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**Guruprasad E. Ghadi**
A.S.P. College (Autonomous)
**Hemant V. Chavan**
A.S.P. College (Autonomous)
**Sardar A. Patil**
sardarpatilasp@gmail.com
A.S.P. College (Autonomous)

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# Groundwater Potential and Quality in Rapidly Urbanising Region of Chiplun, Ratnagiri District (Maharashtra, India): A Geo-Statistical and Hydro-Chemical Analysis

**Guruprasad E. Ghadi[1], Hemant V. Chavan[2], Sardar A. Patil[1,*]**

[1]Department of Geography, A.S.P. College (Autonomous), Devrukh, Dist. Ratnagiri-415804, MH, India.

[2]Department of Chemistry, A.S.P. College (Autonomous), Devrukh, Dist. Ratnagiri-415804, MH, India.

[*]Corresponding author: sardarpatilasp@gmail.com

## ABSTRACT

Groundwater is a vital freshwater resource, particularly in regions with seasonal variations in surface-water availability. This study evaluates the groundwater potential and quality of Chiplun Town and its adjoining region in Ratnagiri District, Maharashtra, India, using an integrated approach that considers groundwater occurrence, yield, physicochemical characteristics, and the Water Quality Index (WQI). A total of 182 groundwater samples, comprising 91 monsoon and 91 post-monsoon samples collected during 2023, were analysed for turbidity, pH, TDS, alkalinity, chloride, fluoride, nitrate, sulphate, total hardness, and iron. Groundwater depth generally ranged from 30–80 m below ground level, with several areas showing favourable yields exceeding 800 L/min, indicating considerable groundwater potential. Physicochemical parameters generally fell within BIS drinking-water limits, with only moderate seasonal variation. WQI assessment classified 12 monsoon samples as Excellent and 79 as Good, while post-monsoon samples included 15 Excellent, 75 Good, and one Poor. The mean WQI increased slightly from 29.44 to 30.71, indicating a minor seasonal decline while maintaining predominantly good water quality. Overall, the study demonstrates considerable groundwater potential and generally good groundwater quality in the Chiplun region. The findings provide a scientific basis for groundwater monitoring, recharge-zone protection, controlled abstraction, and sustainable water-resource management.

**Keywords:** Groundwater potential; Groundwater quality; Chiplun; Ratnagiri; Geostatistical, Hydrochemical Physicochemical parameters; Water Quality Index; Seasonal variation

## 1. Introduction

Freshwater is an indispensable yet finite natural resource supporting human life, ecosystems, agriculture, industry, and socioeconomic development. Although rivers, lakes, reservoirs, ponds, and dams are important water sources, groundwater is a major component of the hydrological system because of its widespread occurrence, natural storage capacity, and relatively stable availability year-round. Groundwater also interacts closely with surface-water systems and contributes to streamflow during dry periods while supporting aquatic ecosystems [1].

Beyond availability, water quality is essential for human health and sustainable resource management. Drinking water must meet prescribed physical, chemical, and microbiological requirements. In India, the Bureau of Indian Standards (BIS) specifies drinking-water quality requirements under IS 10500:2012, covering physicochemical characteristics, inorganic constituents, toxic substances, pesticides, and microbiological parameters. Therefore, systematic groundwater-quality assessment is necessary to determine its suitability for domestic use and identify areas requiring appropriate management.

Globally, water scarcity is increasingly associated with both declining water availability and deteriorating water quality [2]. In India, population growth, urbanisation, agricultural intensification, industrial development, changing land use, and increasing water demand are placing considerable pressure on groundwater resources. Climatic, geological, geomorphological, topographic, soil, hydrological, and anthropogenic factors control groundwater availability. Rainfall and recharge influence groundwater availability, while lithology, permeability, porosity, fractures, drainage, land use, and groundwater abstraction affect its storage and movement. Studies in developing Indian cities have reported that rainfall variability, land-use changes, excessive pumping, and rising water demand significantly affect groundwater sustainability [3].

Groundwater quality is governed by both natural hydrogeochemical processes and anthropogenic activities. Mineral weathering, dissolution, ion exchange, evaporation, recharge conditions, and groundwater–rock interactions influence its chemical composition, while domestic wastewater, agricultural runoff, industrial effluents, and improper waste disposal may introduce contaminants. Previous studies in Maharashtra have reported spatial variations in groundwater chemistry, including elevated nitrate and fluoride levels, emphasising the need for site-specific assessment [4].

Chiplun town and its adjoining region in Ratnagiri district, Maharashtra, provide an important setting for groundwater investigation because of the Vashishti River, Khopad Dam, and the Check Dam at Kamathe–Kapsal. These surface-water bodies may influence groundwater recharge and distribution. Wells, community wells, and boreholes are important water sources for local communities. However, the presence of surface-water and groundwater resources does not necessarily ensure groundwater suitability for human consumption. Seasonal recharge, groundwater–surface-water interactions, local geology, urbanisation, wastewater generation, agricultural activities, and other anthropogenic pressures may cause spatial variations in groundwater quality.

Therefore, an integrated assessment of groundwater potential and quality is needed to understand the region's actual water-resource status. Accordingly, the present study evaluates groundwater potential and physicochemical quality in Chiplun town and its adjoining region in Ratnagiri district, Maharashtra. The study assesses the spatial distribution and availability of groundwater, evaluates its suitability for domestic use against prescribed drinking-water standards, and identifies spatial variations in groundwater quality. The findings are intended to provide a scientific basis for sustainable groundwater utilisation, conservation, and water-resource planning in the region.

## 2. Materials and Methods

### 2.1. STUDY REGION:

The study was conducted in Chiplun Town and its adjoining region of Ratnagiri District, Maharashtra, India. The region forms part of the Konkan coastal belt and is characterised by high monsoonal rainfall, varied topography, and diverse geological formations. The Vashishti River and associated surface-water systems influence the local hydrological conditions. The latitudinal and longitudinal extent of the study region is 17°29’07.83”

north to 17°34’52.02” north and 73°27’01.16” east to 73°33’57.70” east, respectively. (NOAA, 2019) The average elevation of the study region above MSL is about 80.85 meters, with very low relative height except for some hills. According to the 2011 census, the population of Chiplun town is 55139 persons, and 41,419 persons for the adjoining area. (Census of India, 2011) The adjoining region includes Chinchghari, Dhamanvane, Kalambaste, Kaluste, Kapsal, Karjikar Mohalla, Kherdi (CT), Khopad, Kondhe, Majarekashi, Mirjoli, Shiral, Pedhe, Pedhe Parshuram, Uktad, and Walope. **Figure 1 shows** the study region and the locations of the water samples.

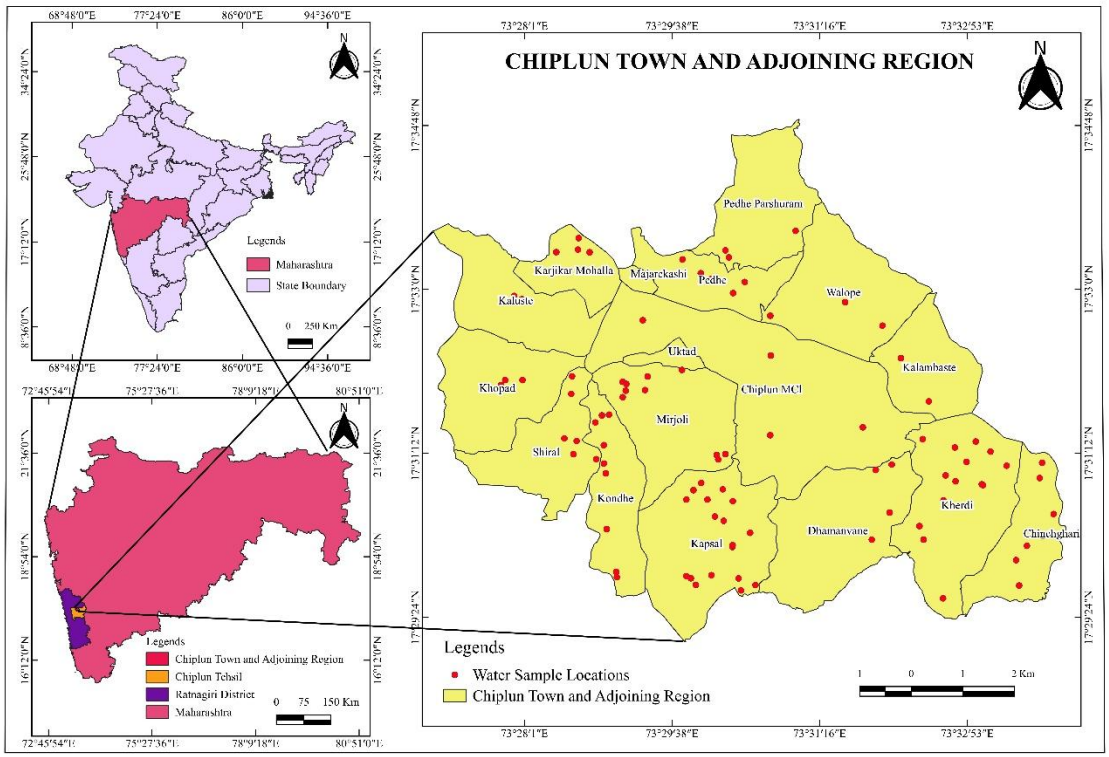


**Figure 1.** The location of the study region

## 2.2 Groundwater Potential Assessment

Groundwater potential was assessed using field observations and spatial evaluation of groundwater depth and yield, together with relevant geological and physiographic characteristics. Groundwater occurrence was evaluated based on lithology, topography, drainage, recharge conditions, geological structures, and proximity to surface-water bodies. Groundwater depth and yield data were compiled for different locations and classified into suitable ranges to identify areas with relatively favourable groundwater potential. Spatial variations in groundwater conditions were subsequently interpreted to

delineate areas of comparatively shallow/deep groundwater occurrence and low- to high-yield zones with spatial interpolation techniques in QGIS.

## 2.3 Groundwater Sampling and Analysis

Researchers collected 182 groundwater samples during the 2023 monsoon and post-monsoon seasons, comprising 91 samples from each season. Researchers collected samples from representative groundwater sources, including wells and borewells, across different villages/localities within the study region. Researchers recorded sampling locations using an Oregon 550 GPS, along with source type and collection dates for each sample.

The collected samples were analysed for selected physicochemical parameters, namely turbidity, pH, total dissolved solids (TDS), alkalinity, chloride, fluoride, nitrate, sulphate, total hardness, and iron. All water samples were tested at the laboratory of the Ratnagiri District Groundwater Development Agency (Maharashtra, India), in accordance with the BIS standards listed below. Researchers followed standard procedures for sample preservation, handling, and physicochemical analysis. The researchers compared the analytical results with the applicable Bureau of Indian Standards (BIS) drinking-water specifications to assess suitability for domestic use.

**Table 1.** Parameters and normal values for drinking water

| Sr. No. | Test Parameter | BIS Specification 10500:2012 Normal Values | |
|---|---|---|---|
| | | Desirable Limits | Permissible Limits |
| 1 | Turbidity (as N.T.U.) | 1.0 | 5.0 |
| 2 | pH Value | 6.5 to 8.5 | No relaxation |
| 3 | Chlorides ($Cl^-$) | 250 | 1000 |
| 4 | Nitrates (as $NO_3$) | 45 | No relaxation |
| 5 | Total Hardness (as $CaCO_3$) | 200 | 600 |
| 6 | Alkalinity (as $CaCO_3$) | 200 | 600 |
| 7 | Total Dissolved Solids (TDS) | 500 | 2000 |
| 8 | Iron (as Fe) | 0.3 | No relaxation |
| 9 | Fluoride (as F) | 1.0 | 1.5 |

Source : ; Water Testing Report from Chiplun Municipal Council

## 2.4 Statistical and Seasonal Analysis

Descriptive statistical parameters, including minimum, maximum, mean, median, mode, and standard deviation, were calculated for the analysed physicochemical parameters for both sampling seasons. Seasonal variations between monsoon and post-monsoon conditions were examined to identify changes in groundwater quality. Spatial interpolation techniques were used to represent the spatial distribution of individual parameters and to identify locations showing relatively higher or lower concentrations.

### 2.5 Water Quality Index (WQI)

The **Water Quality Index (WQI)** was calculated using the methodology and equation described in the study. The selected physicochemical parameters were assigned appropriate weights according to their relative importance to drinking-water quality. Parameter quality ratings and weighted contributions were calculated, and the resulting values were summed to obtain the WQI for each groundwater sample.

Based on the parameter values for each site, the Water Quality Index is calculated using the following equation.

$$WQI = \frac{\sum Qi \times Wi}{\sum Wi} (Brown\ et\ al., 1970)$$

whereas,

$$Wi = \frac{k}{Si} (Brown\ et\ al., 1970)$$

and

$$Qi = \frac{Vi}{Si} \times 100 (Brown\ et\ al., 1970)$$

Based on the above equation, an Excel template was prepared using an advanced Excel tool. Additionally, the multiple linear regression model in SPSS was used to determine the correlation between pH and other parameters. Spatial interpolation techniques in QGIS were used to map spatial patterns of water quality in the study region.

The calculated WQI values were classified into different water-quality categories ranging from Excellent to Poor, with lower WQI values representing better water quality. The WQI results were used to evaluate seasonal variations and spatial patterns in groundwater quality across the study area.

### 2.6 Spatial Assessment

Spatial assessment examined the distribution of groundwater potential and quality across the study region. Sampling locations and groundwater-quality observations were spatially interpreted to identify areas of favourable groundwater potential and variations in WQI. The resulting spatial information was used to characterise groundwater conditions and support an integrated assessment of groundwater availability and quality.

### 2.7 Integrated Assessment

Finally, groundwater potential and quality results were integrated to identify areas having favourable groundwater resources and generally suitable water quality. The combined assessment of groundwater occurrence, yield, physicochemical characteristics, and WQI provides a basis for evaluating the status of groundwater resources and developing appropriate measures for groundwater monitoring, recharge-zone protection, controlled abstraction, and sustainable groundwater management in the Chiplun region.

## 3. Results and Discussion

### 3.1 Groundwater Potential

Groundwater is an important water source for settlements in the Konkan region. In the present study area, groundwater potential is influenced by lithology, heavy monsoonal rainfall, topography, drainage characteristics, and proximity to the Vashishti River. Field observations indicate considerable spatial variation in groundwater depth, with most areas showing groundwater levels of approximately 30–80 m BGL, while relatively shallow groundwater (<30 m BGL) occurs in Shiral, southern and southeastern Khopad, eastern Mirjoli, northern Kapsal, parts of Kondhe, Pedhe, Pedhe-Parshuram, and southern Chiplun.

Groundwater depths of 30–80 meter Below Ground Level (BGL) are observed across Chiplun town, Uktad, Walope, Kalambaste, Kherdi, Chinchghari, Kapsal, Khopad, Mirjoli, Kondhe, Dhamanavane, Karjikar Mohalla, and Kaluste. Deeper groundwater levels (>80 m BGL) are mainly associated with relatively elevated and hilly areas. Figure 2 shows the spatial distribution of groundwater levels**.**

The groundwater-yield map (**Figure 3**) shows substantial spatial variability. Most parts of the study area exhibit yields of 50–100 LPM, whereas southwestern Kapsal, western Khopad, western Kaluste, southern Kondhe, and parts of Shiral and Karjikar Mohalla show yields of 400–800 LPM. High groundwater potential, with yields >800 LPM, occurs in Pedhe-Parshuram, Walope, southern Kherdi, Chinchghari, major parts of

Dhamanavane, Shiral, eastern Kaluste, central Karjikar Mohalla, eastern Mirjoli, southern Chiplun, eastern Kalambaste, northern Kondhe, western Mirjoli, and western Chiplun (Gowalkot).

