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Profile-wise enrichment of metallic pollutants (Pb, Cr and Cd) in various sewage and non-sewage irrigated soils of Prayagraj

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ABSTRACT

The study examined the profile-wise enrichment of metallic pollutants (Pb, Cr and Cd) at different sites, i.e., Naini, Draupadi Ghat, Phaphamau and Beligaon in Prayagraj (U.P.), India. The soil samples were collected from different soil profile depths: 0-15, 15-30, 30-45 and 45-60 cm. It was observed that maximum enrichment of Pb, Cr and Cd was found at the (0-15 cm) depth of sewage and non-sewage irrigated soil (5.12±0.42, 4.08±038 and 3.58±031 mg kg^{-1}) and (1.58±0.09, 1.08±0.09 and 1.02±0.08 mg kg^{-1}) and minimum enrichment was found at the (45-60 cm) depth (2.18, 0.56 and 0.48 mg kg^{-1}) and (0.69±0.04, 0.56±0.04 and 0.47±0.03 mg kg^{-1}) in Naini, respectively. Maximum enrichment of Pb, Cr and Cd was found at the (0-15 cm) depth of sewage and non-sewage irrigated soil (2.44±0.22, 2.19±0.14 and 2.08±0.16 mg kg^{-1}) and (1.09±0.07, 0.97±0.06 and 0.84±0.07 mg kg^{-1}) and minimum enrichment was found at the (45-60 cm) depth (1.01±0.06, 0.98±0.05 and 0.71±0.06 mg kg^{-1}) and (0.19±0.02, 0.15±0.01 and 0.11±0.01 mg kg^{-1}) in Beligaon, respectively. To find the maximum enrichment of heavy metals in Naini and the minimum enrichment in Beligaon. The enrichment of metallic pollution decreased with increasing soil profile depth in both sewage and non-sewage irrigated soils. Metallic contamination in soil can persist for a long time and create serious problems; therefore, proper monitoring of sewage irrigated soils is required to reduce metallic pollution.

Keywords: Enrichment, Sewage irrigated soils, Profile-depths, Metallic pollutants

INTRODUCTION

The world's biggest problem now faces pollution of the environment by heavy metals resulting from untreated industrial waste and sewage irrigation water. These heavy metals are extremely concerning due to their toxicity, persistence, and recalcitrance. The environment, agriculture, human and animal health, and wildlife are all being gravely harmed by metallic pollution (Mohyudin *et al.* 2022). Pollutants of many types, such as heavy metals, herbicides and fertilizers, have contaminated the soil of terrestrial ecosystems (Kumar *et al.* 2012); furthermore, micro-plastics (Iqbal *et al.* 2024). Since they are poisonous, persistent, bioaccumulative and incapable of degrading, metallic contamination is known as pollutants (Jehan *et al.* 2022). According to chemical definitions, any metal or metalloid with an atomic mass more than 20 or five times larger than water molecules and a specific gravity greater than 5 g/cm^3 is considered a heavy metal. Metallic pollution is caused by metallic pollutants that are biologically damaging to vegetation, yet in trace concentrations (Li *et al.* 2019). Metallic pollutants like lead, mercury, cadmium and arsenic, have adverse impacts on plants, even if they are not always dangerous (Ahmad *et al.* 2023).

The main sources of soil pollution in surface waters are solid garbage from cities and industrial effluents. Within industrial regions, industrial effluents from sectors such as metal processing harm the nearby groundwater (Ozyigit *et al.* 2022). Contaminants, both organic and inorganic, including fluoride, heavy metals and salts, result from the production of chemicals and paper (Khan *et al.* 2021a). The higher concentration of heavy metals and organic matter in sewage contaminated soils than non-sewage contamination soils (Usha Rani *et al.* 2015). Global pollution has been steadily increasing since the start of the 20th century due to human activities such as mining, smelting, industrialization, pesticides, chemical fertilizers, disposing of municipal waste and trash burning fossil fuels. As a result of these businesses producing more and more solid, liquid, and gaseous waste every day to fulfill the increasing industrial and agricultural production, they have been driven by the expanding needs

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of the people (Nkoh *et al.* 2022). These are polluting agricultural plants, human health and soil biota equally (Li *et al.* 2023). The Pb accumulation by plants reaches hazardous levels (Singh *et al.* 2015).

