Review

Heavy metals contamination sources in Kano (Nigeria) and their concentrations along Jakara River and its agricultural produce

Nura ABDULLAHI*[1], Enerst Chukwusoro IGWE[2], Munir Abba DANDAGO[1]

[1] *Department of Food Science and Technology, Kano University of Science and Technology Wudil, Kano State, Nigeria*

[2] *Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*

Corresponding author nurafst@gmail.com

Received 04/04/2021
Accepted 20/05/2021

Abstract

Industrialisation, environmental pollution and poor waste management distress food and environmental safety in Kano. Incessant discharge of untreated effluent and sewage, vehicular release, metal and plastic scraps dumping and processing, local dyeing and tanning, atmospheric deposit and excessive use of agrochemicals continue to contaminate the surrounding soil and surface water with toxic heavy metal (HMs). Violation of environmental regulations and failure of environmental regulatory agencies to actively enforce environmental protection laws exacerbate the situation. Soil, water bodies and food produced within the city are under threat due to the HMs contamination. Consumption of contaminated vegetables is the major route for HMs contamination in humans. The concentration of HMs in the irrigation water and soil along the Jakara river exceeds permissible limits and the water is unsafe for drinking and food production. The vegetables produced along the Jakara river were reported to be contaminated with dangerous levels of HMs. The article reviewed relevant literature and provide an overview of the ideal sources of HMs contaminants in Kano and discussed the extensively on HM contaminations in the Jakara river, surrounding soil, fishes and vegetables produced around the river and its tributary. Recommendations were also provided based on the findings of this research.

Keywords: Kano, Jakara River, Heavy Metals, Vegetable Contamination

INTRODUCTION

Accelerated population growth, industrialisation and poor waste management and environmental pollution control possess a grave challenge to food and environmental safety in many developing countries including Nigeria (Abdullahi and Mohammed, 2020; Christopher *et al.*, 2017). Breach of environmental regulations and failure of environmental regulatory agencies to actively enforce environmental protection laws contributed immensely to the poor quality of surface water in Nigeria (Ighalo and Adeniyi, 2020). Vigorous industrialisation and the incessant release of effluents account for the continuous accumulation of HMs in the environment (Danjuma and Abdulkadir, 2018). Heavy metals are elements with metallic properties and an atomic number >20, atomic weight between 63.545 and 200.5 g and a specific gravity greater than 4 (Mbong et al., 2014; Tangahu *et al.*, 2011). Heavy metals are ubiquitous environmental contaminants found in soil, water and air, they are persistent, can easily contaminate the food chain and causes serious problems to consumers including humans (Ali *et al.*, 2019). The menace of food HMs contamination is a threat to public health and its increasingly becoming a global problem (Abdullahi *et al.*, 2021).

Soil and water bodies in Kano are under threat due to the HMs contamination commonly sourced from industrial wastes and agrochemicals (Christopher *et al.*, 2017). Rivers in Kano are not fit for human consumption and agricultural activities due to HMs contamination from untreated industrial effluents (Shawai *et al.*, 2019). Excessive and indiscriminate use of agricultural inputs also contributed to soil contamination along Jakara river (Abdulkadir *et al.*, 2013). Consumption of vegetables grown in contaminated soil is the major rout for HMs contamination in humans (Habu *et al.*, 2021). The concentration of Cr, Cu, Cd, Zn, Co, Fe, Pb, and Mn in tomatoes, onions and pepper produce in the Kano exceed FAO limits (Bichi and Bello, 2013b). Mohammed and Inuwa (2017) cautioned the use of medicinal plant grown within Kano metropolis due to high pollution index. Abdullahi and Mohammed (2020) and Habu et al (2021) reported that the food products from the Jakara river can be carcinogenic. Despite the foreseeing danger government is very reluctant to take measures that will prevent people from getting contamination through consumption of the foods produced along the river (Sanda *et al.*, 2016).

HMs Pollution Sources in Kano

The HM concentration in Kano irrigation water exceeds permissible limits (Christopher *et al.*, 2017). The ideal sources of pollution to the Jakara river are sewage, industrial waste and agricultural imputes (Mustapha and Aris, 2011b). Wastewater irrigation, agrochemicals and atmospheric deposit stock up the soil around the river with dangerous levels of HMs (Dawaki *et al.*, 2015a). The practice of using urban wastes as compost by urban farmers in Kano (Lewcock, 1995) can be an additional source of HMs to the agricultural soil. The finding of Adamu (2019b) metal uptake by Taraxacum officinale, Ruby's physiologically based extraction test (PBET confirm that the dumpsites around the Jakara river are highly contaminated with dangerous HMs. In addition to chemical contamination, vegetables irrigated with wastewater are also prone to microbiological contamination (Dahiru and Enabulele, 2013).

Excessive land use around the Jakara River accounts for various pollution in the river. Anthropogenic activities around the Jakara River significantly affect the quality of it is water. Household effluent strongly influences the quality of the water by depositing a large quantity of organic contaminants (Mustapha, 2012). Domestic and industrial wastes are discharging into the river without treatment (Ibrahim and Ibrahim, 2017). Local dyeing in some areas of Kano and untreated wastewater from proximate industries are among the prominent sources of heavy metals contamination (Ekevwe and Bartholomew, 2015). Vehicular releases, solid wastes and agrochemicals also contribute to contamination in addition to wastewater (Dawaki *et al.*, 2013). The heavy metals concentration of the irrigation water exceeds the toxic level set by regulation (Dawaki *et al.*, 2015a). The organic pollutant in Jakara River is also alarming, both domestic and industrial wastewater received by the river can deposit organic contaminants (Dawaki *et al.*, 2015; Ekevwe *et al.*, 2018).

