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The Translocation Factor of Metals in Soil-Cassava Plant System from Gokana, Ogoni, Rivers State, South-South, Nigeria

Edori, Onisogen. S., Nwineewii, Jack. D. and Sor, Augustine L.

Department of Chemistry, Ignatius Ajuru University of Education, Rumuolumeni, PMB 5047, Port Harcourt, Rivers State, Nigeria
Email: onisogen.edori@yahoo.com

Abstract Soil and cassava (leaves and tubers) samples were collected from Gokana communities in Rivers State, Nigeria in the months of January and July, 2020. Following standard procedure, the samples were prepared and digested for heavy metals analysis. The analysis for heavy metals was done on the soils, leaves and tubers of cassava using atomic absorption spectrophotometer. The results showed that the concentrations of the heavy metals in the soil were in the order Fe > Cr > Cu > Ni >Pb> Cd in both January and July. In the leaves and tubers, the values were in the order Fe > Cu > Cr > Ni >Pb> Cd for the month of January, while July values were in the order Fe > Cr > Cu > Ni >Pb> Cd. Translocation factor values for soil-leaves, soil-tubers and tubers-leaves showed values > 1. This therefore, indicated that the propensity to accumulated heavy metals in the tissue of the cassava is low and so the cassava plant may not be a source of excess heavy metals intake among its consumers in the area. However, efforts should be put in place to check different anthropogenic activities in the area to avoid any shift towards increase in heavy metals sources.

Keywords Translocation Factor, Soil-Cassava Plant System, heavy metals, anthropogenic activities

Introduction

The result of fast and unrestrained industrial development and expansion placed side by side with demanding agricultural processes, the universal environment has been placed under extensive pressure. Recent progress has led to the unrestricted discharge of a wide range of lethal chemicals into the environment from end to end copious activities executed by humans [1]. The release of heavy metal to the environment through anthropogenic based activities has been found to be several times greater than natural releases [2]. Industrial and economic improvement is accompanied with notable release of heavy metals into the surroundings [3]. The release of these harmful and toxic substances is accompanied with severe risk to human well-being and condition and land-dwelling biomes and this is mostly observed in environments linked to mining and other industrial activities [4-5].

Natural endowments match with essential quantifiable materials foundation which promotes socio-economic advancement. Nonetheless, the importance of mineral assets, exploration, extraction, mining and their application in diverse manufacturing practices have caused severe ecological problems, particularly with regard to heavy metals polluting the environment [6-7]. The incidence of elevated concentrations of detrimental substances such as heavy metals in the surrounding is a probable hazard to human fitness, as well as the ecological system [8]. This is because most of these toxicants possess the propensity to bioaccumulation and are highly retained in the ecology [3].

Heavy metals can mount up to high concentrations in the soil and can travel in the soil environment. Metals in soil can possibly be taken-up by vegetation from their roots and are stored up in vital parts of the plant. Increased levels of metals present in soil can cause distress to the safety of the ecosystem and thus cause mortal damage to environmental flora and fauna, and humans. When there is an elevated level of heavy metals in plant, there is the possibility of inhibition of chlorophyll formation, which results in under productivity of the plant. It also causes increased oxidative stress and decline in the resistance of stomata [9]. The place of heavy metals in environments studies is due to their ecological significance and toxicity at definite concentrations, transfer by food chains and inability to undergo degradation and therefore, accumulate in soil, sediment and biological systems [10].

The transfer of heavy metals from soil to plant and transfer leaf to root is a process that is very important in accumulation and storing of minerals in plants [11]. According to Wu and Zhang [12], oxidative stress on plants caused by heavy metals can dislocate essential metals, interrupt the normal pathways and functions of metabolic processes, and ultimately cause a reduction in the yielding potentials of plants. Besides, prolonged intake of low levels of heavy metals may lead to permanent damaging effects on the well-being of man [12]. The translocation or transfer factor of heavy metals is a pointer of the extent to which heavy metals can accumulate in plants. It gives an idea on the changes or modifications in the amount of heavy metals that is available to plants from the soil. Translocation factor can further be explained to mean the mobility of heavy metals from soil to plant. For the time being, it is taken or known as a serious factor concerning heavy metals accumulation in plants [11].

