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Heavy Metals in Irrigated Crops along Tatsawarki River in Kano, Nigeria

[1]Bichi, M. H., [2]Bello, U. F.
[1,2]Department of Civil Engineering, Bayero University, Kano-Nigeria

ABSTRACT: *Surface and ground irrigation water samples were collected from the three different farmlands along the Tatsawarki River. Control surface and ground water samples were collected from farmlands located away from away from the river. Samples of three crops (tomatoes, onions, and pepper) were collected from the three irrigated farmlands along the river banks. Each of the three crops was collected from each of the farmlands irrigated with surface water as well as from each of the farmlands irrigated with ground water. Sample crops were also collected from control farmland irrigated with fresh water. The analyses of heavy metals (Cr, Cu, Cd, Zn, Co, Fe, Pb, and Mn) concentrations were carried out with an Atomic Absorption Spectrophotometer (AAS). The concentrations of the heavy metals in irrigation water was found to be higher than the FAO guideline values with the exception of Fe and Pb which were found to be below the FAO guideline values. All irrigation water samples were also found to have higher metals level in comparison with the levels found in control sample with the exception of Pb. The crops irrigated with the polluted irrigation water were found to be unfit for human consumption. The high concentration of these heavy metals in the irrigated crops was directly attributed to the metals in the irrigation water as the control crops sample shows low or no heavy metals concentration. It is recommended that the source of food and vegetables consumed in the area should be checked so as to avoid food and vegetables irrigated with polluted water. The consumers should also eat foods that are rich in antioxidants like selenium, vitamin C, E, and beta carotene, since they depend against heavy metals in the food chain. The farmers should also be made aware of the dangers involved and encourage them to grow crops that are less susceptible to heavy metals uptake.*

KEYWORDS: *Heavy Metals, Industrial Pollution, Irrigated Crops, Kano*.

I. INTRODUCTION

The increasing industrial manufacturing at large scale is now being parallel with a corresponding challenge of waste management and disposal even in developing countries. Thus the hitherto clean, fresh and safe ecological setting is today exposed to the hazard of environmental pollution which has a potential of deleterious effect to both plants and animals. An irrigation activity that is gradually gaining recognition is the one being practiced under the urban and peri-urban agriculture (UPA). The system involves the use of stream water to irrigate lands at the banks with the objective of producing fruits and vegetables for the consumption of city dwellers [1]. The heavy metals pollution of Rivers affects on the irrigation water quality along the river, as well as crops irrigated with it. The irrigated crops may take-up these heavy metals and consequently, introduce them into food chain, resulting to gradual accumulation in the humans, and thereafter, present health hazard.

Studies ([2], [3]) have shown that intake of trace metals from dietary sources may represent a significant exposure pathway for human populations. However, dietary exposure to trace metals is highly variable. For example, [4] has observed that for Cd, the principal exposure route for the general population is through uptake by food plants. Where metal concentrations in crops exceed the limits, it may be possible to use this produce in animal feeds in order to minimize the effect upon the human diet. However, animals fed on a metal-enriched diet may have elevated concentrations of these metals in their tissues and milk. Reference [3] has noted that regular consumption of metal-enriched animal products may lead to adverse health effects in humans. Furthermore, [5] have observed that the greatest degree of metal accumulation occurs in offal, such as livers and kidneys.

In vegetables, contaminants as well as micronutrients generally accumulate in the outer skin layer (peel). Reference [6], for example, found that total As and Cu in carrot peel was approximately 2 times and 2.5 times respectively greater than in the core of the carrot. Higher Cd concentrations were also found in potato peel than in the potato tuber [7]. Other findings in India [8] have shown that Cd, Pb and Zn levels in important vegetables like spinach, beet, cauliflower and radish regularly exceed acceptable limits set by the Government of India posing food safety threat to urban consumers using products for home consumption.