Knowledge of the depth-wise distribution of these elements is necessary to comprehend soil contamination and the downward movement of metallic contaminants like lead, chromium, and cadmium. Moreover, numerous plants have roots that extend below the top layer (0-15 cm), which allows them to absorb some of the metallic pollutants deposits from lower levels. Heavy metal distribution in soils fluctuates constantly as a result of both natural and man-made turnover in the rock, soil, and plant systems below 60 cm in the soil profile. These heavy metals have many kinds of connections with various soil components that influence their mobility and position within the soil profile (Adelekan and Alawode, 2011). The enrichment factor (EF) is one way to measure how much human activity has affected soil by heavy metals and is used to determine the normalized enrichment factor (EF) for metal concentrations higher than background levels of contamination (Dickinson et al. 1996). When an enrichment factor value is between 0.5 ≤ and 1.5, it indicates that natural weathering activities are the origin of the increased trace metal concentration (Zhang and Liu, 2002). When the metal enrichment factor is almost one (EF = 1), it means that the element originated from soil (Chiarenzelli *et al.* 2001). Whereas an enrichment factor greater than 1.5 implies that a considerable fraction of trace metals were transported from non-crustal materials (Sutherland, 2000). Anthropogenic pollution is expressed using a five-category rating system. Whereas, EF < 2 denotes low to insignificant contamination, EF = 2-5 denotes medium or moderate contamination, EF = 5-20 denotes high contamination, EF = 20-40 denotes very high contamination, and EF > 40 denotes extremely high contamination (Sutherland *et al.* 2000).

In view of the aforementioned details, the current study's objectives were as follows: (a) to investigate the physico-chemical properties of various sewage-irrigated soils (b) to evaluate the concentration of Pb, Cr, and Cd profile-wise in the sewage-irrigated soils (c) the metallic pollution enrichment factor is present at numerous sites, including Naini, Draupadi Ghat, Phaphamau and Beligaon. This will inform people of the possible health problems associated with heavy metal intake and contribute to environmental protection. The knowledge would also benefit farmers to obtain maximum agricultural production.

MATERIALS AND METHODS

The research was carried out in several locations around Prayagraj: Naini, Draupadi Ghat, Phaphamau and Beligaon. These locations are situated in the humid sub-tropical zone of Indo-Gangetic plain and are elevated above sea level at 90 m. They are situated between longitudes 81º 52'-81º 86' E and latitudes 25º 20'-25º 57' N. Prayagraj has an average annual rainfall of 850-934 mm, relative humidity in the summer is around 42%, and in the monsoon season, it is around 87%, with an average of 66%. Soil samples were collected before sowing crops at various profile depths (0-15, 15-30, 30-45 and 45-60 cm) through the auger soil sampler. The soil samples underwent a 48-hour drying process at 40° C, were crushed, and were analyzed for the heavy metals Pb, Cr, and Cd. A di-acid mixture was used to detect these metals. A known amount (1 g) of oven-dry soil was transferred to a 50-ml beaker, and a di-acid mixture was concentrated with HNO_3 and $HClO_4$ (1:4 v/v) (Kumar and Mani, 2010a). Then the mixture was heated at 105° C for one hour and, after that, increased to 140° C until the sample was completely dry. The mixture was passed through Whatman No. 42 filter papers and analyzed for Pb, Cr, and Cd using an Atomic Absorption Spectrophotometer. The soil pH was determined using 10 g of soil and 25 ml of water (1:2.5 soil:water ratio) using a digital pH meter. To estimate organic carbon in soil samples, one g of finely powdered soil is digested with sulphuric acid and potassium dichromate. Diluted with distilled water, orthophosphoric acid and diphenylamine indicator, the solution takes on a violet hue and undergoes titration with ferrous ammonium sulphate (N/2), transforming into purple and green (Chopra and Kanwar, 1999). The CEC was measured using a neutral 1N ammonium acetate solution, followed by mixing 5g of soil with 25 ml of the solution and shaking for five minutes, then filtering using Whatman No. 42 filter paper. The soil was digested using a mixture of selenium dioxide, sulfuric acid, and nitrates, and the micro-Kjeldahl technique was used to determine the nitrogen content in the soil sample. The study involved combining the soil sample with 70% $HClO_4$, heating to a white point, mixing with HNO_3, and adding 30 ml of ammonium molybdate standard solution to determine the total concentration of (P) phosphorus in the soil (Kumar and Mani, 2010b). The enrichment factor measures soil pollution by comparing the accumulation of metallic pollutants in sewage soil to non-sewage soils. It is calculated that EF = (mean metal content in the contaminated sample) / (mean metal content in the uncontaminated sample) (Loska et al. 1997).

STATISTICAL ANALYSIS

Every value is represented by ±, which is the standard error (SE) for three replications. The software GraphPad Prism (version 10) has been used to draw the figures.

