



SEWAGE IRRIGATION CAUSE HEAVY METAL ACCUMULATION IN CORIANDER (*coriandrum sativum*) FIELD CROP: A CASE STUDY

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Abstract: Sewage irrigation of local crops is common in developing countries where centralized sewage treatment plants (STPs) are still not functioning. Under a low-cost approach, sewage irrigation has been promoted not only to dispose of sewage locally and safely but at the same time also to reduce the cost of chemical fertilizer inputs in local crops. This study aimed to investigate the role of continuous sewage irrigation practices on heavy metal bioaccumulation in coriander grown in the periphery of Sri Ganganagar City, India. The leaf samples were collected from some selected sewage-irrigated sites of the city and analysed for the heavy metal load. Soil metal load was also analysed and results showed values in the ranges (mg kg^{-1}) of 58.71 – 90.52 mg kg^{-1} , 14.85 – 24.70 mg kg^{-1} , 15.42 – 24.62 mg kg^{-1} , 16.85 – 30.25 mg kg^{-1} , 17.85 – 27.52 mg kg^{-1} , 1.52 – 5.16 mg kg^{-1} and 15.85 – 25.01 mg kg^{-1} for Fe, Zn, Pb, Ni, Cu, Cd and Cr. Results suggested a high content of heavy metals in coriander : Fe (226.20 mg kg^{-1}), Zn (26.77 mg kg^{-1}), Pb (6.83 mg kg^{-1}), Ni (42.92 mg kg^{-1}), Cu (14.50 mg kg^{-1}), Cd (16.07 mg kg^{-1}) and Cr (73.95 mg kg^{-1}). The high values of bioconcentration factor (BCF) suggested the translocation of heavy metals from soil to plant vegetative parts. The metal level was higher than the safe limits for a few metal species which indicates a high daily metal intake in the residents due to a high load of metals in vegetables grown in sewage-irrigated belts. The present study revealed that the continuous consumption of such contaminated vegetables could pose serious health hazards to residents of the concerned area.

Index Terms: Metal toxicity, Bioaccumulation, Wastewater irrigation, Soil contamination

1. INTRODUCTION

The disposal of treated and untreated wastewater is one of the alarming issues in the majority of urban settlements in developing countries. In India, domestic wastewater management has become a big challenge for city managers as infrastructural development and regulations have not kept pace with the ever-growing human population growth and rapid urbanization (Sayo et al., 2020). Already, there is enormous pressure on planners to provide utility services and water supply is a priority, especially where peri-urban water is exported formally or informally to fulfil city requirements (Amerasinghe et al., 2013). Thus urban environmental management is a big challenge for policy maker and urbanization trend has been putting extra pressure continuous at global scale. On the other hand water supply for agriculture practices is again a big challenge for rural and peri-urban farmers as water resources are being diverted for various other purposes such as sanitation, drinking water supply, industrial units and other domestic purposes. In such cases, dependency on the reuse of wastewater resources has increased significantly in such areas for sustainable farming practices (Becerra-Castro et al., 2015). In a country like India where freshwater resources face enormous human pressure on the utility of wastewater sources especially sewage water and industrial effluents is being promoted as the central policy to solve two issues simultaneously: safe disposal

of treated or untreated wastewater in the environment and cutting the dependency on freshwater resources for crop production (SouDakouré et al., 2013).

Sewage water contains a high organic load and nutrients (Nitrate, Phosphate, Sulphate, etc.) which could be beneficial for soil fertility enhancements. Also, this may solve the issue of soil productivity and fertility and also the scarcity of water resources for agriculture practices. But sustainable wastewater reuse in agriculture systems needs close monitoring of soil contamination levels and crop productivity. Sewage water contains several toxic substances (emerging molecules, heavy metals and other industrial chemicals) (Alghobar & Suresha, 2017; Abeed et al., 2022) which can cause serious issues of plant contamination with toxic chemical compounds and human health risks. Thus, wastewater can be considered both a resource and a problem and its uses need specific attention in terms of ecosystem and human health well-being.

This study aimed to investigate the effect of long-term sewage irrigation practices on the soil nutrient and heavy metal built-up in soils and coriander crops in the periphery of Sri Ganganagar City Rajasthan, India. Due to the non-availability of centralized wastewater treatment facilities, the sewage generated from the city is disposed in nearby agricultural fields through untapped water channels and farmers in adjoining rural areas have been using such sewage water for vegetable farming. In this study, the load of heavy metals in sewage-irrigated soils and coriander crops was investigated and a comparison of soil and plant metal load was also made through sampling in the groundwater-irrigated plots. The translocation of metal from soil to plant biomass was also calculated by measuring the bioconcentration factor (BCF).

