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A Comprehensive Study on Heavy Metal Contamination in Irrigation Water and Soil from Farmland Located Near Dravyavati River in Jaipur

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Abstract

The environmental issue today is the contamination of river water and soil by heavy metals. Various pollutants are generated and continuously increasing because of various human activities, which are affecting the environment. Numerous varieties of chemical substances are being discharged into the water and soil through different resources and processes, which affect the environmental quality in multiple ways. Highly toxic metals present in water and soil pose a high number of health risks to humans and animals. Heavy metals are among the primary pollutants. In this study, five soil samples were analyzed for heavy metals, including nickel, mercury, arsenic, copper, lead, and zinc. Additionally, five water samples were collected and examined such as copper (Cu), lead (Pb), nickel (Ni), mercury (Hg), zinc (Zn), and arsenic (As) for the detection of heavy metals in them. Soil samples collected from five different villages, and water samples were obtained from four villages near the Dravyavati River, including Mohanpura, Baas Beelwa, Baadh Shyopur, Ashawala, and Sukhdevpura Urf Nohra. The samples were analyzed using Atomic Absorption Spectrometry (AAS), a technique used to detect trace element concentrations in soil and water. The study's findings indicated that copper and lead levels in all five soil samples were below the permissible limits set by the WHO (1996), while zinc levels exceeded the permissible limits in all samples. Nickel concentrations were higher in the soil of Sukhdevpura Urf Nohra and Mohanpura but lower in the other three villages. Mercury and arsenic were below BLQ level when all five samples were analysed. However, industrial effluents discharged into the environment around the Dravyavati River Basin, now known as Amanishah Nallah, have severely impacted the basin's ecosystem. Industrialization has had a detrimental effect on the soil irrigated by its waters.

Keywords

Atomic Absorption Spectrometry, below limit of quantification, Dravyavati river

Abbreviations

BLQ- Below Limit of Quantification, LOQ-Limit of Quantification.
AAS-Atomic Absorption Spectrometry, WHO-World Health Organization
USEPA-United States Environmental Protection Agency
IS-International standard

1. Introduction

Heavy metals are bioaccumulated and transferred through both natural processes and human activities. Contamination of plants and water by heavy metals is a critical global issue, requiring urgent attention as elevated levels pose serious threats to plant and animal life. The investigation's aim is to assess the presence level of all the heavy metals in soil and water in five villages located in the area adjacent to Dravyavati river. In addition to heavy metal analysis, the samples were tested for various properties like physico-chemical. Samples of water were randomly collected from five villages adjacent to the Dravyavati River—Baas Beelwa, Baadh Shyopur, Ashawala, and Sukhdevpura Urf Nohra. The samples were analyzed for zinc, copper, nickel, arsenic, mercury, and lead content, with Atomic Absorption Spectrometry (AAS) used as the analytical method.

The " An in-depth study on heavy metal contamination in irrigation water and soil from farmland located near the Dravyavati River in Jaipur." investigates the pressing issue of contamination of heavy metals in the river and the potential consequences for the environment, agriculture, and public health. Once a thriving river in Jaipur, the Dravyavati River has been severely degraded by rapid industrialization and urbanization in the surrounding area, transforming it into what is now commonly known as the Amanishah Nallah. This Nallah collects stormwater and wastewater from the Ambabari and Naharika Nallahs as it flows. The wastewater from the Nallah is frequently used by local farmers to irrigate their crops.

Figure 1. Water Pumps along the Dravyavati river to draw water for irrigation.

Figure 2. Polluted river basin in Sanganer Area, Jaipur

The study assessed heavy metal contamination (Nickel, Mercury, Arsenic, Copper, Lead, and Zinc) in soil and water from villages near the Dravyavati River in Jaipur, Rajasthan. Using Atomic Absorption Spectrometry (AAS), it found elevated levels of Zinc and Nickel in soil, and high Copper levels in some water samples. The results indicate significant environmental and health risks due to industrial pollution, emphasizing the need for urgent remediation efforts.

