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Assessment of Heavy Metals Accumulated in Wastewater Irrigated Soils and Lettuce (*Lactuca sativa*) in Kwadon, Gombe State Nigeria

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Abstracts: Vegetables provide the human body with the essential bioavailable trace elements and a constant supply of these various elements is necessary for healthy daily life. However, high levels of these elements in soil and crop can have detrimental effects on soil fertility as well as crop yield and its consumers. Therefore, levels of some heavy metals (Fe, Zn, Cd, Cu, Pb and Cr) in soil and Lettuce were analyzed using atomic absorption spectrophotometer. The results showed that the levels of the heavy metals in the soil and Lettuce were below the threshold levels, but the concentrations were higher in the soil than in the vegetable. The results also revealed the trend in soil metals concentration as Fe > Zn > Cd > Pb > Cu > Cr and for the plant as Fe > Zn > Cd > Cu > Pb > Cr. Transfer factors (TF) decreased in the following order: Fe > Zn > Cu > Cd > Cr > Pb. Therefore the soil was healthy and the vegetable was safe for human consumption.

Key words: Soil · *Lactuca sativa* · Heavy metals · Fertilizers · Transfer factors

INTRODUCTION

Trace metals are metallic elements that are present in both natural and contaminated environments. In natural environments, they occur at low concentrations [1]. However, in contaminated environments, the concentrations of the elements are high. Anthropogenic activities like mining, smelting operations and other industrial activities are recognized as some of the major sources of metals in the environments. However, Wilson and Pyatt [2] pointed out that, potentially harmful metal in soil may come from the bedrock itself. Yongming, *et al*. [3] reported that cement derived fugitive dusts from a cement plant (industry) could contain high levels of heavy elements, especially Cr, Cu, Pb and Zn and once the metals are released to the atmosphere, they can travel for long distances and are deposited onto soil, vegetation and water [4, 5]. Heavy metals get accumulated with time in soils and plants due to waste water irrigation and absorbed minerals settle in edible tissue of the vegetables [6] Heavy metals are potentially toxic for plants: phytotoxicity results in chlorosis, weak plant growth, yield depression and may even be accompanied by reduced nutrient uptake, disorders in plant metabolism and in leguminous plants, reduced ability to fix molecular nitrogen [7, 8]. Heavy metals not only inhibit root growth but can also hamper many physiological processes including uptake of nutrients.

Field studies of metal contaminated soils have shown that elevated metal loadings can result in decreased microbial community size Konapka *et al*. [9]; and decreases organic matter mineralization (Chander and Brookes 1991), leaf litter decomposition [10]; and N_2 fixation [11], thereby leading to a decline in soil fertility.

In heavy- metal-polluted soils, plant growth can be inhibited by metal absorption. However, some plant species are able to accumulate fairly large amounts of heavy metals without showing stress, which present a potential risk for animals and humans [12]. Heavy metals uptake by crops growing in contaminated soils is a potential hazard to human health because of transmission in the food chain [13, 14]. Recent reports indicated that heavy metals take driver's seat among the chief contaminants of leafy vegetables. Papafilippaki *et al*. [15] reported that some heavy metals, in small concentrations are not toxic to plants or animals. However, lead, cadmium and mercury are exception, as they are toxic even in very low concentrations, [16].

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Distribution of heavy metals in plants depends upon availability and concentrations of heavy metals as well as plant species and its populations [17]. Many researchers have shown that some common vegetables are capable of accumulating high levels of metals from the soils [18-20]. Certain species of Brassica (cabbage) are hyper-accumulators of heavy metals into their edible tissues [18]. Metals transfer from soil to plants is the main way for humans' exposure to the contamination of the soil. Vegetables take these elements up and accumulate them in their tissues. Therefore, knowing the characteristics of the transfer of trace elements from soil to plants is very important. Many people could be at risk of adverse health effects from consuming common vegetables cultivated in contaminated soil. The populations most affected by heavy metal toxicity are pregnant women or very young children [21]. Neurological disorders, central nervous system (CNS) destruction and cancers of various body organs are some of the reported effects of heavy metal poisoning [22, 23, 24]. Low birth weight and severe mental retardation of newborn children have been reported in some cases where the pregnant women ingested toxic amounts of heavy metal through direct or indirect consumption of vegetables [25].

