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ASSESSMENT OF HEAVY METALS IN CONTAMINATED SOIL AND WATERLEAF (*Talinum triangulare*) CULTIVATED FROM SELECTED DUMPSITES IN PORT HARCOURT, NIGERIA

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Abstract

Heavy metal levels such as copper, magnesium, vanadium, cadmium, and cobalt were examined in dumpsite soil and one species of leafy vegetable *Talinum triangulare* (waterleaf) from three (3) locations of Port Harcourt metropolis, Rivers State, South-South, Nigeria. The samples were digested with a 3:1 mixture of mineral acids, HCl and HNO_3 were assessed following the procedure of Atomic Absorption Spectrophotometer (AAS). The results obtained showed that Magnesium (Mn) was the most abundant metal, with the highest concentration observed at the Port Harcourt -Town dumpsite in both the soil (4.679±0.085) Mg/kg and the leaf (4.382±0.031) Mg/kg. The least concentrated metal in the dumpsites was Cadmium (Cd) in both the soil and the leaf with the lowest value observed at the Trans Amadi (0.012±0.055) Mg/kg dumpsite for the soil and Eleme – Junction (0.001±0.019) mg/kg dumpsite for the leaf. The order of the metal concentrations in the dumpsites for both soil and leaf was Mn>Cu>V>Co>Cd. All the metals except cadmium (Cd) were below the required permissible limit in soils by WHO/FAO (2001). All the metals except Cobalt (Co) were below the required permissible limit in waterleaf (*Talinum triangulare*). The contamination factor showed that the soils were within the uncontaminated – moderately contaminated in the various dumpsites for all the metals except Cd which was slightly – moderately contaminated and Co which showed signs of contamination shortly. The contamination factor (Cf) and transfer factor (Tf) also revealed that dumpsite soils and vegetable (*Talinum triangulare*) leaves accumulate higher metal concentrations. This portends health risks for consumers of waterleaf (*Talinum triangulare*) and other farms produced concerning the heavy metals examined in the studied area.

Keywords: Heavy Metals, Waterleaf, (*Talinum triangulare),* Concentration, Contamination factor (Cf),

Introduction

Waterleaf (*Talnium triangulare*) is one of the most common leafy vegetables in Nigeria and is part of daily diets in many households (Rumteke et al., 2016). Waterleaf is common almost throughout the year, even during the dry seasons, because it can survive drought. Waterleaf is known to be a perennial herbaceous plant widely grown and consumed as a vegetable (Wilberforce, 2016). Studies have shown that waterleaf contains important nutrients and phytochemicals such as flavonoids and polyphenols, crude protein, lipids, essential oils, cardiac glycosides, omega-3 -3-fatty acids, minerals, soluble fibres and vitamins (Swarna & Ravindhran, 2013). The availability and nutritional composition make it one of the most sought vegetables (Deribachew et al., 2015). Water leaves are made up of mostly cellulose, hemicellulose and pectin substances that give them their texture and firmness (Sobukola & Dairo, 2007). These substances help to build bone, and teeth and protect the body from diseases. Leafy vegetables are used for dietary purposes and to increase the quality of soup. (Sobukola & Dairo, 2007). Vegetables contain about 70-75% water which is good for the body system and has antioxidative effects (Jena et al., 2012). They are important for the maintenance of health, prevention and treatment of various diseases, and essential protective food (D' Mello, 2003). Generally, Studies have reported that soil-to-plant transfer of heavy metals is the major pathway of human exposure to soil contamination (Cui et al., 2004).

The role of vegetables health-wise has led to an increasing demand for vegetables. As a result, the majority of people in the semi-urban areas of Port Harcourt including the studied locations take part in urban agriculture. More so, sources of this vegetable, most especially in Port Harcourt metropolis, need assessment, considering the current scope of pollution in Nigerian cities (Ogundele et al., 2017; Olujimi et al., 2015). Although most consumers consider undamaged, dark green and big leaves as characteristics of good quality leafy vegetables, however, the external morphology of vegetables cannot guarantee safety from combination. Mapanda et al. (2005) reported that heavy metals rank high amongst the chief contaminants of leafy vegetables.

Based on the persistent and cumulative nature, as well as the probability of potential toxicity effects of heavy metals as a result of consumption of leafy vegetables and fruits, there is a necessity to test and analyze this food item from time to time to ensure that the levels of these trace elements meet the agreed international requirement (Tongesayi et al., 2013).

