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EFFECT OF BIO-RESIDUES AS HEAVY METAL IMMOBILIZERS IN CUCUMBER AND IRRIGATION WATER AT JAKARA, KANO

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ABSTRACT

Heavy metal contamination is a common problem in areas where industrial effluents are being discharged into the irrigation water. Farmlands along the Jakara River were not exceptions in which high concentrations of heavy metals are reported. This study was intended to evaluate the effect of some selected bio-residues: rice husk, groundnut shell, millet chaff, and sawdust for immobilization of heavy metals on cucumber crops at Jakara irrigated farm. Irrigation water samples were first collected and treated with rice husk and groundnut shell before application to the farm to understand the best treatment material. Similarly, the soil was treated with various quantities of the bio-residues, applied with irrigation water, and allowed for one week to achieve full decomposition of the materials. Thereafter, the cucumber seeds were planted in each treated plot and control plot. The results show that a rice husk of 1.5 g/l is the best bio-residue for water irrigation water treatment. It was found the concentrations of heavy metals in the cucumber yields were reduced by about 34% in the plot treated with 1.5 g/m^2 of rice husk bio-residue. Moreover, both the Soil-to-cucumber Transfer Coefficient and Bio-residual Performance Index revealed that there is a highly significant effect of the application of bio-residual materials in managing the concentration of heavy metals in the cucumber yields.

Keywords: Bio-residual Performance Index, Groundnut Shell, Millet Chaff, Rice Husk, Soil-to-Cucumber Transfer Coefficient

INTRODUCTION

Cucumber consumption has increased in recent years and it now forms an important part of the human diet and nutrition. This is because cucumbers contain important dietary components such as vitamins, protein, minerals, trace elements, and other nutrients (Imam, 2012; Maleki et al., 2014). Another important function of vegetables is to act as a buffer for acidic and some toxic substances produced during digestion. Despite this, nutritional value and consumer acceptance must be considered when considering vegetables as foodstuffs because vegetables can contain both essential and toxic elements in varying concentrations (Abubakar & Yakasai, 2015). As a result, food safety concerns and potential health risks are major public concerns around the world, making it one of the most serious environmental concerns.

Heavy metals are well known to be among the major contaminants of foodstuffs and can be considered one of the most serious problems for human health due to their long biological half-lives, non-biodegradability, and accumulation potential in various organic bodies (Dawaki et al., 2014). Vegetables may become contaminated with heavy metals if grown on soil contaminated by natural or anthropogenic sources such as industrial and agricultural activities. As a result, the consumption of heavy metal-contaminated vegetables may pose a direct threat to human health and is regarded as one of the most critical aspects of food quality (Maleki et al., 2014). Due to increased awareness of the risk that toxic metals pose to food chain contamination, the international and national food quality regulations have lowered their maximum permissible levels of toxic metals in food items. Heavy metal metals in the environment have increased as a result of unorganized urbanization and rapid industrial and agricultural development (Nasidi et al., 2014; Zakari et al., 2020). Heavy metal contamination of soil is common, and it can be a major source of metals to crops, as well as a primary path of human exposure to these potentially toxic metals. Several authors have identified heavy metals as significant contaminants in vegetables. However, bioaccumulation of elements in vegetables is more complicated because plant uptake is affected by climate, soil properties, atmospheric depositions, irrigating water quality, and other factors (Nasidi et al., 2020; Zakari et al., 2017).

Jakara River is one of the growing agricultural areas in the Kano state, Challawa, and Watari Rivers in Kano and its surrounding region. The agricultural activities especially vegetables in the area are increasing despite that warning alert by the management on health issues. Agricultural activities in this area are influenced by polluted irrigation water and increased toxic metals resulting from industrial influents and metal-based pesticides, and transportation (Abubakar & Yakasai, 2015; Imam, 2015). Since crop irrigation is mostly dependent upon surface water, a concern in Jakara agricultural products should be given due attention because of the transfer of toxic metals from vegetables through the food chain to humans. For example, it has been estimated that vegetable consumption contributes up to 70% of the dietary intake of Cd (Nabulo et al., 2010). Adekunle et al., (2009) reported that Pb in vegetables exceeded the recommended values for three cities in Nigeria. 10 Demirezen and Aksoy, 2016 have shown high concentrations of [lead (Pb), cadmium (Cd), and copper (Cu)] in *Abelmoschus esculentus* collected from urban areas of Kayseri, Turkey. Similarly, Maleki and Zarasvand, 2008 observed high concentrations of Pb, Cd, and Cr in sweet basil, parsley, leek, and garden cress collected from peri-urban areas of Sanandaj, Iran. Maleki et al., (2014) have reported heavy metal concentrations to exceed food standards for vegetables grown close to metal smelters. Thus, monitoring and assessment of heavy metal concentrations in the vegetables like cucumber whose irrigation water is coming from urban areas are necessary, especially in developing countries.

