Comprehensive assessment of heavy metals contamination in soil and water in peri-urban areas of National Capital Territory, Delhi

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ABSTRACT

Contamination of soil and irrigation water by heavy metals (HMs) is a genuine concern due to the possible effect on human well-being via food chain. Thus, an assessment was carried out to find HMs concentration level in water and soil samples of peri-urban areas of National Capital Territory (NCT) Delhi. Analytical results revealed that significant amount of HMs concentration were found in irrigation water, out of which concentrations of Cu (2590 μg/L), Fe (5549 μg/L), Cr (1910 μg/L), Mn (2570 μg/L), Zn (2155 μg/L) and Cd (405 μg/L) in drain water were exceeded the permissible limit of FAO. Cu (108.94 μg/g) and Pb (163 μg/g) concentration in surface soils of majority of sites were recorded beyond the permissible limit of FAO. The overall mean HMs concentration in soil found in the sequence Zn>Cu>Fe>Mn>Cr>Ni>Pb>Cd. It reveals that increasing trend of HMs concentration in water used for irrigation results in metal accumulation in soil, and their consequent accrual in the crops lead to adverse impact on human well-being.

Introduction

Peri-urban areas have dominance in a wide range of allied activities along with arable farming and are often used for production of horticulture, floriculture, poultry and dairy development due heavy demands and profitability. But majority of peri-urban lands are polluted with toxic metals by various sources such as industrial effluents, dumping sites, sewerage, vehicular emission, human induced pollution and indiscriminate use of chemicals fertilizers (Bhattacharya et al., 2015; Bhardwaj et al., 2020). Irrigation water is contaminated with toxic metals due to various sources (Khan et al., 2015; Singh et al., 2021). Thus, agriculture products grown in these areas are likely to be contaminated by heavy metals (HMs). HMs contamination of cultivated soils may create great ecological and environmental issues. Besides, their movement from soil-to-crop is the main pathway of human exposure to these metals. Continuous population growth leads to increased food requirement, large consumption of pesticides, manures, fertilizers and so on is also on the rise besides use of wastewater for agricultural irrigation. Such practices not only led to deterioration of food quality but also have serious impact on food security. Since, the physicochemical characteristics of soil and nature of plant species is important factor for HMs accumulation (Khan et al., 2015; Chabukdhara et al., 2016; Singh et al., 2021). Globally more than 70% water is consumed by the agriculture sector (Mancosu et al., 2015). However, the availability of fresh groundwater for agriculture is decreasing largely due to increasing demand of water from energy and municipal
industries in urban as well as peri-urban regions. Irrigation with metal contaminated water i.e. drain, river, groundwater can lead to increase in metals concentration in cultivated soil (Gola et al., 2020). Normally, wastewater contains noteworthy quantity of beneficial nutrients and toxic HMs. Increased use of agro-chemicals also causes polluted crop land by HMs (Balkhair and Ashraf, 2016).

River Yamuna is the imperative water source for northern India, and covered about 48 km of the national capital territory (NCT), Delhi, and contributing about 94%, 4% and 2% for irrigation, household and industrial and other applications, respectively (CPCB 2006). Due to metropolitan city and capital of India, industrialization and urbanization are major factor for water and soil pollution. NCT of Delhi has an impenetrable population of around 160 lakhs (Census 2011). It has the larger load of small to medium size industries deals in electroplating steel processing, battery, dyeing, electrical appliances manufacturing and printing etc. The effluents produced from these various industries are discharged into open drains or into sewerage lines which are finally disposed into river Yamuna (Bhattacharya et al., 2015).

Moreover, the river is also connected by around 23 drains carrying huge quantity of sewage/wastewater that released into the river without proper treatment and hence contributed sources of pollution. Considering the above problem the study was conducted to assess the HMs concentration in irrigation water as well as soil at different places belongs to NCT of Delhi.

Material and Methods

Sampling: In Per-urban and urban area of Delhi NCT, total 10 sampling sites were identified for soil and water samples collection. A Location map of sampling site is given in Figure 1. Water samples were collected from various sources such (i) drains from Najafgarh (S1), Wazirabad (S2) and Nizamuddin (S3), (ii) Yamuna River from Yamuna Vihar (S4) and Sonia Vihar (S5) and (iii) Tube wells water from Ranhaula (S6), SaritaVihar (S7), Dinchaon Kalan (S8), Madanpur Khadar (S9) and Jagatpur (S10) during post-monsoon in 2019 and 2020. Besides, soil samples from surface (0-30cm) and subsurface (30-60cm) layers were also collected from cultivated fields, which have different contamination sources due to industrialization and urbanization of Delhi NCT.

