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FULL LENGTH ARTICLE

Evaluation of metal accumulation in soil and tomatoes irrigated with sewage water from Mysore city, Karnataka, India

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Abstract The results have indicated that application of sewage water for irrigation led to a significant difference in pH and EC of soil. The concentrations of K, Na and Cl did not show any significant difference in all the sewage irrigation sites. But there are significant differences on mean values in the concentrations of Ca, Mg, and SO_4 for sewage applied sites. There was significant increase in the total nitrogen in the soil for sewage water (SW) and treated sewage water (TSW) applied sites as compared to the groundwater (GW) irrigation site. Effect of irrigation with different qualities of sewage on the concentration of heavy metals. It is apparent that the concentrations of heavy metals in soils with different kinds of irrigation water were lower in background values and non-significant; all the other heavy metals exhibit values below background concentrations for heavy metals in soils taken from FAO. The heavy metal concentrations (SW) applied site was, however, below the safe limits of Indian (Awashthi, 2000) and EU standard (European Union, 2002). The results of statistical analysis of total N, total P, Ca, K, Na, and Zn mg/kg^{-1} in tomatoes crop were significantly higher than the groundwater treated plants.

1. Introduction

The quality of irrigation water available to farmers and others has a considerable impact on the type of plants that can be grown, the productivity of the plants, water infiltration and other soil physical conditions. The first step in understanding how an irrigation water source can affect soil–plant system can be understood by analyzing in a laboratory. Irrigation with wastewater is known to contribute significantly to the heavy metals content of soil (Mapanda et al., 2005; Nan et al., 2002). Polluted water, directly affects soil, not only in industrial areas but also in agricultural fields, as well as river

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beds (JI et al., 2012; Srivastava et al., 2012a; Singh et al., 2012; Taghinia Hejabi et al., 2010). Wastewater and sewage effluents contain significant amounts of heavy metals and other substances that can be beneficial to horticultural crops (Butler et al., 1964; Sanderson, 1986; Ali and Shakrani, 2011). Soil contamination with heavy metals is an environmental problem on a global scale and it is becoming increasingly important with the rapid growth of industrialization (Chandra et al., 2008; Salvatore et al., 2009; Ladwani et al., 2012). Heavy metals are ubiquitous in the environment, as a result of both natural and anthropogenic activities, and the people are exposed to them through various ways (Srivastava et al., 2012b; Wilson and Pyatt, 2007). However, plants also can be affected by heavy metal content by factors such as the application of fertilizers, use of sewage sludge or irrigation with sewage water (Devkota and Schmidt, 2000; Frost and Ketchum, 2000; Mangwayana, 1995; Muchuweti et al., 2006; Nyamangara and Mzezewa, 1999). Heavy metal contamination of agricultural soils can pose long-term environmental problems and is not without health implications (Sauve et al., 1996; Chumbley, 1982; Nagajyoti et al., 2010; Mapanda et al., 2005). In recent years, it has become an important agronomic procedure because it contains some amount of N, P and K nutrients and can contribute to organic matter recycling and restoring the soils fertility (Samia et al., 2013).

Irrigation by sewage water effluents is the main reason for the accumulation of heavy metals in vegetables (Amin et al., 2013; Sinha et al., 2008). Long term irrigation with sewage water can induce changes in the quality of soil and trace element inputs are sustained over long periods (Zhang et al., 2008). There are various reports (Singh et al., 2004; Bharose et al., 2013), where sewage water is being used for the irrigation of edible plants and it is a matter of great concern due to the presence of pollutants particularly, toxic metals.

Disproportionate accretion of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination, but also affect food quality and safety (Chung et al., 2011; Mapanda et al., 2005).

Heavy metals show a significant buildup by continuous irrigation with wastewater and long-term irrigation of farmlands with sewage water has led to contamination of food crops in the study area (Arora et al., 2008). A number of studies showed elevated levels of heavy metals in vegetables grown in areas having long-term use of treated or untreated wastewater (Sharma et al., 2006, 2007; Gupta et al., 2012; Lone et al., 2003). Though the sewage water contains low levels of the heavy metals (Fe, Mn, Pb, Cd, and Cr), the soil and plant samples showed higher values due to their accumulation. The trend of metal accumulation in wastewater-irrigated soil is in the following order: Fe > Mn > Pb > Cr > Cd (Gupta et al., 2010).

Therefore, the main objective of the present investigation was to study and compare the influence and find the difference in chemical elements levels between soils and plants that result from applying wastewater, treated wastewater and mixed water (wastewater with pure water) and pure water alone when they are used for irrigation. We will then compare these chemical elements levels with those irrigated by groundwater on soil and tomatoes crop composition.