Bichi and Bello (2013a) attributed the higher concentration of HMs in Kano streams to the vigorous tanning activities going on in the city and the failure of the tanneries to respect effluent discharge guidelines. Tannery wastes are toxic and can be lethal to aquatic life (Sivakumar *et al.*, 2016). Untreated effluent from tanneries and textile industries are among the leading sources of environmental HMs (Danjuma and Abdulkadir, 2018). Bichi and Dan'Azumi (2010) also reported that the concentrations of Cr, Cu, Pb, and Zn in the effluents discharged by chemical processing companies in Kano exceed the permissible limits recommended by the Federal Environmental Protection Agency of Nigeria (FEPA) and WHO. The concentrations of Cr, Fe, Zn, Cu, Pb were found to be above the standard limits for effluent discharge approved by WHO (Imam, 2012).

Unauthorised dumping of wastes in Kano accounts for more than 66 % of the total wastes dumping, and these wastes emit dangerous contaminants to the city (Nabegu, 2010). Sharfaddeen *et al.* (2020) reported higher concentrations of Zn, Fe, Cr, Co, Rb, Lu, Ta and Th in the soil samples collected around waste dumpsites in Kano city. Used medical wastes, which are mostly plastic, are disposed by pit burning, small-scale incineration, burial or open dumping, toxic chemicals from these wastes can leach into soil and contaminate the environment (Oke, 2008) a report on immunization wastes management in Kano State (Nigeria). Untreated wastewater is associated with an unpleasant odour and provides a conducive breeding ground for highly contagious diseases such as malaria and typhoid (Abdullahi *et al.*, 2016). Ahmed (2020) identified nematodes, flukes, and protozoa parasites in cabbage, carrot, lettuce, onion and tomatoes grown along the Jakara river. The situation is getting worse due to inadequate effluent treatment facilitates, noncompliance with standards, lack of active monitoring and enforcement and ignorance (Bichi, 2013). Consumption of HMs through food can be minimised by effective monitoring and enforcement of environmental laws and the establishment of a workable food safety monitoring system (Abdullahi *et al.*, 2021).

The Jakara River

Jakara River took its name from early historic settlements near Dala hill in Kano city (Agbazue *et al.*, 2015). The river started around Jakara pass through the city and drains into Wasai reservoir which owns significant ecological value (Magaji and Rabiu, 2020). The Getsi tributary which joins the Jakara River at Magami is carrying domestic wastewater and industrial effluent from Bombai industrial area. The wastewater in the Getsi stream is characterised by a high level of metal contaminants (Maconachie, 2008). Different vegetables including tomato, pepper, cabbage, amaranth, garden egg, cauliflower, lettuce, okra, etc. are produced along the river in about 5000 hectares of active agricultural land (Ahmed and Sadau, 2015).

The river is seen by some researchers as a mere source of domestic contaminant and many believe that it carries only organic contaminants. This is far from true as many local activities are injecting effluents with higher concentrations of dangerous chemicals including HMs. Examples, the local dying activity vigorously going on around Kurna and Tudun Bojuwa, the traditional tanneries and dying pits within the old city released their wastewater into the river and the scrap-work around Jakara, Kasuwar Kurmi and Kofarruwa, which include various forms of metal and plastic wastes, E-wastes and used batteries among others. Chukwuma *et al.* (2011) reported HMs contamination in river water close to metal scrap dumpsite. Dangerous levels of Pb and Mn were found in the blood and urine of metalworkers around Jakara (Sani and Abdullahi, 2017) Lead (Pb. DNA damage was also reported by Sani and Abdullahi (2016) in the blood samples of metal workers collected around Jakara.

Mukhtar (2016) reported higher concentrations of Zn, Mn, Pb and Cd in water samples collected from Kwakwaci and Kofarruwa tributaries. Similar values for Cu, Ni, Pb and Cd were reported by Dawaki *et al.* (2014) in soil samples collected from Jakara and Challawa irrigation sites. Concerning vegetable consumption risk, Dawaki *et al.* (2013) ranked Jakara irrigation site as the most riskier source of vegetables in Kano city. Yusuf (2010) reported higher concentrations of Zn, Fe, Mn, Cu, Cd, Cr and Ni in the soil around Jakara than in the soil around streams carrying industrial effluents in the other parts of Kano, he associated that to population density, sewage disposal, traffic and automobile activities. In an ideal situation, there is no way these sources can contribute HMs contamination more than untreated industrial effluents from tanneries, plastic and other chemical processing industries. The findings of Yusuf (2010) support this argument and revealed how dangerous these local chemical processing are. Bichi and Halliru (2010) associated higher concentrations of HMs in the river with the domestic use of synthetic chemicals, human and land use activities, population growth and agrochemicals.

Irrigation Water along Jakara River

Jakara river is used for irrigation, domestic use and fishing (Bichi and Halliru, 2010; Bichi, 2013)2007 and FEPA, 1999 respectively. However, the research findings show that almost all samples reveal lead pollution. The highest value is recorded as 0.86 mg/l at the Industrial discharge point (X4 July. The quality of the water is influenced by many anthropogenic activities (Mustapha, 2013) including urbanisation, industrial activities (Andleeb and Hashmi, 2017), population growth and climate change (Shawai *et al.*, 2019). Pollution sources in the Jakara river are usually anthropogenic during the dry season and natural during the wet season (Mustapha *et al.*, 2012a). Direct dumping of wastewater into the river and its tributaries continue to ruin the quality of the water (Ibrahim and Said, 2010; Mustapha *et al*, 2013). The pH of the water is slightly acid to slightly alkaline depending on the season (Agbazue *et al.*, 2015; Badamasi, 2014). Mukhtar (2016) reported alkaline pH in water samples collected from the Kofarruwa tributary.

