# Status of Heavy Metals in Irrigation water in the Central Narmada Valley Zone of Madhya Pradesh, India


## ABSTRACT

Water quality deteriorating due to the growing global population. In the present study, a total of 104 water samples were collected from Central Narmada Valley zone Madhya Pradesh and analyzed using ICP- MS/MS in the laboratory the results showed that the mean concentrations of 3.49 $\mu gL^{-1}$, 4.203 $\mu gL^{-1}$,40.43 $mgL^{-1}$, 0.24 $\mu gL^{-1}$, 10.42 $\mu gL^{-1}$, 0.58 $\mu gL^{-1}$, 4.81 $\mu gL^{-1}$, 0.344 $\mu gL^{-1}$,0.019 $\mu gL^{-1}$, 1.58 $\mu gL^{-1}$, and 1.97 $\mu gL^{-1}$, of Cu, Zn, Mn, Fe, Cr, Co, Ni, Cd , Hg , Pb and As respectively. The concentrations of these metals varied across the districts, with substantial fluctuations indicated by high coefficients of variation (CV %). The Cu and Zn showed high CV%, in Narsinghpur (120.51%) and Narmadapuram (164.51%), suggesting irregular distribution. Mn status showed considerable variation, with extreme values in Narmadapuram, while Fe concentrations were relatively low, Although the concentrations of Fe, Cr and As occasionally exceeded lower thresholds, all metals remained within the permissible limits set by the WHO. The highest CV% was observed for Hg in Harda, indicating considerable variability in status. The results revealed that the western areas appear to have higher contamination levels than eastern part. Overall, the findings, continuous monitoring is recommended to ensure the safety of irrigation water.



**Keyword:** Heavy Metals, Irrigation Water, GIS, GPS. Arsenic, Mercury


## 1. INTRODUCTION

Water is a vital resource and about 2.5% of surface fresh water is used for agriculture, domestic activities, industry, and supporting aquatic life Baker et al., (2016). Declining water quality impacts agricultural use and consumption by humans and animals. Heavy metal contamination in irrigation water poses serious risks to both environmental sustainability and public health. The study area is extensively cultivated with wheat, soybean and moonbeam whose irrigation water playing a critical role in supporting local farming practices. However, over the years, the quality of irrigation water has been compromised due to the increasing presence of heavy metals.

As these metals accumulate in the soil, they can be taken up by crops, ultimately entering the food chain and affecting the health of local communities. Furthermore, the persistent and non-biodegradable nature of heavy metals exacerbates the problem, making it a long-term challenge for the region. Understanding the trends of heavy metals is vital for developing effective strategies for water management and pollution mitigation in Flouchi et al., 2021). Presence of heavy metals in water degrades its quality. Various methods are available for detecting heavy metal contamination in water, including inductively coupled plasma mass spectrometry (ICP-MS/MS).

Heavy metals are non-biodegradable and therefore persist for a long time in aquatic and terrestrial environments. They can be transported from soil to groundwater or taken up by plants (Jamali et al., 2009). They can enter the human body through the food chain, accumulating over time and leading to various health problems, including kidney disease, hormonal imbalances, hair loss, cardiovascular issues, neurological and endocrine disorders, cancer, and respiratory and digestive problems. Furthermore, the distribution of heavy metals in aquatic ecosystems can disrupt the biotic community, influencing biogeochemical processes and forming harmful complexes with organic matter. Long-term studies have shown that using contaminated water for irrigation can elevate the risk of heavy metal accumulation in soil and crops, ultimately threatening food safety and public health WHO (2012). Assessment of heavy metals in water is therefore crucial for safeguarding human health.

## 2. MATERIAL AND METHODS

### 2.1 Study area for water sampling

The study focuses on the Central Narmada Valley zone, which includes the districts of Narsinghpur, Hoshangabad, Harda, and parts of Sehore and Raisen in Madhya Pradesh (Fig. 1). This region lies between latitudes 22° and 23° and longitudes 76° and 79°. The area is predominantly composed of irrigated land, utilizing canals, tubewells, and wells, with deep black, sandy loam, and medium black soils. It receives annual rainfall between 1200 and 1600 mm, and the primary cropping system is Sugarcane based in Narsinghpur and wheat-soybean-summer moonbeam.

