E-ISSN: 2278-3229

IJGHC; December 2012 – February 2013; Vol.2, No.1, 81-90.

International Journal of Green and Herbal Chemistry

Available online at www.ijghc.org

Green Chemistry

Research Article

Heavy Metal Accumulation in Some Vegetables Irrigated With Treated Wastewater

Yahia Y. I. Mosleh[1, 2*] and Omar Abed El-Hakeem Almagrabi[2]

[1]Biology Department, King Abdul Aziz University, North Jeddah, Jeddah, KSA.

[2] Department of Aquatic Environment, Suez University, Faculty of Fish Recourses, Suez, Egypt.

Received: 5 November 2012; **Revised:** 16 January 2013; **Accepted:** 19 January-2013.

Abstracts: The present study investigated the accumulation of heavy metals in some vegetables irrigated with treated wastewater at sites having long-term uses of treated wastewater for irrigation. Samples of vegetables, water and soil were collected from 3 experimental vegetable farms in Jeddah to evaluate the concentration of heavy metals, Cu, Cd, Zn, Fe and Pb with flame atomic absorption spectrophotometer. The results indicated that the high level of Zn and Pb was found in soils (11.24 and 8.32 $mg.kg^{-1}$), while the concentrations of Zn and Pb in sewage sludge was 22.23 and 18.98 $mg.kg^{-1}$. The values of heavy metals in treated wastewater was 19.98 $mg.L^{-1}$ for Zn, 0.98 $mg.L^{-1}$ for Cu, 8.0 $mg.L^{-1}$ for Fe, 0.4 $mg.L^{-1}$ for Cd and 2.1 mgL^{-1} for Pb. The concentrations of heavy metal showed a trend of Fe > Zn > Cd > Cu > Pb in vegetable fruits, Fe > Cd > Zn > Cu > Pb in vegetable leafs. The accumulation of Cu in eggplant fruits was highest 7.67 $mg.kg^{-1}$. The low concentrations of Pb (0.21, 0.26 and 0.32 $mg.kg^{-1}$) reported in leaves of lettuce, squash and garden rocket respectively. While the concentrations of Fe in leaf tissues of the vegetables averaged 88.83, 56.93, 21.32 and 13.93 $mg.kg^{-1}$ for eggplant, tomatoes, lettuce and squash respectively. Higher concentration of Fe was found in eggplant fruits 59.03 $mg.kg^{-1}$. Most of the vegetables species growing in metal polluted soils are unusable to avoid the absorption of these metals. Soils may accumulate metals in sufficient quantities to cause clinical problems to both animals and human beings consuming these metal rich plants.

Keywords: Heavy metals, vegetables, soil and treated wastewater.

INTRODUCTION

Saudi Arabia is a desert country with no permanent rivers or lakes and very little rainfall. Water is scarce and extremely valuable, and with the country's rapid growth, the demand for water is increasing. Saudi

Arabia, therefore, has turned to innovative ways to provide enough water to support its development. Aquifers are a major source of water in Saudi Arabia[1]; they are vast underground reservoirs of water. In the 1970s, the government undertook a major effort to locate and map such aquifers and estimate their capacity. As a result, it was able to drill tens of thousands of deep tube wells in the most promising areas for both urban and agricultural use. Another major source of water is the sea this is done through desalination, a process that produces potable water from brackish seawater[2-3-4].

Saudi Arabia is the world's largest producer of desalinated water, an expanding source of water is the use of recycled water. The Kingdom aims to recycle as much as 40 percent of the water used for domestic purposes in urban areas. To this end, recycling plants have been built in Riyadh, Jeddah and other major urban industrial centers. Recycled water is used for irrigation of farm fields and urban parks. The use of wastewater is emerging as a potential alternative to augment the water supply in Saudi Arabia, especially in the agricultural sector [5-6-7]. The use of treated waste water for different purposes one of the most important strategic alternatives for renewable water in many countries of the world, especially those that suffer from a shortage of traditional water resources. The use of wastewater in agriculture is provides water, N and P, as well as organic matter to the soils, but there is a concern about the accumulation of potentially toxic elements such as Cd, Cu, Fe, Mn, Pb and Zn from both domestic and industrial sources[8-9]. Heavy metals can also accumulate in the soil at toxic levels as are salt of long-term application of untreated and treated wastewaters. Soils irrigated by wastewater accumulate heavy metals such as Cr, Zn, Pb, Cd, Ni, etc in surface soil. When the capacity of the soil to retain heavy metals is reduced due to repeated application of waste water, heavy metals leaching to ground water or soil solution available for plant uptake. For the metals derived from anthropogenic sources, this can strongly influence their speciation and hence bioavailability[10].