The observed variation indicates that groundwater potential is controlled not only by groundwater depth but also by lithology, permeability, recharge conditions, geological structures, and groundwater–surface-water interaction. Overall, the study region exhibits favourable groundwater potential in several locations, particularly those showing yields above 800 LPM, which may be important for sustainable groundwater development.

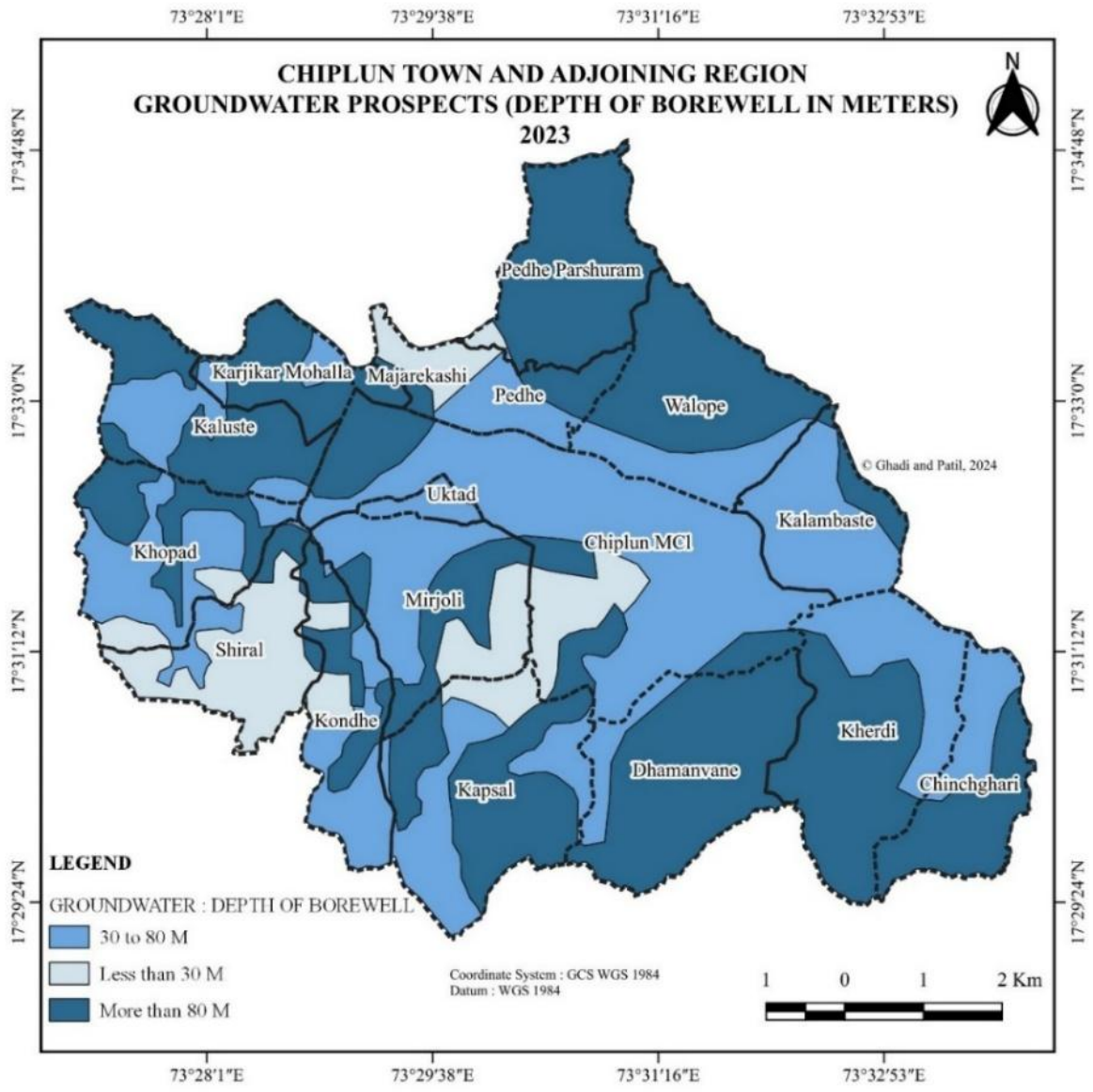


*Figure 2: The spatial distribution of groundwater levels*

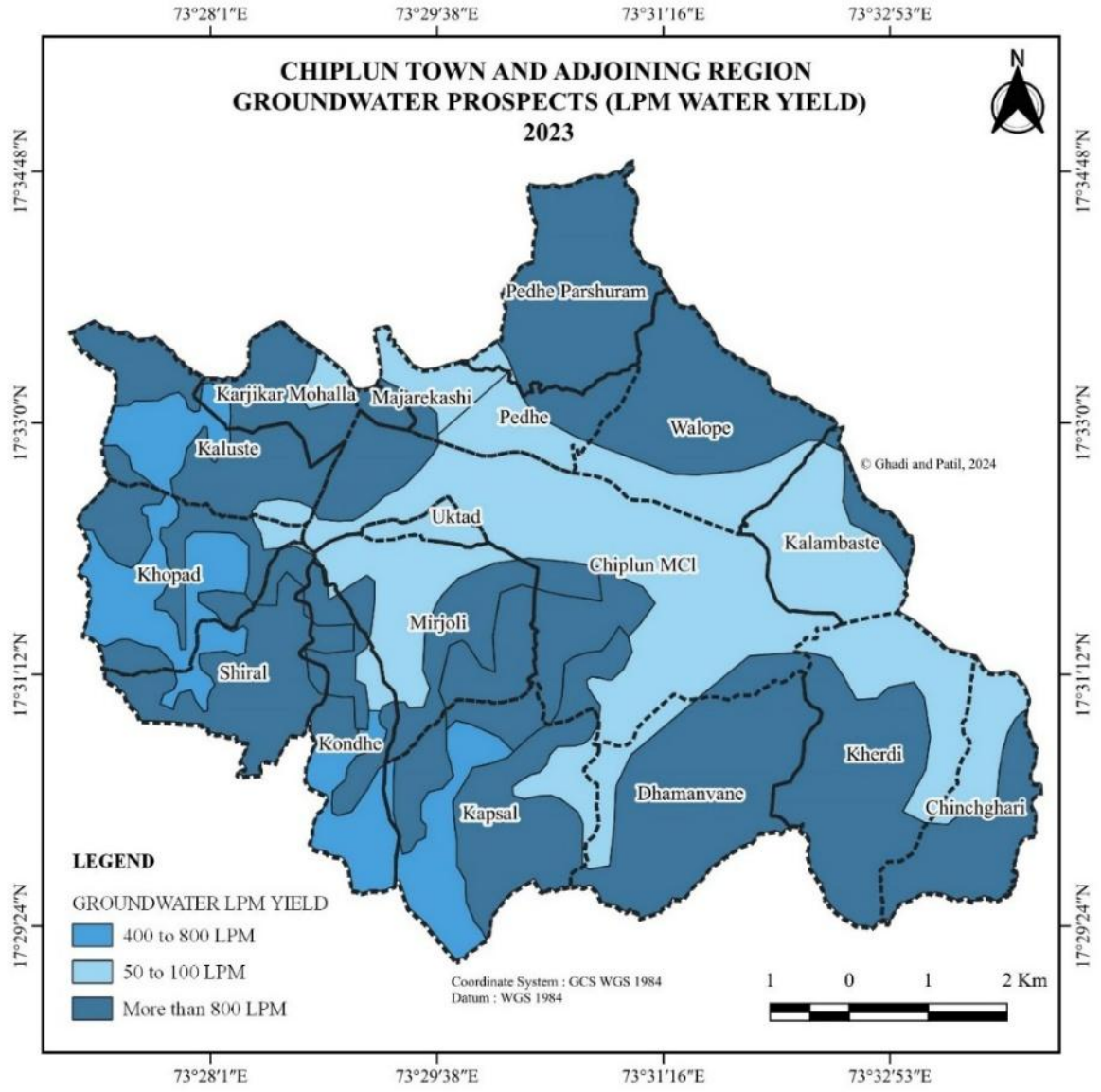


*Figure 3: The groundwater-yield map (Source: Ministry of Drinking Water and Sanitation [5])*

### 3.2 Water Quality Analysis

Water quality is generally assessed using physical, chemical, and biological parameters. In the present study, turbidity, pH, TDS, alkalinity, chloride, fluoride, nitrate, sulphate, total hardness, and iron were selected as key physicochemical parameters for evaluating groundwater quality [6,7,8].

Researchers collected 182 groundwater samples from the study region: 91 during the monsoon and 91 during the post-monsoon season of 2023. The samples were analysed for the above parameters, and Tables 2 and 3 present the results. The tables also provide information on sampling location, source type, sampling date, Water Quality Index (WQI), and overall water-quality classification.

The analytical results indicate that the measured physicochemical parameters were within the permissible limits prescribed by BIS for drinking water. The WQI assessment further shows that 17 samples during the monsoon and 15 samples during the post-monsoon season were classified as having excellent water quality. The remaining samples fall into other WQI categories, indicating spatial and seasonal variations in groundwater quality. The individual parameters are discussed below.

### 3.2.1 Turbidity

Turbidity indicates water cloudiness caused by suspended particles such as clay, silt, and other particulate matter. In the study region, turbidity values ranged from 0.03–1.65 NTU during the monsoon and 0.06–3.05 NTU during the post-monsoon season (**Figure 4**). About 94.51% of the monsoon samples and 85.71% of the post-monsoon samples recorded turbidity below 1.00 NTU. Some locations showed slightly higher values, including Kapsal, Walope, Mirjoli, Khopad, Kondhe, Karjikar Mohalla, and Shiral.

The mean turbidity increased from 0.28 NTU during the monsoon to 0.41 NTU during the post-monsoon season, while the median and mode remained unchanged at 0.16 and 0.11 NTU, respectively. The standard deviation was 0.31 NTU during the monsoon and 0.52 NTU during the post-monsoon season, indicating greater variability after the monsoon. The slightly higher post-monsoon turbidity may be associated with seasonal changes in groundwater conditions and declining groundwater levels. All recorded values were well below the permissible limit of 5 NTU, indicating low turbidity and generally good groundwater quality, with no significant concern related to suspended matter.

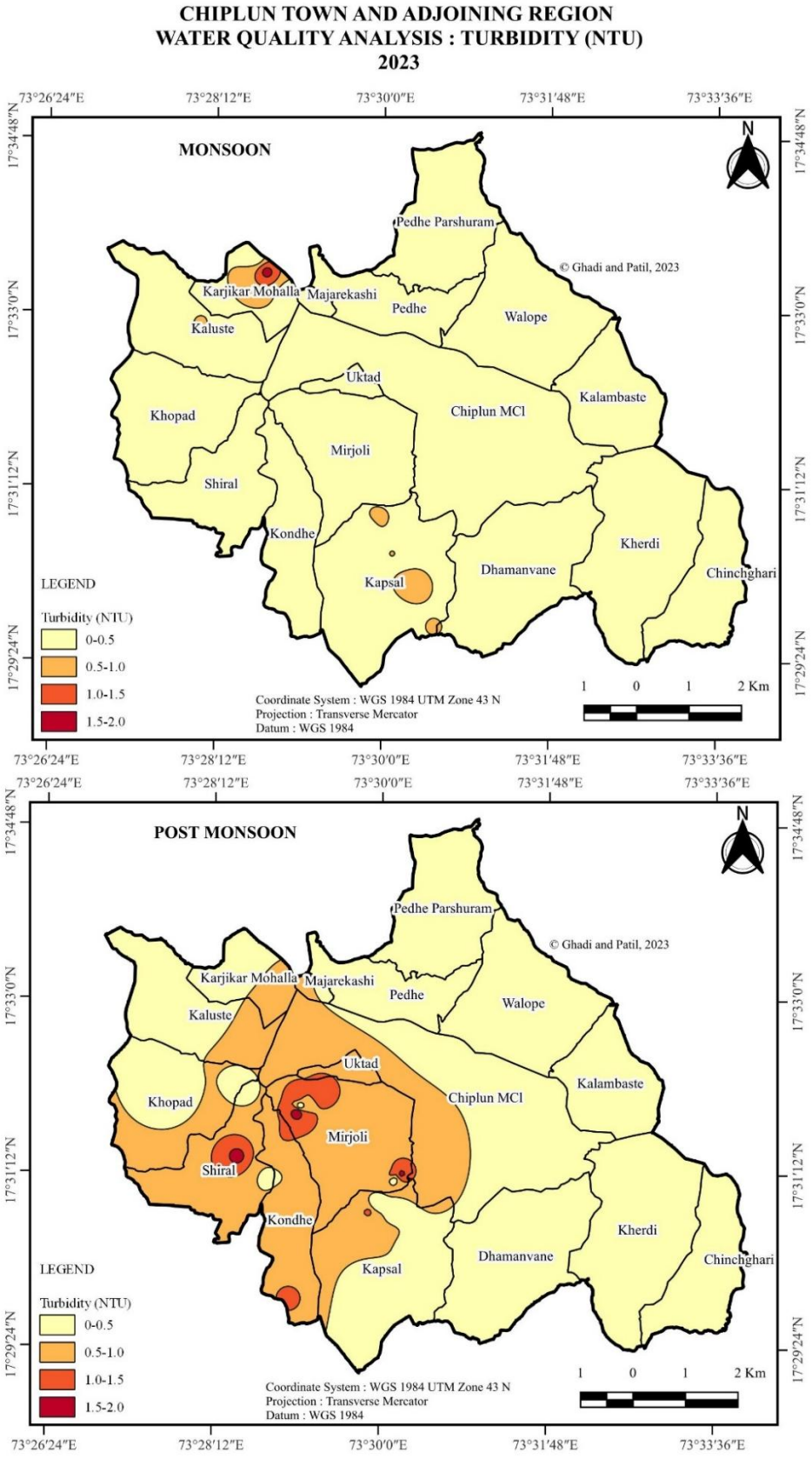


**Figure 4:** Turbidity values during the monsoon and post-monsoon season

### 3.2.2 Potential of Hydrogen (pH)

pH values indicate the acidity or alkalinity of water, with 7 representing neutrality. Values below 7 indicate acidic conditions, whereas values above 7 indicate alkaline conditions. The desirable pH range for potable water is approximately 6.5–8.5 as per BIS drinking-water standards.

In the study region, pH values ranged from 6.5–8.1 during the monsoon and 6.5–8.0 during the post-monsoon season (**Figure 5**). The lowest pH of 6.5 was recorded in some samples from Kapsal, Kondhe, Chinchghari, and Pedhe, whereas relatively higher values of 8.0–8.1 were observed at Dukankhori and Teperwadi (Kapsal), Udyogvasahat (Kherdi), Nayatwadi (Shiral), and Dhamanavane GP PWSS.

During the monsoon, 59.37% of samples had pH values between 7.5 and 8.0, 18.68% between 7.0 and 7.5, and 17.58% between 6.5 and 7.0, while only 4.40% exceeded pH 8.0. During the post-monsoon season, 50.55% of samples were within 7.5–8.0, 27.47% within 7.0–7.5, and 21.98% within 6.5–7.0.

Overall, the groundwater was near-neutral to mildly alkaline, with all recorded values falling within the acceptable BIS range. Although groundwater in parts of the Konkan region may be slightly acidic due to high rainfall, the relatively neutral to mildly alkaline nature observed in the study area may reflect local lithology and water–rock interactions. Tables 3 and 4 present descriptive statistics for monsoon and post-monsoon pH values.