In recent years, attention has been more to the contamination of the environment with heavy metals because of the negative consequences on living organisms. Heavy metals mostly are toxic to humans, plants and animals regardless of their concentration and have a high density (Oves et al., 2012). Studies have shown that human exposure to heavy metals and their intake were basically through food, inhalation and dermal contact (Khan et al., 2014; Martorrell et al., 2011). The reports about heavy metals in food plants show that leafy and non-leafy vegetables are good accumulators of heavy metals (Khan et al. 2015). The contaminated soils on which plants were cultivated could be a primary route of human exposure to metal toxicants (Nabulo, 2011). Therefore heavy metals are seen as an international problem because of their effects on the ecosystem in most countries (Egila et al., 2014).

Open dumps are usually a public health concern and a cause of environmental pollution. Open dumps consist of a variety of chemical waste such as phenol, ammonia, cyanides, thiocyanates, phenol formaldehyde, and heavy metals like mercury, chromium, zinc, lead, cadmium, copper and nickel, which pollute the soil (Chandana et al., 2009). The application of chemical fertilizers (like phosphate and zinc fertilizers) and herbicides also pollute the soil (Demi et al., 2004).

The study aims to evaluate the amount of heavy metals in water leaf (*Talnium triangulare)* and soil growing in the vicinity of Port Harcourt Metropolis from selected dumpsites, to ascertain the safety of consumption of water leaf by humans (Consumers)

Materials and Methods

Three different study locations were chosen one (1) from Obio /Akpor local government area and two (2) from Port Harcourt local government area of Rivers State. Port Harcourt is located within latitudes 658 N to 76'N and longitude 440'E to 455'E. It falls almost entirely within the lowland swamp forest ecological zone and is flanked in the east, west and southern limits by mangrove swamp forest (Braide et al., 2004; Chindah, 2004). Port Harcourt constitutes an important terminal for connection to the outlying villages in the delta area. It is rated the second-largest port in Nigeria in terms of tonnage handling. Port Harcourt being the capital of Rivers State has become an important administrative center with regular air connections to other parts of Nigeria. The area experiences heavy rainfall averaging 2500 mm/annum. It rains about eight, months (March – October) during the year, and even the months considered as dry months are not free from occasional rainfall (Gobo, 1990).

Despite its economic importance, the city experiences intermittent flooding in a large number of areas. Some of the most affected areas include Waterlines Junction (by the College of Education bus stop), Olu Obasanjo Road (Police Station) by Omoku Street, Diobu (Mile Three Building Material Area), Diobu (Mile One Market Area), etc. The town is an important industrial and commercial centre. Access to cheap energy from oil and natural gas, in addition to good communication, has created favourable conditions for Port Harcourt to become Nigeria's most important industrial town. It has an almost flat topography and is underlain by superficial soil that consists of silty clays mixed with silty sand. The combination of excessive rainfall, inadequate and poorly maintained drainages, and low permeability of the superficial soils dispose the area to flooding on an annual basis whenever rainfall is more than 100 mm. The water table is less than 10 m before the ground surface.

Random sampling techniques were employed to collect samples of the water leaf (*Talinum triangulare*) from three sites (Eleme Junction, Trans Amadi and Port Harcourt–Town). The vegetable samples were found growing on farmland close to refuse dumpsites within the Port Harcourt metropolis. The samples were labelled with the identification codes (EJ, TA and PH-Town). Five samples were collected on each plot of the studied area and homogenized to constitute a sample site. The area of study has light annual rainfall and the rainy season runs between June to September thus dry season farming thrives in the area.

Random samples of soils were collected from (Eleme Junction, Trans Amadi and Port Harcourt – Town) farmland close to refuse dumpsites. The samples were taken at a uniform depth of 15 cm with the aid of a hand trowel that had been pre-cleaned with concentrated nitric acid to prevent heavy contamination before analysis.

The fresh vegetable samples of (*Talinum triangulare*) were properly identified, after which they were taken to the laboratory, chemistry department at Ignatius Ajuru University of Education, Port Harcourt. They were thoroughly washed with running water and properly rinsed with double distilled water to remove possible particulate pollutants.

The moisture and water droplets were carefully removed with the help of blotting papers. The samples were air-dried and oven-dried at low temperatures and thereafter grounded and sieved to required particle sizes using a sieve that was pre-cleaned. They were then put in sample bottles, labelled and capped, and then taken to the Ebic Integrated Services Limited laboratory in Port Harcourt for further preparation and analysis.

