Advances in Research

17(2): 1-9, 2018; Article no.AIR.42497
ISSN: 2348-0394, NLM ID: 101666096

Impacts of Ogbese River Irrigation on Soil and Vegetable (*Celosia argentea*) Crops Grown in Ogbese with Special Reference to Heavy Metals

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Authors' contributions

This work was carried out in collaboration between both authors. Author OO Olubanjo designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OO Olubanjo and OO Olanrewaju managed the analyses of the study. Author OO Olanrewaju managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2018/42497
Editor(s):
(1) Dr. Magdalena Valsikova, Professor, Horticulture and Landscape Engineering, Slovak University of Agriculture, Nitra, Slovakia.
Reviewers:
(1) Bruno Fiorelini Pereira, Universidade Estadual Paulista -UNESP, Brazil.
(2) Sana Sungur Mustafa, Kemal University, Turkey.
(3) Roushan K. Thakur, Gurukula Kangri Vishwavidyalaya, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/27180

Original Research Article

Received 01 June 2018
Accepted 16 September 2018
Published 14 November 2018

ABSTRACT

The bank of River Ogbese during the wet and dry season is influenced by anthropogenic activities such as wastes disposal, dumping of sewage, runoffs from an artificial application of fertiliser on farmlands. Runoff of rainwater could carry various ionic species along with heavy metals from top layer of soil due to the soil erosion into the river or leave them as sediments on the farm soils and these ionic species and heavy metals accumulated in River Ogbese irrigated soil, moreover translocate from root to upper parts of vegetables grown on them. This gave the drive to investigate the concentrations of Pb, Cr, Cd, Ni, Zn, Fe, Cu and Mg in the river, soil, and vegetable (Lagos spinach) cultivated along the bank of River Ogbese using AAS (AAS buck scientific 210 vgp). The mean concentrations (mg/kg) of Pb, Cr, Cd, Ni, Zn, Fe, Cu and Mg in water, vegetable, soil, control vegetable, and control soil were observed and recorded respectively. The concentration of lead in Water, Soil and Vegetable leaves were found higher when compared with standards of WHO (2002, 2009). Furthermore, Cr, Cd, Ni, Zn, Fe, Cu and Mg were observed below the prescribed limit of

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WHO (2002, 2009). The values of the heavy metals were analysed for various samples along with samples along dumpsites which were higher than from the control site thus, suggesting possible mobility of metals from dumpsite to farmlands through leaching and runoffs, but all the control site values were observed below the prescribed limit of WHO (2002, 2009). Hence, the anthropogenic activities on the river bank are not yet controlled; these might influence the heavy metals concentration in future. It was concluded that vegetables grown in River Ogbese irrigated soil were not fit for local population. At such, there will be an urgent need to take important action from local authorities at various levels to ensure adequate waste disposal to prevent indiscriminate dumping of waste into water bodies and the need to increase public awareness in order to protect the river should be encouraged.

Keywords: Atomic Absorption Spectrophotometer (AAS); heavy metals; Celosia argentea; vegetable (Lagos spinach).

1. INTRODUCTION

Water is a free gift of nature, a natural solvent and highly essential for life on earth. Water is a vital source of life which is essential for survival of all living organisms. Water is not only the most important essential constituent of all animals, plants and other organisms but also the pivotal for the survivability of mankind in the biosphere. Water covered a significant portion of the earth crush i.e. the hydrosphere. Upon the high usefulness of water to living creatures, it can be a source of ill-health and other water-borne related diseases, being a harbour for disease pathogens, carcinogenic substances and other toxic chemicals including heavy metals in the environment. There are channels through which the hydrosphere (including underground water (which is usually harnessed through bore holes and wells), surface water like streams, rivers, lakes and rain water) can be contaminated. As a result, all these sources are subject to contamination by organic and inorganic substances in the environment. The heavy metal contamination of water sources has being majorly through anthropogenic (industrial, domestic and environmental) activities. At extremely low levels, most heavy metals are toxic to living organisms [1]. Due to intense anthropogenic activities such as emission of harmful gases from rapidly expanding industrial areas, discharge of domestic wastes, wastewater and industrial effluents in water bodies, runoff of excess fertilisers and pesticides used on the farm, dispose of garbage, electronic wastes, radioactive waste, coal combustion residues, spillage of petrochemicals, atmospheric deposition etc. to water bodies, most studies in Nigeria [2,3,4] have reported high levels of heavy metals in ground water, streams, oceans and rivers, in various communities. River Ogbese is one of the prominent water bodies in Ondo State, Nigeria, in which several human activities (such as domestic, industrial and agricultural) are carried out. River Ogbese is of strategic importance to the people of Ogbese town in Ondo State, Nigeria. The river is a channel of water supply to the community and it is also used for irrigation along its course. Ogbese River is one of the most important rivers in both the Central and Northern zone of Ondo state [5]. Although there are no known waste management and control measures on the river, Akinbile [6] reported that waste management has become increasingly complex due to the increase in human population, industrial and technological revolutions.

