



Heavy Metal Pollution Assessment Of Groundwater In The Itanagar Capital Region Using Hpi

John Yigam^{1*}, Narah Welly², Chukhu Naka³, Ajay Bharti⁴

ABSTRACT

Groundwater has always been a major source of drinking water in Itanagar Capital Region (ICR), Arunachal Pradesh. However, the quality of groundwater is getting compromised mainly due to fast urbanisation and man-made activities. Groundwater pollution in terms of heavy metals is quantitatively evaluated in this study using the Heavy Metal Pollution Index (HPI).

Water gathered from wells, borewells, and springs scattered in Itanagar, Naharlagun, and Nirjuli during the pre-monsoon and post-monsoon seasons were tested for resulting concentrations of Fe, Pb, Cr, Cu, Cd, Zn, Hg, and As. Comparison of these values was done with the standards laid down by both Bureau of Indian Standards and World Health Organisation. The assessment results show that the levels of most of the metals are still considered safe. Higher concentrations of Fe, Pb, and Cr have been found only at a few locations. At some locations, pre-monsoon iron concentration was as high as 2.05 mg/L than the permissible limit of 0.3 mg/L. Other two heavy metals Chromium and Lead at Sites 10 and 17 also went beyond the safe limits.

Heavy Metal Pollution Index (HPI) results unveiled that most sites have low to moderate level of heavy metal pollution except the Sites 10, 17, and 20 which showed high pollution levels. It is generally observed that metal concentrations in post-monsoon water tend to be lower than that of pre-monsoon waters. This is a natural consequence of dilution and groundwater recharge. This report points out that, in general, the water quality in ICR is good. At the same time, it highlights that localized regions getting contaminated with a great deal of the elements require not only constant vigilance but also application of specific water treatment techniques.

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1. Introduction

Groundwater is an essential natural resource, forming the backbone of many domestic, agricultural, and industrial applications worldwide (Brindha et al., 2020; Molinari et al., 2018). Especially in developing countries, groundwater is considered the major source of safe drinking water, due to its availability, cost-effectiveness, and purity compared to other sources of water from surface water bodies (Jadoon et al., 2024). Nevertheless, the combination of rampant urbanization, population growth, industrial activities, and poor wastewater disposal practices has led to drastic deterioration of water quality, particularly due to metal pollution (Okeh et al., 2023). The contamination represents an environmental emergency and is based on the natural features of toxic, persistent, and non-biodegradable nature of such contaminants along with their ability to bioaccumulate throughout the food chain (Satyaprakash et al., 2025). The contaminants, including iron, lead, chromium, cadmium, mercury, arsenic, copper, and zinc, enter the underground water resources via the combination of natural and anthropogenic processes (Ullah et al., 2022). Whereas natural weathering of rocks is considered the baseline geogenic source of contamination, the anthropogenic factors, such as urban runoff, leaching from solid waste landfills, sewerage seepage, increased agricultural practices, infrastructure development, pipe corrosion, and vehicle exhausts, contribute substantially to the levels of these toxic elements (Rana et al., 2022). Regular consumption of contaminated water with heavy metals has been reported to cause various pathologies, including neurotoxicity, nephrotoxicity, heart problems, liver problems, developmental defects, and carcinogenic complications (Shayo et al., 2023). As a result, the scientific assessment of groundwater quality concerning its potability through proven indices like the Heavy Metal Pollution Index is essential to determine areas that need urgent action due to elevated levels of pollutants (Olatunji et al., 2026). For instance, in the case of the ICR, the particular geological formation and construction activities have created different avenues for movement of contaminants into underground water supplies (Zhang et al., 2023). The absence of sewage networks in the region may be facilitating contamination of underground aquifers by leachate from pollutants, which may contain hazardous trace metals (Badeenezhad et al., 2023; Han et al., 2023). The issue of contamination becomes even more serious due to the high amount of precipitation that occurs annually within the region and leads to faster leaching of heavy metals from geologic layers and disposed anthropogenic waste (Deepthi et al., 2024; Kaur & Pandey, 2026).

The contamination of groundwater in India is one of the critical problems faced today. The situation is aggravated by urbanization trends and dependence on non-treated sources of drinking water (Anthati, 2025). There have been many scientific observations confirming high levels of heavy metals present in drinking sources in urban and peri-urban areas (Deeksha, 2024; P et al., 2026). Although a considerable body of research has been conducted on the quality of water in various regions of the country, yet there exists an identifiable void of knowledge about the northeast Himalayas, particularly Arunachal Pradesh where the need for groundwater has been rising (Lapworth et al., 2018; NGEMU et al., 2026). ICR, which includes Itanagar, Naharlagun, and Nirjuli, is one of the fast-growing urban settlements in Arunachal Pradesh (Mahato et al., 2021). Considering the fact that access to treated municipal water is insufficient, residents often tend to use raw groundwater such as wells, borewells, and springs. The increasing pressure associated with urbanization and land-use patterns is considered a serious challenge to groundwater quality (Iqbal et al., 2023). The assessment of groundwater pollution with heavy metals is essential for ensuring safe consumption and a consistent supply of potable water (Ullah et al., 2022). The use of HPI provides an excellent basis for analysing such a condition because it integrates different metallic pollutants into a single score (Deeksha, 2024; Olatunji et al., 2026). Utilising the HPI in the present study, an attempt will be made to assess the quality of the ICR groundwater (Ram et al., 2021). The samples were taken during pre-and post-monsoon periods for the determination of concentration levels of iron (Fe), lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), zinc (Zn), mercury (Hg), and arsenic (As). This information was then compared with BIS and WHO standards to determine its suitability for drinking purposes. Moreover, this study provides an insight into the seasonal changes and identifies contaminated zones.

2. Study Area

The case study was done on the Itanagar Capital Region in the Indian state of Arunachal Pradesh (as shown in Fig. 1). The research area includes cities like Itanagar, Naharlagun, and Nirjuli, and it falls in the Eastern Himalaya foothills. The research site falls between the geographic coordinates 27°05'N – 27°15'N latitude and 93°35'E – 93°45'E longitude (as shown in Table 1). The climatic conditions of the research area are marked by humid subtropical weather conditions and monsoonal precipitation patterns (Sandeep et al., 2023).