RESULTS AND DISCUSSION

Physico-chemical properties

Various sewage irrigated soil samples received a physico-chemical investigation, which is recorded and shown in Table 1. The percentages of sand, silt, and clay at Naini, Draupadi Ghat, Phaphamau, and Beligaon were found to be different: (66.40±4.52, 18.32±2.16, and 15.28±1.84), (44.50±4.38, 38.30±1.46 and 17.20±1.46), (69.42±5.12, 17.19±1.72 and 13.39±1.26) and (32.28±3.18, 13.58±1.52 and 54.14±2.38%), respectively. Phaphamau has the highest percentage of sand, whereas Beligaon has the highest percentage of clay. The soil pH varies with locations Beligaon has the greatest pH, 7.8±0.92, while Draupadi Ghat has the lowest pH, 6.4±0.64. The EC values at various places range from 0.36±0.02 to 0.44±0.03 dSm^{-1}, the highest EC is found on Draupadi Ghat, while the lowest EC is found on Phaphamau. The CEC ranges from 11.16±2.18 to 16.19±2.07 cmol. (p+) kg^{-1}) at Draupadi Ghat has a minimum and Phaphamau has a maximum. The OC ranges from (0.46±0.03 to 0.68±0.05%) at Beligaon, which has the highest, whereas Draupadi Ghat has the lowest. The maximum total nitrogen at Beligaon was 0.52±0.04%, while the minimum was 0.38±0.02% at Naini. The maximum available nitrogen was measured at 178.39±4.83 kg ha^{-1} in Beligaon, while the minimum was measured at 156.46±2.74 kg ha^{-1} in Phaphamau. Phaphamau has a maximum available P_2O_5 of 39.48±2.76 kg ha^{-1}, while Draupadi Ghat has a minimum of 26.18±3.11 kg ha^{-1}. The total K_2O maximum was 468.84±3.88 kg ha^{-1} at Phaphamu, while at Naini minimum, it was 418.24±4.92 kg ha^{-1}, and we also found similar results that are associated with the present study (Annu and Garg, 2015).

Table 1: To investigate the physico-chemical properties of various sewage irrigated soils

Parameters	Units	Naini	Draupadi Ghat	Phaphamau	Beligaon
Sand	(%)	66.40±4.52	44.50±4.38	69.42±5.12	32.28±3.18
Silt	(%)	18.32±2.16	38.30±1.46	17.19±1.72	13.58±1.52
Clay	(%)	15.28±1.84	17.20±1.46	13.39±1.26	54.14±2.38
pH	_	7.6±0.78	6.4±0.64	7.5±0.81	7.8±0.92
Organic Carbon	(%)	0.49±0.05	0.46±0.03	0.52±0.04	0.68±0.05
EC	(dSm^{-1} at 25°C)	0.38±0.02	0.44±0.03	0.36±0.02	0.42±0.04
CEC	cmol (p+)kg^{-1}	14.38±2.34	11.16±2.18	16.19±2.07	13.46±2.88
Total Nitrogen	(%)	0.38±0.02	0.41±0.02	0.46±0.03	0.52±0.04
Available N	(kg ha^{-1})	172.14±3.18	166.32±2.98	156.46±2.74	178.39±4.83
Total P_2O_5	(%)	0.16±0.01	0.19±0.02	0.26±0.03	0.22±0.02
Available P_2O_5	(kg ha^{-1})	34.28±3.42	26.18±3.11	39.48±2.76	37.76±2.54
Available K_2O	(kg ha^{-1})	418.24±4.92	443.38±5.44	468.84±3.88	439.96±2.96

Note: *that every value is represented by ±, which is the standard error (SE) for three replications, CEC stands for Cation Exchange Capacity, and EC refers to Electrical Conductivity*

Results and discussion of heavy metals

The current research was conducted to examine at four locations (Naini, Draupadi Ghat, Phaphamau and Beligaon) the different metal concentrations of soil on the accumulation of metallic pollutants (Cd, Pb and Cr) in sewage and non-sewage irrigated soil profiles. We evaluated the heavy metal (Cd, Pb and Cr) distribution at various depths (0-15, 15-30, 30-45, and 45-60 cm.) in sewage and non-sewage irrigated soils. The Cd, Pb and Cr concentrations decrease with the increasing depth of soil profiles at different sites.

Concentration of Pb in sewage irrigated soils

At different depths, the Pb concentration in sewage irrigated soils ranged from 1.71±0.12 to 5.12±0.42 mg kg^{-1}, as shown in Table 2 and Fig. 1. The sewage irrigated soils of Draupadi Ghat (1.09±0.08 to 4.16±0.38 mg kg^{-1}), Phaphamau (1.06±0.08 to 3.22±0.24 mg kg^{-1}) and Beligaon (1.01±0.12 to 2.44±0.22 mg kg^{-1}) have the lowest concentrations of Pb at various depths, while the sewage irrigated soils of Naini profiles have the highest Pb concentrations (02.18±0.16 to 5.12±0.42 mg kg^{-1}). At different depths, the Pb concentration in sewage irrigated soils ranged from 1.71±0.12 to 5.12±0.42 mg kg^{-1}, as shown in Table 3 and Fig. 2. The sewage irrigated soils of Draupadi Ghat (1.09±0.08 to 4.16±0.38 mg kg^{-1}), Phaphamau (1.06±0.08 to 3.22±0.24 mg kg^{-1}) and Beligaon (1.01±0.12 to 2.44±0.22 mg kg^{-1}) have the lowest concentrations of Pb at various depths, while the sewage irrigated soils of Naini profiles have the highest Pb concentrations (02.18±0.16 to 5.12±0.42 mg kg^{-1}). Lead buildup is due to increased soil pollutants, possibly from vehicle exhausts. According to this study, these characteristics have a major impact on Pb concentration. In particular, EC and organic carbon are key factors in Pb accumulation in sewage irrigated soils. In lower horizons, there was comparatively less available lead because of the lower horizons (Aubert and Pinta, 1977). The adsorption of lead by organic matter, clay, etc. may have prevented lead from reaching sub-surface soil profiles when lead and organic matter combined to generate an insoluble mixture (Garg and Totawat, 2005). There is a significant relative concentration of heavy metals in these soils because of the rapid weathering of carbonate minerals (Nowack et al. 2001).

