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ACCUMULATION OF POTENTIALLY TOXIC ELEMENTS BY SOME VEGETABLES IN DOGON – DAWA IRRIGATION SITES, BICHI, KANO STATE, NIGERIA

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ABSTRACT

Heavy metals pollution is a major environmental problem especially in vegetables irrigation sites. This study investigated the concentrations of potentially toxic elements (Cd, Cr, Pb, Mn, Co and Ni) and their accumulation in five selected vegetables using Atomic Absorption Spectrophotometer. The results obtained showed Cr concentration in the vegetables was in the range of 0.067 - 0.083 mg/kg and Cd was not detectable. The highest concentration (5.889±0.301 mg/kg) of Mn was found in lettuce. Pb was highly absorbed (2.113±0.022 mg/kg) by Cabbage. The highest concentration (1.747±0.21 mg/kg) of Ni was found in pepper, and the highest concentration (0.541±0.017mg/kg) of Co was found in lettuce. All the metals, except Pb were within the WHO/FAO permissible limits. The range of values obtained for the transfer factors are Cr (0.35 – 0.95), Co (0.21 – 0.49), Pb (0.16 – 0.34), Mn (0.02 – 0.56) and Ni (0.20 – 0.73), which indicated none of the vegetables is a hyper accumulator of the metals studied. However, do to Pb concentrations observed, the vegetables are unsafe for consumption. Thus, stringent guidelines set for cultivation and consumption of leafy vegetables grown on contaminated soils should be totally enforced to avoid health risks.

Keywords: Accumulation, Heavy metals, Vegetables, Contamination, Soil

INTRODUCTION

Globally, increasing attention is given to plants as source of healthy human food components [1]. Vegetables are good sources of micronutrients, vitamins and fiber, which lower the body cholesterol level, consequently decrease the risk of cardiovascular diseases [2]. It provides most of the essential nutrients for the body functions when consumed in appropriate combination.

In many parts of West Africa, vegetables are used as spices, condiments or herbal medicines for treatment of several ailments such as dysentery, hypertensive complications, constipation and stimulant [3]. Most preferred food consumed today are made up of vegetable parts such as leaves, fruits, whole seeds and oils extracted from the seeds.

As the world population grows and the demand for high quality food increases, cultivation of vegetables in small fields with intensive use of inputs is gaining popularity and fetching profitability in peri-urban areas of mega cities. This is a matter of serious concern, as vegetables grown in high inputs soil contain both essential and toxic metals of varying concentrations [4,5].

Heavy metals like cadmium, lead, nickel, mercury and chromium can be phytotoxic. They accumulate in aquatic and terrestrial habitats and simultaneously contaminate the animal and human food chains [6]. Plants usually uptake and accumulate toxic metals from soils, water or air [7, 8]. Heavy metal concentration in soil solution plays an important role in controlling metal bioavailability to plants. Most studies [9] showed use of contaminated water for irrigation increases the level of heavy metal contents of soils. Ultimately, increasing heavy metals content in soil also increases the metals uptake by plants depending upon the soil type, plant growth stages and plant species [10].

Vegetable plants have higher ability to accumulate metals from contaminated environment [11]. Although there are several pathways for human exposure to heavy metals, eating contaminated food is one of the major pathways [12]. Vegetables particularly leafy ones, being prolific accumulators of heavy metals provide an easy entry into food chain to the toxic metals [13]. Accumulation of potentially toxic elements (PTEs) such as cadmium, lead, chromium, cobalt, and nickel in vegetables plant is of great concern due to the effects of the metals in the body. Its ingestion causes disruption of numerous biological processes, leading to cardiovascular, nervous, kidney and bone diseases [14]. This informed the reason for the investigation on the five vegetables: cabbage, lettuce, okra, spinach and pepper due to their nutritional importance, shorter life cycle (maturity), suitability to local climate, availability and higher rate of consumption.

The main objective of the study is to determine the concentration and accumulation of potentially toxic elements in the selected vegetables and to offer suggestions on the safety of consuming the vegetables.

The study Area

The study area is a site where Watari dam water channel is being used for irrigation at Dogon-dawa village in Bichi Local Government area in Kano state, Nigeria. Bichi has an estimated population of over 277,099 at the 2006 census and covers a total area of 612 square kilometers [15]. It is bordered to four other local governments; namely, Bagwai, Dawakin–Tofa, Makoda and Tsanyawa local government areas. The inhabitants of the study area cultivate different varieties of vegetable crops along the bank of Watari water channel for commercial purposes. Different synthetic chemical fertilizers and domestic wastes such as sludge, animals, local tanning and market wastes are commonly being used as fertilizers by the farmers. In order to have a comprehensive report on the vegetables being consumed in Bichi and its environs, potentially toxic elements were investigated in the vegetables.