Soil, a medium on which plant grows, could also be contaminated through accumulation of heavy metals via different anthropogenic sources such as wastewater irrigation of field crops, application of fertilisers, pesticides, animal manures, sewage sludge etc. to enrich planted crops on the soil [7, 8]. This medium serves as a major sink for heavy metals in the environment. Heavy metals are very persistent on the soil [9] because they mostly do not undergo microbial or chemical degradation [10]. Elevated concentrations of heavy metals in soils may cause phyto-toxicity, direct hazard to human health, indirect effects due to transmission through the food chain or contamination of ground waters. Many metals act as biological poisons even at parts per billion levels. The toxic elements accumulated in organic matter in soils are taken up by growing plants [11].

Consumption of food crops grown on heavy metal-contaminated soil may pose health risks to humans and the ecosystem in diverse ways [12, 13]. Vegetables are an important part of the human diet. Notwithstanding, contamination of vegetables with heavy metals due to soil and atmospheric contamination is a threat to its quality and safety. High concentrations of heavy metals in fruits and vegetables were linked to the occurrence of upper gastrointestinal cancer [14]. Contamination of vegetables with heavy metal may be due to irrigation with contaminated water, the addition of fertilisers and metal-based pesticides, industrial emissions, transportation, the harvesting process, storage or at the point of sale. It is well known that plants take up metals by absorbing them from contaminated soil as well as from deposits on parts of the plants exposed to the air from polluted environments [15,16].

Lagos spinach (quail grass, 'soko', *Celosia argentea*, feather cockscomb) is a vigorous, broadleaf annual plant belonging to the Amaranth family (*Amaranthaceae*). *C. argentea* is grown successfully in temperate as well as tropical regions. It grows widely across Northern South America, tropical Africa, the West Indies and tropical Asia as a native or naturalised wildflower, and it is cultivated as a nutritious leafy green vegetable. It is traditionally found in countries of Central and West Africa, and is one of the leading leafy green vegetables in Nigeria, which is locally known as 'sokoyokoto', meaning 'make husbands fat and happy.' *C. argentea* grows rapidly from seed and, depending upon the variety and soil fertility, it can reach a height of 200 cm (6.5 ft.). Medicinal uses of *C. argentea* have been reported where its use as a leafy vegetable has been adapted into the culture. Ailments treated with *C. argentea* include: abscesses, colic, cough, *Diabetes mellitus*, diarrhoea, dysentery, eczema, eye infection, gonorrhoea, infected sores, liver ailments, menstruation disorder, muscle impairment, skin eruptions, snakebites, and wounds [17]. The roots have diuretic properties, and in Kenya, the Masai people make a body wash from the leaves and flowers for convalescents. The specific objectives of the study was to determine the heavy metal analysis of River Ogbese used for irrigation and assess the accumulation level in Vegetable leaves (Lagos spinach) and farming soil along the river bank, and review the health implications of heavy metals on the human being.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experimental site is Ogbese River along Akure – Benin expressway in Akure North Local Government Area (ANLGA) of Ondo state. The area lies within latitude 6° 43¹N and longitude 5° 26¹E¹. The river has its source from Ayede – Ekiti in Ekiti State and flows through Ogbese in Ondo State to Edo state. It flows for approximately 22 km from its source to meet River Ose which is 265 km long and discharges into the Atlantic Ocean through an intricate series of creeks and lagoons. Ogbese community is about 10km distance from Akure, the Ondo State capital and has a population of about 20,000 people [18]. It is a unique town because of its nodal nature similar to that of Ore in the Southern part of Ondo State. This makes it a commercial hub for farmers and people from neighbouring towns to market their goods. The Ogbese community has undergone great economic development in recent years, the very popular market (Ogbese market) and the timber business coupled with unequalled agricultural practices have drawn people from several cultural backgrounds in the country to make the settlement inter-tribal.

