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Original article

A comparative study of metals concentration in agricultural soil and vegetables irrigated by wastewater and tube well water

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ABSTRACT

This study was aimed to evaluate the metals concentration in agricultural soil and vegetables irrigated by different irrigation sources. For this purpose agricultural soil and eight vegetables used for commercial consumption were collected from waste-water and tube-well water irrigated sites of Lahore district. Metals i.e. iron (Fe), sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca) were analyzed via flame atomic absorption spectrophotometer. Concentration of metals in soil and vegetables irrigated by wastewater was higher considerably as compared to the soil and vegetables irrigated by tube well water. Among heavy metals concentration in vegetables irrigated by waste-water, trend was appeared as K > Na > Ca > Mg > Fe, while vegetables cultivated by tube-well water, trend was appeared as K > Ca > Na > Mg > Fe. Similarly, leafy vegetables accumulated higher heavy metals levels as compared to non-leafy vegetables.

1. Introduction

Urbanization and industrialization that has arisen over last decades has been escorted by exceptional changes in environment. Heavy metals pollution of soil is an growing problem of environmental pollution due to irrigation with untreated municipal and industrial waste-water, vehicle emission and other activities in Pakistan. Agricultural and urban soil being the prime part of environment act as a chief reservoir or sink of pollutants including heavy metals in food chain (Kelly et al., 1996; Mielke et al., 1999; Aiman et al., 2016). Long term influx of heavy metals into soil may disturb bio-geochemical cycle in ecosystem by changing soil properties (Papa et al., 2010). Studies have exposed that heavy metals in soil are non-degradable and may bio-accumulate in food crops when grown on contaminated land/soil. Contaminated food stuff is a vital pathway of heavy metals exposure to human well-being (Abrahams, 2002; Davydova, 2005; Möller et al., 2005; Mahmood and Malik, 2014).

A number of studies on heavy metals contamination in food chain have been conducted in developed countries (Al-Dhabi et al., 2019a;Al-Dhabi et al., 2019b). However, in developing regions a few studies have been conducted (Zhang et al., 2005; Lu and Bai, 2006; Wong et al., 2006; Akbar et al., 2009; Khan et al. 2010; Jan et al. 2010). In Pakistan, published data on food chain contamination with heavy metals is not considerable; a few reports are available (Jamali et al., 2009; Akbar et al., 2009; Jan et al., 2010; Khan et al., 2010; Aiman et al., 2016; Mahmood and Malik, 2014). Cultivation of vegetables with the industrial and municipal effluents is a common practice in the agricultural land towards the north of Lahore. These vegetables are used at large scale in the urban and rural areas. The current research was aimed to assess the heavy metals concentration in agricultural soil and vegetables irrigated by waste-water and tube-well water, resulted uptake of heavy metals by food crops and to make a

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comparison of irrigation mode on vegetables in term of metals accumulation.

2. Materials and methods

2.1. Study area

Current study was performed in Lahore district, Punjab Province, Pakistan and study site was located at north of Lahore, which is located at 31°32′59″N and 74°20′37″E with an area of 1772 km^2 having total population of 12500,000. Lahore is situated 217 meter (712 ft) above the sea level (ASL). Eight sites were selected and each site was subdivided into three sub-sites. Four sites were being irrigated by municipal and industrial waste-water while other four sites were being irrigated by the tube-well water. Figure 1 shows location map of the study area and respeted site.

2.2. Plant sampling

Edible parts of*Solanum tuberosum* L., *Brassica oleracea capitata*, *Brassica oleracea*, *Brassica campestris* L., *Brassica rapa* L., *Spinacia oleracea* L.., *Daucus carota* L. and *Coriandrum sativum* L. were collected in triplicate from each site of the study area. Vegetables were stored in labeled polythene bags and brought to the Environmental Biology and Ecotoxicology Laboratory, Quaid-I-Azam University, Islamabad, Pakistan, where samples were washed with excess of distilled water to remove any dust or soil particle, chopped into small pieces, then dried in oven and finally, grinded into powder form (Jamali et al., 2009).

2.3. Soil sampling

Soil samples were collected by quarrying a monolith of $10 \times 10 \times 15$ cm^3 size. Samples were collected in triplicate from each sub site of allocated sites. Soil was stored in labeled polythene bags and transported to the Ecotoxicology Laboratory, Quaid-I-Azam University, Islamabad, Pakistan. Soil was air dried, grinded and sieved with 2 mm sieve and stored at the room temperature for further analysis (Jamali et al., 2009).

