



HEAVY METAL UPTAKE OF LEAFY VEGETABLE AND ITS HUMAN HEALTH IMPLICATION IN VEGETABLE-GROWING AREAS OF OGUN AND OYO STATE, NIGERIA

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ABSTRACT

The study assessed the heavy metal pollution extent of irrigation water and soils used for the cultivation of Jute mallow and African spinach in selected vegetable-growing areas of Ogun and Oyo states, Nigeria. Composite water, soil, and vegetable samples were collected from 11 farms in replicates. The concentrations of selected heavy metals (Copper (Cu), Chromium (Cr), Nickel (Ni), Lead (Pb), and Cadmium (Cd)) were analyzed. The geo-accumulation index (I_{geo}), bio-accumulation factor (BAF), hazard quotient (HQ), hazard index (HI), and cancer risk (CR) were used to assess health risk. The result revealed that while Cu, Cr, Pb, and Cd were predominant in soil, water, and in both vegetables in the majority of the farms, Ni was only found in the vegetables with higher concentration in African Spinach than the Jute Mallow. The African spinach also adsorbed Cd more than the Jute mallow in the farms. Indications revealed that Cu in vegetables may be absorbed from both the irrigation water and the soil polluted by organic manure, agrochemicals, and cattle grazing activities around the farms. While Pb and Cd pollution may be a result of vehicular emissions along the farm path and indiscriminate burning of waste on the farms, respectively. The Cr and Pb were the major contributors to both the non-carcinogenic and carcinogenic health risk in the irrigation water and soils among all the heavy metals examined, hence, the associated indirect effect on the populations using the irrigation water and soils for cultivation of vegetable. It was noted that the soils in the area were in the moderately polluted category with respect to *I_{geo}* assessment. The capacity of Jute mallow and African spinach to accumulate heavy metals in the farm locations decreased in the order of Coker > Ilaro > FUNAAB > Atan > Ado-odo > Odogbolu in Ogun state, and Kisi > Iresa > Ijaye > Lalupon > Ido in Oyo state. The regulatory authorities should be advised to provide effective controls to reduce heavy metal pollution of surface water and soils in the study areas.

Keywords: Soil, Water, Vegetable, Heavy, Metal, Pollution

INTRODUCTION

The major concern of farmers in Africa and in developing nations in particular, is on making economic profit from good yield rather than considering the potential environmental and possible human health risk associated with exposure to heavy metals through diet (Briffa *et al.*, 2020). Water and soil quality concerns have often been neglected because they are sufficiently available to produce good yield. However, in the recent decades because of changing climate and increasing poverty level resulting from farmers and herdsmen clashes, banditry and communal clashes in Nigeria, farmers now rely on lower quality and less desirable water and soil close to their village communities for the cultivation of crops, particularly the vegetables. The use of these undesirable resources have long term potential health risk on the vegetable consumers who are ignorant of the fact that fresh crop may contain invisible contaminants, since their interest is on buying and consuming fresh organic vegetables. Consequently, it is paramount to avoid problems associated with contaminated water and soil used for vegetable cultivation by sound planning to ensure that the quality of resources available is put to the best use. While the major quality problem associated with vegetable yield like in other crops is salinity, the inorganic and organic pollutant uptake by food biomass crops is known to impose serious and irreversible human health risks (Afonne and Ifediba, 2020). Among the dangerous contaminants of vegetables according to Taiwo *et al.* (2021) are the toxic metals derived from soils



used for cultivation; industrial and domestic wastewater used for irrigation and amended contaminated sewage sludge used as fertilizer; and planting along the highways. Although, metals are regarded as both essential and nonessential for human body metabolism and physiological functions, the essential metals, however, when consumed in large concentration may cause ailments such as lung disease, neurological degeneration, osteoporosis and anemia, among others (Kothadia *et al.* 2016). While the nonessential metals are noted to be carcinogenic, neurotoxic, and pediatric poisonous human health risk. Studies have shown that children are more vulnerable to the effects of heavy metal exposure, particularly in Nigeria due to consumption of highly contaminated foods and water sources (Scruton, 2023; Ogbeide and Henry, 2024). Kothadia *et al.* (2016) reported that over 400 children died in Zamfara State, Nigeria through exposure to high concentration metal in 2010. Taiwo *et al.*, (2021) suggested that increasing mortality rate was experienced in the recent decade due to Government school feeding programme, hence it is important to understand the effect of water and soil quality on vegetables in order to assist in selecting suitable alternatives to mitigate the potential quality related problems so as to safeguard the public health (Taiwo 2019). In Nigeria, research have been conducted on heavy metal concentrations in vegetables (e.g., Udom *et al.*, 2022; Taiwo, 2023). None of these studies had assessed the human risk of metals in leafy vegetables and also determine the sources of contamination.

Oyo and Ogun state are among the Government's pilot scheme states for 'food feeding programmes' in Nigeria. Both states has also been experiencing rapid structural socio-economic changes. Intensive urbanization, industrialization, and agricultural alteration of land use through metal-contained agrochemicals, wastes, and sewages has degraded the agricultural environment. Previous studies in Nigeria revealed an obvious increase of heavy metals, especially cadmium (Cd) and lead (Pb) in soils in the past decades (e.g., Tefera *et al.*, 2019; Udom *et al.*, 2022; Taiwo, 2023). The results of research have also shown that increased heavy metals in soil do not only lead to soil quality deteriorating but may also affect agricultural product safety. There is a probable accumulation of heavy metals in vegetables grown in these states which may consequently be the most important single health risk contributor to consumers. Dietary intake through contaminated foods has become the main route of heavy metal intake by humans. Therefore, the risk assessment of exposure to heavy metals through diet has becomes an important health issue. Hence the need to assess the human risk of metals in leafy vegetables and also determine the sources of contamination. The objectives of this study are: (1) to determine the concentration of heavy metal in irrigation water and soil used for the cultivation of vegetable. (2) to determine the concentrations of essential (Cu, Cr, Ni,) and non-essential (Cd, Pb) metals in vegetables, and (3) to assess the human health risk of these metals in the leafy vegetable samples.