Amongst agronomic goods in Rivers State, cassava (*Manihot spp*) is extensively eaten as a food. Consequently, in the event of contamination, it possibly will turn out to be an important nutritional basis of lethal substances when related with other viable and edible food crops in the state. Thus, the quality of cassava eaten or processed for ruminants, can greatly affect animal and human health. Therefore, the contamination of agricultural soils with harmful substances such as heavy metals and their transfer into plants tissues have become of utmost concern all over the globe [13].

Therefore, this work examined the concentrations of heavy metals in soil and cassava from Gokana, Rivers State and the translocation factor between the soil and cassava parts and between the leaf and tuber of the cassava plant.

Materials and Methods

Samples of soil from agricultural farmlands in Gokana communities were collected at 0 -15 cm depth with soil auger. Random samples were obtained and pooled together to form composite sample. The samples were quickly put into a water proof container and sealed immediately. Before collection of the sample, the water proof container was washed and treated with dilute nitric acid and allowed to dry. The soil samples were taken underneath the cassava plant used for the same experiment.

Tubers and leaves of cassava were also collected at the same points where the soil samples were collected. The tubers were detached from the cassava stem and leaves also plucked off from the stem. They were separately put into different polythene containers and sealed. Both soil and cassava parts were instantly moved to the Jaros Base Scientific Laboratory, along Iwofe/Rumuolumeni Road, Port Harcourt.

In the laboratory, the soil samples were air dried to a constant weight for 14 days. Furthermore, the weight of the samples were taken and then allowed to dry for another week. Thereafter, a constant weight was observed. The dry soils were crushed using pestle and mortar. The pulverized soil samples were sifted with 2mm mesh to obtain fine particles. The uniform soil samples put in dry acid pre-washed glass vials and then preserved for digestion.

Samples of cassava parts from the farms were washed at the first instance with water from borehole to remove dirt and soil particles. Afterwards, they were washed again with de-ionized water collected from the laboratory. The leaves were placed in an oven regulated at a temperature of 60 ºC to dry. They were allowed in the oven for six hours and are removed when a constant weight was observed. The tubers were initially peeled and white edible part of the cassava were sliced to small sizes and oven dried to constant weight at 60 ^{o}C for twelve hours.

The dried leaves and tubers were separately milled with an electric mortar to fine powder. The powdered cassava parts were placed in nitric acid pre-cleansed plastic bottles and stored until time for investigation.

Exactly 2.0 g of each cassava part were transferred to digesting receptacles earlier acid washed and 7 ml of 70% nitric acid, 2 ml of (35%) hydrogen peroxide and 1ml of 37% HCl were placed in the separate receptacles. All the receptacles were tightly closed and positioned in a steam bath operated at 60 ^oC. The receptacles were steam heated 90 minutes and a clear colour of the digest was observed. Then, 25 ml of de-ionized water was added and allowed to be heated for 30 minutes. The receptacles were removed from the digester and allowed to cool. The obtained digests were removed and decanted to 50 ml vials. At that point, appropriate volume of de-ionized water was added up to 50 ml mark and stored in a refrigerator kept at 4^oC while waiting for analysis.

Accurately weighed 2 g of soil samples were placed in digestion flasks and 6 ml of HNO_3, 2 ml of HCl and 2 ml of H_2O_2 of 70, 48 and 35% purity respectively were added to the containers. All the containers were firmly sealed and placed on the digester. All other processes were done as was described above for cassava samples.

The obtained digests from the soil and cassava parts were determined for heavy metals using atomic absorption spectrometry (AAS), model 71906. Triplicate measurements was done for all the samples.

The translocation factor (soil-cassava parts) was obtained by using the ratio of metal concentration in cassava parts divided by the metal's concentration in the soil, while the translocation of metals between the root and the leaves was calculated as; the concentrations of metal in the leaf divided by the concentration in the root [14-15]

$$Soil - plant\ translocation\ (Tsp) \quad = \frac{Cp}{Cs}, \text{ and}$$

$$Leaf - root\ translocation\ (Tlr)\ = \frac{Cl}{Cr}$$

Where, Cp is the concentration of the metal in the cassava's part, and Cs is the concentration of the metal in soil from same spot, Cl is the concentration of the metal in the leaf of the cassava and Cr is the concentration of the metal in the root of the cassava. If the TF values are ≥ 1.0 it shows a higher uptake of metal from soil by the plant, while lower values mean less absorption of the metal from the soil, and the plant can be used for consumption [16].