2. MATERIALS AND METHODS

2.1 Study Site

After the initial survey, three sites (Site 1 - village 2E Chhoti & 3E Chhoti, Site 2 - village Chak 3A and Site 3 - village Sobha Singh Wala & Sahuwala) were selected for the study, where farmers have been using sewage water for vegetable crops. These villages are adjoining (appx. 2.5 – 3 km) to the city area and the soils of this area are sandy and loamy. The region is considered a hot and dry zone and the annual precipitation rate in this region is 20.70 cm. The minimum and maximum temperature in this region is recorded as 0.6°C and 50°C during winter and summer, respectively. Three plots were selected from each sampling site and a study on soil and plant metal enrichment was performed.

2.2 Soil and plant sampling

The samples of topsoil (20 cm depth) were collected from each experimental plot with coriander cropping systems. In each sampling plot, a total of three samples were collected: first, at the entry of the field where the wastewater channel enters into the field, second in mid of the plot and third from the terminal part of the plot. All soil samples were mixed to produce a representative soil sample (100 g) for chemical analysis. For each cropping system, a total of three replicate plots (10 × 10 m) were selected and soil samples were collected by following the standard procedure as described by APHA (2005). Leafy part of coriander was collected from the same point where the soil was collected and then packed into polythene bags.

2.3 Heavy metal analysis and BCF

Soil and plant samples were brought to the lab and then dried in the shed for 1 week and then ground to powder form using a mechanical blender. Samples were sieved (1 mm) and then dried in a hot air oven at 80°C. The soil and plant samples were digested in an acid mixture by following the standard method (APHA, 2005). The heavy metal concentration analyzed by using Atomic Absorption Spectrophotometer (AAS).

The bio-concentration factor (BCF), an index of the ability of the vegetable to accumulate a particular metal concerning its concentration in the soil substrate was calculated as follows:

$$BCF = C_{\text{plant}} / C_{\text{soil}}$$

Where: C_{plant} and C_{soil} represent the heavy metal concentration in the edible part of vegetables and soils, respectively.

2.4 Statistical analysis

Data were analysed for mean and standard deviation (SD) values using SPSS software (Windows version 17.0). One-way ANOVAs were used to measure the statistically significant difference among sampling sites for metal load in soils and plants.

3. RESULTS AND DISCUSSION

3.1 Soil metal concentration

ANOVA results indicate statistically significant differences among sampling sites for Fe ($F = 47.714$, $p < 0.05$), Zn ($F = 7.098$, $p < 0.05$), Pb ($F = 55.356$, $p < 0.05$), Cd ($F = 22.476$, $p < 0.05$) and Cr ($F =$

39.812, $p < 0.05$) while there was no statistically significant difference among sampling plots for a load of Ni ($F = 0.892$, $p = 0.458$) and Cu ($F = 0.324$, $p = 0.735$) in soil. The average soil metal load was found to be in the ranges (mg kg^{-1}) of 58.71 – 90.52 mg kg^{-1} , 14.85 – 24.70 mg kg^{-1} , 15.42 – 24.62 mg kg^{-1} , 16.85 – 30.25 mg kg^{-1} , 17.85 – 27.52 mg kg^{-1} , 1.52 – 5.16 mg kg^{-1} and 15.85 – 25.01 mg kg^{-1} for Fe, Zn, Pb, Ni, Cu, Cd and Cr.

Fe was found in the highest concentration in soils and the order of metal in soil was as follows: $\text{Fe} > \text{Ni} > \text{Cu} > \text{Zn} > \text{Pb} > \text{Cr} > \text{Cd}$, based on average values of the heavy metal load in soils. The results of metal load in studied sites are described in Table 1.

