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# Vertical distribution of heavy metals in soil profile of peri-urban areas of Haryana

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ABSTRACT

Soil serves as a sink for various heavy metals where they present long period of time in the soil and create a many harmful effects on soil health. A survey was carried out in peri-urban areas of Mohindergarh and Narnaul city, Haryana irrigated by sewage and tube-well water. Study was conducted on vertical distribution of heavy metals in profile soil samples. Soil samples were analyzed for initial properties of soil and DTPA extractable heavy metals (Zn, Cu, Cd, Cr, Pb, Ni and Co). The results revealed that the soluble heavy metals, viz. Zn, Cu, Cr, Cd, Pb and Co content in both sewage and tube-well irrigated profile soil samples decreased with increased depth of soil in both Mohindergarh and Narnaul areas. But, the Ni content increased with depth in both areas of sewage and tube-well irrigated soils. It is concluded that the profile soil samples were found below the permissible limit of soluble heavy metals concentration.

**Keywords**: Heavy metals, Profile, Sewage, Vertical distribution

In India, agriculture has been major sector of water user and maximum amount of water used in irrigation is likely to be decreased by 15–20% in next two decades (Ray and Datta 2016). So, the use of domestic, sewage sludge and industrial waste water for irrigation increasing day by day. This waste water contain large amount of heavy metals. Due to long-term application of waste water build-up of the heavy metals in soils (Roy *et al.* 2013). The use of sewage effluent water for crop production on the account of scarcity of good quality water for irrigation and high cost of fertilizers results their accumulation in soil (Singh *et al.* 2013). Heavy metals are very harmful to the soil, plant and environment when they are above permissible limits (Louhar *et al.* 2019). They don't decay with time due to their non-biodegradable nature and persists for a long period of time after their introduction. Unscientific usage of sewage water without good quality water creates clogging of soil pores which resulted into decreased soil permeability (Rattan *et al.* 2005). Unhygienic nature and lack of aeration in sewage water produces toxic gases which adversely affect the crop production along with human health and environmental quality. Heavy metals present at a background level and strongly interact with the soil matrix; consequently, heavy metals in soils can become mobile leached into the surface water or groundwater (Zhang *et al.* 2018).

The binding mechanisms of heavy metals vary with soil depth, depending on the physico-chemical properties of the soil such as pH, organic carbon, texture, redox potential and water content, all these plays an important role for the rate of chemical transformation of an element in a solid phase (Khan *et al.* 2016). The objectives of this study were: (i) to study the changes in physico-chemical properties of soils irrigated by sewage and tube-well water; (ii) to assess the effects of sewage and tube-well water use on metal contents in soils.

## MATERIALS AND METHODS

The study of vertical distribution of heavy metals in soil profile was carried out during 2018–19 in peri-urban areas of Mohindergarh (28.2710º N and 76.1494º E) and Narnaul (28.0658° N and 76.1015° E) cities of Haryana, India. Profile soil samples were analyzed for *p*H and electrical conductivity (EC) as per the standard procedure as outlines by Jackson (1973) using (1:2) soil : water suspension. Soil organic carbon content was estimated by wet digestion method (Walkley and Black 1934). Calcium carbonate content was determined using rapid titration method (Puri 1949). International Pipette method as described by Piper (1950) was used for determination of soil texture. Cation exchange capacity (CEC) was determined by ammonium acetate method (Hesse 1971). Lindsay and Norvell (1978) DTPA extractable method used for heavy-metal analysis (Zn, Cu, Cd, Cr, Pb, Ni and Co) in the soil samples.