The Soil samples were air dried for 48 hours, ground and sieved using a 0.5 mm mesh size sieve to have uniform particle size. Each sample was properly labelled and stored in a dry plastic container that had been pre-cleaned with concentrated nitric acid before analysis with Atomic Absorption Spectrophotometer (AAS), flame model SE - 71096

A 10 g representative of the leafy vegetable was placed in a porcelain crucible and ignited in a furnace at 550 for 2 hours to ash. The ash was dissolved in dilute acid and then made up to a volume of 100 ml, with deionized water. The filtrate was saved for the determination of metals (Magnesium, Copper, Vanadium, Cobalt and Cadmium) in the water leaf plant. The metals were determined on the filtrate of sole digested by optical emission spectroscopy, using the Solar Thermo Elemental Atomic Absorption Spectrophotometer (AAS), flame model SE – 71096. Test results were validated with calibration curves obtained with certified metal standards, while quantitation was obtained with Agilent Expert 11 software.

20 ml of acid-extracting solution was added to 10 g of soil sample in a beaker. The mixture was heated on a hotplate at 100 for 30 minutes. The mixture was allowed to cool to 25 ^{o}C. Thereafter, 2 ml of charcoal suspension was added to the mixture and shaken for 5 minutes. The mixture was then filtered. The heavy metals in the filtrate were analyzed using the Solar Thermo Elemental Atomic Absorption Spectrophotometer (AAS), flame model SE – 71096. The results obtained from the heavy metal analysis were expressed as mean ± SD. of the concentrations in mg/Kg.
The heavy metals results were further subjected to index models evaluation: Cf and Tf

The contamination factor is a quantification of the degree of contamination relative to either the average crustal composition of a respective metal or to the measured background values from a geologically similar and uncontaminated area. It is expressed as:

CF = Cm/Bm
Where; Cm is the mean concentration, while Bm is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area. CF in this study was considered as
CF < 1- Low contamination factor
1 < CF < 3 – Moderate contamination factor
3 < CF < 6 – Considerable contamination factor
6 > CF – Very high contamination factor (Uriah et al., 2014)

Transfer factor of Heavy metals from soil to plants is one simple way to explain human exposure to metals through the food chain (Kadovic, 2011). Metal uptake from soil to plants measured by transfer factor (TF) is an index used to assess metal mobility from soil to plants measured by particular metal can vary greatly depending on the type of plant, as well as from one environment to another. The main parameters that modify (Tf) are; physical and chemical characteristics of soils, behavior of trace metals in soils and plants, and environmental changes (Cervantes-Trejo, 2018). Transfer factor from soil to plant is calculated as the ratio of metal concentration in plant and metal concentration in soil as stated below:

$$TF = \frac{\text{metal concentration in plant}}{\text{metal concentration in soil}}$$

Result

The mean heavy metals concentration mg/kg (dry weight) in the dumpsites soils and vegetables have been presented in Tables 1 and 2, while the contamination factor and transfer factor of the metals have been presented in Tables 3 and 4 respectively.

Table 1: Mean Concentrations (mg/Kg) of Heavy Metals from Selected Dumpsites Soils in Port Harcourt Metropolis (n =6)

		Heavy Metals			
Station	**Cu**	**Mn**	**V**	**Cd**	**Co**
Eleme Junction	3.178 ± 0.027	2.776 ± 0.20	0.1036 ± 0.015	0.038 ± 0.027	0.253 ± 0.017
Trans Amadi	3.265 ± 0.026	3.979 ±0.026	0.122 ± 0.056	0.012 ± 0.055	0.190 ± 0.014
PH-Town	0.531 ± 0.027	4.679 ± 0.085	0.124 ± 0.017	0.020 ± 0.095	0.245 ± 0.017

PH-Town = Port Harcourt - Town

Table 2: Mean Concentrations (mg/Kg) of Heavy Metals from Selected Dumpsites Waterleaf in Port Harcourt Metropolis (n =6)

		Heavy Metals			
Station	**Cu**	**Mn**	**V**	**Cd**	**Co**
Eleme Junction	1.810 ± 0.021	4.108 ± 0.19	0.101 ± 0.021	0.001 ± 0.019	0.164 ± 0.022
Trans Amadi	2.039 ± 0.047	3.134 ±0.018	2.115 ± 0.031	0.075 ± 0.011	0.190 ± 0.0261
PH-Town	3.578 ± 0.002	4.382 ± 0.031	0.049 ± 0.035	0.042 ± 0.033	0.401 ± 0.026

