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Potential health risk assessment of potato (*Solanum tuberosum* L.) grown on metal contaminated soils in the central zone of Punjab, Pakistan

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HIGHLIGHTS

- Sewage water treated crop and soil have higher metal concentrations.
- Vegetables cultivated on soil treated with sewage water are a potent threat for human health.

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ABSTRACT

Metal buildup was estimated in potato (*Solanum tuberosum* L.), grown in central Punjab, Pakistan. This crop was irrigated with multiple water sources like ground, sewage and canal water. Concentrations of different metals like zinc (Zn), arsenic (As), lead (Pb), iron (Fe), nickel (Ni), molybdenum (Mo), copper (Cu), and selenium (Se) were assessed in the potato crop irrigated with different types of waters. Sewage water treated crop and soil had higher metal concentrations than those treated with other two treatments. All metals had positive and significant correlation except for Mo which was non-significantly correlated between the vegetable and soil. Highest daily intake was observed for Fe (0.267), whereas the lowest was seen for Se (0.003). The enrichment factor and health index varied between 0.135-15.08 and 0.285–83.77, respectively. This study concludes that vegetables cultivated on soil treated with sewage water is a potent threat for human health as the metals manifest toxicity after entering the food chain.

1. Introduction

Various anthropogenic factors contribute to contaminating soils and water with heavy metals (Qadir et al., 2014). These soils are a major source of metal transmission in crops growing over them; these metals ultimately find their way into the food chain (Rattan et al., 2005; Singh et al., 2010a). Heavy metals potentially induce metabolic disorder in plants resulting in lower plant yield. Nickel (Ni) is highly toxic and a known carcinogen (Sanders et al., 1987; Al-Qurainy and Abdel-Megeed, 2009; Sharma et al., 2011). Arsenic (As) influences the metabolic processes in human body and it is also a carcinogen. It also affects cardiac activity (Conesaa et al., 2006) and production of platelets and red blood cells at lower concentration. Minor levels of metals such as iron (Fe), copper (Cu), zinc (Zn), chromium (Cr) and manganese (Mn) are required in the human body (Duffus, 2002) but excessive buildup causes serious health implications.

The metal uptake by plants is dependent on multiple factors like composition of soil, capacity to exchange cations, organic matter, pH of soil, plant species and its age (Qadir et al., 2014). Soil pH is a good indicator of availability of nutrients and metals to plants (Adriano, 1986; Espinoza et al., 1991). In view of all these reports the major investigative aim of this study was the estimation of metal accumulation (Mo, Zn, Fe, Se, Pb, Ni, Cu and As) in potato crop

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treated with three water types viz. ground, canal and sewage water. It was to be determined whether potato crop irrigated with these waters was suitable for human consumption or not. Soil to plant metal translocation has also been ascertained in this investigation.

2. Materials and methods

2.1. Study area

The study on potato crop was carried out in Khushab city, Pakistan. This city is located at 32.30°N 72.34°E. There is a wide fluctuation of temperature from summer (25–49 °C) to winter (5–23 °C). Annual rainfall is approximately 526 mm. Three sites were selected for sampling, i.e. Joiya (Site-I), Talokar (Site-II) and Khushab (Site-III). Soil, water and plant samples were taken from three sites which were separately irrigated with ground (GWI), canal (CWI) and sewage water (SWI). Three replicates of each sample were collected. Sampling was done in January 2015.

2.2. Sample collection

Water samples, each of 100 mL, from three sites were taken in labeled plastic bottles. To avoid microbial growth, 1 mL of conc. nitric acid (HNO_3) was added. The samples were refrigerated before further processing. Then, 1 kg soil was taken randomly from the three sites where the crop was cultivated. The samples were air-dried initially and kept in an oven at 72 °C for 5 days to force moisture out of the soil. Soil pulverization was done using a mortar and pestle and then the powdered material was passed through a sieve (mesh size of 2 mm). Vegetable samples were collected by randomly uprooting the plants from all sites. Only the edible portion (potato tubers) was selected for analysis. Thorough washing in distilled water was done and the samples were dried in an oven for 6 days at 70 °C. An electric machine was used to crush the samples.