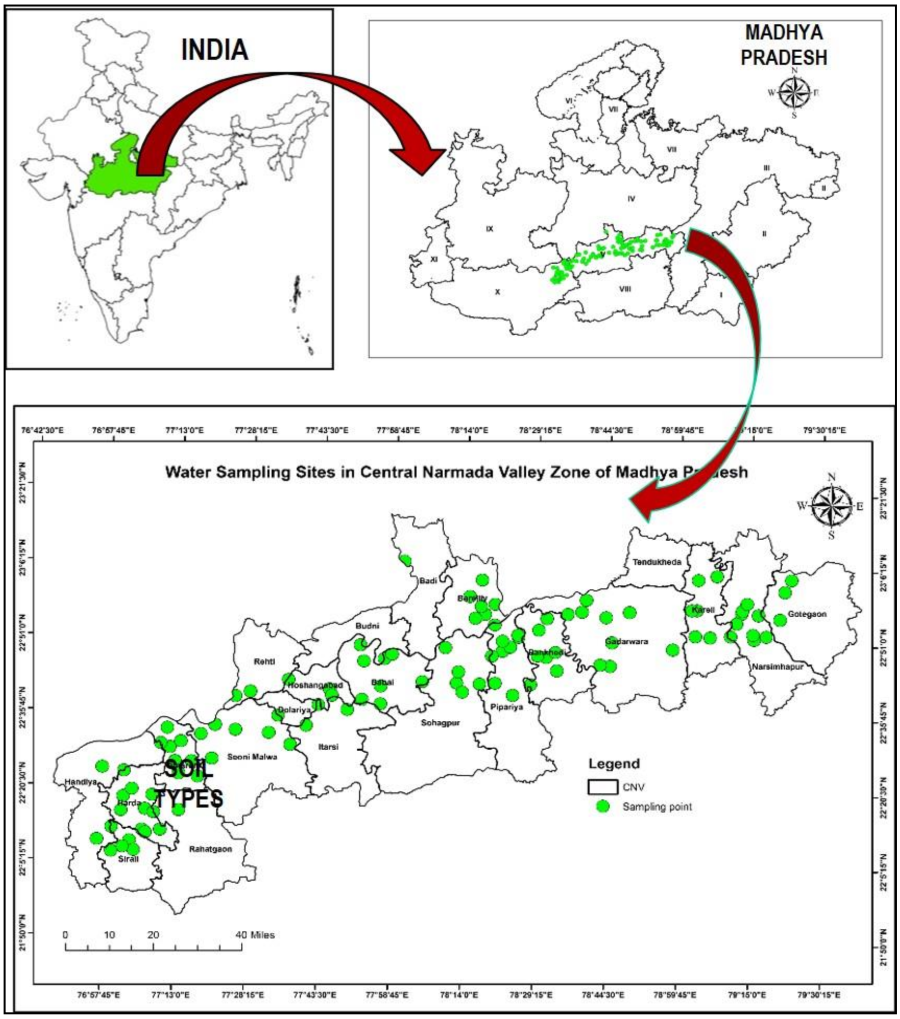


**Fig. 1 Study area of sampling sites**

## 2.2 Sample collection and analysis

Water samples were collected in 500 ml PVC bottles, carefully labeled, and thoroughly cleaned by washing with distilled water before collection. In the Central Narmada Valley Zone, a total of 104 water samples were gathered from different districts: 28 from Narsinghpur, 42 from Narmadapura, 26 from Harda, 6 from partly Bareli and 2 from partly Raheti. These samples were collected from a variety of sources, including rivers, canals, wells, ponds, and tube wells, to examine the chemical quality of water in the region. Various heavy Matels, including arsenic (As), chromium (Cr), cobalt (Co), copper (Cu), cadmium (Cd), mercury (Hg), nickel (Ni), lead (Pb), zinc (Zn) and iron (Fe) concentration, were measured to assess the quality of irrigation water. In order to determine the metal content, the collected sample was filtered and placed 5 ml in test tube and treated with 0.25 ml of nitric acid and 0.15 ml hydrochloric acid (Trace metal grade). Heavy metals content in irrigation water samples were determined by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) and standards curve (Fig .2).