2.2 Planting of Vegetable (*Celosia argentea*)

The seed that was used for this work was sourced from Agricultural Development Project (ADP) Akure, Ondo State, Nigeria. The seeds are of two varieties in which one of the variety has its own edible leaves (broad and green) and the leaf of the second variety is of both purple and green colour with purple flower grown on it. For the purpose of this work, the seed with fully green colour was used. The seed was planted using broadcasting method of planting. The field was divided into three parts indicating three replicate. It was measured with a crown cover and scattered (sown) on the soil surface in a control atmosphere to avoid contact with rain water. The vegetable (control) was irrigated with rain water twice a day viz., during the evening time so that the plant can make use of water before day break. Water from River Ogbese was used to irrigate the vegetable and hand watering irrigation method was employed so that water can seep down into the root zone inside the soil for plant to take up water when it is needed. Irrigation was stopped when *Celosia argentea* is about to produce seeds, that is, showing sign of maturity and the seed starts germinating after six (6) days of planting.

2.3 Harvesting and Collection of Plant Sample (Vegetable)

The *Celosia argentea* (Lagos spinach) leaves were harvested from mature plants after 4 weeks and 3 days post-planting using once-overharvest by uprooting the whole plant so as to avoid re-growth which was measured with ruler and the height ranged from 21 to 27 cm (8.2 inches). The harvested leaves were placed under double distilled water to wash off the dirt in them. At the study site, at least a total of 40 (20 leaves per species) fresh leaves were harvested and taken to the laboratory for heavy metal analysis.

2.4 Preparation of Vegetable (*Celosia argentea*)

The leaf sample (Lagos spinach) in each of the groups was air dried at room temperature for three months to remove the moisture and water droplets simultaneously. The leaf was dried to a constant weight in an oven at a maintained temperature and pulverised to fine powder using a laboratory grinder. The ground leaves were collected into well labeled polythene bags and placed in a desiccator. Each sample was carefully weighed into clean platinum crucible, crushed to ash at a particular temperature and then cooled to room temperature in a desiccator. The ash was dissolved in hydrochloric acid and the solution was carefully transferred into a volumetric flask. The crucible flask was well rinsed with distilled water, the solution was transferred to the flask and made up to the mark with distilled water, adequately shaken to mix well. The resulting sample solutions were taken to the laboratory for the determination of heavy metals concentration using Atomic Absorption Spectrophotometer (AAS buck scientific 210 vgp).

2.5 Collection and Preparation of Water Sample

Ogbese River was constructed as a bridge along Owo Traffic Road in Ondo State. The water from this river is diverted for irrigating crop fields and for aquaculture (fish rearing). Three sampling stations designated as A, B, C were established in the river covering its whole area for the collection of water samples, with 15 metres interval from one another. One sampling point was at the right side of the bridge, the second point was under the bridge where it divided the bridge into left and right (where human activities were at the peak because of accessibility to the river and presence of waste dumpsite so as to ascertain the seepage of heavy metals from the dumpsite through washing of rain into the river), and third sampling point at the left side of the bridge. Samples were collected using polyethylene sampling bottles. The sampling bottles were pre-conditioned with 5% HNO_3 and was thoroughly rinsed with distilled de-ionised water at each point. The bottles were rinsed at least three times and clean polyethylene sampling bottles were immersed about 10cm below the water surface. One (1) litre of water was taken at the three points, immediately acidified with 10% HNO_3 to a pH of less than 2 and was transported to the laboratory in an ice bath. The samples were filtered through a micropore membrane filter and was kept at 4°C before heavy metal determination. The heavy metal parameters were determined in the laboratory using Atomic Adsorption Spectrophotometer (AAS buck scientific 210 vgp).

2.6 Collection and Preservation of Soil Sample

Soil was randomly collected along the experimental site while avoiding areas with obvious signs of disturbance such as animal burrowing and landfills. The distance between sampling sites was 50 to 100 km, three samples were collected at the locations. At the location, soil samples were collected randomly with three replication. Soil was sampled at the surface (0 to 28 cm depth) in a ring form just at the base of the plant from which the vegetable leaf were plucked using hand-driven stainless-steel augers. The same procedure was used for control soil sample. Soil samples were collected in polythene bags and kept on ice. The samples were subsequently transported to the laboratory and kept at 4°C.

