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Effects of Treated Municipal Wastewater and Sea Water **Irrigation on Soil and Plant Characteristics**

Ahmed, T. A.* and Al-Hajri, H. H.

Biological and Environmental Sciences Department, College of Arts and Sciences, Qatar University, Qatar

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ABSTRACT: The increasing need emergence of wastewater application agricultural irrigation can provide mor- but their heavy metal applications eff both the plant and its consumer. The treated wastewater on soil chemic accumulation of heavy metals in pla greenhouse in the growing season of pond in Doha City, Qatar. The soil was were used in this study; grain sorghur Plants were irrigated with four differe in addition to potable water as a cont well as concentration of the nutrier determined at the end of the experime irrigated with portable tap water and Cu, As, Cd and Pb did not show sig Sorghum soils have significantly less soils. Sorghum was found to accume and 92.00 mg/L, respectively) than that higher concentration of Cr compared	In for agriculture and landscope e adequate supply of high qua- fect must be regulated to ensi- e objective of the present re- al properties and plant gu- nt tissues. This research w f 2007. Treated wastewater is a mixture of sand and clay w in (<i>Sorghum bicolor</i> L.) and int mixtures of wastewater ar rol. The accumulation of sa- tis and heavy metal accum int. Cr, Mn and Zn showed so other irrigation treatments. gnificant differences among concentration of Co, Cu and alate significantly higher co- at of Sunflower. On the other	ape. Using treated wastewater in ality water for human consumption, sure no physiological problems for esearch was to study the effects of rowth characteristics as well as was conducted at Qatar university was obtained from Abu Nakhala with ratio of (1:1). Two crop plants Sunflower (<i>Helianthus annuus</i> L). nd sea water (1:0, 1:1, 3:1, and 0:1) alts and heavy metals in the soil as nulation in the plant tissues were significant differences between soil On the other hand, Al, Fe, Ni, Co, g the irrigation water treatments. I As compared to that of Sunflower oncentration of Mn and Zn (72.47

Key words: Wastewater, Irrigation, Soil, Plant, Heavy metals, Environment

IINTRODUCTION

In developing countries, especially in arid and semi-arid areas such as Gulf countries, wastewater is very important. Municipal wastewater could be defined as water that has been used in homes and businesses that is not for reuse unless treated by a wastewater facility. Wastewater should be treated to reduce pathogenic micro-organisms to acceptable levels, to ensure there is no threat to human health. Oatar faces a great challenge to meet water demands and manage its limited hydrological resources. Wastewater reuse should be an alternative water resource especially for the

*Corresponding author E-mail:t.alfattah@qu.edu.qa

agricultural irrigation. Using treated wastewater in agricultural irrigation can provide more adequate supply of high quality water for human consumption, but their heavy metal applications effect must be regulated to ensure no physiological problems for both the plant and its consumer.

Treated wastewater has been used for crop irrigation in the developing countries (Kansel and Singh, 1983; Abdel-Reheem et al., 1986; Bahri, 1988). Municipal wastewater generally contains high concentrations of suspended and dissolved solids (chloride, sodium, boron and heavy metals) and little of any added salt is removed during conventional (secondary and tertiary) treatments. Hydrological soil properties are especially sensitive to wastewater compounds. Indeed, numerous studies (Pescod, 1992; Bresler, 1981; Tarchitzky *et al.*, 1984; Vinten *et al.*, 1991) have highlighted hydraulic conductivity reduction in wastewater irrigated soil, ascribing it to a partial biological clogging of soil pores due to increased biomass and suspended solids. However accurate effluent management strategies, including wastewater treatment level, crops grown, irrigation methods, and cultivation and harvesting practices, can reduce contamination of irrigated vegetables and soil (Phene *et al.*, 1992; Ayars *et al.*, 1999; Pereira *et al.*, 2002; Assadian *et al.*, 1999).

There is potential for inorganic nutrients present in recycled water to be used as a fertilizer source. Soil microorganisms have been observed to increase metabolic activity when sewage effluent is used for irrigation (Meli et al., 2002; Ramirez-Fuentes et al., 2002). On the other hand, irrigation with wastewater raises sanitary problems (risk of viral and bacterial infection both for farmers and crops) and problems of agronomic nature, due to the presence of toxic substances. To avoid health hazards and damage to the natural environment wastewater must be treated before it can be used for agricultural and landscape irrigation (Pereira et al., 2002). The effluent for reuse must comply with reuse standards to minimize environmental and health risks (WHO, 1989).

However, the need to preserve existing water resources has led to a re-evaluation of this practice focusing on more environmentally sound methods. Various studies have shown that land application of treated municipal wastewater as water and/or nutrient source for agricultural crop production can represent a sustainable alternative (Day and Tucker, 1959; Quin, 1978; Feigin et al., 1991; Pescod, 1992; Al Salem, 1996; Biswas et al., 1999; Yadav et al., 2002) although such practice is traditionally still affected by problems of public acceptance (Pollice et al., 2004). Nevertheless, Hespanhol (1999) emphasized that the utilization of new water sources is crucial because an increase of sustainable agricultural production may not be attained simply by expansion of cultivated areas.