2. Methodology use for soil samples testing

2.1. Areas of study

Samples of soil were gathered from the villages adjacent to the Dravyavati river, including Mohanpura, Baas Beelwa, Baadh Shyopur, Ashawala, and Sukhdevpura Urf Nohra. The collected samples were stored in clean polythene bags and were properly labeled with the quantity and location to prevent any confusion between them. They were then taken to the laboratory and were analyzed.

Figure 3. Soil samples kept in sealed polythene bags

2.2. Procedure of the Sample Collection

Samples of soil were taken from five villages near the Dravyavati River, including Mohanpura, Baas Beelwa, Baadh Shyopur, Ashawala, and Sukhdevpura Urf Nohra. Using a small core sampler, samples were randomly taken from the surface in each location. The collected samples were placed properly in a clean polyethylene bag, properly tagged to prevent accidental mix-ups, and sent to the laboratory, where they were stored in an air-dried area before undergoing heavy metal analysis.

2.3. Preparation of Soil Samples

Waste and unwanted matter such as leaves, small stones were manually separated and removed from the samples by hand-picking, which were then air-dried in an oven. The samples were gently mixed, homogenized, and to separate more materials 2-mm mesh sieve was used. After air drying, the soil samples were further kept in an electric oven for drying at approximately 40°C temperature for 30 minutes duration.

Figure 4. Sieve process of soil samples

Figure 5. Oven Drying

3. Experimental Procedure for Water Analysis

3.1. Instruments and Reagents

Atomic Absorption Spectrometer, Aqua regia (35% of HCl, 65% of high purity HNO_3 ,in 3:1 ratio)

3.2. Preparation Aqua regia

Aqua regia is a corrosive acid mixture made by combining nitric acid and hydrochloric acid. The usual ratio of acids is 3 parts of hydrochloric acid to 1 part of nitric acid.

Figure 6. Con HCL 35%

Figure 7. Con HNO3 65%

Figure 8. Addition of nitric acid to HCl

Hydrochloric acid was added to nitic acid. Fuming red or yellow liquid was formed as a resulting mixture. Then the weighed soil samples were transferred into a 250 ml beaker and then digested with an aqua regia solution. Add 15 ml of aqua regia (a mixture of 35% HCl and 65% high purity HNO_3 in a 3:1 ratio) into the sample and heat. After cooling, the solution was filtered by using Whatman filter paper.

Figure 9. Heating of mixture sample

Figure 10. Diluting the filtered sample

Figure 11. For ASS analysis

The prepared samples were cooled and then they were transferred into a volumetric flask, then using deionized water the solutions were diluted to the marked volume. The prepared sample solutions were analyzed for cadmium (Cd), manganese (Mn), chromium (Cr), lead (Pb) concentrations using AAS.

3.3. Preparation of Calibration Standards

3.3.1. Chemicals used

1. Lead nitrate ($Pb(No_3)_2$)
2. Potassium di chromate ($K_2Cr_2O_7$).
3. Manganese sulphate($MnSO_4$)
4. Cadmium chloride ($CdCl_2.2½H_2O$)

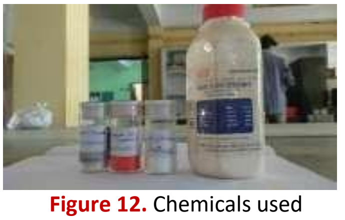

Figure 12. Chemicals used

3.3.2. Method to Prepare Calibration Standards

Standard solutions for lead(Pb), chromium(Cr), cadmium(Cd), and manganese(Mn) were prepared by using stock solutions.

3. Analysis of Soil Samples

Stock solutions were prepared (e.g., 4 ppm, 6 ppm, 8 ppm, etc.). Turn on AAS and the computer. After opening the computer and AAS ,Open the software [Wfx130]. Once the screen on the computer appears, click on the "operation," then "edit analytical method,"option and then click continue. Choose the elements to be analyzed and then prepare the corresponding stock solution. After that, below the instrument compressor to be turned on , then air pipe needs to be activiated given on the side of the ASS instrument (gas inlet), and open gas cylinder.