Results of the Water Quality Index study conducted by Mustapha and Aris (2011) placed the river water under very bad category and the results of their findings also indicated that the water is unsafe and is not physically, chemically or biologically acceptable for use as raw water for drinking, animal herding, recreational activities and irrigation. Using wastewater for vegetable production along the Jakara River posed a serious risk to the environment and humans (Dawaki *et al.*, 2013). The quality of the water varies along the river. Construction activities including land clearing and some natural processes such as erosion and runoff account for the quality variation of the irrigation water used along the river (Mustapha *et al.*, 2013a). The metal contents of the water and soil around the Jakara River are getting higher due to the discharge of various contaminants into the water body (Sanda *et al.*, 2016).

Irrigation using wastewater elevated the concentration of heavy metals in the soil (Dawaki *et al.*, 2015b). These domestic and industrial toxins are reaching dangerous levels in the irrigation areas (Maconachie, 2008). A positive correlation between water and soil metal concentration along the river was reported by Dawaki and Shu'aibu (2013). These contaminants are passed to the growing vegetables through the soil (Dawaki *et al.*, 2013). Agricultural activities around the river reduce the contamination pressure in the water (Mustapha, 2012). Because it serves as a channel for passing metal contaminants to humans through consumption of the food irrigated with the water. The heavy metals content of vegetables produce along the Jakara River is higher than that produced in other irrigation areas of Kano (Lawal and Audu, 2011).

Odour and colour of the irrigation water change sporadically, this commonly happens during dry season (Binns *et al.*, 2003). Mustapha *et al.* (2012b) and Agbazue *et al.* (2015) reported seasonal variation on the properties and qualities of the irrigation water along the river. The variation in the overall water quality resulted from HMs contamination (Mustapha and Aris, 2012). The concentrations of Cr, Fe, Zn, Cu, Pb in the irrigation water are significantly affected by year season (Imam, 2012). Binns *et al.* (2003) also reported variation in the HMs content in irrigation water samples collected at different times of a day. Badamasi (2014) reported a trivial seasonal variation on Pb and Zn content in water samples collected from the Wasai dam. Mustapha *et al.* (2013b) opined that the variation in the irrigation water quality is due to irrigation agriculture, construction, clearing of land, domestic waste disposal and natural processes such as erosion and runoff. This can be supported by the findings of Razali *et al.* (2020) who also reported that these activities can cause seasonal variation and increase the risk of HMs health implications.

The water in the Jakara river is unsafe for food production due to the higher levels of HMs (Dawaki and Shu'aibu, 2013). The average concentrations of Cd, Cu, Cr, Pb, Fe and Zn in the water exceeded the allowable limits set by WHO (Ekevwe and Bartholomew, 2015). The concentrations of Fe, Cr and Pb also exceeded WHO and SON threshold (Agbazue *et al.*, 2015). Getsi tributary possesses higher concentrations of Cd, Cr, Ni, and Pb (Jamila and Sule, 2020). Tributaries with different chemical compositions are draining into the Jakara river. The effects of confluence on the river water HM concentrations was reported by Binns *et al.* (2003) and Bichi and Halliru (2010).

Continuous wastewater irrigation stock-up soil with dangerous HMs, this is a threat to the safety of underground water since the metal can infiltrate and contaminate groundwater (Rehman *et al.*, 2019). Sa'eed and Mahmoud (2014) reported a dangerous level of Pb in a borehole water sample collected around Kwarin Gogau. Shawai *et al.* (2017) associated the higher concentration of HMs in the groundwater samples collected from Gezewa Local Government to its closeness to Wasai dam which receives wastewater from the Jakara river.

The soil around Jakara River

Contamination of soil, water and produce from urban farms by domestic and industrial toxins is attaining hazardously high levels in Kano city (Binns *et al.*, 2003). Pollution index between 5.2 and 9.3 was reported by Inuwa and Mohammed (2018). The soil along the river was characterised by low fertility (with organic matter content of 3.22 % around Hajj Camp) due to massive agricultural activities taking place year-round (Adamu and Dawaki, 2008). A slight increase in the organic matter content was reported twelve years later by Abubakar *et al.* (2020). In contrast, Abdulkadir *et al.* (2013) reported positive nutrients balances in Kano urban and peri-urban agricultural systems. Farming activities around the river involve the use of both inorganic (NPK and urea) and organic fertilizer (Abdullahi *et al.*, 2020). The excessive use of both fertilizer and manure influences soil HMs content (Massoud *et al.*, 2019). Sawut *et al.* (2018) reported livestock keeping among the major anthropogenic activities causes vegetable HMs contamination.

Bioavailability of HMs depends on soil pH (Zhou *et al.*, 2019), low soil pH and higher organic matter content favoured HMs uptake by crops (Eid *et al.*, 2020; Hou *et al.*, 2019; Hu *et al.*, 2017; Liu *et al.*, 2020; Ouyang *et al.*, 2020). Alkaline pH lowers HMs solubility (Świątek *et al.*, 2019), therefore, alkaline soil retains HMs and prevents their uptake by plants (Hamid *et al.*, 2019; Martínez-Cortijo and Ruiz-Canales, 2018). The pH of the soil around the river is slightly acidic to slightly alkaline (Adamu, 2019b). The soils around Akija, Airport Road and Magami are slightly alkaline with medium to high organic carbon (Dawaki *et al.*, 2014). This can justify the lower contaminations reported by Mansur and Garba (2010) in these areas. The soil around the Kofarruwa tributary it's also slightly alkaline with low organic matter (Mukhtar and Samndi, 2016). The soil condition around the river will depress HMs uptake by the crops.

