Article

Bioaccumulation of chromium by *Zea mays* in wastewater-irrigated soil: An experimental study

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Abstract

The use of wastewater to irrigate plants is a common in many countries. This study aims to compare the bioaccumulation of chromium in *Zea mays* that irrigated with wastewater and tap water. The study was carried out in the field of waste water treatment plant in Birjand for 4 successive months from 16 August 2011 to 16 November 2011. 0.5 kg soil and 5 g of the root, stem and leave of *Z. mays* were collected monthly. *Z. mays* samples were digested by cloridric acid and soil samples were digested with nitric acid. Chromium concentration in the samples was determined by AA-7000 series of atomic absorption spectrophotometer. The average concentrations of chromium in wastewater and tap water were 12 ppb and 5 ppb respectively. The concentration of chromium in soils, which is irrigated with wastewater and tap water, were 26.68 ppm and 11.15 ppm respectively. The mean concentration of chromium in roots of *Z. mays* that is irrigated with wastewater and tap water were 10.28 ppm and 3.92 ppm respectively. The mean concentration of chromium in the stem of *Z. mays* which is irrigated with wastewater and tap water were 4.19 ppm and 1.17 ppm respectively while the mean concentration of chromium in leaves of *Z. mays* which is irrigated with wastewater and tap water were 2.27ppm and 0.44ppm respectively. The Study showed higher accumulation of chromium in soils and *Z. mays* plants which irrigated by wastewater. Cr is immobilized mainly in roots. The ratio of transfer factor of root:leaves is more than ratio of transfer factor of root:stems. It is noticeable that the transfer factor of Cr is decreasing with increase of Cr concentration. The transfer factor between roots and shoots of *Z. mays* irrigated with wastewater was lower than *Z. mays* irrigated with tap water. Cr was accumulate and immobilized mainly in roots than the other parts.

Keywords bioaccumulation; wastewater; tap water; Cr; *Zea mays*.

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1 Introduction

Phytoremediation is the use of plants to eliminate, replace, stabilize and reduce pollutants in soil, sediment and water (Prabha et al., 2007). The expense of phytoremediation is low and this technology is environmentally friendly (Pilon-Smits, 2005). The most important factors for successful use of phytoremediation are the site situations, anticipated land use and the kinds of plants (Thangavel and Subhuram, 2004). Treated wastewater disposal is a problem in developing countries (Chipo et al., 2011). The increase in anthropogenic activities such as quick industrialization, urbanization and anthropogenic sources can cause emission of various pollutants into the environment (Telesca and Lovallo, 2011; Zhang et al., 2011; Prajapati, 2012a, b; Sayadi and Rezaei, 2014; Ediagbonya et al., 2013). The most heavy metals that have been identified in polluted water include arsenic, copper, cadmium, lead, chromium, nickel mercury and zinc (Akpor and Muchie, 2010). Main effects of chromium in plants are decreases of plant growth , damage of the membrane and chlorosis of plants (Gardea-Torresdey et al., 2005; Jada and Fulekar, 2009). Uses of wastewater for irrigation in agricultural activities cause the biomagnification and accumulation of heavy metals in food chain (Chipo et al., 2011; Akpor and Muchie, 2010). In other hand, reuse of wastewater is the conservation of water in arid and semi-arid conditions (Prabha et al., 2007). According to Dougherty and Hall (1995), the long term use of wastewater in an agricultural land increase concentration of heavy metals like zinc, cadmium, copper, and nickel, lead, manganese, iron, mercury and chromium in the soil that was irrigated with wastewater. Zoubi et al. (2008) indicated that Cr increased in roots of plants as the sludge application. Chen and Cutright (2001) showed *Helianthus annuus* (Asteraceae) can also be utilized for the removal of Cd, Cr, and Ni. Baker and Brooks (1989) showed that the plant species Leptospermum scoparium (Myrtaceae) is an accumulator of Cr when grown on serpentine soils. This study aims to assess and compare the bioaccumulation of chromium in Z. mays, which irrigated with wastewater and tap water.

2 Material and Method

The study was carried out in the field of waste water treatment plant where is located in Northwest of Birjand city. The longitude of Birjand is 32°59′ N and latitude of Birjand is 52°12′E. Average annual rainfall is about 148.8 mm and the average annual temperature is 17.1 ℃. *Z. mays* were cultured into the 2 areas with 4 square meters. The samples were irrigated with tap water and wastewater treatment plant for 4 consecutive months from 16 August 2011 to 16 November 2011. The plants were watered to reach the field capacity. 5g Samples of the root, stem and leave of *Z. mays* were collected monthly. Samples of *Z. mays* were washed with distilled water and dried, then ashed in a furnace at 600°C for 6 h. Three replicate of dried samples were digested with 5cc cloridric acid and digested samples were diluted to 25 ml (Schmidt, 2003). The pH of soil was determined by using pH meter CRI (microph 2002 model) in the 1:2.5 soil-water suspend. 0.5 kg soil samples were collected in the triple at depth 0-30 cm and mixed. The samples were dried at 105°C and sieved through a 2mm sieve. Then 2 g soils samples were digested with 15 ml nitric acid in the microwave. The digested samples were diluted to 25 ml and were put in the water bath for 12 h (Radojevic, 1999). The digested samples were analyzed for chromium by AA-7000 series of atomic absorption. The transfer factor is the mobility of a heavy metal from the root to the shoot (stem and leaves) of the plant was calculated using the following formula (Kim et al., 2003):