Table 1: Locations of Sampling Sites in ICR

Site	Groundwater source	Coordinates	Locations
1	Borewell	27°05'15.90"N 93°36'30.96"E	Itanagar, Near RKMH
2	Borewell	27°04'03.30"N 93°35'38.82"E	Itanagar, Chimpu, Near Forest Guest House.
3	Borewell	27°04'09.90"N 93°35'41.34"E	Itanagar, Chimpu, Near RBI Office.
4	Spring Water	27°04'25.32"N 93°35'25.62"E	Itanagar, Gohpur

5	Ring well	27°04'10.86"N 93°37'04.98"E	Itanagar, Lower Chimpu
6	Ring well	27°06'07.50"N 93°37'16.44"E	Itanagar, Mow-II
7	Bore well	27°05'10.70"N 93°37'00.66"E	Itanagar, Abotani Colony
8	Bore well	27°05'19.26"N 93°36'55.92"E	Itanagar, Near State Library Office
9	Bore well	27°05'17.40"N 93°37'05.64"E	Itanagar, near the Panchayat office
10	Bore well	27°04'19.80"N 93°35'43.14"E	Itanagar, Opposite to KV No.2 School
11	Ring well	27°04'54.12"N 93°36'11.34"E	Itanagar, near the BJP office
12	Ring well	27°05'06.90"N 93°36'16.20"E	Itanagar, H-Sector
13	Ring well	27°05'19.56"N 93°41'40.74"E	Naharlagun, Pachin, Near ABVN School
14	Ring well	27°05'14.76"N 93°41'39.66"E	Naharlagun, Pachin, Minister Colony.
15	Bore well	27°05'31.50"N 93°41'32.82"E	Naharlagun, Pachin, Near G.S.S Pachin.
16	Bore well	27°05'29.40"N 93°41'38.10"E	Naharlagun, Pachin Market.
17	Spring water	27°05'19.62"N 93°41'14.16"E	Naharlagun, Tigdo
18	Ring well	27°05'45.12"N 93°40'25.86"E	Naharlagun, Down Press Colony
19	Spring Water	27°06'29.10"N 93°42'42.18"E	Naharlagun, Near G.H.S.S Kankar Nallah
20	Borewell	27°07'58.14"N 93°45'17.34"E	Nirjuli, NERIST Type-I Colony
21	Ring well	27°07'44.58"N 93°45'08.34"E	Nirjuli, P-Sector
22	Bore well	27°07'53.52"N 93°45'12.18"E	Nirjuli, NERIST Type-I Colony
23	Bore well	27°07'49.86"N 93°44'42.06"E	Nirjuli, Near NERIST Powerhouse.
24	Ring well	27°07'53.28"N 93°44'58.62"E	Nirjuli, Near Nirjuli Town Baptist Church.

3. Materials and Methods

Total 24 groundwater samples were taken from different locations within the study area namely Itanagar, Naharlagun, and Nirjuli during pre-monsoon and post-monsoon periods (As illustrated in fig 1). Sources of water collection include wells, ring wells, bore wells, and spring water. Polyethylene terephthalate (PET) bottles were used as a container to collect the samples. Prior to taking the samples, bottles were extensively washed using distilled water and repeatedly rinsed with water to be sampled. Each bottle was labelled with sample ID, location, date, and time of collection (Gabielli et al., 2023). The collected samples were preserved at approximately 5°C and transported carefully for analysis (Belew et al., 2024).

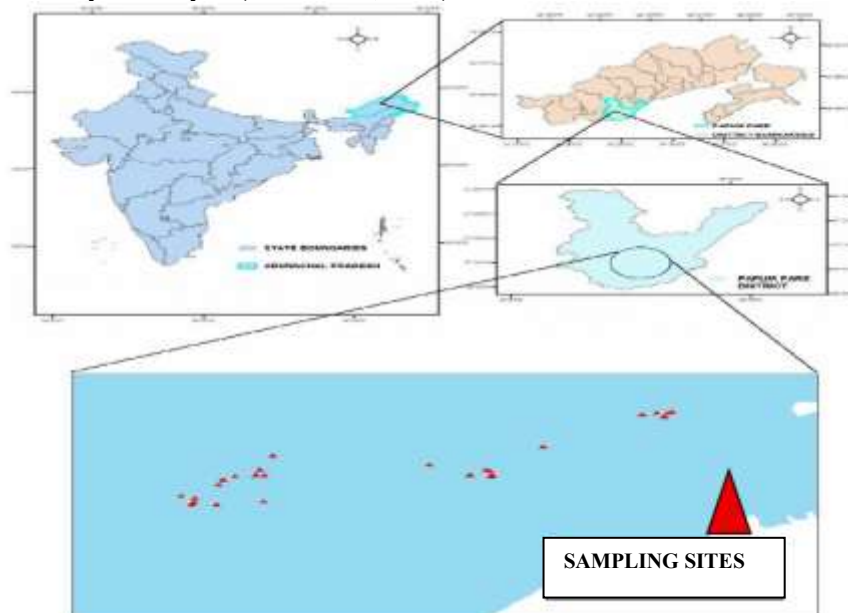


Fig. 1: Map showing the study area and Sampling Sites

The concentrations of Fe, Hg, Cu, Pb, Cr, Cd, As, and Zn were analysed using standard procedures. The obtained concentrations were compared with BIS (IS 10500:2012) (shown in Table 2) and WHO drinking water standards (Shown in Table 3).