Reference [9] presented an overview of knowledge on heavy metal phytotoxicity to plants in Australian environment. From the overview, it became evident that metal concentrations at which plants showed phytotoxicity were dependent on a number of factors that included soil type, plant type, soil properties and the bioavailable metal concentrations. Different soils may have the same total metal concentrations but remarkably different effect on plant metal uptake and potential for metal phytotoxicity. This suggested that total metal concentration may not be appropriate and sensitive indicator for phytotoxicity.

Reference [10] investigated alfalfa plants grown in soil at different growth stages using separate batches of Cr (VI) at 100 mg/L, and Cd(II), Cu(II), Ni(II), or Zn(II) at 500mg/L. Four days after germination, all metals, except Zn (II), had lethal effects on the seedlings. When applied 16 days after germination, Cr(VI) and Ni(II) still had lethal effects on the seedlings and Cd(II) and Cu(II) destroyed more than 50% of the plant population. While approximately 90% of the plants exposed to Cd(II), Cu(II) and Zn(II) were able to grow without apparent negative effects 20 days after germination, Cr (VI) and Ni(II) still showed lethal effects. These results demonstrated that the tolerance of alfalfa plants to Cd, Cu and Zn was positively correlated with the age of the plants. Thus, alfalfa seedlings tolerated Zn(II) at 500 mg/l at the growth stage of 4 days after germination. Alfalfa plant could be considered potentially feasible to be transplanted in uncontaminated soils where the concentrations of Cd, Cu or Zn are high enough to interfere with alfalfa seed germination.

Reference [11] concluded that heavy metals are largely transported apoplastically in plant tissue. To be able to reach the xylem vessels of the roots, the metals have to cross the endodermis and the suberinized casparian strips. Consequently, most of the metal uptake is performed by the younger parts of the roots where the casparian strips are not yet fully developed. Studies ([12], [13]) have also shown that the translocation of metals to the shoot is performed in the xylem and is promoted by transpiration of water via leaves. A young plant, however, has a small ratio of shoot-to-root mass and in such plants the root pressure determines the translocation of xylem sap to the shoot. Translocation is also promoted for some metal ions by cation exchange at the negative charges of the xylem vessel walls.

Reference [8] have studied the soil to plant transfer of some heavy metals (arsenic, copper, lead, thallium and zinc) by vegetables bean (phaseolus vulgaris L. and dwarf bean), kohlrabi (Brassica oleracea var. gongylodes L.), mangold (Beta vulgaris var. macrorhiza), lettuce (Lactuca sativa L. 'American gathering brown'), carrot (Daucus carota L.'Rotin', Sperlings's), and celery [Apium graveiolus var. dulce (Mill.) Pers.] from a control soil (Ap horizon of an Entisol) and from a contaminated soil (1:1 soil-slag mixtures). The transfer coefficients for plant uptake of As, Cu, Pb, and Zn from soils contaminated by two slags were considerably smaller compared with an uncontaminated soil. The results revealed that for a given type of slag and a given metal, not only the concentration ratios, but also the relative availability of a metal in the slag for plant uptake with respect to its uptake from a control soil depended strongly on the plant species. Thallium from both types of slags was more available for plant uptake by kohlrabi, carrots, and celery than soil-borne TI. For several vegetables, however, the availability for root uptake from slag with respect to the control soil was reduced by the same factor. The results thus demonstrated that the factor by which the metal uptake of a plant from slag is decreased (or increased) with respect to an uncontaminated soil could be plant specific, suggesting that some plants are able to mobilize the metals in the slag to a higher extent. Thus, plant-specific effects for metal mobilization might therefore be a cause for a moderate success of estimation in the laboratory for the availability of a metal for plant uptake from solid contaminant by leaching tests with extractants.