Excessive accumulation of heavy metals in agricultural soils through irrigation with treated wastewater may not only result in soil contamination, but also affect food quality and safety. Important sources of heavy metals in wastewater are urban and industrial effluents and deterioration of sewerage pipelines. Irrigation with wastewater is known to contribute significantly to the heavy metal content of soils[11-12]. Sewage sludge may also contain high levels of toxic metals such as Pb, Cd, Ni, Cr, Hg, etc. due to the mixing of industrial wastewater with sewage[13-14]. Besides heavy metals, other harmful toxics such as pharmaceuticals, detergents, various salts, pesticides, toxic organics, flame retardants and hormone disruptors can also be present in the sewage sludge[12-15-16]. However, the heavy metal content in plants can also be affected by other factors such as the application of fertilizers, sewage sludge or irrigation with wastewater[17-18]. Other anthropogenic sources of heavy metals include the addition of manures, sewage sludge, fertilizers and pesticides, which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter and bioavailability of heavy metals in the soil. Found[15] that increasing concentrations of heavy metals in soil increased the crop uptake. Also studies have shown that heavy metals are potentially toxic to crops, animals and humans when contaminated soils are used for crop production[19]. Heavy metals may enter the human body through inhalation of dust, consumption of contaminated drinking water, direct ingestion of soil and consumption of food plants grown in metal-contaminated soil[20-21]. Food and water are the main sources of our essential metals; these are also the media through which we are exposed to various toxic metals. Heavy metals are easily accumulated in the edible parts of plants[22]. Vegetables constitute an important part of the human diet since they contain proteins, vitamins, as well as carbohydrates, minerals, and trace elements. It is known that serious systemic health problems can develop as a result of excessive accumulation of dietary heavy metals such as Cd, Cr, and Pb in the human body[23]. High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastro interestinal cancer[22]. For most of the people, the main route of exposure to heavy metals is through the diet except occupational exposures at related industries. Regulations have been set up in many countries and for different industrial set up to control the emission of heavy metals. The uptake and bioaccumulation of heavy metals in vegetables are influenced by a number of factors such as climate, atmospheric depositions, the concentrations of heavy metals in soil, the nature of soil on which the vegetables are grown and the degree of maturity of the plants at the time of harvest[24-25]. The main objectives of this study were to determine the concentrations of Cu, Zn, Cd, Pb, and Fe in soils, treated wastewater and some vegetables (lettuce, tomatoes, squash, sweet pepper, garden rocket and eggplant) collected from experimental gardens irrigated with treated sewage effluent at Jeddah, Musk Lake.

MATERIAL AND METHODS

Three small experimental vegetable farms, were selected to study the level of trace metal contamination in vegetables. This farm is irrigated with treated wastewater and these farms are found in the north of Jeddah city. Samples of soil, water and vegetables were collected from the selected farms, prepared and preserved in the laboratory until analyzed as described below.

Collection, preparation and preservation of water samples: Water samples were collected from the shallow, large-diameter tubewells, used for agricultural irrigation with treated wastewater. The wastewater samples were filtered during collection or prior to analysis, stored in polyethylene bottles which were and preserved with 1.0 mL of 70% HNO_3. The filtered samples were stored in a refrigerator to minimize volatilization and biodegradation between sampling and analysis periods[26]. Collected samples were analyzed for pH, total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (T-N), nitrate as well as cadmium (Cd), zinc (Zn), copper (Cu), and lead (Pb). Analyses of treated wastewater were carried out following the standard methods for the examination of treated water and wastewater[27]. Concentration of TSS was measured using drying method at 103–105 °C described by standard methods 19th edition 2540 D, total nitrogen by Kjeldahl Method, biological oxygen demand (BOD) using 5-day BOD test described by standard methods 19th edition 5210 D, while chemical oxygen demand (COD) was measured using closed reflux, titrimetric method was described by standard methods 19th edition 5220 D. Finally Cd, Cu, Zn, Fe and Pb were analyzed using an atomic absorption spectrophotometer equipped with a graphite furnace (Perkin Elmer; Model Analyst 300).

Extraction of metals from water samples: A 50 mL of each treated wastewater sample was measured into a 100 mL volumetric flask and the pH adjusted to 3.0 with 0.5 M HNO_3. One mL of 1% APDC solution was added into each sample and the contents shaken to ensure mixing. Then, 10 mL MIBK was added into each flask and the contents shaken for 30 s. After the two phases were separated, the metal content in the organic phase was determined. The standards and blanks were prepared in the same way[27].