2.3. Sample preparation

For it, 10 mL of conc. HNO_3 was used to digest the collected water samples. The samples were heated at 80 °C until they became colorless. Final volume, 50 mL was made using distilled water. For preparation of the soil and vegetable samples, 1 g of each sample was taken in a glass flask having 4 mL H_2SO_4 and 8 mL H_2O_2. Transparency of the sample was noted after the digestion process. The samples were then filtered and collected in separate plastic bottles and the distilled water was added to make 50 mL volume of each sample.

2.4. Metal detection

The metal detection was done using an atomic absorption spectrophotometer (Model AAS 5000; Perkin-Elmer Corp., 1980). Iron (Fe), Ni, Cu, Zn and Pb were estimated using this method. For Mo quantification, the AAS was equipped with a D_2 corrector and a graphite furnace (Perkin-Elmer Model 503), and the flow injection hydride generation AAS (Perkin Elmer Analyst 400) was used for determining As (Welsch et al., 1990). For Se, the flourometric method was used (Watkinson, 1966).

Other parameters like pH, electrical conductivity, soil organic matter and texture of soil were also measured. The Bouyoucos hydrometer method was used to appraise soil texture (Gee and Bauder, 1986). Organic content of soil was analyzed using the modified Walkey-Black method i.e. Anne method (McLean, 1982). For electrical conductivity and pH, 1:2 soil to water extract was used (Mathieu and Pieltain, 2003).

2.5. Bio-concentration factor

To check the metal translocation from soil to vegetable, bio-concentration factor was estimated following Cui et al. (2004).

2.6. Pollution load index (PLI)

This index was applied to calculate the extent of metal contamination following Liu et al. (2005).

2.7. Health risk index

Following Cui et al. (2004), the ratio for oral reference dose and daily metal intake was estimated as part of health risk index.

Daily intake of metal (DIM) and Health risk index (HRI) were determined following USEPA (2002).

2.8. Enrichment factor (EF)

Extent of soil contamination and accumulation of heavy metals in plants and soil in relation to uncontaminated plants and soil is called as EF (Kisku et al., 2000). It was devised by Buat-Menard and Chesselet (1979).

2.9. Statistical analysis

SPSS (version 17) was used for statistical analysis. One-way ANOVA was deemed appropriate for metal findings in water, vegetable and soil. Correlation of metals between the soil and the vegetable was also determined. The level of significance for comparison of means was kept at 0.001, 0.01 and 0.05 levels (Steel and Torrie, 1980).

3. Results

ANOVA showed a non-significant effect ($p \leq 0.05$) of the irrigation regimes on water Zn while a significant effect ($p \leq 0.05$) was observed in case of water Cu, Pb, Se, Ni, Mo, Fe and As (Table 1). Only two metals, Mo and Pb were higher than the permissible limits in water sampled from the three treatments (Table 2).

The physico-chemical variables including pH, electrical conductivity and soil texture were measured for the soil sampled from sewage, ground and canal water (Table 3). Soil turned out to be loamy after its detailed analysis. The pH ranged from 7.57 to 8.56 at the three sites. Electrical conductivity varied from 0.85 to 1.05 dS m^{-1}. The three sites did not show much variation in organic matter because it varied from 0.58 to 0.79%. Analysis on soil from three sites suggested that the metals (Se, Zn, Cu, Mo, Fe, and Ni) were below the PML except arsenic. At the three sampling sites, metals were in the sequence of As > Fe > Pb > Ni > Mo > Cu > Zn > Se with respect to concentration (Table 4;

Table 1
One-way ANOVA of data for metal concentrations in water, soil and potato at three different sites.

Metals and metalloids	Water	Soil	Potato
As	0.001**	48.96***	2.561**
Cu	0.001**	1.654***	28.96***
Fe	0.031**	70.82ns	108.1ns
Mo	0.002ns	3.557***	2.154**
Ni	0.005***	3.179***	2.656*
Pb	0.006**	102.8***	1.504**
Se	0.001**	1.225***	0.055***
Zn	0.002ns	1.656***	53.57***

*, ** and *** = significant at 0.05, 0.01 and 0.001 levels, respectively; ns, non-significant.