Table 2: BIS (IS 10500:2012) Acceptable /Permissible limits for Heavy Metals in Drinking water

Heavy Metal	Acceptable Limit (mg/L)	Permissible limit (mg/L)
Lead	0.01	No relaxation

Iron	0.3	1.0
Cadmium	0.003	No Relaxation
Mercury	0.001	No Relaxation
Arsenic	0.01	0.05
Chromium	0.05	No Relaxation
Copper	0.05	1.5
Zinc	5	15

Table 3: WHO Guidelines for Heavy Metals in Drinking Water

Heavy Metal	WHO guideline Value (mg/L)
Lead	0.01
Iron	No health-based guideline; aesthetic limit \approx 0.3
Cadmium	0.003
Mercury	0.006
Arsenic	0.01
Chromium	0.05
Copper	2
Zinc	No health-based limit

3.1 Heavy Metal Pollution Index (HPI)

The Heavy Metal Pollution Index (HPI) was used to evaluate the overall quality status of groundwater with respect to heavy metal contamination. HPI values were calculated using the weighted arithmetic index method: $HPI = \frac{\sum(W_i Q_i)}{\sum W_i}$, (Prasad et al., 2013; Rahman et al., 2020)

Where, W_i = Unit weight of each parameter and Q_i = Sub-index value of each parameter. The classification of HPI values used in the study was: $HPI < 15$: Low Pollution, $HPI = 15-30$: Medium Pollution, $HPI > 30$: High Pollution (Eid et al., 2024; Singh & Kamal, 2016), shown in Table 4.

Table 4: Classification of HPI values	
HPI value	Level
<15	Low
15-30	Medium
>30	High

4. Results and Discussion

Different variations in concentrations of heavy metals were noticed for samples from different areas in the ICR while carrying out analysis. These variations were compared with standards set by BIS and WHO for drinking water quality. From the variations noted, it is evident that geological and human interventions are responsible for changes in the groundwater.

Table 5: Heavy Metals Concentration during Pre-Monsoon (mg/L)								
Site No.	Fe	Hg	Cu	Pb	Cr	Cd	Zn	As
1	1.05	0	0.03	0.002	0.041	0.001	0.72	0
2	0.78	0	0.025	0.002	0.001	0.001	0.98	0
3	1.03	0	0.031	0.002	0.002	0.002	1.12	0
4	1.01	0	0.041	0.007	0.005	0.003	0.97	0

5	0.98	0	0.045	0.002	0.01	0	0.001	0
6	0.66	0	0.009	0.007	0.035	0.002	0.089	0
7	1	0	0.06	0.004	0.041	0.002	0.087	0
8	1.61	0	0.067	0.006	0.047	0.003	0.891	0
9	0.56	0	0.057	0.002	0.004	0.002	0.97	0
10	0.16	0.001	1.1	0.009	0.07	0	1.2	0
11	0.157	0	0.037	0.002	0.004	0.001	0.97	0
12	0.145	0	0.013	0.002	0.002	0.001	0.951	0
13	0.33	0	0.011	0.002	0.001	0	0.05	0
14	0.3	0	0.27	0.001	0	0	0	0
15	0.18	0	0.17	0	0	0.001	0	0
16	0.25	0	0.21	0.003	0.001	0	0.001	0
17	1.17	0.001	0.001	0.021	0.03	0	0.11	0
18	1.05	0	0.301	0.009	0.01	0.001	0.055	0
19	0.91	0	0.67	0	0	0	0.001	0
20	2.05	0	0.69	0.005	0.012	0.002	0.016	0
21	0.6	0	0	0	0.001	0	0	0
22	1.9	0	0.003	0.002	0	0.001	0.011	0
23	1.05	0	0.003	0	0.003	0.001	0.014	0
24	1.5	0	0.002	0.002	0.010	0	0	0
Mean	0.851	0	0.160	0.004	0.012	0.001	0.42	0

Table 5 illustrates the levels of heavy metals found during the pre-monsoon season. The seasonal variation in groundwater quality was also analyzed post-monsoon, and the results are shown in Table 6 below. Comparing the two seasons will assist in gaining insight into the impact of rainwater, surface water runoff, dilution effects, and human activities on heavy metal concentrations in groundwater sources.

Site No.	Fe	Hg	Cu	Pb	Cr	Cd	Zn	As
1	0.12	0	0.001	0	0.03	0	0	0
2	0.1	0	0	0	0	0	0.002	0
3	0.09	0	0	0	0	0	0	0
4	0.1	0	0.03	0.006	0.025	0.001	0	0
5	0.16	0	0.04	0.002	0.01	0	0.001	0
6	0.06	0	0.002	0	0.02	0	0	0
7	0.09	0	0.01	0.003	0	0	0.002	0
8	0.35	0	0.06	0.005	0.045	0.002	0.002	0
9	0.27	0	0.05	0.002	0.003	0	0	0
10	0.03	0	0.08	0.008	0.065	0.002	0.05	0
11	0.02	0	0.03	0	0	0	0	0
12	0.018	0	0.01	0	0.019	0	0	0
13	0.25	0	0	0	0	0	0.001	0
14	0.2	0	0.1	0	0	0	0	0
15	0.05	0	0.02	0.001	0	0.001	0	0
16	0.17	0	0.01	0	0.002	0	0	0
17	1.05	0	0.04	0.003	0.02	0.002	0.003	0
18	0.9	0	0.03	0.001	0.008	0.001	0.001	0
19	0.75	0	0.01	0	0	0	0	0
20	1.1	0	0.003	0.002	0.002	0.001	0.007	0
21	0.6	0	0	0	0	0	0	0
22	1	0	0.001	0.001	0	0	0.001	0
23	0.9	0	0.002	0	0.001	0.001	0.003	0

24	1	0	0.001	0.001	0.002	0	0	0
Mean	0.391	0	0.022	0.002	0.011	0.001	0.003	0

4.1 Seasonal Variation of Heavy Metals

The concentration of heavy metals in groundwater samples collected from the ICR changed noticeably from season to season (Table 7). In general, higher concentrations of heavy metals were observed during the pre-monsoon season, whereas comparatively lower concentrations were recorded after the monsoon. This seasonal reduction may be attributed to the dilution of contaminants resulting from rainfall infiltration and the recharge of groundwater aquifers. Among the analysed metals, iron (Fe) was consistently detected at the highest concentrations across most sampling locations, followed by copper (Cu) and zinc (Zn). Although the concentrations of most heavy metals remained within the prescribed limits, elevated levels of chromium (Cr) and lead (Pb) were recorded at a few sites, suggesting the presence of localised sources of contamination within the study area.