In this study, the transfer of heavy metals in to crops that are irrigated with the effluent polluted waters along River Tatsawarki in Kano, Nigeria was examined. The level of heavy metals in crops irrigated along the river bank was determined and compared with the level of heavy metals obtained in the control crops irrigated away from the river bank. The results were also compared with the standards acceptable limits set by the Food and Agricultural Organization (FAO). The research was conducted in the dry season, as it represents the worst condition, when the river bears low flow with high concentration of pollutants.

II. MATERIALS AND METHODS

II.1 Project Area and Sampling Locations

The project area lies in the Southern part of Kano within the Kano River basin. The river basin drains the southern part of Kano metropolis, including two of the largest industrial estates of Challawa and Sharada which also discharges mostly untreated effluents within the basin. Rivers Tatsawarki collects the entire domestic and industrial wastes from the southern part of the metropolis and discharges into the Challawa River, just before its confluence point with the Kano River [14]. The basin, besides being the main source of water for metropolitan Kano, is also extensively being used for irrigation of vegetable crops.

Three irrigation areas were selected at Magami village (M-Upstream); Gidan Kwanso village (G- Midstream) just before the confluence with the effluent channel from the nearby Tamburawa Water Works; and Tsafe (T-Downstream) just before the discharge point in to River Challawa (Figure 1). The control farmland was located at Kwarin Matage village, away from the river bank and uses fresh surface and ground waters.

II.2 Surface and Ground Water Sampling

Surface water samples were collected from the three different points along the River. Sample S1: at the beginning of the project area; Sample S2: before its confluence with the waste water channel from Tamburawa water works, and Sample S3: before its confluence with River Challawa (Fig. 1). Ground water samples were also collected from farmlands located in the three areas (G1, G2, and G3). Control surface and ground water samples were collected from farmlands located away from away from the river.

Sample collection was done as described by the Department of waters affairs and forestry Pretoria (SA) [15]. The sample label, zone and time and date of collection, place of collection and pH were recorded at the site of collection. Two litres (2L) polyethylene bottles, after being thoroughly washed with detergent, rinsed with water and then distilled water and then soaked in 5% HNO_3 for 24 hours were used for collection of the water samples. The samples are preserved using 1-2 ml of concentrated HNO_3 in order to get a required pH of 2.2 to 2.8. The samples were refrigerated in order to stabilize the metal before analyzing.