Table 2: The profile-wise distribution of Pb (mg kg^{-1}) in sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	5.12±0.42	4.16±0.38	3.22±0.24	2.44±0.22
15-30	4.36±0.37	3.46±0.31	2.74±0.12	1.98±0.14
30-45	3.04±0.26	2.38±0.28	1.66±0.09	1.42±0.09
45-60	2.18±0.16	1.09±0.08	1.06±0.08	1.01±0.06
Mean	3.67±0.30	2.77±0.26	2.17±0.13	1.71±0.12

Note: that every value is represented by ±, which is the standard error (SE) for three replications

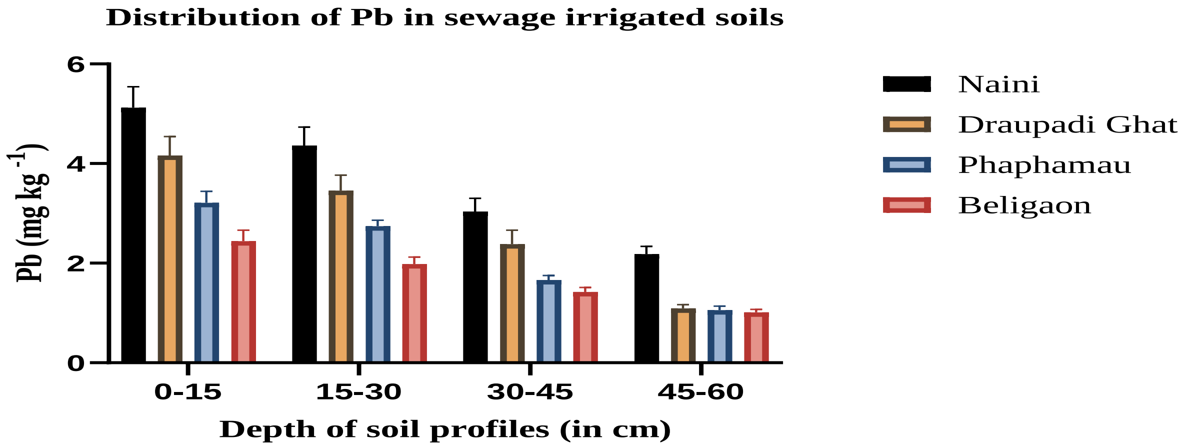

Fig. 1: Distribution of Pb in sewage irrigated soils

Concentration of Pb in non-sewage irrigated soils

At different depths, the Pb concentration in non-sewage irrigated soils ranged from 0.59±0.04 to 1.58±0.09 mg kg^{-1}, as shown in Table 3 and Fig. 2. The non-sewage irrigated soils of Draupadi Ghat (0.28±0.03 to 1.42±0.08 mg kg^{-1}), Phaphamau (0.26±0.02 to 1.22±0.09 mg kg^{-1}), and Beligaon (0.19±0.02 to 1.09±0.07 mg kg^{-1}) have the lowest concentrations of Pb at various depths, while the non-sewage irrigated soils of Naini profiles have the highest Pb concentrations (0.69±0.04 to 1.58±0.09 mg kg^{-1}). In non-sewage irrigation water, the mean concentration of Pb was many times lower than in sewage irrigation water. Sharma and Shukla (2013) have also reported that physicochemical analysis of waste water and soil samples have heavy load of metals resulting into continuous addition to the agricultural fields.

Table 3: The profile-wise distribution of Pb (mg kg^{-1}) in non-sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	1.58±0.09	1.42±0.08	1.22±0.09	1.09±0.07
15-30	1.01±0.07	0.98±0.08	0.92±0.07	0.88±0.06
30-45	0.86±0.08	0.44±0.03	0.36±0.02	0.23±0.03
45-60	0.69±0.04	0.28±0.03	0.26±0.02	0.19±0.02
Mean	1.03±0.07	0.78±0.05	0.69±0.05	0.59±0.04

Note: that every value is represented by ±, which is the standard error (SE) for three replications