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## RESULTS AND DISCUSSION

*Initial physico-chemical properties of soils*: Among the soil physico-chemical properties, the *p*H of sewage and tube-well irrigated soil (Table 1) was found moderately alkaline (*p*H 7.96 and 8.63) and (*p*H 7.91 and 8.49) in Mohindergarh and Narnaul soils, respectively. Similar results of soil *p*H observed by Parth *et al*. (2011) which ranged from 5.7-8.9 and was recorded acidic to near neutral and alkaline in nature. The solubility and mobility of the heavy metals are higher in acidic soils than to neutral and/or slightly alkaline soils. In case of soluble-salt content (dS/m), i.e. EC of sewage and tube-well irrigated soil (Table 1) was found non-saline (0.49 and 0.32 dS/m) and (0.62 and 0.45 dS/m) in Mohindergarh and Narnaul soils, respectively. Mollahoseini (2013) studied that presence of high soluble salts in sewage water resulted in higher EC of soils irrigated with sewage water. In both the soils, i.e. Mohindergarh and Narnaul cities, higher organic carbon (OC) content (0.96-0.99%) was recorded in sewage irrigated soils compared with tube-well irrigated ones where, medium levels (0.49–0.56%) of OC content was found (Table 1). High organic carbon content in sewage water irrigated soil mainly due to very high organic load of sewage water and rapid decomposition of organic compounds of sewage effluents (Singh *et al.* 2012). Further, the percent calcium carbonate content ranged from 0.24–0.69% and 0.69–1.87%, in sewage and tube-well water irrigated soils of Mohindergarh and Narnaul cities, respectively (Table 1). Low calcium carbonate content in soil samples were due to non-calcareous nature soil reported by Yerima *et al.* (2013). The texture of peri-urban soils was found sandy in Mohindergarh and sandy loam in Narnaul city (Table 1). Similarly, Jangir *et al.* (2019) in their study reported loamy to loamy sand textures of soils collected from Panchkula. Textures of soils are mainly controlled by parent materials from which the soils have been developed. The CEC [cmol ($p^+$)/kg] of sewage and tube-well water irrigated soils was found low to medium status in soil. It was 9.92 and 19.12 cmol ($p^+$)/kg in sewage irrigated soils while, in case of tube-well irrigated soils it was 8.20 and 15.16 cmol ($p^+$)/kg in the soils of Mohinderagrh and Naranul, respectively (Table 1). Adrover *et al.* (2012) found that waste-water irrigated soil had CEC [cmol ($p^+$)/kg] of 15.3 compared to non-wastewater irrigated soil with CEC of 17.2 cmol/kg may be a varying mineralogical site probably dominated by 2:1 clay minerals of the smectite or vermiculite group.

Table 1 Initial physico-chemical properties of Mohindergarh and Narnaul soils (Haryana)

| Soil properties | Mohindergarh | | Narnaul | |
|---|---|---|---|---|
| | Sewage irrigated | Tube-well irrigated | Sewage irrigated | Tube-well irrigated |
| *p*H (1:2) | 7.96 | 8.63 | 7.91 | 8.49 |
| EC (dS/m) | 0.49 | 0.32 | 0.62 | 0.45 |
| Organic carbon (%) | 0.96 | 0.49 | 0.99 | 0.56 |
| CEC (cmol/kg) | 9.92 | 8.20 | 19.12 | 15.16 |
| $CaCO_3$ (%) | 0.24 | 0.69 | 0.69 | 1.87 |
| Sand (%) | 88.09 | 90.18 | 78.58 | 74.83 |
| Silt (%) | 4.64 | 4.09 | 8.17 | 11.42 |
| Clay (%) | 7.27 | 5.73 | 13.25 | 13.75 |

*DTPA extractable heavy metal contents in profile samples*: Results of the present study revealed a significantly higher accumulation of all the heavy metal contents in surface soils compared with deeper soil layers both in sewage water irrigated and tube-well irrigated soils collected from both the sites, i.e. Mohindergarh and Narnaul cities.

*DTPA extractable zinc (Zn)*: In Mohindergarh city, DTPA-extractable Zn of both sewage and tube-well irrigated profile soil samples decreased with increasing soil depth (Table 2). Similarly, in Narnaul city, DTPA extractable Zn of sewage irrigated and tube-well irrigated soil profile decreased with increasing soil depth (Table 3). Heavy metals distribution with soil depth varies according to the soil type and element. Koupai *et al.* (2006) and Jayadev and Puttaih (2012) got the similar results in accordance with present study and reported that Zn content decreases with depth due to increasing pH and $CaCO_3$.

*DTPA extractable copper (Cu)*: Results revealed that the DTPA extractable Cu also recorded the similar trends like Zn in sewage and tube-well irrigated profile soil of Mohindergarh city and it decreased with increasing soil depth (Table 2). Similarly, in Narnaul city, DTPA extractable Cu of sewage and tube-well irrigated soil profile decreased with increasing soil depth (Table 3). Aydinalp and Cresser (2009) observed that prolonged irrigation with polluted canal water resulted in higher heavy metals accumulation in upper horizon. Presence of high organic matter in surface soil and the affinity of heavy metals to organic matter resulted in higher accumulation of these metals in surface soil compared with lower soil depths (Agbenin and Latifatu 2004).

*DTPA extractable cadmium (Cd)*: Results of the present study delineated a decrease in DTPA-extractable Cd with increasing soil depth in both the soils. The highest accumulation was recorded in surface soil followed by other soil depths. Guo *et al.* (2013) got similar results while they were studying the profile samples of Dongguan City (China). They found that higher contents of Cu, Zn, Pb, Cd, and Hg in topsoils than in the subsoil of vegetable fields and Cd have accumulated only in topsoil of vegetable fields. Cadmium contents at the bottom of the profiles were far below an average value of 10.3 mg/kg reported by the Mashi and Alhassan (2007) from Kano, Nigeria.