2. Materials and methods

2.1. Study sites

The study was conducted near Vidyaranyapuram sewage treatment plant situated at the suburban area in the south western part of Mysore city, Karnataka, India (latitude 12.273681 to 12.270031°N and longitude 76.650737 to 76.655947°E) where the facility was constructed in 2002 with an area of 27.21 sq. km and a sewer length of 7000 m. It is a biological treatment plant situated next to the solid waste disposal area at the foothills of Chamundi Hills; the treated wastewater of Vidyaranyapuram sewage treatment plant crosses the Dalvai Lake and reaches drinking water source that is the Kabini River. The southwestern drainage connects 67.65 million liters per day to Vidyaranyapuram sewage treatment plant. More than fifty percent of the sewage generated in Mysore city is received by Vidyaranyapuram sewage treatment plant.

Although the capacity of sewage treatment plant is 67.75 million liters per day the inflow rate of wastewater varies with many influencing factors such as seasonal changes, tourist inflow; however there will be an approximate difference of 7–9 million liters per day between the raw wastewater received and the treated wastewater liberated due to seepage (Sulthana et al., 2013). The farmers use this untreated wastewater for irrigation of various crops. The study area is presented in Fig. 1.

2.2. Water, soil and plant sampling

Samples of water used for irrigation of soil and tomatoes, were randomly collected from the farmlands of selected areas of Vidyaranyapuram in Mysore. The samples were collected during January–August of the year 2013; experiment consisted of four treatments with three replicates, randomized complete block design (RCBD) with split plot arrangements.

2.2.1. Water

All water samples were collected in 2000 ml polythene bottles and transported immediately for laboratory analysis. Experimental treatments were four: sewage water (SW), mixed water (sewage water and pure water) (MW), treated sewage water (TSW) and groundwater (GW).

2.2.2. Soil

Soil samples (three samples from each field) were taken randomly at three depths (0–20, 20–40 and 40–60 cm) in each block, during planting by using an Auger. The soil collected from each depth was mixed, dried, crushed and sieved with a 2 mm sieve. The prepared soil samples were then stored in polyethylene bottles for analysis.

2.2.3. Plant

Leaves of tomatoes were hand harvested. All the collected samples of tomatoes leaves were washed with double distilled water to remove airborne pollutants. All the samples were then oven-dried in a hot air oven at 70–80 °C for 24 h to remove moisture. Dried samples were powdered using a pestle and mortar and sieved through muslin cloth.