MATERIALS AND METHODS

Sample Collection and Field Assessment

The samples of irrigation water, cultivating soil and vegetables {Jute mallow (*Corchorus olitorius*) and African Spinach (*Amaranthus hybridus*)} used for determination of heavy metal concentrations were collected from agricultural settlement areas of Ogun and Oyo states in Nigeria, recognized by the States Agricultural Development Programme (OGADEP and OYSADEP). Samples were also collected from the organic farm of the Federal University of Agriculture, Abeokuta (FUNAAB), in addition to the farm settlements. All samples were collected by a systematic random sampling method during the dry season November 2024 to February 2025. The irrigation water, cultivating soil, and vegetable were sampled on the same day. The soil, vegetable, and water samples were packed in a sterilized manner and conveyed to the Yaba college of Technology, Central Laboratory in Lagos for sample treatment, storage, and analysis. 250 ml of irrigation water in triplicate sets from the upstream, at farm location, and downstream sides of streams at the farms in the selected 11 farm settlement areas were collected into pre-cleaned polyethene bottles and labeled accordingly, resulting in a total of ninety-nine (99) water samples. One set of the water samples was acidified to a pH < 2 with 60 % nitric acid, for stabilization to reduce the chemisorptions of trace metal ions onto the surfaces and to prevent the hydrolysis and precipitation of cations. Whereas the



other water samples remain unacidified. The cultivating soil samples were collected randomly and mixed to form one representative composite sample of a minimum of 500 g from 3 farms in each of the 11 selected farm settlements, with three replicates. The soils were collected using a clean plastic shovel, and put in a cleaned zip-lock plastic bag for the laboratory analysis. While six duplicate composite good quality and matured indigenous leafy vegetables (Jute mallow and African spinach) were collected randomly from six beds in the vegetable farms. In the laboratory, the vegetables were separated into stem and leaves with a stainless knife and washed three times with double distilled water to remove air-borne pollutants, soil, metal debris from the watering can, and other contaminants. The water, soil and, vegetable stem and leaf were analyzed for the essential (Cu, Cr and Ni) and nonessential (Cd and Pb) metals using Atomic Absorption Spectrophotometer (AAS) model Bulk Scientific, 210, USA following the method of APHA (1995) after digestion with nitric and perchloric acid in the ratio of 2:1 as stipulated by Franson *et al.* (1998).

Heavy Metal Indices Analysis Method

The geo-accumulation index (I_{geo}) were used to assess the status of Cu, Cr, Ni, Cd, and Pb in the soil samples following the method described by Yang *et al.* (2019). While the study employed the approach of Zhang *et al.* (2015) to assess the bio-accumulation factor (BAF) of heavy metals species in vegetable. Furthermore, the non-carcinogenic and carcinogenic human health risk for heavy metals in the water samples with exposure through the ingestion pathway were assessed using the Average Daily Dose (ADD), Hazard Quotient (HQ), Hazard Index (HI), and Cancer Risk (CR) indices following the procedures described in USEPA (2007).

RESULTS AND DISCUSSION

Heavy Metals Levels in Irrigation Water, Field Soils, Jute Mallow and African Spinach Cultivation Sites

The mean concentration of essential heavy metals (Cu, Cr, Ni) in irrigation water, cultivating soils, and vegetables {Jute mallow (*Corchorus olitorius*) and African Spinach (*Amaranthus hybridus*)} samples in Figure 1 revealed that the levels of Cu was pronounced in soil and vegetable at all the farm locations and in water at Ado-odo, Atan and Kisi. Whereas Cr was obvious in soil, but more predominant in water. Furthermore, Ni was only found in the vegetables with higher concentration in African Spinach than the Jute Mallow in majority of the farm. The Cu, Cr and Ni exceeded the 2.0, 0.05 and 0.07 mg/L, respectively, regulatory limits of the World Health Organization (WHO, 2017) wherever they are available. The Cu detection levels exceeded limit in water, soils and vegetables in all farms, while Cr levels were higher than the WHO, 0.05 mg/L limits in both water and soil. A comparison of the mean concentration of the essential heavy metals in irrigation water, soil and vegetables revealed a decreasing order of Cu > Cr > Ni. Though, Ni were rarely detected in the irrigation water, soils and Jute Mallow samples in Ogun and Oyo, it was however found in African spinach, particularly at Ado-odo, Odogbolu, FUNAAB and Kisi. The high Cu in vegetables were noticed to be absorbed from both the irrigation water and the soil, while, the Ni were adsorbed from the atmosphere. The sources of Cu in the farms may be from the organic manure, mineral fertilizers, pesticides applied by farmers and also the cattle grazing activities around the farms. The high level Cu exposure may cause neurological damage and organ dysfunction, among others as suggested by Gibbs *et al.* (2000). He further expressed that high level Cr exposure may lead to eye irritation and damage, perforated eardrums, liver damage, kidney damage, upper abdominal pain, respiratory cancer, among others.

On the other hand, the mean concentration of non-essential heavy metals as shown in Figure 2, further revealed Pb presence in water, soil and both vegetables in Coker, Ilaro, in Ogun State; and Ido, Lalupon, Iresa and Ijaye, in Oyo State. While Cd in water, soil and both vegetables were observed in Ado-odo and Ijaye, Ogun State. The mean Pb and Cd levels exceeding the regulatory limit of 0.010 mg/L and 0.003 mg/L, respectively in all locations wherein they were detected. The irrigation water and cultivating soils in Ilaro in Ogun state, and Ido and Iresa in Oyo states were highly polluted with Pb, consequently affecting the Jute Mallow and African Spinach grown in the farms. The source of Pb in the farms may be associated with vehicular emission along the farm path, and this may affect

multiple organs in the body, in particular, the nervous system. Cadmium were observed more in cultivating soils than irrigation water in majority of the farms. The African spinach was observed to adsorb Cd more than the Jute mallow and, the source of Cd contamination in the farms may likely be more in the soils than in water. The source of Cd in the soil may be related to indiscriminate burning of waste on the farms. The data of metals determined in water, soil and vegetables samples are highly variable due to the anthropogenic and Agricultural activities at farms (Taiwo, 2021). The majority of the farm vegetable adsorbed high level of Pb and Cd from water and soils, except Cd at Ido with the source being linked to atmospheric condition.