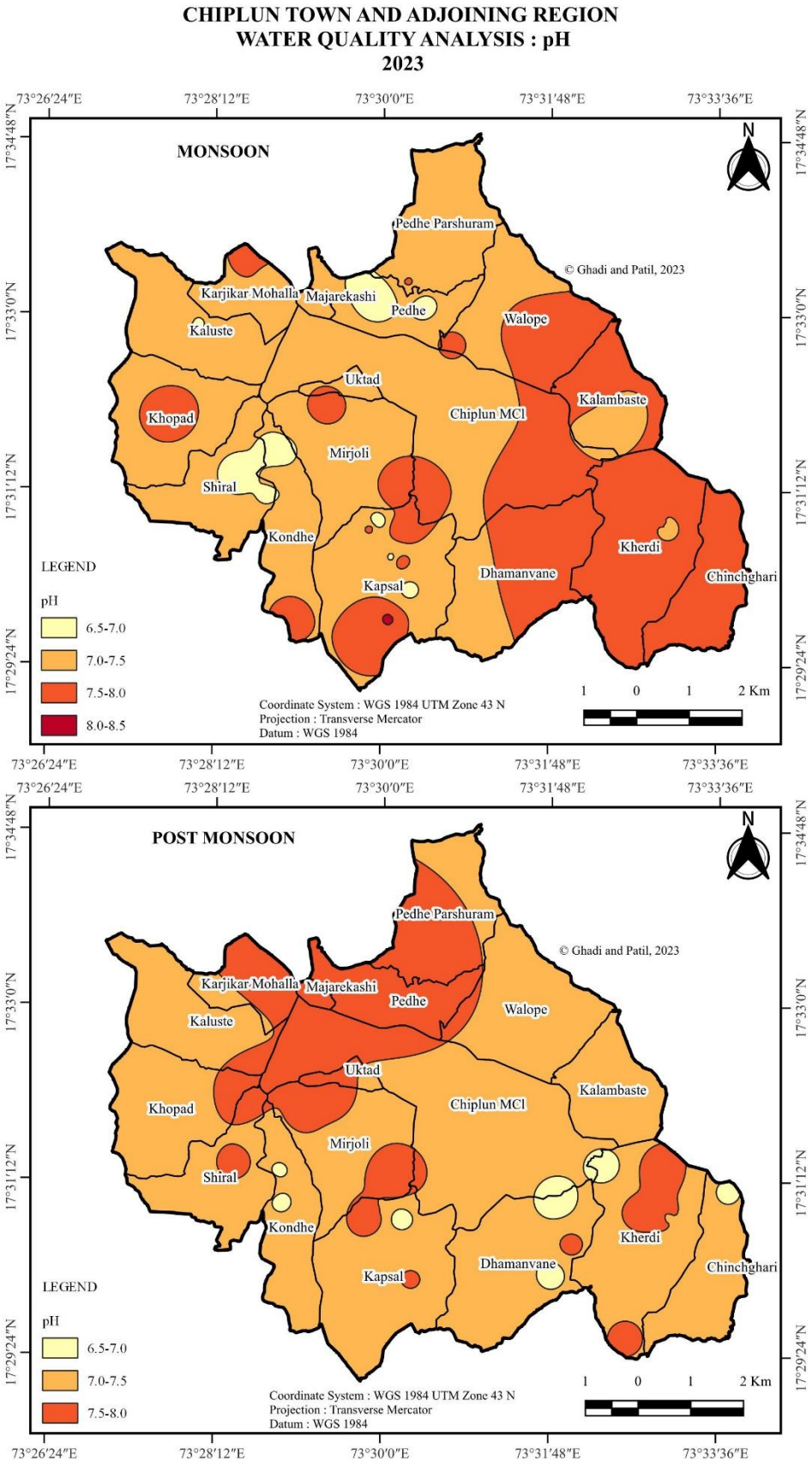


**Figure 5:** pH values during the monsoon and post-monsoon season

### 3.2.3 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) represent the dissolved inorganic and organic constituents present in water. In the study region, TDS values ranged from 159–578 mg/L (**Figure 6**). Most samples were below the BIS desirable limit of 500 mg/L, while only 2.73% of samples exceeded this value, mainly from Shiral, Dhamanavane, Majarekashi, Mirjoli, Khopad, and Kaluste.

The mean TDS increased from 322.71 mg/L during the monsoon to 333.91 mg/L during the post-monsoon, indicating a slight seasonal increase. The observed ranges were 228–502 mg/L during the monsoon and 159–578 mg/L during the post-monsoon. The higher post-monsoon TDS may be associated with reduced groundwater levels and increased concentration of dissolved constituents.

Overall, 97.27% of the samples were within the BIS desirable limit, indicating generally good groundwater quality with respect to TDS. **Tables 3 and 4** present the descriptive statistics for TDS during the monsoon and post-monsoon seasons.

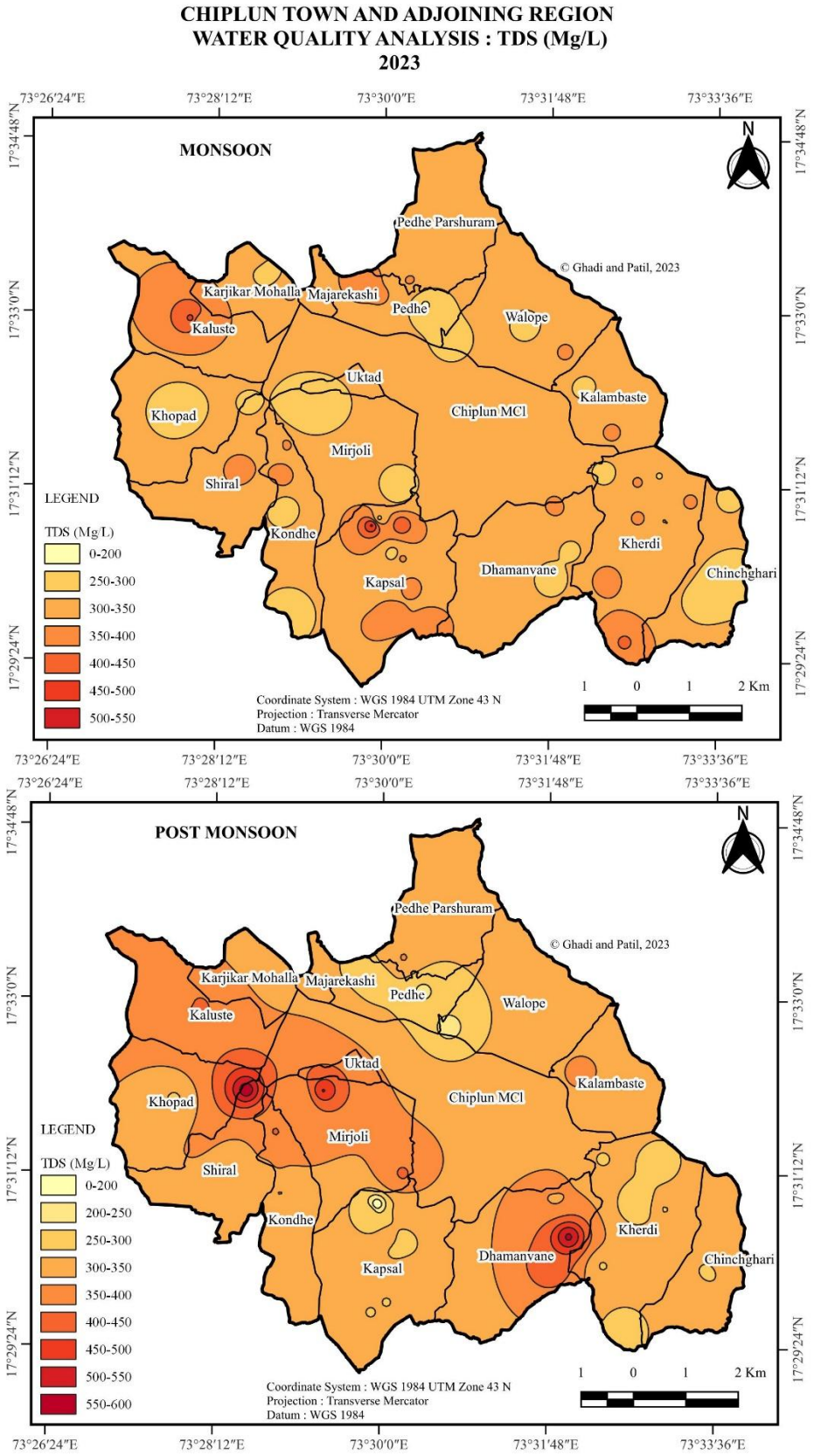


**Figure 6:** TDS values during the monsoon and post-monsoon season

### 3.2.4 Alkalinity

Alkalinity represents the acid-neutralising capacity of water, primarily contributed by bicarbonates, carbonates, and hydroxides. In the study region, alkalinity ranged from 80–332 mg/L during the monsoon and 32–372 mg/L during the post-monsoon season (**Figure 7**). The mean alkalinity was 144.62 mg/L during the monsoon, with a median and mode of 140 mg/L, whereas post-monsoon values showed greater variability, with a standard deviation of 72.99 mg/L compared with 32.99 mg/L during the monsoon.

Only 4 samples (2.18%) exceeded 300 mg/L, while 10.92% of the samples had alkalinity ≥200 mg/L. All samples were below the BIS permissible limit of 600 mg/L. Alkalinity was generally higher during the post-monsoon season, indicating pronounced seasonal variation, possibly associated with changes in groundwater levels and dissolved carbonate species.

Overall, the observed alkalinity levels indicate no significant concern related to carbonate or bicarbonate content, and the groundwater was within the BIS permissible limit. Figure 7 illustrates spatial and seasonal variations.

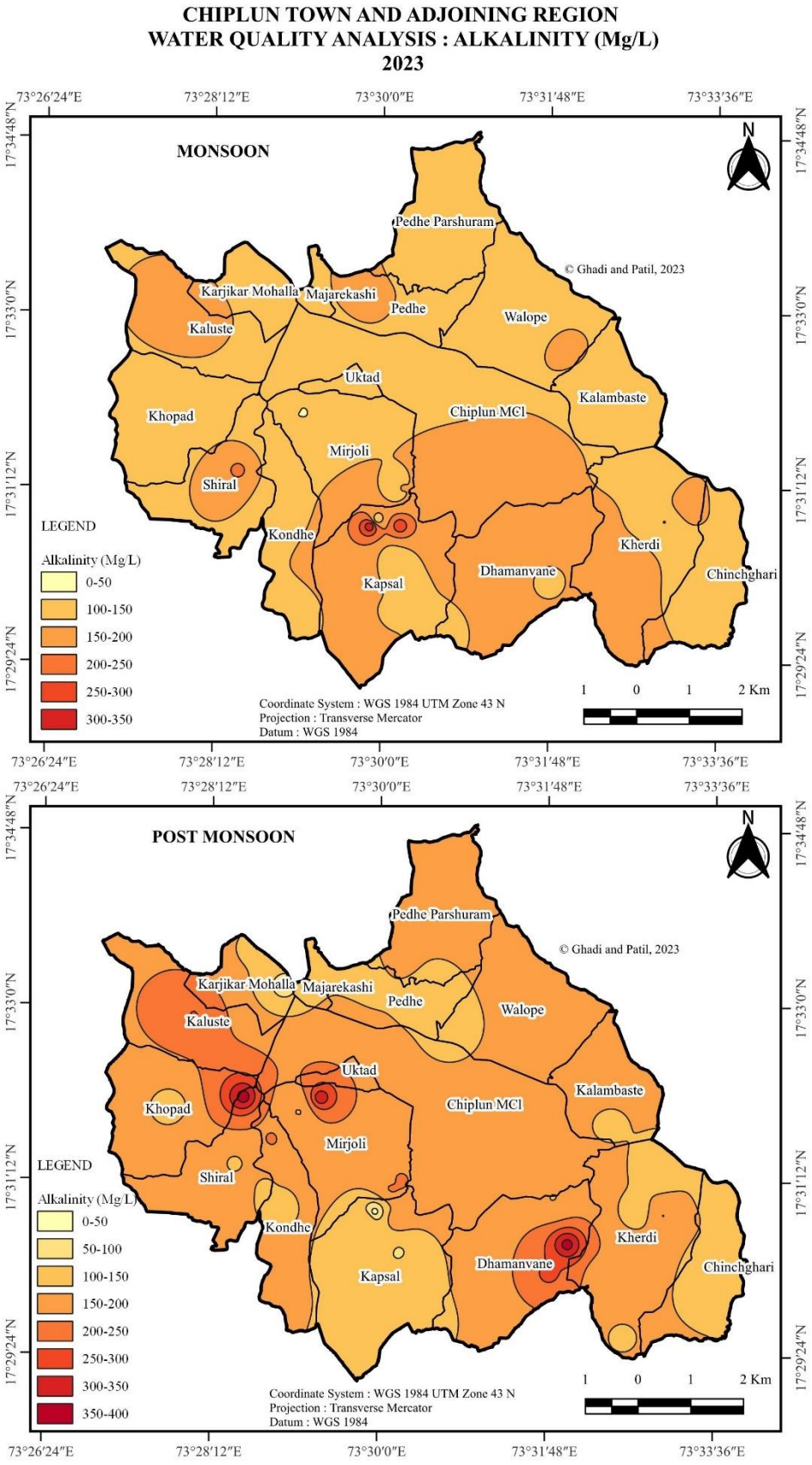


**Figure 7:** Alkalinity values during the monsoon and post-monsoon season

### 3.2.5 Chlorides

Chloride is a naturally occurring ion in surface and groundwater, mainly present as salts of sodium, calcium, and magnesium. Its concentration may be influenced by rock weathering, agricultural runoff, and wastewater inputs. Although chloride is generally not harmful at typical concentrations, elevated levels may impart a salty taste to drinking water [9](Omer, 2019; Hong et al., 2023).

In the study region, chloride concentrations ranged from 20–70 mg/L during monsoon and 24–76 mg/L during post-monsoon (**Figure 8**). Lower concentrations (20–22 mg/L) were observed at Kapsal-Madhaliwadi, Khokarwadi, and Mirjoli Mohalla, while higher values (70–76 mg/L) occurred at Chinchghari-Guravwadi, Shiral-Bauddhwadi, Kherdi-Shigvanwadi, and Kapsal-Sonarwadi. The mean, median, and mode were 37.21, 34.0, and 30.0 mg/L during monsoon and 37.10, 36.0, and 24.0 mg/L during post-monsoon, respectively. The standard deviation was 11.48 mg/L. All values were well below the BIS desirable (250 mg/L) and permissible (1000 mg/L) limits, indicating no significant concern regarding chloride content or salty taste.

