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UPTAKE AND ACCUMULATION OF SOME HEAVY METALS BY THE LEGUME, (Arachis hypogea)

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ABSTRACT
Food chain contamination is one of the important pathways which contributes 90% of heavy metals in comparison of other sources like inhalation and dermal contact. The increased uptake of heavy metals by plants may sometimes produce toxic effects in plants and subsequently to its consumers along the chain. In this study, the accumulation of the metals; Cd, Cr, Co, Cu, Zn, Ni, and Pb in the roots, stem, leaves and seeds of *Arachis hypogea* were determined. Fresh sample of roots, stem, leaves and seeds of groundnut were obtained from six different farms located in three different sites in Biriyel, Bayo Local Government Area, dried, ground and sieved. The sieved sample was analyzed using atomic absorption spectroscopy following digestion with aqua regia (3ml HNO_3 + 9ml HCl i.e. ratio 1:3). The results showed that, the levels; 0.311±0.03, 0.018±0.07, 0.021±0.11, 0.023±0.08, and 0.021±0.22 µg/g Cd were observed in the soil, roots, stem, leaves and the seed respectively. Chromium and Cobalt were not detected in the stem, leaves and the seed of the crop. Copper had the concentrations of, 0.451±0.21, 0.097±0.09, 0.075±0.15, 0.090±0.03 and 0.126±0.07 µg/g Cu in the soil, roots, stem, leaves and the seed respectively. High levels of 0.390±0.36, 0.359±0.25, 0.032±0.10 and 0.304±0.11µg/g Zn were observed in the root, stem, leaves and the seed of the crop in the order; seed >leaves >stem >root. High level of Ni was observed in the seed (0.085±0.03µg/g Ni) followed by the leaves 0.054±0.09 µg/g, and the root had 0.041±0.31µg/g whereas the stem has the lowest concentration of 0.008±0.12 µg/g. The levels; 1.375±0.35, 1.408±0.19, 1.463±1.02 and 1.429±0.51 µg/g were observed for Pb in the root, stem, leaves and the seed of the crop respectively. Concentrations of the elements observed in this study were all within the maximum permissible limits of consumption set by FAO/WHO which signify the safety of consuming the crop. All results were found significantly not different at P = 0.05

Keywords:
Crop, Consumption, Contamination, Environment, Heavy metal, Pollution

INTRODUCTION

Soil is a naturally occurring, unconsolidated mineral and organic material at the earth's surface that provides an environment for living organisms. It has been referred to as the earth's "critical zone" and as deserving special status, because of its role in controlling the earth's environment and thus affecting the sustainability of life on the planet [1]. Soil is a dynamic habitat for an enormous variety of life-forms. It gives mechanical support to plants from which they extract nutrients. Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition [2, 3]. Soil serves as a sink for some noxious elements known as heavy metals like chromium, cadmium, nickel and lead where they remain in soil for long times effecting the quality of agricultural soil and crops [4]. The anthropogenic activities contribute these dangerous metals in soil which indirectly attack on human's health through food chain [5]. The upper 25cm surface region of the soil is mostly affected by the toxic metals where roots of the plants/crops are located [6]. Soil is therefore not only the key nutrient-bearing environment for plant life [7] but also a supplier of many pollutants to plants because plants can uptake toxic substances through their roots from soils [8].
Food chain contamination is one of the important pathways which contributes 90% of heavy metals in comparison of other sources like inhalation and dermal contact [9]. Contamination of soil, water and food systems by heavy metals is progressive issue due to its potential threats to human, animal's health and

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environmental quality degradation. The accumulation of heavy metals in soil and plants is of major concern because of its toxicity to food chain contamination. Contamination level arises when heavy metals are present above their permissible limits which is considered a threat for food chain [10]. Plants when grow on such type of contaminated soil take up these metals and then find their way to animals and humans [11]. Several studies related to heavy metal uptake by plants grown in polluted soils have shown that elevated levels of metals in soil may lead to increased uptake by plants but, without a strong relationship between the concentrations in soil and plants [12]. The increased uptake by plants may sometimes produce toxic effects in plants and also to its consumers. Reports has it that, consumption of toxic metals in food causes incidence of cancer [13].