Kiziloglu et al. (2008) investigated the effects of irrigation with untreated, and preliminary and primary treated wastewater on macro- and micronutrient distribution within the soil profile, yield and mineral content of cauliflower and red cabbage plants grown on a calcareous soils. They reported that wastewater irrigation affected significantly soil chemical properties in the 0-30 cm soil layer and plant nutrient content after harvest. In addition, application of wastewater increased soil salinity, organic matter, exchangeable Na, K, Ca, Mg, plant available phosphorus and microelements, and decreased soil pH. Wastewater irrigation treatments also increased the yield as well as N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, Pb, Ni and Cd contents of cauliflower and red cabbage plants. However, problems with wastewater disposal and water scarcity in arid areas can be decreased by using treated wastewater for irrigation. In case of soils with poor fertility, it is an important source of nutrients for crop production (Kiziloglu et al., 2007).

Rahil and Antonopoulos (2007) examined the effects of irrigation with reclaimed wastewater and nitrogen fertilizer applications on plant growth, water and nitrogen distribution in the soil profile, water and nitrogen balance components and nitrogen leaching to groundwater. They concluded that municipal wastewater reclaimed by activated sludge and nitrification/denitrification can be used as valuable source of irrigation without contaminating groundwater. However, this quality of wastewater can replace only a small portion of plant N requirements.

Some investigations demonstrated that the plants play active roles towards mobilizing and uptake of metals bound in soil with considerable differences among plant species and cultivars (Helal, 1990; Hinsley et al., 1978; Mench et al., 1989; Petterson, 1977). Plant characteristics and activities may affect heavy metal uptake in different ways. These include the modification of soil properties related to heavy metal availability, the control of heavy metal transfer across cell membranes, the binding of metals in various plant tissues, and the interaction between the nutritional status of the plant as well as environmental stress conditions with these activities. The objective of the present study was to study the effects of treated wastewater on soil chemical properties and plant growth characteristics as well as accumulation of heavy metals in plant tissues.

MATERIALS & METHODS

As the wastewater reaches Abu Nakhala station at south of Doha, Qatar, it is treated and then discharged into an artificial pond through a pipeline. The pond lies next to the station. The land around the pond – at the margins - is covered with a dense plant cover. The land that is covered with the treated water sometimes gained a dark brown color, which is due to the high alkalinity level of the soil with the pH above 8. The study was conducted at Qatar university greenhouse in the growing season of 2007 using large size pots. Treated wastewater samples were collected from Abu-Nakhala pond, Doha, Qatar once a week for three months period. Pots were filled with a mixture of sand and clay soils with ratio of (1:1). Two crop plants were used in this study; grain sorghum (Sorghum bicolor L.) and Sunflower (Helianthus annuus L). Plants were irrigated with four different mixtures of treated wastewater (TWW) and sea water (SW) (1:0, 1:1, 3:1, and 0:1) in addition to potable tap water (PTW) as a control. The water characteristics were determined prior to irrigation treatment application. At the end of the experiment, composite soil samples from each pot were taken and prepared for analysis. Plant samples from each treatment were washed with de-ionized water, followed by cleaning with a dilute solution of 0.005% HCl and then they were thoroughly washed, by means of a special detergent (alconox 0.1%), and rewashed repeatedly (four times) with distilled water, left to drain on a filter paper, and dried in a ventilated oven at 70 °C. They were then ground by means of a special hammer mill, and were ready for chemical analysis.

Samples chemical analyses were carried out as described in standard methods (APHA, 1989) in order to determine electrical conductivity (EC), pH, total dissolved solids (TDS), total nitrogen (N), phosphate (P), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) contents.In addition heavy metals such as cadmium (Cd), zinc (Zn), copper (Cu), lead (Pb), chromium (Cr) and other elements were determined using Spectrophotometer and its ready kits.The core facilities of the Central Agricultural laboratory in Doha was used for water, soil and plant samples chemical analyses The results of soil and plant analyses were submitted to analyses of variance. The statistical analyses were performed for water treatments and crop plants. Variables showing significant F-test (P < 0.05) were submitted to mean comparisons by L.S.D. test (P < 0.05). All statistical analyses were carried out using the Minitab program.

RESULTS & DISCUSSION

Quality of treated wastewater, sea water and potable tap water used for irrigation are shown in Table 1. The composition of the potable tap water was less variable than that of both treated wastewater and sea water. The chemical characteristics of treated waste water were in general satisfactory. On an average basis the pH, EC and TDS were higher in treated wastewater than that of potable tap water but still very little compared to sea water (Table 1). Nutrient concentrations and heavy metals in the treated waste water appear to be under the critical limits. Cd, Pb and all other elements concentrations in TWW found to be in the acceptable range based on FAO standards (Pescod, 1992).Some chemical properties of the soil after irrigation with treated wastewater, mixture of TWW plus sea water, sea water and portable tap water are shown in (Table 2). The pH and EC of soil irrigated with 100 % treated waste water were in the acceptable limits according to FAO standard levels (Pescod, 1992).

Anions and Cations were in their lowest concentration on soil irrigated with PTW than both of TWW, mixture of TWW and SW and SW. The concentrations of anions and cations were increased gradually starting from treated wastewater passing through the mixture of TWW and SW reaching to their highest level on soil irrigated with 100 % Sea water. The differences between control treatment and each other treatment were statistically significant based on LSD test except for N %. The two crop plants (Sorghum and Sunflower) did not show significant differences in concentration of anions and cations in their soils. The concentration of micro elements and heavy metals in the soil due to irrigation with wastewater and other water irrigation treatments and two crop plants at the end of growing season