MATERIALS AND METHODS

All chemical used in this study were of analytical grade and deionized water was used throughout the experiment.

Sample Collection

The five vegetable samples: cabbage, lettuce, okra, spinach and pepper were harvested after eight weeks by uprooting using plastic hand trowel and gently removed [16]. The vegetables were then washed, separated into root and leaves, and chopped with clean stainless steel knife. The samples were air dried, grinded using mortar and pestle, and stored in labeled containers.

Soil samples were collected from the block of each vegetable sample within 0 – 15 cm depth. The samples were air dried and screened for pebbles, stones and thoroughly mixed to established homogeneity by sieving through 2mm plastic sieve and stored in labeled containers.

Sample Treatment

The soil pH measurement was made using pH-meter 2602 model in soil- water suspension (1:5 w/v) ratio. Electric Conductivity was also measured using 10 g of soil sample and 50 cm^3 of deionized water. After calibration of conductivity meter with 0.01M potassium chloride, readings of the suspension were taken directly [17]. The organic matter (OM) content of the soil was also determined using Schulte and Hoskins [18] method for soil organic matter test.

The soil samples were dried at 40 ^oC for 48 hours in hot air oven, crushed and passed through a 2 mm nylon sieve. About 5gof soil sample was transferred into 100cm^3 beaker and 30cm^3 of diacid (25cm^3 concentrated HNO_3 and 5 cm^3perchloric acid in 5:1 ratio) mixture was added. The mixture was placed on a hot plate at 105 ^oC for one hour and then temperature was increased to 140 ^oC until the sample completely dried. The digest obtained was filtered through Whatman No. 42 filter paper and diluted to 50 cm^3 volumetric flask [19 - 21]. The procedure was repeated to all the samples including the control sample.

Ground vegetables sample/tissues were weighed (1 g) separately into 250 cm^3 Pyrex beaker and 12 cm^3 of di-acid (HNO_3 and $HClO_4$ in the ratio 3:1) mixture was added. The mixture was heated on hot plate to the reddish brown fumes of per chloric acid appearance. The digested sample was dissolved and diluted to 50 cm^3 volumetric flask for analysis [19 - 21]. This was repeated to all samples and control sample.

Samples Analysis

Analyses of potentially toxic elements (Cd, Cr, Pb, Co, Mn and Ni) were performed using atomic absorption spectrophotometer (Agilent Technologies 200 Series AA) at the Soil Science Laboratory Bayero University, Kano. All measurements were carried out in triplicates.

RESULTS AND DISCUSSION

Physicochemical properties of the soil

The study analyzed some physicochemical properties such pH, organic matter, electrical conductivity and potentially toxic metals (such as cadmium, chromium, cobalt, lead, manganese and nickel) in both soil and vegetable samples. The result showed the soil pH was 6.7 ± 0.23, and Organic matter contents and electrical conductivity of the soil were 5.16 ± 0.057% and 75.23 ± 0.057 mS/cm respectively. The result (Table 1) shows the concentration of manganese (10.438 ± 9.55 mg/kg), lead (6.177 ± 5.22 mg/kg) and nickel (2.388 ± 0.894 mg/kg), while cadmium was not detected in the soil.

Table 1: Some physicochemical properties of the soil

Parameters	Soil sample	Limits [22]
Ph	6.7 ± 0.23	-
Electrical conductivity (mS/cm)	75.23 ± 0.057	-
Organic matter (%)	5.16 ± 0.057	-
Clay (%)	28.13 ± 0.115	-
Cadmium (mg/kg)	BDL	3.00
Chromium (mg/kg)	0.189 ± 0.223	100
Cobalt (mg/kg)	1.095 ± 0.005	50
Lead (mg/kg)	6.177 ± 5.22	100
Manganese (mg/kg)	10.438 ± 9.55	200
Nickel (mg/kg)	2.388 ± 0.894	50

Heavy Metals Concentration in the Vegetables Samples.