In Kwadon, Gombe state lettuce is cultivated on a commercial scale using waste water for irrigation, but there is no information on the level of heavy metals in the soils and the vegetables produce in this area. This study determined the levels of some heavy metals (Zn, Fe, Cu, Cd, Cr and Pb) in the soils and in edible portions of *Lactuca sativa* with a view to determine the level of soil and plant pollution and risk of human health.

MATERIALS AND METHODS

The Study Area: Kwadon is located about 9 KM on Gombe- Biu road in Yamaltu-Deba local Government area of Gombe State, Nigeria. The site is situated between latitudes 10°27'N and between longitudes 11°28' E and 306 M altitude above sea level in the northern Guinea Savannah ecological zone of Nigeria [26].

Sample collection and Treatment: Composite samples of soils and lettuce leaves were randomly collected from four different communities' farms. The plants samples were washed with tap water first and then followed by double washing with distilled water [27]. The plant samples were chopped in to small pieces and packed in labeled bags. The soil samples were also parked in polythene bags. Both the soil and plant samples were analyzed for Fe, Zn, Cd, Cu, Pb and Cr as described by USEPA [28].

Transfer Factors (TF) for Heavy Metals from Soil to Vegetables: Transfer factor is the ratio of the concentration of heavy metals in a plant to the concentration of heavy metals in soil. The transfer factors (TF) for each heavy metal were computed as described by Cui *et al*. [29];

$$TF = \frac{\text{Element concentration in plant, dry weight (mg kg}^{-1}\text{)}}{\text{Element concentration in soil, dry weight (mg kg}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

Some of the physico –chemical properties of the experimental farms are shown in Table 1. The texture of the soils is sandy loam. The pH ranged from 6.1 to 7.4 with mean 7.0; organic Carbon from 0.97 to 2.43% with mean of 1.6%; and CEC from 9.90 to 13.46 with mean of 11.78 Cmol kg^{-1}

Concentrations of Cu, Zn, Fe, Pb, Cd and Cr in the Soils: The levels of heavy metals in the soils samples are presented in Table 2. The values of Cu ranged from 0.79 to 1.01; Zn, from 3.18 to 4.56; Fe from 3.43 to 4,10; Pb, 1.00 – 1.46; Cd, 2.30 - 3.66 and Cr, from 0.40 to 0.53, with the means of 0.91, 3.79, 1.32, 2.93 and 0.47 Mg kg^{-1} soil, respectively. These values were lower than both the British and Germany permissible limits (Table 3) except, Cd (2.93) which was higher than the Germany permissible limits (1.5) for metals ($mgkg^{-1}$) in soils Ghorbani *et al*; [30]. However, the results obtained in this study were higher than the values reported by Uwah *et al*, [31] of heavy metals in the soils irrigated with waste water from beverages industry in Maiduguri, Nigeria.

Doelman [32] reported that both N mineralization and nitrification were inhibited at high concentrations of heavy metals around 1000mg kg^{-1} for Zn, Cu and Ni, around 100-500 $mgkg^{-1}$ for Pb and Cr and around 10-100$mgkg^{-1}$for Cd. Berg, *et al*, [33] observed a decrease in the mineralization of leaf litter and other organic matter, sometimes resulting in an increase accumulation in the litter layer, in severely contaminated forest soils around smelters. Chander and Brooks [34] reported that soil at Ludington contaminated with Cu at 3.7 times the UK permitted concentration contained 32% more organic

Table 1: Physico-Chemical properties of the four farms in Kwadom, Gombe State

Farms	% Sand	% Silt	Clay	% Texture	% pH	CEC OC	Cmol kg^{-1}
1	81.5	1.28	17.2	SL	7.4	1.54	13.46
2	74.8	5.28	19.7	SL	7.4	0.97	9.90
3	78.8	3.28	17.9	SL	7.2	1.83	11.11
4	81.5	3.28	15.2	SL	6.1	2.43	12.63
Mean	79.15	3.28	17.5	7.02	1.7	11.77	

Table 2: Heavy metal levels (mg/kg) in soils irrigated with waste water in Kwadon, Gombe State