Collection, preparation and preservation of soil samples: Surface soil samples were collected from randomly distributed sampling points within the study farms using plastic spade in the same periods as the vegetable samples. Soil sample was collected by removing the surface soil and sampling vertically from 0 to 15 cm borehole. Three samples were collected and thoroughly mixed in the field, from which three composite samples weighing about 1 k g each brought to the laboratory packed in plastic bags[27, 28]. All samples were well mixed again and quartered in the laboratory and one fourth of each sample was dried in an oven at 105 °C for 12 h. The dried samples were then ground and sieved with 200 mesh (75 mm) sieve and kept packed until analysis. The exchangeable Na, K and Ca in soil and sewage sludge were extracted by using repeated leaching procedure described by[29]. The pH of the soil and sewage sludge was measured in the suspension of 1:5 (w/v) with the help of a pH meter (Model EA940, Orion, USA) standardized with pH 4, 7 and 9.2 reference buffers. Conductivity was measured by a conductivity meter (Model 303, Systronics). Samples were shaken in ammonium acetate solution for 2 h and then allowed to stand for overnight to settle the soil particles. Again the samples were shaken and then filtered. The concentrations of exchangeable cations were determined with the help of flame a Atomic Absorption Spectrophotometer (Model 2380, Perkins Elmer, Inc., Norwalk, CT, USA) on dry weight basis. Available phosphorous in the samples was quantified by the $NaHCO_3$ extraction method given by[30]. Organic carbon and total nitrogen contents in the soil and sewage sludge samples were determined by Walkley and Black's rapid titration method[31] and by the Gerhardt automatic N analyzer (Model KB 8S, Germany), respectively.For heavy metals analysis in the soil and sewage sludge samples, 1 g air-dried sample was digested in 20 ml of tri acid mixture (HNO_3 :H_2SO_4 :$HClO_4$:5:1:1) for 8 h at 80 °C following the method described by[32]. After complete digestion, the solution was filtered and the filtrate was analyzed for heavy metals. Heavy metal concentrations in the filterate were determined by using flame Atomic Absorption Spectrophotometer (Model 2380, Perkins Elmer, Inc., Norwalk, CT, USA) on dry weight basis.

Collection, preparation and preservation of vegetables: Composite samples of vegetation leaves of (lettuce, tomatoes, squash, sweet pepper, garden rocket and eggplant) and fruits of (tomatoes, squash, sweet pepper and eggplant) were collected from three experimental gardens irrigated with treated wastewater. The vegetables are grown on small sections of land for sale in nearby markets. Ten leaf samples and the same number of fruit samples were collected from each garden, the vegetables samples were taken to the laboratory within 1h of harvesting, collected samples were analyzed for Cu, Zn, Cd, Pb, and Fe, leaves and fruits were first washed with distilled water, dried at 50 °C until constant weight and then the samples were homogenized. Then 0.2 g was dissolved in 10 ml conc. HCl in a 100-ml beaker. The beaker was covered with a watch glass, and the contents were boiled on a hot plate for approximately 30 min. The contents were then evaporated to near dryness. After cooling, 20 ml of 0.1 M HCl was added, and the contents were gently boiled. The contents were quantitatively transferred into 100 ml volumetric flask by filtering through Whatman no. 2 filter paper. The residues were thoroughly washed with 0.1 M HCl and the volume was adjusted with the same solution to 100 ml. The digest obtained was analyzed for Cd, Zn, Cd, Pb and Fe using flame Atomic Absorption Spectrophotometer (Model 2380, Perkins Elmer, Inc., Norwalk, CT, USA) on dry weight basis [32].

Percentage recoveries of metals from soil and vegetables samples: A soil with concentrations certified for the elements Cu, Cd, Zn, Pb and Fe was analyzed using the method described for soil analysis. A spiking experiment involving the addition of known a mounts of standard solutions containing the elements of interest into the soil sample was also carried out employing the same procedure. The measured certified concentrations were compared with Cu, Cd, Zn, Pb and Fe. Also, the known concentrations of the spiked metals and the percentage recoveries were calculated (**Table1**).

The analytical procedure for vegetable samples was validated employing spiking experiments, in which known volumes of mixed standard solutions containing 10 mg element/L were added into 0.25 g portions of the vegetable samples. The samples were treated with the method described for vegetable analysis above and their percentage recoveries calculated (**Table 1**). The recovery rate was taken into account when calculating residue concentrations.

Table-1: %Recoveries of heavy metals in water, soil and vegetable samples.

Heavy metals	% Metals recoveries			Detection limits ($\mu g.kg^{-1}$)
	Water	Vegetables	Soil	
Cu	95.43	90.32	93.12	30
Cd	91.21	82.32	84.21	10
Zn	92.12	87.43	89.0	20
Pb	94.31	89.23	90.1	100
Fe	91.01	85.34	87.2	100

Statistical analysis: Data presented are means ± standard deviations. Data were analyzed with two-way analyses of variance and pairwise multiple comparison procedure (Student–Newman–Keuls method).