The soil HMs concentration along the river is a function of year season (Mohammed and Olowolafe, 2020). Imam (2012)B, C, D, E, and F. Acid-washed (1L reported effects of seasons on the accumulation pattern of HMs, a higher concentration of Zn was reported during the dry season and a higher concentration of Fe was found during the wet season. Data reported by Dawaki *et al.* (2015) showed a downstream decrease in Pb, Cd, Cu, Ni and Zn concentrations in soil samples collected during dry season. The concentration of HMs in lettuce, spinach (Dike and Odunze, 2016), okra, tomato and onion (Lawal and Audu, 2011) produced along the river is determined by the growing season. Mohammed and Olowolafe (2020) attributed seasonal variation in the soil HMs content to the leaching, run-off and dissolution that commonly occur during rainy season. The uptake of HMs by plants depends on the plant physiology and the concentration of HMs in the growing soil (Mohammed and Inuwa, 2017). Different plants have different HM accumulation capacities, leafy foods accumulate more metals than tuber crops (Babandi *et al.*, 2012).

The HM contents of the soil along the river exceed international permissible limits (Dike and Odunze, 2016). The findings of Haruna *et al.* (2011) confirmed that continuous irrigation with wastewater increases the soil HMs content. The Pb and Cd in the soil around the river are highly mobile and readily available for plant uptake (Y. A. Adamu, 2019b). The soil along the river is severely polluted with Pb, Cd and Cr (Dawaki and Shu'aibu, 2013). Samples of soil and spinach recently collected around Kwakwachi found to contain metals in the following order Ni>Cd>Pb>Zn>Cu>Cr (Abdullahi and Mohammed, 2020).

The data in most published papers are deficient in some vital information that will assist readers in understanding the trends of metal accumulation along the river, for an instant, sampling time and date were not reported by many researchers, even sampling locations were not fully defined in some publications. These account for un-unanimous data with many irregularities and without any specific pattern. Data reported in the same year from samples collected from nearby locations reported with very wide variations, examples, the wide variations reported by Mansur and Garba (2010) and Yusuf (2010) on the concentrations of Cd and Cu in soil samples.

Adamu (2019a) recommended a phytoremediation technique for the removal of Pb, Cd and Cr from the agricultural soil around the Jakara river using Lantana camara and Nerium oleander. Suleiman *et al.*, (2020) reported that untreated rice husk can effectively absorb Cr from tannery effluent when its pH adjusted to 4.

Foods Contamination along the River

Irrigation with wastewater contaminates growing crops and humans through the consumption of the contaminated crops (Danjuma and Abdulkadir, 2018). The vegetables produced along the river were found to be contaminated with HMs, severe contamination was found in cabbage, lettuce, okra, spinach and pepper (Doka *et al.*, 2020). Onion irrigated with river water contains number of organic contaminants (Ekevwe *et al.*, 2017). The lettuce produces along the river contains Pb, Cd and Cr above FAO/WHO permissible limits (Dawaki and Shu'aibu, 2013). Spinach produced along the river is severely contaminated with Pb and Ni (Abdullahi and Mohammed, 2020). Spinach, okra, onions and tomatoes grown along the Jakara river possess higher concentrations of Co, Cu, Zn and Cr (Lawal and Audu, 2011). The onion produced along the river is characterised by higher bioaccumulation capacity and pollution index above 1 (Habu *et al.*, 2021).

The fluctuation of the physicochemical parameters along the river affects zooplankton abundance and richness (Imam and Balarabe, 2012). Zooplanktons are essential food for fishes and their presence in water control algae and bacterial abundances (Mustapha, 2008). Contaminated industrial effluent from Bompai destroys the zooplanktons and lower the species richness and organism's density (Imam *et al.*, 2011). This affects the life of aquatic organisms including fishes (Imam *et al.*, 2010). Tannery effluent with high Cr content can affect oxygen consumption and bioaccumulation in fishes and can deposit large amounts of Cr at the gills (Sivakumar *et al.*, 2016). Higher concentrations of Zn, Cu, Fe, Cr and Pb were found in fish samples collected from Wasai Dam (Agbazue *et al.*, 2015). Tilapia obtained from the Jakara river has Pb content above the permissible limit (Ibrahim and Said, 2010). Sani *et al.* (2020) also reported that Kano abattoir effluent alters the river water pH and dissolved oxygen content and these changes are toxic to the blood, gills and liver tissue of *Clarias gariepinus*.

Recommendations

• Genuine and sincere enforcement of environmental protection laws is necessary to protect human lives and ensure the safety of food produced by urban agriculture. The existing environmental laws need to be reviewed, and more should be enacted to effectively protect soil and surface water meant for irrigation in Kano.

• There is a need for massive collaborative research between agricultural scientists, health specialists and urban planners to tackle the foreseeing challenge on safety and sustainability of urban and peri-urban food production in Kano.

• Public enlightenment and adequate treatment of wastewater before use for irrigation purposes will reduce HMs food crops contamination

• There is a need for Kano State Government to establish a wastewater management agency.

• Provision of alternative farmlands for vegetable production in the city, use of soil management practices that hinders HMs uptake and production of HMs-tolerant vegetable species will certainly minimise HMs consumption through foods.

CONCLUSION

The menace of food HMs contamination is a threat to public health and its increasingly becoming a global problem. Contaminated soil in cities can pose a health risk to urban dwellers. People living in urban areas are at risk of been contaminated by heavy metals through the ingestion of contaminated food and water. Consumption of contaminated vegetables is the major route for HMs contamination in humans. The article reviewed relevant literature and provide an overview of the ideal sources of HMs contaminants in Kano and discussed extensively on HM contaminations in the Jakara river, surrounding soil, fishes and vegetables produced along the river and its tributaries. Most of the processing industries in Kano do not have adequate effluent treatment facilities, hence, compliance with regulations becomes a problem to them. The activity of enforcement agencies is also surrounded by many questionable attitudes. Vigorous industrialisation and the incessant release of effluents account for the continuous accumulation of HMs along the Jakara river. The HM contents of the water and the soil along the river exceeds international permissible limits and continues irrigation with the wastewater increases the soil HMs content. The water in the Jakara river is unsafe for drinking and food production. The vegetables produced along the Jakara river were reported to be contaminated with dangerous levels of HMs.