Food legume crops represent an important component of agricultural food crops consumed in developing countries, especially in Sub-Saharan African countries, Nigeria in particular. They complement cereal crops as a source of protein and minerals. They also serve as rotation crops on the farmland with cereals, reducing soil pathogens and supplying nitrogen to the cereal crop. Food legume crops are considered vital crops for achieving food and nutritional security for both poor producers and consumers [1]. Groundnut (*Arachis hypogea L.)* otherwise called peanut, monkey nut, gobber pea and *arachide* belongs to the family *leguminosea*. It originated from Latin America and the Portuguese who were responsible for its introduction into West Africa from Brazil in the 16th Century [14, 15]. Developing countries account for nearly 95 percent of world production [16].

Groundnut is the 13th most important food crop and 4th in oil seed crop of the world. Groundnut seeds (kernels) contain 40-50% fat, 20-50% protein and 10-20% carbohydrates [17]. Groundnut production, marketing and trade served as major sources of employment, income and foreign exchange before Nigeria became independent. Groundnut seeds contain high quality edible oil (50%), easily digestible protein (25%) and carbohydrate (20%). It is grown on 26.4 million ha worldwide with a total production of 36.1 million metric tons, and an average productivity of 1.4 metric tons ha., [18]. The groundnut sector provided the basis for the agro-industrial development and contributed significantly to the commercialization, monetization and integration of the natural rural sector [19]. The success of groundnut as an agricultural commodity in Nigeria was as a result of government setting prices, purchase and export agricultural produce through the commodity marketing boards. Groundnut is one of the most popular commercial crops in Nigeria. Nigeria produces 41% of the total groundnut production in West Africa [15].

In Nigeria, groundnut is predominantly produced in 15 states - Jigawa, Kaduna, Kano, Katsina, Bauchi, Benue, Borno, Gombe, Kebbi, Kwara, Nasarawa, Niger, Taraba, Yobe and Zamfara states. There are however other states with climate also favourable to groundnut production. There are currently about 14,000 registered groundnut farmers across 26 states of the federation [20]. In these states, groundnut is produced as a smallholder crop. The haulms (stalks of groundnut) are important fodder for livestock, especially, sheep and goat and in particular ram. The plant, through its biological activities nitrogen fixation, is an important soil fertility conserver. The nuts are consumed roasted, boiled or as confectionary, snack nuts, peanut butter or in cookies. The nut is crushed to produce oil which is principally used for cooking. But is also used for other industrial purposes such as; pharmaceuticals as carrier, cosmetics. It is also used for the production of margarine. The by-product, meal (cake) is used for both human and livestock consumption [21].

In Bayo Local Government Area of Borno State, Nigeria, the economy is mixed agricultural, based on herding cattle, goats, sheep, horses, and donkeys and farming sorghum, millet, maize, cowpea and cotton. Agriculture consists mostly of small farms using traditional methods although production of groundnut is only second to Hawul Local Government Area in the southern parts of the state as shown in figure one (1). Food legumes also have higher prices, compared to cereals, and are increasingly grown to supplement farmers' incomes. The important and diverse role played by food legumes in the farming systems and in diets of people makes them ideal crops for achieving developmental goals of reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience [1]. Due to all these reasons it is quite important therefore to monitor the level of heavy metals in food items for safety assessment of animals', human's health and entire environment. The purpose of this study was to assess the accumulation of some heavy metals in groundnuts from Bayo local government Area of Borno State, Nigeria.