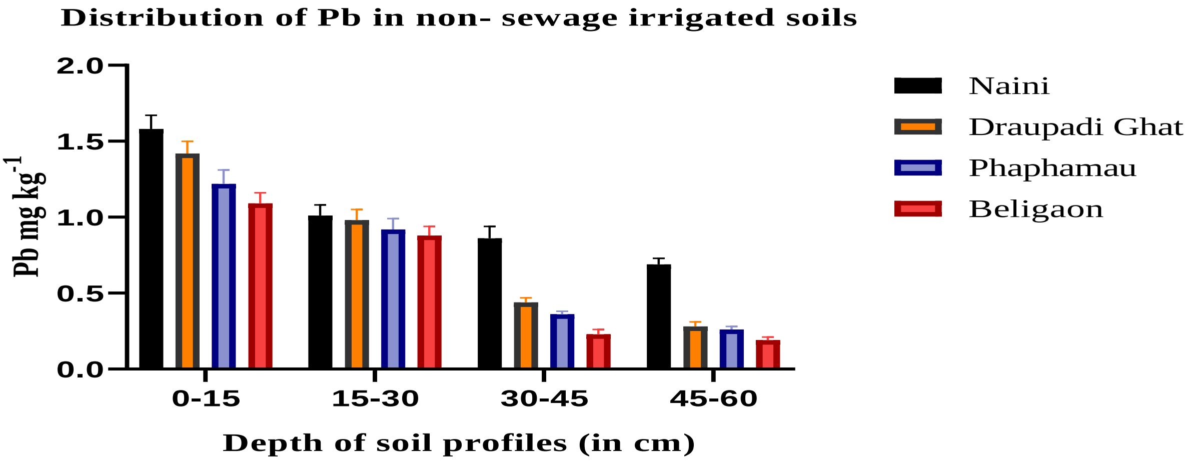

Fig. 2: Distribution of Pb in non sewage irrigated soils

Concentration of Cr in sewage irrigated soils

At different depths, the Cr concentration in sewage irrigated soils ranged from 1.61±0.33 to 4.08±0.38 mg kg^{-1}, as shown in Table 4 and Fig. 3. The sewage irrigated soils of Draupadi Ghat (1.54±0.09 to 3.29±0.28 mg kg^{-1}), Phaphamau (1.41±0.08 to 2.99±0.32 mg kg^{-1}), and Beligaon (0.98±0.05 to 2.19±0.14 mg kg^{-1}) have the lowest concentrations of Cr at various depths, while the sewage irrigated soils of Naini profiles have the highest Cr concentrations (1.88±0.09 to 4.08±0.38 mg kg^{-1}). Chromium levels increase in soil is due to various sectors like electroplating, leather processing, steel production, tanning, and textile coloring. The study showed that certain soil characteristics, particularly EC and organic matter, which were crucial to Cr accumulation in sewage irrigated soils, have a highly substantial impact on Cr concentration. The tendency for Cr concentration in the surface layer is shown by the greater concentration of Cr in the top soil layer than the lower soil surface, according to Ghafoor et al. (2005).

Table 4: The profile-wise distribution of Cr (mg kg^{-1}) in sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	4.08±0.38	3.29±0.28	2.99±0.32	2.19±0.14
15-30	3.32±0.24	2.84±0.24	2.72±0.14	1.94±0.08
30-45	2.43±0.18	1.98±0.12	1.82±0.09	1.33±0.06
45-60	1.88±0.09	1.54±0.09	1.41±0.08	0.98±0.05
Mean	2.91±0.89	2.41±0.73	2.23±0.63	1.61±0.33

Note: that every value is represented by ±, which is the standard error (SE) for three replications