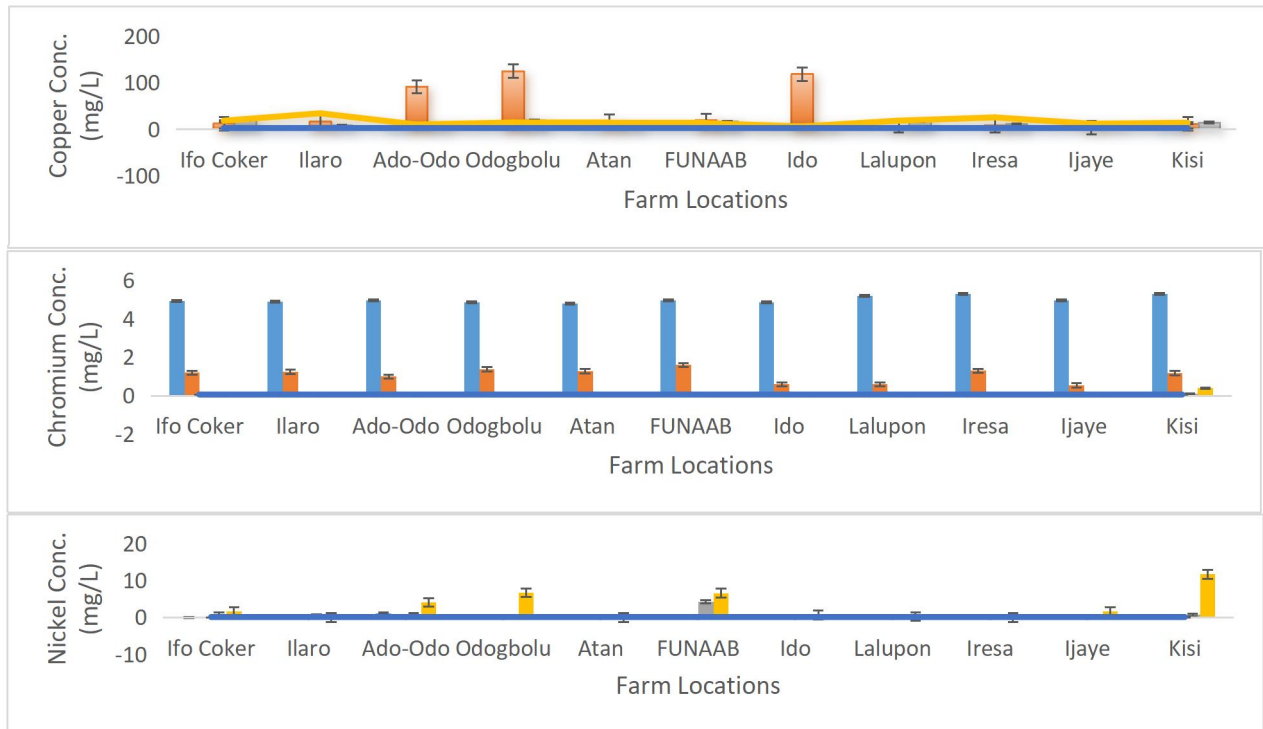


Figure 1. Mean Concentration of Essential Metals (Cu, Cr and Ni) in Water, Soil, Jute Mallow and African Spinach in Selected Farm Settlement Areas of Ogun and Oyo States

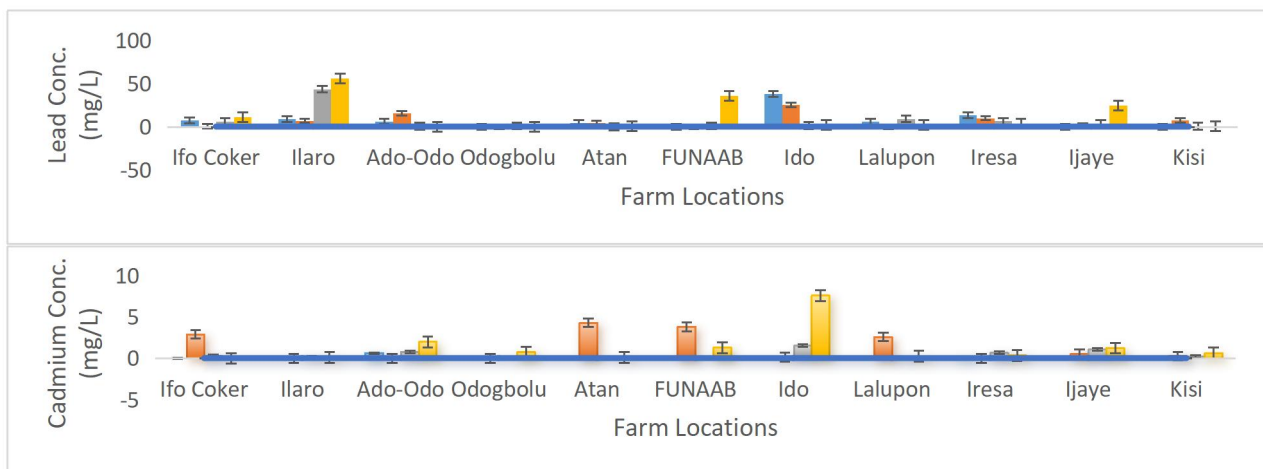


Figure 2. Mean Concentration of Non-Essential Metals (Pb and Cd) in Water, Soil, Jute Mallow and African Spinach in Selected Farm Settlement Areas of Ogun and Oyo States

Heavy Metal Human Health Risk Assessment of Irrigation Water Used for Jute Mallow and African Spinach Cultivation

The estimated non-carcinogenic risk (HQ) of the heavy metals in the irrigation water used in the cultivation of Jute Mallow and African Spinach to human population in selected farmsettlement in Ogun and Oyo states is presented in Figures 3 and 4. The HQ values of Cr and Pb in water used in irrigation exceeded 1 in majority of sampling locations in both Ogun and Oyo states. This therefore makes Cr and Pb to be the contributors (both contributing above 50%) to the noncarcinogenic health risk via the irrigation water route among all the heavy metals examined. While Cr was of similar trend and availability in all the soil samples in all location, Pb was highly conspicuous in Coker, Ilaro, Ado-odo, Ido and Iresa. This indicates that populations consuming the stream water may be exposed to toxic metals and greater risk of adverse non-carcinogenic health effects. The streams in Ido and Iresa exhibited the highest HQ value of Pb when compared to streams in other locations. There is no non-carcinogenic risk of Cu, Ni and Cd via irrigation water as indicated in majority of the farm settlements area in Ogun and Oyo states as all HQ values were below 1.