Figure 13. Wfx 130 Software

Figure 14. Check for flame

Figure 15. Sample Solution

3.1. Experimental Results

Table 1: Heavy Metal Concentration in Soil Samples from Different Locations

Sample no.	Sample Type	Location	Test method	Copper(Cu) concentration (mg/Kg)	Lead(Pb) concentration (mg/Kg)	Zinc(Zn) concentrationn (mg/Kg)
1.	Soil	Sukhdevpura Urf Nohra	USEPA 3050 B:1996	15.35	41.95	83.0
2.	Soil	Mohanpuraa	USEPA 3050 B:1996	16.70	27.30	38.60
3.	Soil	Badh Shyopur	USEPA 3050 B:1996	23.10	41.95	69.95
4.	Soil	Bas Beelwa	USEPA 3050 B:1996	23.95	41.95	71.75
5.	Soil	Ashawala	USEPA 3050 B:1996	12.50	41.95	56.70

Table 1 continued ……..

Sample no.	Sample Type	Location	Test method	Nickel (Ni) concentration (mg/Kg)	Mercury(Hg) concentration (mg/Kg)	Arsenic(As) concentration (mg/Kg)
1.	Soil	Sukhdevpura Urf Nohra	USEPA 3050 B:1996	72.65	*BLQ (**LOQ-0.005)	*BLQ (**LOQ -0.05)
2.	Soil	Mohanpuraa	USEPA 3050 B:1996	72.65	*BLQ (**LOQ-0.005)	*BLQ (**LOQ -0.05)
3.	Soil	Badh Shy-opur	USEPA 3050 B:1996	18.65	*BLQ (**LOQ-0.005)	*BLQ (**LOQ -0.05)
4.	Soil	Bas Beelwa	USEPA 3050 B:1996	21.70	*BLQ (**LOQ-0.005)	*BLQ (**LOQ -0.05)
5.	Soil	Ashawala	USEPA 3050 B:1996	20.65	*BLQ (**LOQ-0.005)	*BLQ (**LOQ -0.05)

***BLQ-Below limit of Quantification, **LOQ-Limit of Quantification**

Table 2. Permissible limits of heavy metals in soils as per WHO

S. No.	Element	Permissible limit (mg/Kg)
1	Copper (Cu)	36
2	Lead (Pb)	85
3	Zinc (Zn)	50
4	Nickel (Ni)	35
5	Mercury (Hg)	0.300
6	Arsenic (As)	20