Bio-residues have been found effective in managing the concentration of heavy metals in several studies (Adegoke et al., 2022; Demirezen & Aksoy, 2016; Maleki & Zarasvand, 2008). Heavy metals such as lead, zinc, and chromium are used in a wide range of products such as basic steel, paper and pulp, leather tanning, organo-chemicals, petrochemicals, fertilizers, and others. The primary sources of lead pollution are automobiles and battery manufacturers. Zinc and chromium are predominantly used in fertilizers and leather tanning, respectively (Adegoke et al., 2022). However, the application of bio-residual immobilizers such as Rice Husk Ash, Groundnut Shell, and Saw Dung have considerably reduced heavy metal concentrations in both vegetables and irrigation water (Chuah et al., 2005; Joseph et al., 2021). As a result, these low-value agricultural byproducts can be converted into various adsorbents used in heavy metal and dye removal. It has been investigated as a replacement for currently expensive methods of heavy metal removal from foodstuff and water for both domestic and irrigation purposes. Therefore, the present study aimed to determine the effect of bio-residual immobilizers on managing the concentrations of heavy metals in cucumber crops. Similar to other edible vegetables grown at Jakara farms, cucumber fruits are directly consumed by humans which could have serious health issues considering the source of the irrigation water.

METHODOLOGY

Description of the Study Area

This research was carried out at an irrigation farm along the banks of the Jakara, River in Kano and its surrounding region. River Jakara is located between longitude 8°31′ E to 8°45′ E and latitude 12°10′ N to 12°13′ N and is about 481 m (1,580ft) above mean sea level, covering an area of about 150 km^2. The mean total rainfall of the region is ranging from 800 to 1000 mm per year with 80 to 85% of the river's annual discharge in the wet season, with an average temperature of 25o C (Mustapha et al., 2012). The Global Positioning System (GPS) and ground reconnaissance were used to identify and geo-reference the location of the experimental farm. The difference in effluent source into irrigation water guides site selection. Jakara primarily receives domestic effluents, whereas Challawa primarily receives industrial effluents. Kano is located in Nigeria's dry-sub humid agro-ecological zone. Basement complex geology is the dominant geology (Olofin, 1985; KNARDA, 1998). According to the USDA soil taxonomy, the area's dominant soil class is Alfisol, according to Ahmad (2008). Leafy vegetables such as lettuce and spinach are the most commonly irrigated crops in the areas.