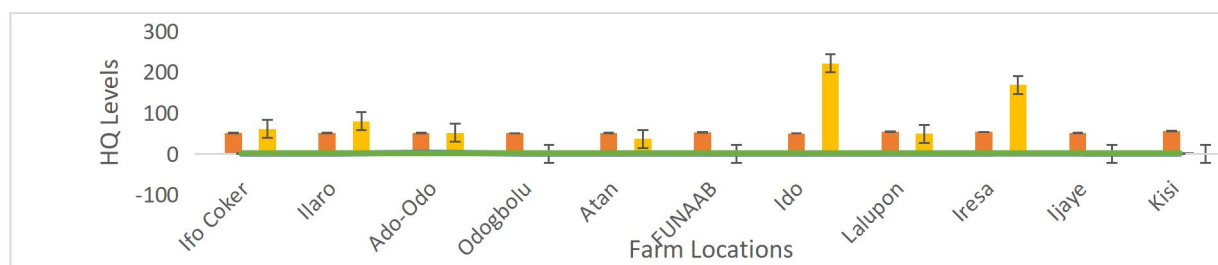


Figure 3. Mean Concentration of Hazard Quotient Levels of Heavy Metal in Irrigation Water Samples Used for Jute Mallow and African Spinach Cultivation in Ogun and Oyo State

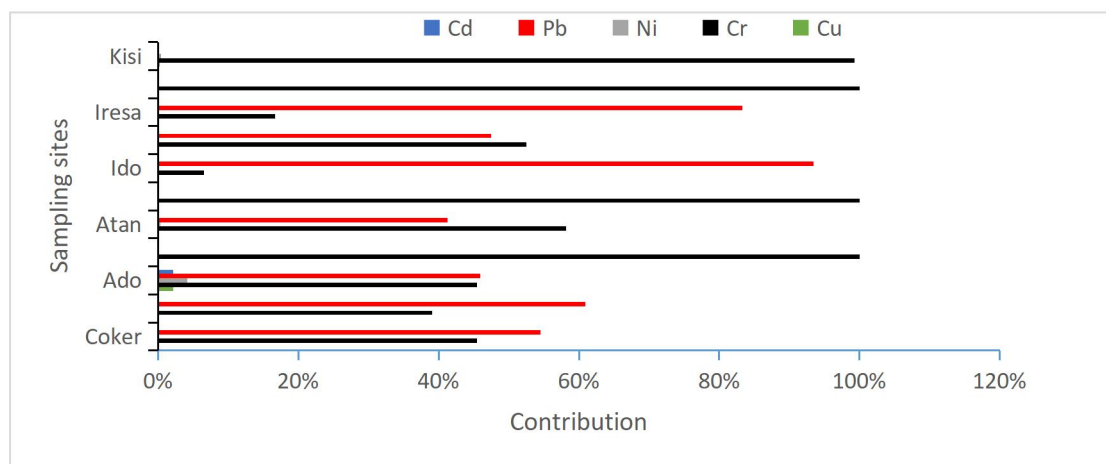


Figure 4: Contribution of Heavy Metal in Irrigation Water to Noncacinogenic Effects

Heavy Metal Cancer Risk Assessment of Irrigation Water Used for Jute Mallow and African Spinach Cultivation

The probability of an individual developing cancer during the lifetime due to his exposure to an environmental toxin or carcinogen is determined using Carcinogenic risk assessment. The carcinogenic risks (CR) values ranges between $10.00E-6$ (negligible) and $10.00E-4$ (serious or high) acceptable cancer risk limit. This is implies cancer risk of between 1 in 1,000,000 to 1 in 10,000 persons (Oni et al., 2022). The CR, Ni, and Pb via irrigation water used in cultivation were all observed to higher than $10.00E-4$ limit for carcinogenic risks (Figure 5), suggesting a high carcinogenic risk in individuals exposed to these metals through irrigation water contamination. The main contributors to the carcinogenic health risk via the irrigation water route among all the heavy metals examined in all the farm were Ni in Kisi, Ijaye, Iresa, Lalupon, Ido, FUNAAB, Atan,

Odogbolu, Ado-odo, Ilaro and Coker (93%, 100%, 85%, 96%, 80%, 100%, 93%, 100%, 40%, 96% and 98%, respectively) ; Pb (5%) in Kisi; Cd (15%) in Iresa; Cd (2%) in Lalupon; Cd (22%) in Ido; Pb (4%) and Cd (2%) in Atan; Pb (44%) and Cd (2%) in Ado-odo; Cd (4%) in Ilaro; and Cd (3%) in Coker as shown in Figure 6.

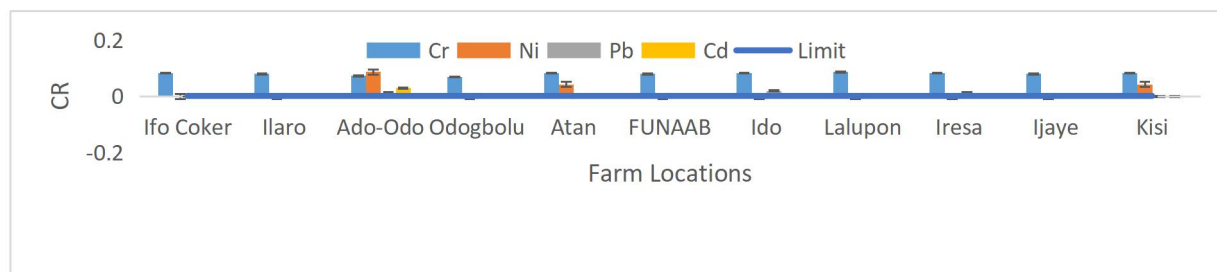


Figure 5. Mean Concentration of Cancer Risk Levels of Heavy Metal in Irrigation Water Samples Used for Vegetable Cultivation in Ogun and Oyo State