RESULTS AND DISCUSSION

The physicochemical parameters of the agricultural soils and sewage sludge considered in this study are presented in (**Table 2**). The pH of all samples of agricultural soil was 7.43 ± 0.08, while the pH values of the composite sewage sludge samples found 7.82 ± 0.09. At low pH the mobility and leaching of heavy metals increases and their mobility and availability decreases as the pH approaches neutral or rises above pH 7. The organic matter is an important component because it tends to either form soluble or insoluble complexes with the heavy metals, to migrate, or to be retained in the soil. The results show that the soil contains 4.90 ± 0.54 and 6.31 ± 0.92 $g.kg^{-1}$ organic matters for soils and sewage sludge respectively. In addition, the soil has 189.30 ± 22 kg ha^{-1} available nitrogen and 29.9 ± 0.63 $mg.kg^{-1}$ available phosphorus. While samples of sewage sludge have 0.46 ± 0.098 $dS.m^{-1}$ CEC, 798.32 $kg.ha^{-1}$ nitrogen, 678.9 $mg.kg^{-1}$ available phosphorus. The concentration of extractable heavy metals in soil and sewage sludge shown in **Table 2.** The results indicated that high level of Zn and Pb found in soils (11.24 ± 0.27 and 8.32 ± 0.91 $mg.kg^{-1}$), while the concentration of Zn and Pb in sewage sludge was (22.23 and 18.98 $mg.kg^{-1}$). However, the Cd concentrations in all soil samples are within the normal range (0.690 ± 0.56 $mg.kg^{-1}$) reported for the world soils[33], the levels of Cd in sewage sludge was 1.32 $mg.kg^{-1}$. The mean concentrations of Cu were found 6.89 and 13.25 $mg.kg^{-1}$ dry for agricultural soil and sewage sludge respectively. The level of Fe in sewage sludge obtained was 2.34 $mg.kg^{-1}$, while in soil it found 1.31 $mg.kg^{-1}$.

Table-2: Selected physico-chemical properties and some heavy metals of sewage sludge and soil of vegetables plants (Mean of 3 replicates ± SE)

Characteristic	**Sewage sludge**	**Vegetables soil (0-15 cm)**
pH	7.82 ± 0.09	7.43 ± 0.08
Electrical conductivity ($dS.m^{-1}$)	0.46 ± 0.098	0.39± 0.12
Cation exchange capacity (CEC) C mol (P^{+}) kg^{-1}	46.32 ± 3.08	36.40 ± 2.3
Free $CaCO_3$%	5.21 ± 0.21	3.41
Organic matter ($g.kg^{-1}$)	6.31 ± 0.92	4.90 ± 0.54
Total nitrogen ($mg.kg^{-1}$)	8964 ± 211.1	1988.93 ± 45.23
Available nitrogen ($kg.ha^{-1}$)	798.32 ± 21.1	189.30± 22
Total sulphur ($mg.kg^{-1}$)	678.9 ± 3.32	734.98 ± 21.2
Available phosphorus ($mg.kg^{-1}$)	20.89 ± 0.21	29.9 ± 0.63
Available micronutrient ($mg.kg^{-1}$)		
Fe	2.34 ± 0.87	1.31 ± 0.41
Zn	22.23 ± 2.12	11.24 ± 0.27
Cu	13.25 ± 56	6.89 ± 0.15
Pb	18.98 ± 0.98	8.32 ± 0.912
Cd	1.32 ± 0.42	0.690 ± 0.56

The reuse of treated wastewaters for purposes such as agricultural irrigation can reduce the amount of water that needs to be extracted from environmental water sources [34]. Therefore, there is an increasing necessity to irrigate with water that already contains salts, such as saline groundwater, drainage water, and treated wastewater [35]. Land application of treated wastewater on cultivated fields may serve as a viable way of disposing of effluents, and sustaining agricultural production in regions experiencing shortage in fresh water. Accumulation of micronutrients and heavy metals as a result of wastewater application could be caused directly by the wastewater composition or indirectly through increasing solubility of the indigenous insoluble soil heavy metals as a result of the acidification action of the applied wastewater[36]. The bioavailability of heavy metals depends on different factors such as soil pH and amount of clay in soil. An increase of soil pH and amount of clay can decrease the uptake of heavy metals by vegetables. In presence of organic matter, heavy metals can be found as chelates, which increase the ability of vegetables to uptake heavy metals. Irrigation of soil by wastewater increases soil organic matter and decrease soil pH therefore, the uptake of heavy metals by plants increases. The EC, BOD, COD, TSS, trace metal concentrations and pH of the raw wastewater and treated wastewater samples collected from diversion points are given in **Table 3 and Table 4**.

Table-3: Quality of raw and treated wastewater.

