The Effect of Treated Wastewater Irrigation on Accumulation of Heavy metals in Selected Plants

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ABSTRACT

A study was carried out to investigate the effects of treated wastewater on accumulation of heavy metals in plants. Plant samplings of 15 farms irrigated with treated wastewater and well water were taken from an area in north of Isfahan province, center of Iran. The experiment consisted of six plants including wheat, alfalfa, corn, tomato, cucumber and cantaloupe. Samples of both wastewater and well water irrigated plants were analyzed to investigate the accumulation of heavy metals in different parts of selected plants. The evidences provided by this experiment indicated that treated wastewater caused increase of heavy metals in most plant samples, particularly for Mn, Zn and Cu. However, some plants such as corn and alfalfa irrigated with well water, had slightly higher values of Cu, Fe and Mn. The results also showed that only the amount of Fe was higher than critical limit for both irrigation types. Deficiency in zinc amount of samples was observed even in plants irrigated with treated wastewater.

INTRODUCTION

In arid and semi-arid regions, water resources of good quality are becoming scarcer and are being allocated with priority for urban water supply. Therefore, there is an increasing necessity to irrigate with water that already contains salts, such as saline groundwater, drainage water, and treated wastewater (Jalali et al., 2007). One of the sources of water which might be used economically and effectively is treated municipal and industrial wastewater.
Obviously, with regard to climate conditions and limited water resources in Iran, use of water sources and especially urban wastewater in agriculture is inevitable and justifiable (Harati et al., 2011).
However, wastewater contains substantial amounts of toxic heavy metals, which create problems. Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination, but also affect food quality and safety. 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 (Arora et al., 2008). The effluent for reuse must comply with reuse standards to minimize environmental and health risks (WHO, 1989). The required quality of effluent will depend on water uses, crops to be irrigated, soil conditions and the irrigation system (Pereira et al., 2002).
Heavy metal uptake by the plants grown in polluted soils (mostly from anthropogenic activities such as wastewater and sewage sludge application) has been extensively studied ((Karatas, 2006). Shadma et al (2010)) found that plants accumulated heavy metals in their shoot (Ni, 13.65; Cr, 19.73; Zn, 21.6 and Cu 14.76 1g g-1 dry weight) and root (Ni, 41.4; Cr, 31.6; Zn, 30.2 and Cu 15.85 1g g-1 dry weight) in high concentrations after irrigation with undiluted industrial waste water. Use of industrial waste water, in such form, on agricultural lands is not found suitable without proper treatment. It could be injurious to plants growth

and may be a potential threat to food web. Harati (2003), during a study of wastewater effects on corn, concluded that macro (N, P and K) and micro elements in the wastewater improve growth and yield of maize, while accumulation of heavy metals such as cadmium and lead in corn was more than the standard limits and critical step for animal feeding.
Vafabakhsh and Kharghany (2000) studied the effects of treated municipal wastewater on quality and yield of cucumber and carrot. They concluded that the macro- and micronutrients in stem, leaf and fruit was increased in treatments irrigated with treated wastewater compared to well water. Angelova et al. (2004) observed that fiber crops such as flax and cotton did take up heavy metals when grown in heavily contaminated soils, however the concentrations detected in the leaves and seeds were only a small percentage of the concentration present in the soil.
The present study was conducted with an aim to compare the heavy metals (such as Cd, Pb, Zn, Mn, Fe and Cu) accumulation in some of the commonly grown plants (wheat, corn, alfalfa, cucumber, tomatoes and cantaloupe) irrigated with wastewater or well water in Isfahan, Iran. Irrigation of plants with wastewater is a very common practice in this area. The effect of irrigation with wastewater is also studied in these plants to observe the concentration of accumulated metals to which human beings are exposed.

MATERIALS AND METHODS

In this study, 15 farms irrigated with treated wastewater of north Isfahan province (in the center of Iran) wastewater treatment plant Number 2 and well water were selected to represent a range of cropping patterns in the area, and almost uniform soil characteristics. The experimental site is 1561.5 m above sea level. Mean annual temperature is 16 Cº, annual rainfall is 131 mm and the climate in this region is arid. Using soil taxonomy (USDA, 1998) soils of this region were classified as Typic Haplocambids.
The crops under investigation were wheat, corn, alfalfa, cucumber, tomatoes and cantaloupe. Fields were irrigated with treated wastewater for about 8 years. Survey information was taken from each farmer concerning their crop pattern, source of irrigation water, fertilizing regime, irrigation regime, etc. The farms under study were around wastewater treatment plant located north of Isfahan City. The treatment system was a biological-activated sludge process and was considered to be a secondary treatment. The quality of reclaimed water from north Isfahan (Wastewater treatment plant Number 2) was evaluated by following the guidelines for interpretation of water quality for irrigation by (FAO 29) Ayers and Westcot, (1985).
After considering a range of situations, areas were selected and at each site, three composite plant samples such as forage, stem and leaves and fruit were taken at harvest time. The plants were analysed for Cd, Pb, Fe, Mn, Zn and Cu accordance the Standard Methods (APHA, 1998). Finally, by analysing and interpreting plants heavy metals in areas irrigated with treated wastewater, and comparing with areas irrigated with well water, conclusions were drawn about the concentration of some potentially toxic elements.