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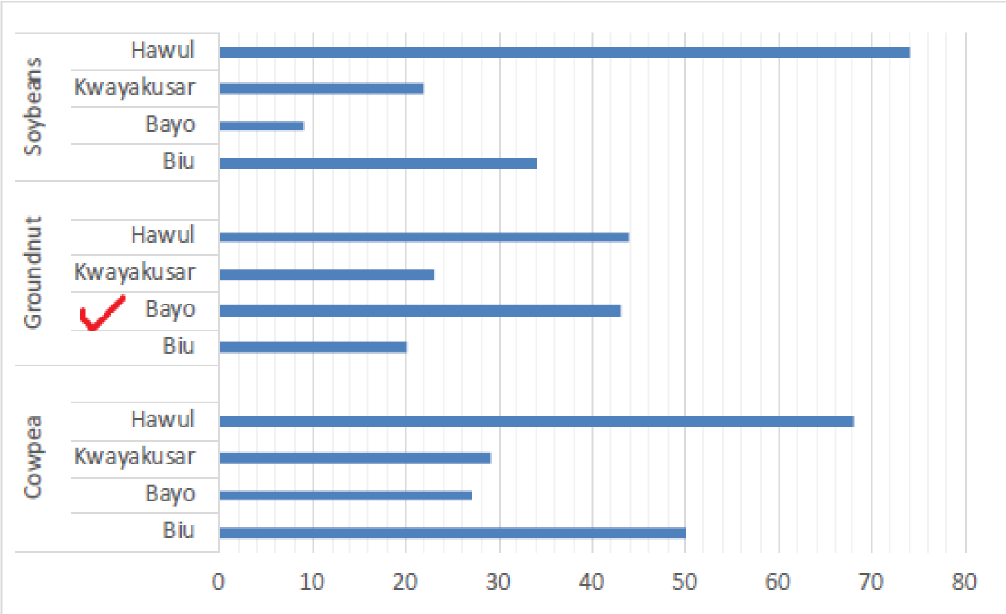

Fig. 1: showing the rate of production of groundnut across Four Local Government Areas (Bayo, Biu, Hawul and Kwaya kusar) in Southern Borno State. **Source: Ogunsanmi [21]**

MATERIALS AND METHODS

Sampling Area

Samples of the groundnut (roots, stems and leaves) and the soil of the same farm were collected from six different farms located in three different sites in Biriyel, Bayo Local Government Area, Borno state, Nigeria (Figure 2).

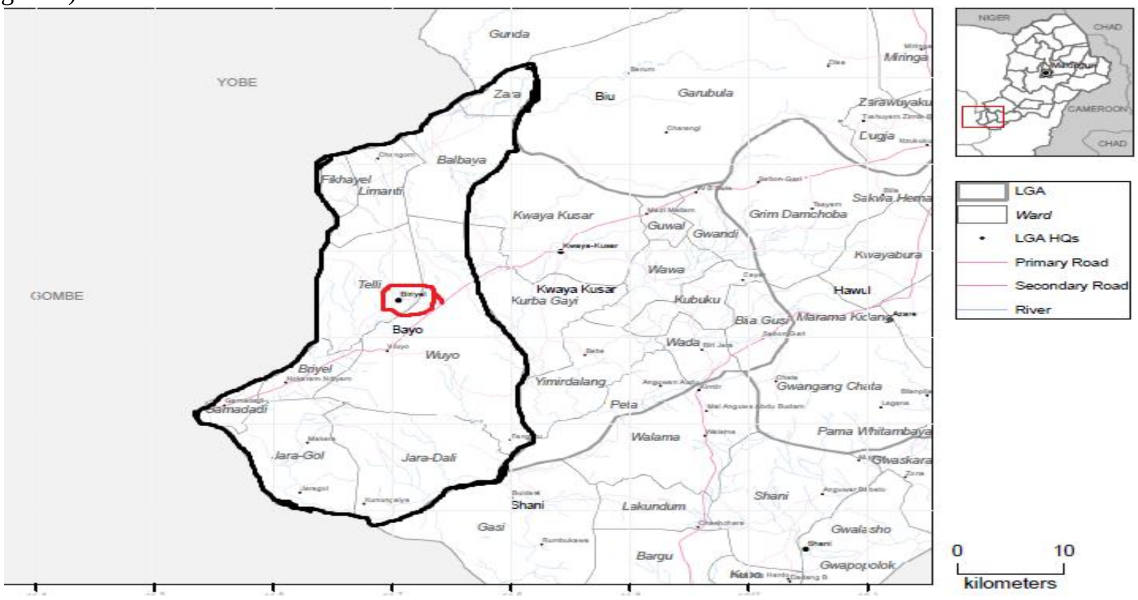

Figure 2: Map of Bayo Local Government Area showing sampling site, Biriyel.
Sources: https://www.humanitarianresponse.info/en/operations/nigeria[22]