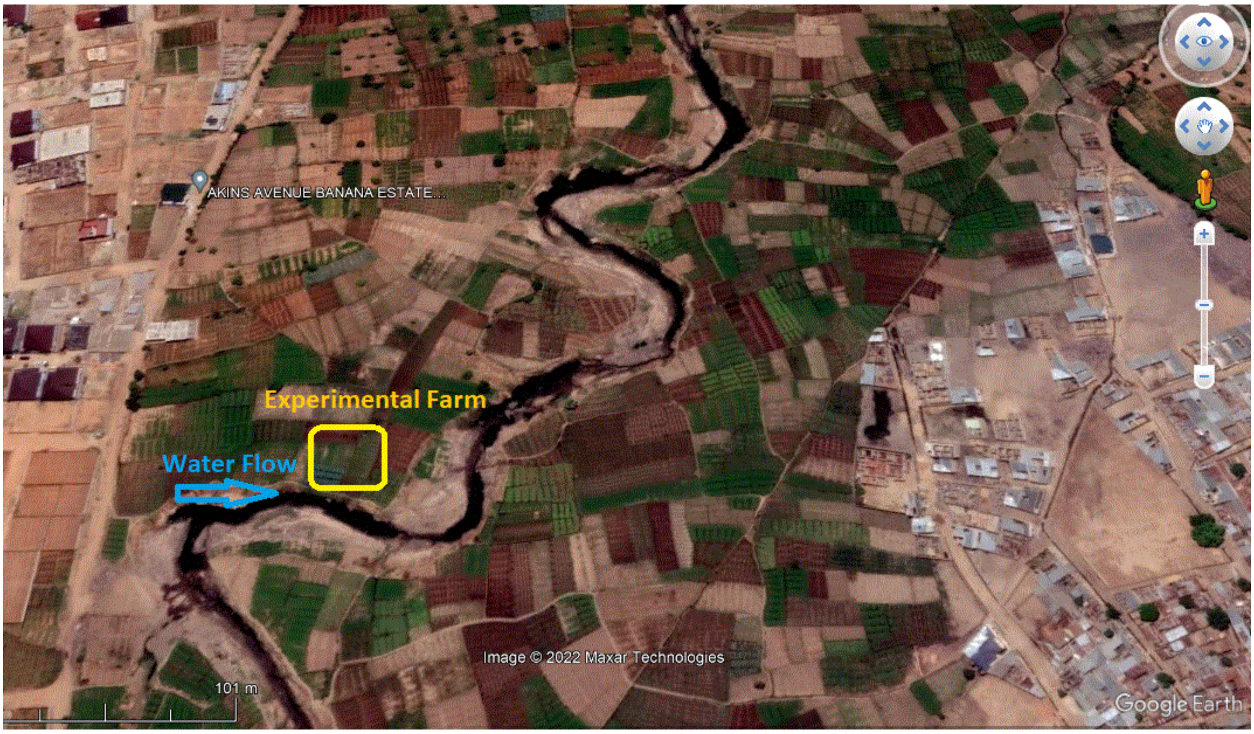

Figure 1: Jakara River showing the experimental farms

Water Samples Collection

The survey was led by the principal investigator and other research team members. During the survey, a physical field observation was conducted, and some farmers were interviewed based on their farming practices and irrigation water use. The farmers revealed there are two sources of water to Jakara River, the wastewater from domestic which includes water from the abattoir, and the water from Bompai areas which is mostly from industries. The farmers comfortably make use of contaminated water to irrigate their crops in the area with their perception of the water is of good quality that the water from tube well and wash bore as it was reported by the farmers. Thus, the total of 27 samples irrigation water were collected from locations of entry to farm and within the farm to ensure actual status of water used for the iiriagation of the cucumber.

Determination of pH, EC, and HM in the Irrigated Water

Concentrations of heavy metals (Pub, MN, Cu, Zn, Fe, Ni, and Cd.), pH, and EC were determined from the irrigation water before the application of treatment using an atomic absorption spectrometer (AAS). The laboratory at the center for Dryland Agriculture, Bayero University Kano was used for this work.

Similarly, the soil and water samples were collected again after the treatment. The analyses to be conducted are the determination of HM, pH, and EC present in the experimental field for both irrigated soil and water. The Electrical conductivity was determined by a conductivity meter immersed in the water samples (Okalebo et al., 2002). Moreover, the pH was determined using a pH meter with a combined glass electrode at a 1:2.5 (soil: water) ratio as described by Carter (1993). The water samples collected for heavy metal determination were obtained by adding 2 mL of concentrated HNO_3 and 5 mL of concentrated HCl to a 100 mL aliquot of the collected water sample. This is to determine the concentration of heavy metals which has been practiced by several researchers (eg. Abubakar & Yakasai, 2015; Dawaki et al., 2014; Maleki et al., 2014). The solution was also covered with a watch glass and heated at 95°C until the volume was reduced to 15 mL before cooling and proceeding with the procedure as prescribed by Imam (2015). Thereafter, the AAS machine was used to estimate the concentrations of Cu, Zn, Fe, Mn, Cd, Ni, and Pb in water filtrate.

Determination of Heavy Metals Concentrations in Cucumber

In this study, the soil samples collected in the field were thoroughly mixed to form a composite sample, which was then oven-dried at 105°C for six hours to achieve constant weight. Following that, the oven-dried samples were ground and sieved through 2.0 mm wire mesh. The AAS was outfitted with a specific lamp made of a specific heavy metal, while the other conditions remained constant as explained by Welz and Sperling (1999). This method have been applied by Dantala et al., (2019) to investigate the concentration of heavy metals in cucumber crop and successful in achieving the targeted objective. Similarly, Garba & Bi, (2022) have recently analyzed the concentration of heavy metal at Sharada using the same approach, and therefore this study adopted it to analyses the concentration of heavy metals in both irrigation water and cucumber crop at Jakara irrigation farm.

Effect of Bio-residual the Immobilizers of Heavy Metals.

The experiment was conducted to evaluate the effect of some selected bio-residues (rice husk, groundnut shell, rice husk, and sawdust) for the immobilization of heavy metals on the cucumber (*market more79*) crop at the Jakara irrigation field. A land area of (15.5 x 13) m^2 was prepared into (1 x 1.5) m^2 basins with 0.5 m buffer zones throughout the basins. The field experiment consists of twenty (20) treatments. The treatments comprised of four bio-residues, rice husk and groundnut shell for water treatments while millet chaff and sawdust for soil treatment. Three levels of bio-residues application (5 g/L, 10 g/L, and 15 g/L) for water were adopted after which the most effective result obtained was used as treated water (T) for irrigating the experimental field, and also three levels for soil application (0.5 kg/m^2, 1.0 kg/m^2 and 1.5 kg/m^2 for sawdust; millet chaff and rice husk respectively). The 20 treatments were replicated three times making a total of sixty (60) experimental runs. The treatments were laid on the field in a split-plot design (Figure 2).

