PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 26 (12) 1887-1894 December 2022

Heavy Metals Accumulation and Phytoremediation Ability of Onion (*Allium cepa)* and Garlic (*Allium sativum)* Grown on Contaminated Soils from Challawa Industrial Estate, Kano, Nigeria

[*1]ALKALI, I; [2]AUDU, AA; [3]BELLO, U; [4]DARMA, SM; [5]AHMAD, AT

*[*1]Department of Science Education, Abubakar Tafawa Balewa University, PMB 0248 Bauchi, Nigeria*
[2]Department of Pure and Industrial Chemistry, Bayero University Kano, PMB 3011 – Kano, Kano State – Nigeria
[3]Department of Chemistry, Abubakar Tafawa Balewa University, PMB 0248 Bauchi, Nigeria
[4]Department of Applied Chemistry, Federal University Dutsin-ma, PMB 5001, Katsina, Nigeria
[5]Department of Biological Sciences, Federal University of Kashere, PMB 0182 - Gombe, Nigeria

**Corresponding Author Email: ialkali@atbu.edu.ng*
Co-Authors Email: aaaudu.chm@buk.edu.ng; usmanbello088@gmail.com; smdarma@fudutsinma.edu.ng; atahmadyakasai@gmail.com

ABSTRACT: This work was designed to assess and compare the heavy metals accumulation and phytoremediation ability of some allium species (Garlic; *Allium sativum* and Onion; *Allium cepa*) grown on two different soils (contaminated and Control soils) using standard methods. Heavy metals (of Cr, Fe, Mn, Ni, Pb, and Zn) Concentrations (mg/Kg) were determined using atomic absorption spectrophotometry (AAS Model: 210VGP). Plants growth and biomass production were assessed. Biological concentration factors (BCF) and translocation factors (TF) were calculated. The mean levels of elements obtained ranged widely from 0.55 mg/Kg Ni to 1830.64 mg/Kg Fe. The results showed that onion accumulated higher concentrations of all the heavy metals compared to garlic with exception of Zn. However, the differences in heavy metal concentrations where significant only in Cr and Mn. Phytoremediation efficiency indices (BCF and TF) showed a similar trend for both onion and garlic. The mean BCF values of Pb, Cr, Zn, Mn and Fe in onion were generally high > 1. Ni and Pb had their mean TF values greater than 1. Thus, onion can be used as potential phytoextraction plant. The similarities in most of these metal accumulation trends, BCF and TF between onion and garlic might be due to their being similar species with similar physiological features and from the same family.

DOI: https://dx.doi.org/10.4314/jasem.v26i12.1

Open Access Policy: All articles published by **JASEM** are open access articles under **PKP** powered by **AJOL**. The articles are made immediately available worldwide after publication. No special permission is required to reuse all or part of the article published by **JASEM**, including plates, figures and tables.

Copyright Policy: © 2022 by the Authors. This article is an open access article distributed under the terms and conditions of the **Creative Commons Attribution 4.0 International (CC-BY- 4.0)** license. Any part of the article may be reused without permission provided that the original article is clearly cited.

Cite this paper as: ALKALI, I; AUDU, A. A; BELLO, U; DARMA, S. M; AHMAD, A. T. (2022). Heavy Metals Accumulation and Phytoremediation Ability of Onion (*Allium cepa)* and Garlic (*Allium sativum)* Grown on Contaminated Soils from Challawa Industrial Estate, Kano, Nigeria. *J. Appl. Sci. Environ. Manage.* 26 (12) 1887-1894

Dates: Received: 21 November 2022; Revised: 07 December 2022; Accepted: 19 December 2022; Published: 31st December 2022

Keywords: Phytoremediation; accumulation; heavy metals; contaminated soil; vegetable.