REFERENCE

Abdulkadir A., Leffelaar P.A., Agbenin J.O., and Giller K.E. (2013). Nutrient Flows and Balances in Urban and Peri-urban Agroecosystems of Kano, Nigeria. *Nutrient Cycling in Agroecosystems,* 95: 231–254.

Abdullahi A.H., Kibon A.U., Tasi'u Y.R., and Mallam I. (2016). An Analysis of the Environmental and Health Implications of Wastewater Discharge in Kano Metropolis, Nigeria. *Biological and Environmental Sciences Journal for the Tropics,* 13: 81–90.

Abdullahi A.S., Kwaru A.H., Adamu K.U., and Sule I.D. (2020). Usage and Effectiveness of Fertility Enhancement Techniques among Small-Holder Farmers in the Kano Close Settled Zone, Kano State. FUDMA. *Journal of Sciences*, 4: 69–75.

Abdullahi N., Igwe E.C., and Dandago M.A. (2021). Heavy metals contamination through consumption of contaminated food crops. *Moroccan Journal of Agricultural Sciences,* 2: 52–60.

Abdullahi Y.A., and Mohammed M.A. (2020). Speciation, Bioavailability and Human Health Risk of Heavy Metals in Soil and Spinach (*Amaranthus* spp.) in Kano Metropolis, Northwestern-Nigeria. *ChemSearch Journal,* 11: 35–43.

Abubakar M.A., Dawaki M.U., and Ogbe V.B. (2020). Using Soil Depth Functions to Display Profile Organic Carbon Content along three Rivers in Nigeria. *Agricultural Research Journal,* 57:31.

Adamu G.K., and Dawaki M.U. (2008). Fertility Status of Soils under Irrigation along the Jakara Stream in Metropolitan Kano. *Bayero Journal of Pure and Applied Sciences,* 1: 67–70.

Adamu Y.A. (2019a). Accumulation of Lead, Cadmium and Chromium by *Lantana camara* and *Nerium oleande. Dutse Journal of Pure and Applied Sciences,* 5: 79–85.

Adamu Y.A. (2019b). Relationship of Soil Properties to Fractionation and Mobility of Lead and Cadmium in Soil. *Dutse Journal of Pure and Applied Sciences,* 5: 215–222.

Agbazue V.E., Ekere N.R., and Samira M.I. (2015). Physico-Chemical Parameters and Heavy Metal Levels in Water and Fish Samples from River Jakara and Jakara dam, Kano State, Nigeria. *Asian Journal of Chemistry*, 27: 3794–3798.

Ahmed U.A. (2020). Effect of Indiscriminate Defaecation and Disposal of Faecal Material on Peri-Urban Cultivated Crops Potentials to Expose Parasites to Community. *Central Asian Journal of Environmental Science and Technology Innovation*, 3: 130–133.

Ahmed U.A., and Sadau M.A. (2015). Vegetable Crops of Peri–Urban Farms along Jakara River and Associated Insect Pests. *Academic Conference of African Scholar Publications & Research International on Indiscipline Approaches*, 6: 1–5.

Ali H., Khan E., and Ilahi I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. *Journal of Chemistry,* 6730305.

Andleeb K.B., and Hashmi I. (2017). Effects of Selective Meteorological Parameters on Water Quality of Wastewater Treatment Systems. *Pakistan Journal of Meteorology*, 14: 13–23.

Babandi A., Atiku M.K., Alhassan A.J., Ibrahim A., and Shehu D. (2012). Level of Heavy Metals in Soil and some Vegetables Irrigated with Industrial Waste Water around Sharada Industrial Area, Kano, Nigeria. *Chemsearch Journal,* 3: 34–38.

Badamasi I. (2014). Distribution of Stomach Food Content of Fish Species Collected from Industrial Waste Water Effluents a Case Study of Jakara Dam, Kano, Nigeria. *International Journal of Innovation, Management and Technology*, 5: 124–129.

Bichi A.A., and Halliru S.L. (2010). Determination of Heavy Metals along River Jakara in Urban Kano and their Health Implication; For Sustainable Development in Nigeria. *International Conference on Chemical, Biological and Environmental Engineering*, 220–224.

Bichi M.H. (2013). Management of Industrial Effluents: A Review of the Experiences in Kano, Northern Nigeria. *International Journal of Advanced Research*, 1: 213–216.

Bichi M.H., and Bello U.F. (2013a). Heavy Metal Pollution in Surface and Ground Waters Used for Irrigation along River Tatsawarki in the Kano, Nigeria. *IOSR Journal of Engineering,* 3: 01–09.

Bichi M.H., and Bello U.F. (2013b). Heavy Metals in Irrigated Crops along Tatsawarki River in Kano, Nigeria. *International Journal of Modern Engineering Research*, 3: 2382–2388.

Bichi M.H., and Dan'Azumi S. (2010). Industrial Pollution and Heavy Metals Profile of Challawa River in Kano, Nigeria. *Journal of Applied Sciences in Environmental Sanitation,* 5: 23–29.

Binns J.A., Maconachie R.A., and Tanko A.I. (2003). Water, Land and Health in Urban and Peri-urban Food Production: The Case of Kano, Nigeria. *Land Degradation and Development*, 14: 431–444.

Christopher I.K.L., Chukwuemeka N.H., and Silas T.V. (2017). The Unsafe Regions and Health Implications of the Deposition of Heavy Metals in Nigeria 'A Systematic Review Focusing on Lead and Cadmium.' *Health Sciences Research*, 4: 29–40.