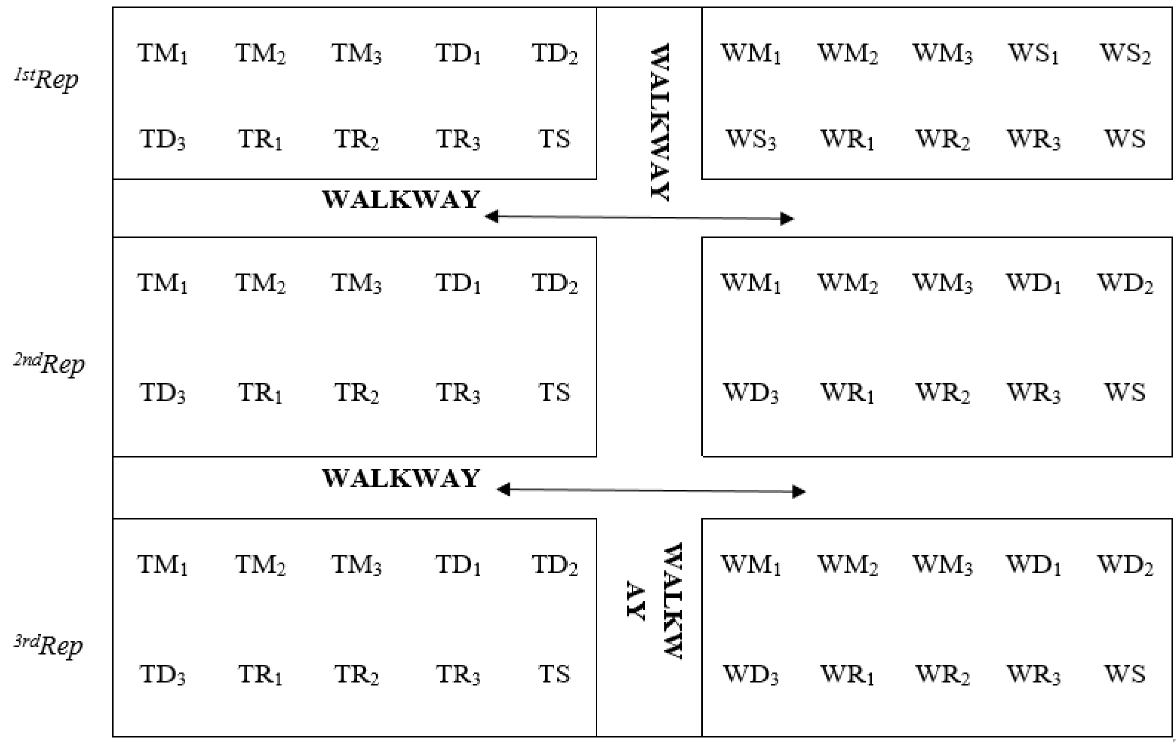

Figure 2: Experimental field layout split plot design

Key: T = Treated water, R_1 = Rice husk at 0.5 kg/m^2, R_2 = Rice husk at 1.0 kg/m^2 and R_3 = Rice husk at 1.5 kg/m^2, M_1 = Millet chaff at 0.5 kg/m^2, M_2 = Millet chaff at 1.0 kg/m^2, M_3 = Millet chaff at 1.5 kg/m^2, D_1 = Saw dust at 1.5 kg/m^2, D_2 = Saw dust at 1.0 kg/m^2 and D_3 = Saw dust at 1.5 kg/m^2, W = untreated water and S = untreated soil.

Agronomical Operation

The experimental field was satisfactorily irrigated before planting and the planting was accomplished after an incubation period of one week for the application of the bio-residues (M, R, and D). Cucumbers (*market more79)* were planted in a row at plant spacing of 60cm between plants and 65cm between rows and the plant population per unit plot is approximately (4) cucumbers and consequently, (240) cucumbers stand for the entire sixty (60) experimental plots. The weed control operation was done whenever the need arises on every plot. The systemic insecticide was provided and applied following the prescription given. All other agronomic operations were fully adopted (Dantala et al., 2021; Nasidi et al., 2021).

Irrigation Water Treatment and Application

The surface irrigation method was adopted throughout the growing periods of the cucumber crop. The irrigation water was pumped from river Jakara and conveyed into the field reservoir tank through a pipe system and eventually serve the basins manually using a calibrated container. A water tank of 1000 liters capacity was brought and installed in the field for treating the raw water. The sourced water was supplied to the tank and the organic materials (Rice husk) were measured and applied to the water for the treatment. On the 3rd of April 2022. The two experimental blocks were irrigated with treated and untreated water respectively. On the same day, the planting was carried out and the agronomic practices of the farmers in the study area were followed. The irrigation was taking place in three days intervals for the block irrigated with treated water and the one irrigated with untreated water. It was noticed that the crop starts germinating about one week after planting. The irrigation continues while the plant is growing, and it was noticed that the grasses are coming out from the plot of soil treated with millet chaff. Irrigation water applications were based on actual crop evapotranspiration (ET_C) and crop coefficient (kc) of cucumber at different growing stages. The volume of water to be applied after treatment was estimated using Equation (1) (Makinde *et al.*, 2016).

$$V = ET_C \times A \times Nd \qquad (1)$$

Where, V= Volume (m^3), ET_C= Actual crop evapotranspiration (mm/day), A= area of plot *= 1 x 1.5 = 1.5m² and Nd. = Number of days.*

Actual crop evapotranspiration was estimated using Equation 2.

$$ET_C = ETo \times K_C \qquad (2)$$

Where: ET_C = actual crop evapotranspiration (mm/day), ET_O = is reference evapotranspiration (mm/day) and kc = is crop coefficient of cucumber was obtained from the literature.

Evaluating the Harvested Cucumber Crop.

The harvested crop was oven dried at 105°C and then kept at 80°C for 72 h. The oven-dried samples were then grounded and sieved through a mesh of 2 mm size and weighed for the analysis of the heavy metals concentration in the crop. The weighed sample (cucumber) was placed into a high-form porcelain crucible, after which the furnace temperature was slowly increased from room temperature to 450º C for 1 h and ash for 12h. The ash sample was then digested following the analytical procedures reported by Sahu and Kacholi's (2016).