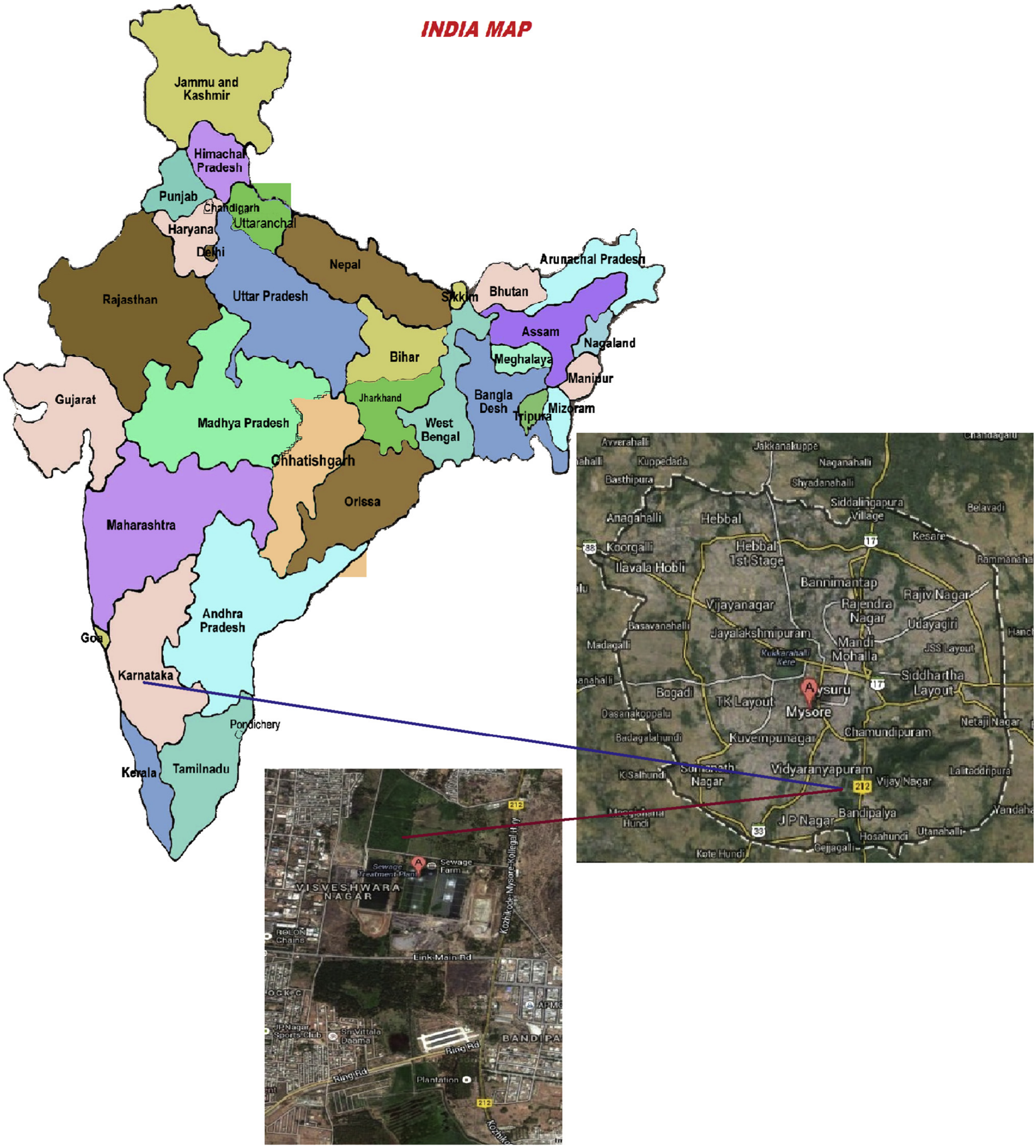

Figure 1 Study area.

2.3. Chemical analysis of water, soil and tomatoes samples

2.3.1. Water

For heavy metals analysis an aliquot consisting of 500 mL of sewage water and groundwater was added to 15 mL of HNO_3 (69%) and evaporated to near dryness on a hot plate. Then, the contents were digested with 15 mL of HNO_3 (69%) and 20 mL of $HClO_4$ (70%) according to Brar et al., (2000). The residue was taken in 15 mL of 6 N HCl and made to the volume (50 mL) and contents were filtered. The filtrate was analyzed for the contents of Pb, Zn, Cu, Co, Cr, Cd, Fe, Mn and Ni using ICP–OES (Perkin Elmer model 8000 DV). Sewage effluent samples were measured for pH and electrical conductivity using a pH meter and conductivity meter. Carbonates and bicarbonates were estimated by titrating aliquot of effluent samples with HCl.

2.3.2. Soil

Soil pH was measured in suspension (soil paste) according to McKeague (1978) and McLean (1982). The water samples were filtered and analyzed for major cations (Ca, Mg, Na, K) using inductively coupled plasma optical emission spectrometry (ICP–OES). The concentrations of Cl, CO_3 and HCO_3 were determined by titration. Total N was determined using the Kjeldahl procedure (Bremner and Mulvaney, 1982; Buresh et al., 1982), and available P was determined according to Olsen et al. (1954). Sulfate (SO_4) was determined using the turbidimetric method and the resulting turbidity was measured by a spectrometer (Sparks et al., 1996). Moreover, the total content of heavy metals (Fe, Mn, Cu, Zn, Pb, Cd, As, Cr, Ni and Co) in the soil was determined after digestion using the Hossner method (Hossner, 1996). Specifically, soil samples were digested using $HF–H_2SO_4–HClO_4$. The concentrations of total metals were analyzed using ICP–OES (Perkin Elmer, Model 8000 DV).

2.3.3. Plant

For the digestion of tomato samples, wet digestion method was used followed by ICP_OES. For each analysis 0.5 g of the sample was accurately weighed and digested with 1 ml of perchloric acid ($HClO_4$) and 4 ml of Nitric (HNO_3). The samples were allowed to cool and the contents were filtered off using Whatman 42 filter paper. The filtrate was made to 25 ml with distilled water. Blank solution was made using the same procedure except the addition of vegetable sample. The plant material was then treated in the same way as done for the soil samples.

2.4. Statistical analysis

A completely randomized block design (CRBD) was used in these experiments. Analyses of variance (ANOVA) were performed using the Statistical Analysis Systems Computer Package (SAS Institute, 2004). Treatment means were compared by the least significant difference test at $p < 0.05$.

3. Results and discussion

3.1. Physico-chemical properties of the used sewage water and groundwater

Data presented in Table 1 show the characteristics of sewage water (SW), treated sewage water (TSW), mixed water (MW) and groundwater (GW), which were used for irrigation of tomatoes. The chemical parameters measured were temperature, pH, electric conductivity (EC), dissolved oxygen, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS), calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, total nitrogen, total phosphors, sulfates, iron, manganese, copper, zinc, cadmium, nickel, lead, cobalt and chromium. There were obvious differences in several measured parameters when the results were compared from site to site. The average values of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Table 1) in sewage water (SW) were very high when compared to the FAO values (1992). The dissolved oxygen (DO) and Total Dissolved Solids (TDS) content of (SW), (TSW), (MW) and (GW) were very low when compared to the FAO values (1992). The pH of sewage water (SW), treated Sewage water (TSW), mixed Water (MW) and groundwater (GW) were 7.50, 8.13, 9.19 and 8.30 respectively. According to the FAO (1992) the tolerance limit of pH of water samples for irrigation showed be 6.50–8.40. The pH of the mixed water was 9.19, indicating alkaline nature of the mixed water in the Lake. The electrical conductivity (EC) (1032, 1225, 906 and 1099 $\mu s/cm^{-1}$) indicated the salinity of the water (Rattan et al., 2005).