Environmental contamination due to the heavy metals is a major global concern which negatively affect the ecosystem and eventually enters the food chain thereby posing health threat to human. This is caused by many factors, among others; sewage sludge application to agricultural soil, mining and smelting of metalliferous ores, soil erosion, disposal of industrial (such as tannery) and urban wastes. Research by Nnaji and Okoye (2004) reported that out of the Nigeria's 36 states; Lagos, Kaduna, Kano and Rivers housed 80% of the Nigeria's industries and only about 18% of the industries carry out rudimentary treatment of their wastes before discharge, Kano State is a commercial hub to Northern Nigeria and its metropolis home is about 70 percent of the Nigeria's tanning industries (Akan *et al.*, 2009). These industries discharge their effluents in an untreated form to the nearby river Challawa (Abdullahi *et al.*, 2008a) which consequently raise the levels of the heavy metals in this environment. Vegetables are known to constitute

**Corresponding Author Email: ialkali@atbu.edu.ng*

rich source of many balance diets such as vitamins, minerals and fibres. They also possess a good antioxidant property (Lawal and Audu, 2011) and they are widely used for various purposes as food, spices, herbs e.t.c. Onion and garlic are recognised among important ancient cultivated vegetables that belong to genus *Allium* where a large number of its species are been used for various purposes. However, consuming vegetables that are contaminated with heavy metals endanger the human health. This is because over time, these heavy metals can accumulate in human system and they can be toxic at high concentrations (Lawal and Audu, 2011). The effects of heavy metals poisoning include carcinogenicity, immunotoxicity and neurotoxicity. All these occur through the production of oxygen radicals that causes oxidative stress (Golan-goldhirsh, 2006) and negatively affect the physiological and biochemical characteristics. When heavy metals are at concentrations higher than the physiological demand of the plants not only could they enter the food chain and pose potential threat to human health but also could administer toxic effects in the plants (Alkali *et al.*, 2022) thereby affecting the crop yield, soil biomass and fertility (Bhargava *et al.*, 2012). However, plants that can tolerate (or those that have high potential to tolerate) high level of heavy metals are regarded as hyper accumulators and could be used for phytoremediation of heavy metal contaminated soils and water (Golan-goldhirsh, 2006). Heavy metal clean-up of soils involved either *in-situ* or *ex-situ* methods.

In the later the contaminated substrate is removed, treated and returned; it conventionally include excavation, detoxification and/or destruction of contaminants by physical or chemical method (Leguizamo *et al.*, 2017). Additionally, the contaminants may further be subjected to stabilization, solidification, immobilization, incineration or destruction (Sadowsky, 1999). Most of the ex-situ conventional remediation technologies are not cost-effective, ecofriendly and further aggravate damages to the already distressed soils (Alkali, 2020), they also affect the biological properties of the soils where they are deployed. While, in-situ methods do not require for excavation of the contaminated soils, rather they employ technologies that destroy or transform the contaminants in the substrate (Ghosh and Singh, 2005). Other on-side contamination containment and management include; diluting the heavy metal contaminated soil to safe level by mixing it with imported clean soil (Musgrove, 1991), covering the top soil with inert material, immobilization of the inorganic contaminants by either complexing the contaminants or through increasing the soil pH by liming (Alloway and Jackson, 1991). Increased soil pH > 5 decreases the solubility of the heavy metals (Ghosh and Singh, 2005). All these methods do not reduce the concentrations of the contaminants, they only reduce the risk of potential exposure to the plants and animals (Ghosh and Singh, 2005). Thus, the plant based bioremediations (collectively termed phytoremediation) remain the key driver, best and novel remediation for the inorganic contaminants. Therefore, the objectives of this study was to assess and compare the heavy metals accumulation and phytoremediation ability of some allium species (Garlic; *Allium sativum* ans Onion; *Allium cepa*) grown on two different soils.

MATERIALS AND METHOD

Reagents: Analytical reagent (AnalaR) grade chemicals and distilled water were used throughout the study. All glassware and plastic containers used were washed with detergent solution followed by 20% (v/v) nitric acid and then rinsed with tap water and finally with distilled water.

Study Site: The global location of Challawa industrial estate is between latitude (11^0 54^I 03^{II}) North of the equator and longitude (08^0 25^I 21^{II}) East of the Greenwich Meridian in Kumbotso Local Government Area, Kano State, Nigeria. It is the industrial hub of Kano State where most of the industrial plants including tannery, agrochemicals, textiles e.t.c are located. The industrial plants were big and occupy very large number of landmass (Udofia, 2018).

Experimental Design: The field work was conducted using pot experiment. Two (2) separate treatments (control and polluted) were designed to contain ten (10) replicates of perforated plastic pots sized 12 cm × 20 cm each. 2.00 Kg of homogenized soil from UMYU Biological garden was used in each pot in the control treatment and 2.00 Kg of homogenized soil from the study site was used in each pot in the polluted treatment.

