BRILL

Studies on soil physico-chemical properties and biochemical composition of selected vegetables collected from locally irrigated farmland with municipal wastewater in Minna, Niger State, Nigeria

Aishatu A. Gado[a,*], Ibrahim A. Salihu[a], Muhammad A.I. Audu[a], Alhaji L. Abubakar[b], Yusuf O.A. Daudu[a] and Muhammad A. Salihu[c]

[a] Department of Plant Biology, School of Life Sciences, Federal University of Technology Minna, P.M.B. 65, Niger State, Nigeria
[b] Department of Food Technology, Federal College of Freshwater Fisheries Technology, P.M.B. 1500, New-Bussa, Niger State, Nigeria
[c] Department of Chemical and Pharmaceutical, Energy Fuels and Mineral Division, Raw Materials Research and Development Council, Abuja, Nigeria
*Corresponding author; e-mail: gado.aishatu@futminna.edu.ng
ORCID iDs: Gado: 0000-0002-2933-1546; I. A. Salihu: 0000-0002-7981-9136; Audu: 0000-0003-4063-1336;
Daudu: 0000-0001-5134-7897; M. A. Salihu: 0000-0002-6062-6609

ABSTRACT

Vegetables have become an indispensable part of human nutrition. This study aimed at analyzing the biochemical compositions of three leafy vegetables (*Corchuorus olitorius, Telfairia occidentalis and Spinacia oleracea*) collected from local farm irrigated with municipal wastewater. The biochemical parameters were assayed following standard laboratory protocols. Results revealed significantly ($P < 0.05$) higher Ca (207.33 mg/kg) and Mg (182.53 mg/kg) contents in wastewater with Mg contents in both clean water (72.80 mg/kg) and wastewater (182.53 mg/kg) exceeding the FAO safe limits. The wastewater had significantly ($P < 0.05$) higher (Fe) and (Cd) contents (1.72 and 0.42 mg/kg), than clean water from the modern farm (0.67 and 0.13 mg/kg). Both water samples had heavy metals, exceeding the FAO safe limits. The Mn, Fe and Pb contents determined in the three vegetables collected from both farms were within FAO safe limits except Cd content which ranged from 0.05–0.87 mg/kg which is above FAO acceptable limits of 0.02 mg/kg. Results on mineral composition revealed significantly higher ($P < 0.05$) Na, K, Ca and Mg contents in the three vegetables collected from the local farm, *Telfairia occidentalis* having the highest Na (123.33 mg/kg), K (6500 mg/kg) and P (6.19 mg/kg) while, *Corchuorus olitorius* had the highest Ca (2.15 mg/kg) and Mg (2.12 mg/kg). The result of this study shows that municipal wastewater irrigation could be utilized in improving the mineral compositions of leafy vegetables. However, it is highly recommended that the wastewater is treated properly to avoid heavy metal contamination.

ARTICLE HISTORY
Received 3 August 2022
Accepted 28 May 2023
Published online
22 June 2023
Published in issue
24 November 2023

KEYWORDS
Biochemical; heavy metals; irrigation; vegetables and wastewater

Introduction

Vegetables are a group of crops that are an important part of the human diet as they provide minerals, proteins and fats, and are an economical source of energy (Naz *et al*., 2018). They are consumed by all categories of people and can be eaten raw or processed (Inyinbor *et al*., 2019). Globally, vegetables play a salient role in meeting the food requirement of people because they are important sources of various essential elements. In addition, they also provide sustainable incomes to peri-urban, urban and rural communities (Mwadzingeni *et al*., 2021). The presence of various phytochemical compounds in vegetables accounts for their beneficial health properties (Kurina *et al*., 2021). As a result of their nutritional significance and valuable health effects, the consumption of green leafy vegetables has increased in recent years and has led to a continuous upsurge in the demand for vegetables. Thus, there is a need to cultivate the crops all year round (Olumakinde *et al*., 2019). This has in turn led to a great dependence on other sources of water for irrigation during periods of drought or long dry seasons.

According to Habu *et al*. (2021), most local farmers often utilize wastewater in irrigating vegetables as a result of water scarcity. Wastewater is generated throughout the year (Hsien *et al.*, 2019) and its use in irrigation has been an old-age practice (Xavier and Varghese, 2020). It has several advantages which include

Published with license by Koninklijke Brill NV | doi: 10.1163/22238980-bja10082
| ISSN: 0792-9978 (print) 2223-8980 (online)

increasing soil organic matter content (Makhadem *et al.*, 2021), reducing fertilizer requirements and adding various amounts of elements such as Na, Ca, and Mg to the soil (Singh, 2021). However, wastewater may also contain various potentially toxic elements and organic matter with highly harmful effects on humans and generally in the ecosystem. Wastewater contains cyanide (CN^-) and heavy metal ions such as iron (Fe^{2+}), chromium (Cr^{3+}), nickel (Ni^{3+}), zinc (Zn^{2+}), lead (Pb^{2+}), copper (Cu^{2+}) and manganese (Mn^{2+}) (Olumakinde *et al.*, 2019).

According to Ghori *et al.* (2019), heavy metal toxicity is the most common stress living organisms encounter in different ecosystems. Excessive accumulation of heavy metals in plant organs inhibits their growth and productivity (Hananingtyas *et al.*, 2022) and could pose damages at both cellular and organismal levels and are detrimental even at low concentrations. Heavy metals accumulation in plants shows phytotoxic effects on plants which result in reduced nutrient uptake and yield reductions and could also have adverse effects as they cause chemical and physiological alterations which change or interferes with the active component or secondary metabolites levels, especially in medicinal plants (Shen *et al.*, 2020).