Results and Discussion

The concentrations of heavy metals in soil, leaves and tubers of cassava from the study area are shown in Tables 1 and 2. The concentrations of Cd were 1.501±0.142, 0.127±0.110 and 0.019±0.019 mg/Kg for soil, leaves and tubers respectively in January and the values for July were 1.724±0.411, 0.181±0.101 and 0.024±0.013 mg/Kg for soil, leaves and tubers respectively. Cadmium values in the soil were higher than the average value of Cd in shale, while the values observed in the leaves and tubers were within the recommended value of 0.1-0.2 mg/Kg by FAO/WHO [17] for consumable food crops. Cadmium is known to be a carcinogen in animals and has the capacity to subdue plant growth irrespective of the source of the Cd whether soil, air or irrigation water [18]. Cadmium sources may include vehicle tires, used engine oil, wear and tear of brake pedals and materials used road surfacing [19].

The observed values of Pb in January were 2.685±0.382, 1.297±0.124 and 0.377±0.341 mg/Kg for soil, leaves and tubers respectively, while the respective values of 2.869±0.581, 1.943±0.214 and 0.579±0.217 mg/Kg were observed in soil, leaves and tubers in July. The concentrations of Pb observed in the soils were lower than the world average value in shale, and those of the leaves and tubers of cassava plant were within the required range of 0.1 - 2.0 mg/Kg in food given by FAO/WHO [20]. Lead is an undesirable element in both plants and animal tissues due its hazardous effect. Human health effects of Pb include placental damage, inducing of abortion at the early stages, affects the brain of an unborn child, increases incidence of disease attack, kidney and liver diseases [21].

The concentrations of Cr observed in January were 4.185±0.740, 2.410±0.736 and 1.126±0.067 mg/Kg in the soil, leaves and tubers of cassava respectively, while July values were 5.265±0.841, 2.814±0.672 and 1.923±0.172 mg/Kg for the soil, leaves and tubers of cassava plant. The observed values of Cr in the soil were lower than shale average value of 90 mg/Kg. Cr is a vital component which help to breakdown triglycerides, cholesterol, fat, and carbohydrates in animal system. Deficiency of Cr results in hyperglycemia, elevated fat content in the body, decreased sperm value in spermatozoa fluid, but are known to be toxic and carcinogenic at high concentrations [22-23].

The concentrations of Cu observed in January were 174.914±28.497, 98.566±9.767 and 96.600±7.137mg/Kg in the soil, leaves and tubers of cassava respectively, while July values were 4.368±0.336, 2.562±0.257and 1.583±0.235

mg/Kg for the soil, leaves and tubers of cassava plant. Cu play several roles in plants which include building of cells and transformation of tyrosine. The leave of plants is where majority of Cu is found, of which the chloroplast contains more of it. Cu affects carbohydrate and protein content in plants and regulates the stability of plant hormones which enhances the total content of carbohydrates, lipids, and vitamins. Cu inhibits the process of getting old quickly and support the dynamic growth of leaves. Cu is taken up as Cu^{2+} ions or its chelated form [24].

The observed values of Fe in January were 174.914±28.497, 98.566±9.767 and 96.600±7.137 mg/Kg for soil, leaves and tubers respectively, while the respective values of 178.823±18.394, 101.231±10.426 and 99.541±6.562 mg/Kg were observed in soil, leaves and tubers in July. The value observed in the soil and cassava parts for Fe were lower than the standard values in soil, and FAO/WHO [20]. Fe is notably important in the photosynthetic process, which take place in the green leafy part of plant (the chloroplast). Fe has the tendency to accumulate in the leaves of plants because of the presence of chloroplast. The leaves being the centre of food processing in the plant and Fe being a notable component of the leaf (as part of the magnesium porphyrin) absorbs sunlight and promotes transpiration, thus increasing the concentration of Fe in the leaves of plant [25].

The concentrations of Ni were 3.809±0.596, 2.306±0.480 and 0.654±0.654 mg/Kg for soil, leaves and tubers respectively in January and the values for July were 3.814±0.095, 2.317±0.503 and 0.681±0.132 mg/Kg for soil, leaves and tubers respectively. The Ni content of the soils were lower than the world average value in shale. The values of Ni in the cassava leaves is higher than the WHO/FAO [17] permissible limit, while the concentration observed in the tubers were lower than the WHO/FAO [17] allowable limit of 1.63 mg/Kg in consumable plants. Ni, metal is absorbed into plants from the soil as Ni ion, while other absorbable forms that are accessible to plants are transformed to water-soluble forms, modified or absorbed, before uptake by plants [24].