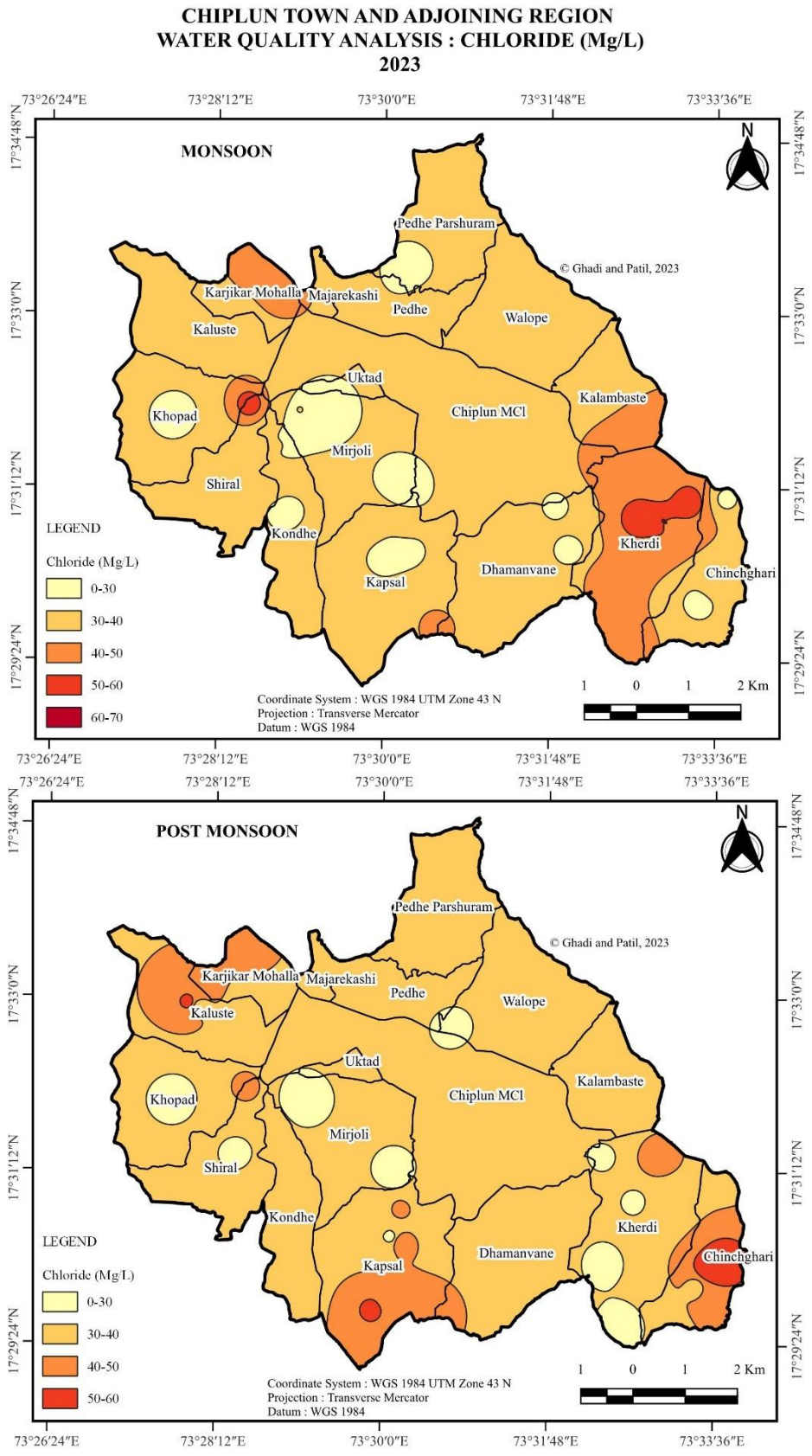


**Figure 8:** Chloride concentration during the monsoon and post-monsoon season

### 3.2.6 Fluoride

Fluoride in drinking water at appropriate concentrations supports dental health (Omer, 2019). In the study region, fluoride concentrations ranged from 0.05–0.92 mg/L (**Figure 9**). Higher values (0.51–0.92 mg/L) were observed at Kondhe-Madhaliwadi, Kulewadi, Chinchghari-Shankarwadi, Mirjoli, and Bauddhwadi, with the maximum of 0.92 mg/L recorded at Kondhe-Madhaliwadi.

Seasonal variation was observed, with concentrations ranging from 0.05–0.63 mg/L during monsoon and reaching 0.92 mg/L during post-monsoon. All values were below the BIS desirable and permissible limits of 1.0 and 1.5 mg/L, respectively, indicating no concern regarding excessive fluoride. However, very low fluoride concentrations at some locations may provide less protection against dental caries.

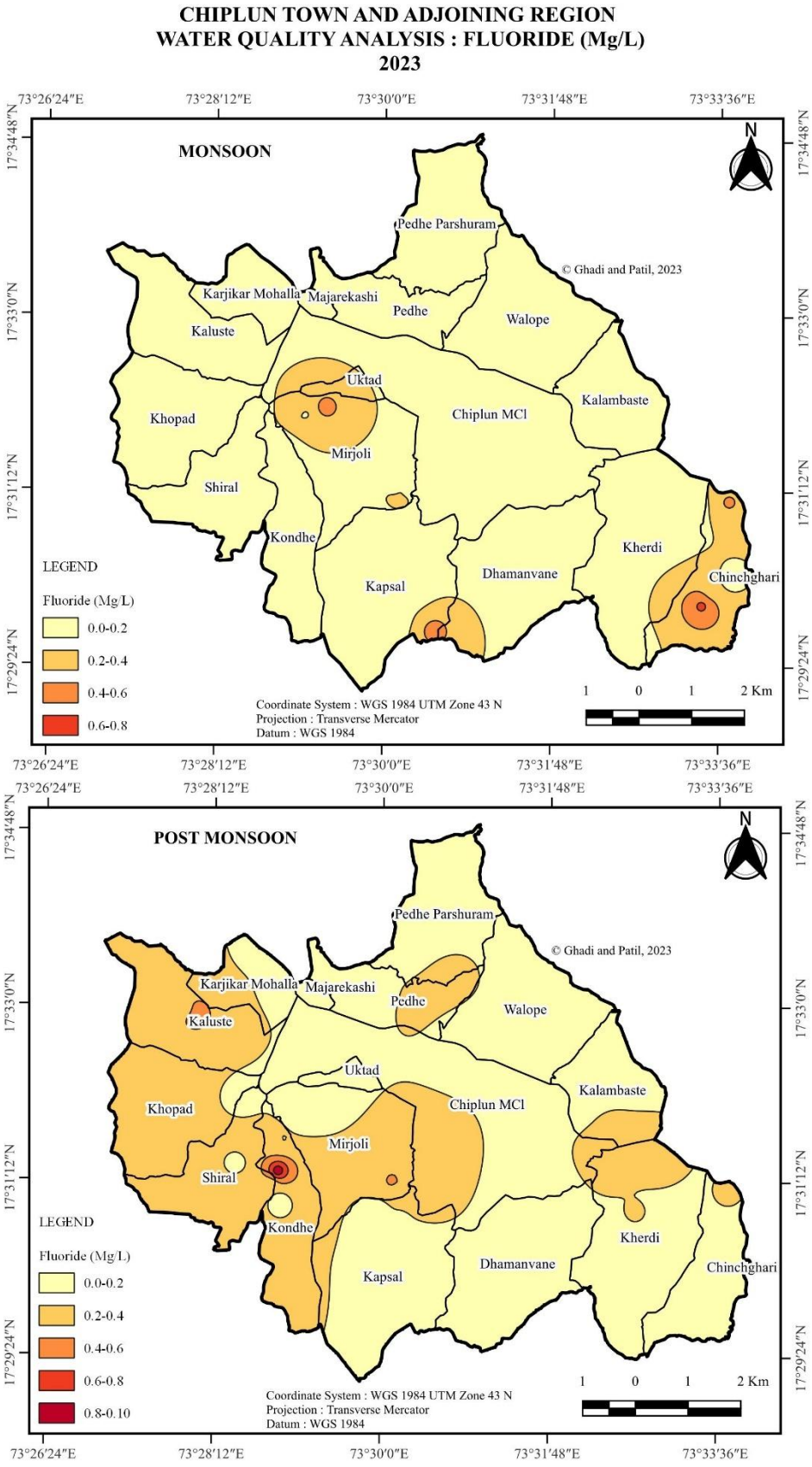


**Figure 9:** Fluoride concentration during the monsoon and post-monsoon season

### 3.2.7 Nitrate

Nitrate is a naturally occurring nitrogen compound in water, with elevated concentrations commonly associated with agricultural runoff and contamination from human or animal wastes [5, 10]; Shimadzu Corporation, 2023). In the study region, nitrate concentrations ranged from 0.01–3.05 mg/L (**Figure 10**). Lower concentrations (0.01–0.05 mg/L) were observed at Walope, Majarekashi, Chinchghari, Kherdi, Pedhe-Parshuram, Kalambaste, and Dhamanavane, while relatively higher values (2.01–2.19 mg/L) occurred at Kondhe, Mirjoli, Shiral, and Kapsal. A concentration of 3.05 mg/L was recorded at several locations.

Seasonal variation was observed, with mean nitrate concentrations of 0.88 mg/L during monsoon and 0.46 mg/L during post-monsoon. The median, mode, and standard deviation were 1.11, 0.11, and 0.72 mg/L during monsoon and 0.11, 0.01, and 0.61 mg/L during post-monsoon, respectively. All values were well below the BIS permissible limit of 45 mg/L, indicating no significant concern regarding nitrate contamination or associated health risks.

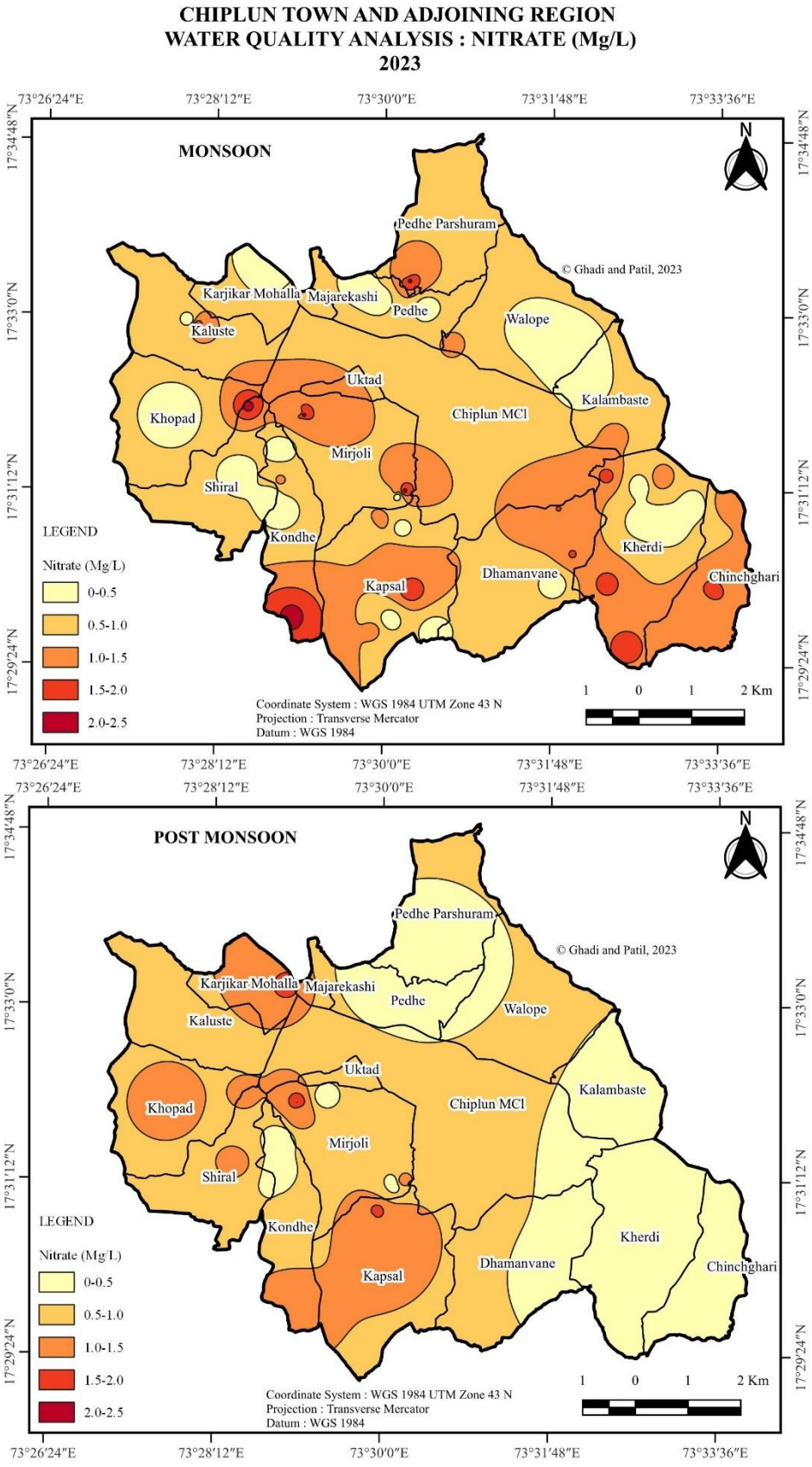


**Figure 10:** Nitrate concentration during the monsoon and post-monsoon season

### 3.2.8 Sulphate

Sulphate occurs naturally in surface and groundwater and may originate from mineral dissolution, oxidation of sulphide ores, shale formations, and municipal or industrial discharges [5, 11]. In the study region, sulphate concentrations ranged from 0.01–9.35 mg/L (**Figure 11**). Higher concentrations (4.05–6.29 mg/L) were observed at Khopad-Palikadchiwadi, Bauddhwadi-Mirjoli-Mahalaxminagar, and Kondhe-Karanjkarwadi, while the maximum value of 9.35 mg/L was recorded at Nayatwadi, Shiral.

Seasonal variation was evident, with concentrations of 0.01–2.69 mg/L during monsoon and 0.02–9.35 mg/L during post-monsoon. Overall, the mean, median, and mode were 0.19, 0.11, and 0.11 mg/L, respectively, with a standard deviation of 1.21 mg/L. We observed a very weak positive correlation with pH ($r = 0.17$). All values were well below the BIS permissible limit, indicating no significant concern related to sulphate content or associated taste and laxative effects.

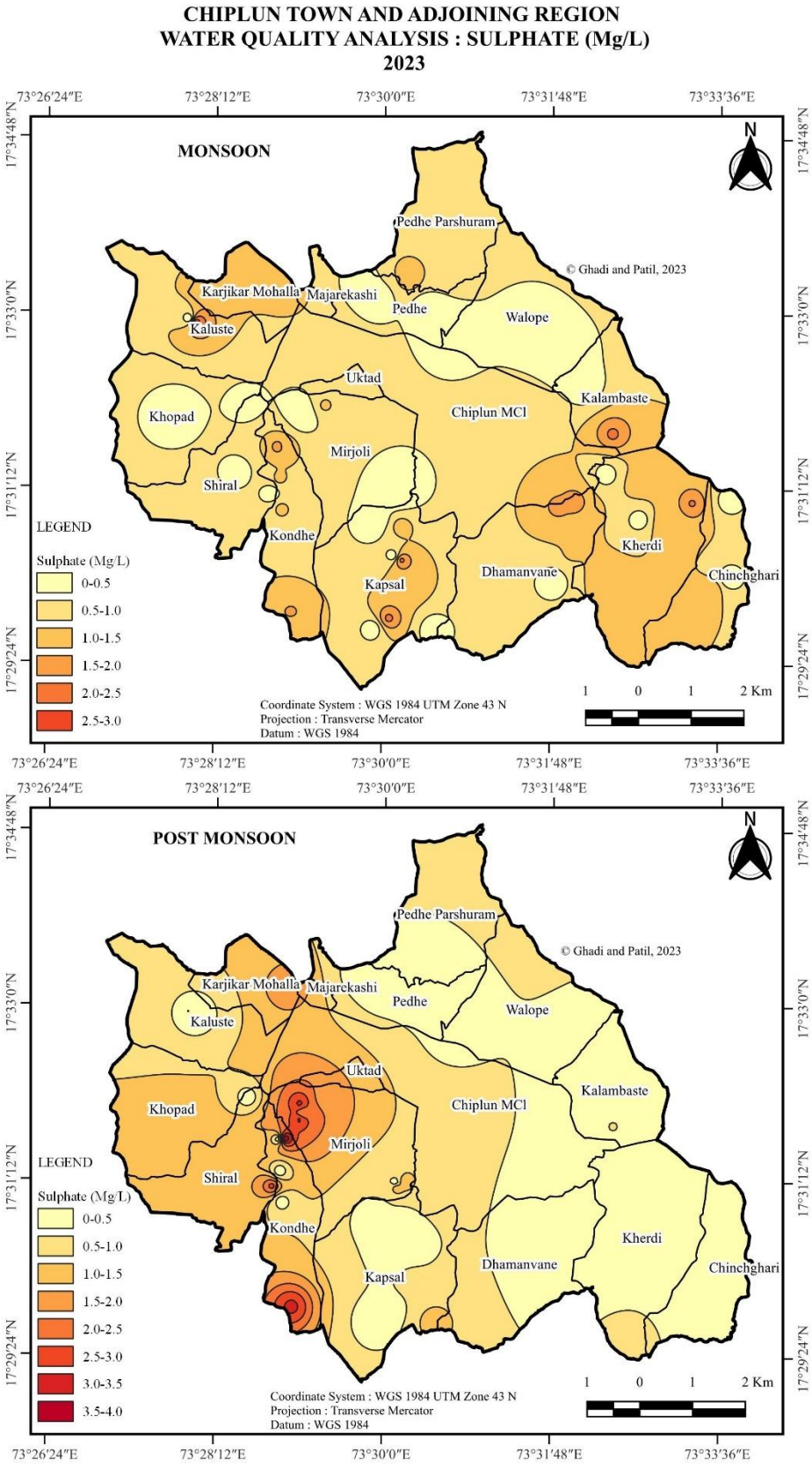


**Figure 11:** Sulphate concentration during the monsoon and post-monsoon season

### 3.2.9 Total Hardness

Total hardness primarily reflects the concentration of calcium and magnesium ions in water, with minor contributions from ions such as iron, manganese, zinc, and aluminium [12]. It mainly results from the dissolution of mineral salts from soil and geological formations [13].