The use of wastewater on agricultural soils deposits a large number of heavy metals on the soil which have an antagonistic effect on crop growth rate (Munir *et al.*, 2022). These heavy metals not only pollute the soil but also deteriorate food quality and safety when vegetables and other food crops are grown on these soils (Naz *et al.*, 2018). Intake of vegetables grown on heavy metals contaminated soil has been one of the most common food chain routes for exposure of humans to heavy metals (Habu *et al.*, 2021), others being inhalation and skin application (Sanaei *et al.*, 2021). These heavy metals cause deleterious effects on human health (Rizk *et al.*, 2022).

Although much research has been conducted on the use of wastewater for irrigation farming of vegetables in Nigeria, in north-central Nigeria, this group of vegetables that are highly nutritive and of great medicinal significance has not received any research attention. This research, thus, investigated the Physico-chemical parameters of soil and the biochemical compositions of three vegetables {*Corchuorus olitorius* (Jute), *Spinacia oleracea* (Spinach) and *Telfairia occidentalis* (Fluted pumpkin)} collected from a local farm irrigated with municipal wastewater.

Materials and methods

Study area

Three (3) vegetable samples were collected from a local irrigation farm, Sauken Gwari along Mandela road, Minna, Niger state, Nigeria (15° N 9°37′13″ N 6° 34′1″ E) on 28th April 2021 while the control was collected from a modern irrigation farm (Al-Amin farm), Maitumbi Area, Minna, Niger state, Nigeria (152° SE 9°33′60″ N 6°33′4″ E) on 21st May 2021 (Fig. 1).

Sample collection

Soil, vegetables and water samples were collected from Mandela local farm and Al-Amin modern farm which were about 2.5 km apart. Both farms have the same soil type and irrigation pattern. Eighteen (18) soil samples were randomly collected, nine (9) from each farm at a depth of 15 cm after uprooting the vegetables. Fifteen (15) leaf samples were collected for each vegetable type from the two farms during the dry season and were noted for dry season farming, which gave a total of ninety (90) samples. The collected leaf samples were taken from the mid-growth flowering of the youngest mature plant. The samples were air-dried ground using a mortar and pestle.

Identification of vegetables

The vegetable samples collected were taken to the herbarium of the Department of Plant Biology, Federal University of Technology Minna, Nigeria for identification and authentication. The vegetables were identified as *Corchuorus olitorius* (Jute), *Spinacia oleracea* (Spinach) and *Telfairia occidentalis* (Fluted pumpkin) with voucher's number FUT/PLB/MAL/005, FUT/PLB/AMA/002 and FUT/PLB/CUC/003, respectively.

Water sample analyses

The municipal wastewater from the Sauken Gwari (Lamnu) was collected in a sample bottle and a clean water sample for irrigation was also collected from Al-Amin farms in a sample bottle. The water samples were collected in triplicate and were conveyed to Usman

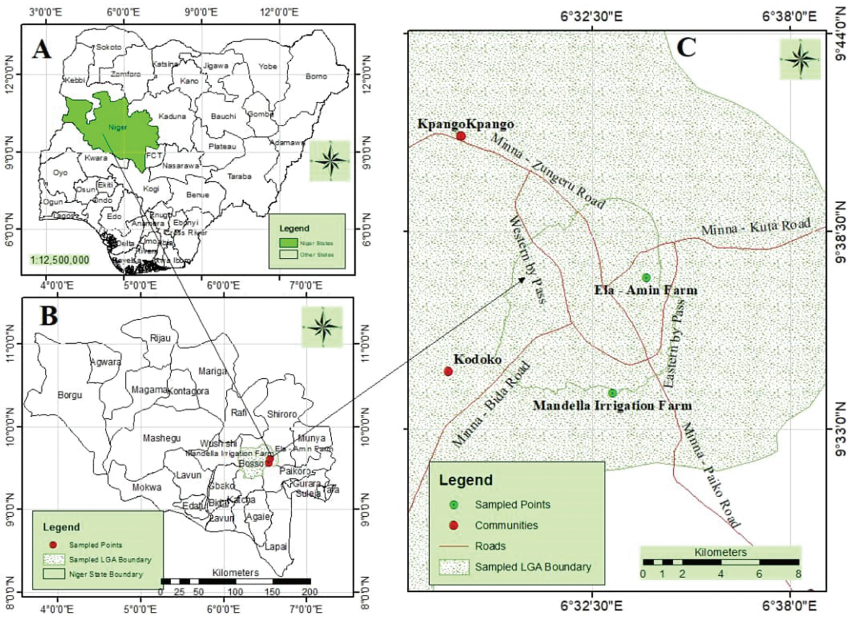

Figure 1. Map of Sauken Gwari along Mandela road, Minna, Niger state, Nigeria and Al-Amin farm, Maitumbi Area, Minna, Niger state, Nigeria.

Danfodio University Sokoto, Sokoto State, Nigeria for physicochemical analyses.

Chemical composition of water

Temperature

The air and water temperatures were taken from both farms in degrees centigrade using a mercury glass bulb thermometer (0–110°C). Readings were taken at the level of the eye meniscus. The air temperature was determined by holding the thermometer above water for exactly 2 minutes until it stabilized before reading following the standard procedures of EPA (2002). The water temperature was determined by lowering the thermometer into the water and the reading was taken, when established, following the method of EPA (2002).

Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH

These were determined according to APHA (2014) using a pre-calibrated microprocessor pH/EC/TDS. The pre-calibrated pH, TDS and conductivity meter electrode was washed out using distilled water and the cell constant of the conductivity meter was checked. The electrode meter was dipped inside the water and left for about 10 seconds. The Electrical Conductivity (EC), Total Dissolved Solid (TDS) and pH readings were obtained from the microprocessor meter. The process was repeated thrice for both water samples.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) was determined using a portable dissolved oxygen analyzer (APHA, 2014). The DO meter was standardized using distilled water and buffer solution and was placed into the water samples (untreated and clean water) for about 60 seconds, after which the reading was taken from the DO meter. This was repeated in triplicate for all water samples.