2.7 Pre-treatment of Soil Samples

Soil samples meant for total metal analysis were placed in porcelain crucibles and oven dried at 80°C for 24 hours. The dried samples were ground using a porcelain mortar and pestle, and kept in desiccators to attain constant weight before being transferred into air tight plastic bottles. All the samples were sieved with a 200 um mesh sieve before metal analysis.

2.8 Soil Sample Preparation and Digestion

Two grams each of the sieved soil samples was placed into a 100ml beaker and moistened with few drops of distilled water. Five (5) ml Aqua regia (a combination of HNO_3 and HCl in ratio 1:3) was added. The beaker was covered with a watch glass and placed on a hot plate in a fume

Plate 1. View of River Ogbese during the experimental research (April, 2016)

cupboard. The mixture was boiled on a hot plate for 3 hours and allowed to simmer for 35 minutes. The mixture was then removed from the hot plate and placed on a heat-proofed mat where it was allowed to cool. The watch glass was removed, allowing any liquid to drain into the beaker. The content of the beaker was filtered through a Whatman 541 filter paper and washed with 15ml of deionised water into a volumetric flask. The filtrate was made up to the mark of 100ml in a standard volumetric flask. The volumetric flask was inverted several times to ensure mixing and homogenisation of the solution. The solution was then transferred into a labeled sample bottle and was analysed for heavy metal using Atomic Absorption Spectrophotometer (AAS buck scientific 210 vgp).

2.9 Statistical Analysis

Analysis of Variance (ANOVA) was used to determine river water significance level on soil and vegetables. This was carried out using Statistical Packages for Social Sciences (SPSS) version 20.

3. RESULTS AND DISCUSSION

This showed the mean and standard deviation for each sample with their parameters compared to a recommended standard (World Health Organization) were computed as shown in tables below:

4. DISCUSSION

From Table 1, the mean concentration (0.043 mg/kg) of lead (Pb) in the water was higher when compared to recommended standard of WHO [19,20] (0.02 and 0.02 mg/kg) respectively. According to Miettinien [21] and Bryan [22], lead is very toxic and has very chronic health implication even at very low concentration, ingestion of lead (Pb) could cause mental retardation in children, colic anaemia and renal diseases [23]. Essien [24] also reported that long term exposure to lead can cause serious health hazard which include inhibition of the synthesis of haemoglobin and also adversely affect the central and peripheral nervous system as well as the kidney [25]. The increase in lead in the river might be due to dumping of sewage into the river, runoffs of refuse dump by rain into the river. Moreover, the river is also surrounded by many farming activities such as the addition of artificial fertiliser and pesticides which can easily find their way into the river when washed by rain. Lead concentration was higher in the river than the one available in control. Also, there was a little concentration of chromium (Cr) (0.002 mg/kg) but falls below the recommended standard of WHO (0.1 mg/kg), and higher than the control. From the result, cadmium was not detected in the water. The mean concentration of nickel was a little bit high in the water but still falls below the recommended standard of WHO [19,20] (1.2 and 1.2 mg/kg). Nriagu and Pagna [26] reported that nickel (Ni) becomes hazardous if its concentration exceeds more than the recommended limit of 1.2 mg/kg. Misra and Dinesh [27] stated that when the concentration of nickel is high, it can results to degradation of basal ganglia of liver and brain, and mental retardation in human and animals. Although, the nickel in the water is 1.16 mg/kg but there is tendency it might go high in future if human activities such as dumping of sewage and dumping of refuse is not controlled. The mean concentration of Zinc (0.17 mg/kg) falls below the recommended standard of WHO [19,20] (0.6 and 0.5 mg/kg) but higher than the control. Concentration of iron (1.76 mg/kg) falls below the recommended standard of WHO [19,20] (5.0 and 4.8 mg/kg). Mean concentration of copper and magnesium (0.14 and 0.45 mg/kg) still falls below recommended standard of WHO [19,20] (0.3 and 0.2 mg/kg) and (50 and 47 mg/kg) respectively. It was higher than the values recorded at control.