	Elements (Mg/Kg^{-1} soil)					
Farms	Cu	Zn	Fe	Pb	Cd	Cr
1	0.95	4.56	4.10	1.46	2.46	0.43
2	1.01	3.80	3.43	1.00	3.66	0.53
3	0.79	3.66	4.50	1.46	3.30	0.40
4	0.88	3.18	3.83	1.33	2.30	0.50
Mean	0.91	3.79	3.97	1.32	2.93	0.47

Table 3: Permissible limits for total metals (mg/kg) in soil

	UK (1989)			Germany (1992)	
Metals	pH 6-7	pH 5.5-6	pH 5-5.5	pH > 6	pH 5-6
Zn	300	250	200	200	150
Cu	135	100	80	60	60
Ni	75	6o	50	50	50
Cd	3	3	3	1.5	1.0
Cr	400*	400*	400*	100	100
Pb	300	300	300	100	100

*Permissible

Adapted from: Ghorbani, *et al*, [30]

Table 4: Heavy metal levels (mg/kg) in lettuce irrigated with waste water in Kwadon, Gombe State

	Metals (Mg/Kg^{-1})					
Farms	Cu	Zn	Fe	Pb	Cd	Cr
1	0.70	3.60	2.87	0.09	1.80	0.13
2	0.83	2.20	2.60	0.72	2.10	0.27
3	0.43	2.20	3.03	0.70	2.50	0.14
4	0.47	2.60	2.93	0.69	1.20	0.27
Mean	0.61	2.65	2.85	0.56	1.90	0.20

matter than a soil with uncontaminated sludge. The rate of mineralization of soil organic matter appears to be sensitive to metal contamination in forest Baath, [35], whereas for agricultural soils the results are conflicting [36].

Nitrogen cycling processes [37] and especially N_2 fixation, has been shown to be sensitive to small concentrations of heavy metals in soil. N_2 fixation by free-living heterotrophic bacteria was considerably reduced in Russian, Soil contaminated with Cu and Zn or Pb and Zn at various concentrations. Letunova *et al*. [38]. Found potential heterotrophic N_2- fixation to be sensitive to additions of Cu and Cr salts. Strong sensitive of heterotrophic N_2 fixation activity to metals – was also found in soil to which metal – contaminated sewage sludge had been applied [39]. They also observed even stronger inhibition of cyanobacteria (autotrophic N_2 fixer) in a Swedish clay soil to which metal contaminated sludge had been applied, resulting in a high concentration of Zn, Ni, Cd, Cu and Pb. A significant reduction in rhizoidal numbers occurred at metal concentration well below the UK and European Union upper limits and the most toxic metals to rhizobia were Zn and Cd. Nitrogen fixation by *Rhizobium Leguminosarum* in symbiosis with white clover (*T. ripens*) was negatively affected by the present of heavy metals in sludge soils [30].

At high concentrations, all heavy metals have also strong toxic effects on plants which results in weak growth, yield depression, disorders in plant metabolism and reduced nutrient uptake [7, 8]. Heavy metals not only inhibit root growth but also can hamper many physiological processes and, in particularly the uptake of nutrients [40]. Studies on interactions between heavy metals and uptake of nutrients such as Mn [41], P, [42]; Ca and Mg, [43, 44]. Asp *et al*; [40] observed K influx decreased in roots of Birch (*Betula pendula*) seedlings that had been exposed to Cd^{2+} and Cu^{2+}. Durieux and; [45] reported Al inhibition of nitrate (NO^{-3}) uptake, while Nichol *et al*, [46] observed stimulation of No^3 uptake by this element. In maize, the rate of NO^3 uptake was inhibited by Al^{+3}, but there was little measurable effect on the NH^{4+} uptake [45]. Copper reduced the uptake of NH^{4+} in roots of mycorrhizal p*inus sycrestris* seedlings [47]. Inhibition of nutrient uptake will lead to nutrient deficiency and losses in crop yield.

Concentrations of Heavy Metals in the Lettuce: The levels of heavy metals in the vegetables are shown in Table 4. The concentration of Cu ranged from 0.43 to 0.83; Zn from 2.20 to 3.60; Fe, from 2.60 to 3.03; Pb, from 0.09 to 0.22 mgkg^{-1} with a mean value of 0.61, 2.65, 0.56, 1.90 and 0.20 mgkg^{-1}dried weight of plant, respectively. These values were lower than maximum permissible limits of India with the exception of Cd [48].