Table 1 – Heavy metal concentration in soils irrigated with sewage water at different sampling sites

Metal		Site-1	Site-2	Site-3
Fe (mg kg^{-1})	Mean	60.36	85.11	88.54
	Std. Deviation	1.98	5.82	2.60
Zn (mg kg^{-1})	Mean	22.42	16.00	17.11
	Std. Deviation	3.05	1.37	1.93
Pb (mg kg^{-1})	Mean	16.60	17.01	23.55
	Std. Deviation	1.07	0.47	1.05
Ni (mg kg^{-1})	Mean	21.15	25.63	25.28
	Std. Deviation	2.36	1.79	7.34
Cu (mg kg^{-1})	Mean	18.12	26.86	25.88
	Std. Deviation	0.44	0.57	1.02
Cd (mg kg^{-1})	Mean	2.04	4.01	4.73
	Std. Deviation	0.52	0.49	0.52
Cr (mg kg^{-1})	Mean	16.60	21.89	24.36
	Std. Deviation	0.85	1.50	0.76

The Ni in the environment mainly comes from anthropogenic sources and sewage water mixed with wastewater from mechanical shops, metal plating, washing stations, etc. could be the major source of Ni in the sewage water. It is suggested that such point sources in the city are contributing to the Ni load in soils irrigated with the untreated sewage water. Cr is also a toxic metal and it shows a high bio-accumulative property a high load in the soil further leads to the transfer of such Cr substances to standing crops and other biotas. Cr is sewage mainly comes from paint and agrochemicals being used for fungal pathogen suppression. Some unknown sources of sewage might have contributed to the high load of Cr in local soils being irrigated with the raw sewage water. Pb contamination due to anthropogenic sources such as waste dumping practices and vehicle pollution in this region. Cu mainly comes from industrial disposal and pesticides application in the field. Several reports suggested the contribution of sewage irrigation practices to the buildup of heavy metal load in soils in different parts of the world (Rattan et al., 2005; Wiessner et al., 2010; Chung et al., 2011; Balkhair and Ashraf, 2016; Meng et al., 2016; Sayo et al., 2020). The results of the heavy metal load of this study are in line with some previous researchers who have reported a significant concentration of elements in soils being irrigated with wastewater under long-term crop irrigation practices.

3.2 Heavy metal concentration in Coriander

Leafy vegetables comparatively showed a high content of heavy metal than root and tuber-type crops. The level of heavy metals in crops depends on various factors like crop type, the water content in the crop, plant metabolism, plant photosynthesis rate, bioaccumulation rate for a particular metal species, crop irrigation frequencies and weather conditions (Rattan et al., 2005; Yang et al., 2011; Rahman et al., 2014; Pandey et al., 2016; Rezapour et al., 2019; ur Rehman et al., 2019). Results suggested a high content of heavy metals in coriander and average metal content was found to be as Fe (226.20 mg kg^{-1}), Zn (26.77 mg kg^{-1}), Pb (6.83 mg kg^{-1}), Ni (42.92 mg kg^{-1}), Cu (14.50 mg kg^{-1}), Cd (16.07 mg kg^{-1}) and Cr (73.95 mg kg^{-1}).

The leafy vegetable showed a high level of metals mainly due to a high photosynthesis rate and high metal transfer factors.

Table 2 – Descriptive analysis of heavy metal contents in Coriander crop irrigated with sewage water

	Fe	Zn	Pb	Ni	Cu	Cd	Cr
Mean	226.20	26.77	6.83	42.92	14.50	16.07	73.95
Std. Deviation	15.35	1.29	0.47	1.86	1.16	1.93	2.41
Minimum	209.00	25.00	6.22	40.60	12.56	12.88	70.89
Maximum	245.00	28.45	7.42	45.80	15.60	17.85	76.80
Range	36.00	3.45	1.20	5.20	3.04	4.97	5.91
Variance	235.70	1.67	0.22	3.47	1.34	3.74	5.82

Few previous studies have also exhibited a similar trend of results where leafy vegetables showed higher metal concentrations than that tuber and fruit vegetables. For example, Qureshi et al. (2016), reported an accumulation of heavy metals (Cr, Fe, Zn and Cu) in a few vegetable crops (lettuce, radish and carrots) grown in treated municipal wastewater. They found that heavy metal content in vegetables harvested from wastewater-irrigated plots was far lower than the food safety limit decided by monitoring agencies. The bioaccumulation factors (BAF) for heavy metals showed a distinct trend in all vegetables, showing the following order: Fe > Zn > Cu > Cr. The metal transfer factor also depends on the plant species type and there was a different level of metal transfer among the studies vegetable crops in this study human health risk can be reduced significantly by selecting the types of crops to be grown in such soils, irrigated with wastewater. Similarly, a study by Hu et al. (2017), along the Yellow Sea of China demonstrated the high content in the Shandong Province of China revealed a high content of Cd (0.21 mg kg^{-1}), As (7.12 mg kg^{-1}), Hg (0.05 mg kg^{-1}), Pb (19.81 mg kg^{-1}), Cu (24.95 mg kg^{-1}) and Zn (94.11 mg kg^{-1}) in greenhouse soils and vegetables were grown under greenhouse farming systems. Their study revealed that leafy vegetables showed more metal concentration than that rootstalk and fruit vegetables.