The sewage water contains considerable amounts of total nitrogen (78.4 $mg\ L^{-1}$), phosphate (4.55 $mg\ L^{-1}$), and potassium (24 $mg\ L^{-1}$) which are considered essential nutrients for productivity levels (plant growth) and soil fertility. The Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, and Cr contents ranged between 0.040 (Ni) and 2.93 $mg\ L^{-1}$ (Table 2). Micronutrients and heavy metals concentrations in the sewage water are relatively lower than standard norms prescribed for sewage water reuse as irrigation. But with continuous application of wastewater these metallic elements could get accumulated in the soil. Nine elements examined in effluent contaminated water were used for irrigation in Mysore area, concentrations of Fe were 2.93, 2.48, 2.39 and 0.075 $mg\ L^{-1}$, of Mn were 0.157, 0.041, 0.068 and 0.043 $mg\ L^{-1}$, Cu was lowest (<0.05) and it was lower than the values (0.07–6.30 $mg\ L^{-1}$) reported by Gupta et al. (2008) and for Zn the values were 0.133, 0.278, 0.356 and 0.363 $mg\ L^{-1}$. Cadmium concentrations were 0.047, 0.047, 0.048 and 0.047 $mg\ L^{-1}$ which are in good agreement with the previous findings of Sharma et al. (2006) (0.02–0.04 $mg\ L^{-1}$). Maximum Ni concentration in water was 0.040 $mg\ L^{-1}$ and Pb concentrations were 0.053, 0.053, 0.052 and 0.051 $mg\ L^{-1}$. Co contents ranged from 0.055 to 0.053 $mg\ L^{-1}$ and Cr was found to be 0.032–0.031 $mg\ L^{-1}$. In comparison with the standard guideline of irrigation water (FAO: Pescod 1992), it was found that the mean concentrations of Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, and Cr were within the safe limits.

Table 1 Chemical analysis of water samples.

Water quality	T (°C)	pH	EC (μs/cm)	DO ($mg\ L^{-1}$)	COD ($mg\ L^{-1}$)	BOD ($mg\ L^{-1}$)	TDS ($mg\ L^{-1}$)	Cation ($mg\ L^{-1}$)				Anion ($mg\ L^{-1}$)			
								Na^+	K^+	Ca^{++}	Mg^{++}	HCo_3^-	CO_3^-	Cl^-	$SO_4^=$
Sewage water (SW)	25	7.50	1032	Nil	964	650	560	48	24	43.37	27.01	296	Nil	93	24
Treated sewage water (TSW)	25	8.13	1225	2.3	145	30	624	60	20	62.64	28.89	392	Nil	115	20
Mixed water (MW)	25	9.19	906	3.3	281	60	504	56	12	27.30	41.46	204	48	117	16
Groundwater (GW)	25	8.30	1099	6.9	16	2	696	56	20	56.22	68.50	544	40	17	52
Standard limit for irrigation FAO: Pescod (1992) and FAO (1985)		6.5–8.5	<3000	<9	80–500	100	2000	900	0.2	400	60	600	6	1100	1000

Table 2 Macro and micro nutrients (mg L^{-1}) in water samples.

Water quality	TN	TP	Fe	Mn	Cu	Zn	Cd	Ni	Pb	Co	Cr
Sewage water (SW)	78.4	4.55	2.93	0.157	< 0.05	0.133	0.047	0.040	0.053	0.055	0.032
Treated sewage water (TSW)	61.6	2.40	2.48	0.041	< 0.05	0.278	0.047	0.036	0.053	0.054	0.031
Mixed water (MW)	11.2	0.89	2.39	0.068	< 0.05	0.356	0.048	0.038	0.052	0.053	0.031
Groundwater (GW)	0.56	0.053	0.075	0.043	< 0.05	0.363	0.047	0.034	0.051	0.054	0.032
Standard limit for irrigation FAO (1992) and FAO (1985)	30	20	5	0.2	0.1	2	0.01	5	2	0.05	0.1

Table 3 Mean values of chemical contents of soils irrigated with different water samples.