*DTPA extractable chromium (Cr)*: In Mohindergarh city, DTPA-extractable Cr of sewage and tube-well irrigated profile soil decreased with increasing soil depth (Table 2). Concurrently, in Narnaul city, DTPA-extractable Cr of sewage and tube-well irrigated soil profile decreased with increasing soil depth (Table 3). Yerima *et al.* (2013) also got the similar results in Ethiopia, while studying chromium content of *Vertisols* and *Vertic Inceptisols* and reported that decrease in Cr content with depth and reduction in metals

Table 2 DTPA extractable heavy metals content (mg/kg) in sewage and tubewell irrigated profile soils of Mohindergarh city (Haryana)

| Site ID | Depth (cm) | Sewage irrigated | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Zn | Cu | Cd | Cr | Pb | Ni | Co |
| M(S)-1 | 0 – 15 | 1.88 | 1.38 | 0.06 | 0.24 | 0.59 | 0.03 | 0.14 |
| | 15 – 30 | 1.64 | 1.12 | 0.04 | 0.19 | 0.48 | 0.11 | 0.09 |
| | 30 – 60 | 0.87 | 0.67 | 0.02 | 0.10 | 0.24 | 0.23 | 0.05 |
| | 60 - 90 | 0.24 | 0.22 | 0.00 | 0.04 | 0.08 | 0.26 | 0.02 |
| M(S)-2 | 0 – 15 | 1.51 | 1.09 | 0.05 | 0.22 | 0.57 | 0.04 | 0.13 |
| | 15 – 30 | 1.43 | 0.94 | 0.03 | 0.18 | 0.46 | 0.14 | 0.11 |
| | 30 – 60 | 0.74 | 0.32 | 0.01 | 0.08 | 0.21 | 0.23 | 0.07 |
| | 60 - 90 | 0.18 | 0.12 | 0.00 | 0.03 | 0.07 | 0.29 | 0.02 |
| | | | | *Tube-well irrigated* | | | | |
| M(T)-1 | 0 – 15 | 0.78 | 0.41 | 0.03 | 0.19 | 0.38 | 0.02 | 0.08 |
| | 15 – 30 | 0.65 | 0.32 | 0.04 | 0.14 | 0.26 | 0.07 | 0.06 |
| | 30 – 60 | 0.21 | 0.15 | 0.02 | 0.08 | 0.12 | 0.12 | 0.02 |
| | 60 - 90 | 0.11 | 0.05 | 0.00 | 0.03 | 0.05 | 0.19 | 0.02 |
| M(T)-2 | 0 – 15 | 0.97 | 0.49 | 0.02 | 0.17 | 0.34 | 0.01 | 0.09 |
| | 15 – 30 | 0.78 | 0.37 | 0.02 | 0.15 | 0.24 | 0.04 | 0.07 |
| | 30 – 60 | 0.23 | 0.11 | 0.01 | 0.08 | 0.13 | 0.13 | 0.03 |
| | 60 - 90 | 0.11 | 0.04 | 0.00 | 0.02 | 0.05 | 0.18 | 0.03 |

M(S)-1=Sewage irrigated Mohindergarh site-1; M(S)-2=Sewage irrigated Mohindergarh site 2; M(T)-1=Tube-well irrigated Mohindergarh site-1; M(T)-2=Tube-well irrigated Mohindergarh site-2

Table 3 DTPA extractable heavy metals content (mg/kg) in sewage and tube-well irrigated profile soils of Narnaul city (Haryana)