4. Results

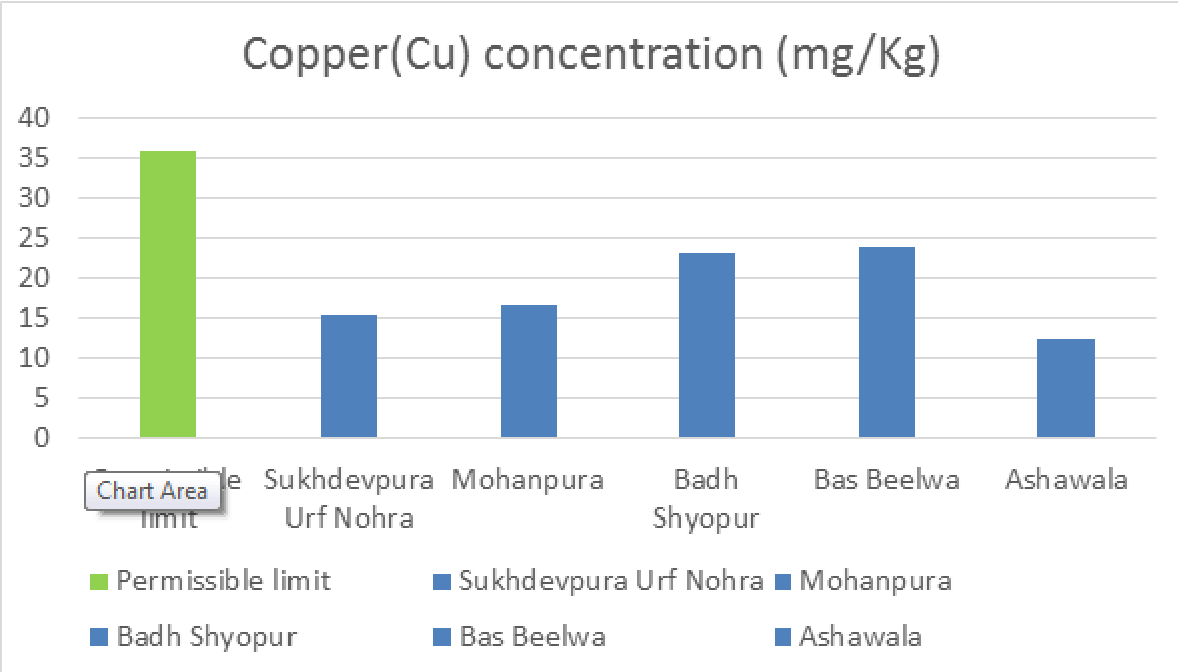

Figure 16. Copper, Cu conc. (mg/Kg) vs Permissible limit

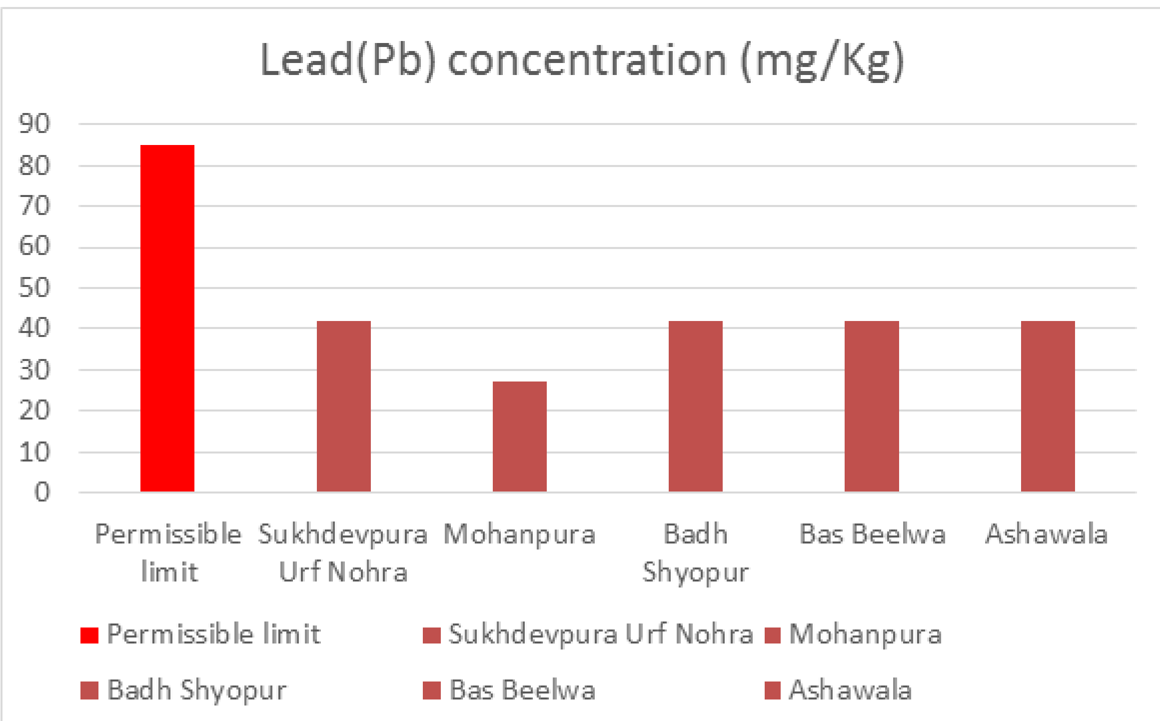

Figure 17. Lead, Pb conc. (mg/Kg) vs Permissible limit

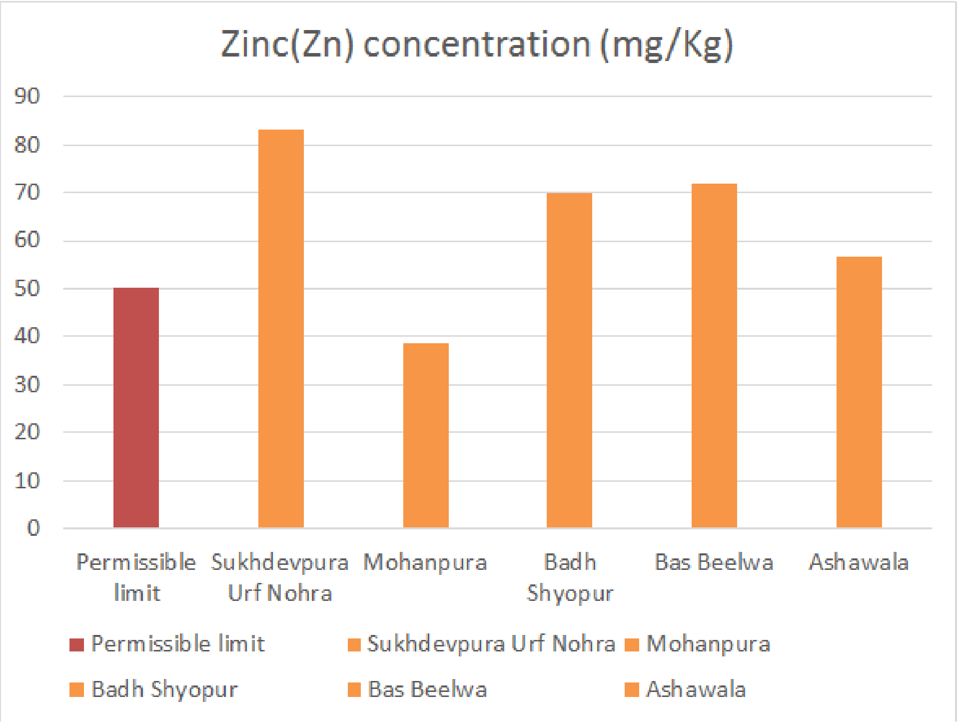

Figure 18. Zinc, Zn conc. (mg/Kg) vs Permissible limit