In the study region, total hardness ranged from 15.7 to 252 mg/L, with the highest value recorded at Shiral-Nayatwadi, Kaluste-Madhaliwadi, Kapsal-Payarwadi, Majrekashi-Marathwadi, and Kondhe-Kulewadi (**Figure 12**). About 69.39% of samples had hardness between 100–200 mg/L, 27.88% were below 100 mg/L, and only 2.73% exceeded 200 mg/L. The mean, median, mode, and standard deviation were 116, 120, 120, and 30.62 mg/L, respectively. Slight seasonal variation was observed. Overall, the groundwater ranged from soft to moderately hard, with all samples within the BIS permissible limit, indicating no significant concern regarding total hardness.

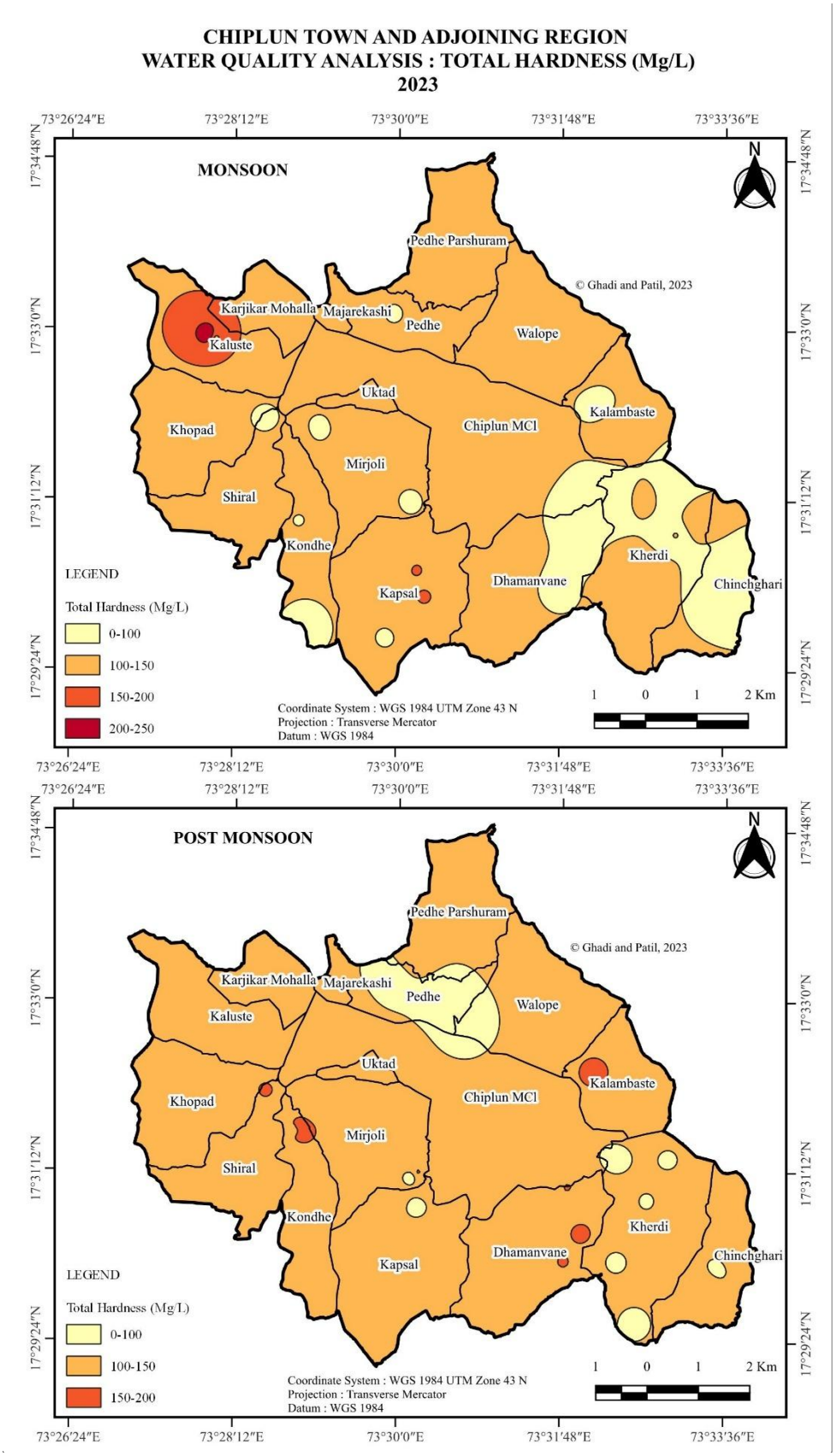


**Figure 12:** Total hardness during the monsoon and post-monsoon season

### 3.2.10 Iron

Iron in groundwater generally occurs as soluble ferrous ($Fe^{2+}$) ions and may oxidise to insoluble ferric ($Fe^{3+}$) forms upon exposure to air, potentially causing turbidity, taste, and staining [5]. In the study region, iron concentrations ranged from 0.01–0.41 mg/L, with slight seasonal variation (**Figure 13**). The overall mean, median, and mode were 0.125, 0.11, and 0.11 mg/L, respectively, with a standard deviation of 0.06 mg/L. The relatively low iron concentrations indicate no significant concern regarding metallic taste or staining. Seasonal descriptive statistics are presented in **Tables 3** and **4**.

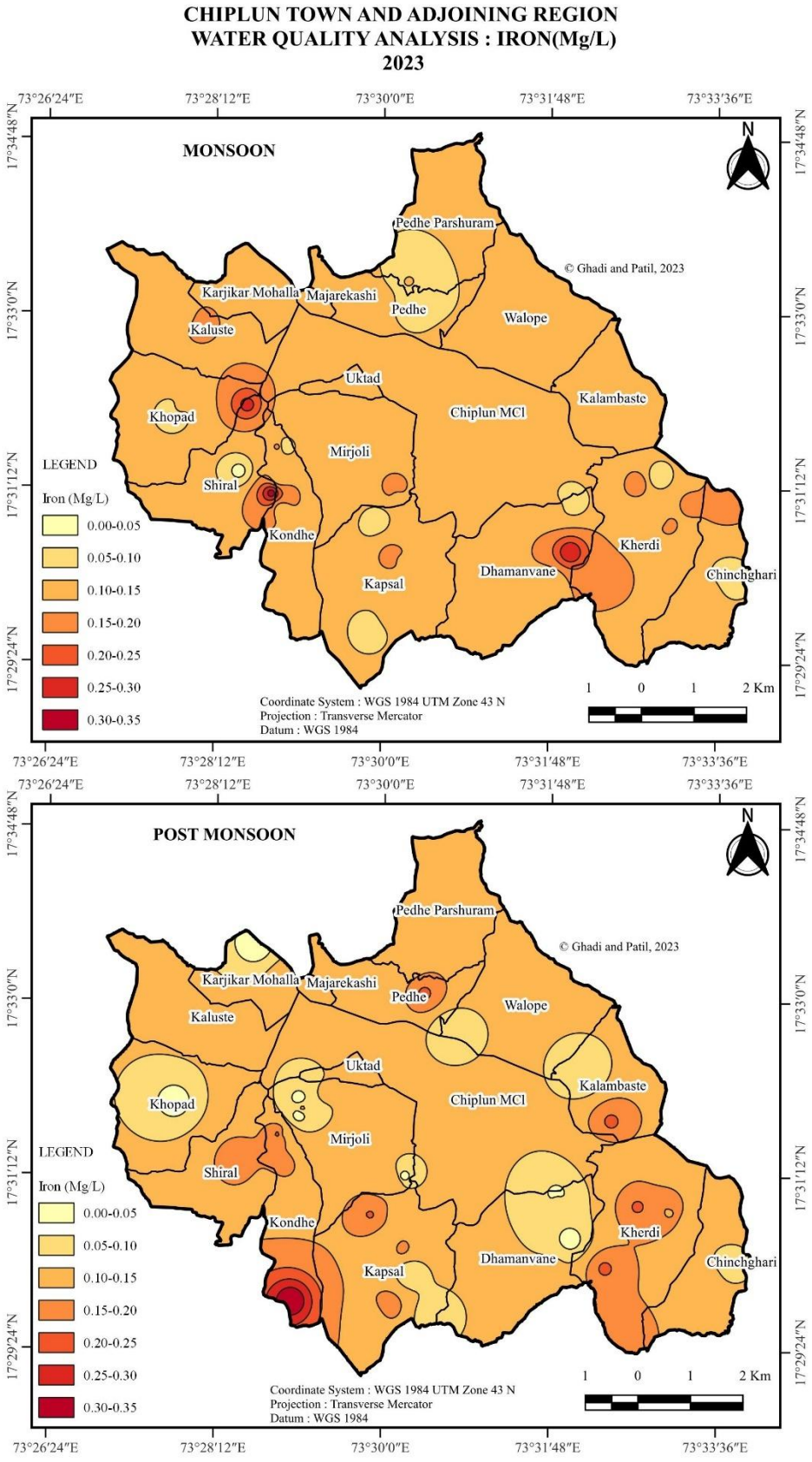


**Figure 13:** Iron concentration during the monsoon and post-monsoon season

### 3.2.11 Overall Descriptive Statistical Analysis

The overall analysis of groundwater quality during the 2023 monsoon and post-monsoon seasons indicates relatively good and stable water quality (**Tables 3** and **4**). The mean WQI increased slightly from 29.44 during monsoon to 30.71 during post-monsoon, indicating minor seasonal variation while remaining within the good-quality category.

The mean pH decreased slightly from 7.41 to 7.33, whereas TDS increased from 322.71 to 333.91 mg/L, indicating a slight increase in dissolved constituents during post-monsoon. Nitrate decreased from 0.88 to 0.46 mg/L, while total hardness increased from 110.55 to 125.05 mg/L. Chloride and sulphate remained low, and fluoride and iron concentrations were within acceptable limits. Overall, the observed seasonal variations reflect changes in groundwater recharge, dilution, mineral dissolution, and water–rock interaction.

Most physicochemical parameters remained within the BIS drinking-water limits, with no significant concern for domestic use. The results indicate generally good groundwater quality, although continued seasonal monitoring is recommended for sustainable groundwater management.

### 3.2.12 Water Quality Index (WQI)

The Water Quality Index (WQI) was calculated using the methodology described in the study. During the monsoon, 12 samples were classified as Excellent and 79 as Good. During the post-monsoon, 15 samples were classified as Excellent, 75 as Good, and 1 as Poor. Excellent-quality samples were mainly observed in Shiral, Pedhe, Kondhe, Kapsal, Pedhe-Parshuram, and Mirjoli. Tables 2, 3, 5, and 6 and Figure 15 present the WQI classification and spatial distribution.

Since lower WQI values indicate better water quality, the mean WQI of 29.44 during monsoon and 30.71 during post-monsoon indicates a slight seasonal decline in water quality after the monsoon. Overall, groundwater quality remained predominantly good, with only one post-monsoon sample falling in the poor category.

**Table 2.** Water quality analysis of the samples collected during monsoon

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHINCHGHARI | PWSS | 21.06.2023 | 0.19 | 7.7 | 265 | 136 | 30 | 0.11 | 1.42 | 0.11 | 88 | 0.05 | 25.47 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.18 | 7.7 | 296 | 144 | 34 | 0.34 | 1.73 | 1.34 | 92 | 0.13 | 31.95 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.17 | 7.5 | 285 | 140 | 24 | 0.63 | 1.11 | 1.11 | 96 | 0.11 | 32.08 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.15 | 7.5 | 287 | 144 | 26 | 0.42 | 1.41 | 0.14 | 100 | 0.19 | 33.18 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.22 | 7.9 | 284 | 128 | 40 | 0.13 | 1.94 | 0.16 | 68 | 0.15 | 29.84 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.21 | 7.8 | 288 | 144 | 38 | 0.16 | 1.39 | 0.15 | 92 | 0.11 | 30.02 | Good |
| CHINCHGHARI | BOREWELL | 21.06.2023 | 0.16 | 7.6 | 300 | 156 | 26 | 0.29 | 1.35 | 0.13 | 104 | 0.2 | 33.93 | Good |
| DHAMANVANE | OPENWELL | 23.06.2023 | 0.41 | 7.7 | 277 | 144 | 30 | 0.05 | 0.11 | 0.06 | 88 | 0.11 | 27.24 | Good |
| DHAMANVANE | OPENWELL | 23.06.2023 | 0.13 | 7.7 | 289 | 152 | 24 | 0.11 | 1.53 | 1.05 | 92 | 0.3 | 35.11 | Good |
| DHAMANVANE | PWSS | 23.06.2023 | 0.11 | 7.5 | 369 | 200 | 26 | 0.05 | 1.51 | 1.63 | 96 | 0.11 | 31.15 | Good |
| DHAMANVANE | PWSS | 23.06.2023 | 0.25 | 8 | 305 | 172 | 30 | 0.13 | 1.38 | 1.75 | 92 | 0.05 | 30.55 | Good |
| KALAMBASTE | PWSS | 23.06.2023 | 0.11 | 7.1 | 358 | 140 | 40 | 0.11 | 1.11 | 2.11 | 120 | 0.11 | 27.56 | Good |
| KALAMBASTE | BOREWELL | 23.06.2023 | 0.25 | 7.6 | 289 | 140 | 38 | 0.05 | 0.05 | 0.11 | 92 | 0.13 | 27.77 | Good |
| KALUSTE BK. | PWSS | 05.07.2023 | 0.21 | 7.2 | 459 | 172 | 40 | 0.11 | 0.13 | 0.13 | 240 | 0.11 | 37.54 | Good |
| KALUSTE BK. | JACKWELL | 02.08.2023 | 0.61 | 6.9 | 370 | 180 | 40 | 0.13 | 1.69 | 2.69 | 144 | 0.19 | 32.74 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.31 | 7.6 | 356 | 172 | 34 | 0.11 | 1.11 | 0.12 | 88 | 0.05 | 28.53 | Good |
| KAPSAL | BOREWELL | 26.06.2023 | 0.53 | 7.1 | 362 | 140 | 46 | 0.49 | 0.11 | 0.05 | 112 | 0.13 | 31.66 | Good |
| KAPSAL | PWSS | 26.06.2023 | 0.85 | 6.8 | 355 | 144 | 40 | 0.12 | 1.95 | 1.35 | 156 | 0.13 | 28.49 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.51 | 6.9 | 269 | 120 | 20 | 0.14 | 1.38 | 0.19 | 120 | 0.19 | 25.61 | Good |
| KAPSAL | PWSS | 26.06.2023 | 0.92 | 6.5 | 293 | 120 | 40 | 0.13 | 1.35 | 0.16 | 120 | 0.05 | 19.49 | Excellent |