3.3 Bio-concentration factor (BCF)

BCF is an indicator of metal translocation rates of different metals from the surrounding medium to the biota. There were significant variations among different metals for BCF values. The respective values of BCF for Fe, Zn, Pb, Ni, Cu, Cd and Cr were recorded at 2.90, 1.45, 0.36, 1.79, 0.61, 4.48 and 3.53 (Fig. 1). Overall Cd showed the highest BCF range followed by Cr, Fe, Ni, Zn, Cu and Pb.

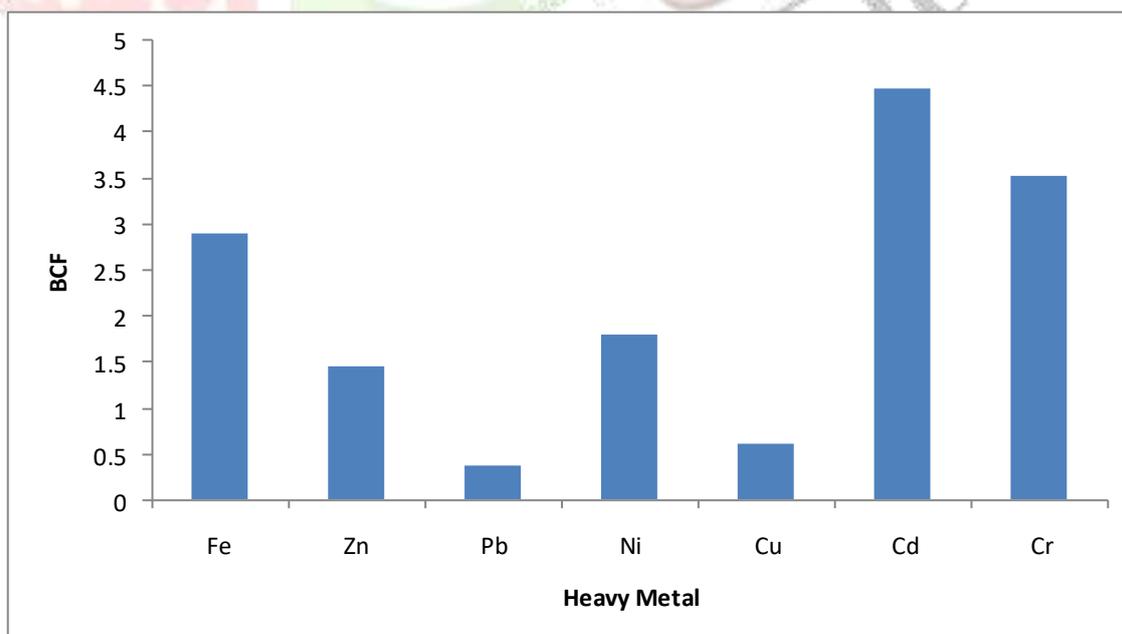


Fig. 1 – BCF for different heavy metals calculated for Coriander crop

The high BCF indicates the high accumulative potential of vegetables for heavy metals and storage capacity to transfer the contamination through the food chain to other organisms. Our results of BCF are in

line with a few earlier researchers who have reported a high metal transfer in leafy vegetables (Sridhara Chary et al., 2008; Alghobar and Suresha, 2017; Sonu et al., 2019).

4. CONCLUSION

The utility of wastewater as water for crop irrigation has been in practice since last many decades but its impact on soil and crop metal uptakes is again a topic of debate and research interest. In this study, we investigated the impact of long-term sewage irrigation practices on soil metal built-up and uptake of heavy metals by coriander crops under a field investigation. Sewage-irrigated soils showed a high content of Fe, Zn, Pb, Ni, Cu, Cd and Cr, suggesting the anthropogenic sources of such elements in agricultural soils. Coriander crops showed a high accumulation of metals in leafy parts which suggested that sewage irrigation could pose serious threats to the metal availability of food crops. The results of metal translocation from soil to coriander crop were also validated by high values of BCF obtained for a few metal species.

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