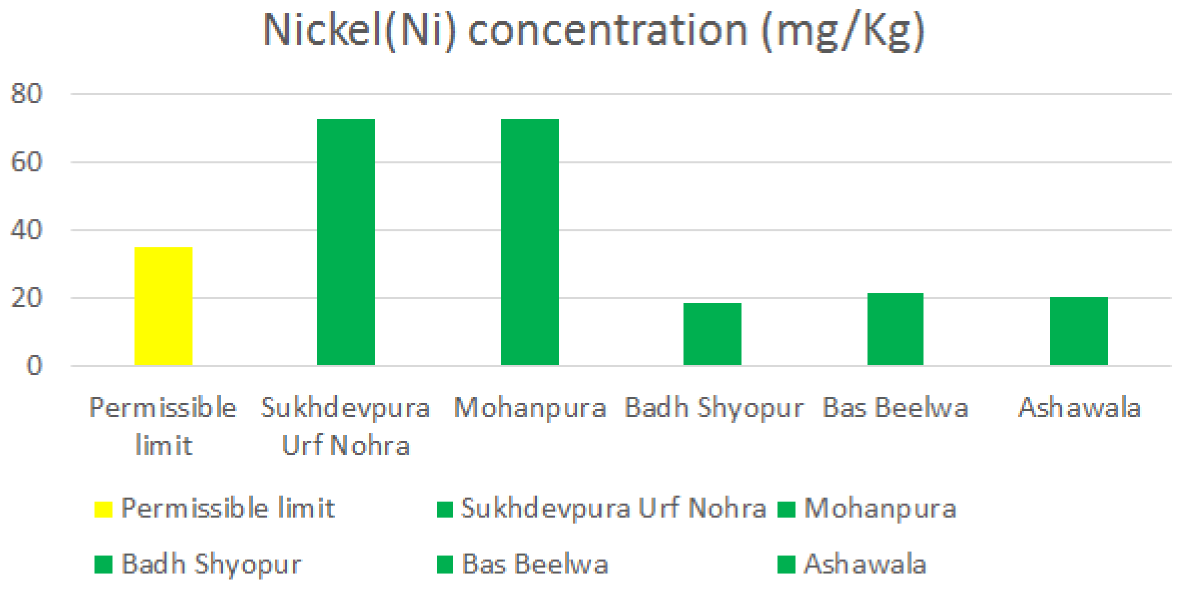

Figure 19. Nickel, Ni conc. (mg/Kg) vs Permissible limit

In the overall analysis and study, the results show variability in soil samples that were collected from villages adjacent to the Dravyavati River. After the study the overall findings are as follows:

