water to remove soil particles and were separated into leaves, stems and roots. These vegetable parts were oven dried at 55°C to a constant weight. The dried vegetable samples were powdered using clean electronic grinder and then stored in clean labeled polythene bags at room temperature for further analysis.

2.4 Sample Dissolution

2.4.1 Soil digestion

Digestion of soil was done according to the method described by Udo *et al.* [18]. About 1g of the remaining soil sample was weighed into a digestion flask and 10ml of perchloric acid and 20ml of HNO₃ added to it. The sample was digested on a hot plate until the colour of the digest changed to white. The sample was cooled and 50ml of deionised water added to the digestion flask. The solution was filtered using a Whatman No.541 filter paper into a clean volumetric flask and stored for trace metals analysis.

2.4.2 Vegetable digestion

Approximately 0.5g of the remaining powdered vegetable sample was weighed into a digestion flask. About 10ml of perchloric acid and 20ml of HNO₃ were added to the flask. The sample was digested using a hot plate until the colour of the digest changed to white. This indicated the completion of digestion process [18]. The digestion flask was allowed to cool and 50ml of distilled water added to it. The solution was filtered with a Whatman No. 541 filter paper into a clean volumetric flask for the determination of trace metals concentration.

2.5 Determination of Trace Metals levels in Soil and Vegetable

The trace metals (Pb, Zn, Cu, Co and Cd) in soil, and vegetables were analyzed using atomic absorption spectrophotometer (Unicam' 969 equipped with air-acetylene atomization gas mixture, with detection limits of 1-20µg/ml). A calibration curve was prepared for each metal using different concentrations of standard solutions and the concentration of the metals in digested samples were determined from the curve. The samples were aspirated into the atomic absorption spectrophotometer and the absorbance recorded.

2.6 Transfer factors (TF) for Trace Metals

Transfer factor is the ratio of the level of trace metals in a plant to the level of trace metals in the soil. The Transfer Factors (TF) for each trace metal were based on the method described by Harrison and Chirgawi [19]. Metal levels in the extracts of soil and plant were calculated on the basis of dry weight as follows:

$$TF = \frac{\text{Level of trace metal in plant}}{\text{Level of trace metal in soil}}$$

2.7 Data Analysis

Data collected were subjected to statistical tests of significance using Students t-test for soil samples and analysis of variance (ANOVA) at P<.05, was used to assess result pairs in the test and control for the leaves, stems and roots.

3. RESULTS AND DISCUSSION

3.1 Levels of Toxic Heavy Metals in Soil

The level of trace metals in the soil from Ukpenekang, Mkpanak and Iwuochang and control sites are presented in Fig.1. The results revealed higher levels of Zn and Co in the soils with a metal concentration trend of Zn>Co>Cu>Cd = Pb. Metal concentrations ranged from 85.56mg/kg to 143.84mg/kg for Zn, 39.24mg/kg to 52.55mg/kg for Co, 2.66mg/kg to 4.50mg/kg for Cu and 0.01 mg/kg for Pb and Cd in the soil. The order of metal concentration across sites were: Mkpanak>Ukpenekang>Iwuochang>Control.

Higher levels (P<0.05) of metals were measured in soils at the various locations in Ibeno compared to the control soil. This may be due to additions of Zn, Co and Cu from anthropogenic inputs to the soil at sampled locations. Trace metal levels obtained from soils in this study were higher than the levels reported for soils in other parts of the Niger Delta region of Nigeria except for Pb and Cd [20, 21], but lower than values reported by Etim *et al.* [14]. However, trace metal levels obtained in this study were below Federal Environmental Protection Agency (FEPA), Nigeria limits for agricultural soils except for Co. The low levels of Pb and Cd in Ibeno soil may in part be attributed to the porous sandy soil texture and heavy rainfall experienced in the area which allow a high degree of flushing. Sandy and loamy marine sediments are especially prone to leaching due to sandy textures. The high levels of Zn, Co and Cu in the soil may be attributed to anthropogenic activities such as oil exploration, vehicular traffic and run-offs from industrial effluents [21].

