International Journal of Modern Science and Technology, 2020;5(8):218-223.
ISSN: 2456-0235.
www.ijmst.co

Research Article

Determination of Arsenic and Cadmium in Soil, Water and Some Vegetables Irrigated with River Tudun Wada, Kaduna State, Nigeria

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Abstract

The concentrations of Arsenic (As) and Cadmium (Cd) were determined in soil, water and three vegetables (*Moringa oleifera* leaves, Spinach leaves and cassava leaves) around river Tudun Wada, Kaduna State, Nigeria. The results of the soil, samples revealed the mean concentration of 8.04 ± 3.3 µg/kg As and 31767 ± 11403 µg/kg Cd; in water 0.0085 ± 0.003 µg/L As and 279 ± 2.9 µg/L Cd and in vegetables: Moringa Oleifera (7.90 ± 0.2 µg/kg As and 14850 ± 100 µg/kg Cd); Spinach (7.70 ± 0.3 µg/kg As and 14800 ± 346 µg/kg Cd) and Cassava (8.10 ± 0.5 µg/kg As and 14950 ± 574 µg/kg Cd) respectively. The values of As recorded in this research in soil, water and vegetables are below FAO/WHO permissible limits with exception of Cd which is higher than FAO/WHO permissible limits in all the samples analyzed. Therefore, we solicit that farmers should engage in prudent agricultural practice to minimize the uptake of toxic metals by plants.

Keywords: Arsenic; Cadmium; River Tudun Wada; Vegetables.

Introduction

Vegetables are parts of any plant such as fruits, seeds, roots, tubers, bulbs, stems, leaves or flowers used as food. They are known sources of vitamins A and C, iron, calcium, folic acid, dietary fibre, proteins, fats, carbohydrates, and moisture also; they are good anti-oxidants [1]. Vegetables are widely used for culinary purposes; they are used to increase the quality of soups and also for their dietary purposes [2].

They are very important protective food and useful for the maintenance of good health, prevention and treatment of various diseases [3]. Vegetables contain both essential and non-essential toxic elements at varying concentrations. Various human activities such as mining, industrial processing, vehicular emissions, pesticides and fertilizer application, especially the huge annual applications of organic livestock manure, which is the traditional agricultural fertilizer, are causing elevated heavy metal concentrations in the environment [4].

The uptake of heavy metals by vegetables and accumulation in their edible and inedible parts higher than the tolerable amount is a potential danger to animals and humans [5]. Heavy metals are extremely persistent in the environment because of their non-biodegradable nature, long biological half-lives, thermal stability and potential to accumulate to toxic levels in both plants and animals [6]. Even at low concentrations, heavy metals have been reported to produce damaging effects on man and animals because there is no good mechanism for their elimination from the body [7].

The study of heavy metal contamination of vegetables is very important in ensuring food quality [8]. Heavy metal contamination of vegetables may be enhanced by factors such as plant species, concentration of the metal, metal availability in solution, application of agrochemicals, run–off of sewage, wastewater and irrigated water [9]. This research is aimed at investigating the presence and concentrations of arsenic and cadmium in soil, water and some vegetables irrigated with River Tudun Wada, Kaduna State, Nigeria.

Received: 23.07.2020; Received after Revision: 14.08.2020; Accepted: 15.08.2020; Published: 30.08.2020

Materials and methods

Study Area

The study was carried out in Tudun Wada, Kaduna State, Nigeria. Tudun wada has a River which its water content empties into River Kaduna. Tannery wastewaters from tannery activities are discharged into this river. Vegetables which are cultivated and irrigated with the river water are not only consumed locally but are supply to other parts of the state. The sampling points were identified as A, B, C, D and E. The geographical coordinates are: Latitude $10^0$30’36s N and Longitude $7^0$25’9s E, latitude $10^0$30’4s N and longitude $7^0$25,9s E, latitude $10^0$30’3s N and longitude $7^0$25’8s E, latitude $10^0$30’1s N and longitude $7^0$25’6s E and latitude $10^0$30’2s N and longitude $7^0$25’7s E.

Sample collection and analysis

Collection of water samples

Water samples were collected from River Tudun wada in five (5) places marked A, B, C, D and E using a large clean container and rinsing it three times with the river water to be collected. When collected, the water was swirl gently in the large container before been decanted into the sample bottles. A total of six (6) water samples were collected including point of discharge into the river by the tannery factory to serve as control at the depth of 0-10 cm. The samples were treated with 3 mL HNO_3 and transported to the laboratory for storage in the refrigerator for subsequent analysis.