a. Copper and Lead: The concentrations of copper and lead in all five soil samples are below the permissible limits set by WHO (1996). This is likely due to the continuous absorption and up taking of metals by crops (such as cereals and vegetables) that usually grows in the soil irrigated by wastewater, as well as the leaching of heavy metals into deeper soil layers, which may contribute to the lower concentration levels compared to the permissible limits.

b. Zinc and Nickel: Zinc levels in all five soil samples exceed the permissible limits, while nickel concentrations are higher in the soils of Sukhdevpura Urf Nohra and Mohanpura villages but lower in the other three villages. This is likely due to the use of chemical fertilizers, which increase the accumulation and bioavailability of nickel and zinc in the soil, suggesting that these heavy metals are contaminants from the application of inorganic fertilizers.

c. Mercury and Arsenic: In all five samples, mercury and arsenic levels are below the limit of quantification (BLQ), indicating that their concentrations are too low to be detected by the assay used.

Overall, the areas studied are affected by sewage discharge and the toxic effluents from the industries nearby and also by heavy vehicular emissions. The current levels of copper, lead, arsenic, and mercury are not excessively high, the water and soil are contaminated by toxic heavy metals, particularly nickel and zinc.

5. Methodology Used for Water Samples Testing

5.1. Sample Collection

Water samples were gathered from four villages along the Dravyavati River: Baas Beelwa, Baadh Shyopur, Ashawala, and Sukhdevpura (also known as Nohra), specifically from wells, as these represent the primary water sources of the areas. The water samples were collected in 0.75-liter plastic bottles. Before using, the plastic bottles were cleaned by a detergent solution, rinsed thoroughly using distilled water, and then with acetone. Each bottle was labelled to indicate the sampling location.

5.2. Sample preparation

To avoid contamination from metals, water samples were collected in bottles rather than glass. Then 0.75 Liters of each sample were transferred to a clean digestion flask digestion. To this, 9 ml of conc. nitric acid (HNO3) and 3 ml of conc. hydrochloric acid (HCl) were added. On a hot plate, the mixture was heated until the release of brown fumes (indicative of nitrogenous compounds) ceased, signaling that digestion was complete. After this process, the samples were allowed to cool. Following cooling, distilled water was added, and after that the mixture was filtered into a standard flask. For analysis using AAS instrument, the filtered sample is then transferred to a plastic reagent bottle.

Figure 20. Atomic Absorption Spectrometer (AAS)

5.3. Calibration of Atomic Absorption Spectrometry

The concentration of an element such as lead was determined in a solution, a calibration curve was created. This involves calibrating the Atomic Absorption Spectrometer with several solutions of known concentrations. As more concentrated solutions are introduced, the calibration curve is adjusted accordingly. This curve plots the concentration of the element against the amount of radiation absorbed. Higher concentrations absorb more radiation up to a certain limit, allowing for accurate determination of unknown concentrations based on the calibration data.

5.4. Sample Characterization

The samples collected from the area of study were analysed using Atomic Absorption Spectroscopy to identify trace amounts of heavy metals.