Water	рН	EC	T DS	А	nion meq	/L		Cation	s meq/L	
type	pn	MS/Cm	(mg/L)	HCO ₃	Cl	SO ₄	Ca	Mg	Na	K
TWW	8.34	12.43	7460	60.97	60.97	93	51.37	70.9	70.9	3.12
SW	8.28	57.6	34500	3.09	585.86	296.78	25.24	190.55	656	13.13
PTW	8.16	0.17	104.7	1.69	0.52	0	0.95	0.09	0.5	0.08
				Τα	tal Eleme	ents (mg/L	<i>(</i>)			
	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
TWW	0.0021	0.0094	0.001	5.084	0.0014	0.0133	0.0303	0.0086	0.0002	0.0016
SW	0.0018	0.051	0.0004	2.51	0.0008	0.0037	0.205	0.0206	0.0002	0.0048
PTW	0.0523	0.072	0.028	3.103	0.0209	0.0542	0.757	0.0236	0.0002	0.0021

Table 1. Water samples chemical characteristics used in the experiment

EC: Electrical conductivity M.Mhos/cm (at $25^{\circ}C$), TDS: Total Dissolved Solids

TWW: Treated Waste Water; SW: Sea Water; PTW: Potable Tap Water

is shown in Table 3. Cr, Mn and Zn showed significant differences between soil irrigated with portable tap water and other irrigation treatments. On the other hand, Al, Fe, Ni, Co, Cu, As, Cd and Pb did not show significant differences among the irrigation water treatments. These results are in agreement with other researchers. Boll et al. (1986) reported that irrigation using wastewater irrigation increased the concentration of Zn to toxic levels in the soil. Abedi-Koupai et al. (2006) found that application of wastewater treatment had no significant effect on the accumulation of soil Fe, Cd, Ni, Cu and Zn.Table 2.Soil physical and chemical characteristics in the end of the experiment.

In general, there were significant differences between heavy metals in soil for the two crop plants. Sorghum soils have significantly less concentration of Co, Cu and As compared to that of Sunflower soils (Table 3). Many studies showed that vegetation is an important factor influencing the mobility of metals in soil, directly as well as indirectly (Caron *et al.*, 1996). Plants may increase metal mobility through the formation of preferential pathways along root channels or the complex of metals with root exudates in the rhizome. On the other hand, they may also retard metal leaching through reducing deep seepage by taking up water, adsorption of metals to root surfaces, plant uptake of metals, and simulated microbial immobilization in rhizome (McBride *et al.*, 1997).

Sorghum was found to accumulate significantly higher concentration of Mn and Zn (72.47 and 92.00 mg/L, respectively) than that of Sunflower. On the other hand, Sunflower has significantly higher concentration of Cr compared to that of Sorghum (Table 4). Murillo et al. (1999) studied the accumulation of chemical elements in soil and in two crops sunflower and sorghum - affected by heavy metals spill. They reported that leaves of spillaffected crop plants had higher nutrient (K, Ca and Mg for sunflower and N and K for sorghum) concentrations than controls, indicating a 'fertilizing' effect caused by the sludge. Seeds of spill-affected sunflower plants did accumulate more As, Cd, Cu and Zn than controls, but values were below toxic levels. Leaves of sorghum plants accumulated more As, Bi, Cd, Mn, Pb and Zn than controls, however these values were also below toxic levels for livestock consumption. In general, none of the heavy metals studied in both crops reached either phototoxic or toxic levels for humans or livestock.