Biological Oxygen Demand (BOD)

To determine the biological oxygen demand (OD), the sample bottles were filled with water samples and wrapped with black polythene bags to avoid any form of light penetration and were kept in a dark cupboard. After five (5) days, the procedure was repeated to check the amount of oxygen that has been used up by microorganisms (APHA, 2014).

Total alkalinity

This was determined by titration methods following the method of APHA (2014). The water samples were measured to 50 ml and poured into a clean 150 ml conical flask, and 3 drops of phenolphthalein indicator were added to the water sample. The sample was titrated with 0.05 ml of H_2SO_4, until the colour disappeared.

To the colourless solution, 3 drops of methyl orange indicator were added and titrated further until the colour changed from yellow to permanent reddish or orange-red colour and the titrated values were recorded and used to compute the alkalinity.

Total hardness

The water sample was thoroughly shaken and 25 ml was taken and diluted to 50 ml with distilled water. Exactly two (2) ml of Phosphate buffer solution was added to bring the pH of the water sample to 10. An aliquot of three (3) drops of ferrochrome black indicator was also added. This was titrated with 0.01 Mol/L EDTA to a blue colour endpoint. Hardness was then calculated in line with APHA (2014).

Phosphate-phosphorus (PO_4-P)

This was determined by the colourimetric method following the procedures of APHA (2014). Exactly 2 ml of the water sample was put in a 25 ml volumetric flask and a single drop of phenolphthalein indicator was added followed by 2 ml of ammonium molybdate and 1 ml of freshly diluted stannous chloride solution. These were made up to 25ml volume with distilled water and mixed thoroughly. The colour intensity (absorbance) was measured at a wavelength of 660 nm in a Spectrophotometer (Optima SP 300, UK) after about 5–6 minutes.

Nitrate-Nitrogen (NO_3-N)

To determine the nitrate content, the pH of the water samples was adjusted to approximately 7.0 using acetic acid or sodium hydroxide solution, as appropriate. The samples were filtered and an aliquot of 10 ml of the sample was transferred into a sample tube and 2 ml of 30% sodium chloride (NaCl) solution was added to the sample the contents of the tubes were mixed thoroughly by swirling and the samples were placed in a cold-water bath (0–10°C) for 10 minutes. An aliquot of 10 ml of sulfuric acid solution was added to the sample tubes and 0.5 ml of brucine sulfuric acid reagent was added to each test tube and the test tubes were transferred into a 100°C water bath for 25 minutes. After which the tubes were transferred to a cold-water bath and were allowed to cool. The absorbance of the sample was read at 410 nm using a Spectrophotometer (Optima SP 300, UK) according to EPA (2002).

Determination of heavy metals in water

This was determined following the method of Olafisoye *et al.* (2013). An aliquot of 2.5 ml of concentrated nitric acid (HNO_3) was added to 50 ml of the water samples and digested until a colourless solution was obtained. Insoluble materials were then removed from the digested samples through filtration and the volume was made up to 50 ml with distilled water.

Soil analysis

Cation exchange capacity (CEC) was determined according to Sumner and Miller (1996). The Kjeldahl method (Bremner, 1996) was used to determine total Nitrogen while plant available phosphorus was determined using Olsen *et al*. (1954). Electrical conductivity was measured according to Rhoades (1996). Soil pH was determined according to De-Frees *et al.* (1982). Soil organic matter was determined using the Smith–Weldon method according to Nelson and Sommers (1996). Ammonium acetate buffered at pH7 (Thomas, 1982) was used to determine exchangeable cations. Microelements in the soils were determined by Diethylene Triamine Penta Acetic acid (DTPA) extraction methods (Lindsay and Norwell, 1969).

Determination of heavy metals in soil

Five replicate soil samples each from the modern irrigation farm and local farm irrigated with municipal wastewater were randomly collected for determination of heavy metals using an atomic absorption Spectrophotometer instrument (Optima SP 300, U.) following the methods of Abbruzzini *et al.* (2014). An aliquot of 2 g of soil was taken from each sample, then dissolved in 5 ml HNO3, 0.5 mL HF, and 0.5 ml HCl in a Teflon vessel and was placed in a Microwave Digestion System. The digested samples were then transferred into a Teflon beaker and the volume was completed to 50 mL with de-ionized water. The digested solution was filtered by using 0.45 mm filter paper and stored in 50 mL polypropylene tubes to be analysed.

Sample preparation for heavy metals and nutritional composition analyses

Vegetable samples were prepared for analyses following the method of Akan *et al*. (2009). Vegetable samples collected from local irrigation farm and

Al-Amin farms were thoroughly washed, sliced and air-dried at room temperature (+25°C) for seven (7) days. The dried vegetables were separately pounded with mortar and pestle followed by sieving using and the powdered samples were preserved for further analysis in a refrigerator at 4°C.

Sample digestion

The vegetable samples were digested following the standard procedure of Awofolu (2005). Exactly 0.5 g of sieved dried samples of each vegetable was weighed into a 100 cm^3 beaker and a mixture of 5 cm^3 concentrated HNO_3 and 2 cm^3 $HClO_4$ were added to dissolve the sample. The beaker was heated at a moderate temperature of 110 °C on a hot plate for an hour in a fume hood until the content was about 2 cm^3. The digest was allowed to cool and was filtered into a 50 cm^3 standard volumetric flask and made up to the mark with distilled deionized water.

Heavy metal analysis in vegetables

A serial dilution method was used to prepare the working standards and the concentration of the metals (i.e., Mn, Fe, Pb and Cd) in each sample digest was determined using a spectrophotometer (Optima SP 300, UK) equipped with a digital readout system at Department of Agriculture, Usman Danfodio University Sokoto, Sokoto State, Nigeria.

Nutritional analysis

The vegetable extracts' nutritional composition was carried out per the Association of Official Analytical Chemists (AOAC, 2020) methods.

Data analyses

Data obtained were subjected to an independent sample student t-test to assess significant differences between the means at a 5% level of probability using Statistical Package for Social Sciences (SPSS version 23.0).