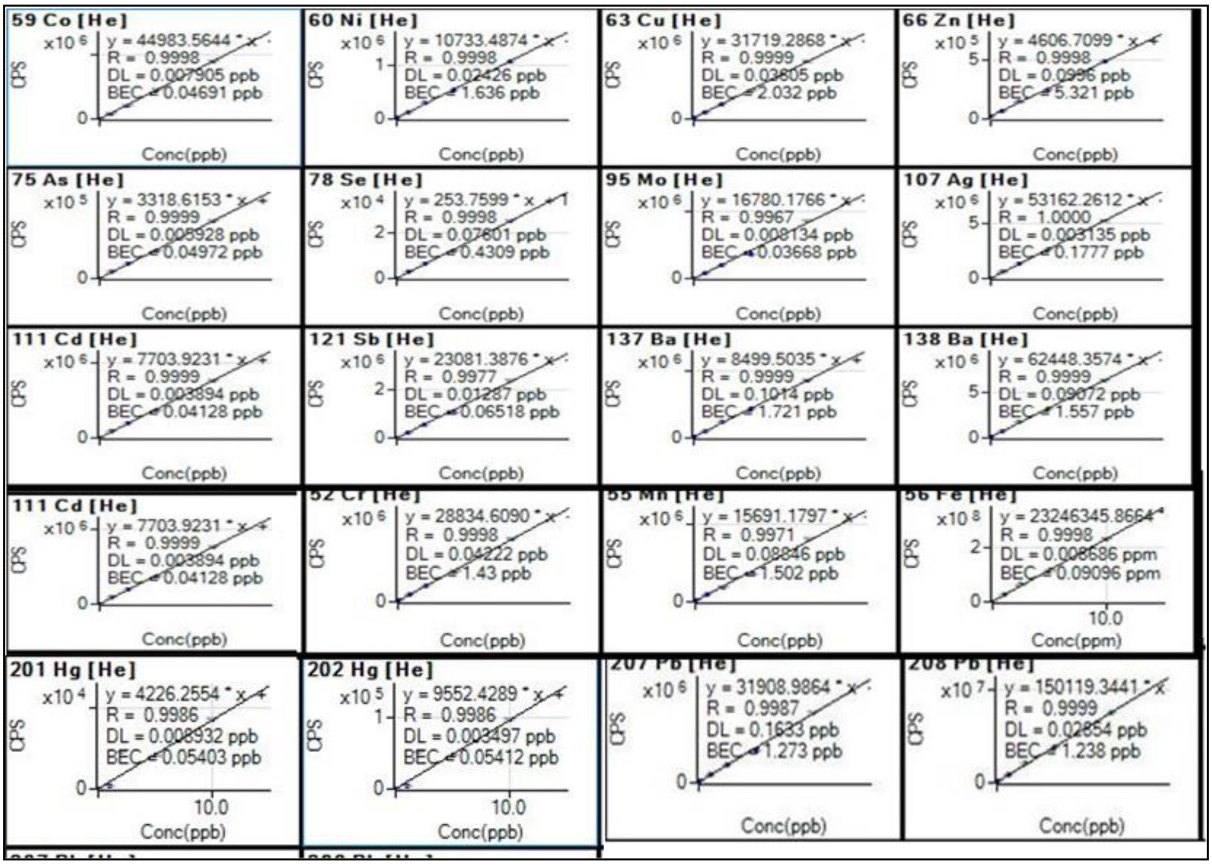


**Fig. 2 Standard curve for Heavy metal content analysis using ICP-MS**

### 2.3 Statistical methods

The minimum, maximum, mean and coefficient of variation value. The coefficient of variation (CV) can be used to describe the dispersion degree of each sample, CV< 10% belongs to weak variation, 10%_ CV_ 100% belongs to moderate variation, and CV> 100% belongs to strong variation (Zhou et al. 2016).

## 3. RESULTS AND DISCUSSION

### 3.1 Copper (Cu)

The status of Cu in the water samples is presented in Table 1, it ranged from 0.30 to 41.94, 0.04 to 22.41, 0.04 to 0.19, 0.30 to 13.46 and 0.08 to 0.17 μg$L^{-1}$ with a mean value of 6.92, 3.29, 0.08, 4.75 and 0.12 μg$L^{-1}$ in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti)district, respectively. The CV of 120.51, 164.51, 39.59, 109.19 and 50.69%, respectively. Overall ranged from 0.04µgL$^{-1}$ (Narmdapura) to 41.94 µgL$^{-1}$ (Narsinghpur) with a mean value 3.49µgL$^{-1}$ (The lowest in Narmdapura and The highest in Narsinghpur). High coefficients of variation (CV %) for Cu, particularly in Narsingpur (120.51%) and Narmdapura (164.51%), suggest irregular patterns of contamination. In overall all the samples fall under the permissible limit of 2000 µgL$^{-1}$according to WHO (2017).

**3.2 Zinc (Zn)**

The status of Zn in the water samples is presented in Table 1, it ranged from 0.090 to 24.242, 0.004 to 57.864, 0.009 to 0.111, 0.25 to 29.15 and 0.012 to 0.031 ugL$^{-1}$ with a mean value and CV of 5.18, 5.269, 0.032, 11.622 and 0.022 ugL$^{-1}$ and 96.29, 38.18, 139.18, 111.53 and 159.86 % in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it was ranged from 0.004 µgL$^{-1}$ (Narmdapuram) to 57.86 µgL$^{-1}$ (Narmdapura) with a mean value 4.20 µgL$^{-1}$ (The lowest in Harda and the highest in Partly Bareli). The highest CV% was found in Partly Raheti (159.86%), indicating significant fluctuations in Zn contamination. The obtained values were under the permissible levels of 1000 µgL$^{-1}$according to WHO (2017).