5.5. Experimental Result

5.5.1. Sample Type- Water

Table 3. Heavy metals concentration in water samples and its permissible limit

S. No	Test Parameters	Test method	Location	Concentration (mg/L)	Limit as Per IS:10500-2012	
					Acceptable	Permissible Limit
1.	Copper (Cu)	APHA (23rd Edition)3 113B:2017	1.Ashawala	0.07	0.05	1.5
			2.Badh Shyopur	0.06		
			3.Sukhdevpura Urf Nohra	*BLQ (**LOQ-0.05)		
			4.Bas Beelwa	*BLQ (**LOQ-0.05)		
2.	Lead(Pb)	APHA (23rd Edition)3 030 D,3113B: 2017	1.Ashawala	*BLQ (**LOQ-0.05)	0.01	No relaxation
			2.Badh Shyopur	*BLQ (**LOQ-0.05)		
			3.Sukhdevpura Urf Nohra	*BLQ (**LOQ-0.05)		
			4.Bas Beelwa	*BLQ (**LOQ-0.05)		
3.	Mercury (Hg)	APHA (23rd Edition)3 113C:2017	1.Ashawala	*BLQ (**LOQ-0.001)	0.01	No relaxation
			2.Badh Shyopur	*BLQ (**LOQ-0.001)		
			3.Sukhdevpura Urf Nohra	*BLQ (**LOQ-0.001)		
			4.Bas Beelwa	*BLQ (**LOQ-0.001)		
4.	Nickel (Ni)	APHA (23rd Edition)3 030 D,3113B:	1.Ashawala	*BLQ (**LOQ-0.05)	0.02	No relaxation
			2.Badh Shyopur	*BLQ (**LOQ-0.05)		
			3.Sukhdevpura Urf Nohra	*BLQ (**LOQ-0.05)		

		2017	4.Bas Beelwa	*BLQ (**LOQ-0.05)		
5.	Zinc(Zn)	APHA (23rd Edition)3 030 D,3113B: 2017	1.Ashawala	*BLQ (**LOQ-0.20)	5.0	15.0
			2.Badh Shyopur	*BLQ (**LOQ-0.20)		
			3.Sukhdevpura Urf Nohra	0.32		
			4.Bas Beelwa	*BLQ (**LOQ-0.20)		
6.	Arsenic (As)	APHA (23rd Edition)3 114C:2017	1.Ashawala	*BLQ (**LOQ-0.005)	-	-
			2.Badh Shyopur	*BLQ (**LOQ-0.005)		
			3.Sukhdevpura Urf Nohra	*BLQ (**LOQ-0.005)		
			4.Bas Beelwa	*BLQ (**LOQ-0.005)		

*BLQ-Below limit of Quantification, **LOQ-Limit of Quantification.

6. Results and Discussion

a. The allowable limit for zinc in water, as per WHO standards, is 5 mg/l. All collected water samples showed zinc concentrations below this threshold.
b. The permissible limit for lead in water, as per WHO standards, is 0.01 mg/l. In the study area, lead concentrations in all water samples were found below the detection limit.
c. WHO standards set the permissible limit for copper in water at 0.05 mg/l. The study results indicate that copper concentrations exceed this limit in the water samples from Ashawala and Badh Shoypur, while samples from Sukhdev Urf Nohra and Baas Beelwa were below the detection limit.
d. Overconsumption of copper can cause health problems, including headaches, vomiting, diarrhea, stomach cramps, nausea, liver damage, kidney disease, and a reduction in the oxygen-carrying ability of red blood cells.Mercury, arsenic, and nickel concentrations in all collected water samples were found to be below the permissible limits.
e. The elevated copper levels in Ashawala and Badh Shoypur compared to other regions suggest that industrial activities might be contributing to the increased presence of these heavy metals.

7. Conclusion

This comprehensive study highlights the significant contamination of irrigation water and soil with heavy metals in farmlands near the Dravyavati River in Jaipur, particularly in the areas of Sukhdevpura Urf Nohra, Mohanpura, and Baadh Shyopur. The findings indicate that while copper and lead concentrations in the soil samples remain below WHO's permissible limits, zinc and nickel levels exceed these thresholds, pointing to potential risks associated with agricultural practices and the use of chemical fertilizers. The presence of industrial pollutants has had a detrimental impact on the soil quality, affecting both agricultural productivity and public health. In the water samples, copper levels were found to exceed WHO standards in certain areas, which could pose health risks to local communities. However, the concentrations of other heavy metals such as lead, mercury, and arsenic were below detectable limits, suggesting that not all heavy metals are present at dangerous levels. The study underscores the urgent need for environmental management strategies to mitigate the impact of industrial effluents and enhance the safety of agricultural practices in this region. Monitoring and remediation efforts are essential to safeguard the health of both the environment and the population that depends on these resources.