Heavy Metal	Pre-Monsoon (mg/L)	Post-Monsoon (mg/L)
Fe	0.82	0.56
Pb	0.012	0.007
Cr	0.041	0.033
Cu	0.065	0.051
Cd	0.002	0.001
Zn	0.154	0.121
Hg	0.0004	0.0002
As	0.003	0.002

The overall reduction of heavy metal concentration during post-monsoon indicates the influence of monsoonal recharge on groundwater quality. Similar seasonal trends have been reported in groundwater studies conducted in other parts of Northeast India and the Himalayan regions.

4.2 Iron (Fe)

Iron was found to be the dominant heavy metal in the groundwater samples. The concentration of Fe ranged from 0.145 mg/L (at site 12) to 2.05 mg/L (at site 20) during the pre-monsoon season and from 0.018 mg/L (at site 12) to 1.1 mg/L (at site 20) during the post-monsoon season (Shown in Table 5). The maximum Fe concentration was recorded at Site-20 during the pre-monsoon season, exceeding the BIS permissible limit of 1.0 mg/L. Elevated iron concentration in groundwater may be associated with natural weathering of iron-bearing rocks and soil minerals present in the region. In addition, corrosion of pipelines and anthropogenic Activities may also contribute to increased Fe concentration at certain locations. The excessive concentration of iron may affect the taste, staining properties, and overall acceptability of drinking water. Long-term consumption of water containing elevated iron concentration may also pose health concerns.

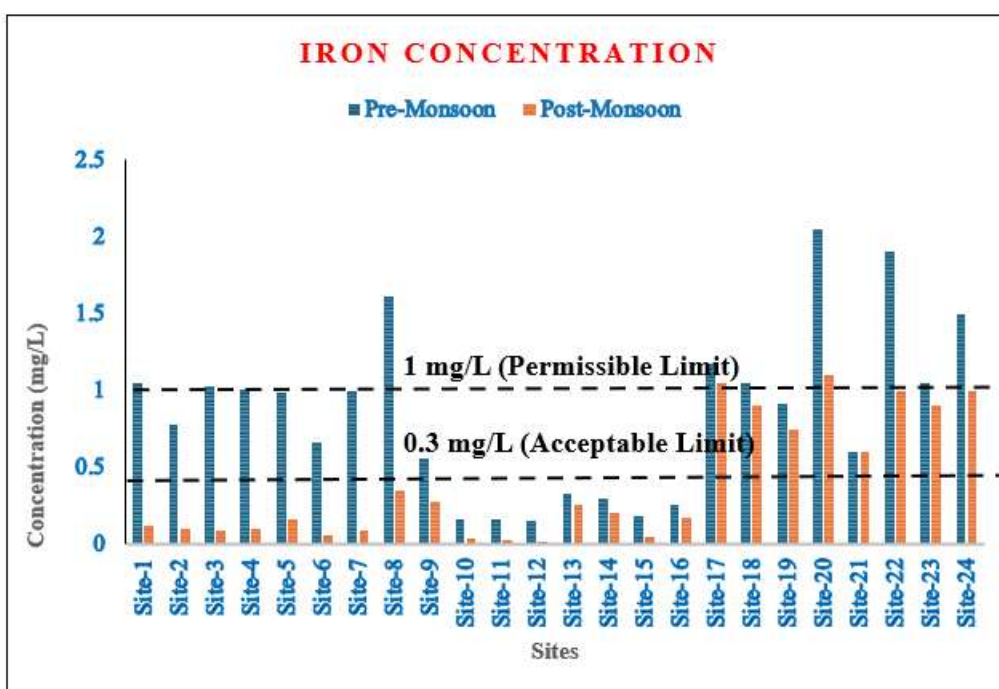


Fig. 2: Concentration of Iron at different Sites during Pre & Post Monsoon

4.3 Chromium (Cr)

Chromium concentration exceeded the permissible limit of 0.05 mg/L at Site-10 during both seasons. The recorded concentrations were 0.07 mg/L during the pre-monsoon and 0.065 mg/L during the post-monsoon season (Shown in fig 3).