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treatment PH MS/Cm T1 7.4 5.0 T2 7.4 13.2 T3 7.4 13.2 T4 7.4 11.7 T4 7.4 11.7 T4 7.4 11.7 C 7.9 11.8 C 7.9 1.4 Mean 7.5 11.8 Wer T2 7.9 6.8 T1 7.3 6.8 11.4 Wer T2 7.4 14.1 Wer T2 7.4 14.1 Wer T2 7.4 14.1 Wer T2 7.4 14.1 Wer T2 7.4 27.9 Wer T3 7.5 13.5 Wer T4 7.4 27.9 Wer T4 7.4 27.9 C 7.9 0.8 0.8 C 7.9 0.8 0.8 <th>Crop</th> <th>Water</th> <th></th> <th>ЪС</th> <th>CEC</th> <th>Ma</th> <th>Macro Nutrients</th> <th>ents</th> <th>7</th> <th>Anions meq/L</th> <th>. 1</th> <th>C</th> <th>Cations meq/L</th> <th>/T</th>	Crop	Water		ЪС	CEC	Ma	Macro Nutrients	ents	7	Anions meq/L	. 1	C	Cations meq/L	/T
T1 74 50 12.67 0.12 6.87 0.97 1.923 22.29 32.51 23.47 T2 74 13.2 13.27 0.09 7.77 2.17 2.02 92.78 60.07 96.53 T3 74 11.7 5.73 0.10 9.23 1.97 1.91 76.21 58.46 78.97 T4 74 11.7 5.73 0.108 0.12 10.09 4.97 1.72 227.37 118.03 243.87 C 79 14 279 0.13 9.16 0.37 1.52 6.07 6.97 4.965 Mean 75 11.8 9.19 0.11 8.62 2.07 1.87 8.967 3.653 r 73 6.81 0.13 8.15 2.34 1.57 8.975 8.975 3.653 r 73 6.83 0.13 8.30 2.34 1.57 8.975 9.757 9.757 9.756<	ptant	treatment	ЬH	MS/Cm		z %	P mg/L	K mg/L	HCO ₃	a	SO_4	Ca	Mg	Na
T2 74 132 1327 0.09 7.77 2.17 2.02 92.78 60.07 96.53 T3 74 11.7 5.73 0.10 9.23 1.97 1.91 76.21 58.46 78.97 T4 74 11.7 5.73 0.10 9.23 1.97 1.91 76.21 58.46 78.97 T4 74 279 10.80 0.12 10.09 4.97 1.72 277.37 118.03 243.87 C 79 14 3.47 0.13 9.16 0.37 1.52 6.07 6.97 4.70 Mean 75 11.8 9.19 0.11 8.62 2.07 1.87 8.95 6.97 4.70 Mean 75 11.8 9.19 0.11 8.62 2.07 1.67 8.95 6.97 6.97 6.97 6.97 6.97 T1 73 6.8 5.13 1.67 1.67 1.67		T1	7.4	5.0	12.67	0.12	6.87	0.97	1.923	22.29	32.51	23.47	8.96	23.47
T3 T4 11.7 5.73 0.10 9.23 1.97 1.91 76.21 58.46 78.97 T4 7.4 27.9 10.80 0.12 10.09 4.97 1.72 227.37 118.03 243.87 C 7.9 1.4 3.47 0.13 9.16 0.37 1.52 6.07 6.97 4.70 Mean 7.5 11.8 9.19 0.11 8.62 2.07 1.87 84.98 55.19 89.57 Mean 7.5 11.8 9.19 0.11 8.62 2.07 1.87 84.98 55.19 89.57 T1 7.3 6.8 5.33 0.15 8.47 1.52 1.67 84.98 55.19 89.57 T1 7.3 6.8 5.33 0.13 8.30 2.34 1.57 84.58 65.92 60.173 65.92 61.73 65.92 61.73 65.92 61.73 65.92 61.73 67.54 94.56		T2	7.4	13.2	13.27	0.09	7.77	2.17	2.02	92.78	60.07	96.53	22.26	96.53
T47.427.910.800.1210.094.971.72227.37118.03243.87C7.91.43.470.139.160.371.526.076.974.70Mean7.511.89.190.118.622.071.8784.9855.1989.57T17.36.85.530.139.471.521.6731.6347.3733.63T17.36.85.530.138.302.341.5784.9855.1989.57T27.414.14.470.138.302.341.5798.256.392101.73T27.414.14.470.138.302.341.5798.276.72794.56T37.513.50.130.0910.593.971.79.36107.7394.56T47.422.917.730.0910.660.171.672.674.051.73Mean7.511.78.440.159.002.061.632.061.632.674.051.73Mean7.511.78.440.129.002.061.632.674.051.73Mean7.511.78.440.129.002.061.632.674.051.73Mean7.511.78.440.129.002.061.632.674.051.73Mean7.511.78.4	Sorghum	T3	7.4	11.7	5.73	0.10	9.23	1.97	1.91	76.21	58.46	78.97	21.32	78.97