Sample preparation and heavy metal analysis: 15ml of Di-acid mixture (HNO₃ and HClO₄ in 9:4 ratio) was added in 100 ml of water samples and heated at 80°C till a clear solution was attained. After cooling, this sample was filtered by filter paper (Whatman # 42) and make up the volume of the filtrate to 100 ml with double distill water. Further, One gram of soil sample was digested subsequently adding 15 ml of tri-acid mixture (nitric, sulfuric and perchloric acids in ratio 5:1:1) at 80°C until a clear solution was achieved. Sample was cooled and filtered by Whatman No. 42 filter paper and make up the volume of the filtrate to 25 mL with double distilled water (Singh et al., 2021). Copper (Cu), Iron (Fe), manganese (Mn) nickel (Ni), lead (Pb), zinc (Zn), cadmium (Cd) and chromium (Cr), in prepared water and soil samples were examined through an atomic absorption spectrophotometer (AAS4141, ECIL, India). The instrument was calibrated by a manually prepared standard solution of each metals and drift blanks. Standard stock solutions of 1000ppm used for all metals.
Results and Discussion

Irrigation water: A comprehensive range of eight HMs concentrations (μg/L) present in Yamuna River, associated drains and tube well water of Delhi NCT is compared with the previous studies (Table 1). Figure 2 a, b, and c representing the each metal concentrations at different sampling sites from S1 to S3 for drain, from S4 and 5 for river and S6 to S10 for tube well water. The overall mean with standard deviation (SD) of Cu, Fe, Mn, Ni, Pb, Cd, Cr, and Zn were found 795.4±1153.2, 1784.4±2353.8, 893.1±1045.4, 218.4±260.4, 5137±618, 133±163.8, 472.2±693.5 and 776.1±915.7μg/L, respectively. Results reveal that, the HMs i.e. Cd, Cr, Ni and Pb in tube-well water were reported below detection limit (BDL) whereas, all the metals concentration in tube-well water were recorded as under permissible limit as suggested by FAO for irrigation. The AAS-4141 detection limit for Cu, Fe, Mn, Ni, Pb, Cd, Cr, and Zn was 40, 50, 30, 200, 200, 10, 60 and 10 μg/L, respectively. Highest concentration of Cd (405 μg/L) and Cr (1910 μg/L), Fe (5549 μg/L), Mn (2570 μg/L), Ni (612 μg/L), Pb (1490 μg/L), and Zn (2155 μg/L) were recorded at Najafgarh site followed by Nizamuddin. It may be due to contamination by industrial effluents dyes as Najafgarh site has major drain which carries lots of industrials and municipal wastewaters/ effluents. Farmers in peri-urban areas along these drains are frequently uses this water as irrigational purposes. Hence, it is serious concern to monitor the quality of soil and agricultural produce. Moreover, Cu concentration (2590 μg/L) was recorded at Nizamuddin site followed by Najafgarh. Nizamuddin sites also having industrials belt including Okhla area and carries wastewaters. Moreover, Patel et al. (2019) was reported Cr concentration 10.1– 73.6 μg/g, which is almost close to present finding. Lower heavy metal concentration was recorded in sub-surface soil in comparison to surface soil. Minimum HMs concentrations were recorded in

Heavy metals concentration in soil of peri-urban areas: HMs concentration (μg/g) in cultivated soils of different peri-urban areas and Yamuna sites of Delhi NCT is given in Table 2. The overall mean with SD of Cd, Cu, Mn, Fe, Ni, Pb, Cr and Zn in farming soil were found 1.72±0.42, 59.53±23.99, 47.9±14.7, 54.91±11.55, 35.06±7.61, 33.56±9.81, 43.13±12.2, and 92.02±26.45 μg/g, respectively. The overall mean metal concentration reported in decrease order Zn>Cu>Fe>Mn>Cr>Ni>Pb>Cd. Concentration of all these eight metals at each sampling sites were recorded in Figure3. Maximum concentrations of Cd (2.76 μg/g), Cr (66.44 μg/g), Cu (108.94 μg/g), Ni (51.92μg/g) and Pb (162.99 μg/g) were recorded at Najafgarh site followed by Nizamuddin. This is probably due to frequent use of Najafgarh and Nizamuddin drains water for irrigation. More or less similar concentration of HMs were reported by Bhattacharya et al. (2015) for Zn (130–2220 μg/L), Bhardwaj et al. (2017) for Fe (878.5–53940 μg/L), Cr (2.6–1983 μg/L), and Cd (1.7–433 μg/L) (Table 1). Najafgarh drain is highly polluted, mainly due to the effluent release of the nearby industrial enclaves (alloy, pickling, printing, steel, battery, plastic, chemical, electroplating, dyeing, galvanization and leather). Nizamuddin drain is the confluence point of several drains, hence carry significant amount of pollutants from small scale industrial effluents, sewage and sludge.
Table 1: Range of heavy metal concentration (μg/L) in water of Yamuna River and associated drains in Delhi NCT