In the present work, the concentrations of heavy metals in the leaves of the cassava plant were found to be higher than that of the tubers. This observation is in agreement with those of Bu-Olayan and Thomas [26]. This observation may be as a result of such factors as the exposure area of the leaves directly to external atmospheric conditions, the direct absorption of surface particles, elevated degree of absorption of essential metals from the surrounding and the fact that it is the organ exposable for synthesis and distribution of nutrients to other parts of the plant [27-28].

Also, the levels of heavy metals observed in soils were quite higher than those of the leaves and tubers of the cassava plant. This is because heavy metals and other nutrients are mobilized from the soil by the roots to the leaves of plants, where photosynthetic activities was carried out and the products distributed to all other parts [27, 29].

Table 1: Concentrations of Heavy Metals in Soil, and Cassava Leaf and Tubers in Gokana Communities in January

Heavy Metals (mg/Kg)	Soil	Leaves	Tuber
Cd	1.501±0.142	0.127±0.110	0.019±0.019
Pb	2.685±0.382	1.297±0.124	0.377±0.341
Cr	4.185±0.740	2.410±0.736	1.126±0.067
Cu	4.021±0.540	2.536±0.284	1.567±0.304
Fe	174.914±28.497	98.566±9.767	96.600±7.137
Ni	3.809±0.596	2.306±0.480	0.654±0.654

Fe > Cu > Cr > Ni > Pb > Cd

Table 2: Concentrations of Heavy Metals in Soil, and Cassava Leaf and Tubers in Gokana Communities in July

Heavy Metals (mg/Kg)	Soil	Leaves	Tuber
Cd	1.724±0.411	0.181±0.101	0.024±0.013
Pb	2.869±0.581	1.943±0.214	0.579±0.217
Cr	5.265±0.841	2.814±0.672	1.923±0.172
Cu	4.368±0.336	2.562±0.257	1.583±0.235
Fe	178.823±18.394	101.231±10.426	99.541±6.562
Ni	3.814±0.095	2.317±0.503	0.681±0.132

The translocation factor of the cassava parts are shown in Tables 3 and 4. Plants remain a veritable center for the accumulation of heavy metals. There is great variation in the concentrations of heavy metals in both water and land dwelling plant, which is influenced by the nature of the environment, the specific nature or species of plant and the activities which has been present within the area over a period of time [30].

Table 3: Translocation Factor between soil and Cassava Parts and between leaves and Tubers in January

Heavy Metal	Soil-Leaves	Soil-Tubers	Leaves-Tubers
Cd	0.085	0.013	0.150
Pb	0.483	0.140	0.291
Cr	0.576	0.269	0.467
Cu	0.631	0.390	0.618
Fe	0.564	0.552	0.980
Ni	0.605	0.172	0.284

Table 4: Translocation Factor between soil and Cassava Parts and between leaves and Tubers in July

Heavy Metal	Soil-Leaves	Soil-Tubers	Leaves-Tubers
Cd	0.105	0.014	0.133
Pb	0.677	0.202	0.297
Cr	0.535	0.365	0.683
Cu	0.586	0.362	0.617
Fe	0.566	0.557	0.983
Ni	0.607	0.179	0.293

The level of heavy metals found in a plant give insight of the capacity of the plant to retain them. Consequently, the level of required and undesirable heavy metals in edible and curative plants above the allowable boundary is a problem that call for the involvement of both public and private establishments for safety concerns in the world [31]. In order to fully understand the accumulation tendencies of different plant species, especially those of economic and health importance, there is the need to carry out an all-round assessment of the amount of heavy metals in soil and plant. The level of a particular metal present in a plant is a function of the transport factor and this is based on the interaction between the plant and the soil [31].

The transport factor of heavy metals from the soil to the leaves and tubers of cassava plant and from leaves to the tubers are shown in Table 2. The transfer factors for Cd in the leaves of the cassava plant were 0.085, 0.013 and 0.150 for leaves, tubers and between leaves and tubers of the cassava plant respectively in the month of January, in July the values were 0.105, 0.014 and 0.133 for leaves, tubers and between leaves and tubers of the cassava plant respectively. The values of transfer factor for Cd in this work were either lower or higher than the values of Ratko *et al*. [32], in grasses from relaxation Park of Lake Plateau, Durmitor, Montenegro and those of Al-Saad *et al* [33], in some garden crops planted in Al-Nadwa-Riyadh Province of Saudi Arabia, but generally lower than those of Mbong *et al* [34], in *Citrus reticulate* planted in a densely populated and rural areas of Uyo L. G. A., Akwa Ibom State, Nigeria and those of Mirecki *et al* [35] in corn, cowpea, pepper, potato, carbage, lettuce and plantain from the province of Kosovska-Mitrovica, Kosovo.