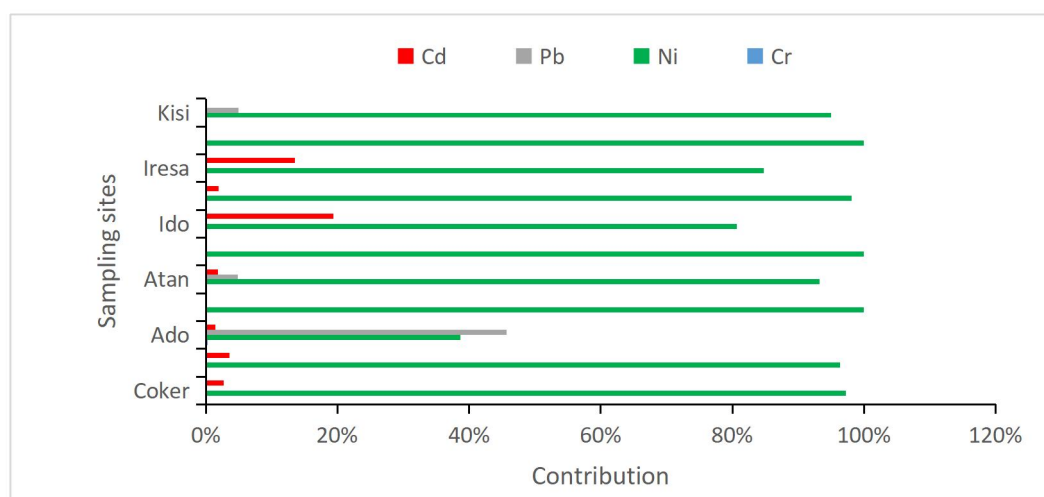


Figure 6: Contribution of Heavy Metal in Irrigation Water to Cacinogenic Effects

Geo-accumulation Index (*I*_{geo}) of Heavy Metals in Soil Used for Jute mallow and African Spinach Cultivation

The pollution sources of heavy metals in soil from farm in the settlement areas in both Ogun and Oyo state based on *I*_{geo} as shown in Figure 7 revealed that the soils in all the farm both states were unpolluted with Cr, Ni and Cd . However, The soil in Ogun state has mean *I*_{geo} of Cu ranging from 0.14 to 0.66 and in Oyo ranging from 0.08 to 0.34. The highest *I*_{geo} Cu value is primarily concentrated in Ilaro in Ogun sate and Ido in Oyo state, though, they are still within the unpolluted to moderately polluted category of soil pollution. The soils quality in Ogun and Oyo states were also in the unpolluted to moderately polluted category of Pb *I*_{geo} detection in analysis. The soil in Ogun state has mean *I*_{geo} of Pb ranging from 0.00 to 0.33 and in Oyo ranging from 0.00 to 0.47. There were no pollution in soil in Ifo Coker, Odogbolu, and FUNAAB in ogun state and in Lalupon in Oyo state. However, moderate pollution were detected in Ilaro, Ado-odo and Atan in Ogun State, While moderate pollution were also found in Ido, Iresa, Ijaye and Kisi in Oyo state. The moderate pollution of Cu may be due to cattle grazing activities in the vicinity, leading to animal excreta and urine thus contaminate soil, and also contamination from fertilizers and pesticides application in farmland. While the Pb detected may be primarily due to ignorance on the part of farmers by using lead-containing pesticides and fertilizers, as well as the application of sewage sludge as manure. It may also be as a result of emissions from vehicles traveling along the roadsides and farmers indiscriminate burning of waste on the farms.

Accumulation and Behaviour of Heavy Metal in Soil, Jute Mallow and African Spinach Cultivated

The bio-concentration factor (BCF) of Cu, Cr, Ni, Pb, and Cd in the different Jute mallow and African spinach in the farm settlement areas of Ogun and Oyo states is shown in Tables 1 and 2. The BCF for the heavy metals in Jute mallow decreased in the order of Pb (68.40) > Cu (3.95) > Cr (0.07) > Ni (0) and Cd (0) in Ogun state and Cd (7.15) > Cu (6.31) > Pb (1.38) > Cr (0.13) > Ni (0) in Oyo state. The capacity of Jute mallow to accumulate Cu, Cr, Ni, Pb, and Cd decreased in the order of Coker > Ilaro > FUNAAB > Atan > Ado-odo > Odogbolu in Ogun state, and Kisi > Iresa > Ijaye > Lalupon > Ido in Oyo state. The high BCF for Pb and Cu in most locations indicate that the Jute mallow may have special mechanism to absorb and translocate these metals to the leaves and stem. The low BCF for Cr and Ni in Jute mallow may be as a result of their toxicity. The poor uptake of Cr may result from neutral pH in soil causing strong adhesion of Cr to soil thereby making it bioavailable for plant uptake (Hamilton *et al.*, 2007). The BCF for the heavy metals in African spinach was observed to decreased in the order of Pb (8.57) > Cu (4.63) > Cr (0.15) > Ni (0) and Cd (0) in Ogun state and Pb (23.91) > Cu (10.64) > Cd (5.61) > Cr (0.5) > Ni (0) in Oyo state (Table 2). The capacity of African spinach to accumulate Cu, Cr, Ni, Pb, and Cd decreased in the order of Ilaro > Atan > Coker > FUNAAB > Ado-odo > Odogbolu in Ogun state, and Ijaye > Iresa > Kisi > Lalupon > Ido in Oyo state. The high BCF for Pb and Cu in most locations indicated absorption and translocation of these metals to the leaves and stem. The low BCF for Cr and Ni in African spinach may also be as a result of their toxicity. The poor uptake of Cr may result from neutral pH in soil causing strong adhesion of Cr to soil as earlier mentioned (Hamilton *et al.*, 2007).

Heavy Metal Human Health Risk Assessment of Jute Mallow Cultivated

The estimated non-carcinogenic risk (HI and HQ) of the heavy metals in the Jute mallow cultivation to human population in selected farm settlement in Ogun and Oyo states is presented in Table 3. The HQ values of Jute Mallow for Cu, Pb and Cd in majority of farms in Ogun and Oyo states exceeded 1 with mean concentration of Cu ranging from 5.62 to 14.75 in Ogun state and 0.21 to 13.50 in Oyo state; whereas mean concentration of Pb ranged from 0.00 to 41.68 in Ogun and 0.65 to 71.34 in Oyo state, while for Cd ranged from 0.00 to 25.68 in Ogun and 0.88 to 50.67 in Oyo state. The main contributors to heavy metal non-carcinogenic risk in Jute Mallow is Cu, Pb and Cd to the non-carcinogenic health risk via the ingestion of Jute Mallow among all the heavy metals examined. This result also indicates that populations orally exposed to toxic metals in ingestion may be at greater risk of adverse non-carcinogenic health effects. Similar to the HQ value in Kisi for Cr and Coker, Ado-odo, FUNAAB and Kisi for Ni via ingestion exceeded the HQ exposure values of 1. The HI for both states ranged from 7.67 in Atan to 331.90 in Ilaro. On the other hand, the estimated non-carcinogenic risk (HI and HQ) in the African Spinach cultivation to human population in Ogun and Oyo states as presented in Table 4, revealed that The HQ values of Cu, Ni, Pb and Cd in majority of farms in Ogun and Oyo states exceeded 1 with mean concentration of Cu ranging from 8.20 to 27.24 in Ogun state and 4.83 to 18.76 in Oyo state; mean concentration of Ni ranged from 0.00 to 11.61 in Ogun and 0.00 to 18.75 in Oyo state, whereas mean