No.	Parameters	Unit	Soil SW	Soil TSW	Soil MW	Soil GW	Vinogradov (1959) (%)	Indian standards (1983) and Awashthi (2000) (mg/kg^{-1})
1.	pH	–	6.64 c	7.43 b	7.45 b	8.02 a	–	–
2.	EC	µs/cm	297 a	210 b	211 b	172 c	–	–
3.	Ca	%	0.75 a	0.79 a	0.59 ab	0.46 b	1.4	0–3500
4.	Mg	%	0.54 a	0.50 a	0.36 b	0.35 b	0.6	0–500
5.	Na	%	0.052 a	0.057 a	0.061 a	0.058 a	1.26	0–300
6.	K	%	0.074 a	0.071 a	0.096 a	0.069 a	1.3	0–450
7.	Cl	%	0.002 a	0.002	.001 a	0.002	0.01	–
8.	Total N	%	0.47 a	0.46 a	0.067 b	0.058 b	0.1	–
9.	Total P	%	0.051 a	0.048 a	0.062 a	0.064 a	0.08	0–20
10	So_4	%	0.0023 a	0.0023 a	0.0010 b	0.0010 b	0.06	0–45
11.	Fe	%	4.51 a	4.26 a	4.11 a	4.01 a	3.7	–
12.	Mn	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.08	–
13.	Cu	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.004	135–270
14.	Zn	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.005	300–600
15.	Cd	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	-	3–6
16.	Ni	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.008	75–150
17.	Pb	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	–	250–500
18.	Co	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.0016	–
19	Cr	mg/kg^{-1}	< 0.05 a	< 0.05 a	< 0.05 a	< 0.05 a	0.04	–

Different letters within the same rows followed by values indicate significant differences by Duncan's multiple range tests at $P < 0.05$.

3.2. Effect of sewage water and groundwater irrigation on soil nutrients

Chemical properties as well as concentrations of heavy metals in soil with the use of different qualities of sewage water and groundwater are shown in Table 3.

The results of the study have indicated that application of sewage water led to significant differences in pH and EC. The pH values for the different sites SW, TSW, MW and GW were 6.64, 7.43, 7.45 and 8.02, respectively and the ECs for the same sites were 297, 210, 211 and 172 µs/cm^{-1} respectively. The highest pH change in the soils by increasing sewage water irrigation might be due to higher inputs of sulfate in wastewater (Usman and Ghallab, 2006). The soil pH decreased as a result of sewage irrigation which might be due to higher inputs of organic matter and was increased from 17% to 30% as a result of long-term sewage irrigation (Al Omron et al., 2012). Release of exchangeable cations (Kiziloglu et al., 2008). These observations were confirmed by Malla et al. (2007). The soil pH plays an important role in the mobility of metals as in their bioavailability for plants. The main cause of essential element deficiency in soils is high pH. Thus, by reducing the soil pH, the availability of nutrients for plants increased. EC value of sewage water was higher than groundwater. Our investigation was in agreement with the previous works obtained by Malla et al. (2007), Saffari and Saffari (2013) and Zalawadia et al. (1997) that the application of sewage water would be expected to increase soil EC.

As regards the concentrations of K, Na and Cl there were no significant differences in between the sites, whereas there were significant differences observed on mean values for concentration of Ca, Mg, and SO_4 for the different sites such as SW, TSW, MW and GW which were 0.75, 0.79, 0.59 and 0.46 3.58 mg L^{-1}, 0.54, 0.50, 0.36 and 0.35 mg L^{-1} and 0.0023, 0.0023, 0.0010 and 0.0010 mg/L^{-1} respectively. Effluent irrigation generally adds significant quantities of salts to the soil environment, and in cloud sulfates, phosphates, bicarbonates and chlorides of the cations sodium, calcium, potassium, and magnesium; they stimulate the growth at lower concentrations but inhibit at higher concentrations (Patterson et al., 2008). The results show high significant increase of total nitrogen in the soil for SW and TSW as compared to the treatment of the control GW. This is due to the content of wastewater and treated wastewater with high concentrations of nitrogen, which are 78.4 and 61.6 mg L^{-1} respectively as shown in Table 2. These results are consistent with Bernal et al. (2006) and Galavi et al. (2010). The results content indicated that application of sewage water led to a significant difference in SO_4 than groundwater treatment; *K* significantly increased; *P* significantly reduced in sewage water as compared to groundwater treatment. The lower concentration of *P* in GW site may be due to the soil pH playing an important role in the bioavailability of phosphorus for plants. Moderate pH change of the soil with increased wastewater irrigation might increase availability of soil phosphorous to the plants.

Effect of irrigation with different qualities of sewage on the concentration of heavy metals is shown in Table 2. It is apparent that the concentrations of heavy metals in soils with different kinds of irrigation water were lower in background values and non-significant; all the other heavy metals exhibit values below background concentrations for heavy metals in soils taken from FAO. The heavy metal concentrations were, however, below the safe limits of Indian (Awashthi, 2000) and EU standards (European Union, 2002) except for Fe where the results showed an increase in the concentration of Fe for three treatments (TSW, SW and MW), compared to the treatment GW. This is due to the contamination of water samples (TSW, SW and MW) because of their low concentrations of Fe. This result is consistent with the study conducted by Ministry of Water and Environment (2003) and inconsistent with Mohamed et al. (2004), Soliman et al. (2003) and Mageed and Kareem (1997)). To increase concentration of Fe in the soil irrigates with wastewater instead of pure water.