Collection of soil samples

Soil samples were collected at the bank of River Tudun wada in five (5) places marked A, B, C, D and E. A total of six (6) soil samples including the tannery site were collected at the depth of 0 - 20 cm. The samples were taken and transferred into polythene bags and transported to the laboratory. The soil samples were placed on a plastic tray and spread to air-dry. The soil samples were redistributed twice daily for two weeks for effective drying. When dried, the soil samples were crushed in a mortar and sieved through 2 mm pore sieve into plastic containers and stored for subsequent analysis.

Collection of vegetable samples

Vegetable Samples were collected at the bank of River Tudun wada from five farms marked A, B, C, D and E. The leaves and stalk were acquired; all samples appeared suitable for human consumption and had no signs of rotting. The samples were washed with distilled water to remove dust, sand and any other deposits on it. The samples were transported to the laboratory for analysis.

Digestion of soil samples

One gram (1.0 g) of the soil samples were placed in a 250 mL digestion tube and 10 mL of concentrated HNO_3 was added. The mixture was boiled gently for 30 minutes to oxidize all easily oxidizable matter. After cooling, 5 mL of 70 % $HClO_4$ was added and the mixture was boiled gently until dense white fumes appeared. The solution was cooled, filtered and transferred quantitatively to a 100 mL volumetric flask by adding distilled water [10].

Digestion of water sample

Exactly 100 mL aliquot of thoroughly mixed water samples were transferred to a beaker followed by addition of 2 mL of concentrated HNO_3 and 5 mL of concentrated HCl. The sample was covered with a watch glass and heated on a hot plate until the volume reduced to 20 mL. The beaker was removed and allowed to cool, then filtered into a 100 mL volumetric flask and made up to mark with distilled water [11].

Digestion of vegetable samples

One gram (1.0 g) of ground dried plant sample was placed in a small beaker. Exactly 5.0 mL of an acid mixture composed of HNO_3 and $HClO_4$ (4:1) was added to each sample and heated on a hot plate in a fume chamber. Then the digests were allowed to cool, filtered and transferred to a 100 mL volumetric flask and made up to mark with distilled water for analysis [12].

Result and discussion

Arsenic (As) in soil

The concentration of As in the soil irrigated with river Tudun Wada is in the range of 1.40 – 9.82 µg/kg as presented in Table 1. The highest As concentration was recorded at point BS (9.82 µg/kg) and the lowest concentration at point MS (1.40 µg/kg) which is the point of discharge of the tannery wastewater into river Tudun Wada. The high value of As recorded in the soil may be coming from sources other than the river water used for irrigation. The average concentration of

As in four (4) farms in Barkin-Ladi Local Government Area of Plateau State irrigated with tin mine pond water was reported to be 1220 µg/kg [13] which is higher than the values recorded in this analysis probably due to differences in anthropogenic activities. The value of As recorded in this research is below FAO/ WHO recommended limits.

Cadmium (Cd) in soil

The concentration of Cd in the soil irrigated with river Tudun Wada is in the range of 8500 – 36900 µg/kg as presented in Table 1. The highest Cd concentration was recorded at point BS (36900 µg/kg) and the lowest concentration at point MS (8500 µg/kg) which is the point of discharge of the tannery wastewater into river Tudun Wada. The concentration of Cd in some selected dumpsites along river Kaduna used for irrigation of farms was reported to be 17890 ± 3130 µg/kg [14]. The values recorded are in agreement with this research work. The average concentration of Cd levels in soil from sewage irrigated area of Geriyo was 105400 µg/kg [15] which is higher than the value reported in this analysis and could be attributed to agricultural practice. Cd levels in soil irrigated with Mpape river in FCT, Abuja was investigated and reported to be 10 µg/kg [16]. The value of Cd recorded in this research is below FAO/ WHO recommended limits.

Arsenic (As) in Tudun Wada river

The concentrations of As in river Tudun Wada are presented in Table 2 with MW (the point of discharge) recording the highest value (0.0130 µg/L) and AW recording the least value (0.00500 µg/L). The concentration of As in surface water sources in Kaduna Metropolis was reported to be 1010 µg/L [17] which is higher than the value recorded in this research probably due to geography and agricultural activities. The concentration of As in African groundwater ranges from 0.02 – 1760 µg/L and in surface water in the range of 10000 µg/L [18]. The value of As recorded in this research is below FAO/ WHO recommended limits.