Soil to cucumber Transfer Coefficient (%).

The soil-to-cucumber transfer coefficient was calculated as a ratio of a heavy metal in a plant (dry weight) to a total heavy metal concentration in the soil as shown in the following Equation, (3) (David and Minati, 2018).

$$TC = (C_{cucumber}/C_{soil}) \times 100 \qquad (3)$$

Where TC is the transfer coefficient (%), C_{cucumber} is heavy metal concentration in cucumber tissue (mg/100 g), and C_{soil} is metal concentration in soil (mg/100 g dry soil).

Determination of Bio-residual Performance Index

The number of heavy metal ions adsorbed by adsorbent (rice husk, groundnut shell, poultry manure, and sawdust) (P) and efficiency (E) were evaluated using the following equations:

$$P = \frac{(Mo - Me)V}{m} \qquad (4)$$

$$E\% = (Mo\ - Me/Mo) \times 10 \qquad (5)$$

(Jang et al., 1988; Prabha and Udayashankara, 2014).

Where, Mo = Initial concentration of the metal ions in solution (mg/L) Me = Final concentration of the metal ions solution (mg/L) V = solution volume (L), and m = mass of the sorbent (g).

Statistical Techniques

The collected data was subjected to both descriptive and inferential statistics. In this study, Analysis of variance (ANOVA) was used to compare means, and significantly different means were separated using LSD; Pearson moment correlation analysis was also performed to relate soil properties and metal content in the soil, all using the SAS package 9.2. (SAS, 2007). Figure 3 presents the various activities conducted during the field and laboratory procedure. The Irrigation water treatment was conducted right at the beginning of the experiment. Soil treatments with bio-residues were followed and labeled accordingly. thereafter, the matured cucumber Crops were collected for heavy metal analysis after harvesting (Nasidi et al., 2014, 2020).

Figure 3: Research activities, (A) Irrigation water treatment, (B) Soil Treatments with bio-residues, (C) Matured Cucumber Crops in the field, and (D) Samples of Cucumber Yield after harvest.

RESULTS AND DISCUSSION

Analysis of the Irrigation Water

The result of heavy metal analysis in the irrigation water revealed that rice husk performed well and better than all other bio-residues and thus, was selected for treating the water during the experiment. Figure 4 shows the result of water treatment with various levels of heavy metal constituents in the treated water. It can be observed that rice husk outperformed both groundnut shells and control in reducing the concentration of heavy metals in the irrigation water. Almost all the heavy metals tested (Cd, Fe, Cu, Pb, and Mn) were found to be drastically reduced when treated with rice husk at 1.5 kg/l. except in the case of Zn, the concentration was slightly reduced compared with the control plots. However, there is an insignificant decrease in the heavy metal contact under the application of groundnut shells. Moreover, both Zn and Fe contents in the irrigation water were found to increase beyond the control sample. Thus, this study considers the application of rice husk to the irrigation water for treatment during the growing period of the cucumber crop instead of the groundnut shell.

Several studies have been conducted to analyze the concentration heavy metals in the domestic and irrigation water (eg. Abubakar & Yakasai, 2015; Dawaki et al., 2014; Duan et al., 2015). The results have shown figures which are in agreement with the current work. For example, Dawaki et al., (2014) evaluated heavy metals concentration presence in agricultural soil and irrigation water and discovered that the levels were above the recommended by FAO. Similarly, the same analysis was repeated by Abubakar & Yakasai, (2015) at Jakara irrigation farms which they obtained similar results on irrigation water.