Chukwuma C.C., Joseph E.E., Adagadzu K.J., and Okorie I.A. (2011). Seasonal Variations of Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb) Concentrations in Selected Surface Waters of Enugu State of Nigeria. *International Journal of Biosciences,* 1: 86–93.

Dahiru M., and Enabulele O.I. (2013). Potentials of Flies in the Transmission of Escherichia coli 0157:H7 and other Enteric Bacteria associated with Wastewater. *International Journal of Science, Environment, and Technology*, 2: 826–838.

Danjuma M.S., and Abdulkadir B. (2018). An Overview of Heavy Metal Contamination of Water and its Effect on Human Health. *UMYU Journal of Microbiology Research*, 3: 44–49.

Dawaki M.U., Dikko A.U., Noma S.S., and Aliyu U.A. (2013). Pollution as a threat factor to urban food security in metropolitan Kano, Nigeria. *Food and Energy Security,* 2: 20–33.

Dawaki M.U., and Shu'aibu A.U. (2013). Lettuce (*Latuca sativa* L.) Along The Jakara Valley in Metropolitan Kano, Nigeria: Potentials And Threats. International Conference on Drylands, 232–241.

Dawaki U., Dikko A., Noma S., and Aliyu U. (2015). Effects of Wastewater Irrigation on Quality of Urban Soils in Kano, Nigeria. *International Journal of Plant & Soil Science*, 4:312–325.

Dawaki UM, Dikko A., Noma S., and Aliyu U. (2014). Heavy Metals and Physicochemical Properties of Soils in Kano Urban Agricultural Lands. *Nigerian Journal of Basic and Applied Sciences,* 21: 239–246.

Dike N.I., and Odunze A.C. (2016). Elemental Contents of Spinach and Lettuce from Irrigated Gardens in Kano, Nigeria. *Environment and Pollution*, 5: 73.

Doka M.G., Tasiu N., Aloba I., Abdullahi S.I., and Yau D. (2020). Comparative Analysis of Potentially Toxic Elements in the Soils and some Vegetables Collected from Wastewater and River water Irrigated Areas in Kano city and Bichi town, Kano State, Nigeria. *World Journal of Advanced Research and Reviews,* 7: 63–74.

Eid E.M., Shaltout K.H., Alamri S.A.M., Sewelam N.A., and Galal T.M. (2020). Uptake Prediction of Ten Heavy Metals by *Corchorus olitorius* L. Cultivated in Soil Mixed with Sewage Sludge. *Food and Energy Security*, 9: 1–13.

Ekevwe A., Aloba I., and Doka G.M. (2017). Proximate Evaluation of Organic Pollutants in Onion Plants Cultivated Along the Bank of River Jakara Kano State of Nigeria. *Advances in Biochemistry*, 5: 41–46.

Ekevwe A.E., and Bartholomew G.M. (2015). Quantitative Investigation of Heavy Metals in Water Samples of River Jakara in Kano State of Nigeria. *International Journal of Innovation in Science and Mathematics*, 3: 257–259.

Ekevwe A.E., Isaac1 A., Bartholomew G., and Aroh A.O. (2018). Review of Organic Pollutants in Wastewater along the Course of River Gwagwarwa and River Rafin Malam in Kano State-Nigeria. *Journal of Biotechnology and Bioengineering,* 2: 36.

Habu M.A., Bawa U., and Musa S.I. (2021). Health Risk Assessment and Heavy Metal Bioaccumulation in Vegetables Irrigated with Waste Water in Kano State , Nigeria. *Notulae Scientia Biologicae Journal*, 13: 1–8.

Hamid Y., Tang L., Sohail M.I., Cao X., Hussain B., Aziz M.Z., Usman M., He Z. li, and Yang X. (2019). An Explanation of Soil Amendments to Reduce Cadmium Phytoavailability and Transfer to Food Chain. *Science of the Total Environment,* 660: 80–96.

Haruna A., Uzairu A., and Harrison G.F.S. (2011). Chemical Fractionation of Trace Metals in Sewage Water-Irrigated Soils. *International Journal of Environmental Research*, 5: 733–744.

Hou S., Zheng N., Tang L., Ji X., and Li Y. (2019). Effect of Soil pH and Organic Matter Content on Heavy Metals Availability in Maize (*Zea mays* L.) Rhizospheric Soil of Non-Ferrous Metals Smelting Area. *Environmental Monitoring and Assessment,* 191: 1–10.

Hu W., Huang B., Tian K., Holm P.E., and Zhang Y. (2017). Heavy Metals in Intensive Greenhouse Vegetable Production Systems along Yellow Sea of China: Levels, Transfer and Health Risk. *Chemosphere,* 167: 82–90.

Ibrahim S., and Ibrahim A.A. (2017). Assessing the Water Quality of Jakara Dam, Kano-Nigeria By the Use of Macronivertebrates. *International Journal of Applied Biological Research*, 8: 123–132.

Ibrahim S., and Sa'id H. (2010). Heavy Metals Load in Tilapia Species: A Case Study of Jakara River and Kusalla Dam, Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 3: 87–90.

Ighalo J.O., and Adeniyi A.G. (2020). A Comprehensive Review of Water Quality Monitoring and Assessment in Nigeria. *Chemosphere*, 260: 127569.

Imam T., Balarabe M., and Oyeyi T. (2011). Spatial and Temporal Variation of Zooplanktonic Fauna Composition and Distribution in the Jakara-Getsi River System, Kano, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 4: 45–52.

Imam T.S. (2012). 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: 103–108.

Imam T.S., Bala U., Balarabe M.L., and Oyeyi T.I. (2010). Length-Weight Relationship and Condition Factor of Four Fish Species from Wasai Reservoir in Kano , Nigeria. *African Journal of General Agriculture*, 6: 125–130.