$$TF=\frac{\text{Element of shoots(stem and leaves)(ppm)}}{\text{Element of roots(ppm)}}\times 100$$

3 Results

The texture of soil (proportion of sand, silt and clay) and pH of soil are shown in Table 1. Soil pH is an important factor for uptaking of metals in the soil by plants (Zoubi et al., 2008).

Table 1 The texture and pH of the soil used.

Soil components	Values
Sand(%)	39
Silt(%)	48
Clay(%)	13
pH	7.37
Texture	Loam

As shown in Table 2,The concentration of chromium in waste water and tap water were 12 ppb and 5 ppb respectively, The concentration of chromium in soils which is irrigated with wastewater and tap water were 26.68 ppm and 11.15 ppm respectively . As shown in Table 3, The mean concentration of chromium in roots of *Z. mays* which is irrigated with wastewater and tap water were 10.28 ppm and 3.92 ppm respectively, The mean concentration of chromium in the stem of Zea Mays which is irrigated with wastewater and tap water were 4.19 ppm and 1.17 ppm respectively. The mean concentration of chromium in leaves of *Z. mays* which is irrigated with wastewater and tap water were 2. 27 ppm and 0.44 ppm respectively.

Table 2 Mean Cr concentrations in wastewater, tap water and soil.

	Chromium concentrations		
	Waste water (ppb)	Tap water (ppb)	Soil (ppm)
***Z. mays* irrigated with wastewater**	12		26.68
***Z. mays* irrigated with tap water**		5	11.15

Table 3 The Cr concentration in different parts of *Z. mays* (ppm).

	Tap water			**Waste water**		
Months	**Root**	**Stem**	**leaves**	**Root**	**Stem**	**leaves**
August	2.7	0.6	0.08	9.8	3.51	1.81
September	3.9	0.9	0.35	10.1	3.84	1.89
October	3.98	1.1	0.51	10.51	4.45	2.59
November	5.1	2.1	0.82	10.71	4.98	2.81
Mean	3.92	1.17	0.44	10.28	4.195	2.275
SD	0.98	0.58	0.31	0.41	0.65	0.5

4 Discussion

The research revealed that concentration of Cr in *Z. mays* irrigated with wastewater is more than *Z. mays* irrigated with tap water (Fig. 1). The concentration of Cr in the roots was highest followed by stem and leaves in the tap water and wastewater treatment. It means Cr is more accumulate in the root then stem and leaves accumulate lowest level of Cr concentration. This confirm with Chipo et al. (2011) that concentrations of heavy metals (copper, zinc, cadmium, nickel, chromium and lead) on vegetables were irrigated with wastewater for ten years were higher than vegetables were irrigated with tap water.

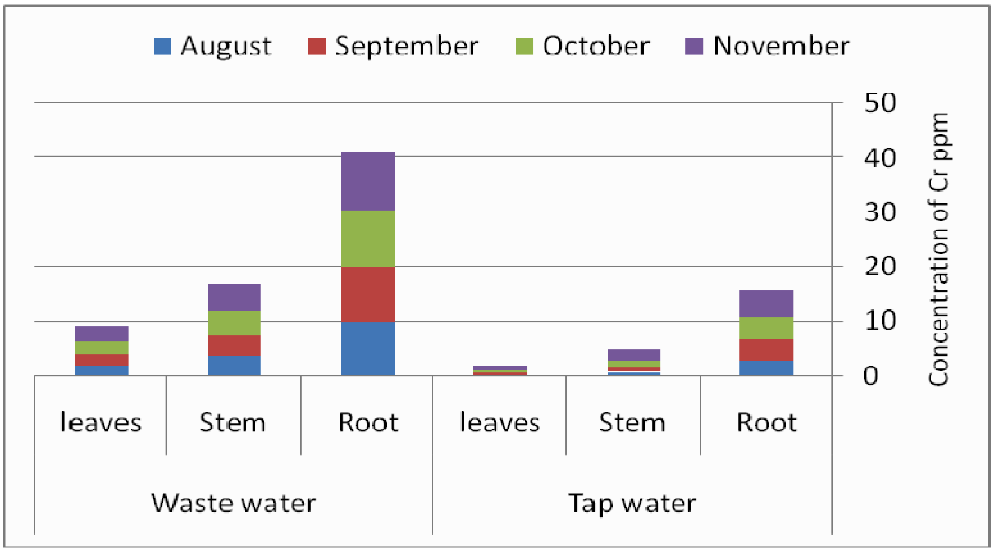

Fig. 1 Comparision of Cr concentration in *Z. mays* irrigated with wastewater and tap water.