Figure 7. Mean Value of Geo-Accumulation Index of Heavy Metal in Soil Samples Used For Jute Mallow and African Spinach Cultivation in Ogun and Oyo State



Table 1. Bio-Accumulation Factor of Heavy Metal in Jute Mallow Cultivated in Selected Farm Settlements Areas of Ogun and Oyo State

Location	Bio-accumulation factor				
	Cu	Cr	Ni	Pb	Cd
Ifo Coker	1.77	0	0	62.18	0
Ilaro	0.65		0	0	6.21
Ado-Odo	0.11		0	0	0.01
Odogbolu	0.03		0.07	0	0
Atan	0.30		0	0	0
FUNAAB Farm	1.09		0	0	0
Ido	0.01		0	0	0
Lalupon	2.86		0	0	0
Iresa	2.18		0	0	1.38
Ijaye	0.13		0	0	3.02
Kisi	1.13		0.13	0	4.13

Table 2. Bio-Accumulation Factor of Heavy Metal in African Spinach Cultivated in Selected Farm Settlements Areas of Ogun and Oyo State

Location	Bio-accumulation factor				
	Cu	Cr	Ni	Pb	Cd
Ifo Coker	1.45	0	0	0	0
Ilaro	0.89		0	0	8.53
Ado-Odo	0.11		0	0	0
Odogbolu	0.01		0	0	0
Atan	1.26		0.15	0	0.04
FUNAAB Farm	0.91		0	0	0
Ido	0.02		0	0	0
Lalupon	3.29		0	0	0.21
Iresa	5.96		0	0	0
Ijaye	0		0	0	23.86
Kisi	1.37		0.5	0	0.05



Table 3: Range, Mean, Sd And Rfd Concentration of Hazard Quotient and Hazard Index Values of Heavy Metal in Jute Mallow Cultivated in Selected Farm Settlement Areas of Ogun and Oyo State

State	Farm settlement area	HI	Concentration of essential heavy metal HQ			Concentration of non-essential heavy metal HQ	
			Cu (RfD = 0.04)	Cr (RfD = 0.003)	Ni (RfD = 0.02)	Pb (RfD = 0.004)	Cd (RfD = 0.001)
Ogun	Ifo Coker	65.27	(12.22-16.45); 14.75 ± 1.80	(0.00-0.00); 0.00 ± 0.00	(0.00-3.44); 1.64 ± 1.80	(0.00-83.65); 41.68 ± 45.65	(0.00-15.40); 7.20 ± 7.91
	Ilaro	331.90	(3.50-8.64); 5.62 ± 2.30	(0.00-0.00); 0.00 ± 0.00	(0.00-1.89); 0.90 ± 0.98	(324.60-354.59); 339.54 ± 10.45	(0.00-12.69); 5.85 ± 6.43
	Ado-Odo	33.10	(4.12-7.86); 5.69 ± 1.67	(0.00-0.00); 0.00 ± 0.00	(0.27-2.64); 1.36 ± 1.10	(0.00-0.86); 0.37 ± 0.42	(0.00-51.86); 25.68 ± 28.13
	Odogbolu	23.38	(7.68-21.02); 14.60 ± 6.53	(0.00-1.25); 0.58 ± 0.63	(0.00-0.00); 0.00 ± 0.00	(0.00-17.36); 8.21 ± 9.01	(0.00-0.00); 0.00 ± 0.00
	Atan	7.67	(4.01-11.94); 7.67 ± 4.03	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00
	FUNAAB	22.47	(10.06-16.34); 13.64 ± 2.86	(0.00-0.00); 0.00 ± 0.00	(6.23-7.70); 6.89 ± 0.62	(0.00-4.09); 1.95 ± 2.13	(0.00-0.00); 0.00 ± 0.00
Oyo	Ido	59.57	(2.51-2.83); 2.72 ± 0.14	(0.00-0.00); 0.00 ± 0.00	(0.00-1.41); 0.65 ± 0.72	(0.00-11.24); 5.52 ± 6.05	(0.00-104.34); 50.67 ± 55.54
	Lalupon	85.73	(10.24-16.82); 13.50 ± 3.37	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(0.00-152.43); 71.34 ± 78.39	(0.00-1.89); 0.88 ± 0.97
	Iresa	83.89	(2.79-14.47); 8.59 ± 6.31	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(0.47-108.43); 52.99 ± 57.49	(0.00-45.26); 22.31 ± 24.31
	Ijaye	64.97	(0.00-0.45); 0.21 ± 0.23	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(0.00-66.16); 32.75 ± 35.88	(12.86-53.11); 33.00 ± 20.91
	Kisi	24.11	(9.35-17.30); 11.42 ± 2.01	(0.00-2.40); 1.13 ± 1.24	(0.00-2.64); 1.29 ± 1.41	(0.00-1.36); 0.65 ± 0.72	(0.00-19.49); 9.62 ± 10.54

Table 4: Range, Mean and Rfd Concentration of Hazard Quotient and Hazard Index Values of Heavy Metal in African Spinach Cultivated in Selected Farm Settlement Areas of Ogun and Oyo State