Cadmium (Cd) in Tudun Wada River

The concentration of Cd in river Tudun Wada are presented in Table 2 with MW (the point of discharge) recording the highest value (282 µg/l) and points AW and CW recording the least values (275 µg/l) for Cd. The distribution of the metals in river Tudun Wada show some appreciable level of dilution as the water flows and a gradual build up as about emptying into river Kaduna, this could be as a result of precipitation of the metal ions by river Kaduna water. The value of Cd recorded in this research is below FAO/ WHO recommended limits.

Table 1. Concentrations (µg/kg) of As and Cd in Soil along River Tudun Wada, Kaduna State

Soil Sample	AS	BS	CS	DS	ES	MS
As	9.10	9.82	9.10	9.62	9.22	1.40
Cd	36100	36900	36100	36700	36300	8500

Table 2. Concentrations (µg/l) of As and Cd in River Tudun Wada, Kaduna State

Water Samples	AW	BW	CW	DW	EW	MW
As	0.00500	0.00700	0.00600	0.0110	0.00900	0.0130
Cd	275	279	275	281	279	282

Arsenic (As) in vegetables

The concentrations of As in three vegetable species; *Moringa oleifera*, Spinach and Cassava leaves analyzed across the sampled stations is in the range of 7.31 – 8.60 µg/kg as presented in Table 3. The levels of As in six vegetables in Jos were reported in the range: As 552 – 3010 µg/kg [19]. The concentrations of As in cabbage was reported to be 1840 µg/kg [20]. The value of As recorded in this research is below FAO/ WHO recommended limits.

Cadmium (Cd) in vegetables

The concentrations of Cd in three vegetable species; *Moringa oleifera*, Spinach and Cassava leaves analyzed across the sampled stations is in the range of 14500 – 15700 µg/kg as presented in Table 3. The concentration of Cd in the range of 340 to 5440 µg/kg in vegetable samples like spinach (*Amaranth caudatus*), lettuce (*lactuca sativa*), Cabbage (*Brassica olemcea*) and Onion (*Allium cepa*) harvested from four agricultural locations in Biu Local Government Area, Borno State, Nigeria was reported [21].

Table 3. Concentrations (µg/kg) of As and Cd in Vegetables Cultivated Irrigated with River Tudun Wada, Kaduna State

Sample Code	Sample Name	As (µg/kg)	Cd (µg/kg)
A1	*Moringa Oleifera* leaves	8.00	14900
A2	Spinach leaves	7.60	14700
A3	Cassava leaves	8.20	14500
B1	*Moringa Oleifera* leaves	8.00	14900
B2	Spinach leaves	8.20	15300
B3	Cassava leaves	8.60	15700
C1	*Moringa Oleifera* leaves	8.00	14900
C2	Spinach leaves	7.40	14500
C3	Cassava leaves	8.11	15100
D1	*Moringa Oleifera* leaves	7.60	14700
D2	Spinach leaves	7.60	14700
D3	Cassava leaves	7.40	14500
E1	Moringa Oleifera leaves	7.31	14500
E2	Spinach leaves	8.11	15100
E3	Cassava leaves	7.60	14700

Cd content of lettuce, cabbage, carrot and tomato from Kano State was reported to be 1340 µg/kg, 1220 µg/kg, 320 µg/kg and 230 µg/kg respectively [22]. The Cd content of spinach and African egg plant were reported to be 17.0 µg/kg and 10.0 µg/kg from Mpape river, FCT, Abuja, Nigeria [16]. The level of Cd in some vegetables selected from markets in Bayelsa State was reported in the range of 28.0 to 1487 µg/kg [23]. The mean concentration of Cd from vegetables selected from markets in Lagos, Nigeria was 28.0 to 91.0 µg/kg [24]. The value of Cd recorded in this research is above that reported by similar researchers, this could be as a result of the tannery wastewater discharged into the river which is used for the irrigation of the respective crops and is below the FAO/ WHO recommended limits [25,26].

Conclusions

The concentrations of As and Cd in soil, water and vegetables irrigated with River Tudun Wada, Kaduna State indicated that the concentration of As in all the samples analyzed are below the FAO/WHO permissible limits of 5000 µg/kg As and 1000 µg/kg Cd in soil, 100 µg/l and 10 µg/l Cd in water and 100 µg/kg As and 200 µg/kg Cd in vegetables with exception of Cd which is higher than the FAO/WHO permissible limit. We observed that there are other possible sources (sewage, refuse, farming activities and so on) of pollution apart from the tannery wastewater discharged into River Tudun wada which is used for the irrigation of these crops and we recommend for proper education of the habitants to adopt adequate waste management culture to minimize endangering the aquatic and terrestrial environments

Conflict of interest

Authors have declared no conflict of interests.

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