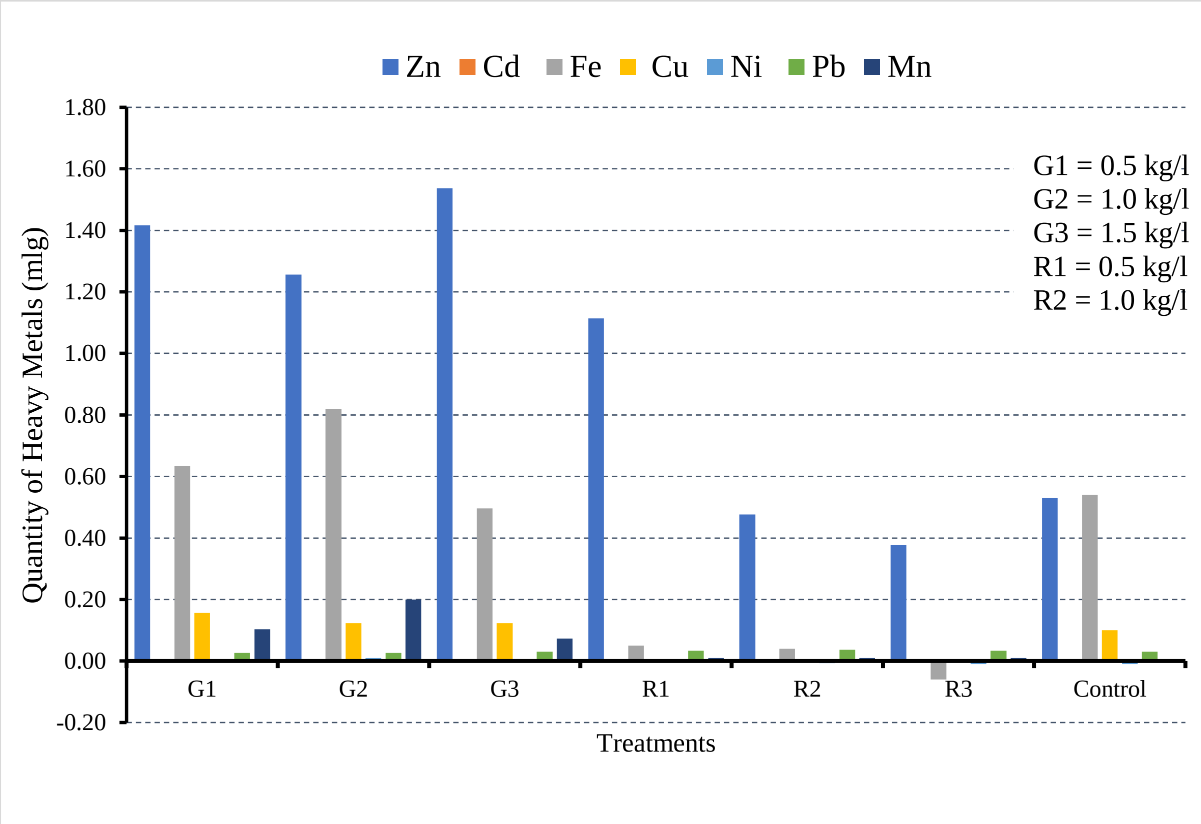

Figure 4: Heavy Metals Present In Water after Treatment with the Bio-residues
Where: G = Groundnut Shell, R = Rice Husk

Analysis of Heavy Metals in the Cucumber Yields

The concentration of heavy metal in the cucumber was tested and found that various levels are corresponding to the type and dosage of bio-reduces used. For example, for the same biomaterial applied, there are variations in heavy metal contents after varying the quantity of the same material. Figure 5 shows three levels of the four bio-residues used in the experiment with their corresponding heavy metals quantities of heavy metals in the cucumber. Rice husk and saw dung were found to reduce more heavy metals than both Millet chaff and groundnut shell. However, all the treatments have resulted into low concentration of the chemicals relative to the control.

This result validated several works that were been conducted on heavy metal concentrations in irrigation water and agricultural soils. The effect of rice husk in reducing the heavy metals concentration has been observed in the work of Abubakar & Yakasai, (2015). Comparable to current study, Fe concentrations were controlled by applying millet chaff in studies conducted by Imam, (2015). Similarly, level of Cu concentration in cucumber crop was reduced by 31% when treated with 1 g/m^2 of groundnut shell by Abubakar & Yakasai, (2015) which corresponds to the outcome of this work. However, the untreated irrigation water in Jakara River has high concentration of heavy metals especially Ni and Mn which negatively affect quality of most crops. Nevertheless, with application of bio-residues immobilizes, the concentration of such metals were considerably reduced. Moreover, Koumolou et al., (2013) evaluated the risk of heavy metals to human health when consuming crops irrigated with water at Benin. The outcome shows indicates a serious danger of potentials diseases which require medical attentions. Thus, it is of great public interest to lower the concentration heavy metals in the irrigation water to avoid outbreak of several diseases.