The transport or transfer factor for Pb in the leaves, tubers and between the leaves and tubers of the cassava plant were 0.483, 0.140 and 0.291 respectively in January and 0.677, 0.202 and 0.297 in July. The transport factor for Pb in cassava leaves were higher than those of Mirecki *et al* [35], in different consumable crops, but lower than the values obtained for plantain observed by same authors, while the values observed in the tubers were within the range observed by Mirecki *et al* [35] except for plantain. The values obtained for Pb in the present work were slightly lower than those of Lato *et al* [24], in maize grains harvested from a sewage treated soil. However, these values were higher than the values obtained from twenty-four ornamental plants from the premises of Al-Nadwa Garden Riyadh, Saudi Arabia.

The translocation (transport) factor of Cr in the leaves, tubers and between the leaves and tubers of the cassava plant were 0.576, 0.269 and 0.467 respectively in January and 0.535, 0.365 and 0.683 in July respectively. The values of transfer factor for Cr obtained in the leaves and tubers of cassava in the present work is within the range of values observed in tangerine harvested from urban and rural areas of Uyo, Akwa Ibom State, Nigeria [34], but lower than the values of Oladebeye [36], in selected vegetables collected within Ondo and Edo States of Nigeria.

The transport factor of Cu between the soil and the leaves, tubers and between leaves and tubers were 0.631, 0.390 and 0.618 respectively in January and 0.586, 0.362 and 0.617 respectively in July. The transfer factor for Cu in the parts of cassava examined in the present work is higher than the values obtained from selected edible fruits and food crops except those of plantain collected from Kosovska Mitrovica, Kosovo province in Southern Serbia [35], but higher than those of Lato *et al* [24], in maize treated with sewage sludge obtained from USAMVB`s Research Station from Timisoara, Romania.

For that of Fe in the leaves, tubers and between the leaves and the tubers, the transfer factor were 0.564, 0.552 and 0.980 respectively in January and 0.566, 0.557 and 0.983 respectively in July. The observed values of transfer factor for Fe in the cassava parts in the present work is either higher or lower than the values of Oladebeye [36], in selected vegetables collected within Ondo and Edo States of Nigeria, lower or within the range of values observed in maize planted in sewage sludge fertilized soil from USAMVB`s Research Station from Timisoara, Romania and also those of Mbong *et al* [34], in *Citrus reticulate* from Uyo, Akwa Ibom State, Nigeria.

The transport factor of Ni in the cassava leaves, tubers and between the leaves and tubers were 0.605, 0.172 and 0.284 respectively in January and 0.607, 0.179 and 0.293 respectively in July. The transport factor for Ni in the present research is lower than those of Bu-Olayan and Thomas [26] in different plant species cultivated in Kuwait Governorate.

The concept behind the translocation of heavy metals from soil to plants is a multidimensional procedure which involves several factors that play diverse roles that culminates in different mechanisms. A number of these factors are the speciation of the metals, the hydrogen potential of the soil, the organic composition of the soil, the plant type, the dynamics of climatic changes, and content of water used for irrigation [37-38]. Heavy metals uptake from soil solution by plants is best when the metals are in ionic forms. The assimilation and mobility or translocation of these components follows a well-controlled and regulated steps which requires diversity of molecules, which are part of trans-membrane transport, complexation and successive restoration of ions, element or molecule. This process of metal absorption from their solutions in the soil is facilitated through specific transporters combined with proteins resident in membrane tissues of root cells [39].

Conclusion

The concentrations of the heavy metals examined in soil and the cassava parts were found to be lower than the different reference standards. Despite this fact, since at higher levels heavy metals are toxic and are likely to increase or bioaccumulate in the plant, both the soil and cassava plants that may be planted in the area be subjected to routine compulsory check. This will help to promote consistent records assemblage, research, lawmaking and guidelines by government agencies. This will also help to prevent risks that may possibly arise as a result of consuming contaminated products.

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