PH-Town = Port Harcourt – Town

Table 3: Contamination Factor (Cf/) of Heavy Metals from selected Dumpsites soils in Port Harcourt Metropolis, Rivers State

		Contamination Factor of Heavy Metals			
Station	**Cu**	**Mn**	**V**	**Cd**	**Co**
Eleme Junction	0.071	0.033	0.079	0.13	0.014
Trans Amadi	0.073	0.047	0.094	0.04	0.011
PH-Town	0.042	0.0057	0.095	0.07	0.014

PH-Town = Port Harcourt – Town

Table 4: Transfer Factor (Tf/) of Heavy Metals from selected Dumpsites water leaf in Port Harcourt Metropolis, Rivers State.

		Transfer Factor of Heavy Metals			
Station	**Cu**	**Mn**	**V**	**Cd**	**Co**
Eleme Junction	0.57	1.48	0.97	0.03	0.65
Trans Amadi	0.62	78.8	17.3	6.25	1
PH-Town	6.76	0.94	0.39	2.1	1.64

PH-Town = Port Harcourt – Town

Discussion

Heavy Metals in selected Dumpsites Soils

The values of Copper (Cu) ranged from 0.531 ± 0.027 – 3.265 ± 0.026 mg/Kg in the sampled stations. Trans Amadi station recorded the highest value, while the lowest value was detected in Port Harcourt–Town station. The values of Magnesium (Mn) differed between 2.776 ± 0.20 – 4.679 ± 0.085 mg/Kg in the stations. The highest peak of Mn was recorded in Port Harcourt–Town, while the lowest was observed in Eleme Junction. The observed values for Vanadium (V) ranged from 0.122 ± 0.056 – 0.1036 ± 0.015 mg/Kg, the higher value occurred in the Eleme Junction station while the lowest value was recorded in the Trans Amadi station. Cadmium (Cd) concentrations from the sampled station were within the range of 0.012 ± 0.055 – 0.038 ± 0.027 mg/Kg. The highest value occurred in Eleme Junction station while the lowest value was recorded in Trans Amadi station. Cobalt (Co) values differed within 0.190 ± 0.014 – 0.253 ± 0.017 mg/Kg concentrations. The peak values of Cobalt occurred in Eleme Junction station while the lower value was recorded in Trans Amadi station (Table 1).

A comparison of the concentrations of the heavy metals investigated showed that their concentrations in the dumpsite soils were all lower than the recommended values by DPR, China and the World average value in shale. An increase in heavy metal contents in soils from dumpsites has been observed in many studies (Ojo et al, 2015). An increase in metal concentrations in soils from dumpsites could result from the deposition of wastes which have high metal content (Adjia et al., 2008). The degradation of organic components of waste in dumpsites can also contribute to the metal increase of the soils from the dumpsites. The oxidation state of metals and the redox potential of the system also contribute to an increase in the metal content of any soil environment. However, (Adedosu et al., 2013) observed other factors such as the nature of the waste, the time taken before the waste was evacuated from the dumpsites and the non-stabilization or treatment of the waste before being discarded at the dumpsite are responsible for the increase in metals contents of dumpsite soils. The biodegradation of solid wastes in dumpsites leads to the release of minerals (mineralization) and an increase in the release of basic cations into the soil which causes increases in soil physicochemical properties (Eneje, 2012).

The concentrations of the heavy metals observed from the dumpsites in Port Harcourt metropolis of this study are far higher than those observed in other cities in Nigeria, such as Ibadan (Adewuyi, 2010), Owerri and Abuja (Useh, 2015), but either lower or higher than the values obtained from dumpsites in Akure, Ondo State (Anietie, 2015), slightly higher (except in the case of cadmium) in an earlier study on dumpsites within Port Harcourt metropolis (Ogbonna, 2009). However, the observed values of the heavy metals from the dumpsites were quite lower than those observed in dumpsites within Lagos Metropolis (Awokunmi, 2010). The observed higher values of these heavy metals in Port Harcourt metropolis may be due to the presence of industries and the higher population density within the settlement area in Port Harcourt, which may have affected the nature of waste generated.