3.2 Trace Metals in Vegetables

Mean levels of Pb, Zn, Cu, Co, Cd in vegetables from the study locations and control are presented in Figs. 2 - 6. The results reveal higher lead levels in *Telfaria occidentalis* and *Spinacia oleracea* than in *Talinum triangulare* (Fig. 2). The roots had the highest concentration of trace

metals with a root>stem>leaf gradient. For the studied locations, concentration of Pb in soils and vegetables from Ukpenekang and Mkpanak were higher than those from the control sites. However, the Pb levels from stems ranged from 0.01mg/kg to 13.52mg/kg with the highest concentration 13.52mg/kg from *Spinacia oleracea* stem in Ukpenekang. Detectable levels of lead in vegetable roots ranged from 0.01mg/kg to 17.47mg/kg. The highest value 17.47mg/kg was obtained from *Telfaria occidentalis* roots in Ukpenekang.

The Pb level of 5.00mg/kg in *Telfaria occidentalis* leaves in Ukpenekang and 10.99mg/kg in *Spinacia oleracea* leaves in Mkpanak were higher than the 1.0 mg/kg allowable limit of lead in food meant for human consumption [22]. Essiet *et al* [23] have reported lead values of 0.97mg/kg for *Costusafer*, 0.72mg/kg for *Anthoclei stavogelii* and 0.43mg/kg for *Raphialo okeri* from oil polluted soils in Akwa Ibom. Lead being a serious cumulative body poison reportedly enters the body system through air, water and food, and cannot be removed by washing contaminated fruits and vegetables [24]. The high level of Pb in some of these vegetables may probably be attributed to pollutants in irrigation water, from soil or due to pollution from highway traffic [25]. The level of Pb reported for vegetables in this study is comparable to those reported for apples (0.19mg/kg), water melon (0.30mg/kg), orange (0.15mg/kg) and banana (0.02mg/kg) in Egypt by [26]. Parveen, *et al.* [27] also reported 0.76mg/kg for apple. The concentrations of lead from vegetables in the control site was observed to be very low (0.01mg/kg).

Zn levels in the vegetables were generally high with highest mean value of 306.38mg/kg for *Telfaria occidentalis* stem in Mkpanak and the lowest mean value of 77.69mg/kg for *Telfaria occidentalis* stem at Ukpenekang (Fig. 3). The level of Zn in the vegetables studied was also higher than the 50mg/kg Zn levels in plants allowed by the Romanian legislation. This results showed that the vegetables were highly contaminated with Zn. It has been documented that ingestion of Zn in the excess of 12mg per day may cause lung disturbance in humans [28]

In this study, Cu in edible vegetable parts ranged from 0.70mg/kg to 124.34mg/kg (Fig. 4). The lowest level was obtained from roots of *Talinum triangulare* at the control site and the highest from *Talinum triangulare* root in Mkpanak. The high level of Cu obtained in this work indicated high input Cu from the effluent discharged in the estuary by a petrochemical industry into the soils of the area and are subsequently absorbed by plants. The Cu levels obtained were higher than the 0.00-5.00mg/kg allowable limit for Cu in vegetables by WHO/FAO [29] as well as the 10mg/kg allowable limits for Cu in vegetable by the Romanian legislation. Cu being an essential micro nutrient that combines with iron to maintain a healthy central nervous system, prevent anemia and also promote the functions of Zn and Fe in the body [30] Levels of Cu from both plants and soils in this study were higher compared to other published works elsewhere [26, 27, 31]. However, copper levels in vegetables from the control site were very low with values ranging between 0.70 mg/kg and 21.97 mg/kg.

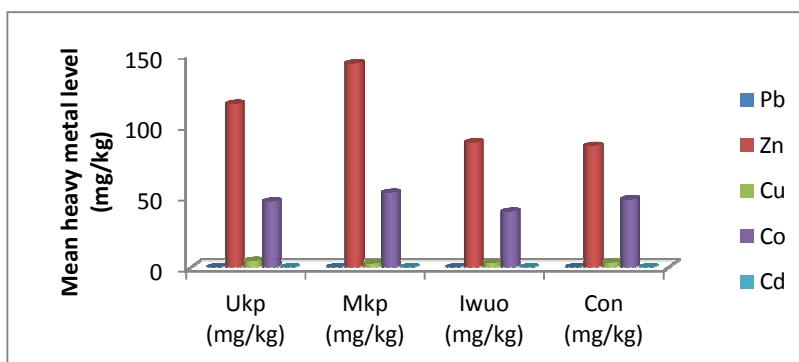


Fig. 1. Mean heavy metal levels in soils at different sampling station
 Key: Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuoachang, Con=control