Imam T.S., and Balarabe M.L. (2012). Impact of Physicochemical Factors on Zooplankton Species Richness and Abundance in Bompai-Jakara Catchment Basin, Kano State, Northern Nigeria. *Bayero Journal of Pure and Applied Sciences,* 5: 34–40.

Inuwa Y., and Mohammed M. (2018). Assessment of Metals Pollution in some Herbs From Kano Metropolis. *Nigerian Research Journal of Chemical Sciences*, 4: 149–161.

Jamila T.S., and Sule S.Y. (2020). Assessments of Quality Index of River Getsi Irrigation Water in Kano Metropolis, Nigeria. *International Research Journal of Pure and Applied Chemistry*, 21: 8–16.

Lawal A.O., and Audu A.A. (2011). Analysis of Heavy Metals Found in Vegetables from some Cultivated Irrigated Gardens in the Kano Metropolis, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, 3:142–148.

Lewcock C. (1995). Farmer use of urban waste in Kano. *Habitat International,* 19: 225–234.

Liu P., Hu W., Tian K., Huang B., Zhao Y., Wang X., Zhou Y., Shi B., Kwon B.O., Choi K., Ryu J., Chen Y., Wang T., and Khim J.S. (2020). Accumulation and Ecological Risk of Heavy Metals in Soils along the Coastal areas of the Bohai Sea and the Yellow Sea: A Comparative Study of China and South Korea. *Environment International*, 137: 1–12.

Maconachie R. (2008). Surface Water Quality and Periurban Food Production in Kano, Nigeria. *Urban Agriculture Magazine*, 20: 22–24.

Magaji A.S., and Rabiu S. (2020). Birds of Wasai Reservoir, Minjibir , Kano - Nigeria. *Science World Journal*, 15: 19–25.

Mansur U.D., and Garba K.A. (2010). Effects of Some Heavy Metal Pollutants on Fertility Characteristics of an Irrigated Savannah Alfisol. *Bayero Journal of Pure and Applied Sciences*, 3: 255–259.

Martínez-Cortijo J., and Ruiz-Canales A. (2018). Effect of Heavy Metals on Rice Irrigated Fields with Waste Water in High pH Mediterranean Soils: The Particular Case of the Valencia Area in Spain. *Agricultural Water Management*, 210: 108–123.

Massoud R., Hadiani M.R., Hamzehlou P., and Khosravi-Darani K. (2019). Bioremediation of Heavy Metals in Food Industry: Application of Saccharomyces cerevisiae. *Electronic Journal of Biotechnology,* 37: 56–60.

Mbong E.O., Akpan E.E., and Osu S.R. (2014). Soil-Plant Heavy Metal Relations and Transfer Factor Index of Habitats Densely Distributed with *Citrus reticulata* (tangerine). *Journal of Research in Environmental Science and Toxicology,* 3: 61–65.

Mohammed M.A., and Olowolafe E.A. (2020). Distribution of Heavy Metals, Soil Microbial Enzymes and their Relationship in Kano, Northwestern Nigeria. *Jurnal Geografi Lingkungan Tropik,* 4: 103–115.

Mohammed M.I., and Inuwa Y. (2017). Assessment of Metals Pollution in some Herbs from Kano Metropolis. *Bayero Journal of Pure and Applied Sciences,* 10: 356–361.

Mukhtar A.A. (2016). Wastewater Qualities used for Urban Agriculture in Metropolitan Kano, Kano State, Nigeria. *Production Agriculture and Technology*, 12: 99–107.

Mukhtar A.A., and Samndi A.M. (2016). Properties and Classification of Urban Agricultural Soils along River Kofar Ruwa in Kano Metropolis, Nigeria. *Production Agriculture and Technology,* 12: 87–98.

Mustapha A. (2012). Identification of Anthropogenic Influences on Water Quality of Jakara River, Northwestern Nigeria. *Journal of Applied Science in Environmental Sanitation*, 7: 11–20.

Mustapha A. (2013). Detecting Surface Water Quality Trends using Mann-Kendall Tests and Sen's Slope Estimates. International Journal of Agriculture *Innovations and Research*, 1: 108–114.

Mustapha A. (2008). Spatial Variation of Zooplankton Abundance and Distribution in a Highly Eutrophic Dry Land River Channel. *International Conference on Drylands*, 180–187.

Mustapha A., and Aris A.Z. (2011a). Application of Water Quality Index Method in Water Quality Assessment. *Elixir Pollution*, 33: 2264–2267.

Mustapha A., and Aris A.Z. (2011b). Spatial Aspect of Surface Water Quality using Chemometric Analysis. *Journal of Applied Sciences in Environmental Sanitation,* 6: 411–426.

Mustapha A., and Aris A.Z. (2012). Multivariate Statistical Analysis and Environmental Modeling of Heavy Metals Pollution By Industries. *Polish Journal of Environmental Studies,* 21: 1359–1367.

Mustapha A., Aris A.Z., Juahir H., and Ramli M.F. (2013). Surface Water Quality Contamination Source Apportionment and Physicochemical Characterization at the Upper Section of the Jakara Basin, Nigeria. *Arabian Journal of Geosciences*, 6:4903–4915.

Mustapha A., Aris A.Z., Juahir H., Ramli M.F., and Kura N.U. (2013a). River Water Quality Assessment using Environmentric Techniques: Case Study of Jakara River Basin. *Environmental Science and Pollution Research*, 20: 5630–5644.

Mustapha A., Aris A.Z., Juahir H., Ramli M.F., and Kura N.U. (2013b). River Water Quality Assessment using Environmentric Techniques: Case Study of Jakara River Basin. *Environmental Science and Pollution Research*, 20: 5630–5644.

