Analysis of Heavy metals (Nickel, Chromium, Cobalt, Cadmium, Lead) in Wheat and Rice grown in agriculture soil

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Abstract: The objective of present study is to evaluate how the five heavy metals nickel, chromium, cobalt, cadmium, and lead are move from soil to rice and wheat, two important Indian crops in terms of nutrition, grown in agriculture soil. Between April and November 2021, soil samples from the research region were taken. With the aid of a flame atomic absorption spectrophotometer, the presence of heavy metals in the soil was discovered. The agricultural soil's mean concentration of heavy metals (mg kg-1) was distributed in the following order: Ni (9.34 ± 0.348) > Pb (8.50 ± 0.42) > Co (7.43 ± 0.28) > Cd (4.07 ± 0.186) > Cr (0.135 ± 0.028) respectively. According to Indian norms, the average level of all examined heavy metals in agricultural soil was below allowable levels.

Keywords: Heavy metals, Atomic Absorption Spectrophotometer, Agricultural Soil, Wheat, Rice

Introduction: The immediate earth surface's soil is an unconsolidated inorganic and organic material that acts as a natural environment for plant growth and other developmental processes[1]. To achieve their requirements, humans occasionally engage in behaviours that have an adverse effect on the environment. These effects may be favourable or unfavourable. The reduction in environmental quality brought on by human activity includes things like the loss of soil quality brought on by waste pollution from residential, commercial, and agricultural operations. Heavy metals are one of the main pollutants or contaminants for soil. Due to the intimate connection between soil and agriculture, these toxins seep into the soil and have a toxicological impact [2].

Naturally occurring heavy metals can be found in soils, which are produced by geological processes such erosion and alteration of subsurface geological elements[3,4]. The potential of excessive heavy metals contaminating soils is also present due to air deposition, the use of herbicides, and the use of fertilisers that have high metal content [5]. Because they are enduring environmental contaminants, heavy metals are poisonous [6,7]. Although their chemical forms may alter, heavy metals are neither eliminated nor reduced, which is a major cause for concern. Recent years have seen a significant increase in the global problem of heavy metal-mediated environmental contamination [8]. The simplest method of exposing people to metals is through soil pollution [9]. Heavy metals that can accumulate in human tissues and cause serious health risks can be found in fruits, cereals, and vegetables grown in contaminated soil [10,11]. The amount of heavy metals that accumulate in crops depends on a variety of factors, including the type of plant, the characteristics of the soil, the selectivity of the crops, and the permissibility of the metals [12, 13]. The term "accumulation factor" is used to define the heavy metal pollution in soil with regard to plants [14,15]. The public is worried about exposure to metals through the digestion of contaminated food crops due to the presence of heavy metals in the soil in industrial locations. The most important human exposure way may be through dietary consumption, however breathing is another exposure method [16,17]. Heavy metals can cause serious health problems even when taken in very small amounts [18]. When essential metals like Cu and Zn exceed their safe limits, they can bioaccumulate in both animal and human bodies and create major health issues [19,20]. After consuming contaminated meals, the body loses several crucial nutrients, which has major health consequences [21]. Heavy metal pollution of crops is a significant problem worldwide [22]. The soil provides plants with a variety of essential nutrients, such as N, P, and K, as well as extra harmful metals, as some plants have a tendency to accumulate excessive levels of heavy metals [23]. Heavy metals can travel from the soil to crops through the roots or shoots of plants [24]. The hazardous elements Pb, Cd, and As that are present in the soil are absorbed and stored by cereal grains [25]. Due to their propensity to migrate from soil to crops, heavy metals' bioaccumulation patterns are biased [26]. The human diet includes weighty amounts of rice and wheat [27]. These plants consumers all over the world can get vitamins, minerals, and amino acids from rice [28]. The prevalence of dangerous metals in arable lands and their transfer to crops like rice are major concerns right now [29]. Crops grown in contaminated soil can accumulate significant levels of heavy metals in their tissues [30,31]. In light of the aforementioned factors, this study was carried out to look at levels of a number of heavy metals in the agricultural soil of the investigated area.