**3.3 Manganese (Mn)**

The status of Cu in the water samples is presented in Table 1, it ranged from 1.74 to 380.06, 0.02 to 752.57, 0.01 to 5.87, 3.99 to 210.91 and 0.05 to 0.07µgL$^{-1}$ with a mean value and CV 55.40, 54.95, 0.44, 55.64 and 0.06µgL$^{-1}$ and 158.24, 257.24, 302.11, 143.88 and 32.05% in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Mn concentration showed a wide range, from 0.01 µgL$^{-1}$ (Harda) to 752.57 µgL$^{-1}$ (Narmdapura) with mean value 40.43µgL$^{-1}$ (The lowest in Partly Sehore and the highest in Partly Raisen). High CV% values, such as 302.11% in Harda, suggest sporadic pollution or localized sources of contamination. The mean concentration of Mn in tested water is permissible limit of 100 µgL$^{-1}$according to WHO (2017).

**3.4 Iron (Fe)**

The status of Fe in the water samples is presented in Table 1, it ranged from 0.05 to 1.50, 0.01 to 2.44, 0.01 to 0.27, 0.04 to 2.57 and 0.01 to 0.03 ugL$^{-1}$ with a mean value and The CV 0.34, 0.22, 0.04, 0.90 and 0.02 ugL$^{-1}$ and 97.95, 53.28, 57.17, 89.91 and 141.42% in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it was ranged from 0.01 to 2.57 ugL$^{-1}$ with a mean value 0.24ugL$^{-1}$. The CV% for Fe ranged from 53.28% in Narmadapuram to 141.42% in Partly Raheti, indicating significant variability in the metal's presence. The obtained values were under the permissible levels of 300 μgL$^{-1}$according to WHO (2017).

**3.5 Chromium (Cr)**

The Cr concentration in the water samples is presented in Table 1, it ranged from 0.916 to 231.82, 0.010 to 133.089, 0.001 to 0.090, 3.923 to 39.681 and 0.012 to 0.013 μgL$^{-1}$ with a mean value and The CV 20.58, 10.176, 0.013, 13.273 and 0.013 μgL$^{-1}$ and 47.986, 41.743, 79.816, 93.287 and 1767.767 % in Narsinghpur, Narmdapuram, Harda, Partly Raisen (**B**areli) and Partly Sehore (Raheti) district, respectively. Over all from 0.001 μgL$^{-1}$ (Harda) to 231.823 μgL-1 (Narsinghpur) with a mean value 37.152 μgL$^{-1}$ (The lowest in Harda and Partly Rahati and the highest in Narsinghpur). The mean concentration of Cr in tested water is below than permissible limit of 50 μgL$^{-1}$ according to WHO (2017).

**3.6 Cobalt (Co)**

The Co concentration in the water sample is presented in Table 1, it ranged from 0.15 to 3.48, 0.06 to 3.94, 0.01 to 1.42, 0.18 to 1.12 and 0.20 to 0.24 μgL$^{-1}$ with a mean value of 0.79, 0.67, 0.29, 0.48 and 0.22μgL$^{-1}$ in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it was ranged from 0.01 μgL$^{-1}$ (Harda) to 3.94μgL$^{-1}$(Narmdapura) with mean value 0.58 μgL$^{-1}$(The lowest in Partly Rahati and the highest in Narsingpur). The CV% for Co ranged from 11.62% in Partly Raheti to 114.09 % in Harda. The mean concentration of cobalt in tested water is below permissible limit of 50 μgL$^{-1}$according to WHO (2017).

**3.7 Nickel (Ni)**

The Ni concentration in the water samples is presented in Table 1, it ranged from 1.09 to 18.58, 0.83 to 49.31, 0.29 to 5.45, 1.19 to 10.43 and 2.49 to 15.56 μgL$^{-1}$ with a mean value 6.36, 5.40, 1.94, 4.52 and 9.03 μgL$^{-1}$ in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it was ranged from 0.29 μgL$^{-1}$(Harda) to 49.31 μgL-1 (Narmdapura) with amean value 4.81ugL$^{-1}$. The highest CV% (159.33%) was found in Narmdapura, reflecting significant variability in contamination levels. The obtained values were corroborated with Adegbe et al., (2015) and finding under the permissible levels of 70 μgL$^{-1}$ according to WHO (2017).

**3.8 Cadmium (Cd)**

The Cd concentration in the water samples is presented in Table 1, it ranged from 0.002 to 0.671, 0.002 to 30.351, 0.002 to 0.092, 0.005 to 0.167 and 0.009 to 0.012 ugL$^{-1}$ with a mean value and The CV 0.087, 0.77, 0.025, 0.057 and 0.011 $ugL^{-1}$ and 61.999, 16.455, 112.754, 91.339 and 494.975 % in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Overall, it was ranged from 0.002 $ugL^{-1-}$ (several locations) to 30.351 $ugL^{-1}$ (Narmdapura) with mean value and CV 0.344 $\mu gL^{-1}$ (The lowest in Partly Raheti and the highest in Narmadapuram) and 11.569%. The obtained values were corroborated with Malan et al., (2015) and overall, the samples fall under the permissible limit of 10 $\mu gL^{-1}$ according to WHO (2017).