Equal volume of polluted water and tap water were used to moisten the soils in the polluted treatment and control treatment respectively prior to sowing the seeds. Continuous irrigation with equal volume of water was maintained for the optimum germination and growth of the plants. The seeds germinated within 2 to 3 weeks and continuous irrigation was maintained for 3 consecutive months until the plants were fully grown and matured. The plants' height (in cm) and number of leaves were recorded at the regular interval of 15 days. The experiment was terminated after three months and plants were harvested.

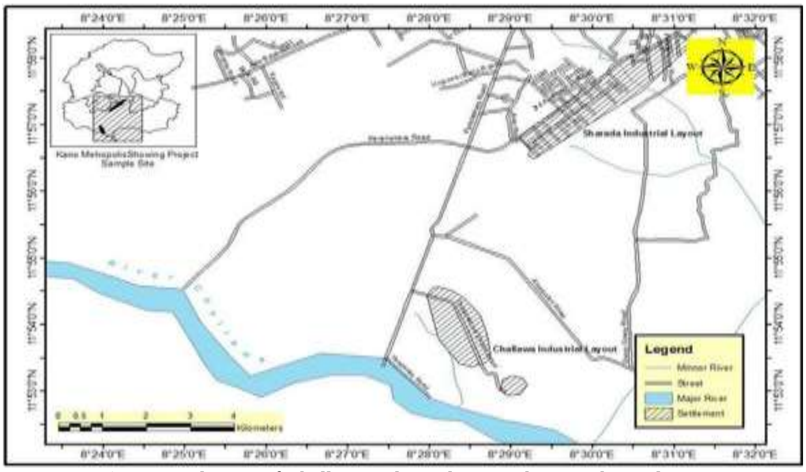

Fig 1. Google map of Challawa Industrial Estate showing the study site

Picture 1: Pot Experiment before Sowing

Picture 2: Pot Experiment before Harvesting

Sampling and Sample treatment: After the harvest, samples were collected separately in a well labelled newspaper and taken to the laboratory where they were washed with tap water, separated into parts (roots, bulbs and leaves) and cut into pieces for easy drying. The pieced samples were placed in clean acid-washed and well labelled porcelain crucible accordingly and were oven-dried at 105ºC for 24 h in Mommert oven (Schutzart DIN 400-50-IP20) so as to protect the sample materials from microbial decomposition. All necessary measures were taken to avoid any source of contamination. The dried sample materials were grinded to powder using ceramic mortar and pestle to ensure the uniform distribution of metals in the sample and then sieved through a 1.5 mm sieve and kept in a clean and well labelled polyethylene bottles for digestion.

Samples Digestion and Analyses: Samples were digested as described by (Kebbekus and Mitra, 1998): 1.00 g fine powdered samples were weighed using digital weighing balance and transferred into a kjeldahl digestion flasks, mixed with 10.00 cm^3 of concentrated trioxonitrate (v) acid and heated at 118°C for 4 hours. The resulting sample solution was filtered through a Whatman filter paper. The filtrate was allowed to cool to room temperature and transferred into a well labelled 60.00 cm^3 screw capped plastic bottles. The solution was made to the mark with distilled water and the content was thoroughly mixed by shaking. Blank was also prepared to detect any potential contamination during the digestion and/or analytical procedure. The digestion was carried out in tenfold for each part of the vegetable sample. The digests were run on the atomic absorption spectrophotometer (AAS, Model; 210VGP) to determine the concentrations of Chromium, Iron, Lead, Manganese, Nickel and Zinc.

Data analysis: IBM SPSS Version 22 was used for data analyses. Significant differences in all plant indices between treatments were analyzed using Duncan's multiple range tests. The statistical significance was $P \leq 0.05$.

RESULTS AND DISCUSSION

The mean pH of the soils and waters for both the control and the polluted treatments were shown in Table 1. The result shows that the polluted soil and polluted water have low pH value than the control soil and control water. This indicates that the heavy metals are more bioavailable in polluted soil than in control soil.