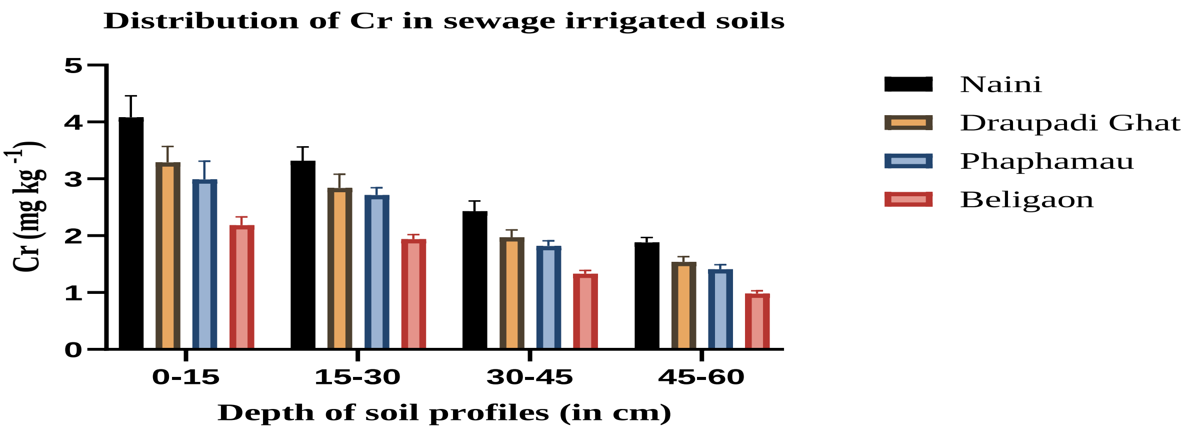

Fig. 3: Distribution of Cr in sewage irrigated soils

Concentration of Cr in non-sewage irrigated soils

At different depths, the Cr concentration in non-sewage irrigated soils ranged from 0.49±0.13 to 1.08±0.09 mg kg^{-1}, as shown in Table 5 and Fig. 4. The sewage irrigated soils of Draupadi Ghat (0.65±0.13 to 1.05±0.06 mg kg^{-1}), Phaphamau (0.18±0.02 to 1.02±0.07 mg kg^{-1}), and Beligaon (0.15±0.01 to 0.97±0.06 mg kg^{-1}) have the lowest concentrations of Cr at various depths, while the non-sewage irrigated soils of Naini profiles have the highest Cr concentrations (0.56±0.04 to 1.08±0.09 mg kg^{-1}). A decrease in depth is connected with a reduction in the organic carbon content and a rise in pH, resulting in a lower metal concentration. This is consistent with the findings by Sharma *et al.* (2006).

Table 5: The profile-wise distribution of Cr (mg kg^{-1}) in non-sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	1.08±0.09	1.05±0.06	1.02±0.07	0.97±0.06
15-30	0.97±0.08	0.93±0.04	0.82±0.06	0.72±0.04
30-45	0.67±0.06	0.38±0.02	0.24±0.03	0.19±0.02
45-60	0.56±0.04	0.24±0.01	0.18±0.02	0.15±0.01
Mean	0.82±0.27	0.65±0.13	0.56±0.18	0.49±0.13

Note: that every value is represented by ±, which is the standard error (SE) for three replications

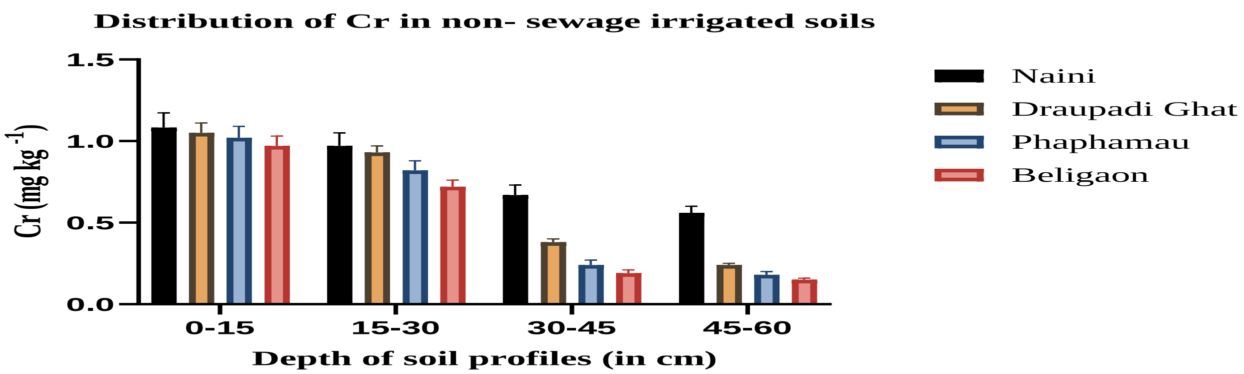

Fig. 4: Distribution of Cr in non-sewage irrigated soils

Concentration of Cd in sewage irrigated soils

At different depths, the Cd concentration in sewage irrigated soils ranged from 1.47±0.44 to 3.58±0.31 mg kg^{-1}, as shown in Table 6 and Fig. 5. The sewage irrigated soils of Draupadi Ghat (1.13±0.12 to 3.12±0.28 mg kg^{-1}), Phaphamau (1.04±0.09 to 2.75±0.26 mg kg^{-1}), and Beligaon (0.71±0.06 to 2.08±0.16 mg kg^{-1}) have the lowest concentration of Cd at various depths, while the sewage irrigated soils of Naini profiles have the highest Cd concentrations (1.21±0.08 to 3.58±0.31 mg kg^{-1}). The content of

Cd in sewage irrigation water was significantly higher nearer to the discharge site and progressively dropped farther away. Different organic sources were present in sewage irrigation water, which contributed to the rise in Cd concentration. Khan *et al.* (2021b) also reported that water in areas near the source of effluent discharge was more contaminated as compared to areas away from the sources.