C7.91.43.470.139.160.371.526.076.974.70Mean7.511.89.190.118.622.071.8784.9855.1989.57T17.36.85.530.159.471.521.6731.6347.3733.63T27.414.14.470.138.302.341.5798.2563.92101.73T37.513.52.330.138.282.311.4789.5767.2794.56T37.513.52.330.138.282.311.4789.5767.2794.56T47.422.917730.1010.593.971.77179.36107.33C7.90.812.130.0910.660.171.672.674.051.73Mean7.511.78440.129.002.061.632.061.6380.2757.6585.98		Τ4	7.4	27.9	10.80	0.12	10.09	4.97	1.72	227.37	118.03	243.87	48.92	243.87
Mean 7.5 11.8 9.19 0.11 8.62 2.07 1.87 84.98 55.19 89.57 T1 7.3 6.8 5.53 0.15 9.47 1.52 1.67 31.63 47.37 33.63 T2 7.4 14.1 4.47 0.13 8.30 2.34 1.57 98.25 63.92 101.73 T3 7.5 135 2.33 0.13 8.30 2.34 1.57 98.57 67.27 94.56 T3 7.5 135 2.33 0.13 8.28 2.31 1.47 89.57 67.27 94.56 T4 7.4 22.9 1773 0.10 10.59 3.97 1.79.36 198.23 C 7.9 0.8 10.59 3.97 1.79.36 1.73 198.23 Wean 7.5 1.9 2.67 9.16 1.73 1.73 V 7.9 10.5 3.90 1.67 1.67 1.7		C	7.9	1.4	3.47	0.13	9.16	0.37	1.52	6.07	6.97	4.70	2.38	4.70
T17.36.85.530.159.471.521.6731.6347.3733.63T27.414.14.470.138.302.341.5798.2563.92101.73T37.513.52.330.138.282.311.4789.5767.2794.56T47.422.917.730.1010.593.971.77179.36105.64198.23C7.90.810.660.1710.562.677.97.51.73Mean7.511.78.440.129.002.061.6380.2757.6585.98		Mean	7.5	11.8	91.9	0.11	8.62	2.07	1.87	84.98	55.19	89.57	20.772	89.57
T2 7.4 14.1 4.47 0.13 8.30 2.34 1.57 98.25 63.92 101.73 T3 7.5 13.5 2.33 0.13 8.28 2.31 1.47 89.57 67.27 94.56 T4 7.4 22.9 17.73 0.10 10.59 3.97 1.77 179.36 198.23 C 7.9 0.8 10.56 0.10 10.59 3.97 1.77 179.36 198.23 Mean 7.5 11.7 8.44 0.12 9.06 2.06 1.63 80.27 57.65 85.98		T1	7.3	6.8	5.53	0.15	9.47	1.52	1.67	31.63	47.37	33.63	13.57	33.63
7.5 13.5 2.33 0.13 8.28 2.31 1.47 89.57 67.27 94.56 7.4 22.9 1773 0.10 10.59 3.97 1.77 179.36 105.64 198.23 7.9 0.8 12.13 0.09 10.66 0.17 1.67 2.67 4.05 1.73 7.5 11.7 8.44 0.12 9.00 2.06 1.63 80.27 57.65 85.98	Sunflower	T2	7.4	14.1	4.47	0.13	8.30	2.34	1.57	98.25	63.92	101.73	23.37	101.73
7.4 22.9 17.73 0.10 10.59 3.97 1.77 179.36 105.64 198.23 7.9 0.8 12.13 0.09 10.66 0.17 1.67 2.67 4.05 1.73 7.5 11.7 8.44 0.12 9.00 2.06 1.63 80.27 57.65 85.98		T3	7.5	13.5	2.33	0.13	8.28	2.31	1.47	89.57	67.27	94.56	20.47	94.56
7.9 0.8 12.13 0.09 10.66 0.17 1.67 2.67 4.05 1.73 7.5 11.7 8.44 0.12 9.00 2.06 1.63 80.27 57.65 85.98		Τ4	7.4	22.9	17.73	0.10	10.59	3.97	1.77	179.36	105.64	198.23	43.42	198.23
7.5 11.7 8.44 0.12 9.00 2.06 1.63 80.27 57.65 85.98		C	7.9	0.8		0.09	10.66	0.17	1.67	2.67	4.05	1.73	0.83	1.73
		Mean	7.5	11.7	8.44	0.12	9.00	2.06	1.63	80.27	57.65	85.98	20.37	85.98