Results

Chemical composition of water

The results on the chemical composition of clean water from modern irrigation farm and municipal wastewater from local irrigation farm are presented in Table 1. No statistical ($P > 0.05$) difference was observed in pH, DO, K, Na, P, BOD, CL, NH_4 and NO_3 contents between clean water from modern irrigation farm and municipal wastewater from local irrigation farm. The highest pH, DO, K, Na, BOD, CL, NH_4 and NO_3 values (6.6 mg/kg, 5.2 mg/kg, 1.5 mg/kg, 0.50 mg/kg, 17.3 mg/kg, 4.8 mg/kg, 0.7 mg/kg and 2.4 mg/kg, respectively) were observed in municipal wastewater from local irrigation farm. The highest P content of 0.48 mg/kg for clean water from modern irrigation farm was significantly higher than the 0.22 mg/kg recorded for municipal wastewater from local irrigation farm (Table 1).

The Ca, Mg, CO_3 and HCO_3 contents of 207 mg/kg, 182 mg/kg, 0.33 and 104, respectively, recorded for municipal wastewater from local irrigation farm were significantly ($P < 0.05$) higher than the Ca, Mg, CO_3 and HCO_3 contents of 75.0 mg/kg, 72.8 mg/kg, 0.00 mg/kg and 55.3 mg/kg, respectively recorded for clean water from modern irrigation farm (Table 1).

Heavy metals composition in water

Table 2 revealed significant ($P < 0.05$) differences in iron (Fe) and cadmium (Cd) contents with the higher value of 1.7 mg/kg and 0.42 mg/kg observed in municipal wastewater than 0.67 mg/kg and 0.13 mg/kg for clean water from modern irrigation farm, respectively. No significant ($P > 0.05$) difference was observed in Mn and Pb concentrations. The results of heavy metals accumulation in the soil are presented in Table 3. No significant differences ($P > 0.05$) were observed in heavy metals concentration in soils from modern farmland

Table 1. Chemical composition of clean water from modern irrigation farm and wastewater from local irrigation farm.

Parameters	**Treatment**		**FAO limits**
	WMIF	**WLIF**	
pH	6.1 ± 0.70	6.6 ± 0.65	6.5–8.4
DO (mg/L)	4.3 ± 0.85	5.2 ± 0.55	>2.00
Ca (mg/kg)	75.0 ± 6.6	207 ± 12.2*	0–400
Mg (mg/kg)	72.8 ± 2.0	182 ± 4.9*	0–60
K (mg/kg)	0.70 ± 0.50	1.5 ± 0.06	0–2
Na (mg/kg)	0.37 ± 0.02	0.50 ± 0.03	0–920
P (mg/kg)	0.48 ± 0.05	0.22 ± 0.06	0–2
BOD (mg/L)	15.6 ± 0.78	17.3 ± 0.50	100
$CO_{3(}$mg/L)	0.00 ± 0.00	0.33 ± 0.02*	0–30
HCO_3 (mg/L)	55.3 ± 7.0	104 ± 7.0*	0–610
Cl (mg/L)	1.6 ± 0.07	4.8 ± 0.60	0–1,050
NH_4 (mg/L)	0.63 ± 0.03	0.73 ± 0.02	0–5
NO_3 (mg/L)	1.3 ± 0.61	2.4 ± 0.40	0–10

Values are mean ± standard error of the mean.

*significant differences at ($P < 0.05$). WMIF: Water from a modern irrigation farm, WLIF: Water from a local irrigation farm.

Table 2. Assessment of heavy metals in water and soil from modern and local irrigation farm.

	Parameters	WMIF	WLIF	FAO
Water (Mg/L)	Mn	0.67 ± 0.13	0.55 ± 0.08	0.447
	Fe	0.67 ± 0.08	1.7 ± 0.17*	0–1.5
	Pb	0.16 ± 0.02	0.12 ± 0.01	0.01
	Cd	0.13 ± 0.04	0.42 ± 0.01*	0.03
Soil (mg/kg)	Mn	0.49 ± 0.29	0.47 ± 0.15	400
	Fe	0.76 ± 0.21	1.3 ± 0.36	100,000
	Pb	0.19 ± 0.15	0.14 ± 0.12	85
	Cd	0.14 ± 0.19	0.40 ± 0.50	0.8

Values are mean ± standard error of the mean.
*significant differences at ($P < 0.05$). SMIF: Soil from modern irrigation farm, SLIF: Soil from local irrigation farm.

Table 3. Physico-chemical parameters of soil from the modern and local irrigated farmland.

Parameters	Treatment	
	Soil MIF	Soil LIF
pH	6.5 ± 0.85	6.5 ± 0.67
Org. C (%)	0.86 ± 0.12*	0.27 ± 0.10
Org. M (%)	1.4 ± 0.19*	0.29 ± 0.01
N (%)	0.09 ± 0.01	0.04 ± 0.00
P (mg/kg)	1.2 ± 0.56	0.77 ± 0.05
Ca (mg/kg)	1.0 ± 0.12	0.65 ± 0.12
Mg (mg/kg)	1.5 ± 0.70	0.43 ± 0.11
K (mg/kg)	0.66 ± 0.08	0.46 ± 0.12
Na (mg/kg)	0.55 ± 0.09	0.33 ± 0.09
CEC (cmol/kg)	11.1 ± 1.0	9.5 ± 1.0
Sand	77.6 ± 2.1	85.5 ± 5.2
Silt	13.5 ± 1.0	11.0 ± 0.12
Clay	9.8 ± 0.96	9.0 ± 1.1

Values are mean ± standard error of the mean.
*significant differences at ($P < 0.05$). MIF: Modern irrigation farm, LIM: Local irrigation farm.

irrigated with clean water and local farmland irrigated with municipal wastewater (Table 2).