Table 6: The profile-wise distribution of Cd (mg kg^{-1}) in sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	3.58±0.31	3.12±0.28	2.75±0.26	2.08±0.16
15-30	2.84±0.26	2.78±0.23	2.62±0.18	1.88±0.13
30-45	1.92±0.17	1.66±0.09	1.51±0.12	1.21±0.09
45-60	1.21±0.08	1.13±0.12	1.04±0.09	0.71±0.06
Mean	2.38±0.82	2.17±0.6	1.98±0.65	1.47±0.44

Note: that every value is represented by ±, which is the standard error (SE) for three replications

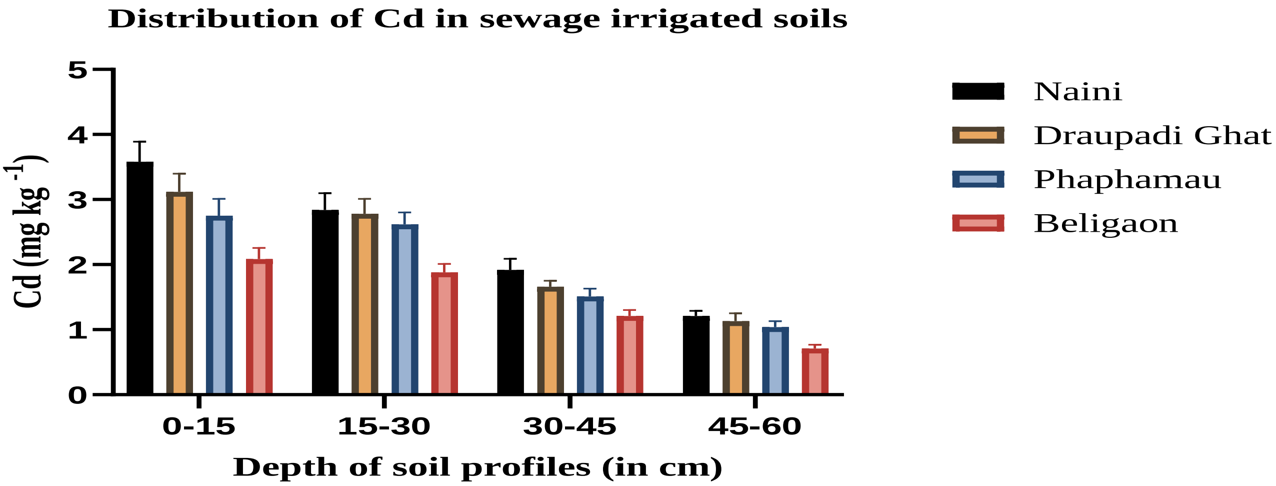

Fig. 5: Distribution of Cd in sewage irrigated soils

Concentration of Cd in non-sewage irrigated soils

At different depths, the Cd concentration in non-sewage irrigated soils ranged from 0.44±0.16 to 1.02±0.08 mg kg^{-1}, as shown in Table 7 and Fig. 6. The sewage irrigated soils of Draupadi Ghat (0.18±0.02 to 1.01±0.06 mg kg^{-1}), Phaphamau (0.14±0.01 to 0.96±0.08 mg kg^{-1}), and Beligaon (0.11±0.01 to 0.84±0.07 mg kg^{-1}) have the lowest concentrations of Cd at various depths, while the non-sewage irrigated soils of Naini profiles have the highest Cd concentrations (0.47±0.03 to 1.02±0.08 mg kg^{-1}). The accumulation of Cd in non-sewage irrigation water is lower than that in sewage irrigation water due to the continuous use of non-sewage irrigation water for more than one decade, and the site nearest to the sewage discharge point contained an appreciably high amount of Cd and gradually decreased as the distance from the discharge point increased. Khurana *et al.* (2004) also reported a higher concentration of heavy metals in sewage irrigated water than non-sewage irrigated water.

Table 7: The profile-wise distribution of Cd (mg kg^{-1}) in non-sewage irrigated soils

Depth of soil profiles in (cm)	Naini	Draupadi Ghat	Phaphamau	Beligaon
0-15	1.02±0.08	1.01±0.06	0.96±0.08	0.84±0.07
15-30	0.91±0.07	0.87±0.05	0.77±0.05	0.68±0.06
30-45	0.52±0.05	0.31±0.03	0.19±0.02	0.15±0.02
45-60	0.47±0.03	0.18±0.02	0.14±0.01	0.11±0.01
Mean	0.73±0.23	0.59±0.16	0.51±0.16	0.44±0.16