| Cd    | Cr   | Cu      | Fe      | Mn   | Ni   | Pb    | Zn    | Water category                  | Reference                   |
|-------|------|---------|---------|------|------|-------|-------|----------------------------------|-----------------------------|
| 20–40 | –    | 80–310  | –       | –    | –    | –     | 0.0–800| 0.0–240 Drain and tube well      | Singh and Kumar (2006)      |
| 0.02–0.07 | –    | 0.18–0.28 | –     | –    | –    | –   | 0.30–0.43 | 0.04–0.06 Tube well | Bhatia et al., (2015) |
| 0.0–70 | 0.0–420 | 20–640 | –   | – | 10–130 | 30–270 | 130–2220 | Yamuna River and linked drains | Bhattacharya et al., (2015) |
| 1.7–433 | 2.6–1983 | 18.4–17642 | 878.5–53940 | –    | 1.4–2748 | 6.8–1112 | 15.4–28520 | Yamuna River and linked drains | Bhardwaj et al., (2017) |
| 1–8    | 60–940 | 50–520 | –   | – | –   | 450–680 | –   | Yamuna River and linked drains | Rahman and Singh (2018) |
| –      | 20–270 | 40–380 | –   | – | 40–230 | 490–970 | 80–760 | Yamuna River | Patel et al., (2019) |
| 0–75   | 0–2436 | 0–2617 | –   | – | 0–596 | 0–1579 | 0–12400 | Drains | Gola et al., (2020) |
| –      | 35–52 | 50–120 | 40–190 | – | 88–253 | 2–40 | 840–1800 | Yamuna River | Patel et al., (2019) |
| BDL-405 | BDL-1910 | 47–2590 | 58–5549 | 51–2570 | BDL-612 | BDL-1490 | 28–2155 | Yamuna River, linked drains and tube well | Present study |

Source: *Mandal et al., (2019).

Table 2: Range of heavy metal concentration (μg/g) in soil in different per-urban and Yamuna sites of Delhi NCT

| Cadmium | Chromium | Copper | Iron | Manganese | Nickel | Lead | Zinc | Place | References |
|---------|----------|--------|------|-----------|--------|------|------|-------|------------|
| 0.6–1.30 | 43–95   | 6.39–39 | 142–651 | 11.8–48 | 9.90–32 | 31–108 | Delhi | Mehra et al., (2000) |
| 2.1–2.5 | –       | 28.8–129.6 | – | – | – | 32.1–59.6 | 83.1–196.3 | Delhi | Singh and Kumar (2006) |
| 2.28–2.51 | –    | 23.75–76.75 | – | – | – | 21.25–59.38 | 73.25–174.5 | Delhi | Bhatia et al., (2015) |
| –      | 10.1–73.6 | 7.1–42.1 | –   | – | 6.4–19.3 | 9.1–25.8 | 13.5–55.6 | Along Yamuna River | Patel et al., (2019) |
| 1.22–2.76 | 21.84–66.44 | 29.67–108.94 | 37.39–79.89 | 28.02–70.73 | 25.11–51.92 | 20.59–53.14 | 56.43–162.99 | Delhi | Present study |
| 3      | 75       | 100    | 5000 | 2000 | 100 | 50   | 300  | -     | FAO/WHO standards a, b |
| 3–6   | NA     | 135–270 | –   | –   | 75–150 | 250–500 | 300–600 | -     | Indian standards c |

Sources: *Gitet et al., (2016), *Nartey et al., (2012), *Bhatia et al., (2015)
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Figure 2: Heavy metals concentrations at different sampling sites in (a) drain, (b) River and (c) tube well water.

Figure 3: Eight heavy metal concentrations in 10 sampling sites of Delhi NCT.
reported occasional use of drain water for irrigation purpose in some of the agricultural fields. A significant amount of HMs concentration was found in soil along Yamuna River sites (S5–S6). Cu and Pb concentration in surface soil of Najafgarh and Nizamuddin were beyond the permissible limit of FAO i.e. 100 and 50 μg/g, respectively. Other metals concentration in soil falls within the permissible limits as per FAO and Indian standards. The availability of HMs and differences in heavy metal level in soils may be due to quality of irrigation water, physico-chemical properties as well as different sources of contaminations such as quality of sludge and sewage, use of agro-chemicals/ fertilizers, pesticides, kind of industrialization close to the sampling locations, industrial emission and industrial waste, nearness of cultivated field from road/highways and urban areas.

**Conclusion**

Majority of soils and irrigation water of peri-urban areas are found to be contaminated with HMs by various sources such as industrial effluents, dumping sites, sewage and sludge, vehicular emission, human induced pollution and indiscriminate use of chemicals fertilizers. HMs concentration in collected samples from different sources of irrigation water along with soils from Delhi NCT reveals that most of metal concentrations in drain water found beyond the permissible limit of FAO. Continuous use of contaminated water for irrigation observed HMs accumulation in soil, agricultural produce and finally in comes into food chain. Arable contaminated soils may create soil health deterioration and long-term ecological issues. Thus, periodic monitoring of soil and water quality could ensure appropriate and safe usage of irrigation water. Irrigation with drainage water should be restricted in cultivated areas of peri-urban.

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**Conflict of interest**

The authors declare that they have no conflict of interest.

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