This is in line with study by Onyedika and Okon (2014) and it confirms that heavy metals accumulation varies inversely with the soil pH, at low pH value, the metal ions showed greater cation exchange capacity (CEC) and tend to be more available in aqueous medium thereby making the metal to be more bioavailable to the plants. According to Nyamangara and Mzezewa (1999), pH and organic matter are some of the most important parameters controlling the accumulation and availability of heavy metals in soil. The mean concentration of the metals in soil sample ranged from Ni (1.34±0.39 mg/Kg) to Fe (1.34±0.39 mg/Kg) in the control treatments and from Ni (1.91±1.01 mg/Kg) to Fe (4244.39±519.50 mg/Kg) in the polluted treatments. On the other hand, the mean concentration of the metals in water sample in the control treatments ranged from 0.01±0.00 mg/Kg to 3.82±2.01 mg/Kg for Pb and Fe respectively. Similarly, the mean concentration of the metals in water sample in the polluted treatments ranged from 0.02±0.02 mg/Kg to 19.34±8.64 mg/Kg for Pb and Fe respectively. The accumulation in control treatment followed the trend Fe > Mn > Cr > Pb > Ni. Similarly, the trend in the polluted treatment followed the order Fe > Cr > Mn > Pb > Ni with interchange in the positions of Cr and Mn. This is due to the high concentration of Cr than Mn in the polluted soil (Table 1).

Table 1: Concentrations of heavy metals (mg/Kg) and pH of soils and waters of the treatments (mean ± SD, n = 10)

Parameters	**Control Treatment**		**Polluted Treatment**	
	Soil	**Water**	**Soil**	**Water**
Cr	11.88±8.24	0.22±0.14	1297.00±94.01	5.13±1.20
Fe	2572.28±306.39	3.82±2.01	4244.39±519.50	19.34±8.64
Mn	23.68±5.45	0.15±0.04	37.90±4.31	0.18±0.09
Ni	1.34±0.39	0.06±0.02	1.91±1.01	0.07±0.05
Pb	2.03±1.39	0.01±0.00	2.36±0.67	0.02±0.02
Zn	7.63±3.39	0.31±0.14	64.92±28.57	0.78±0.09
pH	6.33±0.39	6.05± 0.70	5.24±0.15	6.03±0.63

$P < 0.05$

None of the plants became weak in the treatments, however, it was observed that plants in the polluted treatment were greener than those in the control treatment and results in Table 2 showed a significant difference ($p \leq 0.05$) in shoots' heights between control treatment and polluted treatment during the harvest period . It further showed that, the plants grew higher in polluted treatment (M = 13.85) than in control treatment (M = 10.97). This is dissimilar to the findings of Hseu *et al., (*2013) where they argued that shoots' height was significantly lower when treated with 5.0 mmolkg^{-1} EDDS compared with other treatments.

Table 2: Mean Comparison of Plants' Height (cm) between Control & Polluted Treatments; Onion and Garlic.

Variables	**Plants' Height (cm)**				
	Mean	**SD**	**df**	**T Sig (2 tailed)**	
Control	10.97	1.43	18	-5.497	0.000
Polluted	13.85	0.84			
Onion	13.08	1.91	18	1.686	0.109
Garlic	11.74	1.63			

The results also revealed that there was no significant difference ($p \leq 0.05$) in shoots' height of onion (M = 13.08) compared to shoots' height of garlic (M = 11.74) during the harvest period. This indifference in shoots' height could be as a result of been of the same species (*Allium*).

Table 3 showed the mean comparison of dry material weight of onion and garlic; root and shoot. It revealed no significant difference ($p \leq 0.05$) in dry material weight between onion and garlic. Hence the biomass production of onion and garlic can be referred as similar with dry material weight mean of 1.10 and 0.75 respectively. The average biomass of the plants in this study is comparable to that of Zhang *et al.*, (2011). However, a significant difference ($p \leq 0.05$) in dry material weight was revealed between root and shoot of the plants.

The findings showed that the shoot of the plants were carrying larger amount of the dry material weight (M = 1.72, SD = 0.37) compared to the root of the plants (M = 0.12, SD = 0.02). A good hyper accumulator that can be used practically for phytoextraction in the field is characterized by fast growth and higher biomass production (Zhang *et al*., 2011).