***Note:** that every value is represented by ±, which is the standard error (SE) for three replications*

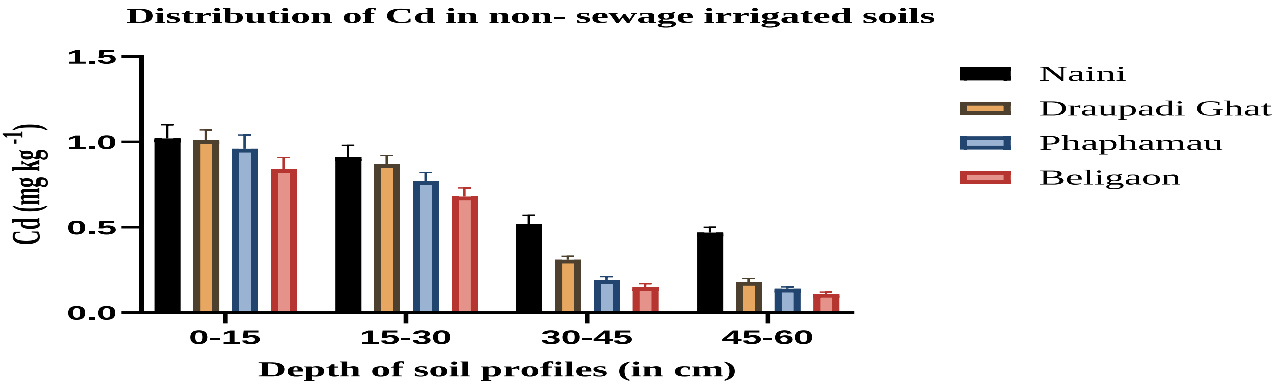

Fig. 6: Distribution of Cd in non-sewage irrigated soils

The enrichment factor of heavy metals in the various sewage irrigated soils

At the Naini sewage irrigated site, the enrichment factor values of Pb (3.55±11) and Cr (3.54±13) are nearly equal, but Cd (3.22±13) has the lowest enrichment factor compared to Pb and Cr. At the Droupadi Ghat, metal enrichment factor are listed in decreasing order: Cr (4.75±07) > Pb (4.45±11) > Cd (3.88±09). At the Phaphamu, Cr (5.41±06) and Cd (5.40±08) are nearly equal, but Pb (3.57±08) has a minimum EF compared to Cr and Cd. Furthermore, Beligaon has a maximum EF of Cd (4.93±10) and a minimum EF of Pb (3.99±09), as shown in Fig. 7. There are three heavy metals Pb, Cr and Cd in the sewage-irrigated soils that were detected. Based on the ranking category, all the data between 2- 5 belong to the moderate group of sites in the enrichment factor. Agriculture practices and domestic sewage are two major factors that impact the maximum enrichment factor and as a result, the heavy metal enrichment in the experimental sites. This might be due to the fact that the heavy metals concentration in sewage effluents emanating from different sources is manifolds higher than non-sewage. As the distance from the sewage discharge site increased and the profiles decreased, a gradual decrease in its concentration was observed. The findings also showed that the discharge of sewage irrigation water and sludge, primarily in the surface layer with minimal mobility down the profile, was contributing to the enrichment of Pb, Cr, and Cd. Datta *et al.* (2000) reported that the soils of the IARI farm receiving sewage irrigation water of mostly domestic origin for more than three decades have only marginally increased the enrichment of heavy metals.

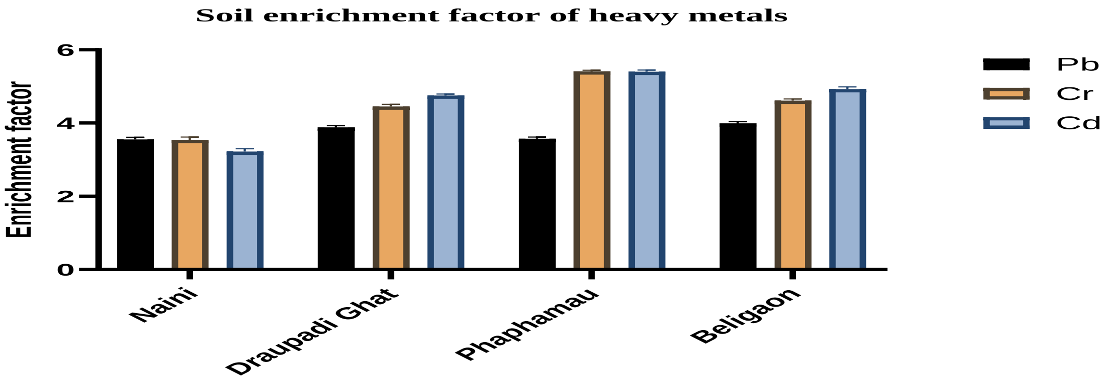

Fig. 7: Heavy metals enrichment factor of sewage irrigated sites

CONCLUSION

Soil contamination has become a major issue due to the continued use of sewage irrigation water at four different locations in Prayagraj with various soil profile depths (0-15, 15-30, 30-45 and 45-60 cm), the concentrations of metallic pollutants Pb, Cr and Cd were considerably greater in sewage irrigated soils than non-sewage irrigated soils. Soils that were watered by sewage had amounts of heavy metals that exceeded allowed levels. Heavy metal concentrations in both sewage and non-sewage-irrigated soils are higher at the surface and sharply decline with depth. Out of the four sites, the soil at Naini was the most contaminated. However, the findings of this study indicate that the accumulation of heavy metals in surface and subsurface soils may be encouraged by the prolonged and careless use of sewage irrigation water containing heavy metals. The presence of metallic pollutants in the soil profile can be hazardous for plants as well as for people who eat the harvested crops. Increasing the amount of metallic pollution in the soil causes plants to absorb more of them, which is harmful to both human and animal health. Therefore, using phytoremediation technology or expanding the capacity of municipal sewage treatment plants before diverting sewage water for agriculture is allowed.

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