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Sample Collection

Samples of fresh, grown up and matured groundnuts plants were collected in the morning hours. Collection was done by careful uprooting of the plant from the soil. The samples collected were washed with water in the laboratory, carefully separated into roots, stem, leaves and the seed. Soil sample was equally collected from the same farm land, collection was made from surface to beneath the roots (0 - 30cm depth) of the plants. This was done using hand trowel. Collected soil samples were put in a clean polyethylene bag and transported to the laboratory for subsequent analysis according to Garba et al. [1].

Sample Preparation and Analysis

The sample preparation method of using freshly prepared aqua regia (3ml HNO_3 + 9ml HCl i.e. ratio 1:3) by Garba et al. [23] was adopted. Physiochemical properties of the soil were determined and the heavy metals; arsenic, cadmium, chromium, nickel, lead, selenium and zinc were determined using Atomic Absorption Spectroscopy (AAS)

DATA HANDLING

All statistical analyses were performed using SPSS package. Differences in heavy metal concentrations among the samples were detected using One-way Repeated ANOVA, followed by multiple comparisons using LSD tests at significance level of P = 0.05.

RESULTS AND DISCUSSION

The level of organic carbon in the soil was observed to be moderate (1.44), and is good for plant growth because it does not exceed the critical level of 1.0 - 1.5 moderate and > 1.5 high as reported by Walkley et al. [24]. The soil pH was found to be moderately acidic with pH of 5.56. Soil pH is one of the factors which influences the bioavailability and mobility of heavy metals and even the anions when dissociated from the metal ions in the soil. It has been reported by Jenne [25] that, heavy metals mobility decreases with increasing soil pH due to precipitation of hydroxide, carbonate or formation of insoluble organic complexes. In this study, the soil pH is slightly acidic, thus supplementing the soil nutrients has become necessary for high yield. Heavy metals are mobile at pH <7 than at pH >7. Soil organisms are also hindered by high acidity, and most agricultural crops do best with mineral pH < 6.5 and organic soils of pH 5.5 [26]. The result shows that, the electric conductivity was found to be 30.40mscm^{-1} and is classified as low and suitable. Electric conductivity critical level <250 is classified as low and suitable whereas >300 is considered high. The cation exchange capacity was observed to be low (14.96). Cation exchange capacity commensurate with the pH of the soil. As the pH of the soil increases the cation exchange capacity of the soil also increases [1]. The texture of the soil was found to be sandy.

Table 2: shows the concentration of the metals determined in the soil, roots, stem leaf and the nuts or seed of the crop (*A. hypogea*) The result indicates that, the concentration metals vary within the different parts of legume. For instance, the level of Cd ranges from 0.018 in the root to 0.023µg/g in the leaves although the soil has the highest level of 0.311µg/g Cd; chromium and cobalt were only observed in the root with the levels, 0.054 and 0.034 respectively; 0.301 and 0.201 µg/g in the soil. The level of Cu ranges from 0.075 in the stem to 0.126 µg/g in the seed. The soil had 0.451 µg/g Cu. Generally, the amount of heavy metals mobilized in the soil environment is a function of pH, soil chemistry, organic matter content, clay content, cationic exchange capacity and other soil property.