| Site ID | Depth (cm) | Sewage irrigated | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Zn | Cu | Cd | Cr | Pb | Ni | Co |
| N(S)-1 | 0 – 15 | 1.65 | 2.88 | 0.08 | 0.32 | 0.90 | 0.06 | 0.19 |
| | 15 – 30 | 1.55 | 2.67 | 0.05 | 0.28 | 0.84 | 0.14 | 0.14 |
| | 30 – 60 | 0.84 | 0.95 | 0.02 | 0.13 | 0.25 | 0.35 | 0.07 |
| | 60 - 90 | 0.38 | 0.41 | 0.01 | 0.06 | 0.10 | 0.41 | 0.02 |
| N(S)-2 | 0 – 15 | 1.92 | 1.56 | 0.14 | 0.31 | 0.84 | 0.03 | 0.18 |
| | 15 – 30 | 1.81 | 1.42 | 0.11 | 0.24 | 0.72 | 0.14 | 0.14 |
| | 30 – 60 | 0.72 | 0.56 | 0.04 | 0.08 | 0.22 | 0.36 | 0.06 |
| | 60 - 90 | 0.31 | 0.12 | 0.01 | 0.02 | 0.08 | 0.45 | 0.01 |
| | | | | *Tube-well irrigated* | | | | |
| N(T)-1 | 0 – 15 | 0.75 | 0.76 | 0.05 | 0.18 | 0.19 | 0.03 | 0.14 |
| | 15 – 30 | 0.64 | 0.66 | 0.04 | 0.16 | 0.15 | 0.09 | 0.13 |
| | 30 – 60 | 0.31 | 0.29 | 0.02 | 0.08 | 0.06 | 0.24 | 0.05 |
| | 60 - 90 | 0.14 | 0.08 | 0.00 | 0.02 | 0.02 | 0.30 | 0.01 |
| N(T)-2 | 0 – 15 | 0.66 | 0.65 | 0.04 | 0.18 | 0.27 | 0.00 | 0.06 |
| | 15 – 30 | 0.57 | 0.53 | 0.04 | 0.14 | 0.21 | 0.04 | 0.04 |
| | 30 – 60 | 0.18 | 0.19 | 0.01 | 0.06 | 0.07 | 0.11 | 0.01 |
| | 60 - 90 | 0.05 | 0.03 | 0.00 | 0.01 | 0.02 | 0.15 | 0.00 |

N(S)-1=Sewage irrigated Narnaul site-1; M(S)-2=Sewage irrigated Narnaul site site-2; N(T)-1=Tube-well irrigated Narnaul site-1; M(T)-2=Tube-well irrigated Narnaul site-2.

solubility due to decrease in organic carbon content and increase in *p*H of soil.

*DTPA-extractable lead (Pb)*: In Mohindergarh city, DTPA-extractable Pb of sewage and tube-well irrigated profile soil decreased with increasing soil depth (Table 2). However, in Narnaul city, DTPA-extractable Pb of sewage and tube-well irrigated soil profile decreased with increasing soil depth (Table 3). Sharma and Prasad (2010) stated that highest Pb contents in surface horizons and a decrease with increasing soil depth because clay content increases significantly with depth. Due to clay forming the complexes with metal, retain and immobilize the heavy metals. Freitas *et al.* (2004) got similar findings and stated that Pb content decreased with soil depth as the usage of treated wastewater having 0.016 (mg/l) Pb content had no significant effect on the soil Pb accumulation compared with the beginning stage.

*DTPA-extractable cobalt (Co)*: Significantly higher DTPA-extractable Co content was recorded at surface soils (0-15 cm) of both Mohindergarh and Narnaul cities irrespective of irrigation methods. Results revealed no significant changes in DTPA-extractable Co content at 30–60 and 60–90 cm soil depths at both the sites irrigated with tube-well water. In Mohindergarh city, DTPA-extractable Co of sewage and tube-well irrigated profile soil decreased with increasing soil depth (Table 2). However in Narnaul city, DTPA-extractable Co of sewage and tube-well irrigated soil profile decreased with increasing soil depth (Table 3). Similar findings were reported by Zhu *et al.* (2018) and stated that Co content decreased with increase in soil depth as application of wastewater having 0.055 mg/l Co had significant effect on the soil Co compared to the beginning of the growing season and groundwater treatment.

*DTPA-extractable nickel (Ni)*: Results showed that effect of sewage water and tube-well water irrigation on DTPA-extractable Ni content in the soil profile observed higher Ni content at 30-60 and 60-90 cm soil depths compared with surface (0-15 cm) and subsurface soils (15-30 cm) at both the sites. In Mohindergarh city, DTPA-extractable Ni of sewage and tube-well irrigated profile soil increased with increasing soil depth (Table 2). However in Narnaul city, DTPA-extractable Ni of sewage and tube-well irrigated soil profile increased with increasing soil depth (Table 3). Yerima *et al.* (2013) reported the similar results in Ethiopia, while studying nickel content of *Vertisols* and *Vertic Inceptisols* and reported that higher contents of nickel at lower profile depth likely due to anthropogenic sources and effects of leaching related translocations which is affected by weathering and excessive rainfall.

From this study, it can be concluded that long-term application of sewage and tube-well water as irrigation water are source of heavy metals. Heavy metals accumulation and their distribution into surface soils and profile soil samples are inevitable due to climatic conditions and anthropogenic activities. The heavy metals contents in studied samples were found within the permissible limit. Therefore, present study is very helpful for analysis of heavy metal contamination and risk associated with them.

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