**3.9 Mercury (Hg)**

The Hg concentration in the water samples is presented in Table 1, it ranged from 0.001 to 0.254, 0.001 to 0.357, 0.001 to 0.004, 0.001 to 0.166 and 0.001 to 0.004 $ugL^{-1}$ with a mean value 0.024, 0.024, 0.002, 0.029 and 0.003 $ugL^{-1}$ in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it ranged from 0.001 to 0.357 $ugL^{-1}$ with a mean value 0.019 $ugL^{-1}$. The CV% for mercury was notably high (213.023 %) in Harda. The obtained results were supported by Garhwal et al., (2019) and indicating all the sample fall under the permissible limit according to WHO (2017).

**3.10 Lead (Pb)**

The Pb concentration in the water samples is presented in Table 1, it ranged from 0.34 to 24.05, 0.01 to 6.51, 0.01 to 1.36, 0.74 to 13.46 and 0.02 to 0.11 $\mu gL^{-1}$ with a mean value and The CV 2.78, 1.17, 0.36, 4.67 and 0.06 $\mu gL^{-1}$ and 63.64, 73.80, 89.21, 90.25, and 92.36% in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it ranged from 0.01 to 24.05 $\mu gL^{-1}$ with a mean value 1.58 $ugL^{-1}$. The CV% for Pb across all locations was 53.51%, reflecting considerable fluctuation. Indicating all the sample fall under the permissible limit of 10$\mu gL^{-1}$ according to WHO (2017).

**3.11 Arsenic (As)**

The As concentration in the water samples is presented in Table 1, it ranged from 0.52 to 14.51, 0.32 to 15.18, 0.05 to 4.94, 0.42 to 4.91 and 0.54 to 4.86 $\mu gL^{-1}$with a mean value 2.79, 1.89, 1.24, 1.59 and 2.70 $\mu gL^{-1}$ in Narsinghpur, Narmdapuram, Harda, Partly Raisen (Bareli) and Partly Sehore (Raheti) district, respectively. Over all, it ranged from 0.05 to 15.18 $\mu gL^{-1}$ with a mean value 1.97 $\mu gL^{-1}$ and the CV% ranged from 79.2% (Narmdapuram) to 103.55% (Narsinghpur). The obtained values were supported by Chaoua et al., (2019) and over all the samples fall under the permissible limit of 10 $\mu gL^{-1}$ according to WHO (2017).