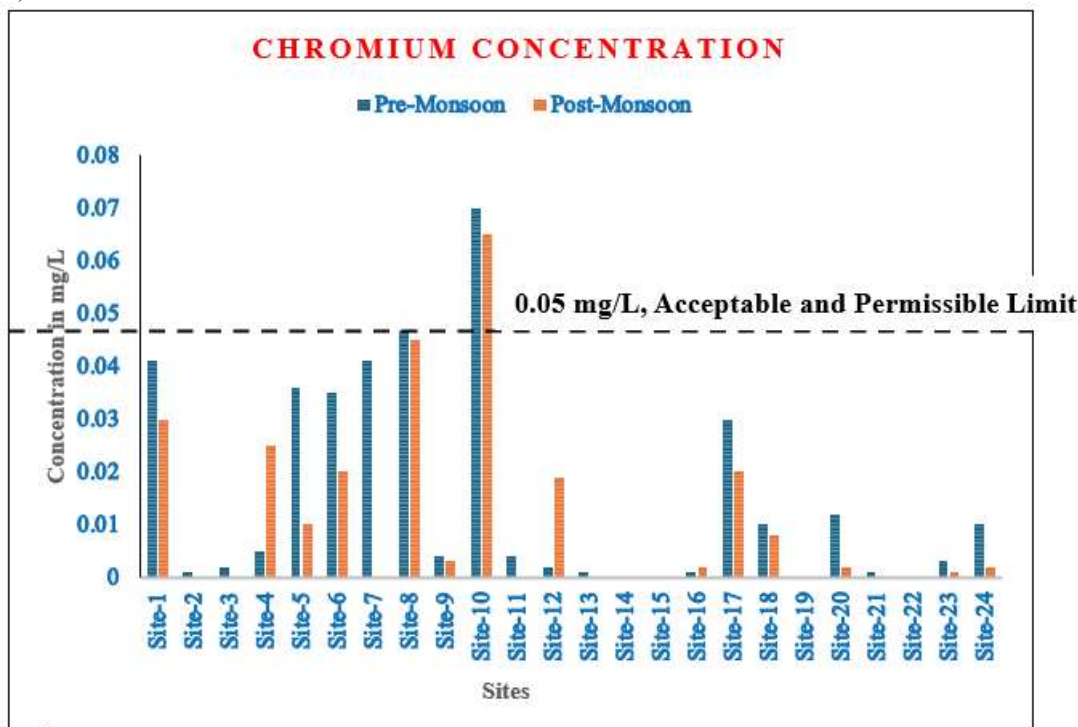


Fig. 3: Concentration of Chromium at different Sites during Pre & Post Monsoon

The persistence of chromium contamination during both seasons indicates localized contamination sources. Possible sources may include urban runoff, waste disposal activities, construction-related materials, and leaching from surrounding geological formations. Chromium contamination is considered hazardous because prolonged exposure may cause skin irritation, kidney damage, respiratory disorders, and carcinogenic effects.

4.4 Lead (Pb)

Lead concentration exceeded the permissible limit of 0.01 mg/L at Site-17 during the pre-monsoon season, with a recorded value of 0.021 mg/L (Shown in fig 4). However, post-monsoon concentration showed comparatively lower values due to dilution effects.

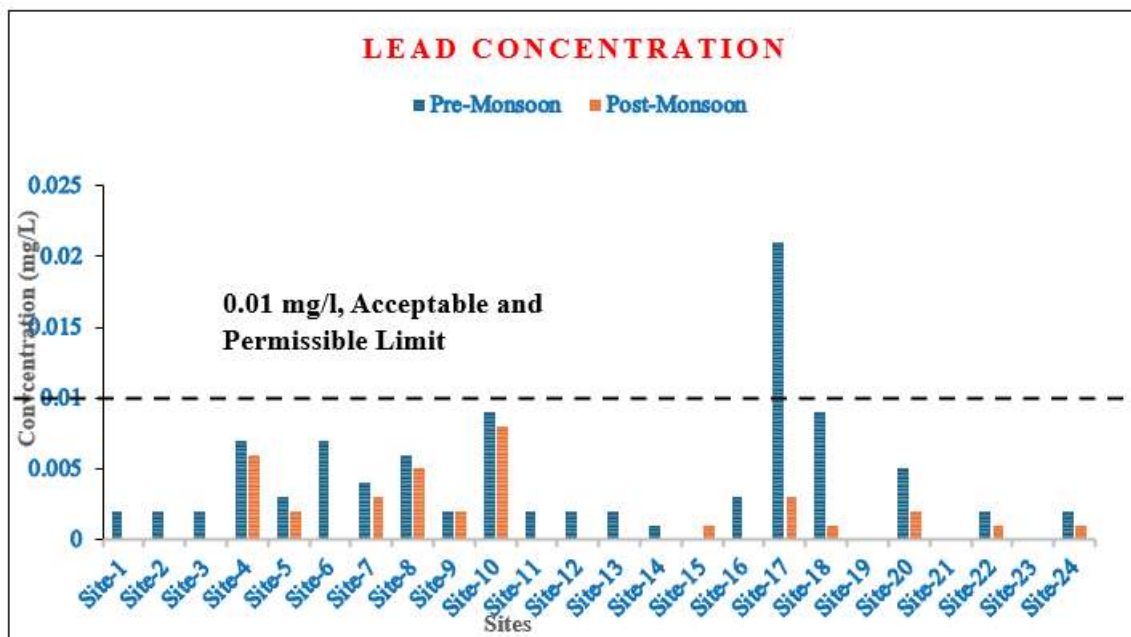


Fig. 4: Concentration of Lead at different Sites during Pre & Post Monsoon

Possible sources of lead contamination include corrosion of old water supply pipelines, vehicular emissions, municipal waste disposal, and urban runoff. Lead is highly toxic even at low concentrations and may adversely affect the nervous system, kidney function, and cognitive development, particularly among children (Rosen et al., 2017; Sankhla, 2019).

4.5 Mercury (Hg), Copper (Cu), Cadmium (Cd), Arsenic (As) and Zinc (Zn).

Cadmium levels were within the allowed maximum level at every sampling site during both seasons (See Fig. 7). Initially the copper and zinc concentrations were a bit high at some places during the pre-monsoon season, but all the results were still meeting the drinking water standard limits (See Fig. 6 and 9). Level of Cadmium, Copper, Zinc, Mercury, and Arsenic in the water samples mainly corresponded with the safety limits of BIS and WHO guidelines. When small amounts of these metals were found, the most probable sources were natural geochemical cycling, urban discharges, household waste, and local human activities.

Being extremely toxic heavy metals, cadmium and mercury were, on the whole, either not present or only detected at very low levels (Shown in Fig. 5), therefore industrial effect in the study area can scarcely be considered. The amounts of copper and zinc in the samples were below the limits set by the safety authorities, which infers a scarcity of contamination either from geogenic sources or from the plumbing system. The levels of arsenic, although conforming to the legal standards (Shown in Fig. 8), just being detected at very low concentration levels means that the authorities need to keep a close watch because of the possibility of long-term health issues due to the carcinogenic nature of arsenic.