3.3. Effect of irrigation with different qualities of wastewater on the content of tomatoes nutrients and heavy metals

Effect of irrigating different qualities of sewage water on the concentration of total nitrogen in the tomatoes is shown in Table 4, Figs. 2 and 3. The results show a high significant increase in the concentration of nitrogen in plants for the three treatments (TSW, SW and MW), as compared to GW. This is due to the contaminant of water samples and (TSW, SW and MW) containing high concentrations of total nitrogen. This result is consistent with the study conducted by Gewaily et al. (2001) in beans and EL-Mowelhi et al. (2001) in sunflower, canola, sugar beets and soybeans. Total *P* content a high significant increase in the total *P* content for TSW, SW and MW treatments as compared to the treatment GW. This is due to the contamination of water samples and (TSW, SW and MW) containing high concentrations of total *P*. This result is consistent with the study conducted by Soliman et al. (2003) in alfalfa. Also the present study shows that the concentrations of Ca, Na and K in tomatoes grown in SW water-irrigated area were significantly higher than the tomatoes grown in the groundwater, water-irrigated control area. Mg, content was not-significant, between the treatments. This is consistent with reports of higher concentrations. Concentration was most nutrients when using wastewater containing low concentrations of trace elements in the leaves of the tomato crop in the range of normal concentrations found in plants grown on irrigated area, groundwater. This is due to the contaminant all the different water samples (SW, TSW, MW and GW) to low concentrations of heavy metals. Except Zn, were results an increase significant this is due to medium concentrations of heavy metals in irrigation water. This is not consistent with reports about higher concentrations of heavy metals in vegetables from sewage-irrigated areas as compared to the clean water-irrigated control areas of Ludhiana City of Punjab (Kawatra and Bakhetia, 2008) as also in Varanasi City, India (Singh et al., 2010).The use of treated wastewater containing low concentrations of trace elements can be used successfully to irrigate crops without the fear of occurrence or deposition of part of these elements in the soil and consequently without the fear of occurrence or accumulation in plants.

Table 4 Mean values of chemical properties of tomatoes irrigated with different water samples.

No.	Parameters	Unit	Soil SW	Soil TSW	Soil MW	Soil GW	Standard limit Bennett (1993), Adriano (1986) and Misra and Mani (1991)	Standard limit Brady (1984)
1.	Ca	%	3.25 a	2.95 a	3.05 a	2.27 b	0.1–1 b	0.2–1.0
2.	Mg	%	1.31 ab	1.11 b	1.20 ab	1.42 a	0.1–0.4 b	0.1–0.4
3.	Na	%	0.35 a	0.25 bc	0.30 ab	0.20 c	0.0–0.10 b	–
4.	K	%	3.47 a	3.17 a	3.24 a	2.00 b	1–5 b	0.5–0.8
5.	Total N	%	4.90 a	3.98 b	4.03 b	2.80 c	2–5 b	1–5
6.	Total P	%	0.30 a	0.26 a	0.28 a	0.16 b	0.2–0.5 b	0.1–0.5
7.	Fe	mg/kg^{-1}	480 a	470 a	496 a	450 a	50–250 b	50–250
8.	Mn	mg/kg^{-1}	113 a	118 a	115 a	120 a	20–300 b	20–200
9.	Cu	mg/kg^{-1}	27 a	29 a	28 a	33 a	5–20 b	5–20
10	Zn	mg/kg^{-1}	200 a	180 b	185 ab	160 c	20–50 b	25–150
11.	Cd	mg/kg^{-1}	13 a	13 a	13 a	13 a	0.05–1.2 a	–
12.	Ni	mg/kg^{-1}	12 a	12 a	12 a	13 a	0–4 a	0.1–1
13.	Pb	mg/kg^{-1}	12 a	12 a	12 a	13 a	0.1–30 a	–
14.	Co	mg/kg^{-1}	8 a	7 a	7 a	9 a	0.05–0.5 m	–
15.	Cr	mg/kg^{-1}	14 a	15 a	15 a	15 a	1–5 a	–

Different letters within the same rows followed by values indicate significant differences by Duncan's multiple range tests at $P < 0.05$.
Standard limit:
a – Adriano (1986).
b – Bennett (1993).
m – Misra and Mani (1991).