Table 3: Mean Comparison of Dry Material Weight (g plant^{-1}) of Onion and Garlic; Root and Shoot

Variables	**Mean**	**SD**	**df**	**t Sig (2 tailed)**	
Onion	1.10	1.01	16	0.91	0.38
Garlic	0.75	0.68			
Root	0.12	0.02	18	-13.82	0.00
Shoot	1.72	0.37			

The accumulation of the heavy metals by the plants' parts in the control treatments was shown in Table 4. Both onion and garlic revealed a somehow similar trend of root > leaf > bulb for Fe and Mn, this further indicates that these heavy metals accumulated in higher concentration at the roots with low transport from roots to shoots; bulb > root > leaf for Cr. Pb in onion and Zn in Garlic showed similar accumulation trend of root > bulb > leaf. Zn in onion and Pb in garlic revealed a similar accumulation trend of root > leaf > bulb.

While no similarity was revealed in Ni accumulation trend between onion's parts (root > bulb > leaf) and garlic's parts (leaf > bulb > root).

Table 4: Average Level of Heavy Metals (mg/Kg) in Vegetables' Part in the Control Treatment

Vegetables Part	Cr	Fe	Mn	Ni	Pb	Zn
			Onion			
Root	$17.45±5.4^{a}$	$5063.60±541.94^{a}$	$53.59±10^{a}$	$3.60±0.48^{a}$	$16.98±1^{.49a}$	$35.06±1.15^{a}$
Bulb	$22.71±3.9^{a}$	$201.73±61.54^{a}$	$15.69±1.28^{b}$	$0.88±0.78^{b}$	$10.10±1.94^{b}$	$3.05±0.52^{c}$
Leaf	$0.18±0.12^{b}$	$226.60±16.00^{a}$	$34.66±2.72^{c}$	$0.40±0.24^{c}$	$7.96±0.37^{c}$	$7.95±0.82^{b}$
			Garlic			
Root	$2.99±0.51^{a}$	$3573.62±136.1^{a}$	$39.50±2.09^{a}$	$0.41±0.38^{a}$	$2.19±1.28^{a}$	$133.10±23.59^{a}$
Bulb	$5.13±0.16^{b}$	$228.50±36.52^{b}$	$14.06±1.13^{b}$	$0.87±0.56^{ab}$	$1.27±0.52^{a}$	$38.00±5.75^{b}$
Leaf	$2.03±0.18^{c}$	$577.14±47.93^{b}$	$24.04±2.10^{c}$	$1.78±0.83^{b}$	$1.68±0.81^{a}$	$12.00±2.62^{c}$

Values are mean ± SD. Mean values in the same column followed by the same superscript letters are not significantly different ($p < 0.05$).

Table 5: Average Level of Heavy Metals (mg/Kg) in Vegetables' Part in the Polluted Treatment

Vegetables Part	Cr	Fe	Mn	Ni	Pb	Zn
			Onion			
Root	$205.95±12.91^{a}$	$4084.70±45.3^{a}$	$36.83±0.67^{a}$	$1.15±0.5^{b}$	$15.78±1.24^{b}$	$63.59±1.24^{a}$
Bulb	$36.39±4.38^{c}$	$291.65±5.22^{c}$	$12.35±1.08^{b}$	$1.93±0.93^{b}$	$13.61±1.31^{b}$	$36.50±1.90^{b}$
Leaf	$72.85±8.85^{b}$	$680.27±34.77^{b}$	$36.07±6.29^{a}$	$2.68±0.83^{a}$	$24.24±3.31^{a}$	$20.36±1.09^{b}$
			Garlic			
Root	$150.18±100.28^{a}$	$3452.54±844.21^{a}$	$14.87±4.06^{a}$	$0.41±0.2^{a}$	$6.78±1.18^{a}$	$65.60±7.71^{a}$
Bulb	$18.91±28.97^{b}$	$373.59±86.02^{b}$	$12.29±3.72^{a}$	$0.58±0.24^{a}$	$20.15±1.48^{c}$	$48.60±6.27^{b}$
Leaf	$36.51±23.56^{b}$	$794.91±203.28^{b}$	$16.44±2.13^{a}$	$0.65±0.37^{a}$	$16.22±0.58^{b}$	$44.54±1.94^{b}$

Values are mean ± SD. Mean values in the same column followed by the same superscript letters are not significantly different ($p < 0.05$).