Physico-chemical parameters of soil

Results of Physico-chemical parameters (Table 3) revealed significant ($P < 0.05$) differences in Org. C and Org. M content between the soil collected from modern farm irrigated with clean water and local farm irrigated with municipal wastewater. The highest pH, Org. C, Org. M, N, P, Ca, Mg, K, Na, CEC, Silt and Clay were observed in soil collected from modern farm irrigated with clean water (6.5, 0.86%, 1.4%, 0.09%, 1.2 mg/kg, 1.0 mg/kg, 1.5 mg/kg, 0.66 mg/kg, 0.55 mg/kg, 11.1 cmol/kg, 13.5 and 9.8, respectively) than soil collected from local farm irrigated with municipal wastewater (6.5, 0.27%, 0.29%, 0.04%, 0.77%, 0.65 mg/kg, 0.43 mg/kg, 0.46 mg/kg, 0.33 mg/kg, 9.5 cmol/kg, 11.0 and 9.0, respectively).

Heavy metals composition in vegetables

Notable variations were observed in the heavy metal composition between vegetables from modern farm irrigated with clean water and local farm irrigated with municipal wastewater (Table 4).

In *C. olitorius* (Jute), the significantly highest ($P < 0.05$) Mn and Cd contents were observed in modern farm irrigated with clean water (0.59 mg/kg and 0.87 mg/kg, respectively) than in local farm irrigated with municipal wastewater (0.15 mg/kg and 0.40 mg/kg, respectively). The results in Table 4 indicated a significantly ($P < 0.05$) higher Fe and Pb contents in vegetables from local irrigation farm (2.2 mg/kg and 0.50 mg/kg, respectively) than from modern irrigation farm (1.5 mg/kg and 0.39 mg/kg, respectively).

In *S. oleracea*, no significant difference ($P > 0.05$) was observed in Mn and Pb contents of vegetables collected from between modern irrigation farm and local irrigation farm (Table 4).

In *T. occidentalis,* a significantly ($P < 0.05$) higher Mn content was recorded in vegetables obtained from modern irrigation farm (1.3 mg/kg) than in vegetables obtained from local irrigation farm (0.30 mg/kg) (Table 4). The significantly highest ($P < 0.05$) Fe, Pb and Cd contents were however recorded in *T. occidentalis* obtained from local irrigation farm (1.5 mg/kg, 0.50 mg/kg and 0.38 mg/kg, respectively).

Mineral composition of vegetables

Significant ($P < 0.05$) differences were observed between the heavy mineral composition of vegetables from modern farm irrigated with clean water and local farm irrigated with municipal wastewater (Table 5).

In *C. olitorius,* significantly ($P < 0.05$) higher Na (88.1 mg/kg), K (3000 mg/kg), Ca (2.2 mg/kg) and Mg (2.2 mg/kg) contents were observed in vegetables collected from local irrigation farm watered with municipal wastewater. However, no significant difference ($P > 0.05$) was observed in P content.

The significantly higher ($P < 0.05$) Na, K and Ca (49.67 mg/kg, 4100 mg/kg and 0.40 mg/kg, respectively) in *S. oleracea* were observed in vegetables collected

Table 4. Heavy metals compositions in some Selected vegetables (mg/kg).

Vegetable	Source	Mn	Fe	Pb	Cd
C. olitorius	MIF	0.59 ± 0.34*	1.5 ± 0.28	0.39 ± 0.05	0.87 ± 0.09*
	LIF	0.15 ± 0.01	2.2 ± 0.13*	0.50 ± 0.06*	0.40 ± 0.04
S. oleracea	MIF	0.65 ± 0.31	0.52 ± 0.28	0.39 ± 0.36	0.33 ± 0.09
	LIF	0.51 ± 0.07	1.2 ± 0.14*	0.43 ± 0.39	0.42 ± 0.02*
T. occidentalis	MIF	1.3 ± 0.03*	0.91 ± 0.11	0.32 ± 0.30	0.05 ± 0.00
	LIF	0.30 ± 0.07	1.5 ± 0.27*	0.50 ± 0.03*	0.38 ± 0.08*
WHO/FAO		0–100	0–100	0–2.00	0–0.02

Values are mean ± standard error of the mean.

*significant differences at ($P < 0.05$)

MIF: Modern irrigation farm, LIM: Local irrigation farm.

Table 5. Mineral composition of some selected vegetables from modern farm irrigated with clean water and local farm irrigated with municipal wastewater (mg/kg).

Vegetables	Source	Na	K	Ca	Mg	P
C. olitorius	MIF	54.8 ± 7.2	2167 ± 35.2	1.5 ± 0.61	1.6 ± 0.45	5.3 ± 0.63
	LIF	88.1 ± 1.7*	3000 ± 20.0*	2.2 ± 0.13*	2.2 ± 0.25*	5.3 ± 0.17
S. oleracea	MIF	31.3 ± 5.0	2800 ± 30.0	0.33 ± 0.28	1.3 ± 0.39	3.4 ± 0.50
	LIF	49.7 ± 3.5*	4100 ± 30.0*	0.40 ± 0.13*	1.4 ± 0.23	3.8 ± 0.30
T. occidentalis	MIF	82.5 ± 3.0	4700 ± 20.0	0.63 ± 0.08	1.7 ± 0.19	5.7 ± 0.37
	LIF	123 ± 7.6*	6500 ± 36.6*	0.90 ± 0.13*	2.1 ± 0.10*	6.2 ± 0.06

Values are mean ± standard error of the mean.

*significant differences at ($P < 0.05$). MIF indicates Modern irrigation farm, and LIM indicates Local irrigation farm.

from local irrigation farm while no significant difference ($P > 0.05$) was observed in Mg and P contents between *S. oleracea* collected from modern irrigation farm and local irrigation farm (Table 5).

