Environment Conservation Journal 23 (1&2): 1-7, 2022

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

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

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ARTICLE INFO

Received : 21 August 2021
Revised : 12 October 2021
Accepted : 08 November 2021

Published online: 31 January 2022

Key Words:
Heavy metals contamination
Soil and water in peri-urban areas
NCT Delhi
Irrigation

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 liked 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

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https://doi.org/10.36953/ECJ.021821-2129

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 (HNO_3 and $HClO_4$ in 9:4 ratio) was added in 100 ml of water samples and heated at 80ºC 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 distil 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 80ºC 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.

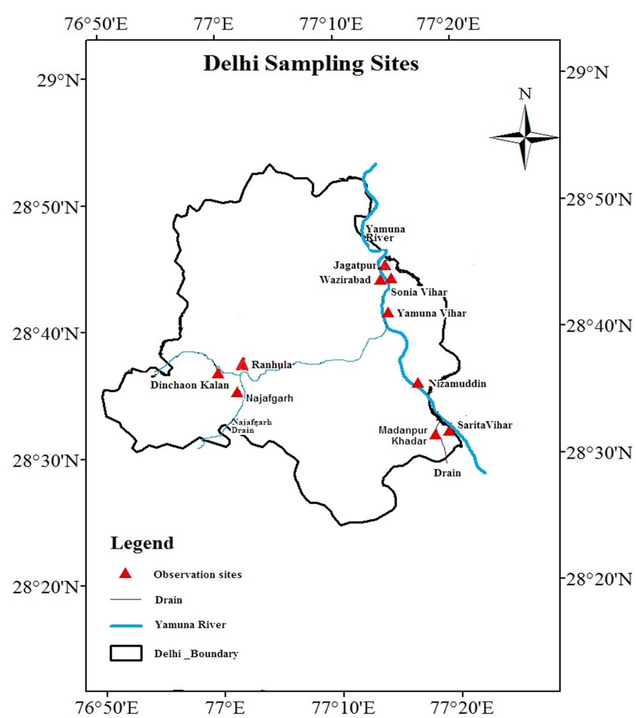

Figure 1: Location map of sampling site in Delhi NCT.

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. However, higher Cu concentration (2590 µg/L) was recorded at Nizamuddin site followed by Najafgarh site. Nizamuddin sites also having industrials belt including Okhla area and carries wastewaters. 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. Yamuna River is ultimately discharge point of all drains of Delhi NCT. The concentrations of Cu, Fe, Mn, Cr, Cd, and Zn in drain water found beyond the permissible limit of FAO, except Fe and Zn concentration at Wazirabad. Pb concentration was within safe limit of FAO at all sampling sites water. Moreover, Cu, Fe, Pb and Zn concentration in river water was within limit of FAO. However, Cd, Cr, Mn and Ni concentration was beyond the permissible limit of FAO.

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 reported 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 Zn (162.99 µg/g) were recorded at Najafgarh site followed by Nizamuddin. However, maximum Fe (79.89 µg/g), Mn (70.73 µg/g) and Ni (53.14 µg/g) concentration were recorded at Nizamuddin followed by Najafgarh. This is probably due to frequent use of Najafgarh and Nizamuddin drains water for irrigation. Moreover, this drain discharges across the industrial sites inflicted with huge effluents, vehicular emission, sewage and sludge, diesel generators and pesticides application in farming. This HMs load is often led to deterioration of soil health as well as contamination of agricultural produce.HMs concentration in soil is mainly depends on soil geogenic property, irrigation water qualities, indiscriminate use of chemical fertilizers and pesticides (Singh *et al.,* 2021). Slightly similar HMs concentration in per-urban soil was observed by Bhatia *et al.* (2015) for Cd (2.28–2.51 µg/g), Pb (21.25- 59.38 µg/g) and Zn (73.25–174.5 µg/g) (Table 2). 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

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	Asim and Rao (2021)
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
10	100	200	5000	200	200	5000	2000	Irrigation water	FAO Safe limit[a]

Source: [a]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: [a]Gitet *et al.,*(2016), [b]Nartey *et al.,*(2012), [c]Bhatia *et al.,*(2015)