RESULTS AND DISCUSSIONS

Table 1 shows the means and ranges of chemical properties and selected heavy metal concentrations of irrigation waters during one year of field data collection.

Table 1. Average and range of the chemical properties and selected heavy metal concentrations in irrigation waters

Parameter	Wastewater		Wells water	
	Range	Mean	Range	Mean
pH	7.9-8.2	8.04	6.9-8	7.51

Electrical conductivity (dS/m)	1.17-1.67	1.39	2.18-8.95	5.47
Sodium Adsorption ratio (SAR)	3.4-4.6	3.9	6.03-18.2	11.72
Iron (mg/l)	0.04-0.22	0.11	-	0.01
Cadmium (mg/l)	0-0.034	0.009	-	0.01
Zinc (mg/l)	0.07-0.16	0.093	-	0.01
Manganese (mg/l)	0.03-0.12	0.05	-	0.08
Lead (mg/l)	0-0.04	0.01	-	0.02
Copper (mg/l)	0.02-0.02	0.029	-	0.01

According to the (FAO 29) guideline, the water quality such that slight to moderate permeability, toxicity and miscellaneous problems, can be expected from use of treated wastewater effluents. The average (and range) of heavy metals was very much lower than the recommended maximum concentration base on threshold levels of trace elements for crop production (National Academy of Sciences, 1972; and Prat, 1972). Wells water have moderate to severe restriction on use. Heavy metals in ground water (well water) were also found to be very low, and were far lower than recommended maximum concentrations. The treated wastewater used for irrigation contained lower levels of salinity and therefore could be used for the cultivation of some moderately sensitive crops. Therefore, in areas where the well water had moderate to severe salinity, farmers who had access to treated wastewater effluents, used both sources of water– either by mixing or by alternate irrigation. These management strategies can reduce the potential problems of using saline water. They can also reduce the heavy metals hazard.

Measurements of heavy metals (such as iron, manganese, zinc and copper) for straw wheat, grain wheat, alfalfa (stem&leaves), corn (stem&leaves), corn (grain), tomatoes (stem&leaves), tomatoes (fruit), cucumber (fruit), cantaloupe (stem&leaves) and cantaloupe (fruit) irrigated with two sources of irrigation water are presented in figure 1. Concentrations of Pb and Cd in plants were below detection levels for both types of irrigation.