A significantly ($P < 0.05$) higher Na (123 mg/kg), K (6500 mg/kg), Ca (0.90 mg/kg) and Mg (2.1 mg/kg) in *T. occidentalis* were observed in vegetables collected from local irrigation farm than in Na (82.5 mg/kg), K (4700 mg/kg), Ca (0.63 mg/kg) and Mg (1.7 mg/kg) contents of vegetables collected from modern irrigation farm (Table 5). No significant ($P > 0.05$) difference was observed in the P content of *T. occidentalis* collected from modern irrigation farm and local irrigation farm.

Discussion

The result of Physico-chemical parameters of clean water from modern irrigation farm and municipal wastewater from local irrigation farm showed an average pH of 6.07 and 6.57, respectively which is within the range of FAO safe limits of 6.00–9.00 for pH of irrigation water (WHO/FAO, 2011). The DO, Ca, K, Na and P observed in the municipal wastewater were also within the FAO threshold limits for wastewater irrigation (WHO/FAO, 2011). DO is an important component of water because it aids in microorganisms and plant survival. The high amount of DO in the municipal wastewater shows the presence of a low concentration of bacteria, this is beneficial to plant growth and nutrient decomposition by microbes (Hassana *et al*., 2020). The values of DO obtained in clean water and wastewater indicate that they were less polluted. High BOD in wastewater reflects a high concentration of biologically degradable substances (Joshi and Santani, 2012: Hassan *et al*., 2022). However, this is not the case with the BOD value obtained in this study. The high content of Ca, Mg and HCO_3 observed in the municipal wastewater could be because wastewater contains high nutrient content (both micro and macro nutrients) that can support plant growth. Similar findings of high Ca and HCO_3 content have been reported by Aijaz *et al.* (2022) in industrial wastewater.

The assessment of heavy metals in water from modern and local irrigation farm revealed that the Mn, Pb and Cd contents recorded in both clean water and wastewater were beyond the WHO/FAO permissible limits in water for irrigation (WHO/FAO, 2011). The presence of high heavy metals in water for irrigation tends to accumulate in the soil where they become easily accessible to crops planted on them. Chaoua *et al*. (2019) opined that the excessive accumulation of heavy metals in agricultural soils is mainly through irrigation with wastewater and poses a major threat to residents who live and consume crops cultivated in the contaminated area.

Heavy metals accumulation in soil from both modern irrigation farm and local irrigation farm were below the WHO/FAO toxic limits. This could be explained by the fact that the wastewater used in this study was municipal and not industrial wastewater and thus contain low concentrations of heavy metals which could not have had high accumulation in the soil samples. Similar findings of low accumulation of heavy metals in soil irrigated with municipal wastewater have been reported by Makhadmeh *et al*. (2021).

The significantly higher Org. C and Org. M contents observed in soil from local farm irrigated with municipal wastewater is in line with reports by Mustapha *et al*. (2020). Irrigation with wastewater could improve soil nutrients and organic carbon (Heinze *et al*., 2014: Asirifi *et al*., 2021). An increase in organic matter in the soil could improve the biological, physical and chemical characteristics of the soil.

The accumulation of Mn, Fe and Pb in the three vegetables viz (Jute, Spinach and fluted pumpkin) collected from modern farm irrigated with clean water and local farm irrigated with municipal wastewater were within the WHO/FAO safe limits (WHO/FAO, 2011). However, the Cd contents observed in the three vegetables from both farms were beyond the WHO/FAO safe limits. The presence of high levels of Cd in crops beyond the recommended limits could cause degenerative bone disease, liver damage, cancer, kidney dysfunction, lung injuries and metabolic syndromes associated with Zn and Cu (Fay *et al*., 2018: Munir *et al*., 2022). The variations observed in the heavy metals accumulation in the three vegetables could be attributed to the differences in the morphology and physiology of the three vegetables for heavy metals usage and the plants' capability to uptake and accumulate heavy metals (Habu *et al*., 2021).

A significant increase observed in the mineral composition of Jute, Spinach and fluted pumpkin irrigated with municipal wastewater over the control group irrigated with clean water could be attributed to the ability of wastewater to supply carbon nutrients and micronutrients to support plant growth and development. Similar findings of improved nutritional composition have been reported in tomatoes irrigated with wastewater by Kekere *et al.* (2020) and in lettuce and spinach by Waheed *et al.* (2019).

Wastewater has been a valuable source of plant nutrients and organic matter. However, Alobaidy *et al.* (2010) opined that it may pose undesirable environmental and health impacts. Certain risk factors have been identified with the continued use of wastewater for irrigation, some of which are short term (microbial pathogens) whereas others have a longer-term impact that increases with the continued use of wastewater such as salinity effects on the soil and accumulation of some compounds in the soil. Thus, so many guidelines have been developed to give a quality criteria and guidance on the use of wastewater for irrigation (EPA, 2004)

Conclusion

This study revealed significantly higher concentrations of Ca and Mg in municipal wastewater and the presence of high concentrations of heavy metals in water from both modern farm and local farm studied, suggesting that they are not fit for irrigation purposes. The study further revealed a high accumulation of Cd in three vegetables collected from both farms and except for cadmium, there was no accumulation of other heavy metals noted in the soil and water in the three vegetables studied. Our investigation also revealed that jute, spinach and fluted pumpkins irrigated with municipal wastewater had higher mineral composition than those from modern farm irrigated with clean water. This implies that municipal wastewater irrigation could be utilized in improving the mineral compositions of leafy vegetables. However, it is highly recommended that the wastewater is treated properly to avoid heavy metal contamination.

References

Abbruzzini, T. F., Silva, C. A., De-Andrade, D. A., De-Oliveira-Carneiro, W. J. (2014). Influence of Digestion Methods on the Recovery of Iron, Zinc, Nickel, Chromium, Cadmium and Lead Contents in 11 Organic Residues. *Brazilian Society of Soil Science*, 38: 166–176.