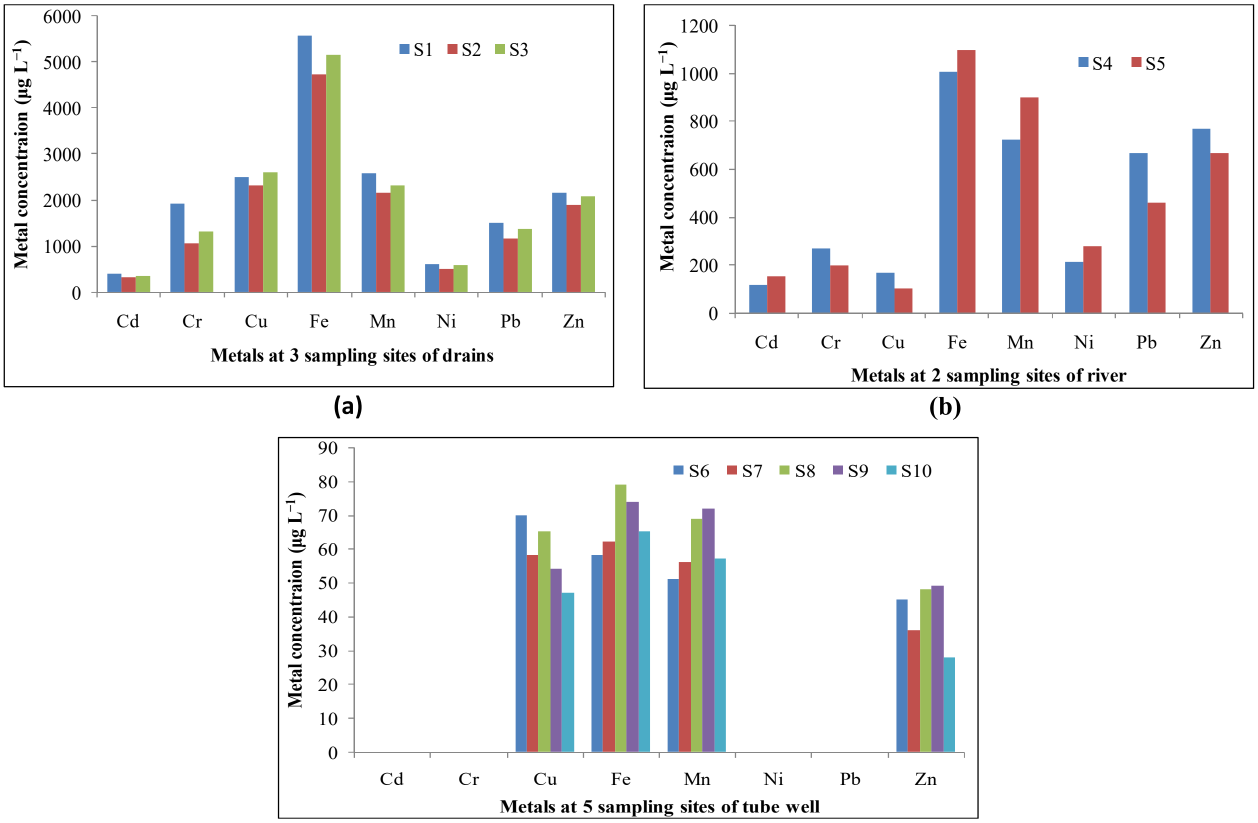

Figure 2: Heavy metals concentrations at different sampling sites in (a) drain, (b) River and (c) tube well water.

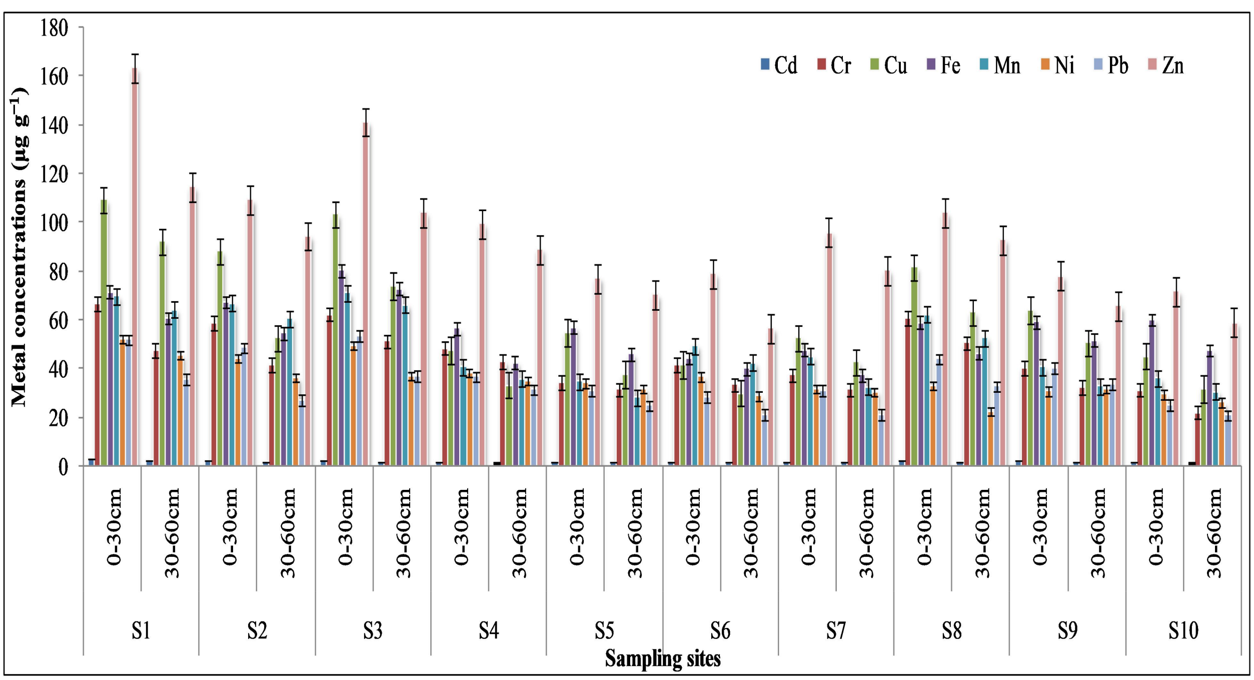

Figure 3: Eight heavy metal concentrations in 10 sampling sites of Delhi NCT.

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.

Acknowledgement

The authors are grateful to National Agricultural Science Fund (NASF, CA-6030), Indian Council of Agricultural Research, New Delhi for providing fund to conduct the research.

Conflict of interest

The authors declare that they have no conflict of interest.

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