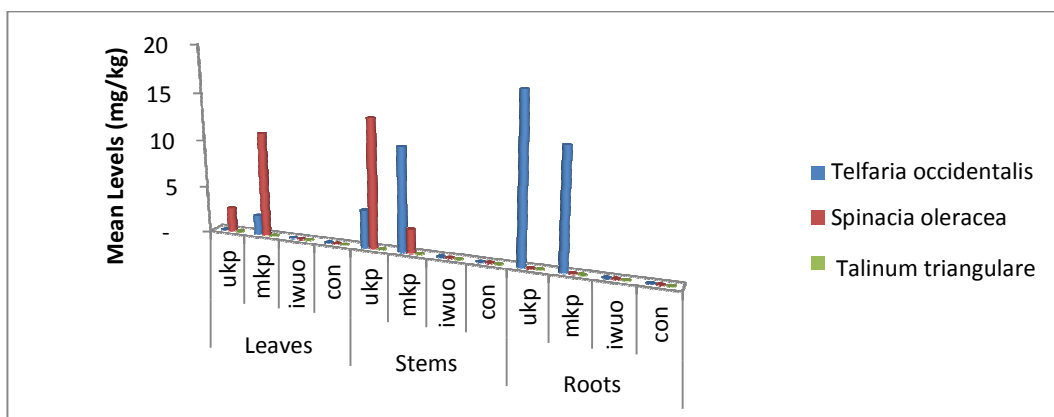


Fig. 2. Mean levels of lead in edible vegetables at different sampling stations

Key : Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuoachang, Con=control

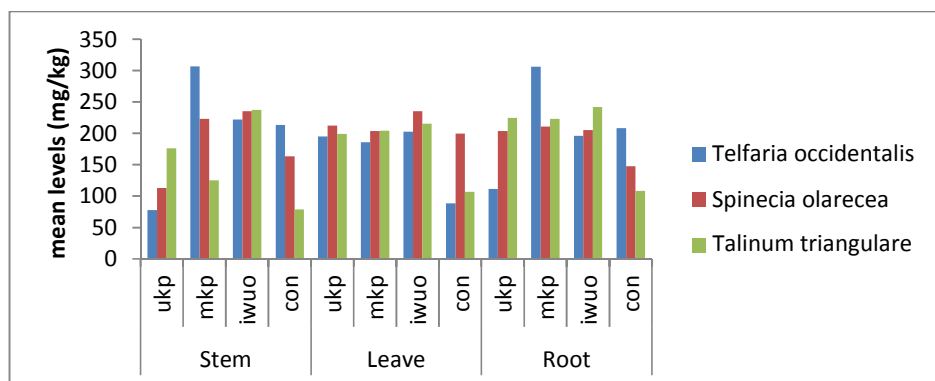


Fig. 3. Mean zinc levels in edible vegetables at different sampling stations

Key : Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuoachang, Con=control

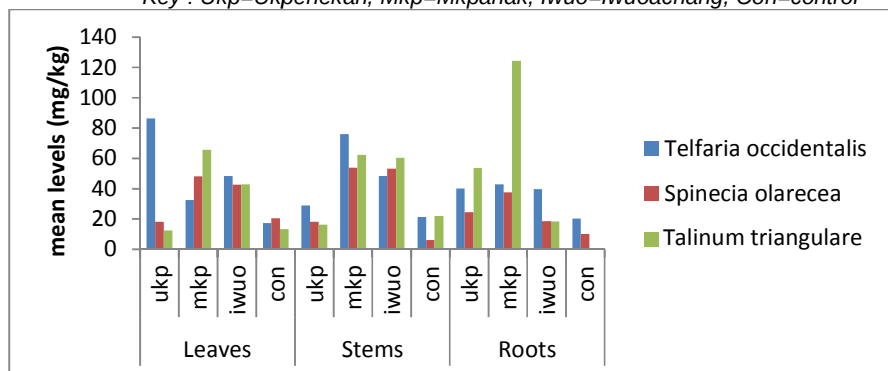


Fig. 4. Mean Cu levels in edible vegetables at different sampling stations

Key : Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuoachang, Con=control

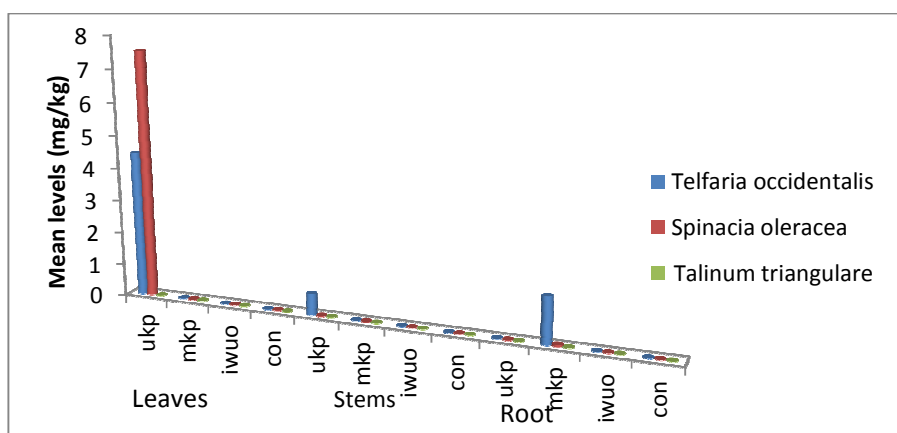


Fig. 5. Mean cobalt levels in edible vegetables at different sampling station

Key : Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuochang, Con=control

Co in edible vegetable parts in this study ranged from 0.01mg/kg to 7.54mg/kg (Fig. 5). Higher levels of Co (0.65 – 7.54mg/kg) was recorded in *Telfaria occidentalis* stem and leaves and *Spinacia oleracea* leaves from Ukpenekang. The level of Cu in the other vegetable samples and in the control sample was low (0.01mg/kg). Generally, mean Co concentrations were higher ($P < 0.05$) at the studied sites than the controls. The Co levels obtained in the area were higher than values reported by [26] in Egypt for *Telfaria occidentalis* well as the WHO/FAO recommended levels for vegetables meant for human consumption [29].