Material and methodology

Study area: For the process of soil and crop sampling, area of a field is selected from Bhiwani district, The normal annual rainfall of the district is 420 mm village. The Indian state of Haryana contains the Bhiwani district. Bhiwani serves as the administrative centre for the Bhiwani District. It is situated 261 kilometres north of Chandigarh, the state capital. The population of Bhiwani District is 1629109. By population, it is the third-largest District in the State.

Soil sampling and Analysis

A total of 40 soil samples were taken across various sampling seasons to assess the content of heavy metals in the soil. To provide a representative sample, four sub-samples of soil were taken from a rectangular grid with a surface area of 0.5 m2 and dug to a depth of 5–10 cm. After eliminating foreign bodies, samples were placed in clean plastic bags and sealed. In preparation for future investigation, soil samples were air dried, pulverised, and then sieved with a 2.0 mm mesh before being kept in airtight containers.

A 5.0 ml (HNO_3 and $HClO_4$) diacid mixture was combined with 0.5g of each soil sample. The sample mixture was then put into Teflon containers that had already been cleaned, left outside for a whole night at room temperature, and then digested in a microwave digester (CEM MarsX, USA). Each digestion setup's operating programme for the microwave digestion system was optimised at 800W of power and 170 °C of maximum operable temperature. When digestion was finished, the vessels were quantitatively transferred into glass beakers and allowed to cool to room temperature. The digests were then heated to between 130 and 150 °C, evaporated to dryness, and the residue was dissolved in double-distilled water to create the required volume (50 ml). After being transferred to polypropylene bottles, extracted solutions were stored in the refrigerator until analysis. Atomic absorption spectrophotometer measurements were made to determine the total amounts of Cd, Ni, Cr, Co, and Pb in soil samples. An oxidising flame was employed to detect all of the chosen heavy metals, however a reducing nitrous oxide flame was used to detect chromium.

Heavy Metal Transfer Factor from Soil to Agricultural Crop Samples

Transfer factors (TF) were determined in order to gauge how well edible agricultural samples absorbed heavy metals. It is calculated as the ratio of the heavy metal concentration in the edible component of agricultural samples to the soil concentration in question (Singh et al., 2014).

$$TF\ Edible = \frac{Ccrop}{Csoil}$$

Where, on a dry weight (DW) basis, Ccrop and Csoil represent the concentrations of heavy metals in the edible portions of agricultural samples (grain, fodder, and vegetables), respectively.

Results and discussion

Heavy metal content in agricultural soil of wheat crop

With a global production of 659.1 million tonnes in 2012–2013, wheat (Triticum aestivum L.) is the most significant crop in terms of basic food commodities, followed by rice and coarse grains (FAO, 2013). The assortment of calculated heavy metal content in wheat fields soil collected in April-May, 2021 was as follows; Ni) 8 - 9 mg kg^{-1} , (Pb) 8 - 9 mg kg^{-1} , (Co) 6 - 7 mg kg^{-1} , (Cr) 0.1 - 0.2 mg kg-1 and (Cd) 3.0 – 4.5 mg kg-1 (Table 1) with mean value of heavy metal content (mg kg-1) was in the following order: Ni (9.34 ± 0.348) > Pb (8.50 ± 0.42) > Co (7.43 ± 0.28) > Cd (4.07 ± 0.186) > Cr (0.135 ± 0.028) (Table 1). The results of the current study showed that agricultural soil had highest content of Ni and lowest content of Cr. Moreover, all the studied heavy metals were within permissible limits of Indian standards (Awashthi, 2000).