2.4. Digestion of samples

1 g of soil/plant was digested with 15 ml mixture of HNO_3, H_2SO_4, and $HClO_4$ in 5:1:1 ratio at 80 C until a transparent solution was obtained ((USEPA Method: 3005A)). Mixture was cooled, filtrate with Whatman No 42 filter paper and volume was raised to 50 ml with distilled water.

2.5. Spectrophotometer analysis

Heavy metal concentrations were determined through (Varian FAAS-240) flame atomic absorption spectrophotometer from Quaid-I-Azam University (Faculty of Biological Sciences), Islamabad, Pakistan.

3. Results and discussion

3.1. Heavy metals in soil

Heavy metals fractions detected from soil samples collected from agricultural areas irrigated with tube well and wastewater is summarized in Table 1. This data revealed considerable higher levels of bioavailable metals fractions in soil samples collected from wastewater as compared to the soil irrigated by tube well water. Levels of Fe (mg/kg) was detected higher from soil collected from both the irrigation sources compared with the other metals i.e. 1340.21 ± 311.59 and 1540.72 ± 205.46 from tube well and waste water irrigated sites, respectively. Levels of Fe were higher from both kind of sites followed by Ca (530.18 ± 381.33 mg/kg and 1387.02 ± 454.83 mg/kg from tube well and waste water irrigation, respectively). Among all the detected metals Na exhibited least concentrations (mg/kg) i.e. 68.17 ± 18.41 and 259.11 ± 106.43 from tube well and waste water irrigation, respectively. Results were further statistically confirmed by ANOVA that revealed a significance difference among both the irrigation sources. Waste water irrigated sites were significantly different from tube well water irrigated sites. As a whole, the levels of Fe, Mg, Na, Ca and K were significantly higher from soil collected from wastewater irrigated sites compared with the soil collected from tube well irrigated sites.

Heavy metals accumulation upsurges time by time once soil uninterruptedly remain irrigated with wastewater. Current research was performed to investigate the difference between tube-well and wastewater irrigation practices and their impact on metals uptake to vegetables. In current situation this report is emphasizing the matter of waste-water irrigation to agricultural soil. Soil act as a media for plants and they uptake nutrients and other essential element from soil media, as result heavy metals

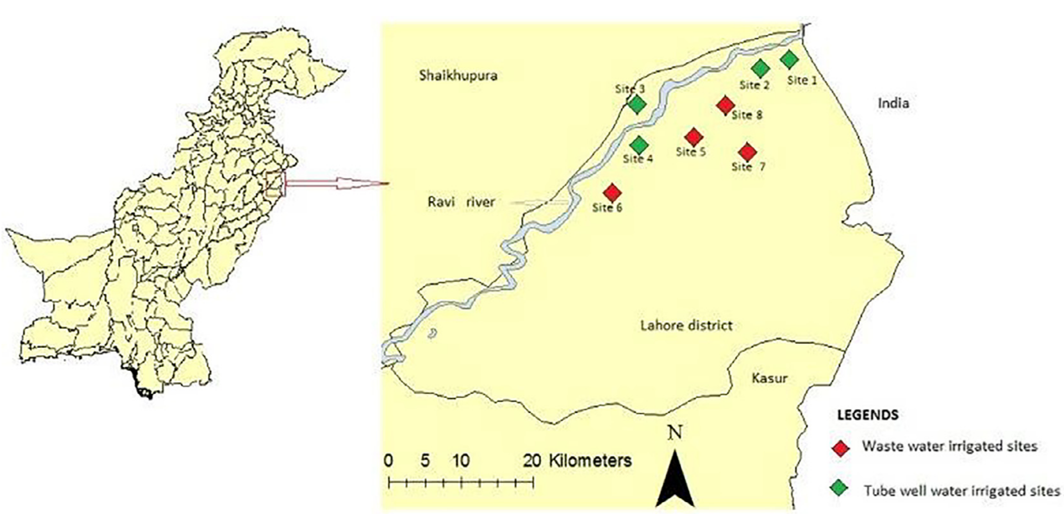

Fig. 1. Map of Pakistan showing the study area and study sites.

Table 1
Concentration of heavy metals (mg/kg) in soil samples irrigated by wastewater and tube well water.

Heavy Metals	Soil of wastewater		Soil of tube well water	
	Range	Value	Range	Value
Fe	1338.39–1749.37	1540.72 ± 205.46	981.96–1548.28	1340.21 ± 311.59
Na	145.48–356.48	259.11 ± 106.43	54.2–89.04	68.17 ± 18.41
Ca	984.23–1856.68	1387.02 ± 454.83	275.39–968.56	530.18 ± 381.33
Mg	426.53–988.18	703.077 ± 281	257.28–603.3	396.81 ± 182.47
K	301.57–847.78	598.15 ± 276.1	197.75–536.91	324.97 ± 184.77

bio-accumulate in food crops/plants that transfer to human and animals body via food chain. High metals levels may result to the disorders in plant and animals.