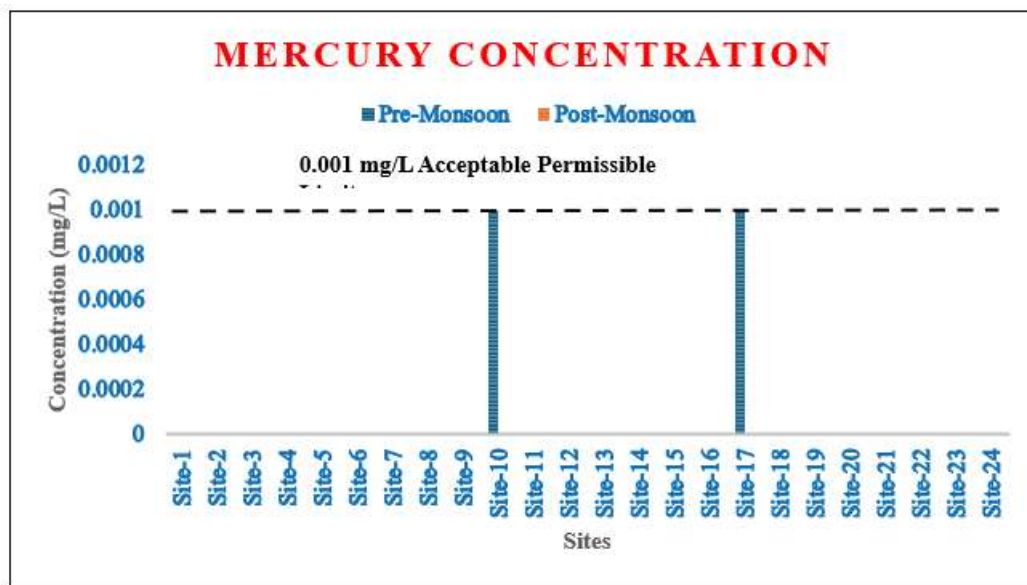


Fig 5: Concentration of Mercury at different Sites during Pre & Post Monsoon

Mercury and arsenic in the study area were either not at the level of detection or found in very small amounts, which means that the risk of contamination from these two metals is relatively low.