Table 1: Range and mean of heavy metals in agricultural soil in Triticum aestivum

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	8.900	8.017	3.821	0.109	7.971
Max.	8.937	8.992	4.414	0.120	6.102
Mean ± SD	9.349±0.348	8.507±0.420	4.078±0.186	0.135±0.028	7.437±0.286

Heavy metal content in wheat grains

Wheat grain samples from ten sampling stations from the study area were collected during wheat harvesting season. All the collected samples were analyzed for Pb, Ni, Cd, Cr and Co content. Heavy metals in the samples of wheat grains collected during April - May, 2021 was: (Pb) 0.011 - 0.083 mg kg-1 , (Ni) 0.065 - 0.097 mg kg-1 , (Cd) 0.010 - 0.019 mg kg-1 , (Co) 0.011 - 0.034 mg kg-1 and Cr was not measurable. The following was the order of the mean value of heavy metal content (mg kg-1) in wheat grains: Ni (0.86 ± 0.016) > Pb (0.329 ± 0.21) > Co (0.251 ± 0.007) > Cd (0.016 ± 0.0032) > Cr (0.00) (Table 2). It is clear from the results that the content of Ni was highest and content of Cr was lowest in the studied wheat grain samples.

Table 2: Concentration of heavy metals in fruit of Triticum aestivum

S. No.	Heavy Metals	Mean
1	Ni	0.086±0.016
2	Pb	0.032±0.021
3	Cd	0.016±0.003
4	Cr	00
5	Co	0.025±0.007

Heavy metal transfer rate from soil to wheat grains

Transfer factor of heavy metal from soil to wheat grains samples collected in April - May, 2021 was: Cr (0.00 - 0.00), Pb (0.005 - 0.039), Cd (0.002 - 0.003), Ni (0.00 - 0.01) and Co (0.001 - 0.004) with mean value was as follows: Ni (0.007 ± 0.001) > Pb (0.003 ± 0.00) = Cd (0.003 ± 0.00) > Co (0.002 ± 0.001)> Cr (0.00 ± 0.00) (Table 8 and Fig. 17 - 20). It is clear from the results that highest transfer factor of Nickel and lowest of Chromium was observed in all the studied samples of wheat grains.

Table 3: Transfer factor for metals in Triticum aestivum

S. No.	Heavy Metals	Mean
1	Ni	0.007±0.001
2	Pb	0.003±0.002
3	Cd	0.003±0.000
4	Cr	00
5	Co	0.002±0.009

Heavy metal content in agricultural soil of rice crop

Over 90% of the world's 7 billion people eat rice as a staple food, and Asia accounts for roughly half of this consumption. Only China, Taiwan, and India account for about 55% of the world's total rice production (IRRI, 2013). The following heavy metal concentrations were found in rice field agricultural soil between October and November 2021: The mean value of heavy metal content (mg kg-1) in the agricultural soil was as follows: (Co) 4.3 - 5.9 mg kg-1, (Cd) 0.15 - 0.45 mg kg-1, (Ni) 7.8 - 8.9 mg kg-1, (Pb) 6.0 - 6.9 mg kg-1, and (Cr) 0.12 - 0.18 mg kg-1. Mean value was in order of : Ni (8.310 ± 0.348) > Pb (6.404 ± 0.338) > Co (5.284 ± 0.495) > Cd (3.542 ± 0.309) > Cr (0.164 ± 0.020) respectively (table 4).

Table 4: Range and mean of heavy metals in agricultural soil in Oryza sativa

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	7.832	6.004	3.113	0.123	4.389
Max.	8.987	6.983	3.987	0.189	5.999
Mean ± SD	8.310±0.348	6.404±0.338	3.542±0.309	0.164±0.020	5.284±0.495

Heavy metal content in grain of rice crop

Rice crop samples from ten sampling stations from the study area were collected during harvesting season. All the collected samples were analysed for Pb, Ni, Cd, Cr and Co content. Heavy metals in the samples of rice collected during October-November , 2021 was: (Pb) 0.009 - 0.027 mg kg^{-1}, (Ni) 0.014 - 0.075 mg kg^{-1}, (Co) 0.006 - 0.012 mg kg^{-1}, (Cd) 0.001 - 0.008 mg kg-1 and Cr was not measurable. Mean value of these heavy metals (mg kg^{-1}) in rice grain samples collected was in the following order: Ni (0.057 ± 0.017) > Pb (0.018 ± 0.006) > Co (0.009 ± 0.001) > Cd (0.003 ± 0.002) > Cr (0.00) (Table 5). It is clear from the results that the amount of Pb was highest and concentration of Cr was lowest in the above studied crop sample.