The result in Table 2 indicates the concentrations of the metal studied in the sampled vegetables. All the analyzed vegetable samples contained varying concentrations of the potentially toxic metals except Cadmium which was beyond the detection level of the machine. Lead concentrations in the vegetables studied were in the decreasing order of 2.113 mg/kg (cabbage) > 1.975±0.012 mg/kg (pepper) > 1.074 mg/kg (lettuce) > 1.061±0.42 mg/kg (okra) > 0.981 mg/kg (spinach). While Co concentrations (mg/kg) in the vegetables were in the following order; Lettuce (0.541) > cabbage (0.502) > spinach (0.406) > okra (0.314 ± 0.001) > pepper (0.230 ± 0.131).

Table 2: Mean heavy metals concentrations (mg/kg) in vegetables

Metals	Cabbage	Lettuce	Spinach	Okro	Pepper	Limits[23]
Cadmium	NA	NA	NA	NA	NA	0.20
Chromium	0.083±0.010	0.077±0.011	0.067±0.20	0.081±0.26	0.080±0.02	0.10
Cobalt	0.502±0.12	0.541±0.017	0.406±0.21	0.314±0.12	0.230±0.13	50.00
Lead	2.113±0.022	1.074±0.202	0.981±0.10	1.061±0.42	1.975±0.42	0.30
Manganese	1.263±021	5.889±0.301	0.198±0.820	2.371±0.01	0.198±1.02	500.00
Nickel	1.474±0.23	0.991±0.004	1.461±0.10	0.485±0.23	1.747±0.21	67.90

NA = Not Available

The highest concentration of Mn was observed in lettuce (5.889 mg/kg), followed by okra (2.37± 0.12 mg/kg), cabbage (1.263± 0.21 mg/kg), spinach (0.98 mg/kg) and lowest in pepper (0.198 ± 1.02 mg/kg). In summary the vegetables accumulated the highest concentration (mg/kg) of Mn (5.889) and Co (0.541) in lettuce, Pb (2.113) and Cr (0.083) in cabbage, and Ni (1.747) in pepper. However, these concentrations were lower when compared to the levels found in the soil.

Bioaccumulation of the Metals by Vegetables

Table 3 shows the Transfer Factor (TF), also called Bioaccumulation factor values of the metals analyzed in the vegetables. The transfer index ranges from 0.354 – 0.952 (Cr), 0.210 – 0.458 (Co), 0159 – 0.342 (Pb), 0.019 – 0.227 (Mn) and 0.203 – 0.732 (Ni). In this study, the TF values of the metals for the different vegetables studied varied with the highest values of Cr (0.952) and Ni (0.732) in pepper, followed by Mn (0.564) in lettuce, while Co (0.458) and Pb (0.342) in cabbage as depicted from the Table.

Table 3: Transfer Factor (TF) of heavy metals in vegetables

Metals	Cabbage	Lettuce	Spinach	Okro	Pepper
Cadmium	NA	NA	NA	NA	NA
Chromium	0.44	0.41	0.35	0.46	0.95
Cobalt	0.46	0.49	0.37	0.29	0.21

Lead	0.34	0.17	0.16	0.17	0.32
Manganese	0.12	0.56	0.02	0.23	0.02
Nickel	0.62	0.42	0.61	0.20	0.73

The mean concentrations of the physicochemical parameters of soil showed the soil was slightly acidic to neutral and within the recommended limit (6.5 – 8.5) for appropriate growth and efficient uptake of nutrients materials from soil [7]. The Organic matter (OM) which serves as a reservoir of nutrients and water in soil and electrical conductivity as an index of soluble salts in soil were relatively high. Soil pH and OM are important properties affecting heavy metal availability in soils for retaining heavy metals in an exchangeable form (24), and thus, can influences the mobility and uptake of heavy metals to vegetables.

All the potentially toxic metals analyzed in the soil were lower compared to the levels found in an amended soil from Kano metropolis [25]. The values were also within the tolerance limits recommended for agricultural purposes [22].

The potentially toxic metals concentration in the vegetables samples recorded the lowest concentration of chromium among the metals analyzed. The concentrations varied from 0.067 to 0.083 mg/kg, with levels being somewhat higher in cabbage than in other vegetables. The values observed in the study were ten times lower than the concentrations found in vegetables Garden [26]. The relatively low concentration of Cr in the vegetables studied may be explained by a passive uptake nature of the metal and its solubility in the soil [27]. Chromium in the soil was probably in trivalent form (Cr^{3+}) which is more stable, heavily adsorbed by particles of sediment and has a low solubility and mobility [28]. This makes the metal generally and hardly available to plants. Thus, explained the low concentration of the metal observed in the vegetables (Table 2). The concentrations of the Cr in this study are lower when compared to the FAO/WHO safe limits [23]. Thus, the metal contents of the vegetables seem not to be alarming, except in the case of excessive consumption.