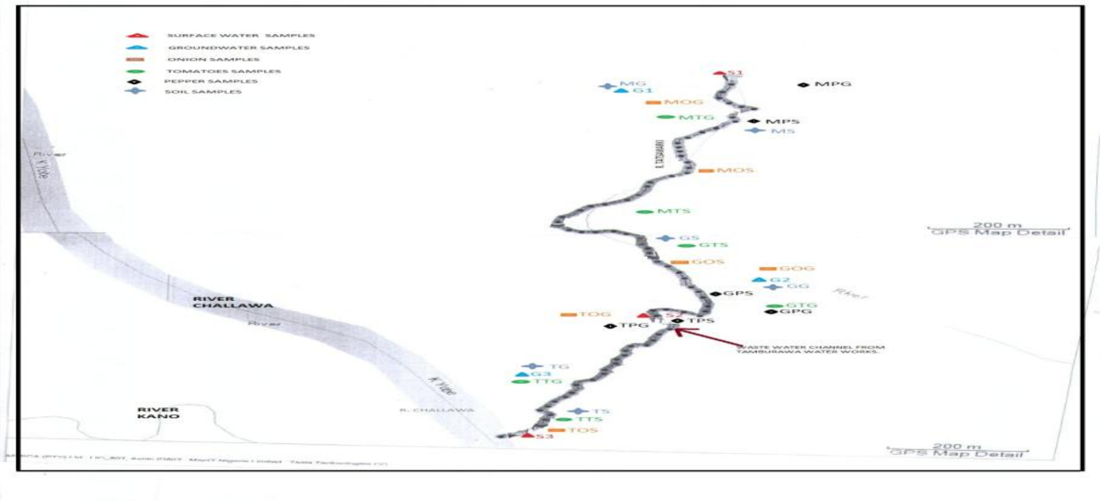

Figure 1: Location of Sampling Points

II.3 Sampling of Vegetable Crops

Three crops (tomatoes, onions, and pepper) that are normally irrigated along the river bank were selected. The sample crops were collected from the three irrigated farmlands along the river banks (Figure 1). Each of the three crops was collected from each of the farmlands irrigated with surface water (TMS, TGS, and TTS for Tomatoes; OMS, OGS, and OTS for Onions; PMS, PGS, and PTS for Pepper); as well as from each of the farmlands irrigated with ground water (TMG, TGG, and TTG for Tomatoes; OMG, OGG, and OTG for Onions; PMG, PGG, and PTG for Pepper). Sample crops were also collected from control farmland irrigated with fresh water. The sampling was done using the procedure described by the Department of waters affairs and forestry Pretoria (SA) [15].

II.4 Analysis of Heavy Metals

2.4.1 Pre-treatment of Samples for Analysis of Metals in Water Samples: The open-beaker digestion (OBD) method was employed using HNO_3 as described in [16] for the chemical analysis of water samples. 50ml of the water samples was measured into a beaker and 10ml HNO_3 was added. The beaker and the content were placed on a hot plate and digested until the brown fumes of HNO_3 escaped. The heating continued until the content reduced to 10ml; the content was then washed into a 50ml volumetric flask and made up to the mark. The digest obtained was subjected to determination of the metals.

2.4.2 Pre-treatment of Samples for Analysis of Metals in Vegetable Samples: The plant samples were thoroughly washed, rinsed with tap water and then with double-distilled water to remove any attached soil particles. It was then cut into small portions and placed in a large crucible where they were oven dried at 60˚C overnight. The dried plant was then grounded into fine particles using a clean mortar and pestle.

The triacid method of digestion was employed. The acids that were used are Nitric acid (HNO_3), Perchloric acid ($HClO_4$) and concentrated sulphuric acid (H_2SO_4) in the ratio of 65:8:2 respectively. 0.2g of the powdered crop sample was weighed into a 100ml glass beaker. 30ml of the acid mix was added and the content swirled and placed on a hot plate. The beaker was heated until the brown fumes of the nitric acid went off; and the heating continued till the content of the beaker reduced to about 5ml. The content was then allowed to cool and a little amount of distilled water added and the beaker swirled again. The content was then poured into 50ml volumetric flask and made up to the required mark. The digest obtained was used for the determination of the metals.

2.4.3 Determination of Heavy Metals: The measurement of heavy metal concentrations were carried out with an Atomic Absorption Spectrophotometer (AAS). All concentrations were determined using the absorbance made with air-acetylene flame. Eight working solutions were prepared from the stock solutions for each of the metals (Cr, Cu, Cd, Zn, Co, Fe, Pb, and Mn) by successive serial dilution and each of the standard solutions was then aspirated into the flame of AAS and the absorbance recorded in each case. A plot of the concentration against the corresponding absorbance gives the calibration curve of each metals. The samples were aspirated into the flame and the absorbance obtained. The values were then extrapolated from the calibration plot to obtain the corresponding concentration.

III. RESULTS AND DISCUSSIONS

The results of the analysis of heavy metal concentration in irrigation waters are presented in Table 1, together with the limiting FAO values [17]. The concentrations of heavy metals in the irrigated crops are presented in Tables 2, 3, and 4 for tomatoes, onions, and pepper respectively. The results are discussed according to each of the heavy metals analyzed.