Parameter	Raw wastewater			Treated wastewater		
	Range	Range	SD	Range	Average	SD
PH	6.6–7.9	7.5	0.21	6.9–7.4	7.2	0.23
TSS ($mg.L^{-1}$)	28–350	275	80.2	15–308	128	150
BOD ($mg.L^{-1}$)	143–1220	942	244.5	213–404	108	200
COD ($mg.L^{-1}$)	83–2251	1712	591.2	31–751	498	500
EC ($ds.m^{-1}$)	1.41–2.10	1.83	0.11	1.23–1.68	1.76	0.2
Nitrate ($mg.L^{-1}$)	0.36–0.82	0.68	0.062	0.42	0.42	-
Total nitrogen ($mg.L^{-1}$)	0.36–0.82	52	-	7.8–13.2	11	70
SAR	2.10 – 3.96	3.3	0.8	1.5–3.2	2.8	9

Data are means ± SD of three independent samples

Table-4: The properties and average heavy metal concentrations of treated wastewater and raw wastewater.

Characteristic	Treated wastewater	Sewage wastewater
Electrical conductivity ($dS\ m^{-1}$)	0.49± 0.010	0.76± 0.23
CO^{3-}	0.31 ± 0.013	0.73 ± 0.04
HCO^{3-}	2.3 ± 0.03	4.78 ± 1.26
Cl^{-}	1.57 ± 0.52	5.43 ± 1.15
Ca ($mg\ L^{-1}$)	2.62 ± 0.01	4.62 ± 0.42
Mg ($mg\ L^{-1}$)	0.53 ± 0.025	1.82 ± 0.03
K ($mg\ L^{-1}$)	0.22± 0.002	0.31 ± 0.09
Micronutrients ($mg\ kg^{-1}$)		
Fe	8.0 ± 2.21	76.0 ± 5.93
Zn	1.98 ± 0.021	989.9 ± 0.048
Cu	0.98 ± 0.01	3.6 ± 0.020
Pb	2.1 ± 0.021	6.65± 0.29
Cd	0.4 ± 0.031	1.77 ± 0.039

Data are means ± SD of three independent samples

The electrical conductivity (EC) measured at 251 °C from 0.76 and 0.49 dS/m for raw swage water and treated wastewater respectively. These values are within the acceptable range recommended for irrigation wastewaters [37]. The pH of the irrigation wastewaters ranged from 6.9 to 7.4 and among the BOD and COD of treated wastewater were 108 and 498 $mg.L^{-1}$ for BOD and COD respectively. The values of heavy metals in treated wastewater were 19.98 $mg.L^{-1}$ for Zn, 0.98 $mg.L^{-1}$ for Cu, 8.0 $mg.L^{-1}$ for Fe, 0.4 $mg.L^{-1}$ for Cd and 2.1 mgL^{-1} for Pb. While the presence of high amounts of these metals in treated, wastewater irrigation may increase their levels in soils, which in turn may boost metal uptake by plants ultimately leading to elevated concentrations in the vegetables.

The concentrations o f heavy metal **(Table 5)** showed a trend of Fe > Zn > Cd > Cu > Pb in fruits, Fe > Cd > Zn > Cu > Pb in the leafs. The data showed that Cd concentration (mg kg^{-1}) trend by vegetables was eggplant (9.34 ± 0.37) > tomatoes (2.51 ± 0.065) > squash (2.44 ± 0.24) > sweet pepper (1.904 ± 0.21) > garden rocket (0.32 ± 0.012) in fruits. While in leafs was eggplant (4.52 ± 0.56) > squash (3.88 ± 0.24) > sweet pepper (2.77 ± 0.31) > tomatoes (2.51 ± 0.065) > lettuce (1.98 ± 0.21) > garden rocket (0.62 ± 0.01). On average, the accumulation of Cu in eggplant fruits was highest 7.67 $mg.kg^{-1}$. While low concentrations of Pb (0.21, 0.26 and 0.32 $mg.kg^{-1}$) reported in leaves of lettuce, squash and garden rocket respectively. While in the fruits the higher Pb concentrations was 0.53, 0.46 and 0.35 for tomatoes, sweet pepper and squash, respectively. Fe concentrations in leaf tissues of the vegetables averaged 88.83, 56.93, 21.32 and 13.93 $mg.kg^{-1}$ for eggplant, tomatoes, lettuce and squash respectively. While the higher concentration of Fe found in eggplant fruits 59.03 $mg.kg^{-1}$.

Table-5: Heavy metal content ($mg.kg^{-1}$) in leaf and fruits of some vegetables plants irrigated with treated wastewater.