Cd in edible vegetable parts in this study ranged from 0.01mg/kg to 2.16mg/kg with the highest value from *Telfaria occidentalis* leaves at Ukpenekang (Fig. 6). Cd levels in the vegetables were generally higher than the natural limits of 0.1-1mg/kg in plant [32]. Cd is a non – essential element in foods and natural waters and it

accumulates principally in the kidneys and liver [24]. The cadmium level in *Telfaria occidentalis* and *Spinacia oleracea* in Mkpanak exceeded the recommended SEPA limits and is an indication of environmental pollution.

3.3 Transfer Factors (TFs) of Trace Metals from Soil to Vegetables

The TFs for Pb, Zn, Cu, Cd, are shown in Tables 1 - 3. At Ukpenekang, Pb was most accumulated by the vegetables with TF values in the order: Pb>Cd>Cu>Zn>Co. The results also indicated that *Telfaria occidentalis* exhibited the most ability to accumulate trace metals followed by *Spinacia oleracea* and *Talinum triangulare*. At Mkpanak, the transfer factors were 5.70×10^{-4} mg/kg for Co, 3.84 to 5.54 mg/kg for Zn, 56.88 to 94.79mg/kg for Cu, 51.00 to 145.00mg/kg for Cd and 3.00 to 2540 mg/kg for Pb.