The similarity in accumulation trend existed in the polluted treatment shown in Table 5 which showed that root > leaf > bulb in accumulation of Cr and Fe; root > bulb > leaf in accumulation of Zn for both onion and garlic. The trend leaf > root > bulb was observed in accumulation of Pb in onion and accumulation of Mn in garlic.

The total accumulation (Fig. 2) shows that garlic is good in accumulating Cr, Mn and Pb while onion is good in accumulating Fe, Ni and Zn and this is in line with the findings of Abdullahi *et al.*, (2008b) that onion was found to accumulate higher level of trace metals (Ni and Zn) above the FAO/WHO and WHO/EU allowed limits.

In all the treatments onion was found to have accumulated more of all the heavy metals with the exception of Zn where garlic accumulated more, this is in line with the findings of Khan *et al.*, (2017) where they showed that garlic has the potential of accumulating higher concentration of Zn.

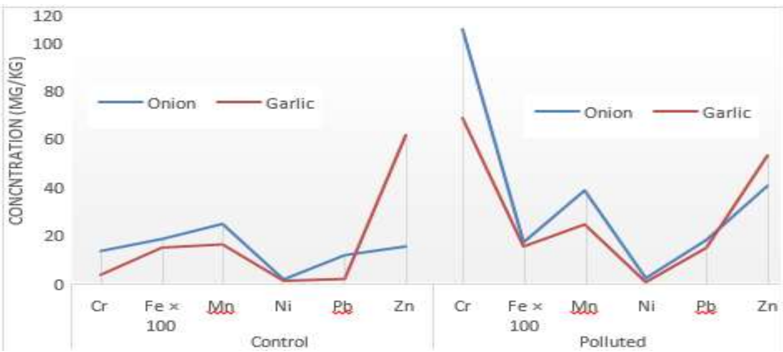

Fig 2: A line diagram showing the total accumulation of the heavy metals by the vegetables in both the control and polluted treatments

Table 6 revealed a significant mean difference in concentrations of Cr and Mn with t values of -9.53 and -4.41 respectively, $p < 0.05$. Findings showed that onion contained higher concentration of Cr (M = 345.69, SD = 17.45) and Mn (M = 23.37, SD = 3.20) compared to their concentrations in garlic (M = 218.71, SD = 15.02) and (M = 15.06, SD = 0.66) respectively. Whereas, there was no significant mean difference observed in the concentration of Fe, Ni, Pb and Zn. It further showed that although onion accumulated higher concentrations of Fe, Ni, Pb (with the exception of Zn) compared to garlic however, the accumulated concentration variation is insignificant. These findings are contrary to the findings of Gaya and Ikechukwu (2016) where they argued that garlic accumulated higher concentrations of Pb and Zn, and that of Audu and Lawal (2006) where they reported that lowest level of Mn and highest levels of Fe, Cu, Zn and Co.

Table 6: Mean comparison of heavy metals' concentration (mg/Kg) in Onion and Garlic

		Onion		Garlic			
Metals	Mean	SD	Mean	SD	df	t	Sig (2 tailed)
Cr	345.69	17.45	218.71	15.02	8	-9.53	0.01
Fe	1653.39	33.77	1381.75	178.39	6	-2.59	0.11
Mn	23.37	3.20	15.06	0.66	6	-4.41	0.04
Ni	1.17	0.85	0.55	0.17	6	-1.24	0.33
Pb	17.72	1.68	14.38	1.06	8	-2.91	0.44
Zn	46.45	7.14	52.91	2.70	8	1.47	0.22

The plants efficiency for phytoextraction were evaluated using two indices; Bio-concentration Factor (BCF) and Translocation Factor (TF) both of which were calculated using a formula. The Bio-concentration factor shows the extent of how plants can accumulate and tolerate heavy metals, the trend of BCF values of the elements for both garlic and onion was Zn > Pb > Cr > Mn > Fe > Ni. In all the BCF of these elements onion superseded garlic except for Zn where the garlic superseded the onion (Fig. 3), this is similar to the findings of Khan *et al.*, (2017) where Zn has the highest BCF. Also, the BCF for Ni and Fe are within the estimations done by Khan *et al.*, (2017). However, bulbs and leaves were used for the bio-concentration factor in the present study.