State	Farm settlement area	HI	Concentration of essential heavy metal HQ			Concentration of non-essential heavy metal HQ	
			Cu (RfD = 0.04)	Cr (RfD = 0.003)	Ni (RfD = 0.02)	Pb (RfD = 0.004)	Cd (RfD = 0.001)
Ogun	Ifo Coker	101.81	(13.20-13.98); 13.41 ± 0.32	(0.00-0.00); 0.00 ± 0.00	(0.00-5.66); 2.67 ± 2.93	(0.00-172.54); 85.74 ± 93.92	(0.00-0.00); 0.00 ± 0.00
	Ilaro	467.37	(11.71-42.03); 27.24 ± 16.19	(0.00-0.00); 0.00 ± 0.00	(0.00-0.00); 0.00 ± 0.00	(390.00-480.20); 435.98 ± 44.37	(0.00-8.49); 4.15 ± 4.55
	Ado-Odo	77.18	(7.70-8.73); 8.20 ± 0.37	(0.00-0.00); 0.00 ± 0.00	(0.00-13.21); 6.60 ± 7.23	(0.00-0.00); 0.00 ± 0.00	(0.00-126.34); 62.39 ± 68.35
	Odogbolu	45.22	(7.70-14.30); 11.10 ± 3.46	(0.00-0.00); 0.00 ± 0.00	(0.00-21.21); 10.35 ± 11.35	(0.00-0.00); 0.00 ± 0.00	(0.00-48.20); 23.76 ± 26.03
	Atan	13.62	(4.20-16.97); 10.49 ± 6.79	(0.00-2.20); 1.08 ± 1.18	(0.00-0.00); 0.00 ± 0.00	(1.22-1.65); 1.44 ± 0.15	(0.00-1.26); 0.62 ± 0.67
	FUNAAB	340.57	(5.20-14.22); 9.63 ± 4.69	(0.00-0.00); 0.00 ± 0.00	(0.00-24.04); 11.61 ± 12.73	(0.22-563.04); 277.15 ± 303.40	(0.00-85.49); 42.18 ± 46.21
Oyo	Ido	58.30	(4.20-5.50); 4.83 ± 0.59	(0.00-0.00); 0.00 ± 0.00	(0.00-24.04); 11.19 ± 12.30	(0.00-0.24); 0.12 ± 0.13	(0.00-85.48); 42.18 ± 46.21
	Lalupon	39.75	(10.42-18.86); 14.08 ± 3.98	(0.00-0.00); 0.00 ± 0.00	(0.00-0.47); 0.22 ± 0.24	(0.00-35.20); 16.85 ± 18.48	(0.00-17.60); 8.60 ± 9.42
	Iresa	66.17	(0.00-38.85); 18.76 ± 20.57	(0.00-1.08); 0.54 ± 0.59	(0.00-0.00); 0.00 ± 0.00	(0.00-61.92); 30.52 ± 33.43	(2.00-31.11); 16.36 ± 15.62
	Ijaye	249.43	(0.00-18.39); 9.15 ± 10.02	(0.00-0.00); 0.00 ± 0.00	(0.00-5.34); 2.65 ± 2.90	(22.90-376.75); 197.02 ± 190.66	(24.50-57.51); 40.61 ± 17.15
	Kisi	55.35	(4.42-16.42); 10.39 ± 6.50	(0.00-8.38); 4.13 ± 4.52	(1.10-36.45); 18.75 ± 19.28	(0.00-3.95); 1.82 ± 2.00	(10.05-30.17); 20.26 ± 10.84

concentration of Pb ranged from 0.00 to 435.98 in Ogun and 0.12 to 197.02 in Oyo state, while for Cd it ranged from 0.00 to 62.39 in Ogun and 8.60 to 42.18 in Oyo state. The main contributors to heavy metal non-carcinogenic risk in African spinach is Cu, Pb and Cd to the non-carcinogenic health risk via the ingestion. Similar to the HQ value in Atan and Kisi for Cr via ingestion exceeded the HQ exposure values of 1. The HI for both states ranged from 13.62 in Atan to 340.57 in FUNAAB.

Heavy Metal Cancer Risk Assessment of Jute Mallow and African Spinach Cultivated

The estimated carcinogenic risk (CR) values of cultivated Jute Mallow in the farm settlements through exposure to heavy metals are presented in Table 5. Ni, Pb, and Cd in cultivated jute mallow were observed in majority of the farms in the settlement to be higher in cancer risk than the $10.00E-4$ limit for carcinogenic risks (Table 6). The areas basically involved in Carcinogenic risk with values higher than $10.00E-4$ limit were Coker, Ilaro, and FUNAAB in Ogun state, and Ido, Lalupon and Kisi in Oyo state. These suggested that the individuals that consumed the Jute mallow cultivated in these areas have high carcinogenic risk due to exposure to these metals through ingestion. The summation of CR varied from $0.00E+00$ to $1.72E-01$ in Ogun state and $7.50E-03$ to $3.21E-01$ in Oyo state. While the estimated carcinogenic risk (CR) values of cultivated African Spinach in the farm settlements through exposure to heavy metals as presented in Table 6 revealed that The Ni, Pb, and Cd were observed in majority of the farms in the settlement to be higher in cancer risk than the $10.00E-4$ limit for carcinogenic risks. The areas exposed to carcinogenic risk in African spinach were Coker, Ilaro, Ado-odo, Odogbolu and FUNAAB in Ogun state, and Ido, Lalupon, Ijaye and Kisi in Oyo state. The summation of CR varied from $5.05E-03$ to $3.92E+00$ in Ogun state and $6.40E-02$ to $1.52E+00$ in Oyo state.

Table 5: Mean and Sd Concentration of Cancer Risk Values of Heavy Metal in Jute Mallow Cultivated in Selected Farm Settlement Areas of Ogun and Oyo State

State	Farm settlement area	ΣCR	Concentration of essential heavy metal CR			
			Cr (SF = 0.5)	Ni (SF = 0.84)	Pb (SF = 0.0085)	Cd (SF = 6.1)
Ogun	Ifo Coker	6.30E-02	0.00E+00; 0.00E+00	2.33E-02; 2.58E-02	1.33E-03; 1.51E-03	3.83E-02; 4.31E-02
	Ilaro	5.50E-02	0.00E+00; 0.00E+00	1.33E-02; 1.51E-02	1.00E-02; 2.65E-19	3.17E-02; 3.49E-02
	Ado-Odo	1.72E-01	0.00E+00; 0.00E+00	1.53E-02; 9.52E-03	1.00E-05; 1.10E-05	1.57E-01; 1.73E-01
	Odogbolu	1.23E-03	1.00E-03; 1.10E-03	0.00E+00; 0.00E+00	2.33E-04; 2.66E-04	0.00E+00; 0.00E+00
	Atan	0.00E+00	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00
	FUNAAB	1.38E-01	0.00E+00; 0.00E+00	1.38E-01; 1.94E-02	5.00E-05; 5.48E-05	0.00E+00; 0.00E+00
Oyo	Ido	3.21E-01	0.00E+00; 0.00E+00	1.40E-02; 1.55E-02	2.00E-04; 2.19E-04	3.07E-01; 3.36E-01
	Lalupon	7.50E-03	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	2.50E-03; 2.74E-03	5.00E-03; 5.48E-03
	Iresa	1.49E-01	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	2.01E-03; 2.19E-03	1.47E-01; 1.61E-01
	Ijaye	1.98E-01	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	1.00E-03; 1.10E-03	1.97E-01; 1.29E-01
	Kisi	8.32E-02	1.50E-03; 1.64E-03	2.00E-02; 2.19E-02	2.00E-05; 2.19E-05	6.17E-02; 6.82E-02