Aijaz, P., Khalida, F., Aftab, K., Shahid, B., Uzmar, R., Nusrat, J., Razia, S., Aijaz, G., Eidan, S. (2022). Utilization of Treated Industrial Wastewater and Accumulation of Heavy Metals in Soil and Okra Vegetable. *Environmental Challenges*, 6: 100–447.

Akan, J. C., Abdul-Rahman, F. I., Sodipo, O. A., Akandu, P. I. (2009). Bioaccumulation of some Heavy Metals of Six Fresh Water Fishes Caught from Lake Chad in Doron Buhari, Borno State, Nigeria. *Journal of Applied Science in Environmental Sanitation*, 4(2): 103–114.

Alobaidy, A., Al-Sameraiy, M., Kadhem, A., Majeed, A. (2010). Evaluation of Treated Municipal Wastewater Quality for Irrigation. *Journal of Environmental Protection*, 1(3): 216–225.

American Public Health Association (APHA) (2014). American Water Works Association, Water Environment Federation., Standard Methods for the Examination of Water and Wastewater. In E. W. Rice and L. Bridgewater, Eds., American Public Health Association, Washington, D.C.

AOAC (2020). Official Methods of Analysis. Washington, DC, U.S.A.

Asirifi, I., Werner, S., Heinze, S., Saba, C. K., Lawson, I. Y., Marschner, B. (2021). Short-term Effect of Biochar on Microbial Biomass, Respiration and Enzymatic Activities in Wastewater Irrigated Soils in Urban Agroecosystems of the West African Savannah. *Agronomy*, *11*(2): 271.

Awofolu, O. R. (2005). A Survey of Trace Metals in Vegetation, Soil and Lower Animal Along some Selected Major Roads in the Metropolitan City of Lagos. *Environmental Monitoring and Assessment*, *105* (1): 431–447.

Bremner, J. M. (1996). Nitrogen-total. *Methods of soil analysis: Part 3 Chemical methods*, *5*, 1085–1121.

Chaoua, S., Boussaa, S., El Gharmali, A., Boumezzough, A. (2019). Impact of Irrigation with Wastewater on Accumulation of Heavy Metals in Soil and Crops in the Region of Marrakech in Morocco. *Journal of the Saudi Society of Agricultural Sciences*, *18*(4): 429–436.

DeFrees, D. J., Loew, G. H., McLean, A. D. (1982). The Rotational Spectra of HCNH/+/and COH/+/ from Quantum Mechanical Calculations. *The Astrophysical Journal*, *257*: 376-382.

Environmental Protection Agency, (2002). National Recommendation Water Quality Criteria 2002. http://www.epa.gov/waterscience/pc/revcom.pdf. Assessed on June, 2021.

Environmental Protection Agency, (2004). “Guidelines for water re-use” EPA625-R-04/018. US Environmental Protection Agency, Cincinnati.

Fay, M. J., Alt, L. A., Ryba, D., Salamah, R., Peach, R., Papaeliou, A., Zawadzka, S., Weiss, A., Patel, N., Rahman, A. (2018). Cadmium Nephrotoxicity Is Associated with Altered MicroRNA Expression in the Rat Renal Cortex. *Toxins*, *6*: 16.

Ghori, N. H., Ghori, T., Hayat, M. Q., Imadi, S. R., Gul, A., Altay, V., Ozturk, M. (2019). Heavy Metal Stress and Responses in Plants. *International Journal of Environmental Science and Technology*, *16*(3): 1807–1828.

Habu, M. A., Bawa, U., Musa, S. I. (2021). Health Risk Assessment and Heavy Metal Bioaccumulation in Vegetables Irrigated with Wastewater in Kano State, Nigeria. *NotulaeScientia Biologicae*, 13(1):10890.

Hananingtyas, I., Nuryanty, C. D., Karlinasari, L., Alikodra, H. S., Jayanegara, A., Sumantri, A. (2022). The Effects of Heavy Metal Exposure in Agriculture Soil on Chlorophyll Content of Agriculture Crops: A Meta-analysis Approach. *Earth and Environmental Science*, 951(1): 12–44.

Hassan, J., Rajib, M. M. R., Akter, M., Khan, M. N. E. A., Khandakar, S., Khalid, F., Rahman, G. M. (2022). Optimizing Textile Dyeing Wastewater Irrigation through Physiochemical Attributes of Tomato, Plant Nutrient Use Efficiency and Pollution Load Index of Irrigated Soil. *Scientific Reports*, 12(1): 1–18.

Hassana, I. M., Ada O. C., Henry, O. (2020). Assessment of Nutritional Value of Spinach (*Spinacia oleracea*) Irrigated with Domestic Wastewater and Potable Water. *International Journal of Environmental Science*, 5: 264–270.

Heinze, S., Chen, Y., El-Nahhal, Y., Hadar, Y., Jung, R., Safi, J., Marschner, B. (2014). Small Scale Stratification of Microbial Activity Parameters in Mediterranean Soils Under Freshwater and Treated Wastewater Irrigation. *Soil Biology and Biochemistry*, *70*: 193–204.

Hsien, C., Low, J. S. C., Chung, S. Y., Tan, D. Z. L. (2019). Quality-based Water and Wastewater Classification for Waste-to-resource Matching. *Resources, Conservation and Recycling*, *151*: 104–477.

Inyinbor, A. A., Bello, O. S., Oluyori, A. P., Inyinbor, H. E., Fadiji, A. E. (2019). Wastewater Conservation and Reuse in Quality Vegetable Cultivation: Overview, Challenges and Future Prospects. *Food Control*, 98: 489–500.

Joshi, V. J., Santani, D. D. (2012). Physicochemical Characterization and Heavy Metal Concentration in Effluent of Textile Industry. *Universal Journal of Environmental Research and Technology*, *2*(2): 93–96.

Kekere, O., Babatunde, A. F., Akinbuwa, O. (2020). Assessment of Growth, Yield and Fruit Nutritional Composition of Tomato and Sweet Pepper Irrigated with Abattoir Wastewater. *Science Letters*, *8*(2), 69–77.