Table 1: Concentrations of Heavy Metals in Surface and Ground Waters used for Irrigation

S/No	Parameters	FAO [17] Guideline for irrigation water	Surface Water					Ground Water				
			Control Sample	S1	S2	S3	Aver-age	Control Sample	G1	G2	G3	Aver-age
1	Chromium (mg/l)	0.1	0.8	8.8	8.5	9.1	8.8	0.8	4.0	4.0	2.0	3.3
2	Copper (mg/l)	0.2	1.2	4.7	4.7	5.3	4.9	1.2	1.3	1.3	2.7	1.8
3	Cadmium (mg/l)	0.01	4.1	17.0	12.2	12.0	13.7	4.1	9.0	8.0	15.0	10.7
4	Zinc (mg/l)	2.0	2.0	11.4	10.3	9.6	10.4	2.0	5.0	5.5	6.8	5.8
5	Cobalt (mg/l)	0.05	0.5	1.9	1.8	1.9	1.9	0.5	1.0	1.0	0.8	0.9
6	Iron (mg/l)	5.0	1.0	0.7	0.9	1.5	1.0	1.0	2.0	1.0	1.5	1.5
7	Lead (mg/l)	5.0	1.9	1.4	1.1	1.4	1.3	1.9	1.4	1.0	1.9	1.4
8	Manganese (mg/l)	0.2	0.9	2.5	3.2	3.5	3.1	0.9	5.0	2.5	3.0	3.5

S1 – Samples collected at point A (upstream)
S2 – Samples collected at point B (midstream)
S3 – Samples collected at point C (downstream)
G1 – Samples collected at Magami Irrigated farmlands
G2 – Samples collected at Gidan-kwanso irrigated farmlands
G3 – Samples collected at Tsafe irrigated farmlands

Table2: Concentrations of Heavy Metals in Tomatoes

SN		PARAMETERS (ppm)							
		Pb	Cr	Cd	Fe	Mn	Co	Zn	Cu
	Control Tomato	**1.3**	**0.4**	**0.4**	**1.2**	**0.9**	**0.0**	**2.3**	**1.6**
1	Sample TMS	1.0	3.6	2.0	1.3	1.5	0.8	7.6	3.0
2	Sample TGS	0.9	1.8	1.4	1.2	2.5	0.8	5.0	3.3
3	Sample TTS	1.1	3.6	1.6	1.3	2.0	0.8	9.0	4.8
	Average	**1.0**	**3.0**	**1.7**	**1.3**	**2.0**	**0.8**	**7.2**	**3.7**
1	Sample TMG	1.4	2.0	1.0	1.5	2.0	0.7	5.6	2.0
2	Sample TGG	0.5	2.2	1.2	1.7	2.8	0.8	6.8	2.1
3	Sample TTG	1.0	2.0	0.5	1.6	3.0	0.4	7.6	2.3
	Average	**1.0**	**2.1**	**0.9**	**1.6**	**2.6**	**0.6**	**6.7**	**2.1**

TMS – Tomato crop – Magami – Surface water irrigated
TGS – Tomato crop – G/kwanso – Surface water irrigated
TTS – Tomato crop – Tsafe – Surface water irrigated
TMG – Tomato crop – Magami – Groundwater irrigated
TGG – Tomato crop – G/kwanso – Groundwater irrigated
TTG – Tomato crop – Tsafe – Groundwater irrigated

Table 3: Concentrations of Heavy Metals in Onions

SN		PARAMETERS (ppm)							
		Pb	Cr	Cd	Fe	Mn	Co	Zn	Cu
	Control Onion	**1.6**	**0.3**	**0.2**	**1.0**	**1.2**	**0.2**	**3.3**	**1.2**
1	Sample OMS	1.0	2.0	2.0	1.0	2.5	1.0	9.1	3.1
2	Sample OGS	1.2	2.0	0.9	1.0	1.2	0.6	7.0	2.7
3	Sample OTS	1.4	1.8	0.0	0.9	3.5	0.7	7.0	2.9
	Average	**1.2**	**1.9**	**1.0**	**1.0**	**2.4**	**0.8**	**7.7**	**2.9**
1	Sample OMG	1.0	1.8	2.0	1.5	5.0	0.4	5.5	2.0
2	Sample OGG	2.4	2.0	1.0	1.5	3.2	0.4	7.0	1.9
3	Sample OTG	0.5	1.4	0.0	1.5	3.1	0.4	9.2	2.2
	Average	**1.3**	**1.7**	**1.0**	**1.5**	**3.8**	**0.4**	**7.2**	**2.0**