Table 5: Concentration of heavy metals in fruit of Oryza sativa

S. No.	Heavy Metals	Mean
1	Ni	0.057±0.017
2	Pb	0.018±0.006
3	Co	0.009±0.001
4	Cr	00
5	Cd	0.003±0.002

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Transfer factor of heavy metal from soil to rice grain
Transfer factor of heavy metal from soil to fruit of crop samples collected in October- November, 2021 was: Cr (0.00 - 0.00), Pb (8.488 - 9.604), Cd (0.003 - 0.006), Ni (0.001 - 0.002) and Co (0.002 - 0.009) with mean value was as follows: Cd (0.009 ± 0.005) > Ni (0.006 ± 0.002) > Pb(0.002 ± 0.001) > Co (0.003 ± 0.001) > Cr (0.00 ± 0.00) (Table 6). It is clear from the results that highest transfer factor of Lead and lowest with nil value of Chromium was observed in all the studied samples of rice grains.

Table 6: Transfer factor for metals in Oryza sativa

S. No.	Heavy Metals	Mean
1	Ni	0.006±0.002
2	Pb	0.002±0.001
3	Cd	0.009±0.005
4	Cr	0
5	Co	0.003±0.001

Refrences:

1. Korner, C. H. (1991). Some often overlooked plant characteristics as determinants of plant growth: a reconsideration. Functional ecology, 162-173.
2. Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M. Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. Toxics, 9(3), 42.
3. Moor, C., Lymberopoulou, T., & Dietrich, V. J. (2001). Determination of heavy metals in soils, sediments and geological materials by ICP-AES and ICP-MS. Microchimica Acta, 136, 123-128.
4. Li, X., & Huang, C. (2007). Environment impact of heavy metals on urban soil in the vicinity of industrial area of Baoji city, PR China. Environmental Geology, 52, 1631-1637.
5. The potential of excessive heavy metals contaminating soils is also present due to air deposition, the use of herbicides, and the use of fertilisers that have high metal content.
6. Sardar, K., Ali, S., Hameed, S., Afzal, S., Fatima, S., Shakoor, M. B., ... & Tauqeer, H. M. (2013). Heavy metals contamination and what are the impacts on living organisms. Greener Journal of Environmental management and public safety, 2(4), 172-179.
7. Passariello, B., Giuliano, V., Quaresima, S., Barbaro, M., Caroli, S., Forte, G., ... & Iavicoli, I. (2002). Evaluation of the environmental contamination at an abandoned mining site. Microchemical Journal, 73(1-2), 245-250.
8. Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6(9), e04691.
9. Grasmück, D., & Scholz, R. W. (2005). Risk perception of heavy metal soil contamination by high-exposed and low-exposed inhabitants: The role of knowledge and emotional concerns. Risk Analysis: An International Journal, 25(3), 611-622.
10. Afonne, O. J., & Ifediba, E. C. (2020). Heavy metals risks in plant foods–need to step up precautionary measures. Current opinion in toxicology, 22, 1-6.
11. Galal, T. M., Hassan, L. M., Ahmed, D. A., Alamri, S. A., Alrumman, S. A., & Eid, E. M. (2021). Heavy metals uptake by the global economic crop (Pisum sativum L.) grown in contaminated soils and its associated health risks. Plos one, 16(6), e0252229.
12. Khan, A., Khan, S., Khan, M. A., Qamar, Z., & Waqas, M. (2015). The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. Environmental science and pollution research, 22, 13772-13799.
13. Hooda, P. S., McNulty, D., Alloway, B. J., & Aitken, M. N. (1997). Plant availability of heavy metals in soils previously amended with heavy applications of sewage sludge. Journal of the Science of Food and Agriculture, 73(4), 446-454.
14. Okedeyi, O. O., Dube, S., Awofolu, O. R., & Nindi, M. M. (2014). Assessing the enrichment of heavy metals in surface soil and plant (Digitaria eriantha) around coal-fired power plants in South Africa. Environmental Science and Pollution Research, 21, 4686-4696.
15. Olguín, E. J., & Sánchez-Galván, G. (2012). Heavy metal removal in phytofiltration and phycoremediation: the need to differentiate between bioadsorption and bioaccumulation. New biotechnology, 30(1), 3-8.
16. Zhang, Q., Xu, E. G., Li, J., Chen, Q., Ma, L., Zeng, E. Y., & Shi, H. (2020). A review of microplastics in table