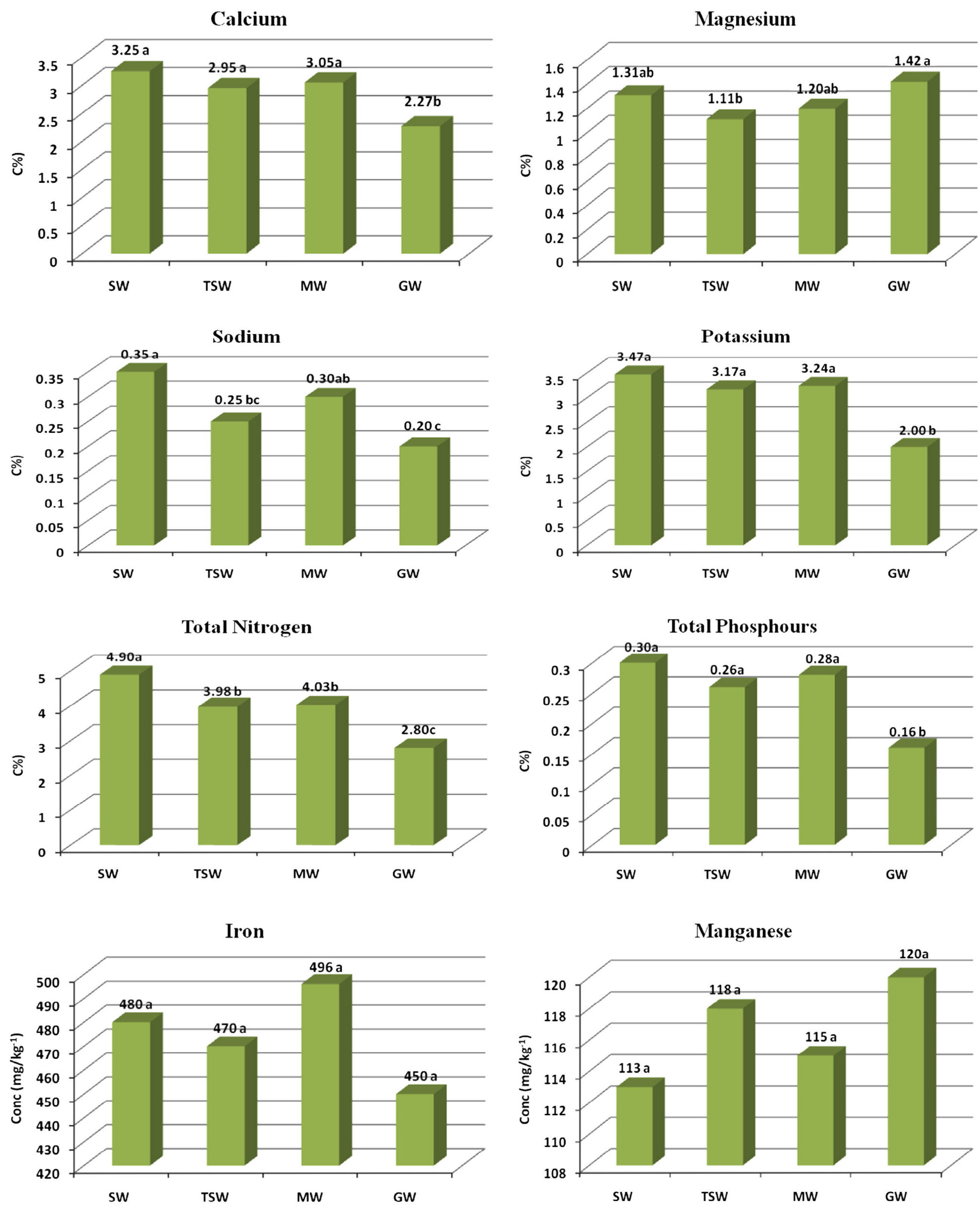

Figure 2 Mean microelements concentration (Ca, Mg, Na, K, N, P, Fe and Mn) in Tomatoes. Different letters within the same figure followed by values indicate significant differences by Duncan's multiple range tests at $P < 0.05$.

4. Conclusion

The used water sources evaluated as a source of irrigation water according to the FAO system of water quality classification which appeared the suitable use of these sources in leaching and irrigating the saline soils especially in the short-time. The results of the present study indicated that application of sewage water led to a significant difference in pH and EC as compared