OMS – Onion crop – Magami – Surface water irrigated
OGS – Onion crop – G/kwanso – Surface water irrigated
OTS – Onion crop – Tsafe – Surface water irrigated
OMG – Onion crop – Magami – Groundwater irrigated
OGG – Onion crop – G/kwanso – Groundwater irrigated
OTG – Onion crop – Tsafe – Groundwater irrigated

Table 4: Concentrations of Heavy Metals in Pepper

SN		PARAMETERS (ppm)

		Pb	Cr	Cd	Fe	Mn	Co	Zn	Cu
	Control Pepper	**1.1**	**0.1**	**0.0**	**0.7**	**0.9**	**0.0**	**2.3**	**1.2**
1	Sample PMS	1.0	4.5	0.3	1.5	2.1	1.0	6.0	4.3
2	Sample PGS	0.8	2.3	0.1	1.5	1.2	0.8	6.2	1.8
3	Sample PTS	1.1	2.2	0.2	1.0	1.8	0.9	5.2	2.0
	Average	**1.0**	**3.0**	**0.2**	**1.2**	**1.7**	**0.9**	**5.8**	**2.7**
1	Sample PMG	1.0	2.0	0.0	2.0	2.5	0.8	6.0	1.6
2	Sample PGG	1.0	2.0	0.0	1.4	5.0	0.9	5.8	1.3
3	Sample PTG	1.2	3.6	0.0	1.4	5.5	0.8	7.1	1.9
	Average	**1.0**	**2.5**	**0.0**	**1.6**	**3.3**	**0.8**	**6.3**	**1.8**

PMS – Pepper crop – Magami – Surface water irrigated
PGS – Pepper crop – G/kwanso – Surface water irrigated
PTS – Pepper crop – Tsafe – Surface water irrigated
PMG – Pepper crop – Magami – Groundwater irrigated
PGG – Pepper crop – G/kwanso – Groundwater irrigated
PTG – Pepper crop – Tsafe – Groundwater irrigated

III.1 Chromium, Cr

The concentration of chromium in the crops irrigated along river Tatsawarki was in the range of 1.8ppm – 4.5ppm, with pepper exhibiting a highest average concentration of 3.0ppm for surface water irrigated pepper and an average concentration value of 2.5ppm by that irrigated with groundwater, while the control pepper crop exhibit chromium concentration of 0.1ppm (Table 4). The concentration of chromium in tomatoes was 3.0ppm on average by surface water irrigated tomatoes and 2.1ppm on average by that irrigated with ground water, while the control tomato crop shows a concentration value of 0.4ppm (Table 2). The chromium concentration in onions irrigated with surface water shows 1.9ppm on average and an average concentration of 1.7ppm for groundwater irrigated onions, while the control onion crop exhibits a concentration of 0.3ppm (Table 3). All the crops show higher chromium contents than the FAO limiting values.

III.2 Copper, Cu

The concentration of the metal copper in the crops samples was in the range of 1.2ppm – 4.8ppm, with tomatoes exhibiting a higher average concentration of 3.7ppm for surface water irrigated tomato and 2.1ppm average for groundwater irrigated tomatoes, while the control tomatoes exhibits a copper concentration of 1.6ppm (Table 2). The concentration of copper in onions irrigated along river Tatsawarki exhibits an average concentration of 2.9ppm for onions irrigated with surface water and 2.0ppm for that irrigated with groundwater, while the control onion was found to have a concentration of 1.2ppm (Table 3). The concentration of copper in pepper samples were found to be 2.7ppm on average for pepper irrigated with surface water and 1.8ppm for pepper irrigated with groundwater, while the control pepper crop shows a concentration value of 1.2ppm (Table 4). The copper concentration in all the crops exceeded the FAO limiting concentrations.