Table 1. Concentration of heavy metals in Vegetables irrigated with Ogbese River (Ogbese, Ondo State, Nigeria) compared to recommended standard (mg/kg)

Heavy metals	Mean	Standard deviation	WHO (2002)
Lead (Pb)	0.0430	0.0021	0.0200
Chromium (Cr)	0.0020	0.0006	0.1000
Cadmium (Cd)	ND	0.0000	0.0100
Nickel (Ni)	1.1600	0.0017	1.2000
Zinc (Zn)	0.1700	0.0100	0.6000
Iron (Fe)	1.7600	0.0017	5.0000
Copper (Cu)	0.1400	0.0012	0.3000
Magnesium (Mg)	0.4500	0.0100	60.0000

Legend: ND - Not Detected

Table 2. Contents of heavy metals (mg/kg) in entire *Celosia argentea* plant at the locations

Heavy metals	Mean	Standard deviation	WHO (2002)
Lead (Pb)	0.0530	0.0020	0.0200
Chromium (Cr)	0.0040	0.0006	0.1000
Cadmium (Cd)	0.0020	0.0058	0.0100
Nickel (Ni)	1.1800	0.2082	1.2000
Zinc (Zn)	0.2620	0.0075	0.6000
Iron (Fe)	1.8600	0.0100	5.0000
Copper (Cu)	0.1700	0.0153	0.3000
Magnesium (Mg)	35.0000	2.5166	60.0000

Table 3. Concentration of heavy metals in control vegetable (Lagos spinach) samples compared to recommended standard (mg/kg)

Heavy metals	Mean	Standard deviation	WHO (2002)
Lead (Pb)	0.0300	0.0000	0.0200
Chromium (Cr)	ND	0.0000	0.1000
Cadmium (Cd)	ND	0.0000	0.0100
Nickel (Ni)	0.5500	0.0200	1.2000
Zinc (Zn)	0.1600	0.0015	6.0000
Iron (Fe)	0.0700	0.0100	5.0000
Copper (Cu)	0.0810	0.0015	0.3000
Magnesium (Mg)	0.1500	0.0100	60.0000

Legend: ND - Not Detected

Table 4. Concentration of heavy metals in irrigated soil compared to recommended standard (mg/kg)

Heavy metals	Mean	Standard deviation	WHO (2002)
Lead (Pb)	0.0480	0.0015	0.0200
Chromium (Cr)	0.0100	0.0006	0.1000
Cadmium (Cd)	0.0010	0.0055	0.0100
Nickel (Ni)	1.1500	0.1528	1.2000
Zinc (Zn)	0.2500	0.0006	0.6000
Iron (Fe)	1.8800	0.0100	5.0000
Copper (Cu)	0.1300	0.0012	0.3000
Magnesium (Mg)	34.0000	1.0000	60.0000

Table 5. Concentration of heavy metals in control soil compared to recommended standard (mg/kg)

Heavy metals	Mean	Standard deviation	WHO (2002)
Lead (Pb)	0.0040	0.0001	0.0200
Chromium (Cr)	0.0050	0.0006	0.1000
Cadmium (Cd)	ND	0.0000	0.0100
Nickel (Ni)	0.0070	0.0100	1.2000
Zinc (Zn)	0.2100	0.0058	0.6000
Iron (Fe)	1.0700	0.0059	5.0000
Copper (Cu)	0.0900	0.0115	0.3000
Magnesium (Mg)	23.0000	1.0000	