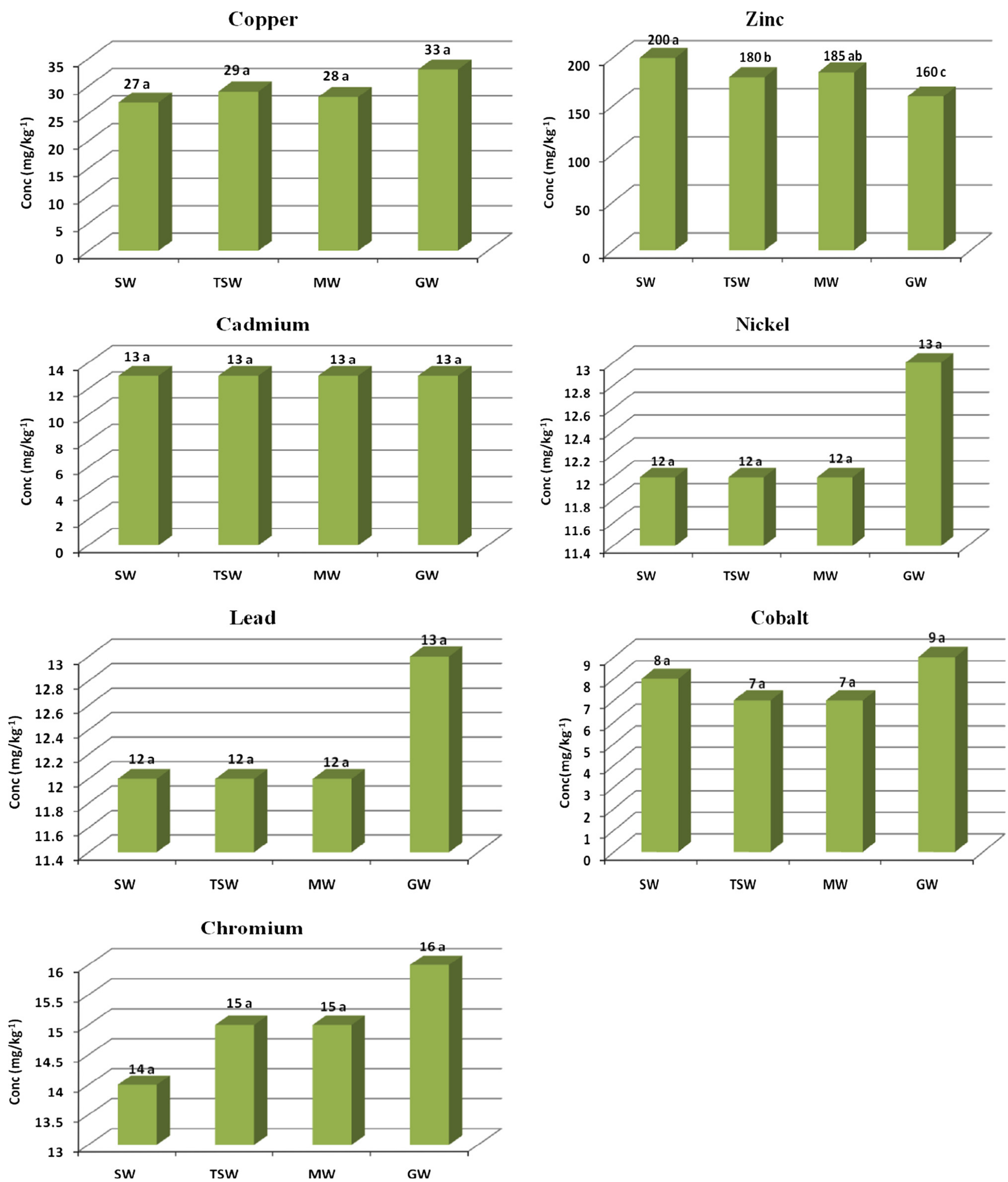

Figure 3 Mean microelements concentration (Cu, Zn, Cd, Ni, Pb, Co and Cr) in Tomatoes. Different letters within the same figure followed by values indicate significant differences by Duncan's multiple range tests at $P < 0.05$.

to other treatments. The concentrations of K, Na and Cl did not show significant differences in all the sites whereas significant difference was observed in the mean values for concentrations of Ca, Mg, and SO_4 for the different sites. Irrigation with different qualities of wastewater influenced the concentration of total nitrogen in the soil where the results show an increase of high significant to the total nitrogen in the soil irrigated with (SW and TSW) as compared to the control GW. It is apparent that the concentrations of heavy metals in soils with different kinds of water were lower in values and non-significant; all the other heavy metals exhibit values below concentrations for heavy metals in soils taken from FAO. The heavy metal concentrations were, however, below the safe limits presented by Indian (Awashthi, 2000) and EU standard (European Union, 2002). The results showed high significant increasing the concentration of nitrogen in plants of all treatments (TSW SW and MW) as compared to the control GW. Also the present study showed that the concentrations of Ca, Na and K in tomatoes grown in SW water-irrigated area were significantly higher than the tomatoes grown in the groundwater, irrigated control area. Mg content was not significantly different between the treatments. Concentrations of trace elements in the leaves of the tomato crop in the range of normal concentrations found in plants grown on irrigated area, groundwater. This is due to the contaminant all the different water samples (SW, TSW, MW and GW) to low concentrations of heavy metals except Zn, were results an increase significant this is due to medium concentrations of heavy metals in irrigation water.

Conflict of interest

There is no conflict of interest.

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