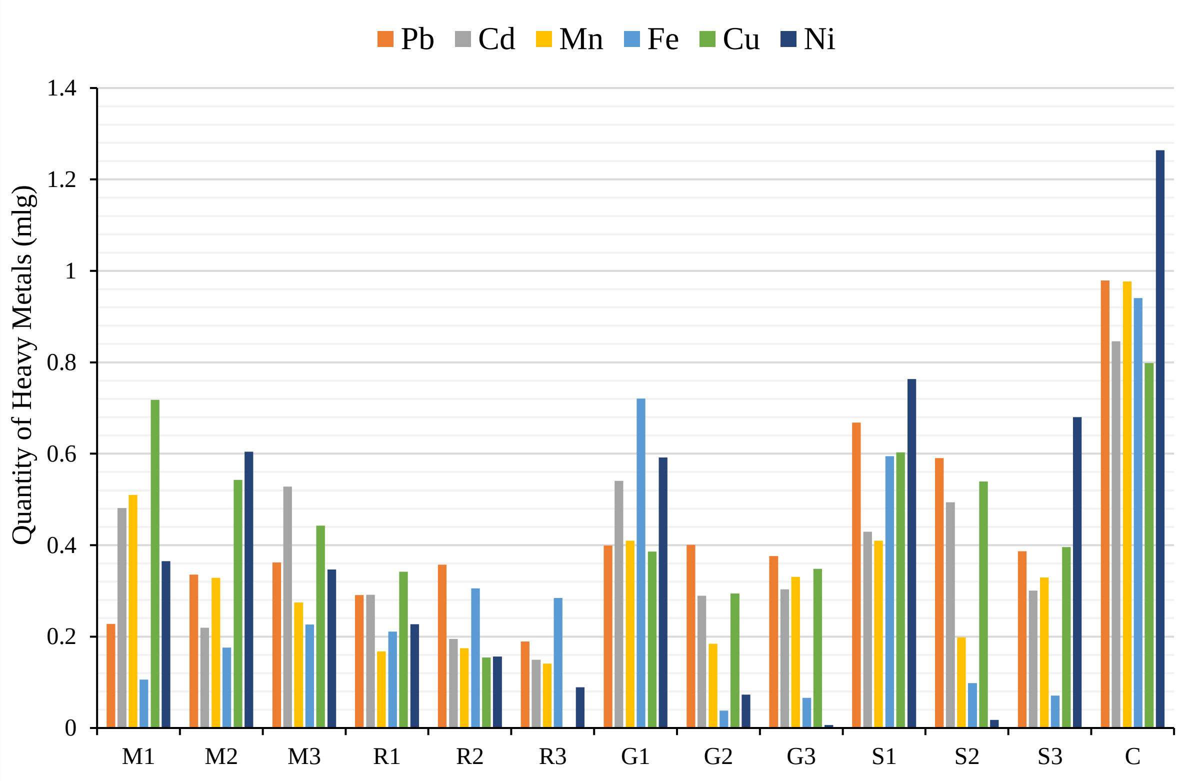

Figure 5: Heavy Metals Contents after Treatment with Bio-Residues

Furthermore, Nasidi et al., (2015) have applied indigenous materials to reclaim degraded soil and improve agricultural production at Barwa Minjibir of Jakara farm. This has shown a clear indication of that, local bio-residues have been supportive to regenerate already damaged soil of contaminated. In addition, effected of the bio-residues have tested by Dawaki et al., (2014) and found capable of reducing the concentration of heavy metals considerably. Another effort made by Adegoke et al., (2022) was recently applied and shows the extent at which those bio-residues immobilized heavy metals from irrigated soils and thereby reduced their hazard drastically. Thus, the findings in the present is in line with current trends and support the production of cucumber at Jakara farm low risk of heavy metals consumption.

CONCLUSION

This study investigates the effect of bio-residues on heavy metals concentration which was conducted on cucumber yields and irrigation water. It was identified that bio-residues are capable of immobilizing the heavy metals in both cucumber crops and irrigation water. Therefore, are recommended for applications in those local areas suffering from heavy metals contamination and abandoned natural biomass. Simply because it will save costs, make use of those materials at the farmers' disposal and save the environment.

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REFERENCES

Abubakar, M. M., & Yakasai, S. M. (2015). Analysis of Heavy Metals in Soil Samples From the Jakara River. *International Journal for Research in Biology & Pharmacy Research*, *2*(2), 11–17.

Adegoke, I. A., Ige, A. R., Adejoba, O. R., Aruwajoye, D. A., & James, J. (2022). Roles of Biomass in the Absorption of Heavy Metals. *European Journal of Energy Research*, *2*(2), 9–13. https://doi.org/10.24018/ejenergy.2022.2.2.47

Adekunle, I., Olorundare, O., & Nwange, C. (2009). Assessments of lead levels and daily intakes from green leafy vegetables of southwest Nigeria. *Nutr Food Sci*, *39*(4), 413–422.

Chuah, T. G., Jumasiah, A., Azni, I., Katayon, S., & Thomas Choong, S. Y. (2005). Rice husk as a potentially low-cost biosorbent for heavy metal and dye removal: an overview. *Desalination*, *175*(3), 305–316. https://doi.org/10.1016/j.desal.2004.10.014

Dantala, M., Babangida, I., Ibrahim, A., Mukhtar, N., Jafar, N., Mohammed, D., Muntaqqa, I., Usman, T., & Ahmad, A. (2019). Effect of rice straw ash on soil properties and yield of cucumber. *Algerian Journal of Engineering*, *00*(2), 34–52. https://doi.org/http://dx.doi.org/10.5281/zenodo.3553067

Dantala, Z. M., Dalhat, H. N., Ohiudi, I. S., Shamsu, S., Ahmadu, S. E., Ibrahim, A., Nasidi, N. M., Shanono, J., & Sabo, A. A. (2021). *Algerian Journal of Engineering and Assessing the farmers ' awareness and practices of irrigation water conservation techniques in Kano – Nigeria*. *05*, 14–18.

Dawaki, U., Dikko, A., Noma, S., & Aliyu, U. (2014). Heavy

Metals and Physicochemical Properties of Soils in Kano Urban Agricultural Lands. *Nigerian Journal of Basic and Applied Sciences*, *21*(3), 239. https://doi.org/10.4314/njbas.v21i3.9

Demirezen, D., & Aksoy, A. (2016). Heavy metal levels in vegetables in turkey are within safe limits for Cu, Zn, Ni AND exceeded FOR Cd AND Pb. *Journal of Food Quality*, *29*(3), 252–265.