**Table 2.** Water quality analysis of the samples collected during monsoon (**continued…)**

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KAPSAL | OPENWELL | 26.06.2023 | 0.41 | 7.7 | 356 | 120 | 24 | 0.16 | 1.31 | 2.09 | 160 | 0.14 | 33.45 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.03 | 8.1 | 359 | 140 | 30 | 0.05 | 0.13 | 2.11 | 144 | 0.13 | 34.88 | Good |
| KAPSAL | DURA | 26.06.2023 | 0.19 | 8 | 449 | 284 | 34 | 0.11 | 0.11 | 1.39 | 120 | 0.11 | 42.09 | Good |
| KAPSAL | BOREWELL | 26.06.2023 | 0.12 | 7.6 | 502 | 332 | 32 | 0.12 | 0.53 | 0.11 | 120 | 0.09 | 42.26 | Good |
| KAPSAL | PWSS | 26.06.2023 | 0.13 | 7.5 | 269 | 120 | 36 | 0.11 | 0.29 | 0.11 | 96 | 0.13 | 26.47 | Good |
| KAPSAL | BOREWELL | 26.06.2023 | 1.51 | 7.6 | 356 | 120 | 48 | 0.11 | 1.31 | 2.05 | 120 | 0.15 | 31.68 | Good |
| KAPSAL | PWSS | 26.06.2023 | 0.11 | 7.6 | 359 | 140 | 60 | 0.05 | 1.11 | 0.11 | 120 | 0.13 | 31.68 | Good |
| KAPSAL | PWSS | 26.06.2023 | 0.69 | 6.8 | 289 | 140 | 20 | 0.11 | 1.95 | 0.13 | 116 | 0.13 | 23.99 | Excellent |
| KAPSAL | PUBLIC DURA | 26.06.2023 | 1.23 | 7.7 | 398 | 120 | 46 | 0.11 | 2.05 | 1.35 | 116 | 0.13 | 32.35 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.28 | 6.7 | 452 | 120 | 60 | 0.15 | 0.13 | 1.11 | 212 | 0.13 | 31.99 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.51 | 7.5 | 356 | 152 | 30 | 0.05 | 0.24 | 1.11 | 112 | 0.13 | 29.85 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 0.11 | 6.7 | 402 | 172 | 70 | 0.11 | 0.13 | 0.05 | 140 | 0.11 | 29.25 | Good |
| KAPSAL | OPENWELL | 26.06.2023 | 1.11 | 7.5 | 356 | 120 | 40 | 0.09 | 1.41 | 1.11 | 144 | 0.11 | 30.30 | Good |
| KARJIKAR MOHALLA | OPENWELL | 03.07.2023 | 0.25 | 7.3 | 356 | 140 | 48 | 0.11 | 0.51 | 1.3 | 132 | 0.1 | 29.28 | Good |
| KARJIKAR MOHALLA | OPENWELL | 03.07.2023 | 0.11 | 7.8 | 320 | 144 | 46 | 0.12 | 0.35 | 1.11 | 128 | 0.15 | 33.52 | Good |
| KARJIKAR MOHALLA | OPENWELL | 03.07.2023 | 1.65 | 7.4 | 266 | 112 | 40 | 0.13 | 0.23 | 1.25 | 112 | 0.14 | 27.03 | Good |

**Table 2.** Water quality analysis of the samples collected during monsoon (**continued…)**

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KARJIKAR MOHALLA | TAKI | 03.07.2023 | 1.35 | 7.3 | 340 | 172 | 34 | 0.13 | 0.41 | 1.69 | 128 | 0.13 | 31.10 | Good |
| KARJIKAR MOHALLA | TAKI | 03.07.2023 | 0.11 | 7.3 | 325 | 140 | 50 | 0.13 | 1.11 | 0.11 | 120 | 0.05 | 26.73 | Good |
| KHERDI (CT) | BOREWELL | 21.06.2023 | 0.15 | 8 | 355 | 140 | 50 | 0.11 | 0.11 | 1.35 | 116 | 0.19 | 36.11 | Good |
| KHERDI (CT) | BOREWELL | 21.06.2023 | 0.13 | 7.8 | 358 | 160 | 58 | 0.11 | 0.13 | 2.05 | 108 | 0.16 | 34.79 | Good |
| KHERDI (CT) | OPENWELL | 21.06.2023 | 0.11 | 7.7 | 369 | 152 | 70 | 0.05 | 0.23 | 1.34 | 92 | 0.11 | 31.34 | Good |
| KHERDI (CT) | OPENWELL | 21.06.2023 | 0.31 | 7.6 | 356 | 148 | 60 | 0.19 | 0.11 | 0.11 | 100 | 0.12 | 31.88 | Good |
| KHERDI (CT) | OPENWELL | 21.06.2023 | 0.41 | 7.5 | 370 | 180 | 50 | 0.13 | 1.71 | 1.41 | 128 | 0.19 | 36.26 | Good |
| KHERDI (CT) | OPENWELL | 21.06.2023 | 0.14 | 7.8 | 405 | 160 | 48 | 0.11 | 1.69 | 1.39 | 140 | 0.11 | 35.58 | Good |
| KHERDI (CT) | PWSS | 21.06.2023 | 0.14 | 7.7 | 298 | 144 | 46 | 0.05 | 1.35 | 1.11 | 68 | 0.05 | 25.60 | Good |
| KHERDI (CT) | PWSS | 21.06.2023 | 0.11 | 7.5 | 277 | 140 | 50 | 0.14 | 1.65 | 0.13 | 72 | 0.11 | 26.92 | Good |
| KHERDI (CT) | OPENWELL | 21.06.2023 | 0.23 | 7.6 | 318 | 156 | 60 | 0.14 | 1.08 | 0.01 | 92 | 0.05 | 28.49 | Good |
| KHERDI (CT) | BOREWELL | 21.06.2023 | 0.14 | 7.9 | 359 | 152 | 50 | 0.13 | 0.35 | 1.11 | 112 | 0.14 | 34.49 | Good |
| KHERDI (CT) | BOREWELL | 22.06.2023 | 0.11 | 7.2 | 289 | 140 | 34 | 0.14 | 0.14 | 1.34 | 104 | 0.19 | 28.52 | Good |
| KHERDI (CT) | BOREWELL | 22.06.2023 | 0.23 | 7.5 | 288 | 128 | 44 | 0.13 | 0.31 | 0.11 | 100 | 0.14 | 28.32 | Good |
| KHERDI (CT) | BOREWELL | 22.06.2023 | 0.51 | 7.5 | 356 | 144 | 60 | 0.11 | 0.13 | 1.69 | 100 | 0.13 | 30.65 | Good |
| KHERDI (CT) | BOREWELL | 22.06.2023 | 0.13 | 7.2 | 377 | 156 | 36 | 0.15 | 0.16 | 0.18 | 108 | 0.11 | 28.74 | Good |
| KHOPAD | OPENWELL | 16.06.2023 | 0.17 | 7.8 | 296 | 132 | 24 | 0.19 | 0.17 | 0.16 | 100 | 0.07 | 28.11 | Good |
| KHOPAD | OPENWELL | 16.06.2023 | 0.11 | 7.6 | 254 | 104 | 30 | 0.16 | 0.14 | 0.35 | 100 | 0.11 | 25.81 | Good |
| KHOPAD | OPENWELL | 16.06.2023 | 0.16 | 7.7 | 228 | 100 | 26 | 0.13 | 0.16 | 0.13 | 92 | 0.16 | 26.56 | Good |
| KONDHE | PWSS | 20.06.2023 | 0.13 | 6.8 | 358 | 128 | 24 | 0.13 | 0.19 | 1.4 | 144 | 0.05 | 23.48 | Excellent |

**Table 2.** Water quality analysis of the samples collected during monsoon (**continued…)**

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KONDHE | OPENWELL | 20.06.2023 | 0.16 | 6.5 | 344 | 144 | 32 | 0.14 | 0.11 | 1.69 | 120 | 0.16 | 24.88 | Excellent |
| KONDHE | OPENWELL | 20.06.2023 | 0.11 | 7.2 | 385 | 140 | 38 | 0.11 | 1.11 | 1.11 | 140 | 0.11 | 29.63 | Good |
| KONDHE | OPENWELL | 20.06.2023 | 0.16 | 7.3 | 250 | 120 | 24 | 0.11 | 0.11 | 1.11 | 96 | 0.13 | 24.29 | Excellent |
| KONDHE | OPENWELL | 20.06.2023 | 0.15 | 7.6 | 278 | 140 | 30 | 0.13 | 2.19 | 1.69 | 92 | 0.11 | 27.91 | Good |
| KONDHE | PWSS | 20.06.2023 | 0.14 | 7.5 | 280 | 144 | 36 | 0.14 | 2.05 | 1.13 | 88 | 0.13 | 28.23 | Good |
| KONDHE | OPENWELL | 20.06.2023 | 0.13 | 7.5 | 245 | 120 | 30 | 0.16 | 0.15 | 1.35 | 92 | 0.12 | 25.75 | Good |
| KONDHE | OPENWELL | 20.06.2023 | 0.11 | 7.2 | 260 | 120 | 26 | 0.13 | 0.13 | 1.05 | 104 | 0.05 | 21.83 | Excellent |
| KONDHE | OPENWELL | 20.06.2023 | 0.25 | 6.7 | 259 | 80 | 30 | 0.13 | 1.35 | 1.35 | 120 | 0.23 | 23.74 | Excellent |
| MIRJOLI | OPENWELL | 16.06.2023 | 0.21 | 7.5 | 259 | 108 | 32 | 0.31 | 1.35 | 0.18 | 100 | 0.13 | 27.96 | Good |
| MIRJOLI | HANDPUMP | 16.06.2023 | 0.16 | 7.5 | 285 | 104 | 26 | 0.31 | 1.11 | 0.19 | 96 | 0.14 | 28.11 | Good |
| MIRJOLI | PWSS | 16.06.2023 | 0.11 | 7.5 | 258 | 88 | 22 | 0.13 | 2.13 | 0.13 | 92 | 0.13 | 24.50 | Excellent |
| MIRJOLI | OPENWELL | 16.06.2023 | 0.19 | 7.8 | 289 | 152 | 24 | 0.16 | 2.11 | 0.11 | 100 | 0.15 | 31.77 | Good |
| MIRJOLI | PWSS | 16.06.2023 | 0.17 | 7.8 | 280 | 140 | 24 | 0.51 | 1.35 | 1.11 | 104 | 0.13 | 33.90 | Good |
| MIRJOLI | HANDPUMP | 16.06.2023 | 0.15 | 7.5 | 260 | 128 | 26 | 0.11 | 1.11 | 0.13 | 96 | 0.19 | 28.47 | Good |
| MIRJOLI | OPENWELL | 16.06.2023 | 0.14 | 7.7 | 277 | 140 | 30 | 0.34 | 0.11 | 0.01 | 92 | 0.13 | 30.78 | Good |
| MIRJOLI | OPENWELL | 16.06.2023 | 0.18 | 7.9 | 295 | 156 | 30 | 0.31 | 1.75 | 1.35 | 88 | 0.14 | 33.54 | Good |
| MIRJOLI | PWSS | 16.06.2023 | 0.13 | 7.5 | 289 | 148 | 34 | 0.23 | 0.11 | 0.17 | 88 | 0.11 | 28.29 | Good |
| MIRJOLI | PWSS | 16.06.2023 | 0.16 | 7.7 | 289 | 144 | 30 | 0.25 | 1.25 | 0.19 | 100 | 0.11 | 30.32 | Good |
| PEDHE | OPENWELL | 22.06.2023 | 0.13 | 6.5 | 356 | 172 | 30 | 0.05 | 0.14 | 0.13 | 92 | 0.11 | 22.40 | Excellent |
| PEDHE | OPENWELL | 22.06.2023 | 0.11 | 6.8 | 245 | 100 | 34 | 0.14 | 0.13 | 0.11 | 100 | 0.05 | 18.04 | Excellent |

**Table 2.** Water quality analysis of the samples collected during monsoon (**continued…)**

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PEDHE | OPENWELL | 22.06.2023 | 0.35 | 6.9 | 385 | 168 | 30 | 0.13 | 0.11 | 0.11 | 112 | 0.12 | 27.60 | Good |
| PEDHE | OPENWELL | 22.06.2023 | 0.14 | 7.1 | 320 | 168 | 34 | 0.31 | 0.11 | 0.16 | 108 | 0.13 | 29.71 | Good |
| PEDHE | OPENWELL | 22.06.2023 | 0.11 | 7.5 | 356 | 144 | 36 | 0.11 | 0.13 | 0.11 | 112 | 0.11 | 29.51 | Good |
| PEDHE PARSHURAM | PWSS | 22.06.2023 | 0.11 | 7.6 | 358 | 144 | 30 | 0.12 | 2.05 | 1.41 | 140 | 0.11 | 31.96 | Good |
| PEDHE PARSHURAM | PWSS | 22.06.2023 | 0.11 | 7.1 | 325 | 140 | 24 | 0.11 | 1.11 | 1.11 | 128 | 0.05 | 24.61 | Excellent |
| PEDHE PARSHURAM | PWSS | 22.06.2023 | 0.25 | 7.5 | 296 | 120 | 26 | 0.13 | 1.35 | 1.38 | 112 | 0.05 | 25.25 | Good |
| SHIRAL | PWSS | 27.06.2023 | 0.14 | 7.2 | 290 | 132 | 60 | 0.13 | 2.11 | 0.11 | 88 | 0.27 | 31.32 | Good |
| SHIRAL | OPENWELL | 27.06.2023 | 0.15 | 6.8 | 325 | 144 | 34 | 0.11 | 0.19 | 0.12 | 116 | 0.32 | 31.36 | Good |
| SHIRAL | OPENWELL | 27.06.2023 | 0.11 | 6.7 | 378 | 212 | 36 | 0.15 | 0.11 | 0.19 | 120 | 0.03 | 26.14 | Good |
| SHIRAL | OPENWELL | 27.06.2023 | 0.19 | 7.2 | 354 | 144 | 70 | 0.19 | 2.09 | 0.13 | 100 | 0.02 | 26.47 | Good |
| SHIRAL | OPENWELL | 27.06.2023 | 0.2 | 6.7 | 300 | 140 | 44 | 0.14 | 1.35 | 0.13 | 100 | 0.01 | 19.82 | Excellent |
| SHIRAL | OPENWELL | 27.06.2023 | 0.13 | 7.1 | 289 | 140 | 36 | 0.13 | 1.25 | 0.21 | 92 | 0.34 | 32.42 | Good |
| VALOPE | PWSS | 22.06.2023 | 0.23 | 7.6 | 286 | 140 | 34 | 0.05 | 1.11 | 0.05 | 100 | 0.13 | 28.19 | Good |
| VALOPE | PWSS | 22.06.2023 | 0.13 | 7.7 | 356 | 156 | 36 | 0.14 | 0.01 | 0.14 | 116 | 0.11 | 31.92 | Good |
| VALOPE | OPENWELL | 22.06.2023 | 0.14 | 7.6 | 289 | 140 | 34 | 0.13 | 0.19 | 0.13 | 100 | 0.13 | 28.84 | Good |