Plant samples	Plant parts used	Concentration of element ($mg.kg^{-1}$ fresh wet)				
		Cu	Cd	Zn	Pb	Fe
Lettuce	Leaves	2.23 ± 0.023	1.98 ± 0.21	2.97 ± 0.21	0.21 ± 0.02	21.32 ± 0.21
Tomatoes	Leaves	4.86 ± 0.092	0.700 ± 0.02	4.78 ± 0.41	0.439 ± 0.03	56.93 ± 0.95
	Fruits	3.6 ± 0.01	2.517 ± 0.06	2.52 ± 0.06	0.532 ± 0.01	37.01 ± 1.23
Squash	Leaves	4.92 ± 0.023	3.88 ± 0.24	3.88 ± 0.10	0.267 ± 0.01	13.93 ± 0.98
	Fruits	1.27 ± 0.03	2.44 ± 0.24	2.44 ± 0.21	0.356 ± 0.021	112.37 ± 3.32
Sweet pepper	Leaves	3.73 ± 0.13	2.77 ± 0.31	3.55 ± 0.22	0.351 ± 0.11	11.65 ± 1.28
	Fruits	1.94 ± 0.23	1.904 ± 0.21	3.71 ± 0.22	0.46 ± 0.11	12.31 ± 1.12
Garden rocket	Leaves	3.34 ± 0.012	0.851 ± 0.01	2.12 ± 0.12	0.321 ± 0.09	11.12 ± 21
Eggplant	Leaves	1.79 ± .018	4.521 ± 0.56	3.48 ± 0.03	0.478 ± 0.03	88.833 ± 3.43
	Fruits	7.67 ± 0288	9.34 ± 0.37	9.36 ± 0.34	0.168 ± 0.01	59.03 ± 6.44

Data are means ± SD of three independent samples

The addition of treated wastewater to soil caused an increase in extractable concentration of heavy metals. Therefore, irrigation with treated wastewater increases the amount of uptake and accumulation of heavy metals in plant. Many investigations, including long and short-term studies, showed that the accumulation of heavy metals in plants increased because of the application of wastes such as wastewater, sewage sludge. In addition, the variations in the concentrations of the heavy metals in vegetables may be ascribed to the heavy metals concentrations of soil, air and wastewater irrigation of their production. No evidence of phytotoxicity of Cu and Zn in the vegetables could be found from the concentrations of Cu and Zn in the vegetable leaves at all vegetables used in this study. The concentrations of Cu in the leaves and fruits were all below[37] the toxic range of 20-100 mg Cu kg^{-1} dry wt. Studies by Berry and Wallace[38] indicated that Zn phytotoxicity in most leafy vegetables (expressed by reduced growth). Earlier studies by Khan and Marwari[39] reported high concentration of heavy metal in vegetables grown in agricultural fields receiving textile waste water. Metal accumulation in vegetables may pose a direct threat to human health [40-41]. Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil, and consumption of food plants grown in metal-contaminated soil[42]. Crop plants growing on heavy metal contaminated medium can accumulate high concentrations of trace elements to cause serious health risk to consumers. Different vegetable species accumulate different metals depending on environmental conditions, metal species and plant available forms of heavy metals. (Singh and Agarwal[43], reported that cowpea, okra raddish, spinach, chickpea, pea and wheat grown in heavy metals contaminated soils affected biomass, yield and metal distribution in different parts of crop plants. Although maximum proportion of heavy metals absorbed by the crops accumulated in their vegetative shoots (leaves, stem root), but substantial proportion of metals transported to seeds and fruits as well[44], conducted a pot study to investigate the toxic effects of certain heavy metals on the plant growth and grain yield of wheat (*Triticum aestivum* L.).

CONCLUSION

The use of sewage water for irrigation has gained importance throughout the world due to limited water sources and costly wastewater treatment for discharge. If land with suitable topography, soil characteristics and drainage is available, sewage effluent can be put to good use as a source of both irrigation water and plant nutrients. Sewage water contains high amount of organic matter, nutrients and some heavy metals which are toxic to plants beyond a certain limit. In our study six vegetable lettuce, tomatoes, squash, sweet pepper, garden rocket and eggplant were collected from 3 experimental farms in Jeddah that were irrigated with treated wastewater. Increased concentrations of metals both in the soils and the vegetables grown on this farms. But, it was noticed that different vegetables accumulate and translocate variable amounts of metals from the soil into their tissues. Most of the crops and vegetables species growing in metal polluted soils are unusable to avoid the absorption of these metals. Soils may accumulate metals in sufficient quantities to cause clinical problems both to animals and human beings consuming these metal rich plants. There is need for an improved food quality assurance system and promotion of the production of vegetables that comply with existing standards on heavy metal concentrations.