**Table 1 Status and distribution of heavy metals in irrigation water in central Narmada valley zone**

| Parameters | | Narsinghpur (n=28) | Narmdapura (n=42) | Harda (n=26) | Partly Bareli (n=6) | Partly Raheti (n=2) | Over all (n=104) |
|---|---|---|---|---|---|---|---|
| Cu ($\mu gL^{-1}$) | Min | 0.3 | 0.04 | 0.04 | 0.3 | 0.08 | 0.04 |
| | Max | 41.94 | 22.41 | 0.19 | 13.46 | 0.17 | 41.94 |
| | Mean | 6.92 | 3.29 | 0.08 | 4.75 | 0.12 | 3.49 |
| | CV% | 120.51 | 164.51 | 39.59 | 109.19 | 50.69 | 176.02 |
| Zn ($\mu gL^{-1}$) | Min | 0.090 | 0.004 | 0.009 | 0.250 | 0.012 | 0.004 |
| | Max | 24.242 | 57.864 | 0.111 | 29.159 | 0.031 | 57.864 |
| | Mean | 5.185 | 5.269 | 0.032 | 11.622 | 0.022 | 4.203 |
| | CV% | 96.299 | 38.184 | 139.13 | 111.533 | 159.861 | 42.601 |
| Mn ($\mu gL^{-1}$) | Min | 1.74 | 0.02 | 0.01 | 3.99 | 0.05 | 0.01 |
| | Max | 380.06 | 752.57 | 5.87 | 210.91 | 0.07 | 752.57 |
| | Mean | 55.4 | 54.95 | 0.44 | 55.64 | 0.06 | 40.43 |
| | CV% | 158.24 | 257.24 | 302.11 | 143.88 | 32.05 | 257.96 |
| Fe ($mgL^{-1}$) | Min | 0.05 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 |
| | Max | 1.50 | 2.44 | 0.27 | 2.57 | 0.03 | 2.57 |
| | Mean | 0.34 | 0.22 | 0.04 | 0.90 | 0.02 | 0.24 |
| | CV% | 97.95 | 53.28 | 57.17 | 89.91 | 141.42 | 56.04 |
| Cr ($\mu gL^{-1}$) | Min | 0.916 | 0.010 | 0.001 | 3.923 | 0.012 | 0.001 |
| | Max | 231.823 | 133.089 | 0.090 | 39.681 | 0.013 | 231.823 |
| | Mean | 20.581 | 10.176 | 0.013 | 13.273 | 0.013 | 10.420 |
| | CV% | 47.986 | 41.743 | 79.816 | 93.287 | 1767.767 | 37.152 |
| Co ($\mu gL^{-1}$) | Min | 0.15 | 0.06 | 0.01 | 0.18 | 0.2 | 0.01 |
| | Max | 3.48 | 3.94 | 1.42 | 1.12 | 0.24 | 3.94 |
| | Mean | 0.79 | 0.67 | 0.29 | 0.48 | 0.22 | 0.58 |
| | CV% | 97.35 | 113.41 | 114.09 | 69.58 | 11.62 | 114.93 |
| Ni ($\mu gL^{-1}$) | Min | 1.09 | 0.83 | 0.29 | 1.19 | 2.49 | 0.29 |
| | Max | 18.58 | 49.31 | 5.45 | 10.43 | 15.56 | 49.31 |
| | Mean | 6.36 | 5.4 | 1.94 | 4.52 | 9.03 | 4.81 |
| | CV% | 65.4 | 159.33 | 69.19 | 77.15 | 102.36 | 129.88 |
| Cd ($\mu gL^{-1}$) | Min | 0.002 | 0.002 | 0.002 | 0.005 | 0.009 | 0.002 |
| | Max | 0.671 | 30.351 | 0.092 | 0.167 | 0.012 | 30.351 |
| | Mean | 0.087 | 0.770 | 0.025 | 0.057 | 0.011 | 0.344 |
| | CV% | 61.999 | 16.455 | 112.75 | 91.339 | 494.975 | 11.569 |
| Hg ($\mu gL^{-1}$) | Min | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | Max | 0.254 | 0.357 | 0.004 | 0.166 | 0.004 | 0.357 |
| | Mean | 0.024 | 0.024 | 0.002 | 0.029 | 0.003 | 0.019 |
| | CV% | 45.356 | 38.557 | 213.02 | 43.808 | 117.851 | 36.322 |
| Pb ($\mu gL^{-1}$) | Min | 0.34 | 0.01 | 0.01 | 0.74 | 0.02 | 0.01 |
| | Max | 24.05 | 6.51 | 1.36 | 13.46 | 0.11 | 24.05 |
| | Mean | 2.78 | 1.17 | 0.36 | 4.67 | 0.06 | 1.58 |
| | CV% | 63.64 | 73.80 | 89.21 | 90.25 | 92.36 | 53.41 |
| As($\mu gL^{-1}$ | Min | 0.52 | 0.32 | 0.05 | 0.42 | 0.54 | 0.05 |
| | Max | 14.51 | 15.18 | 4.94 | 4.91 | 4.86 | 15.18 |
| | Mean | 2.79 | 1.89 | 1.24 | 1.59 | 2.7 | 1.97 |
| | CV% | 103.55 | 79.2 | 99.25 | 94.87 | 88.22 | 87.02 |

### 3.12 Spatial variability map of Heavy metals using GIS

Maps showing heavy metal concentration in the Irrigation water, developed using GIS and spatial analysis techniques, have been an important means of obtaining well-supported, accurate and critical information in spatial visualization and comparative evaluation of water quality parameters (Figs. 3, 4 and 5).

The cationic micronutrients such as Zn, Cu, Fe, and Mn are generally low in the western and Southern parts of Harda district, while the highest concentration of Cu is observed in certain areas of the Northern and South-Eastern parts of the study area. Zinc showed the highest concentration in the Northern part of the region. Additionally, the maps of other metals also indicate low values throughout much of the Western and Southern areas of Harda district. The metal concentrations tend to increase from the western and southern parts toward the Northern, North-Eastern, and North-Western areas of the study area. The distribution of heavy metal concentrations is represented by the maps below, highlighting various points across the region.