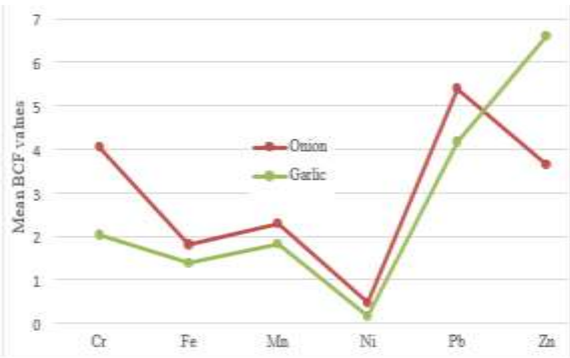

Fig. 3: Mean BCF values f elements in garlic and onion

The BCF values for Ni are generally low for the plants which indicated that the plants had difficulties in mobilizing Ni in the root zone. Furthermore, this result is similar to the field result from Zhuang *et al.*, (2007) where low Pb BCF values were reported for all the plants tested. The mean BCF values of Pb, Cr, Zn, Mn and Fe in onion were generally high > 1, thus, onion can be regarded as potential hyper accumulator of these elements and the mean BCF values of Ni was generally low < 1.

Translocation factor indicates the efficiency of the plants when translocating the accumulated metal from its roots to its shoots (Farraji *et al.*, 2014). The TF ranged from 0.42 Fe to 1.77 Ni. The trends of TF values of the elements were Ni > Pb > Mn > Cr > Zn > Fe. However, the Cr, Ni and Pb TF values in onion were greater than those values in garlic, whereas for Fe, Mn and Zn their TF values in garlic are greater than those in onion (Fig. 4). Conversely, Ni have the highest TF value when compared with its BCF values in the plants. This further indicated that while onion and garlic had difficulties in mobilizing Ni in the root zone, it was easier for them to transport Ni from their roots to their shoots. It can be inferred from figure 6 that only Ni and Pb had their mean TF values greater than 1. According to Yoon *et al.*, (2006), only plant species with TF greater than 1 have the potential to be used for phytoextraction.

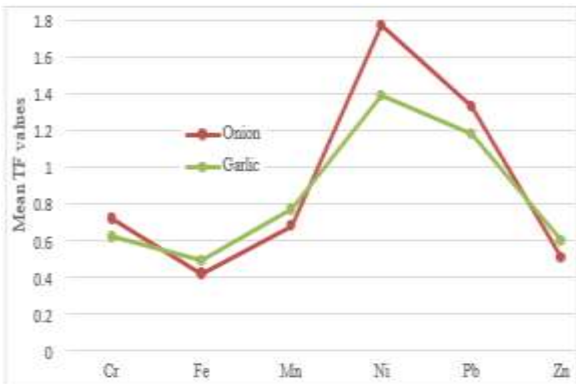

Fig. 4: Mean TF values f elements in garlic and onion

Conclusion: Onion accumulated higher concentrations of all the heavy metals compared to garlic with exception of Zn. However, the differences in heavy metal concentrations where significant only in Cr and Mn. Phytoremediation efficiency indices (BCF and TF) showed a similar trend for both onion and garlic. The mean BCF values of Pb, Cr, Zn, Mn and Fe in onion were generally high > 1. Ni and Pb had their mean TF values greater than 1. Thus, onion could be used as potential phytoextraction plant.

Acknowledgement: The authors appreciate the assistance of Malam Sani Bello of the Biological Garden, UMYU, Katsina; Hajiya Indo S. Bulai of Public Health Laboratory, Civil Engineering Department, ATBU, Bauchi; and Dr. Farouk Hassan of Industrial Chemistry Department, ATBU, Bauchi

REFERENCES

Abdullahi, MS; Uzairu, A; Okunola, OJ (2008a). Determination of some trace metal levels in onion leaves from irrigated farmlands on the bank of River Challawa, Nigeria. *Afr. J. Biotechnol. 7*(10), 1526–1529

Abdullahi, MS; Uzairu, A; Okunola, OJ (2008b). Determination of some trace metal levels in onion leaves from irrigated farmlands on the bank of River Challawa, Nigeria, *African Journal of Biotechnology* 7(10), 1526–1529.