REFERENCES

1. F. Alkolibi, Possible Effects of global warming on agricultural and water resources in Saudi Arabia: Impacts and responses, Climatic Change, 2002, **54**: 225-245.
2. M.A. Al-Sahlawi, Seawater desalination in Saudia Arabia: economic review and demand projection. *Elsever desalination*, 1999, **123**: 143-7.
3. H.T, El-Dessouki, H.M. Ettouney, Fundamentals of salt water desalination. Elsevier Science B.V.2002.
4. A.M. El-Ghonemy, Future sustainable water desalination technologies for the Saudi Arabia: A review. *Renewable and Sustainable Energy Reviews*, 2012, **16:** 6566-6597.
5. S.P. Datta, D.R. Biswas, N. Saharan, S.K. Ghosh, R.K. Rattan, Effect of long-term application of sewage effluents on organic carbon, bioavailable phosphorus, potassium and heavy metals status of soils and uptake of heavy metals by crops. *J. Indian Soc. Soil Sci.,* 2000, **48:** 836–839.
6. F. Mapanda, E.N. Mangwayana, J. Nyamangara, K.E. Giller, The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. *Agric. Ecosyst. Environ*. 2005, **107:** 151-165.
7. N.S. Chary, C.T. Kamala, D.S. Suman Raj, Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol. *Environ. Saf.,* 2008, **69:** 513–524.
8. B. Devkota, G.H. Schmidt, Accumulation of heavy metals in food plants and grasshoppers from the Taigetos Mountains, Greece. *Agric. Ecosyst. Environ*. 2000, **78**: 85–91.
9. R.K. Sharma, M. Agrawal and F.M. Marshall, Heavy metal contamination in vegetables grown in wastewater irrigated areas of Varanasi, *India. Bull. Environ. Contam. Toxicol*. 2006, **77:** 312-318.
10. S. Singh and P.K. Aggarwal, Effect of heavy metal on biomass and yield of different crop species. *Indian J. Agric. Sci.,* 2006, **76:** 688-691.

11. J. Aparicio, L. Santos and E. Alonso, Simultaneous sanitation-assisted extraction, and determination by gas chromatography-mass spectrometry, of di-(2ethylhexyl) phthalate, nonylphenol, nonylphenolethoxyl-ates and polychlorinated biphenyls in sludge from wastewater treatment plants, *Anal. Chim. Acta*. 2007, **584**, 455–461.
12. N. Togay, Y., Togay and Y. Dogan, Effects of municipal sewage sludge doses on the yield, some yield components and heavy metal concentration of dry bean (*Phaseolus vulgaris* L.). *Afr. J. Biotechnol*. 2008, **7**: 3026-3030.
13. A. Tsakou, M. Roulia and N.S. Christodoulakis, Growth of flax plants (*Linumusitatissimum*) as affected by water and sludge from a sewage treatment plant. *Bull. Environ. Contam. Toxicol*. 2002, **68**: 56-63.
14. R.P. Singh M. Agrawal, Use of sewage sludge as fertilizer supplement for *Abelmoschusesculentus* plants: physiological, biochemical and growth responses. *Int. J. Environ. Waste Manage*. 2009, **3**: 91-106.
15. R.L. Reed, M.A. Sanderson, V.G. Allen and R.E. Zartman, Cadmium application and pH effects on growth and cadmium accumulation in swithchgrass. Comm. *Soil Sci. Plant Anal.* 2002, **33** (7 and 8), 1187-1203.
16. R.P. Singh and M. Agrawal, Variations in heavy metal accumulation, growth and yield of rice plants grown at different sewage sludge amendment rates. *Ecotoxicology and Environmental Safety*, 2010, **73:** 632-641.
17. J.Y. Dai, Chen, Ling, Zhao and Jian-fu, M.A, Na, Characteristics of sewage sludge and distribution of heavy metal in plants with amendment of sewage sludge. *J. Environ. Sci.* 2006, **18:** 1094-1100.
18. D. Fytili and A. Zabaniotou, Utilization of sewage sludge in EU application of old and new methods a review. Renew. Sustain. *Energy Rev*. 2006, **12:** 116-140.
19. Y. Anjaneyulu, Technical report on environmental impact assessment of effect of mixing of PETL (P) and PETL (B) with sewage at STP Amberpet and final release of its outlets into River Musi and downstream. Center for Environment, Jawaharlal Nehru Technological University, Hyderabad, India, 2001.
20. K.T. Cambra, A. Martínez Urzelai and E. Alonso, Risk analysis of a farm area near a lead and cadmium contaminated industrial site. *J. Soil Contam*. 1999, **8:** 527–540.
21. S. Dudka and W.P. Miller, Permissible concentrations of arsenic and lead in soils based on risk assessment. *Water Air Soil Poll*, 1999, **11:** 127-132
22. F. Itanna, Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiopian. *J. Health Dev*.2002, **6**: 295-302.
23. Codex Alimentarius Commission (FAO/WHO), Food additives and contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 01/12A:1-2892001..
24. D. Scott, J.M. Keoghan and B.E. Allen, Native and low input grasses a New Zealand high country perspective. *New* Zealand ,*Journal of Agricultural Research*, 1996, **39:** 499-512.
25. D. Voutsa, A. Grimanis and C. Samara, Trace elements in vegetables grown in industrial areas in relation to soil and air particulate matter. *Environmental Pollution*, 1996, **94**: 325-335.
26. Y. Weldegebriel, B. S. Chandravanshi, and W. Taddese, Concentration levels of metals in vegetables grown in soils irrigated with river water in Addis Ababa, Ethiopia. *Ecotoxicology and Environmental Safety*, 2012, **77:** 57-63.
27. L.C. Clesceri, A.E. Greenberg, A.D. Eaton, .Standard Methods for the Examination of Water and Waste Water 20th edition American Health Association, Baltimore (USA) 1998..
28. M. Stoeppler, Sampling and sample preparation: *Practical Guide for Analytical Chemists.* Springer-Verlag, Berlin.1997.
29. M.L. Jackson, Soil Chemical Analysis. Prentice-Hall, Inc., Englewood, NJ,1958, 59-67.
30. S.R. Olsen, L.E. Sommers. Phosphorus. In Page, A.L. et al. (Eds.), Methods of Soil Analysis. Part 2 Agronomy Monograph 9. ASA and SSSA, Madison, WI, 1982, 403-430.
31. A. Jamrah, A. Al-Omari, L. Al-Qasem and N. Abdel Ghani, Assessment of availability and characteristics of grey water in Amman, *Water Int.* 2006, **31**: 210-220.
32. J.M. Mohammed, T.J. Mohammed, N.U. Farhatullah, A.S., Mohammed, A. Shah and U.S. Abbas, 2011. The effect of using waste water for tomato. Pak. J. Bot., **43**: 1033-1044.
33. Anonymous., Guidelines for drinking water quality. Health criteria and other supporting information 34/9960 Mastercom/Wiener Velag-800, Australia1996.