Source : (Groundwater Survey and Development Agency Ratnagiri, 2023)and Water testing analysis in the Lab [14]

**Table 3.** Water quality analysis of the samples collected during post-monsoon

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHINCHGHARI | PWSS | 07.11.2023 | 0.91 | 6.8 | 250 | 80 | 40 | 0.13 | 0.02 | 0.14 | 128 | 0.11 | 20.74 | Excellent |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.63 | 7.2 | 355 | 140 | 72 | 0.13 | 0.02 | 0.11 | 140 | 0.11 | 30.35 | Good |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.19 | 7.1 | 288 | 144 | 60 | 0.05 | 0.04 | 0.13 | 80 | 0.13 | 24.89 | Excellent |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.14 | 6.9 | 305 | 140 | 38 | 0.22 | 0.01 | 0.13 | 120 | 0.12 | 26.18 | Good |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.11 | 7.5 | 325 | 144 | 36 | 0.12 | 0.01 | 0.13 | 132 | 0.13 | 30.63 | Good |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.15 | 7.1 | 325 | 120 | 60 | 0.07 | 0.01 | 0.05 | 140 | 0.06 | 25.29 | Good |
| CHINCHGHARI | PWSS | 07.11.2023 | 0.21 | 6.5 | 285 | 92 | 40 | 0.16 | 0.01 | 0.11 | 140 | 0.15 | 22.20 | Excellent |
| DHAMANVANE | OPENWELL | 09.11.2023 | 0.15 | 6.8 | 449 | 260 | 34 | 0.15 | 0.08 | 0.16 | 152 | 0.11 | 34.81 | Good |
| DHAMANVANE | PWSS | 09.11.2023 | 0.12 | 6.9 | 378 | 140 | 36 | 0.13 | 0.01 | 0.12 | 172 | 0.03 | 26.25 | Good |
| DHAMANVANE | OPENWELL | 09.11.2023 | 0.17 | 7.7 | 559 | 368 | 30 | 0.11 | 0.01 | 0.11 | 160 | 0.02 | 45.24 | Good |
| DHAMANVANE | PWSS | 09.11.2023 | 0.21 | 6.7 | 325 | 172 | 38 | 0.13 | 0.01 | 0.21 | 96 | 0.06 | 22.75 | Excellent |
| KALAMBASTE | BOREWELL | 09.11.2023 | 0.19 | 7.2 | 359 | 160 | 30 | 0.11 | 0.01 | 0.11 | 160 | 0.05 | 28.51 | Good |
| KALAMBASTE | PWSS | 09.11.2023 | 0.14 | 7.1 | 325 | 144 | 36 | 0.21 | 0.01 | 0.51 | 140 | 0.21 | 31.95 | Good |
| KALUSTE BK. | OPENWELL | 15.02.2024 | 0.13 | 7.1 | 245 | 120 | 36 | 0.11 | 1.35 | 3.69 | 144 | 0.11 | 25.47 | Good |
| KALUSTE BK. | OPENWELL | 15.02.2024 | 0.3 | 7.4 | 385 | 216 | 56 | 0.35 | 0.01 | 0.51 | 120 | 0.11 | 36.63 | Good |
| KALUSTE BK. | OPENWELL | 15.02.2024 | 0.39 | 7.2 | 416 | 256 | 34 | 0.49 | 0.01 | 0.05 | 144 | 0.13 | 40.29 | Good |
| KALUSTE BK. | OPENWELL | 15.02.2024 | 0.93 | 7.5 | 436 | 172 | 60 | 0.05 | 0.01 | 0.13 | 116 | 0.41 | 43.12 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.11 | 7.2 | 250 | 120 | 24 | 0.35 | 0.21 | 0.13 | 100 | 0.11 | 25.52 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.13 | 7.1 | 255 | 80 | 50 | 0.11 | 1.05 | 0.11 | 120 | 0.17 | 24.79 | Excellent |
| KAPSAL | BOREWELL | 25.01.2024 | 0.12 | 7.3 | 280 | 120 | 34 | 0.16 | 1.11 | 0.15 | 120 | 0.05 | 24.49 | Excellent |
| KAPSAL | OPENWELL | 25.01.2024 | 0.11 | 6.5 | 320 | 156 | 40 | 0.17 | 1.11 | 0.05 | 120 | 0.11 | 24.09 | Excellent |
| KAPSAL | OPENWELL | 25.01.2024 | 1.11 | 7.9 | 299 | 144 | 30 | 0.18 | 1.35 | 0.14 | 120 | 0.21 | 35.60 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.12 | 6.5 | 308 | 180 | 46 | 0.18 | 1.35 | 0.11 | 80 | 0.13 | 24.12 | Excellent |

**Table 3.** Water quality analysis of the samples collected during post-monsoon (Continued…)

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KAPSAL | OPENWELL | 25.01.2024 | 0.95 | 7.3 | 325 | 148 | 24 | 0.19 | 1.39 | 0.13 | 140 | 0.11 | 29.84 | Good |
| KAPSAL | PWSS | 25.01.2024 | 0.15 | 6.9 | 216 | 152 | 48 | 0.05 | 1.39 | 0.02 | 140 | 0.16 | 26.33 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.13 | 7.5 | 159 | 32 | 30 | 0.07 | 1.71 | 0.13 | 120 | 0.16 | 21.75 | Excellent |
| KAPSAL | PWSS | 25.01.2024 | 0.76 | 6.8 | 335 | 152 | 40 | 0.05 | 2.05 | 0.14 | 140 | 0.08 | 25.27 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.11 | 7.2 | 299 | 120 | 48 | 0.12 | 0.01 | 0.19 | 128 | 0.19 | 29.19 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.18 | 7.5 | 308 | 140 | 46 | 0.14 | 0.01 | 1.35 | 120 | 0.05 | 27.49 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.12 | 7.4 | 299 | 116 | 54 | 0.11 | 0.01 | 0.12 | 120 | 0.11 | 27.39 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.14 | 7.2 | 318 | 120 | 50 | 0.13 | 0.01 | 0.15 | 144 | 0.18 | 30.22 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.06 | 7.3 | 306 | 112 | 52 | 0.15 | 0.01 | 0.13 | 140 | 0.05 | 25.98 | Good |
| KAPSAL | OPENWELL | 25.01.2024 | 0.11 | 7.5 | 325 | 120 | 50 | 0.12 | 0.01 | 0.11 | 144 | 0.13 | 30.59 | Good |
| KAPSAL | PWSS | 25.01.2024 | 0.15 | 7.6 | 326 | 144 | 40 | 0.13 | 0.01 | 0.69 | 140 | 0.05 | 29.34 | Good |
| KAPSAL | PWSS | 25.01.2024 | 0.17 | 7.5 | 318 | 148 | 46 | 0.13 | 0.01 | 1.25 | 120 | 0.18 | 32.32 | Good |
| KARJIKAR MOHALLA | OPENWELL | 15.02.2024 | 0.25 | 7.9 | 320 | 144 | 46 | 0.16 | 1.11 | 1.35 | 120 | 0.01 | 29.71 | Good |
| KARJIKAR MOHALLA | OPENWELL | 15.02.2024 | 0.61 | 7.5 | 318 | 80 | 40 | 0.13 | 1.69 | 2.05 | 140 | 0.15 | 29.13 | Good |
| KARJIKAR MOHALLA | OPENWELL | 15.02.2024 | 0.36 | 7.3 | 369 | 144 | 76 | 0.13 | 0.01 | 0.16 | 100 | 0.05 | 27.63 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.25 | 6.7 | 297 | 144 | 28 | 0.11 | 0.02 | 0.19 | 116 | 0.11 | 22.87 | Excellent |
| KHERDI (CT) | OPENWELL | 08.11.2023 | 0.14 | 7.8 | 329 | 172 | 36 | 0.05 | 0.03 | 0.13 | 120 | 0.21 | 35.48 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.11 | 6.7 | 285 | 148 | 30 | 0.23 | 0.04 | 0.15 | 100 | 0.11 | 23.29 | Excellent |
| KHERDI (CT) | PWSS | 08.11.2023 | 0.13 | 6.7 | 296 | 152 | 26 | 0.31 | 0.09 | 0.19 | 80 | 0.12 | 23.70 | Excellent |
| KHERDI (CT) | OPENWELL | 08.11.2023 | 0.14 | 7.1 | 297 | 168 | 24 | 0.11 | 0.09 | 0.11 | 92 | 0.21 | 28.71 | Good |

**Table 3.** Water quality analysis of the samples collected during post-monsoon (Continued…)

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI CATEGORY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KHERDI (CT) | JACKWELL | 08.11.2023 | 0.11 | 7.9 | 278 | 128 | 50 | 0.31 | 0.12 | 0.11 | 96 | 0.13 | 32.24 | Good |
| KHERDI (CT) | OPENWELL | 08.11.2023 | 0.16 | 7.7 | 255 | 128 | 26 | 0.23 | 0.18 | 0.23 | 96 | 0.21 | 31.37 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.13 | 6.8 | 296 | 140 | 26 | 0.05 | 0.2 | 0.11 | 120 | 0.31 | 29.52 | Good |
| KHERDI (CT) | OPENWELL | 08.11.2023 | 0.14 | 7.6 | 269 | 144 | 24 | 0.19 | 0.01 | 0.91 | 92 | 0.19 | 30.44 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.11 | 7.3 | 285 | 144 | 30 | 0.11 | 0.01 | 0.1 | 100 | 0.11 | 25.88 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.19 | 7.2 | 288 | 180 | 30 | 0.13 | 0.01 | 0.21 | 72 | 0.13 | 26.56 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.21 | 7.5 | 358 | 216 | 30 | 0.34 | 0.01 | 0.11 | 76 | 0.31 | 40.06 | Good |
| KHERDI (CT) | HANDPUMP | 08.11.2023 | 0.19 | 7.6 | 278 | 140 | 24 | 0.11 | 0.01 | 0.11 | 100 | 0.05 | 25.31 | Good |
| KHERDI (CT) | OPENWELL | 08.11.2023 | 0.11 | 7.5 | 369 | 210 | 26 | 0.11 | 0.01 | 0.19 | 80 | 0.14 | 32.04 | Good |
| KHOPAD | OPENWELL | 02.01.2024 | 1.11 | 6.8 | 455 | 284 | 38 | 0.16 | 0.11 | 1.35 | 128 | 0.05 | 33.36 | Good |
| KHOPAD | PWSS | 02.01.2024 | 0.91 | 6.9 | 460 | 272 | 40 | 0.21 | 0.39 | 6.29 | 140 | 0.11 | 36.99 | Good |
| KHOPAD | PWSS | 02.01.2024 | 0.12 | 7.1 | 335 | 140 | 42 | 0.11 | 1.11 | 3.05 | 144 | 0.11 | 28.42 | Good |
| KHOPAD | OPENWELL | 02.01.2024 | 0.21 | 7.2 | 295 | 128 | 24 | 0.21 | 1.25 | 1.11 | 140 | 0.02 | 24.71 | Excellent |
| KHOPAD | HANDPUMP | 02.01.2024 | 0.31 | 7.5 | 331 | 96 | 60 | 0.05 | 1.38 | 5.11 | 156 | 0.14 | 30.71 | Good |
| KONDHE | OPENWELL | 03.01.2024 | 0.49 | 7.2 | 406 | 216 | 40 | 0.29 | 0.11 | 0.13 | 144 | 0.21 | 39.03 | Good |
| KONDHE | PWSS | 03.01.2024 | 1.39 | 7.2 | 378 | 168 | 30 | 0.19 | 0.11 | 4.05 | 172 | 0.13 | 33.69 | Good |
| KONDHE | OPENWELL | 03.01.2024 | 0.11 | 6.9 | 335 | 156 | 36 | 0.15 | 0.11 | 0.65 | 140 | 0.12 | 27.84 | Good |
| KONDHE | OPENWELL | 03.01.2024 | 0.53 | 6.8 | 355 | 172 | 40 | 0.92 | 0.15 | 0.13 | 140 | 0.18 | 38.26 | Good |

**Table 3.** Water quality analysis of the samples collected during post-monsoon (Continued…)

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI CATEGORY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KONDHE | OPENWELL | 03.01.2024 | 0.64 | 6.8 | 299 | 128 | 40 | 0.11 | 0.51 | 0.19 | 128 | 0.13 | 24.67 | Excellent |
| KONDHE | OPENWELL | 03.01.2024 | 0.11 | 6.5 | 375 | 120 | 34 | 0.51 | 1.11 | 0.11 | 216 | 0.13 | 32.02 | Good |
| KONDHE | PWSS | 03.01.2024 | 3.05 | 7.5 | 388 | 212 | 36 | 0.13 | 1.11 | 3.11 | 128 | 0.13 | 35.87 | Good |
| KONDHE | OPENWELL | 03.01.2024 | 0.11 | 7.6 | 325 | 130 | 26 | 0.13 | 1.35 | 1.35 | 156 | 0.13 | 31.85 | Good |
| KONDHE | OPENWELL | 03.01.2024 | 1.11 | 7.5 | 309 | 156 | 34 | 0.31 | 1.39 | 3.15 | 112 | 0.35 | 39.62 | Good |
| MAJAREKASHI | OPENWELL | 1/11/2024 | 0.43 | 7.7 | 528 | 260 | 40 | 0.11 | 0.01 | 3.65 | 216 | 0.11 | 45.62 | Good |
| MIRJOLI | PWSS | 12.12.2023 | 1.25 | 7.6 | 503 | 332 | 30 | 0.09 | 0.01 | 1.69 | 128 | 0.11 | 43.04 | Good |
| MIRJOLI | PWSS | 12.12.2023 | 0.11 | 7.6 | 389 | 216 | 26 | 0.25 | 0.19 | 1.35 | 80 | 0.15 | 35.24 | Good |
| MIRJOLI | HANDPUMP | 12.12.2023 | 1.13 | 7.7 | 395 | 172 | 24 | 0.53 | 0.21 | 0.11 | 100 | 0.13 | 36.93 | Good |
| MIRJOLI | PWSS | 12.12.2023 | 0.11 | 7.9 | 280 | 156 | 26 | 0.11 | 1.05 | 4.11 | 140 | 0.05 | 30.66 | Good |
| MIRJOLI | HANDPUMP | 12.12.2023 | 0.11 | 7.5 | 380 | 144 | 26 | 0.11 | 1.13 | 2.09 | 144 | 0.11 | 31.51 | Good |
| MIRJOLI | OPENWELL | 12.12.2023 | 1.25 | 7.6 | 480 | 252 | 24 | 0.13 | 1.21 | 1.11 | 140 | 0.02 | 36.58 | Good |
| MIRJOLI | OPENWELL | 12.12.2023 | 2.05 | 7.8 | 372 | 172 | 24 | 0.15 | 1.31 | 3.09 | 144 | 0.01 | 32.02 | Good |
| MIRJOLI | OPENWELL | 12.12.2023 | 1.69 | 7.7 | 416 | 216 | 30 | 0.31 | 1.41 | 1.34 | 156 | 0.01 | 36.77 | Good |
| MIRJOLI | OPENWELL | 12.12.2023 | 1.31 | 7.5 | 354 | 152 | 24 | 0.11 | 2.01 | 3.12 | 140 | 0.02 | 28.47 | Good |
| PEDHE | OPENWELL | 08.11.2023 | 0.13 | 7.7 | 275 | 144 | 34 | 0.11 | 0.2 | 0.11 | 80 | 0.11 | 27.56 | Good |
| PEDHE | OPENWELL | 08.11.2023 | 0.21 | 7.6 | 278 | 140 | 34 | 0.11 | 0.21 | 0.11 | 92 | 0.11 | 27.36 | Good |
| PEDHE | OPENWELL | 08.11.2023 | 0.11 | 7.7 | 240 | 128 | 36 | 0.38 | 0.21 | 0.19 | 72 | 0.21 | 31.77 | Good |
| PEDHE | OPENWELL | 08.11.2023 | 0.13 | 7.6 | 258 | 140 | 36 | 0.05 | 0.01 | 0.21 | 60 | 0.13 | 25.46 | Good |