Akan, JC; Abdulrahman, FI; Ayodele, JT; Ogugbuaja, VO (2009). Impact of Tannery and Textile Effluent on the Chemical Characteristics of Challawa River, Kano State, Nigeria. *Australian J. Basic and Appl. Sci. 3*(3), 1933–1947

Alkali, I. (2020). *Assessment of phytoremediation ability and iodine accumulation of some begetables grown on the contaminated soils from Challawa industrial estate Kano, Nigeria*. Umaru Musa Yar'adua University, Katsina.

Alkali1, I; Audu, AA; Khalimullah, S; Suleiman, MD (2022). Phytoremediation Of Heavy Metals Using Spinach (Amarantus Spinosa) Grown On Contaminated Soils. *Afr. J. Environ. Nat. Sci. Res. 5*(1), 1–11.

Audu, AA; Lawal, A; (2006). Variation in Metal Contents of Plants in Vegetable Garden Sites in Kano Metropolis. *J. Appl. Sci. Environ. Manage. 10*(2), 105–109.

Bhargava, A; Carmona, FF; Bhargava, M; Srivastava, S (2012). Approaches for enhanced phytoextraction of heavy metals. *J. Environ. Manage. 105*(2012)

Farraji, H; Abdul Aziz, H; Tajuddin, RM; Mojiri, A (2014). Optimization of Phytoremediation of Lead-contaminated Soil by Spinach (*Spinacia oleracea* L). *Inter. J. Sci. Res. Know. 2*(10), 480–486.

Gaya, UI; Ikechukwu, SA (2016). Heavy metal contamination of selected spices obtained from Nigeria. *J. Appl. Sci. Environ. Manage. 20*(3), 681–688.

Ghosh, M; Singh, SP (2005). A Review on Phytoremediation of Heavy Metals and Utilization of It's by Products. *Asian J. Energy and Environ. 6*(4), 214–231.

Golan-goldhirsh, A. (2006). Plant Tolerance to Heavy Metals: A Risk for Food Toxicity or a Means for Food Fortification with Essential Metals : The Allium Schoenoprasum Model. *Soil and Water Pollute. Monit. Protect. Remed. 3*(23), 479–486.

Hseu, ZY; Jien, SH; Wang, SH; Deng, HW (2013). Using EDDS and NTA for enhanced phytoextraction of Cd by water spinach. *J. Environ. Manage. 117*(2013), 58–64.

Khan, Z. I., Ahmad, K., Akram, N. A., Mehmood, N., & Yasmeen, S. (2017). Heavy Metal Contamination in Water, Soil and a Potential Vegetable Garlic (Allium Sativum L) in Punjab, Pakistan. *Pak. J. Bot.*, *49*(2), 547–552.

Lawal, OA; Audu, AA (2011). Analysis of heavy metals found in vegetables from some cultivated irrigated gardens in the Kano metropolis, Nigeria. *J. Environ. Chem. Ecotoxicol. 3*(6), 142–148.

Leguizamo, AM; Gomez, WDF; Sarmiento, MC (2017). Native herbaceous plant species with potential use in phytoremediation of heavy metals, spotlight on wetlands - A review. *Chemosphere.* 168: 1230–1247.

Nnaji, JC; Okoye, FC (2004). Wastewater aquaculture as a form of environmental pollution control in Nigerian cities. *African Scientist 5*(3), 119–124.

Onyedika, EM; Okon, EE (2014). Bioaccumulation and Mobility of Cadmium (Cd), Lead (Pb) and Zinc (Zn) in Green Spinach Grown on Dumpsite

Soils of Different pH Levels. *Bulletin of Environment, Pharmacology and Life Sci. 4*(1), 85–91.

Sadowsky, MJ (1999). Phytoremediation : past promises and future practises. In *Proceedings of the 8th Inter.national Symposium on Microbial Ecology*. Halifax, Canada.

Yoon J; Cao X; Zhou Q; Ma LQ (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Sci. Total Environ*. 368: 456-464.

Zhang, X; Xia, H; Li, Z; Zhuang, P; Gao, B (2011). Identification of a new potential Cdhyperaccumulator Solanum photeinocarpum by soil seed bank-metal concentration gradient method. *J Hazard. Mat. 189*(1–2), 414–419.

Zhuang, P; Yang, QW; Wang, HB; Shu, WS. (2007). Phytoextraction of Heavy Metals by Eight Plant Species in the Field. *Water Air Soil Pollut*, (184), 235–242