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Table 2: Mean concentration (µg/g) of the metals determined in the soil, roots, stem, leaf and the nuts or seed of the crop (A. hypogea)

Sample Elements	Soil	Roots	Stem	Leaves	Seed
Cd	0.311±0.03	0.018±0.07	0.021±0.11	0.023±0.08	0.021±0.22
Cr	0.301±0.22	0.054±0.10	ND	ND	ND
Co	0.203±0.12	0.034±0.15	ND	ND	ND
Cu	0.451±0.21	0.097±0.09	0.075±0.15	0.090±0.03	0.126±0.07
Zn	0.511±0.28	0.304±0.11	0.032±0.10	0.359±0.25	0.390±0.36
Ni	0.341±0.22	0.041±0.31	0.008±0.12	0.054±0.09	0.085±0.03
Pb	0.128±0.66	0.110±0.35	0.125±0.19	0.211±1.02	0.131±0.51

Data are presented as Mean ± SD (N = 4). No significant difference was observed at P = 0.05 using anova repeated analysis acording to least significant difference test

Copper (Cu)

Copper in the Earth's crust is most abundant in mafic and intermediate rocks and has the tendency to be excluded from carbonate rocks. It forms several minerals of which the common primary minerals are simple and complex sulfides. These minerals are quite easily soluble in weathering processes and release Cu ions, especially in acid environments. Therefore, Cu is considered among the more mobile of the heavy metals in hypergenic processes [27]. The common characteristic of Cu distribution in soil profiles is its accumulation in the top horizons. This phenomenon is an effect of various factors, but above all, Cu concentration in surface soils reflects the bioaccumulation of the metal and also recent anthropogenic sources of the element [27]. Copper is an essential transition metal with two oxidation states under physiologically relevant conditions. Due to its ability to cycle between the oxidized Cu(II) and reduced Cu(I) states, it is involved in biological processes such as photosynthesis, respiration, oxygen superoxide scavenging, ethylene sensing, cell wall metabolism and lignification [28]. For the very reason that it is essential, Cu can also be highly toxic [29]. Free Cu catalyzes Fenton reactions that generate hydroxyl radicals causing damage to lipids, proteins and DNA [30]. Copper also has been reported to interfere with iron homeostasis [31]. An overall reduction of plant biomass, inhibition of root growth, chlorosis, bronzing and necrosis are the usual reported symptoms of a Cu excess due to increased production of reactive oxygen species and harmful interactions at the cellular level. The appropriate content of Cu in plants is essential both for health of the plant and for the nutrient supply to man and animals. Some plant species have a great tolerance to increased concentrations of Cu and can accumulate extremely high amounts of this metal in their tissues. he concentration of Cu in plant tissues seems to be a function of its level in the nutrient solution or in soils. The pattern of this relationship, however, differs among plant species and plant parts [27]. The level of copper reported in this study is several-folds lower than the permissible of 73.3 µg/g set by Codex Alimentarius Commission FAO/WHO [32].

Zinc (Zn)

Zinc is also essential to all organisms and has an important role in metabolism, growth, development and general well-being. It is essential cofactor for large number of enzymes in the body, it is required for the proper maintenance of the body functions. For example, the immune system, proper brain functioning and is vital for the development of fetal growth [23]. Zinc deficiency leads to coronary heart diseases and various metabolic disorders [33]. In this study, the seed has the highest level of Zn (0.390 µg/g) followed by the leaves (0.359µg/g), the root (0.304µg/g) and the stem had 0.032 µg/g Zn, (Table 1). Report has it that, young developing tissues have higher Zn concentration than mature tissues except for seeds. It can also be stored in stems and be mobilized later to growing tissues. Mature seeds contain Zn localized in the embryo [34]. The concentration of zinc reported in this study is very much lower than the permissible limit of 99.4µg/g Zn set by FAO/WHO [32]. Deficiency of zinc can also result from inadequate dietary intake, impaired absorption, excessive excretion or inherited defects in zinc metabolism [35]. Report has it that, deficiency of Zn in the diet may be more dangerous to living organism including human than its high concentration in the diet [23].