Duan, X., Zhang, G., Rong, L., Fang, H., He, D., & Feng, D. (2015). Spatial distribution and environmental factors of catchment-scale soil heavy metal contamination in the dry-hot valley of Upper Red River in southwestern China. *Catena*, *135*, 59–69. https://doi.org/10.1016/j.catena.2015.07.006

Garba, A., & Bi, I. (2022). *Assessment of the Effects of Some Heavy Metals on Biological Properties of Soil around Sharada Industrial Area of Kano , Nigeria*. *3*(5), 17–23.

Imam, T. S. T. (2015). Assessment of Heavy Metals Concentrations in the Surface Water of Bompai-Jakara Drainage Basin, Kano State, Northern Nigeria. *Bayero Journal of Pure and Applied Sciences*, *5*(1), 103 – 108. https://doi.org/10.4314/bajopas.v5i1.19

Joseph, J. A., Lawrence, A. K., & Eunice, Oladipo, O. (2021). Influence of Groundnut and Rice Activated Charcoals Addition on Oil Polluted Soil and Mobility of Heavy Metals in the Root and Shoot of Vigna unguiculata L. Walp in the Tropical Rainforest. *Journal of Experimental Agriculture International*, 6–19. https://doi.org/10.9734/jeai/2021/v43i730709

Koumolou, L., Edorh, P., Montcho, S., Aklikokou, K., Loko, F., Boko, M., & Creppy, E. E. (2013). Health-risk market garden production linked to heavy metals in irrigation water in Benin. *Comptes Rendus - Biologies*, *336*(5–6), 278–283. https://doi.org/10.1016/j.crvi.2013.04.002

Makinde, A.A., Eruola, A.O., Ufoegbune, G.C. and Amori, A. A. (2016). Seasonality and Climatic Period Effects on Cucumber Evapotranspiration and Irrigation Water Requirement. *Agriculture, Applied Tropical Technology, Agricultural*, *21*(3), 112–115.

Maleki, A., Gharibi, F., Alimohammadi, M., Daraei, H., & Zandsalimi, Y. (2014). Concentration levels of heavy metals in irrigation water and vegetables grown in peri-urban areas of Sanandaj , Iran. *J Adv Environ Health Res*, *1*(2), 81–88. https://doi.org/10.22102/jaehr.2013.40129

Maleki, A., & Zarasvand, M. (2008). Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, Iran. *Southeast Asian J Trop Med Public Health*, *39*(2), 335–340.

Nabulo, G., Young, S., & Black, C. (2010). Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils. *Sci Total Environ*, *408*(22), 5338–5351.

Nasidi, N. M., Othman, M. K., Oyebode, M. A., Shanono, N. J., Zakari, M. D., Ibrahim, A., & Shitu, A. (2014). Economic Viability for Reclaiming Irrigated Saline-Sodic Soil using Gypsum as an Amendment at Minjibir Irrigation Scheme, Kano. *Red Sea University Journal of Basic and Applied Science*, *2*(2), 128–133. https://doi.org/10.11648/j.ijema.20140203.11

Nasidi, N. M., Shanono, N. J., Zakari, M. D., Ibrahim, A., & Bello, M. M. (2015). Reclaiming Salt-affected Soil for the Production of Tomato at Barwa-Minjibir Irrigation Scheme , Kano. *1st International Conference on Green Engineering for Sustainable Development, IC-GESD 2015*, 260–261.

Nasidi, N. M., Wayayok, A., Abdullah, A. F., Kassim, M. S. M., & Shanono, N. J. (2021). Spatial variability of soil erodibility in response to different agricultural land use at highland farms. *Basrah Journal of Agricultural Sciences*, *34*(special issue 1), 41–53. https://doi.org/10.37077/25200860.2021.34.SP1.5

Nasidi, N. M., Wayayok, A., Abdullah, F. A., & Kassim, M. S. M. (2020). Vulnerability of Potential Soil Erosion and Risk Assessment at Hilly Farms using InSAR Technology. *Algerian Journal of Engineering*, *02*(2), 44–58. https://doi.org/doi.org/10.5281/zenodo.3841100

Zakari, Audu, I., Jafar Shanono, N., Maina, M., Igbadun, E., Shanono, N., Maina, M. M., Nasidi, N., & Shitu, A. (2017). Yield and Water-Use of Tomato under Deficit-Irrigation and Mulch Practices at Kano River Irrigation Project. *Red Sea University Journal of Basic and Applied Science*, *2*(March), 1858–7658. https://www.researchgate.net/publication/341294605

Zakari, M. D., Audu, I., Igbadun, H. E., Nasidi, N. M., Shanono, N. J., Ibrahim, A., Mohammed, D., Sabo, A. A., Usman, I. M. T., & 1Department. (2020). Effects of Deficit Irrigation and Mulch Practices on Yield and Yield Response Factors of Tomato (Lycopersicon esculentum) at Kano River Irrigation Project (KRIP), Kano-Nigeria. *Bayero Journal of Engineering and Technology (Bjet*, *14*(May), 18.