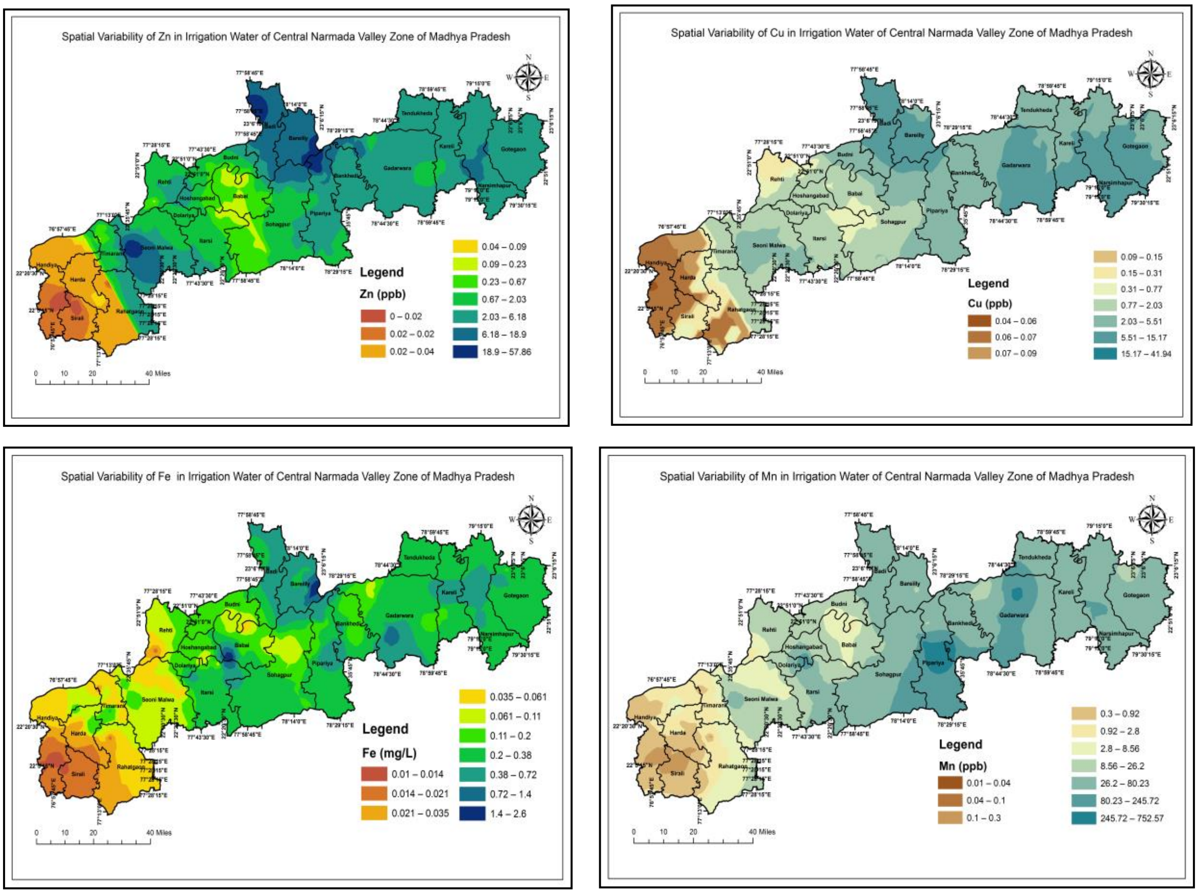


**Fig. 3 Spatial variability maps [Cu, Zn, Mn and Fe] in irrigation water**

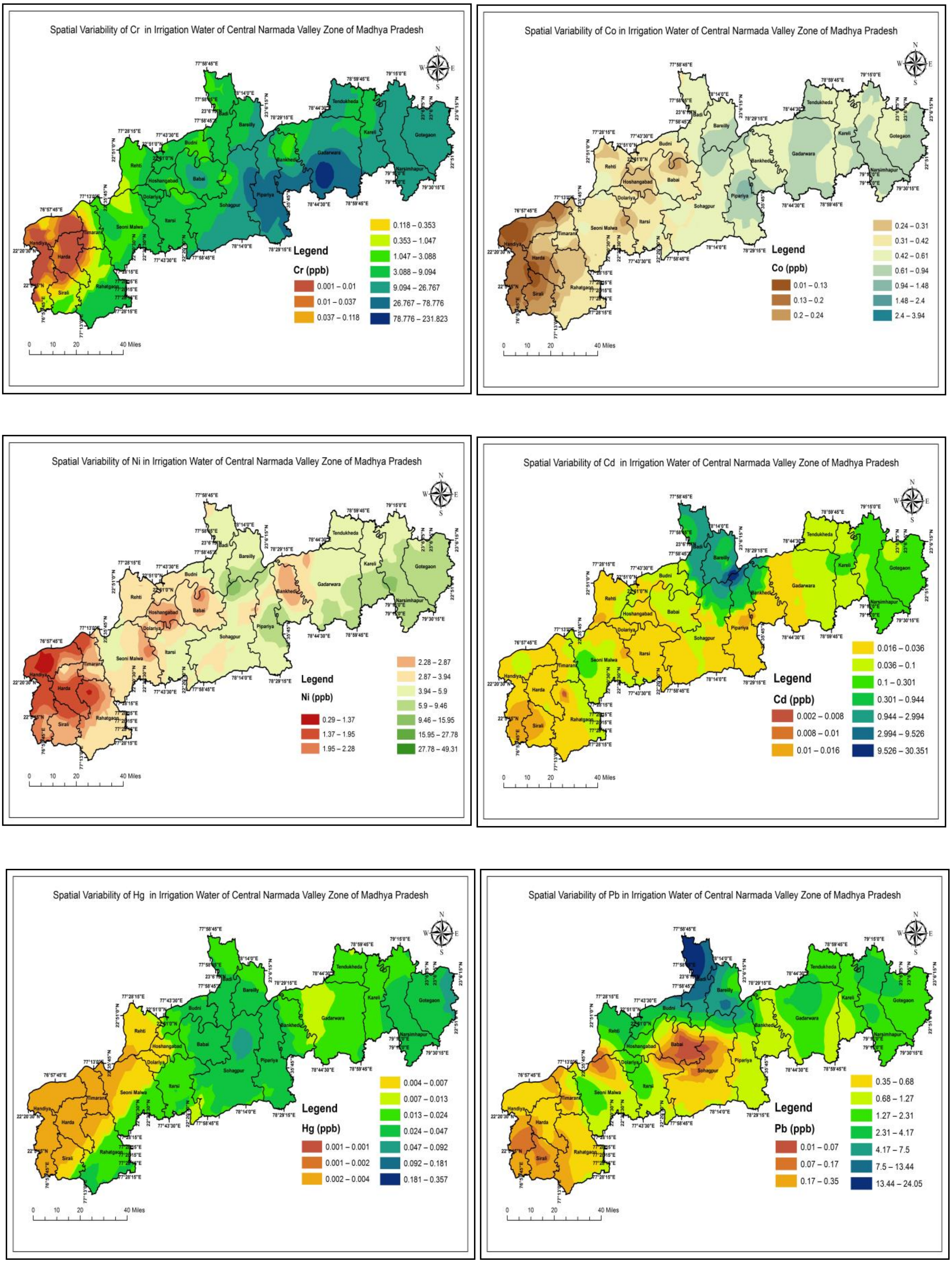


**Fig. 4 Spatial variability maps Cr, Co, Ni, Cd, Pb and Hg in irrigation water**

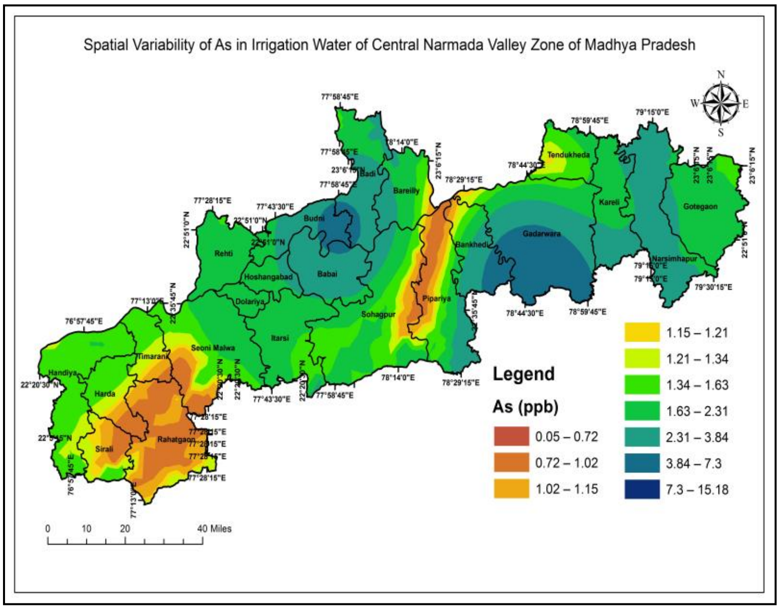


**Fig. 5 Spatial variability maps of As in irrigation water**

## 4. CONCLUSION

The study revealed substantial variability in metal concentrations across the study area. The mean concentrations of Cu, Zn, Mn, Fe, Cr, Co, Ni, Cd, Hg, Pb and As, in tube-well irrigation water in the central Narmada valley zone were as 3.49 $\mu gL^{-1}$, 4.203 $\mu gL^{-1}$,40.43 $mgL^{-1}$, 0.24 $\mu gL^{-1}$, 10.42 $\mu gL^{-1}$, 0.58 $\mu gL^{-1}$, 4.81 $\mu gL^{-1}$, 0.344 $\mu gL^{-1}$,0.019 $\mu gL^{-1}$, 1.58 $\mu gL^{-1}$, and 1.97 $\mu gL^{-1}$, respectively. These values generally fall within the permissible limits set by the WHO for irrigation water. However, the high coefficient of variation (CV%) for several metals indicates that there are areas with significant fluctuations, highlighting the need for more consistent monitoring and potential remediation efforts.

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