References

[1]. A. Al-Hussaini, A. H. Al-Atrushi, and M. I. Abdul Kareem, "The environmental assessment of heavy metal pollution of Diyala River in city of Baghdad, Iraq," Journal of Applied Water Science, vol. 8, pp. 1-6, May 2022.

[2]. D. Mudgal, "Assessment of heavy metals toxicity in contaminated soil and vegetables irrigated with industrial and sewage effluent in Jaipur city and its surrounding area," Ph.D. dissertation, Univ. of Rajasthan, Jaipur, India, May 2022.

[3]. M. Patel, "Investigation and physico-chemical characterization of groundwater quality of Jodhpur district, Western Rajasthan," Ph.D. dissertation, Univ. of Rajasthan, Jodhpur, India, 2018.

[4]. R. Jagariya, "To study the impact of effluent of sewage and industries in East Southern part of Amanishah Nala on soil with reference to agriculture and irrigational purposes," Ph.D. dissertation, Univ. of Rajasthan, Jaipur, India, 2018.

[5]. A. Mitryasova, V. Boyko, and S. Pasternak, "Integrated environmental assessment of the surface waters pollution," in 17th International Multidisciplinary Scientific GeoConference, vol. 7, no. 3, 2017. [Online]. Available: http://dx.doi.org/10.5593/sgem2017H/33/S12.029, Jan. 2021.

[6]. M. Islam, A. S. Islam, M. S. M. Rahman, and S. H. Arefin, "Environmental assessment of water and soil contamination in Rajakhali Canal of Karnaphuli River (Bangladesh) impacted by anthropogenic influences," Journal of Applied Water Science, vol. 7, pp. 997-1010, July 2015.

[7]. S. O. Fakayode, "The impact assessment of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria," African Journal of Environmental Assessment and Management, vol. 10, pp. 209-214, May 2017.

[8]. A. Mehta, "Physico-chemical and microbial studies of groundwater of Sanganer, Tehsil Jaipur Rajasthan and comparison with other regions," Ph.D. dissertation, Poornima Univ., Jaipur, India, 2016.

[9]. O. Phiri, G. B. Mumba, P. Z. Moyo, and W. Kadewa, "The impact of industrial effluents on water quality of receiving river in urban areas of Malawi," International Journal of Environment Science and Technology, vol. 2, pp. 237-244, May 2014.

[10]. P. Venugopal, K. Venkatesan, and A. T. Ramalingam, "The environmental impact assessment and seasonal variation of the groundwater in the vicinity of river Adyar, Chennai," Journal of Environmental Monitoring and Assessment, vol. 9, pp. 81-97, June 2013.

[11]. M. A. Hussain and R. J. Rao, "The effect of industrial effluents on surface water quality of Patancheru, Andhra Pradesh," Journal of Current World Environment, vol. 8, pp. 445-454, Nov. 2013.

[12]. M. S. Islam, M. K. Ahmed, and M. A. Molla, "The effects of solid waste and industrial effluents on water quality of Turag River at Konabari industrial area, Gazipur, Bangladesh," Journal of Environmental Science and Natural Resources, vol. 5, pp. 213-218, April 2013.

[13]. F. M. Azom, M. A. Mahmud, M. S. Sultana, S. M. Rahman, and A. Islam, "The environmental impact assessment (EIA) of tanneries in Hazaribagh, Bangladesh," International Journal of Environmental Science and Development, vol. 3, pp. 152-156, May 2012.

[14]. T. C. Ogwueleka, "Assessment of the quality of water and identification of pollution sources of Kaduna River in Niger state, Nigeria," Journal of Water and Environment, vol. 28, pp. 229, Nov. 2012.

[15]. P. Walakira and W. Okumu, "The impact of industrial effluents on water quality of streams in Nakawa-Ntinda, Uganda," Journal of Applied Science, vol. 15, pp. 154-159, August 2011.