**Table 3.** Water quality analysis of the samples collected during post-monsoon (Continued…)

| Name of Village | Type of Source | Sample Testing Date | Turbidity in NTU | pH | TDS (mg/L) | Alkalinity (MG/L) | Chloride (mg/L) | Fluoride (mg/ L) | Nitrate (mg/ L) | Sulphate (mg/ L) | Total Hardness (mg/ L) | Iron (mg/ L) | WQI | WQI Category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PEDHE PARSHURAM | PWSS | 08.11.2023 | 0.19 | 7.6 | 352 | 156 | 36 | 0.13 | 0.03 | 0.16 | 120 | 0.11 | 31.28 | Good |
| PEDHE PARSHURAM | PWSS | 08.11.2023 | 0.11 | 7.7 | 305 | 140 | 36 | 0.12 | 0.2 | 0.19 | 112 | 0.21 | 33.07 | Good |
| PEDHE PARSHURAM | OPENWELL | 08.11.2023 | 0.13 | 7.7 | 298 | 144 | 34 | 0.05 | 0.2 | 0.23 | 88 | 0.11 | 27.82 | Good |
| SHIRAL | OPENWELL | 02.01.2024 | 0.42 | 7.2 | 425 | 128 | 30 | 0.14 | 0.16 | 1.41 | 252 | 0.14 | 36.25 | Good |
| SHIRAL | OPENWELL | 02.01.2024 | 0.19 | 7.5 | 320 | 140 | 36 | 0.21 | 0.39 | 2.65 | 140 | 0.13 | 31.84 | Good |
| SHIRAL | PWSS | 02.01.2024 | 0.11 | 7.9 | 578 | 372 | 46 | 0.14 | 1.11 | 0.19 | 152 | 0.13 | 51.60 | Poor |
| SHIRAL | OPENWELL | 02.01.2024 | 1.69 | 7.7 | 320 | 144 | 24 | 0.16 | 1.35 | 1.36 | 144 | 0.19 | 34.90 | Good |
| SHIRAL | OPENWELL | 02.01.2024 | 0.16 | 8 | 349 | 144 | 48 | 0.16 | 1.35 | 9.35 | 144 | 0.21 | 39.35 | Good |
| VALOPE | PWSS | 08.11.2023 | 0.13 | 7.5 | 233 | 132 | 26 | 0.11 | 0.01 | 0.15 | 72 | 0.05 | 22.02 | Excellent |
| VALOPE | OPENWELL | 08.11.2023 | 0.11 | 7.8 | 285 | 136 | 42 | 0.19 | 0.01 | 0.31 | 88 | 0.11 | 29.51 | Good |
| VALOPE | PWSS | 08.11.2023 | 1.11 | 7.7 | 284 | 128 | 24 | 0.15 | 0.01 | 0.13 | 92 | 0.11 | 27.59 | Good |

**Table 4.** Descriptive statistics for the selected parameters **during monsoon** months (2023-2024)

| Central Tendency | Turbidity in NTU | pH | TDS (mg/L) | ALKALINITY (mg/L) | Chloride (mg/L) | Fluoride (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) | Total Hardness (mg/L) | Iron (mg/L) | WQI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.28 | 7.41 | 322.71 | 144.62 | 37.21 | 0.15 | 0.88 | 0.75 | 110.55 | 0.13 | 29.44 |
| Std. Error of Mean | 0.03 | 0.04 | 5.56 | 3.46 | 1.25 | 0.01 | 0.08 | 0.07 | 2.68 | 0.01 | 0.45 |
| Median | 0.16 | 7.50 | 305.00 | 140.00 | 34.00 | 0.13 | 1.11 | 0.19 | 104.00 | 0.13 | 29.28 |
| Mode | 0.11 | 7.50 | 356.00 | 140.00 | 30.00 | 0.11 | 0.11 | 0.11 | 92.00[a] | 0.11[a] | 18.04[a] |
| Std. Deviation | 0.31 | 0.39 | 53.02 | 32.99 | 11.92 | 0.10 | 0.72 | 0.70 | 25.57 | 0.06 | 4.28 |
| Variance | 0.10 | 0.15 | 2811.63 | 1088.33 | 142.12 | 0.01 | 0.52 | 0.49 | 653.69 | 0.00 | 18.32 |
| Skewness | 2.85 | -0.73 | 0.78 | 2.84 | 1.02 | 2.52 | 0.25 | 0.56 | 2.25 | 1.15 | 0.16 |
| Std. Error of Skewness | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Kurtosis | 8.10 | -0.27 | 0.66 | 13.91 | 0.51 | 7.41 | -1.44 | -0.93 | 8.53 | 3.21 | 1.03 |
| Std. Error of Kurtosis | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Range | 1.62 | 1.60 | 274.00 | 252.00 | 50.00 | 0.58 | 2.18 | 2.68 | 172.00 | 0.33 | 24.22 |
| Minimum | 0.03 | 6.50 | 228.00 | 80.00 | 20.00 | 0.05 | 0.01 | 0.01 | 68.00 | 0.01 | 18.04 |
| Maximum | 1.65 | 8.10 | 502.00 | 332.00 | 70.00 | 0.63 | 2.19 | 2.69 | 240.00 | 0.34 | 42.26 |
| Percentiles - 25 | 0.13 | 7.20 | 285.00 | 128.00 | 30.00 | 0.11 | 0.13 | 0.13 | 92.00 | 0.11 | 26.73 |
| Percentiles - 50 | 0.16 | 7.50 | 305.00 | 140.00 | 34.00 | 0.13 | 1.11 | 0.19 | 104.00 | 0.13 | 29.28 |
| Percentiles - 75 | 0.25 | 7.70 | 358.00 | 152.00 | 44.00 | 0.15 | 1.39 | 1.35 | 120.00 | 0.14 | 31.95 |

a. Multiple modes exist. The smallest value is shown;

**Source:** Calculated by the researchers using SPSS.

**Table 5.** Descriptive statistics for the selected parameters **during post-monsoon** months (2023-2024)

| Central Tendency | Turbidity in NTU | pH | TDS (mg/L) | ALKALINITY (mg/L) | Chloride (mg/L) | Fluoride (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) | Total Hardness (mg/L) | Iron (mg/L) | WQI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.41 | 7.33 | 333.91 | 333.91 | 37.10 | 0.17 | 0.46 | 0.95 | 125.05 | 0.13 | 30.71 |
| Std. Error of Mean | 0.05 | 0.04 | 7.57 | 7.57 | 1.17 | 0.01 | 0.06 | 0.16 | 3.37 | 0.01 | 0.63 |
| Median | 0.16 | 7.50 | 320.00 | 320.00 | 36.00 | 0.13 | 0.11 | 0.19 | 128.00 | 0.12 | 29.84 |
| Mode | 0.11 | 7.50 | 325.00 | 325.00 | 24.00[a] | 0.11 | 0.01 | 0.11 | 140.00 | 0.11 | 32.02 |
| Std. Deviation | 0.52 | 0.38 | 72.17 | 72.17 | 11.16 | 0.13 | 0.61 | 1.57 | 32.16 | 0.07 | 6.00 |
| Variance | 0.27 | 0.15 | 5208.39 | 5208.39 | 124.47 | 0.02 | 0.37 | 2.45 | 1034.25 | 0.01 | 36.03 |
| Skewness | 2.46 | -0.47 | 1.09 | 1.09 | 1.11 | 3.12 | 0.99 | 2.80 | 0.78 | 1.14 | 0.90 |
| Std. Error of Skewness | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Kurtosis | 7.36 | -0.69 | 1.94 | 1.94 | 1.38 | 13.99 | -0.56 | 9.83 | 2.45 | 2.94 | 0.89 |
| Std. Error of Kurtosis | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Range | 2.99 | 1.50 | 419.00 | 419.00 | 52.00 | 0.87 | 2.04 | 9.33 | 192.00 | 0.40 | 30.86 |
| Minimum | 0.06 | 6.50 | 159.00 | 159.00 | 24.00 | 0.05 | 0.01 | 0.02 | 60.00 | 0.01 | 20.74 |
| Maximum | 3.05 | 8.00 | 578.00 | 578.00 | 76.00 | 0.92 | 2.05 | 9.35 | 252.00 | 0.41 | 51.60 |
| Percentiles - 25 | 0.12 | 7.10 | 288.00 | 288.00 | 30.00 | 0.11 | 0.01 | 0.12 | 100.00 | 0.11 | 25.98 |
| Percentiles - 50 | 0.16 | 7.50 | 320.00 | 320.00 | 36.00 | 0.13 | 0.11 | 0.19 | 128.00 | 0.12 | 29.84 |
| Percentiles - 75 | 0.49 | 7.60 | 369.00 | 369.00 | 42.00 | 0.19 | 1.11 | 1.35 | 140.00 | 0.15 | 34.81 |

a. Multiple modes exist. The smallest value is shown

**Source:** Calculated by the researchers in SPSS.

**Table 6.** Water quality category (2023)

| WQI Category | Number of Water Samples | | | | | |
|---|---|---|---|---|---|---|
| | Borewell | Handpump | Jack Well | Open well | PWSS | Taki |
| Excellent | 2 | 2 | 0 | 13 | 11 | 0 |
| Good | 18 | 10 | 2 | 81 | 39 | 2 |
| Poor | 0 | 0 | 0 | 0 | 1 | 0 |
| Total | 20 | 12 | 2 | 94 | 51 | 2 |

Source: Calculated by the researcher based on Water Quality Analysis

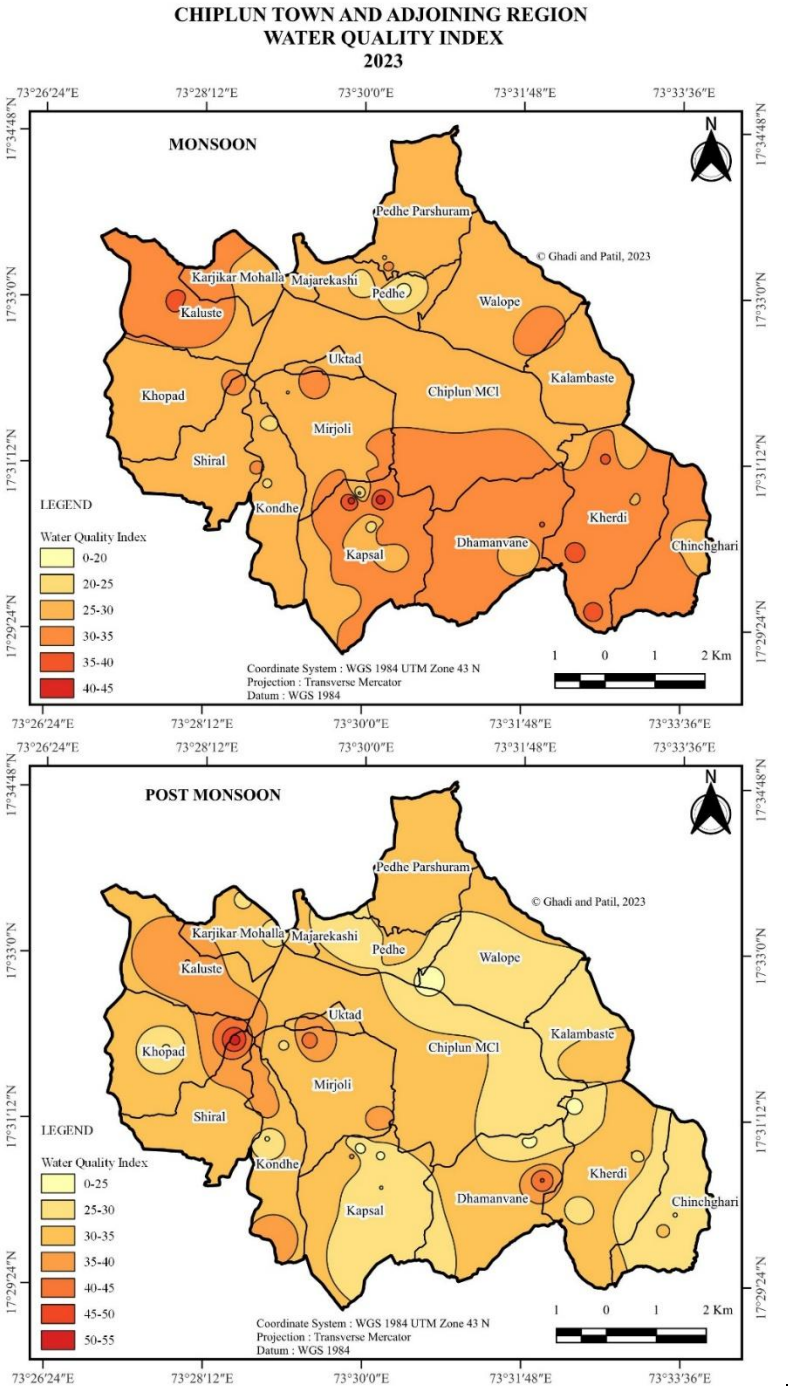


**Figure 14.** The WQI classification and spatial distribution

## 4. Conclusion

The present study provides an integrated assessment of groundwater potential and quality in Chiplun Town and its adjoining region, Ratnagiri District, Maharashtra. The groundwater potential assessment revealed considerable spatial variation in groundwater depth and yield, mainly influenced by lithology, topography, recharge conditions, geological structures, and surface-water interactions. Several areas, including Pedhe-Parshuram, Walope, Dhamanavane, Kherdi, Chinchghari, Shiral, and parts of Mirjoli and Chiplun, showed favourable groundwater potential. Analysis of 182 groundwater samples from the monsoon and post-monsoon seasons showed that the studied physicochemical parameters were generally within BIS drinking-water limits, with only moderate seasonal variations. The WQI assessment further indicated predominantly good groundwater quality, with 12 Excellent and 79 Good samples during monsoon, and 15 Excellent, 75 Good, and one Poor sample during post-monsoon. The mean WQI changed only slightly from 29.44 to 30.71, indicating overall stable and satisfactory groundwater quality. Overall, the study demonstrates that the Chiplun region possesses considerable groundwater potential and generally good groundwater quality. However, spatial and seasonal variations highlight the need for regular monitoring, protection of recharge zones, controlled groundwater abstraction, and sustainable management practices to ensure long-term groundwater security in the region.

## Author contributions

Sardar Patil contributed to the study conception and design. Material preparation, data collection and analysis were performed by Guruprasad Ghadi. The hydro-chemical analysis part was reviewed and interpreted by Hemant Chavan

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## Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate:

Not applicable.

**Consent for publication:**

Not applicable.

**Competing interests:**

The authors declare no competing interests.

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