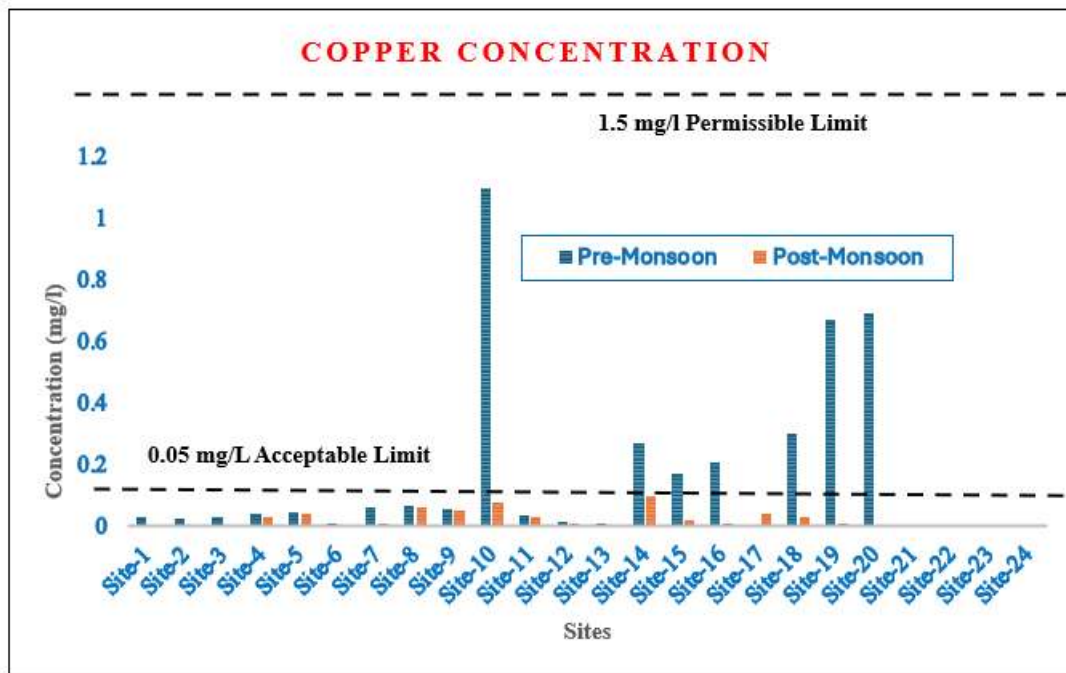


Fig. 6: Concentration of Copper at different Sites during Pre & Post Monsoon

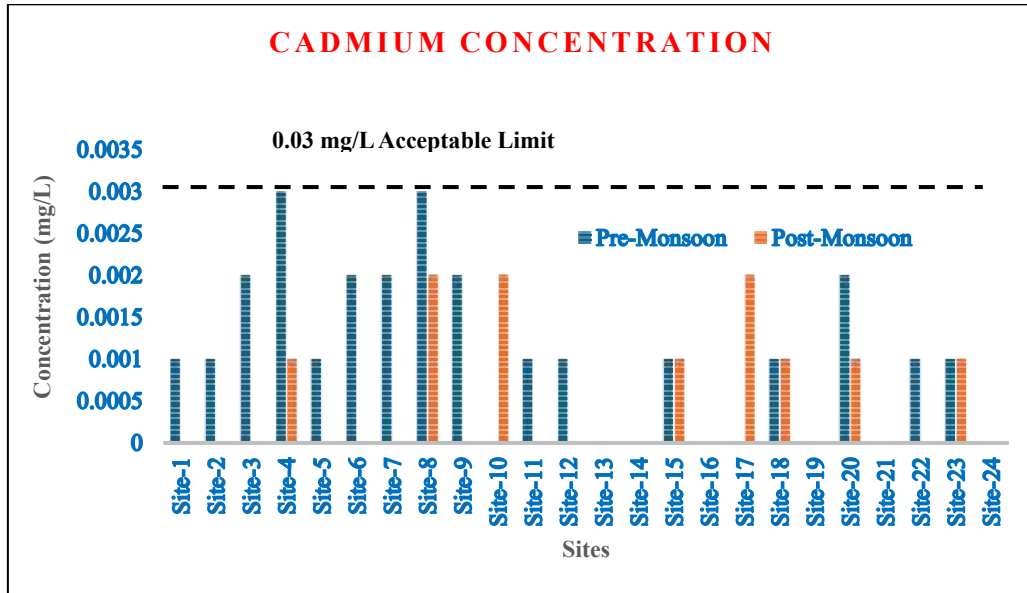


Fig. 7: Concentration of Cadmium at different Sites during Pre & Post Monsoon

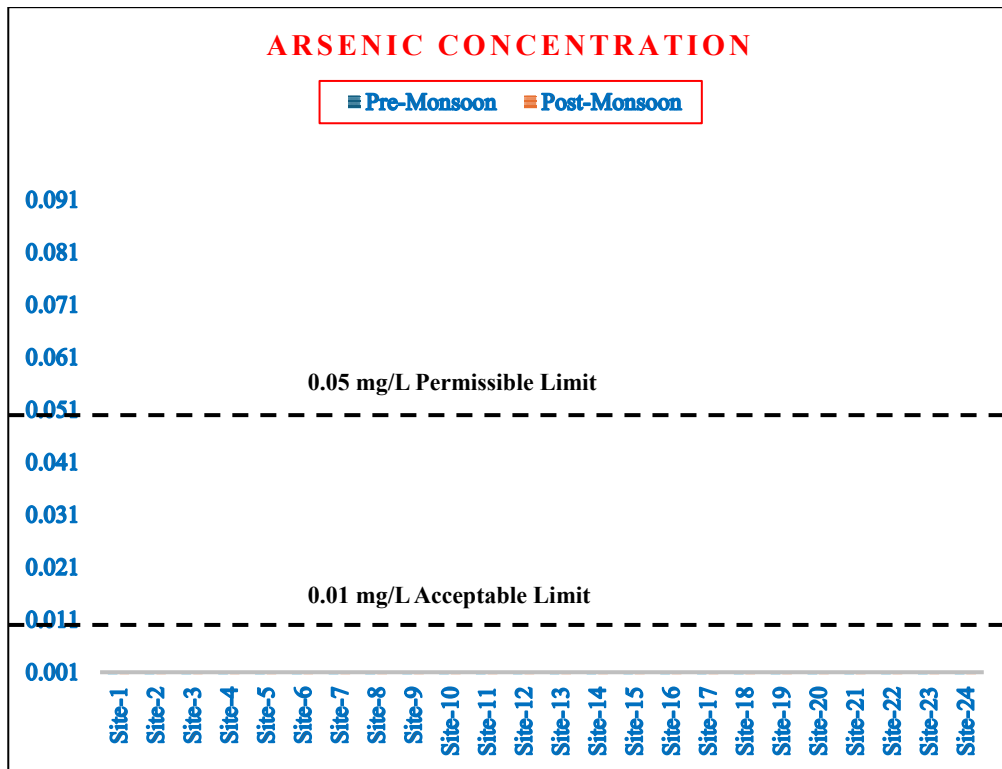


Fig. 8: Concentration of Arsenic at different Sites during Pre & Post Monsoon

The data suggest that the groundwater resources within the ICR currently remain within safe limits concerning Cadmium, Copper, Zinc, Mercury, and Arsenic contamination. Notwithstanding this, ongoing surveillance and the implementation of robust management strategies are essential to avert potential future degradation of groundwater quality as a result of escalating urbanisation and anthropogenic pressures

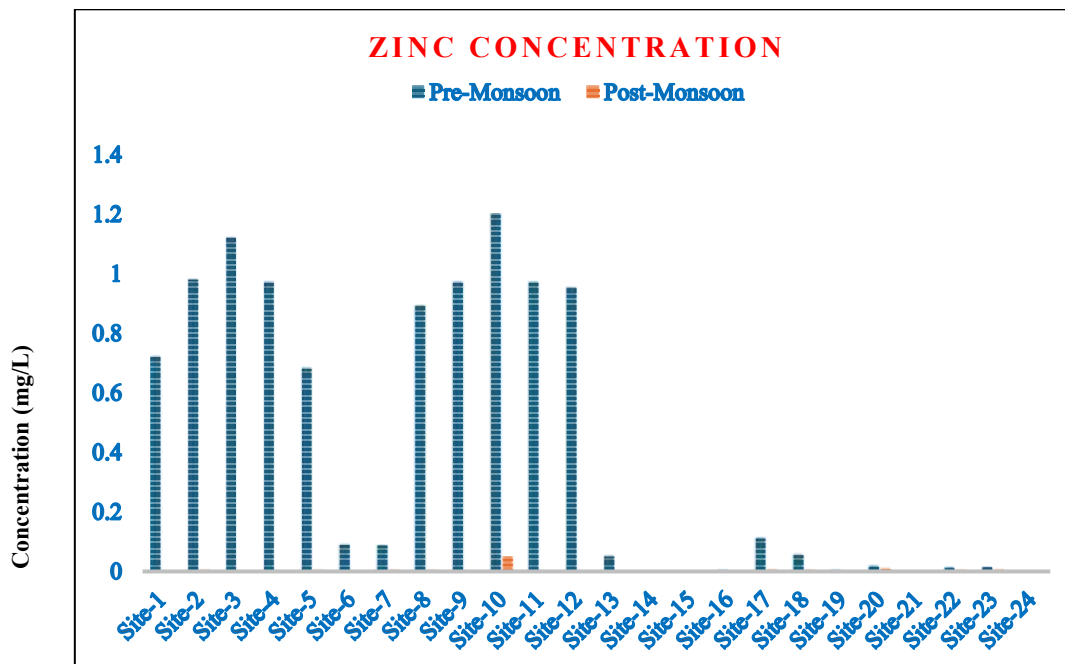


Fig. 9: Concentration of Zinc at different Sites during Pre & Post Monsoon

The comparatively low concentration of these heavy metals suggests that groundwater in most parts of the study area remains suitable for drinking purposes with respect to these parameters.

4.6 Heavy Metal Pollution Index (HPI)

Heavy Metal Pollution Index (HPI) were calculated to assess the overall groundwater pollution status of the study area. The calculated HPI values varied significantly among sampling locations (Shown in Table 8 and fig 10).