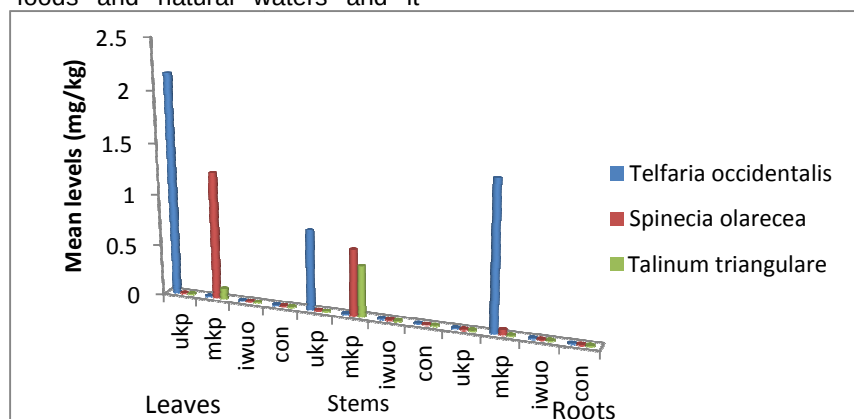


Fig. 6. Mean cadmium levels at different sampling stations

Key : Ukp=Ukpenekan, Mkp=Mkpanak, Iwuo=Iwuochang, Con=control

Table 1. Transfer factor for trace metals from soils to plants at Ukpenehang

Vegetable	Metals				
	Pb	Zn	Cu	Cd	Co
<i>Telfaria occidentalis</i>	2637.00	3.33	34.54	0.10	295.00
<i>Spinacia Oleracia</i>	1604.00	4.59	74.46	0.16	3.00
<i>Talignum Triangulare</i>	3.00	5.18	18.22	6.46x10 ⁻⁴	3.00

Table 2. Transfer factor for trace metals from soils to plants at Mkpanak

Vegetable	Metals				
	Pb	Zn	Cu	Cd	Co
<i>Telfaria occidentalis</i>	2540.00	5.54 mg/kg	56.88	145.00	5.70x10 ⁻⁴
<i>Spinacia Oleracia</i>	1351.00	4.43 mg/kg	52.42	193.00	5.70x10 ⁻⁴
<i>Talignum Triangulare</i>	3.00	3.84 mg/kg	94.79	51.00	5.70x10 ⁻⁴

Table 3. Transfer factor for trace metals from soils to plants at Iwuoachang

Vegetable	Metals				
	Pb	Zn	Cu	Cd	Co
<i>Telfaria occidentalis</i>	3.00	7.05	46.38	3.00	7.64x10 ⁻⁴
<i>Spinacia Oleracia</i>	3.00	7.54	38.99	3.00	7.64x10 ⁻⁴
<i>Talignum Triangulare</i>	3.00	7.89	41.41	3.00	7.64x10 ⁻⁴

At Iwuoachang, Cu had the highest transfer factor of 41.41 to 46.38 mg/kg and was highly accumulated in all vegetables studied followed by Zn, Pb, Cd, and Co. The extent of accumulation of metals appeared to be similar for the plants sampled at Iwuoachang. The high bioaccumulation capacity exhibited by *Telfaria occidentalis* at all the study sites indicated the possibility for its use as an indicator of trace metal pollution in soils. *Telfaria occidentalis* is a biennial plant and the high TFs estimated might be due to the fact that it had stayed much longer than *Spinacia oleracea* and *Talinum triangulare* which are usually harvested fortnightly. The different accumulation trends for various locations can be related to the management of the soil nutrients and to the chemical properties of soil including pH, organic matter and clay contents, loss of ignition and cationic exchange capacity.

Transfer factor decreased with the increase of the respective metal contents in soil indicating an inverse relationship. Such inverse relationship was reported by Wang *et al.* [33] for vegetables. The high TFs estimated in this study was indicative of bioaccumulation of Pb and other trace metals studied and **could** lead to possible toxicity in the system of humans and animals that may consume these vegetables.

4. CONCLUSION

The levels of some of the heavy metals determined in soils and some edible vegetables were higher than the limit set by various regulatory agencies and **was** an indication of environmental pollution. Bioaccumulation of trace elements in vegetables were studied using the soil to plant TFs. The high TFs estimated in this study was indicative of bioaccumulation of the trace metals studied. Hence, the associated health risk due to organ toxicity earlier reported in both humans and animals who consume these vegetable is of immense public health concern. Generally, the transfer factor for metals in *Telfaria occidentalis* were higher than other plant species. The high bioaccumulation capacity exhibited by *Telfaria occidentalis* at all the study sites shows that the vegetable can serve as an indicator of trace metal pollution in soils. There is an urgent need for clean up and enactment of legislative framework to control the inputs of trace metals into the soils of Ibeno so as to forestall dire health consequences in the nearest future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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