salt, drinking water, and air: direct human exposure. Environmental Science & Technology, 54(7), 3740-3751.
17. Wittassek, M., Koch, H. M., Angerer, J., & Brüning, T. (2011). Assessing exposure to phthalates–the human biomonitoring approach. Molecular nutrition & food research, 55(1), 7-31.
18. Nriagu, J. O. (1988). A silent epidemic of environmental metal poisoning?. Environmental pollution, 50(1-2), 139-161.
19. Sandeep, G., Vijayalatha, K. R., & Anitha, T. (2019). Heavy metals and its impact in vegetable crops. Int J Chem Stud, 7(1), 1612-1621.
20. Abarshi, M. M., Dantala, E. O., & Mada, S. B. (2017). Bioaccumulation of heavy metals in some tissues of croaker fish from oil spilled rivers of Niger Delta region, Nigeria. Asian Pacific Journal of Tropical Biomedicine, 7(6), 563-568.
21. Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G., & Ricci, A. (2013). Edible insects in a food safety and nutritional perspective: a critical review. Comprehensive reviews in food science and food safety, 12(3), 296-313.
22. Masindi, V., & Muedi, K. L. (2018). Environmental contamination by heavy metals. Heavy metals, 10, 115-132.
23. Clemens, S. (2006). Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. Biochimie, 88(11), 1707-1719.
24. DalCorso, G., Manara, A., & Furini, A. (2013). An overview of heavy metal challenge in plants: from roots to shoots. Metallomics, 5(9), 1117-1132.
25. Rattan, R. K., Datta, S. P., Chhonkar, P. K., Suribabu, K., & Singh, A. K. (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agriculture, ecosystems & environment, 109(3-4), 310-322.
26. Meena, R. A. A., Sathishkumar, P., Ameen, F., Yusoff, A. R. M., & Gu, F. L. (2018). Heavy metal pollution in immobile and mobile components of lentic ecosystems—a review. Environmental Science and Pollution Research, 25, 4134-4148.
27. Dong, W. Q. Y., Cui, Y., & Liu, X. (2001). Instances of soil and crop heavy metal contamination in China. Soil and Sediment Contamination, 10(5), 497-510.
28. Steinkraus, K. H. (1994). Nutritional significance of fermented foods. Food Research International, 27(3), 259-267.
29. Lokeshwari, H., & Chandrappa, G. T. (2006). Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. Current science, 622-627.
30. Prasad, M. N. V., Hagemeyer, J., Saxena, P. K., KrishnaRaj, S., Dan, T., Perras, M. R., & Vettakkorumakankav, N. N. (1999). Phytoremediation of heavy metal contaminated and polluted soils. Heavy metal stress in plants: from molecules to ecosystems, 305-329.
31. Sandeep, G., Vijayalatha, K. R., & Anitha, T. (2019). Heavy metals and its impact in vegetable crops. Int J Chem Stud, 7(1), 1612-1621.