Lead is a toxic metal that can be harmful to animals. Its ingestion may arise from eating lead contaminated vegetables or foods [29]. Lead is known for lead poisoning which causes damage to central and peripheral nervous system, kidney and highly toxic to infants and pregnant women. Pb in this study were consistently lower to those reported by Akan et al. [30] and Doka et al. [31], but little higher than those reported by Audu and Lawal [26], and also exceeded the recommended limit [23]. Similarly, the study was in agreement with the results reported, where significant concentration of Pb was found in cabbage than other vegetables [32].

Plant uptake of heavy metals depends mainly on the mobility and availability of heavy metals in soils. Other factors such as soil pH, organic matter content and electrical conductivity, also influences metals bioavailability to plants [24]. Therefore, the effect of soil pH and OM on the uptake of Pb by the vegetables was considered in this study. However, some studies revealed that metal uptake by plants not only occur by soil – root transfer, but also by direct transfer of the contaminants from the polluted atmosphere to the aerial parts of plants [33, 34]. Vegetables absorb metals from contaminated soil and from the particulate matter deposited on their parts from the ambient air [12]. Therefore, this could be another reason for the elevated concentration of Pb in the study. The study also indicates the vegetables are unsafe for consumption.

Cobalt is an element essential to human health, but in excess amounts can cause serious effects to lungs and heart [35]. The trend indicated that lettuce had highest ability to accumulate cobalt, while pepper showed the least capacity. However, the concentrations in the vegetables studied were below the permissible limit recommended, hence do not seem to pose any threat to the consumers.

The highest concentration of Mn was observed in lettuce followed by okra, cabbage, spinach and the lowest in pepper. However, the accumulation of observed in lettuce was lower when compared to the concentration reported in the study of lactuca sativa irrigated with waste water [11]. It could be observed that lettuce has higher accumulation capacity for the essential metal (Mn) than the other toxic metals (Cr, Pb, and Ni).

For Ni concentration in the vegetables, pepper recorded the highest amount, while cabbage and spinach have relatively similar concentrations. The highest accumulation of Ni in pepper indicates the ability of the vegetable for the metal, while Lettuce and okra seem to have a mechanism for sequestering or detoxify excess Ni in their vacuoles. Ni is an essential micronutrient to plant which is required by urease enzyme to hydrolyze urea formed in plants and avoid NH_3 toxicity [6]. Ni concentrations in the study were below the permissible limits [23]. Therefore, consumption of the vegetables may not be a threat for Ni to consumers.

In general, the trend of potentially toxic metal levels in the vegetables was found to be Mn>Pb> Ni > Co > Cr and Cd was not detectable. These revealed that the vegetables studied accumulated varying concentrations of the heavy metals analyzed lower than the permissible limits, except for Lead which showed a little higher accumulation above the standard in all the vegetables. Thus, in terms of Pb the vegetables are not safe for consumption.

In further establishing the potential of the vegetables as metals accumulator, the study reports the transfer factor (TF), where all the factors were less than unity (Table 3). This reveals the bioaccumulation ability of the vegetables for the toxic metals were less than one (TF> 1). This implies that, none of the vegetables studied is hyper accumulating the metals. However, the non-accumulator indexes observed, do not mean the vegetables have negative impacts on human food chain, especially with the concentrations of Pb higher than the Food and Agriculture Organization maximum permissible levels. Thus, the vegetables were contaminated with Pb and should be avoided, to avert exposing consumers of the vegetables to bioaccumulation of the metal.

CONCLUSION

The study indicated that all the vegetables sampled accumulated some levels of the potentially toxic metals with exception of Cd which was not detectable. Pb concentrations exceeded the maximum permissible limit. The transfer values showed the vegetables were non-accumulators of the metals. However, the non-accumulation indexes, do not mean the vegetables have negative impacts on human food chain, especially with the concentrations of Pb higher than Food and Agriculture Organization/World Health Organization maximum permissible levels. Therefore, consumption of the vegetables may be unsafe. Thus, stringent guidelines set for cultivation and consumption of leafy vegetables grown on contaminated soils should be totally enforced to avoid health risks.

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