III.3 Iron, Fe

The concentration of iron obtained in the crops irrigated in the research area was in the range of 0.9ppm – 2.0ppm. The concentration of iron was higher in tomatoes which exhibit an average concentration of 1.6ppm by tomatoes irrigated with groundwater and 1.3ppm by that irrigated with surface water, while the control tomato crop exhibits a concentration of 1.2ppm (Table 2). The concentration of iron in pepper was higher than the concentration obtained in onions, as the concentration was found to be 1.6ppm on average for pepper irrigated with groundwater and an average concentration of 1.2ppm for that irrigated with surface water, while the control pepper exhibit a concentration value of 1.0ppm (Table 4). The concentration of iron in the onion crops shows slightly lower value than the value obtained in pepper crops as the concentration was found to be 1.5ppm on average for ground water irrigated onions and an average concentration of 1.0ppm for onions irrigated with surface water, while the concentration of iron in the control sample was 1.0ppm (Table 3). The higher concentration of iron in the crops irrigated with groundwater can be attributed to the higher concentration of iron exhibited by the groundwater more than the surface water (Table 1). All the crops contain lower iron concentrations than the minimum limiting concentrations set by the FAO.

III.4 Manganese, Mn

The concentration of manganese in the crops irrigated in the three irrigated farmlands was found to be in the range of 1.2ppm – 5.5ppm. Onions exhibits the highest concentration of manganese with an average value of 3.8ppm on onions irrigated with groundwater and 2.4ppm on that irrigated with surface water, while the control onion exhibits a concentration of 1.2ppm (Table 3). The manganese concentration in pepper shows a higher value than that observed in tomatoes with an average concentration of 3.3ppm on pepper irrigated with groundwater and 1.7ppm average on that irrigated with surface water, while the concentration of 0.9ppm was observed in the control pepper (Table 4). The average concentration of manganese in tomatoes was found to be 2.6ppm on crops irrigated with groundwater and 2.0ppm on crops irrigated with surface water, while the control tomatoes exhibits a concentration of 0.9ppm. The higher concentration of manganese in the crops irrigated with groundwater can also be attributed to the higher concentration of manganese exhibited by the groundwater more than the surface water (Table 1). The manganese concentrations in all the crops exceeded the FAO limiting values.

III.5 Led, Pb

The concentration of lead in the crops samples in the research area was within the range of 0.5ppm – 2.4ppm. The concentration of the metal in onions was found to be higher than the other vegetables and was found to be 1.3ppm average in crops irrigated with groundwater and 1.2ppm average in that irrigated with surface water, while the control onions exhibit a concentration value of 1.6ppm, higher than the average value obtained in the test samples (Table 3). The concentration of lead obtained in tomatoes was lower than the value obtained in onions and slightly higher than the value obtained in pepper with an average lead concentration of 1.0ppm for both surface and groundwater irrigated crop samples, while the control exhibit a higher lead concentration of 1.3ppm (tables 2 and 3). The concentration of the metal in pepper was of the value 1.0ppm on average for pepper irrigated with surface water and an average value of 0.8ppm in pepper irrigated with groundwater, while the control sample shows a concentration value of 1.1ppm (Table 4). The high lead concentration observed in all control samples can be directly related to the high lead content observed in the control irrigation water as well as high lead concentration in the soil on which the control samples were grown. The lead concentrations in all the samples indicated lower values than the FAO limiting values.