Legend: ND - Not Detected

Table 2 shows that the mean concentration of lead (0.053 mg/kg) in vegetable is higher than the mean of water used in irrigating the vegetable. This might be due to the combined concentration of lead (Pb) from water and soil as a result of the presence of dump-site around where the vegetable (Lagos spinach) was grown and harvested. The mean concentration of lead in the vegetable was higher than the recommended standard of WHO [19,20] (0.02 and 0.02 mg/kg) and also higher than the control (0.01 mg/kg). According to Miettinien [21] and Bryan [22], lead is very toxic and has very chronic health implication even at low concentration. They also reported that ingestion of too much of lead (Pb) could cause mental retardation in children and renal diseases. Mean value of chromium (0.004 mg/kg) falls below recommended standard of WHO (0.1 mg/kg) and also falls below the mean value of control which was not detected. Chromium does not apparently pose a threat to health in view of its concentration levels in the farm soils and vegetables. Cadmium (Cd) of 0.002 mg/kg also falls below the recommended standard by WHO (0.01 mg/kg) but the control value was not detected. Cadmium was either very low or not detected as Puschenreiter and Horak [28] earlier reported that crop absorption of cadmium from soil is very low. Also, Lato et al. [29] reported that leafy vegetables accumulate less cadmium. Nickel (1.18 mg/kg) is a little bit high in the vegetable but still falls below the recommended standard of WHO [19,20] (1.2 and 1.2 mg/kg) and higher than the mean value of the control crops (0.55 mg/kg). Zinc was reportedly low in concentration (0.262 mg/kg) compared to the WHO [19,20] recommended standard (6.0 and 5.0 mg/kg) but also higher than the control mean value of 0.16 mg/kg. Mean concentration of iron (1.86 mg/kg) falls below the recommended standard of WHO [19,20] (0.6 and 0.5 mg/kg) but higher than the mean control value of (0.07 mg/kg), copper (0.17 mg/kg) and magnesium (35 mg/kg) which also falls below the recommended standard of WHO [19,20] (0.3 and 0.2 mg/kg) and (50 and 47 mg/kg) respectively. Their mean values were higher than the control values (0.081 and 0.15 mg/kg). From table 3, which is the control vegetable, all parameters were below the WHO [19,20] recommended standard.

Table 4 shows high level of lead with mean concentration of 0.048 mg/kg in soil when compared to WHO [19,20] recommended standard of 0.02 and 0.02 mg/kg respectively. Lead in small quantity can cause serious damage to health [25]. High amount of lead in the soil might be traceable to human activities such as dumping of refuse on the soil, artificial application of fertiliser which later entered into the soil when washed by rain. The mean concentration of the soil was higher than the control soil value (0.004 mg/kg). There was traces of chromium (0.01 mg/kg) which falls below the recommended standard of WHO (0.1 mg/kg), the mean value of chromium in soil was higher than the control value (0.005 mg/kg). Cadmium concentration (0.01 mg/kg) also falls below the recommended standard of WHO (0.1 mg/kg) and the control which was not detected. Nickel concentration (1.18 mg/kg) was a little bit high but still low when compared to WHO [19, 20] (1.2 and 1.2 mg/kg) which was higher than the mean concentration obtained at control (0.007 mg/kg). Zinc concentration (0.25 mg/kg) was low in the soil compared to WHO [19,20] value of 0.6 and 0.5 mg/kg but a little bit closer to the control (0.21 mg/kg) when compared. Mean concentration of iron (1.88 mg/kg) falls below the recommended standard of 5.0 and 4.8 mg/kg by WHO [19, 20] but higher than the control limit (1.07 mg/kg). Copper (Cu) and magnesium (Mg) falls below the recommended limit of 0.3 and 0.2 mg/kg; and also 60 and 47 mg/kg respectively of WHO [19, 20] but higher than the control limit. Table 5 shows all heavy metals in the soil control which all falls below the recommended standard of WHO [19, 20].

5. CONCLUSION

The concentration of lead, chromium, nickel, zinc, iron, copper, and magnesium in water, soil and vegetables were analysed in the laboratory using Atomic Absorption Spectrophotometer (AAS). Amount of lead accumulated in the water, soil and vegetables (*Celosia argentea*) along dumpsite besides the river was higher than the value recommended by WHO (2002, 2009). The result also revealed that the values of all the heavy metals were analysed in the samples along dumpsites were higher than those obtained from the control site suggesting possible mobility of heavy metals from dumpsites to farmlands through leaching and runoffs. Heavy metals observed in all the control sites were found below the prescribed limit of WHO (2002, 2009). Load of heavy metals pollution on the river bank is increasing day by day due to the various anthropogenic activities nearby river Ogbese. Due to increasing concentration of heavy metals, it might have a serious impact on all the biotic factors through bio-accumulation. From the above results, it can be advised to local population of Ogbese, Ondo State, Nigeria, not to consume river Ogbese-irrigated vegetables. Furthermore, there should be an urgent need for local authorities at various level to ensure adequate waste disposal, to prevent indiscriminate dumping of waste into water bodies and increase public awareness of environmental sanitation in order to protect the river.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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