The mean concentration of Cupper was investigated in leafy vegetables (water leaf plants). The peak (Cu) value in *Talinum triangulare* (3.265 ± 0.026 mg/kg) was detected from Port Harcourt –Town while the least copper (1.810 ± 0.021 mg/kg) in *Talinum triangulare* was recorded in Trans Amadi. Cupper is an essential micronutrient which functions as a biocatalyst required for body pigmentation in addition to iron, to maintain a healthy central nervous system. It prevents anaemia and is interrelated with the functions of zinc and iron in the body (Mekuleyi et al., 2019). However, most plants contain an amount of cupper that is inadequate for normal growth which is usually ensured through artificial or organic fertilizers (Wuana et al., 2011). In the present study, the concentrations of cupper in *Talinum triangulare* from the studied stations were higher than the findings of Divrikli et al. (2006) and Ozcan (2004) who reported cupper concentrations of 0.02 mg/kg and 0.0081 mg/kg respectively for Indian basil. However, the cupper (Cu) levels in the present study were within and slightly above the FAO/WHO permissible limits for cupper intake which is 2.0 mg/kg.

The values of Magnesium (Mn) in *Talinum triangulare* occurred between 3.134 ±0.018 - 4.382 ± 0.031 mg/kg. The highest Magnesium (4.382 ± 0.031 mg/kg) detected in *Talinum triangulare* was recorded at Port Harcourt-Town station, while the lowest level of Magnesium in *Talinum triangulare* (3.134 ±0.018 mg/kg) was recorded in Trans Amadi station. Magnesium (Mn) is a mineral of tremendous importance for bone health, energy production and overall healthy functioning throughout the body since it activates more than 300 cellular enzymes. Like calcium, magnesium must be constantly supplied to maintain the optimal function of the body. Magnesium deficiency seems to be carcinogenic, in the case of solid tumour, a high level of supplemented magnesium inhibits carcinogenesis (Durlach et al., 1986). Magnesium deficiency includes muscle cramps, fatigue, irregular heartbeat, mood swings and even poorquality sleep. In this present study, magnesium content in plant samples from Port Harcourt–Town was higher than the recommended daily intake stated in most literature such as reports of Apkata, (2011) on bitter leaf and pumpkin leaf, and Adotey et al. (2009) which examined the levels of magnesium in tomato, garden egg, onion, pepper and carrot.

The mean concentration of Vanadium (V) differed between 2.115 ± 0.031 - 0.049 ± 0.035 mg/kg in the sampled station. Trans Amadi station recorded the highest value, while the lowest value was detected in Port Harcourt-Town station. Molaltheji, (2005) reported higher levels of Vanadium (V) than those of this study which is between 31 to 35 mg/kg in plants.

The concentration level of Cadmium (Cd) varied from (0.001 ± 0.019 - 0.075 ± 0.011 mg/kg). The highest cadmium (0.075 ± 0.011 mg/kg) content in *Talinum triangulare* was recorded from Trans Amadi station, while the least cadmium content (0.001 ± 0.019 - 0.075 mg/kg) was detected in Eleme – Junction. Cadmium (Cd) is a non–essential element in food and its excess ingestion accumulates principally in the kidneys and liver (Divrikli et al., 2006). Various sources of environmental contamination have been implicated in its presence in foods (Udosen et al., 2006). The values of cadmium obtained in this study were below 1.2-2.5 mg/kg reported by Deribachew et al. (2015) in cabbage samples. The present study was in line with the result reported by Prabu (2009) that Cadmium accumulation was more in leafy vegetables such as lettuce, Swiss chard, spinach and radish (Raphanus sativus). Some values previously reported for leafy vegetables include 0.090 mg/k for fluted pumpkin by Sobukola et al. (2007), and 0.049 mg/kg (Mumhammed & Umer, 2008). However, the values of Cadmium recorded across the stations of this study were within the WHO/FAO safe limit.

Cobalt (Co) varied between 0.164 ± 0.022 - 0.401 ± 0.026 mg/kg. The highest peak of Cobalt occurred in Port Harcourt – Town, while the lowest value was recorded in Eleme Junction. The values of Cobalt in the present study were within the daily intake and health risk index of cobalt (0.00019 - 0.00064 mg/kg /day and 0044 – 0.0150 mg/g/day). Cobalt is toxic to plants at higher concentrations. High levels of Cobalt result in pale–coloured leaves, discoloured veins, and the loss of leaves (ATSDR, 2004). Toxicity of Co excess is linked to oxidative stress, and inhibition of photosynthesis and can also cause iron deficiency in plants.

Cobalt plays a critical role in the overall growth process of stem growth, elongating the coleoptiles, and expanding leaf discs. The daily recommended range of Cobalt (Co) in the human diet is 0.005 Mg/day. It is a critical element needed for plants to reach maturity and for healthy bud development. Cobalt compounds are also used as trace element additives in agriculture and medicine (ATSDR, 2004), (Table 2).