Mustapha A., Aris A.Z., Ramli M.F., and Juahir H. (2012a). Spatial-Temporal Variation of Surface Water Quality in the Downstream Region of the Jakara River, North-Western Nigeria: A Statistical Approach. *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering,* 47: 1551–1560.

Mustapha A., Aris A.Z., Ramli M.F., and Juahir H. (2012b). Temporal Aspects of Surface Water Quality Variation using Robust Statistical Tools. *The Scientific World Journal,* 294540.

Nabegu A.B. (2010). An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria. *Journal of Human Ecology*, 31: 111–119.

Oke I.A. (2008). Management of Immunization Solid Wastes in Kano State, Nigeria. *Waste Management,* 28:2512–2521.

Ouyang J., Liu Z., Zhang L., Wang Y., and Zhou L. (2020). Analysis of Influencing Factors of Heavy Metals Pollution in Farmland-Rice System Around a Uranium Tailings Dam. *Process Safety and Environmental Protection*, 139: 124–132.

Razali A., Syed Ismail S.N., Awang S., Praveena S.M., and Zainal Abidin E. (2020). The Impact of Seasonal Change on River Water Quality and Dissolved Metals in Mountainous Agricultural Areas and Risk To Human Health. *Environmental Forensics*, 21: 195–211.

Rehman ur K., Bukhari S.M., Andleeb S., Mahmood A., Erinle K.O., Naeem M.M., and Imran Q. (2019). Ecological Risk Assessment of Heavy Metals in Vegetables Irrigated with Groundwater and Wastewater: The Particular Case of Sahiwal District in Pakistan. *Agricultural Water Management,* 226: 1–7.

Sa'eed M.D., and Mahmoud A.M. (2014). Determination of Some Physicochemical Parameters and Some Heavy Metals in Boreholes from Fagge L.G.A of Kano Metropholis Kano State- Nigeria. *World Journal of Analytical Chemistry*, 2: 42–46.

Sanda A.R., Ahmad I., and Gaye C.A. (2016). Heavy Metal Content of Abattoir Waste and Municipal Sludge in Soil and Water along Jakara River in Kano, Kano State, Nigeria. *Open Access Library Journal*, 3: e2896.

Sani A., and Abdullahi I.L. (2016). A Bio-assessment of DNA Damage by Alkaline Comet Assay in Metal Workers of Kano Metropolis, Nigeria. *Toxicology Reports*, 3: 804–806.

Sani A., and Abdullahi I.L. (2017). Evaluation of Some Heavy Metals Concentration in Body Fluids of Metal Workers in Kano Metropolis, Nigeria. *Toxicology Reports*, 4:72–76.

Sani A., Ahmad M.I., and Abdullahi I.L. (2020). Toxicity effects of Kano Central Abattoir Effluent on *Clarias Gariepinus* Juveniles. *Heliyon*, 6: e04465.

Sawut R., Kasim N., Maihemuti B., Hu L., Abliz A., Abdujappar A., and Kurban M. (2018). Pollution Characteristics and Health Risk Assessment of Heavy Metals in the Vegetable Bases of Northwest China. *Science of the Total Environment*, 642: 864–878.

Sharfaddeen M.M., Yusuf U., Ali S., and Mannir B. (2020). Assessment of Some Heavy Metals in Soil Samples from some Waste Dumpsites in Kano Metropolis, Nigeria Using INAA Technique. *International Journal of Science for Global Sustainability,* 6: 83–94.

Shawai S. A. A., Abubakar B.B., Nahannu M.S., and Gaya H.S. (2019). Status of Water Used for Drinking and Irrigation in Kano: A Critical Review on Physicochemical and Heavy Metals Concentration. *American Journal of Biomedical Science & Research,* 5: 235–242.

Shawai Sadiq Abdurrahman Abubakar, Nahannu M.S., Mukhtar H.I., Idris A., and Abdullahi I.I. (2017). Assessment of Heavy Metals Concentration in Ground Water from Various Locations of Gezawa Local Government Area of Kano State. *Advances in Materials*, 6: 73–76.

Sivakumar P., Kanagappan M., and Das S.S.M. (2016). Effect of Tannery Effluent on Oxygen Consumption and Accumulation of Toxic Metal in Freshwater Fish Danio rerio. *Journal of Pharmaceutical, Chemical and Biological Sciences,* 3: 601–607.

Suleiman A.U., Dogarai S.B.B., Kwazo H.A., Mohammed S., and Bagna E. (2020). Extraction of Heavy Metal in Tannery Effluent Using Abundant Agricultural Wastes. *International Journal of Science for Global Sustainability*, 6: 48–55.

Świątek B., Woś B., Gruba P., and Pietrzykowski M. (2019). Bioaccumulation of Heavy Metals (Pb, Cd, Cr, Cu) in Fine Roots Under Three Species of Alders (*Alnus* spp.) Plantation at Different Soil Substrates Addition on the Reclaimed Combustion Wastes Landfill. *Water, Air, and Soil Pollution*, 230:1–10.

Tangahu B.V., Sheikh Abdullah S.R., Basri H., Idris M., Anuar N., and Mukhlisin M. (2011). A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants through Phytoremediation. *International Journal of Chemical Engineering*, 2011.

Yusuf M.A. (2010). Evaluation of Heavy Metals in the Soils of Urban and Peri-urban Irrigated Land in Kano, Northern Nigeria. *Bayero Journal of Pure and Applied Sciences*, 3:46–51.

Zhou Y., Jia Z., Wang J., Chen L., Zou M., Li Y., and Zhou S. (2019). Heavy Metal Distribution, Relationship and Prediction in a Wheat-Rice Rotation System. *Geoderma*, 354: 1–11.