Table 8: HPI of Ground Water at different locations of ICR

Site No.	HPI			
	Pre-Monsoon	Level	Post-Monsoon	Level
1	10.857	Low	0.8709	Low
2	9.526	Low	0.071	Low
3	16.927	Medium	0.064	Low
4	27.459	Medium	12.321	Low
5	3.227	Low	2.649	Low
6	20.113	Medium	0.6	Low
7	19.896	Medium	2.219	Low
8	28.972	Medium	20.174	Medium
9	17.305	Medium	2.803	Low
10	98.919	High	22.865	Medium
11	9.468	Low	0.775	Low
12	8.799	Low	0.748	Low
13	1.805	Low	0.176	Low
14	7.694	Low	2.677	Low
15	11.485	Low	8.223	Low
16	7.431	Low	0.424	Low
17	78.345	High	18.257	Medium
18	21.382	Medium	9.278	Low
19	17.636	Medium	0.782	Low
20	36.515	High	9.216	Low
21	0.448	Low	0.423	Low
22	9.729	Low	1.364	Low
23	7.938	Low	7.756	Low

24	2.629	Low	1.414	Low
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Most sampling sites were categorised under low and medium pollution classes, indicating acceptable groundwater quality. However, certain locations exhibited high HPI values during the pre-monsoon season.

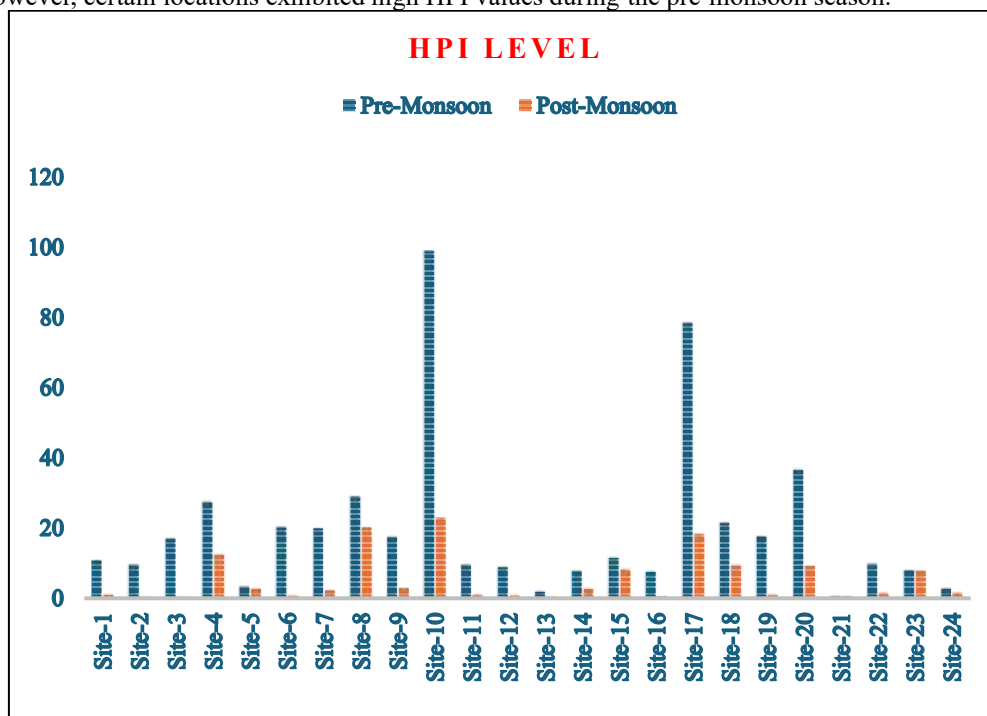


Fig. 10: HPI at different Sites during Pre & Post Monsoon.

Elevated levels of Fe, Pb, and Cr in Sites 10, 17, and 20 could be the reason for the high HPI values. The HPI values dropped in more than half of the places after the monsoon season mainly because of the recharge of the groundwater and dilution effects. The HPI results show that groundwater in the Itanagar Capital Region is quite good globally although some contamination spots can be frequently monitored and given management intervention without delay.

4.7 Comparison with Drinking Water Standards

The concentrations of heavy metals measured were compared with the BIS (IS 10500:2012) and WHO standards for drinking water. Most groundwater samples remained within permissible limits for consumption. But, the elevated levels of Fe, Pb & Cr in few locations highlight health risks that could arise due to continuous consumption of such water (Table 10).

Table 10. Comparison of the maximum observed concentration with the BIS permissible limits

Parameter	Maximum Observed Value (mg/L)	BIS Limit (mg/L)
Fe	2.05 at the Site 20	0.30
Pb	0.021 at Site17	0.010
Cr	0.070 at Site 10	0.050
Cd	0.003 at Site 8	0.003
Cu	1.1 at Site 10	0.050
Zn	1.2 at Site 10	5.000

5. Conclusion

The present investigation assessed the extent of heavy metal contamination in groundwater sources of the Itanagar Capital Region (ICR), Arunachal Pradesh, through the application of the Heavy Metal Pollution Index (HPI). Analysis of groundwater samples collected during the pre-monsoon and post-monsoon seasons revealed clear seasonal variations in the concentration of heavy metals. Among the analysed metals, iron (Fe) was found in the highest concentration and exceeded the permissible limit prescribed for drinking water at several sampling locations, with the maximum concentration recorded at Site-20. Elevated concentrations of chromium (Cr) and lead (Pb) were also observed at a few locations, exceeding the limits recommended by BIS standards and indicating the presence of localised contamination within the study area.

A comparison of seasonal data showed that heavy metal concentrations were generally higher during the pre-monsoon period. In contrast, lower concentrations recorded during the post-monsoon season may be attributed to the dilution effect of rainfall and enhanced groundwater recharge. The concentrations of cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), and copper (Cu) remained within the acceptable limits for drinking water at most of the sampling sites throughout the study period.

The HPI assessment indicated that the majority of groundwater samples fell within the low to medium pollution categories, suggesting that groundwater in most parts of the Itanagar Capital Region is presently suitable for domestic consumption. Nevertheless, comparatively high HPI values observed at Sites 10, 17, and 20 warrant special attention and regular monitoring. These findings suggest that increasing urban development, human activities, and inadequate waste management practices may be contributing to the deterioration of groundwater quality in certain parts of the region.

To ensure the long-term safety and sustainability of groundwater resources, continuous monitoring programmes should be strengthened, along with the adoption of effective waste management practices and regular maintenance of water supply infrastructure. Where necessary, appropriate treatment measures should also be implemented to safeguard drinking water quality and protect public health in the Itanagar Capital Region.

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