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Cobalt (Co)

In nature, Cobalt occurs in two oxidation states, Co^{2+} and Co^{3+}, and formation of the complex anion $Co(OH)_3$ is also possible. During weathering, Co is relatively mobile in oxidizing acid environments, but due to a high sorption by Fe and Mn oxides, as well as by clay minerals, this metal does not migrate in a soluble phase. In soils, certain bacteria are known to mobilize Co already complexed as chelate compounds and, thus, Co^{3+} in solution can be transported away. Cobalt concentration in soils is inherited from parent materials. Soils over mafic rocks and soils derived from clay deposits contain the highest amounts of this metal. Cobalt is a transition metal not essential for plants with seven possible oxidation states. In physiological conditions, the oxidation states of Co are mainly II and III, which makes Co a possible catalyzer of Fenton reactions. Beneficial effects of Co supply have been associated with symbiotic rhizobia that inhabit in the nodules of leguminous plants. Other reported beneficial effects include retardation of leaf senescence through inhibition of ethylene biosynthesis, and increased drought resistance in seeds [36]. Cobalt is an integral component of vitamin B-12 (cobalamin) for the activity of several enzymes involved in nitrogen fixation. It is required in the manufacture of red blood cells and in preventing anemia. An excessive intake of cobalt may cause the over production of red blood cells [37]. Cobalt deficiency is rare in human but cattle are seen to be affected with symptoms like anemia. The daily recommended range of Cobalt in human diet is 0.005 mg/day [38, 39]. For symbiotic association, Cobalt is needed for N_2 fixation in legumes and root nodules of non-legumes [1]. The level of the element in this study was observed only in the root (0.034µg/g) and the soil (0.203µg/g), it was however, found below detection limit in the stem, leaf as well as the seeds (Table 1). The level of Co reported in this study, although observed only in the roots. is lower than the permissible limit (2.3µg/g Co) set by FAO/WHO [32]. Toxicity of Co excess is linked to oxidative stress, inhibition of photosynthesis and iron deficiency [40, 41]. Cobalt has been reported to disrupt iron homeostasis and compete with iron for access to transporters in many organisms including plants [42]. In legumes, Co deficiency inhibits the formation of leghemoglobin and hence N_2 fixation. However, the Co requirement for this process is low. In natural conditions, Co deficiency is not known to retard the growth of either nonlegumes or legumes. There are no reports of Co toxicity to animals attributed to consumption of natural feedstuffs. However, in certain geochemical areas, and under the influence of man-induced pollution, the excess of Cobalt in plants may be a health risk [27].

Nickel (Ni)

Nickel plays some vital role in the body function including enzyme function. In very trace amount it may be beneficial to activate some system but its toxicity at higher levels is more in enzyme prominent [43]. It is one of the essential elements which is present in the environment in trace amount. Ni is known for its involvement in urease activity [44, 45]. It is also considered as indispensable for number of metabolic reactions in living beings [46, 23]. It is present in substantial quantity in all living organisms [1, 47]. Nickel is readily transported from roots to aboveground plant tissues. However, at higher concentrations it can be toxic. Plants have been shown to accumulate " in both vegetative tissues and seeds [1], and therefore represent a source of Ni^{2+} ions to primary and secondary consumers and ultimately man. In this study the highest level of Ni was found in the seed (0.085 µg/g), followed by the leaves (0.054 µg/g), the roots (0.041 µg/g) and the stem had the lowest level of 0.008 µg/g, (Table 2). Ni is usually accumulated in vegetative part of plant body and it is mobile through the plant structure, translocated and concentrated in the leaves but after ageningness of the leaves it is moved to the seeds for accumulation [48]. According to ATSDR [49] the acceptable range of Ni daily intake is 3-7 mg/day.