Contamination index values showed that Cu was lowest at the PH-Town sample station (0.042) and highest at the Trans Amadi sample station (0.073). The values of Mn were least at the Eleme Junction station (0.0057) and highest at the PH-Town station (0.033). The value of V was lowest at the Eleme Junction station (0.079) and highest at the PH-Town station (0.095). The lowest contamination index value of Cd was observed at Trans Amadi (0.04) and highest at the Eleme-Junction sample station (0.04). The contamination index of cobalt (Co) ranged from 0.011 – 0.014 (Table 3). Considering the data obtained in Table 3, and comparing them to the intervals of contamination (Lacatusu, 2000) it follows that all the sample stations were uncontaminated with Cu, Mn, V, Cd and Co.

The transfer factor ranged from 1 to 78.8. The peak of the transfer factor (6.76) of Copper (Cu) was observed at PH – Town, followed by (0.62) observed at Trans Amadi and the least (0.57) was recorded at Eleme Junction station. The highest value of the transfer factor (78.8) of Magnesium (Mn) was observed at Trans Amadi, followed by (1.48) observed in Eleme Junction and the least (0.94) was at PH - Town station.

The peak of the transfer factor (17.3) of Vanadium (V) was observed at Trans Amadi followed by (0.95) observed at Eleme Junction and the least (0.39) was recorded at PH – Town. The highest value of the transfer factor (6.25) of Cadmium (Cd) occurred at Trans Amadi, followed by (2.1) observed at PH - Town and the least (0.03) was at Eleme Junction station. The peak of the transfer factor (1.64) of Cobalt (Co) was observed at PH – Town, followed by (1) which was observed at Trans Amadi and the least (0.65) occurred at Eleme Junction station.

When the transfer factor is less than one, there may be a probability that soil is the main source of metal bioaccumulation in plants. However, reports have shown that when the value is higher than one, the total concentrations of metals in soil do not necessarily correspond to the metal's bioavailability in plants. Adah et al. (2013), reported high transfer factors of trace metals for *Talium triangular*. Higher transfer factor coefficients reflect high soil contents or greater potential of plants to absorb metals and bioaccumulate into tissue (Abah et al., 2012). However, low transfer coefficients have been reported to indicate strong sorption of the soil colloids (Kachenko et al., 2006). (Table 4.4)

Conclusion

The concentration of heavy metals in the leaves of waterleaf (*Talinum triangulare*) obtained from different farmland around refuse dumps in Port Harcourt Metropolis Rivers State, South-South, Nigeria, have been studied in comparison with the soils on which they grow, using Atomic Absorption Spectrophotometer. The concentrations of Co, Mn, V, Cd and Co in both soil and vegetable samples are quite higher than the permissible limit of WHO/FAO for soil and plant. Magnesium was the peak of the metals in both the soil and the plant. Generally, the concentrations of the metals in the soil samples are in the order: of Mn>Cu>V>Co>Cd. The vegetable samples show the same trend of metal concentrations. The index model approach applied to the heavy metal concentration values indicated that anthropogenic activities are a contributory factor in the total heavy metals content/ burden of the different dumpsites soils. Vanadium (V) was observed to be the most noticeable metal in the dumpsites soils amongst others based on the model indices used. Therefore, efforts should be put in place to check the nature of refuse dumped at the different dumpsites and metal scraps be immediately removed for recycling to avoid heavy metals pollution of the soils and its health consequences on man and the environment in general. In addition, the Trans factors of vegetable samples are more pronounced in Mn, Cu, and Cd in the different stations. This suggests that the absorption and retention of metals by the tissues are very high and that there are other non-anthropogenic sources of heavy metal contamination in the plants. In other words, bioaccumulation of metals in plants is sometimes, independent of their bioavailability in the soil. The high transfer factors of *Talinium triangulare* (water leaf) investigated in this study can be applied in the phytoremediation of polluted soil.

Recommendations

Following the findings of this study, it is therefore recommended that:

1. other methods of analysis of metals in soil and vegetable should be applied for the same soil and vegetable samples;
2. the consumers of these leafy vegetables should be screened for any incident of heavy metal contamination in the food chain; the vegetables studied in this research work could be applied for phytoremediation of polluted soils;
3. guidelines by WHO/FAO be reviewed, using XRF techniques as a means of comparing with previous guidelines obtained with ASS.

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