Kurina, A. B., Solovieva, A. E., Khrapalova, I. A., Artemyeva, A. M. (2021). Biochemical Composition of Tomato Fruits of Various Colors. *Vavilov Journal of Genetics and Breeding*, *25*(5): 5–14.

Lindsay, W. L., & Norwell, W. A. (1969). Development of a DTPA Micronutrient Soil Test. *Soil Science Society of America Proceedings*, *35*: 600–602.

Makhadmeh, I. M., Gharaiebeh, S. F., Albalasmeh, A. A. (2021). Impact of Irrigation with Treated Domestic Wastewater on Squash (Cucurbita pepo L.) Fruit and Seed under Semi-Arid Conditions. *Horticulturae*, *7*(8): 226.

Munir, N., Jahangeer, M., Bouyahya, A., El Omari, N., Ghchime, R., Balahbib, A., Aboulaghras, S., Mahmood, Z., Akram, M., Ali-Shah, S. M. (2022). Heavy Metal Contamination of Natural Foods Is a Serious Health Issue: A Review. *Sustainability*, 14: 161.

Mustapha, S., Ndamitso, M. M., Abdulkareem, A. S., Tijani, J. O., Shuaib, D. T., Ajala, A. O., Mohammed, A. K. (2020). Application of TiO2 and ZnO Nanoparticles Immobilized on Clay in Wastewater Treatment: A Review. *Applied Water Science*, *10*(1): 1–36.

Mwadzingeni, L., Afari-Sefa, V., Shimelis, H., N’Danikou, S., Figlan, S., Depenbusch, L., Shayanowako, A. I. T., Chagomoka, T., Mushayi, M., Schreinemachers, P., Derera, J. (2021). Unpacking the Value of Traditional African Vegetables for Food and Nutrition Security. *Food Security*, *13*(5): 1215–1226.

Naz, S., Anjum, M. A., Akhtar, S., Naqvi, S. A. H., Chohan, S., Zulfiqar, M. A. (2018). Effect of Different Irrigation Sources on Proximate Composition and Heavy Metals Uptake in some Selected Vegetables. *Pakistan Journal of Agricultural Research*, 31(4): 336–346.

Nelson, D. W., Sommers, L. E. (1996). Total Carbon, Organic Carbon, and Organic Matter. *Methods of soil analysis: Part 3 Chemical methods*, *5*: 961–1010.

Olafisoye, O. B., Adefioye, T., Osibote, O. A. (2013). Heavy Metals Contamination of Water, Soil and Plants around an Electronic Waste Dumpsite. *Polish Journal of Environmental Studies*, 22: 1431–1439.

Olumakinde, A., Kekere, O., Ezemba, C. (2019). Yield and Nutritional Value of *Abelmoschus esculentus* L. (Okra) and *Telfairia occidentalis* Hook, F. (Fluted pumpkin) as Influenced by Beauty Salon Wastewater. *Asian Journal of Advanced Research and Reports*, 5: 112.

Olsen, S. R. (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate (No. 939). US Department of Agriculture.

Rizk, R., Juzsakova, T., Ali, M. B., Rawash, M. A., Domokos, E., Hedfi, A., Almalki, M., Boufahja, F., Shafik, H. M., Rédey, Á. (2022). Comprehensive Environmental Assessment of Heavy Metal Contamination of Surface Water, Sediments and Nile Tilapia in Lake Nasser, Egypt. *Journal of King Saud University-Science*, *34*: 101748.

Rhoades, J. D. (1996). Salinity: Electrical Conductivity and Total Dissolved Solids. *Methods of soil Analysis: Part 3 Chemical Methods*, 5: 417–435.

Sanaei, F., Amin, M. M., Alavijeh, Z. P., Esfahani, R. A., Sadeghi, M., Bandarrig, N. S., Fatehizadeh, A., Taheri, E., Rezakazemi, M. (2021). Health Risk Assessment of Potentially Toxic Elements Intake via Food Crops Consumption: Monte Carlo Simulation Based Probabilistic and Heavy Metal Pollution Index. *Environmental Science Pollution Research*, 28:1479–1490.

Shen, X., Min, X., Zhang, S., Song, C., Xiong, K. (2020). Effect of Heavy Metal Contamination in the Environment on Antioxidant Function in Wumeng Semi-fine Wool Sheep in Southwest China. *Biological Trace Element Research*, 198:505–514.

Singh, A. (2021). A Review of Wastewater Irrigation: Environmental Implications. Resources, Conservation and Recycling, 168, 105454.

Sumner, M. E., Miller, W. P. (1996). Cation Exchange Capacity and Exchange Coefficients. *Methods of soil analysis: Part 3 Chemical methods*, *5*, 1201–1229.

Thomas, G.W. 1982. Exchangeable cations. In: A.L. Page (ed.). Methods of soil analysis. Part 2: Chemical and microbiological properties (2nd ed.) Agronomy 9:159–165.

Waheed, H., Ilyas, N., Iqbal Raja, N., Mahmood, T., Ali, Z. (2019). Heavy Metal Phyto Accumulation in Leafy Vegetables Irrigated with Municipal Wastewater and Human Health Risk Repercussions. *International Journal of Phytoremediation*, *21*: 170–179.

World Health Organization/ Food and Agriculture Organization of the United Nations, WHO/FAO. Joint Report, Food Standard Programs Codex Committee on Contaminants in Foods (CF/5/IF/1); FAO: Rome, Italy, 2011 March. Accessed [2022 February 20] Available at: http://www.fao.org/tempref/codex/Meetigs/CCCF/CCCF5/cf05_INF.pdf.

Xavier, J., Varghese, A. K. (2020). Effect of Treated and Untreated Domestic Sewage Water Irrigation on Tomato Plants. *Asian Journal of Plant Sciences*, 19: 252–260.