Table 6: Mean and Sd Concentration of Cancer Risk Values of Heavy Metal in African Spinach Cultivated in Selected Farm Settlement Areas Of Ogun and Oyo State

State	Farm settlement area	ΣCR	Concentration of essential heavy metal CR			
			Cr (SF = 0.5)	Ni (SF = 0.84)	Pb (SF = 0.0085)	Cd (SF = 6.1)
Ogun	Ifo Coker	5.13E-02	0.00E+00; 0.00E+00	4.88E-02; 5.34E-02	2.50E-03; 2.81E-03	0.00E+00; 0.00E+00
	Ilaro	4.60E-02	0.00E+00; 0.00E+00	0.00E+00; 0.00E+00	2.10E-02; 5.73E-03	2.50E-02; 2.74E-02
	Ado-Odo	4.73E-01	0.00E+00; 0.00E+00	1.10E-01; 1.20E-01	0.00E+00; 0.00E+00	3.63E-01; 3.99E-01
	Odogbolu	2.73E-01	0.00E+00; 0.00E+00	1.50E-01; 1.67E-01	0.00E+00; 0.00E+00	1.23E-01; 1.38E-01
	Atan	5.05E-03	1.50E-03; 1.64E-03	0.00E+00; 0.00E+00	5.00E-05; 1.04E-21	3.50E-03; 3.89E-03
	FUNAAB	3.92E+00	0.00E+00; 0.00E+00	1.50E-01; 1.76E-01	3.52E+00; 3.88E+00	2.50E-01; 2.74E-01
Oyo	Ido	1.52E+00	0.00E+00; 0.00E+00	7.50E-03; 1.60E-02	5.00E-04; 5.48E-04	1.51E+00; 1.66E+00
	Lalupon	6.40E-02	0.00E+00; 0.00E+00	3.50E-03; 3.89E-03	5.00E-04; 5.48E-04	6.00E-02; 6.60E-02
	Iresa	1.07E-01	1.00E-03; 1.10E-03	0.00E+00; 0.00E+00	1.00E-03; 1.10E-03	1.05E-01; 1.04E-01
	Ijaye	3.19E-01	0.00E+00; 0.00E+00	4.83E-02; 5.31E-02	1.20E-02; 9.02E-03	2.58E-01; 1.19E-01
	Kisi	4.33E-01	5.00E-03; 5.48E-03	3.10E-01; 3.18E-01	5.00E-05; 5.48E-05	1.18E-01; 5.71E-02



CONCLUSION AND RECOMMENDATION

The mean concentration of Cu was pronounced in soil and vegetable at all the farm locations and in water at Ado-odo, Atan and Kisi. Whereas Cr was obvious in soil, but more predominant in water. However, Ni was only found in the vegetables with higher concentration in African Spinach than the Jute Mallow in majority of the farm. The Cu, Cr and Ni exceeded the regulatory limits of the WHO wherever they are available. The essential heavy metals in irrigation water, soil and vegetables revealed a decreasing order of $Cu > Cr > Ni$. The irrigation water and cultivating soils in Ilaro in Ogun state, and Ido and Iresa in Oyo states were highly polluted with Pb resulting from vehicular emission along the farm path, consequently affecting the Jute Mallow and African Spinach grown in the farms. Cadmium contamination from indiscriminate burning of waste on majority of the farms were observed more in cultivating soils than irrigation water. The African spinach was observed to adsorb Cd more than the Jute mallow. There is an indication of human health risk of toxic metals in population consuming vegetables cultivated with soils and water in the farms with Cr and Pb contributing above 50% non-carcinogenic risk (HQ) in both states. Pb contamination was obviously more conspicuous in Coker, Ilaro, Ado-odo, Ido and Iresa. Furthermore, while there were no contamination of soils with CR and Ni, and a moderately pollution with Pb, there was obviously a high carcinogenic risk of CR, Ni, and Pb in water used for irrigation in all the farms. The bioconcentration of heavy metals in the different Jute mallow and African spinach in the farm settlement areas of Ogun and Oyo decreased in the order of $Pb > Cu > Cr > Ni$ and Cd in Jute mallow and African spinach at Ogun state and, $Cd > Cu > Pb > Cr > Ni$ in Jute mallow and $Pb > Cu > Cd > Cr > Ni$ in African spinach at Oyo state. The capacity of Jute mallow to accumulate Cu, Cr, Ni, Pb, and Cd decreased in the order of Coker > Ilaro > FUNAAB > Atan > Ado-odo > Odogbolu in Ogun state, and Kisi > Iresa > Ijaye > Lalupon > Ido in Oyo state. Whereas, The capacity of African spinach to accumulate decreased in the order of Ilaro > Atan > Coker > FUNAAB > Ado-odo > Odogbolu in Ogun state, and Ijaye > Iresa > Kisi > Lalupon > Ido in Oyo state. The high bioconcentration of Pb and Cu in most locations indicated that the Jute mallow may have special mechanism to absorb and translocate these metals to the leaves and stem. Whereas the low bioconcentration in other metals may be as a result of their toxicity and the neutral pH in soil causing their strong adhesion to soil thereby making it bioavailable for plant uptake. Furthermore, there is an indication of human health non-carcinogenic risk of Cu, Pb and Cd in Jute mallow and Cu, Ni, Pb and Cd in African spinach in population consuming vegetables cultivated in majority of farms. There was also an indication of carcinogenic risk of Ni, Pb, and Cd in jute mallow in particular at Coker, Ilaro, and FUNAAB in Ogun state, and Ido, Lalupon and Kisi in Oyo state. While these metals carcinogenic risk in African spinach were more prominent in Ado-odo, Odogbolu and FUNAAB in Ogun state, and Ijaye in Oyo state in addition to the earlier mentioned location.

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