The level of heavy metals in plants depends mainly on the levels of soil contamination and plant species. A plant grown in a soil with a high level of a given heavy metals may likely contain high amount of the metal in its tissue. Similarly different plant species grown in the same soil may contain different levels of the same element.

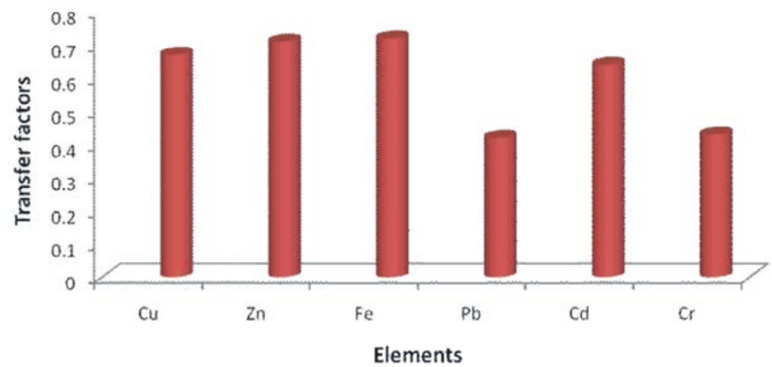

Fig. 1: The transfer factors (TF) of the heavy metals from soils to vegetables

Some plants are hyper- accumulators, example cabbage [18], while others are mono accumulators of a given heavy metals. Benzarti and [49], showed that the concentrations of Cd in alfalfa, lettuce, radish and *T. Caerulescens* increased with increases in doses of Cd in soil. At a given dose, the crops contained different amounts of the element. At a dose of 100 µM of Cd in soil, the concentrations of the metal in alfalfa, lettuce, radish and *1. Caerulescens* were 174.7, 157.7, 268.8 and 366.2 $mgkg^{-1}$, respectively. They also observed the same relationship in Cu and Zn. In a similar study, Shagal *et al*. [50] noted that *Amaranthus spp*, *Hibiscus Sabdariffa* and *Lactuca sativa* grown in the same soil contained Cd, Cu, Pb, Mn and Zn in variables concentrations. For instance, Cd had its lowest concentration of 10.00$mgkg^{-1}$ in *L. sativa* and highest of 16.67 $mgkg^{-1}$ in *H. sabdariffa*.

Transfer Factor of the Heavy Metals from Soils to Plants: The ability of a metal species to migrate from the soil into plant roots is referred to as transfer factor (TF). The factors are based on the root uptake of the metal and discount the foliar absorption of atmospheric metal deposits [6, 51]. The TF of the heavy metals from soils to lettuce in this study are presented in Figure 1. The values obtained were Fe (0.72), Zn (0.71) Cu (0.67), Cd (0.64), Cr (0.43) and Pb (0.42). According to Sajjad *et al*, [52] if the transfer coefficient of a metal is greater than 0.50, the plant will have a greater chance of the metal contamination by anthropogenic activities. This indicates that the concentrations of heavy metals in the plants are low but, there is a chance for it's to be contaminated with Fe, Zn, Cu and Cd by further anthropogenic activities. Variation in transfer factors among different vegetables may be attributed to differences in the concentrations of metals in soil and differences in element uptake by the vegetables [29].

In heavy – metals - polluted soils some plant species are able to accumulate fairly large amounts of heavy metals without showing stress, which represents a potential risk for animals and human health because of transmission in the food chain [12, 13]. Many people could be at risk of adverse health effects from consuming common vegetables grown in contaminated soils.

The populations most affected by heavy metal toxicity are pregnant women and very young children [21]. Neurological disorders, central nervous system destruction and cancers of various body organs are some of the reported effects of heavy metals poisoning [22, 24, 53, 54].

CONCLUSION

The soils and lettuce in Kwadon contain heavy metals Fe, Zn, Cu, Cd, Pb and Cr, in concentrations lower than the maximum permissible limits for heavy metals in soils and crops. Therefore, the lettuces are suitable for human consumption. Further use of waste water for irrigation should be avoided.

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