	plant	treatment					Total	Elements (mg/L)	ng/L)				
			AI	\mathbf{Cr}	\mathbf{Mn}	Fe	C_0	Ni	Cu	\mathbf{Zn}	\mathbf{As}	Cd	Ρb
8 72.43 3621 106 1.11 29.53 17.49 8.37 0.0002 64.35 3163 1.82 0.02 87.42 30.91 11.87 0.0002 64.35 3163 1.82 0.02 87.42 30.91 11.87 0.0002 66.47 37.4 4.76 3.11 58.85 29.39 13.03 2.61 66.07 37.4 4.76 3.11 58.85 29.39 13.03 2.61 66.067 37.4 4.76 3.11 58.85 29.39 13.03 2.61 67.12 3128 13.83 5.31 2.54.40 11.10 2.72 65.36 3270 24.31 4.29 355.84 1.206 0.04 66.36 3182 15.92 0.11 3.89 2.57.89 1.710 0.002 65.36 32.71 0.32 2.41 1.196 9.179 0.002 712 8.37 13.39 2		T1	2449	18.77	80.33	3312	8.20	13.27	15.59	50.84	17.68	13.07	9.2^{2}
0 64.35 3163 1.82 0.002 8.47 0.0002 7 66.64 3774 4.76 3.11 58.32 32.93 11.87 0.0002 7 66.67 3774 4.76 3.11 58.35 22.33 11.87 0.002 7 69.67 3774 4.76 3.11 58.35 29.23 11.00 29.22 0.002 8 69.10 3727 4.76 3.11 58.35 21.33 20.11 38.9 257.89 13.97 41.74 0.02 8 68.14 333 20.11 3.89 257.89 13.97 42.06 0.04 1 $8.37t$ ns $4.11p$ ns $5.75.89$ 13.97 42.06 0.04 1 $8.37t$ ns 4.116 ns 257.89 11.96 $9.17p$ ns 1 $8.37t$ ns 20.11		T2	3256	5.18	72.43	3621	1.06	1.11	29.53	17.49	8.37	0.0002	0.0
64.29 3499 4.11 0.02 87.42 30.91 11.87 0.0002 66.94 3274 8.59 1.22 99.21 17.76 18.07 0.0002 66.94 3274 8.59 1.22 99.21 17.76 18.07 0.0002 81.48 3659 23.24 8.08 257.89 213.30 210.12 0.02 65.36 3127 23210 1.63 261.37 6.99 50.27 0.02 65.36 3127 23210 1.63 261.37 6.99 50.27 0.02 68.14 3333 20.11 3.89 211.36 7.12 35.54 0.27 $8.37t$ ns $4.11p$ ns $5.57.89$ 13.97 42.06 0.04 $8.37t$ ns 4.136 ns $5.57.89$ 13.96 $9.17p$ 0.02 $8.37t$ ns 4.176 0.002	Sorghum	T3	2633	3.10	64.35	3163	1.82	0.02	62.50	29.98	9.47	0.0002	0.0
6694 3274 8.59 1.22 9921 17.76 18.07 0.0002 69.67 3374 4.76 3.11 58.85 29.39 13.03 2.61 69.10 3427 2.324 8.08 2.934 4.174 0.02 69.10 3427 2.3224 8.08 $2.61.37$ 6.99 50.27 0.02 69.10 3427 2.322 0.13 $2.11.36$ 7.12 35.54 0.27 68.14 3333 20.11 3.89 257.89 13.97 42.06 0.04 $8.37t$ ns $4.11p$ ns $56.83p$ 11.96 $9.17p$ ns $rathethethethethethethethethethethethethet$		T4	2943	4.67	64.29	3499	4.11	0.02	87.42	30.91	11.87	0.0002	0.0
0.60.67 3374 4.76 3.11 5.8.85 29.39 13.03 2.61 0 62.12 3128 13.83 5.31 254.40 11.10 29.22 0.02 6 61.0 3427 23.20 1.63 206.53 23.342 41.74 0.02 7 65.36 3182 15.92 0.13 211.36 7.12 35.54 0.27 2 62.66 3182 15.92 0.13 211.36 7.12 35.54 0.27 2 62.66 3182 15.92 0.13 211.36 7.12 35.54 0.27 2 62.66 3182 15.92 0.13 211.36 7.12 35.54 0.27 2 68.14 3333 20.11 389 257.89 13.97 42.06 0.04 1 8.37 ns 7.12 35.54 0.27 60 1 8.37 ns 4.11.6 ns		C	2828	4.07	66.94	3274	8.59	1.22	99.21	17.76	18.07	0.0002	0.0
0 62.12 3128 13.83 5.31 234.40 11.10 29.22 0.02 8 14.8 3659 23.24 8.08 206.53 23.42 41.74 0.02 7 6.63.16 3270 24.31 4.29 355.83 21.125 55.353 0.02 2 6.53.6 3182 15.92 0.13 21.136 7.12 35.54 0.02 2 6.53.6 3182 15.92 0.13 21.136 7.12 35.54 0.02 2 8.37t ns 4.11 ns 5.53 11.96 9.17 no 4 8.37t ns 5.53 11.96 9.17 no 0.02 3 8.37t ns 5.53 11.96 9.17 ns 0.02 4 8.37t ns 5.53 11.96 9.17 ns 0.0 5 9.11 ns 5.53 11.96 9.17 ns		Mean	2822	7.17	69.67	3374	4.76	3.11	58.85	29.39	13.03	2.61	1.8
v 81.48 3659 23.24 8.08 206.53 23.42 41.74 0.02 v 69.10 3427 23.20 1.63 261.37 6.99 50.27 0.02 v 65.36 3270 24.31 4.29 355.83 21.25 55.353 0.02 v 68.14 333 20.11 3.89 257.89 13.97 42.06 0.04 v 8.37t us 4.11p us 56.38p 11.96 9.17p us Table 4. Plant chemical analysis in the end of the experiment 4.11p us 56.38p 11.96 9.17p us v 0.002 0.0002 0.0002 0.0002 0.0002 0.0002 v 41.76 0.0002 0.0002 175 72 24.73 0.0002 v 41.64 55.15 0.0002 0.0002 257 67 44.25 0.0002 v 10.9 41.176		T1	2689	3.09	62.12	3128	13.83	5.31	254.40	11.10	29.22	0.02	0.00
69.10 3427 23.20 1.63 261.37 6.99 50.27 0.02 2 65.36 3182 1592 0.13 211.36 7.12 355.4 0.27 8 68.14 333 20.11 3.89 257.89 13.97 42.06 0.04 1 8.371 ns $56.83p$ 11.96 $9.17p$ ns 1 8.371 ns 20.11 3.89 257.89 13.97 42.06 0.04 1 8.371 ns $4.1p$ ns $56.83p$ 11.96 $9.17p$ ns 1 8.371 ns $56.83p$ 11.96 $9.17p$ ns 1 1.02 333 20.11 3.89 25.89 0.04 1 1.02 0.002 0.0002 0.0002 0.002 0.002 11.06 41.76 0.0002 0.0002 212		T2	3067	4.47	81.48	3659	23.24	8.08	206.53	23.42	41.74	0.02	0.00