34. A.U. Bhatti and S.Perveen, Heavy metals hazards in agriculture in NWFP. Proceedings of *the First International Conference on Environmentally Sustainable Development*. Department of Environmental Sciences, COMSATS Inst. Info. Tech. Abbottabad, Pakistan. 2005, 1513-1518.
35. R.S. Ayers, and D.W. Westcot, Water quality for agriculture. FAO *Irrig. Drain. Paper.* 1985, 29: 1-120.
36. S.M. Ross and J.K. Kaye, The meaning of metal toxicity in soil-plant systems. *In Toxic Metals in Soil-Plant Systems (Ed. S.M. Ross)* pp. 27-62. England: John Wiley and Sons Ltd 1984.
37. M.K. Türkdogan, F. Kilicel, K. Kara, I. Tuncer and I. Uygan,. Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey. *Environmental Toxicology and Pharmacology,* 2003, **13**: 175-179.
38. W.L. Berry and A.Wallace, Zinc phytotoxicity: Physiological responses and diagnostic criteria for tissues and solutions. Soil Sci., 1989, **147**: 390-397.
39. T.I. Khan and R. Marwari, Impact of heavy metal (lead) on environment and human beings. In: Environmental conservation, depleting resources and sustainable development (Eds.: T.I. Khan and H. S. Sharma). *Avishkar Publishers, Jaipur*. 2003,157-177.
40. M. Damek-Poprawa and K. Sawicka-Kapusta 2003. Damage to liver, kidney, and testis with reference to burden of heavy metals in yellow necked mice from areas around steelworks and zinc smelters in Poland. *Toxicology*, 2003, **186**: 1–10.
41. Cambra, K., Martınez, T., Urzelai, A., Alonso, E., 1999. Risk analysis of a farm area near a lead- and cadmium-contaminated industrial site. *J. Soil. Contam.* **8**: 527-540.
42. J.K. Hawley, Assessment of health risk from exposure to contaminated soil. *Risk Anal*., 1985, **5**: 289-302.
43. S. Singh and P.K. Aggarwal Effect of heavy metal on biomass and yield of different crop species. *Indian J. Agric. Sci.,* 2006, **76:** 688-691.
44. R. Athar and M. Ahmad, Heavy metal toxicity: Effect on plant growth and metal uptake by wheat, and on free living Azotobacter. *Water Air Soil Pollu.,* 2002, **138**: 165-180.

Correspondence author: Dr. Yahia Youssef Ismail Mosleh

King Abdul Aziz University, Faculty of Science, Biology Department, North Jeddah, Jeddah, KSA.