Chromium (Cr)

Chromium (III) is an essential element required for normal sugar and fat metabolism. It is effective to the management of diabetes and it is cofactor with insulin. Cr (III) and its compounds are not considered to be health hazard, while the toxicity and carcinogenic properties of Cr (VI) have been known for long time [37]. It is present in human tissues in variable concentrations and its deficiency is characterized by disturbance in glucose, lipid and protein metabolism [23]. As an element, it has been reported that it is usually present in food in the trivalent form; the hexavalent form of it however, is toxic and not normally found in food [50]. It has been reported to cause skin rashes, stomach ulcer, kidney, liver damages, lungs cancer and ultimate death [51]. Chromium (VI) can easily penetrate the cell wall and exert its noxious influence in the cell itself, being also a source of various cancer diseases [52]. Report has it that, the daily dietary intake of 0.05-0.2 mg of chromium contributes to well-being of the human [23]. In this study, Cr was only observed in the roots with 0.0054µg/g and was below detection limit in the stem, leaves and the seeds (Table 2). It has been reported that, chromium

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accumulates mainly in roots and shoots; however, roots accumulate the major part, being usually only a small part translocated to the shoots [53, 54]. Accumulation of Cr in different parts of plant has been reported to follow the following order; roots > stem > leaves > seed [1].

Lead (Pb)

Lead is a serious cumulative body poison which enters into the body system through air, water and food [23]. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human consumption [55]. The contamination of agricultural soils is often a direct or indirect consequence of anthropogenic activities [56]. In this study, of all the elements determined, Pb has the highest level in all the parts of the crop. High level of 0.211µg/g was observed in the leaves followed by the seed (0.131µg/g), the stem (0.125 µg/g), and the root 0.110 µg/g. The high level of Pb observed in the leaves, seed and the stem of this study is contrary to the reports that, lead is easily taken up by plants from the soil, accumulated in root and only a small fraction was translocated upward to the shoots [57]. The level of Pb observed in this study is within the permissible limit (0.3µg/g) set by FAO/WHO [58]. Although Pb is not an essential nutrient for plants, majority of lead is easily taken up by plants from the soil and accumulated in root while only a small fraction was translocated upward to the shoots [57].

Cadmium (Cd)

Cadmium is a heavy metal naturally present in soils. It may also be added to the soil as a contaminant in fertilizer, manure, sewage sludge and from aerial deposition [23]. The amount of cadmium contributed from each source varies with location due to differences in soil formation, management practices and exposure to pollution sources [23], but the level of Cd in the soil appears to be increasing over time [59]. Although plants do not require Cd for growth or reproduction, the bioaccumulation index of Cd in green plants exceeds that of all other trace elements [60]. Plants can accumulate relatively high levels of cadmium, without adverse effects on growth [61]. Cadmium is retained for many years in the human body, so consumption of foods high in Cd may induce chronic toxicity [62]. The World Health Organization set a maximum provisional tolerable intake limit for an adult at 60 to 70 µg Cd per day [63] and the Codex Alimentarius Commission of FAO/WHO is discussing a limit of 0.1 µg/g Cd. Cadmium is highly toxic non-essential heavy metal and it does not have role to play in biological process in living organisms [23]. Thus, even in low concentration Cd could be harmful to living organisms [64]. Cd poisoning in man could lead to anemia, renal damage, bone disorder and cancer of the lungs [65]. In this study, high level of Cd was observed in the leaves (0.023µg/g) and the lowest value of 0.018 µg/g Cd was found in the roots. The seed and the stem had 0.021 µg/g Cd Cadmium (Cd) and Zinc (Zn) are trace elements that are readily translocated from roots to the plant tops and can be effectively absorbed into foliage, move around the plant, be accumulated in leaves and seeds and eventually into the food chain through the casparian strip in the roots, xylem cells which is driven by evapotranspiration process [1, 64]. The food chain contamination by Cd starts with soil-plant transfer of Cd.

CONCLUSION

Food legume crops represent an important component of agricultural food crops consumed in developing countries, its contamination is one of the important pathways which contributes 90% of heavy metals in comparison of other sources like inhalation and dermal contact. The increased uptake off heavy metals by plants may sometimes produce toxic effects in plants and also to its consumers along the chain. Legume crops are considered vital crops for achieving food and nutritional security for both poor producers and consumers. No parts of groundnut that is not consumed by either animal or human's, its contamination therefore, is dangerous to the food chain. In this study however, the level of heavy metals determined are all within the permissible limit of consumption. Chromium and Co were found below detection limit in the stem, leaf and the seed or nuts of the crop.

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