i 65.36 3270 24.31 4.29 355.83 21.25 53.53 0.02 i 62.66 3182 1592 0.13 211.36 7.12 35.54 0.27 i $8.37t$ ns $4.11p$ ns $56.83p$ 11.96 $9.17p$ ns i $8.37t$ ns $4.11p$ ns $56.83p$ 11.96 $9.17p$ ns Table 4. Plant chemical analysis in the end of the experiment $arradial arradial analysis in the end of the experiment arradial arradial analysis in the end of the 257.89 11.96 9.17p ns Mn Fe Co Ni Cu Zn As Cd 98.16 41.76 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 74.04 55.15 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 74.64 55.758 0.0002 0.0002 $	Sunflower	T3	2952	4.03	69.10	3427	23.20	1.63	261.37	6.99	50.27	0.02	0.02
2 62.66 3182 15.92 0.13 211.36 7.12 35.54 0.27 1 8.371 ns $4.11p$ ns $56.83p$ 11.96 $9.17p$ ns Table 4. Bant chemical analysis in the end of the experiment 3.33 20.11 3.89 257.89 11.96 $9.17p$ ns Table 4. Plant chemical analysis in the end of the experiment f f 0.04 ns Table 4. Plant chemical analysis in the end of the experiment 11.96 $9.17p$ ns c Mn Fe Co Ni Cu Zn As Cd 98.16 41.76 0.0002 0.0002 30.0002 30.002 <		T4	2593	3.67	65.36	3270	24.31	4.29	355.83	21.25	53.53	0.02	0.0
8 68.14 333 20.11 3.89 257.89 13.97 42.06 0.04 t 8.37t ns 4.11p ns 56.83p 11.96 9.17p ns Table 4. Bant chemical analysis in the end of the experiment 7 11.96 9.17p ns Table 4. Plant chemical analysis in the end of the experiment 11.96 9.17p ns Table 4. Plant chemical analysis in the end of the experiment 11.96 $9.17p$ ns Mn Fe Co Ni Cu Zn As Cd 98.16 41.76 0.0002 0.0002 306 141 28.687 0.0002 74.04 55.15 0.0002 0.0002 257 67 24.73 0.0002 74.04 55.15 0.0002 0.0002 257 92.73 0.0002 74.64 55.758 0.0002 0.0002 267 92 96.87 0.0002		C	2566	4.462	62.66	3182	15.92	0.13	211.36	7.12	35.54	0.27	2.8
t8.37tns4.11pns56.83p11.969.17pnsTable 4. Plant chemical analysis in the end of the experimentTotal Elements (mg/L)Total Elements (mg/L)MinFeCoNiCuZnAsCd98.1641.760.000230614128.680.000298.1641.760.000230614128.680.000274.0455.150.00020.00022576744.250.000274.0455.150.00022000224254720.000274.0455.150.00020.0002242540.000274.0455.530.00020.00022470.000274.6453.580.00020.00022579236.870.000274.6453.530.00022442530.000212659.770.000211.3651.600.00022442334535.530.000211.36736.730.00022195722.270.000215.6736.730.00022443428.240.000215.6736.730.00022636525.440.000213.25310.3622636525.440.000216.8474.810.0002233242660.000216.8474.810.00020.00022636525		M ean	2773	3.9418	68.14	3333	20.11	3.89	257.89	13.97	42.06	0.04	0.5
Table 4. Plant chemical analysis in the end of the experimentTable 4. Plant chemical analysis in the end of the experimentTotal Elements (mg/L) Mn FeCoNiCu Mn FeCoNiCu 98.16 41.76 0.0002 306 141 28.68 0.0002 98.16 41.76 0.0002 257 67 44.25 0.0002 98.16 41.76 0.0002 0.0002 257 67 61.09 42.15 0.0002 0.0002 242.257 67 44.25 0.0002 74.64 53.58 0.0002 0.0002 257 92 36.87 0.0002 72.447 55.53 0.0002 2573 92.0233 36.87 0.0002 11.3667 36.77 0.0002 2573 9.0002 11.3667 36.73 0.0002 2573 0.0002 11.367 36.73 0.0002 2573 0.0002 15.673 0.0002 0.0002 2573 0.0002 11.3667 36.73 0.0002 0.0002 2133 45 <td></td> <td>L SD 0.05</td> <td>SU</td> <td>5.19t</td> <td>8.37t</td> <td>SU</td> <td>4.11p</td> <td>SU</td> <td>56.83p</td> <td>11.96</td> <td>9.17p</td> <td>ns</td> <td>Ns</td>		L SD 0.05	SU	5.19t	8.37t	SU	4.11p	SU	56.83p	11.96	9.17p	ns	Ns
treatmentAlCrMnFeCoNiCuZnAsCdT1 2.77 34.40 98.16 41.76 0.002 306 141 28.68 0.002 T2 0.02 57.04 74.04 55.15 0.0022 0.002 257 67 44.25 0.002 T3 2.84 33.31 61.09 42.15 0.0002 0.002 175 72 24.73 0.002 T4 16.51 40.13 54.47 95.75 0.0002 0.0002 272 54 26.73 0.002 C 0.02 2.84 33.31 61.09 42.15 0.0002 0.0022 242 54.73 0.002 T4 16.51 40.13 54.47 95.75 0.0002 0.0002 242 54.73 0.002 T 0.02 22.17 74.64 53.58 0.0002 0.0002 242 54.73 0.002 T1 0.02 30.22 113.66 53.53 0.0002 20002 2573 0.002 T1 0.02 30.22 18.42 53.56 0.0002 2573 0.002 T2 0.02 4.41 57.45 57.68 0.002 0.002 2573 0.002 T1 0.02 4.41 57.45 25.49 0.002 0.002 219 57 22.277 0.002 T2 0.02 56.46 15.67 36.73 0.002 244	Crop	Water					Total 1	Elements (n	ng/L)				
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	plant	treatment	ЧI	\mathbf{Cr}	\mathbf{Mn}	Fe	Co	Ni	Cu	Π	\mathbf{As}	Cd	Pb