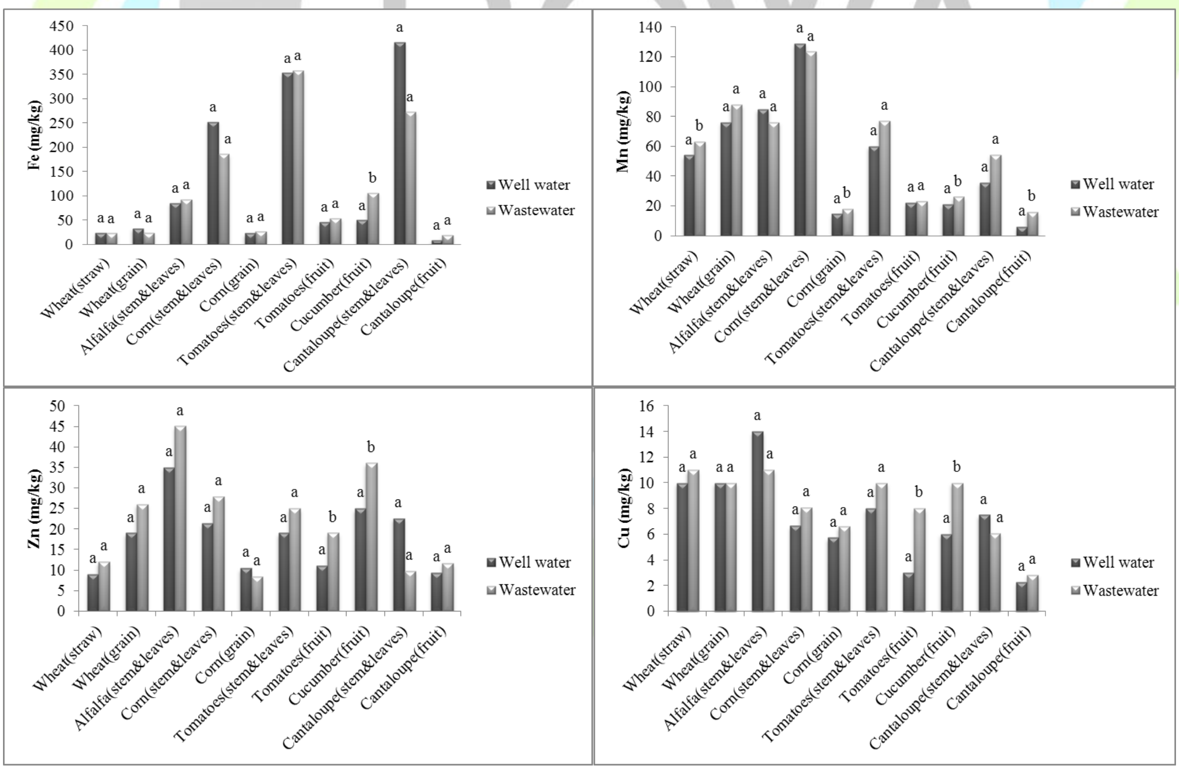

Fig 1. Average concentration of heavy metals in plants; Columns labeled with the same letter are not significantly different at P<0.05.

As is shown in (fig. 1) the differences in Iron contents of cucumber fruit were highly significant, whereas in other plants Iron contents were not significant with different source of irrigation. In grain wheat, stem and leaves of corn and cantaloupe, the rate of iron in well water was slightly higher than treated wastewater. Iron content of corn, tomato and cantaloupe (stem&leaves) is higher than critical limits (100 mg/kg DW) according to Chang et al. (1983).
Comparing manganese for the two types of irrigation water showed that in all crops under study (except alfalfa and stem&leaves of cantaloupe) the mean values are higher with treated wastewater. Whereas, Mn content in corn (grain), wheat (straw), cucumber (fruit) and cantaloupe (fruit) irrigated with treated wastewater were highly significant the values in other plants were close to average. With respect to Kabata and Pendias (1992), Mn content of all plants was within the standard range (30-300 mg/kg DW) and no toxic values were observed. Average zinc concentrations in all plants were higher for the treated wastewater source except for corn (grain) and cantaloupe (stem&leaves). The amount of increase in cucumber (fruit) and tomato (fruit) were significant ($p<0.05$) .Deficiency of zinc values in all plants (irrigated with wastewater and well water) was concluded comparing to Kabata and Pendias (1992). The value of average copper in most of the plants were close and within the normal range (5-30 mg/kg DW) for the two sources, but copper concentration in tomatoes and cucumber fruits, was significantly higher in treated wastewater.

CONCLUSION

Wastewater irrigation reuses water that would have been lost and therefore a constant supply of irrigation water could be provided for farming. However, there are risks that are associated with waste water reuse. Heavy metals may accumulate in soils and plants grown using waste water. This study has shown that presence of heavy metals in wastewater leads to accumulation in soil and finally in crops. The analyses showed that the heavy metals in treated wastewater were lower than recommended maximum concentration. Concentration of Mn, Zn and Cu in straw and grain wheat irrigated with wastewater were higher than wells, the other elements were almost the same for the two types of irrigation. In alfalfa, Fe and Zn concentrations were higher, while Mn and Cu were lower for the treated wastewater irrigation. Mn concentration of corn (grain) is significantly higher in treated wastewater irrigation. Concentrations of Mn, Zn and Cu in tomato stems and leaves, and concentrations of Fe, Zn and Cu in tomato fruit, were more in treated wastewater irrigation than well water irrigation, but differences in concentration Zn and Cu in tomato fruit were significant. For cucumber (fruit), Fe, Mn, Zn and Cu concentrations were higher in irrigation with wastewater. In overall plant analysis, only the amount of Fe was higher than critical level for both irrigation types. In general, heavy metal concentrations in plants are higher in irrigation with wastewater; but there appears to be no significant risk associated with the irrigation of crops such as wheat (grain), alfalfa, corn (stem&leaves), tomatoes (stem&leaves) and cantaloupe (stem&leaves) with treated wastewater so far. It should be noted that microbial content of soil and plant for fecal coliform have to be studied from public health points. Therefore further studies are needed on monitoring soil, plant and health hazard problems especially for vegetables and raw-eaten crops.

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