III.6 Zinc, Zn

The concentration of the metal zinc in the crops samples were found to be in the range of 5.0ppm – 9.1ppm, with onions exhibiting a higher average concentration of 7.7ppm for surface water irrigated onions and 7.2ppm average for groundwater irrigated onions, while the control onions exhibits a zinc concentration of 3.3ppm (Table 3). The concentration of Zinc in tomatoes irrigated along river Tatsawarki exhibits an average concentration of 7.2ppm for tomatoes irrigated with surface water and 6.7ppm for that irrigated with groundwater, while the control tomatoes was found to have a zinc concentration of 2.3ppm (Table 2). The concentration of copper in pepper samples was 5.8ppm on average for pepper irrigated with surface water and 6.3ppm for pepper irrigated with groundwater (Table 4), while the control pepper crop was having a concentration value of 2.3ppm. All the crop samples indicated higher Zinc concentrations than the FAO limiting values.

III.7 Cobalt, Co

The concentration of cobalt in the crops irrigated along river Tatsawarki was in the range of 0.4ppm – 1.0ppm, with pepper exhibiting a slightly higher average concentration of 0.9ppm for surface water irrigated pepper than the average concentration value of 0.8ppm shown by that irrigated with groundwater, while in the control pepper crops no cobalt was found (Table 4). The concentration of cobalt in tomatoes was found to be 0.8ppm on average by surface water irrigated tomatoes and 0.6ppm on average by that irrigated with groundwater, while the control tomato crop was found to have no cobalt in it (Table 2). The cobalt concentration in onions irrigated with surface water was 0.8ppm on average and an average concentration of 0.4ppm for groundwater irrigated onions, while the control onion crop exhibits a concentration of 0.2ppm (Table 3). All the experimental samples indicated higher Cobalt concentrations than the limiting values set by FAO.

III.8 Cadmium, Cd

The concentration of cadmium in the crops irrigated along river Tatsawarki was in the range of 0.0ppm – 2.0ppm, with tomatoes exhibiting a higher average concentration of 1.7ppm for surface water irrigated tomatoes and an average concentration value of 0.9ppm by that irrigated with groundwater, while the control tomatoes crop exhibit cadmium concentration of 0.4ppm (Table 2). The concentration of cadmium in onions was found to be 1.0ppm on average by both surface and groundwater irrigated onions, while the control onion crop was found to have a cadmium concentration value of 0.2ppm (Table 3). The cadmium concentration in pepper irrigated with surface water shows 0.2ppm on average while the groundwater irrigated pepper and the control pepper were found to have no cadmium in them (Table 4). The ground and surface water samples indicated higher Cadmium contents than the FAO limiting values. Higher values were also observed in all the onion and tomato samples as well as pepper samples irrigated with surface water. Only the pepper samples irrigated with the ground water and the control pepper samples show no cadmium contents.

IV. CONCLUSION

The concentrations of the heavy metals in irrigation water was found to be higher than the FAO guideline values with the exception of Fe and Pb which were found to be below the FAO guideline values. This is thus unfit for irrigation. All irrigation water samples were also found to have higher metals level in comparison with the levels obtained in control sample with the exception of Pb. The crops irrigated with the polluted irrigation water were found to be unfit for human consumption as they contain some of these metals in high concentrations. The high concentration of these heavy metals obtained in the irrigated crops is directly attributed to the metals in the irrigation water as the control crops sample shows low or no heavy metals concentration.

As an interim measure, the source of food and vegetables in the affected communities should be regularly checked so as to avoid food and vegetables irrigated with polluted water since the linkage between crops heavy metals content and heavy metals in irrigation water has been established. The communities should also eat foods that are rich in antioxidants like selenium, vitamin C, E, and beta carotene, since they depend against heavy metals as these food crops may end up in the food chain. Awareness should be created among the farmers about the dangers involved and they should be encouraged to grow crops that are less susceptible to heavy metals uptake. The authorities and other stakeholders should device means of and methods to clean the irrigation soils and water off the heavy metals, and the discharges of untreated effluents in to the river system controlled.

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