T2 0.02 57.04 74.04 55.15 0.0002 0.002 257 67 44.25 0.0002 T3 2.84 33.31 61.09 42.15 0.0002 0.0002 175 72 24.73 0.0002 T4 16.51 40.13 54.47 95.75 0.0002 0.0002 242 54 26.73 0.0002 C 0.02 22.17 74.64 53.58 0.0002 0.0002 242 54 26.73 0.0002 Mean 4.41 37.43 72.47 57.68 0.0002 0.0002 257 92 56.77 0.0002 T1 0.02 30.22 18.42 235.53 0.0002 0.0002 257 92 36.87 0.0002 T2 0.02 45.44 25.49 30.21 0.0002 0.0002 257 92 36.87 0.0002 T2 0.02 257 92 36.87 0.0002 0.0002 257 92 36.87 0.0002 T2 0.02 256.46 11.36 51.60 0.0002 0.0002 219 57 22.277 0.0002 T4 0.02 56.46 13.567 30.21 0.0002 0.0002 253 45 35.63 0.0002 T2 0.02 57 25.44 0.0002 256.46 256.46 0.0002 0.0002 263 65 254.46 0.0002 T4 0.02 57 26.86 <td></td> <td>T1</td> <td>2.77</td> <td>34.40</td> <td>98.16</td> <td>41.76</td> <td>0.0002</td> <td>0.0002</td> <td>306</td> <td>141</td> <td>28.68</td> <td>0.0002</td> <td>0.0002</td>		T1	2.77	34.40	98.16	41.76	0.0002	0.0002	306	141	28.68	0.0002	0.0002
T32.8433.3161.0942.150.00020.00021757224.730.0002T416.5140.1354.4795.750.00020.00022425426.730.0002C0.0222.1774.6453.580.00020.00022425426.730.0002Mean4.4137.4372.4757.680.00020.00022425426.730.0002T10.0222.1774.6453.580.00020.00022539236.870.0002T10.0230.2218.42235.530.00020.000225310325.390.0002T20.0248.08111.3651.600.00020.00022195722.270.0002T30.0245.4425.4930.210.00021.36472334535.630.0002T40.0256.4615.6736.730.0002200022443428.240.0002T40.0256.4615.6736.730.00022443428.240.0002T30.0256.4615.6736.730.00022636525.440.0002T40.0256.4615.6736.730.00022636525.440.0002T40.0256.4613.5519.960.00020.00022636525.440.0002Mean0.0247.		T2	0.02	57.04	74.04	55.15	0.0002	0.0002	257	67	44.25	0.0002	0.0002
	Sorghum	Т3	2.84	33.31	61.09	42.15	0.0002	0.0002	175	72	24.73	0.0002	0.0002
C 0.02 22.17 74.64 53.58 0.0002 0.0002 306 126 59.77 0.0002 Mean 4.41 37.43 72.47 57.68 0.0002 0.0002 257 92 36.87 0.0002 T1 0.02 30.22 18.42 235.53 0.0002 0.0002 257 92 36.87 0.0002 T2 0.02 48.08 11.36 51.60 0.0002 0.0002 219 57 22.27 0.0002 T3 0.02 45.44 25.49 30.21 0.0002 1.3647 233 45 35.63 0.0002 T4 0.02 56.46 15.67 36.73 0.0002 0.0002 244 34 28.24 0.0002 C 0.02 58.40 13.25 19.96 0.0002 0.0002 263 65 25.44 0.0002 Mean 0.02 47.72 16.84 74.81 0.0002 0.27353 242 61 27.38 0.0002		T4	16.51	40.13	54.47	95.75	0.0002	0.0002	242	54	26.73	0.0002	0.0002
Mean4.4137.4372.4757.68 0.0002 0.0002 257 92 36.87 0.0002 T1 0.02 30.22 18.42 235.53 0.0002 0.0002 253 103 25.39 0.0002 T2 0.02 48.08 11.36 51.60 0.0002 0.0002 219 57 22.27 0.0002 T3 0.02 45.44 25.49 30.21 0.0002 1.3647 233 45 35.63 0.0002 T4 0.02 56.46 15.67 36.73 0.0002 0.0002 244 34 28.24 0.0002 C 0.02 58.40 13.25 19.96 0.0002 0.0002 263 65 25.44 0.0022 Mean 0.02 47.72 16.84 74.81 0.0002 0.27353 242 61 27.38 0.0002		С	0.02	22.17	74.64	53.58	0.0002	0.0002	306	126	59.77	0.0002	0.0002
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T2 0.02 48.08 11.36 51.60 0.0002 0.0002 219 57 22.27 0.0002 T3 0.02 45.44 25.49 30.21 0.0002 1.3647 233 45 35.63 0.0002 T4 0.02 56.46 15.67 36.73 0.0002 0.0002 244 34 28.24 0.0002 C 0.02 58.40 13.25 19.96 0.0002 0.0002 263 65 25.44 0.002 Mean 0.02 47.72 16.84 74.81 0.002 0.27353 242 61 27.38 0.002		T1	0.02	30.22	18.42	235.53	0.0002	0.0002	253	103	25.39	0.0002	0.0002
T3 0.02 45.44 25.49 30.21 0.0002 1.3647 233 45 35.63 0.0002 T4 0.02 56.46 15.67 36.73 0.0002 0.0002 244 34 28.24 0.0002 C 0.02 58.40 13.25 19.96 0.0002 0.0002 263 65 25.44 0.0002 Mean 0.02 47.72 16.84 74.81 0.0002 0.27353 242 61 27.38 0.0002		T2	0.02	48.08	11.36	51.60	0.0002	0.0002	219	57	22.27	0.0002	0.0002
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Sunflower	Т3	0.02	45.44	25.49	30.21	0.0002	1.3647	233	45	35.63	0.0002	0.0002
0.02 58.40 13.25 19.96 0.0002 0.0002 263 65 25.44 0.0002 1 0.02 47.72 16.84 74.81 0.0002 0.27353 242 61 27.38 0.0002		T4	0.02	56.46	15.67	36.73	0.0002	0.0002	244	34	28.24	0.0002	0.0002
10.02 47.72 16.84 74.81 0.0002 0.27353 242 61 27.38 0.0002		С	0.02	58.40	13.25	19.96	0.0002	0.0002	263	65	25.44	0.0002	0.0002
		Mean	0.02	47.72	16.84	74.81	0.0002	0.27353	242	61	27 38	0 0002	0.000

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ns: not significant; t: water treatment; p: crop plant

CONCLUSION

Sorghum soil irrigated with treated waste water has less concentration of heavy metals such as Co, Cu and As.Moreover, Sorghum tissue found to have accumulation of heavy metals as Mn and Zn.So far the concentrations did not reach the toxic levels.Thus, from the results of this study we recommend that sorghum plants could be used as phyto-remediation candidates to screen the level of heavy metals in polluted areas as well as to reduce the heavy metal levels of such polluted areas.

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