3.2. Heavy metals in vegetables

Concentrations of screened heavy metals from vegetables irrigated with tube-well water and waste-water are presented visually in Fig. 2. A considerable difference among heavy metal levels in waste-water irrigated vegetables and tube-well water irrigated vegetables has been observed. This difference is highly significant. When we look at the metals concentrations in vegetables irrigated with wastewater, trend was found as K > Na > Ca > Mg > Fe, on the other hand tube-well water irrigated vegetables exhibited the trend as K > Ca > Na > Mg > Fe. Potassium (K) was detected higher in *Coriandrum sativum* L. with the concentration (mg/kg) of 399.3 ± 107.3; on the other hand K least concentration (mg/kg) was detected from *Solanum tuberosum* L. that was 131.46 ± 98.4. Similar trend was observed from vegetables irrigated by tube-well water with maximum K concentration (mg/kg) in *Spinacia oleracea* L. (218.46 ± 124.6) and least concentration (mg/kg) *Solanum tuberosum* L. (92.09 ± 69.2). *Coriandrum sativum* L. cultivated by wastewater exhibited maximum 162.87 ± 42.1 mg/kg Fe concentration while *Brassica oleracea capitata* showed minimal 47.34 ± 32.21 mg/kg concentration. Fe was the least dominant metal detected among screened metals. *Spinacia oleracea* L. cultivated by tube-well water exhibited maximum of 87.23 ± 52.1 mg/kg concentrations while *Brassica oleracea capitata* cultivated by tube-well water showed minimum of 9.18 ± 4.28 mg/kg concentration. Current results revealed that vegetables with edible leaves accumulate higher levels of heavy metals when compared to the vegetables with underground edible parts like tubers, modified stem or aerial flower as edible part. These findings showed an analogous pattern of heavy metal levels in varied vegetable groups. Underground edible part containing vegetables were found least bio-accumulators for heavy metals than vegetables with leaves as edible parts. Reported pattern was observed parallel in vegetables cultivated with tube well or wastewater water.

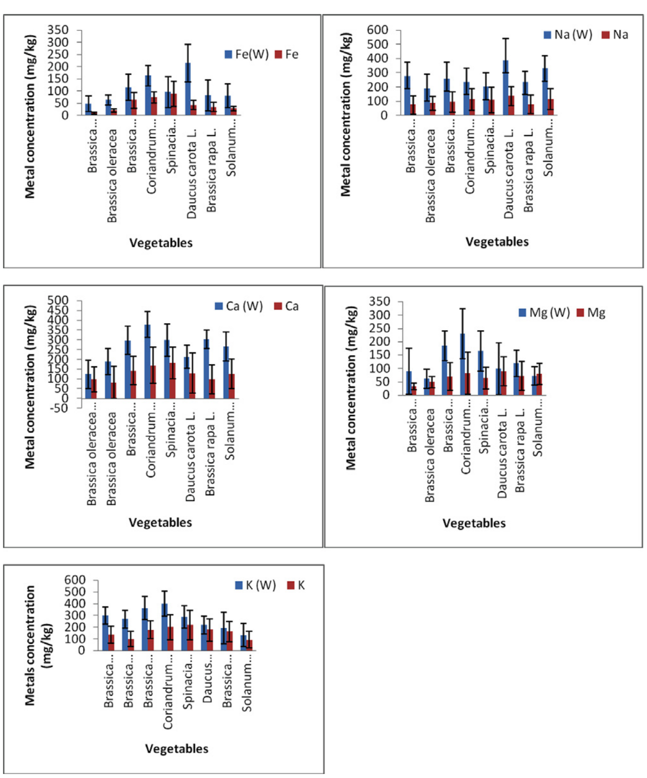

Fig. 2. Comparison of metals concentration (mg/kg) in wastewater irrigated (W) and tube well water irrigated vegetables.

4. Conclusion

Heavy metal levels were screened for mass scale tube well and wastewater irrigation on cultivated vegetables. A substantial variance in heavy metals accumulation was witnessed in vegetables. Crops irrigated by waste water were found more prone metals when compared with crops irrigated by tube well water. Results of statistical analysis also validate difference in behavior of metal accumulations pattern. It was also perceived that leafy vegetables are more inclined towards metals accumulation than the tubers vegetables. Current results should be considered seriously and precautionary actions should be implemented to stop usage of waste water as a source of irrigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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