As shown in Fig. 1 the Cr concentration in the root is higher than other parts because chromium was immobilized mainly in roots than shoots. Studies performed by Zoubi et al. (2008) and Shahandeh and Hossner (2000) on vegetables exposed this point. At low concentrations metals can move through root tissue, mainly through the apoplast and they accumulate near the endoderm. The endoderm barriers translocate metals through the root to the shoots. This may be one of the reasons for the much greater accumulation of metals in roots than shoots (Verma and Dubey, 2003). Other reason can be that the roots are direct contact with contaminated water and the water is absorbed through the roots of plants and then distributed to other parts (Soudek et al., 2006; Intan et al., 2006). Lower accumulation of Cr in leaves than in roots can be related to conservation of photosynthesis from toxic levels of trace elements (Fig. 1) (Victor and Ishola, 2007).

The study calculated the ratio of transfer factor of root:leaves and root:stems which is showed root:leaves transfer factor is more than transfer factor of root:stems in both treatments (Fig. 2). As Fig. 2 shown, transfer factor ration is more in lower concentration of Cr in the both treatments and compare them as in the tap water with lower concentration of Cr show the highest transfer factor ration as well as in the first month (August) shows highest transfer factor followed by next month's viz September, October and November. It can be due to transportation of elements to specific tissues based on the role of the element in plant metabolism, and it is caused higher concentration in a particular part (Soudek et al., 2006). It is observed that transfer factor of Cr is decreasing with increase of Cr concentration (Ghosh and Singh, 2005). Transfer factor showed lower translocation of Cr from roots to shoots (Fig 2).This point indicate that this plant was not effective for translocation of Cr to the aerial parts of *Z. mays*. The same result has been obtained in *Eichhornia crassipes* (Victor and Ishola, 2007).

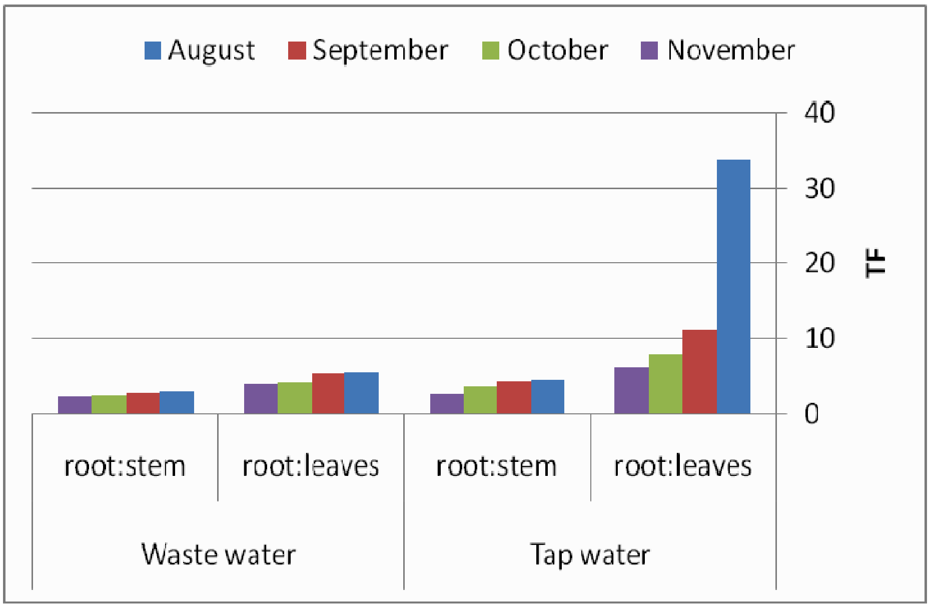

Fig. 2 Root:Stem and Leaves transfer factor (TF) of *Z. mays* in tap water and wastewater treatments.

5 Conclusion

Cr was immobilized mainly in roots. Comparison of chromium concentrations in parts of *Z. mays* is irrigated by wastewater treatment plants are as follows: roots > stems > leaves. The transfer factor between roots and shoots of *Z. mays* irrigated with wastewater was lower than *Z. mays* irrigated with tap water. *Z. mays* seem to be a low chromium accumulating plant, it is not able to clean the contaminated soils even it is species with large biomass and fast growth.

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