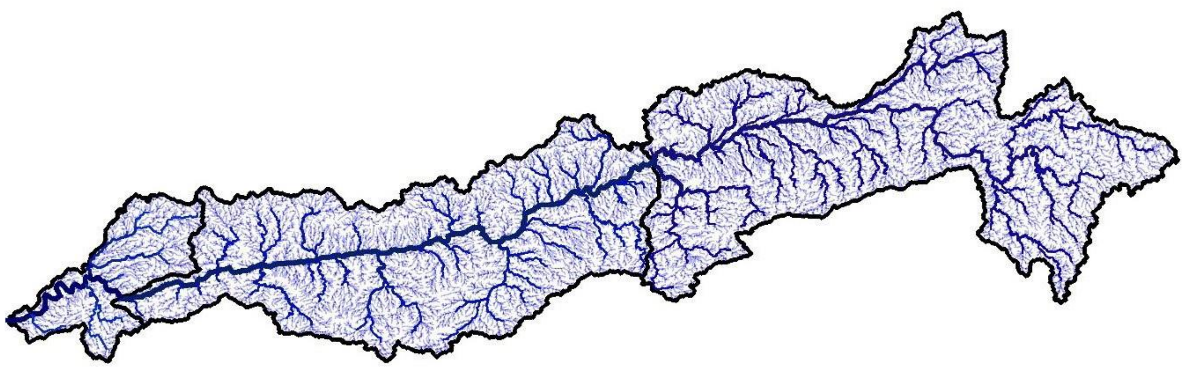
National River Conservation Directorate
Ministry of Jal Shakti, Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Physio-Chemical and Biological profile Report



December 2025

Narmada River Basin Physio-Chemical and Biological Profile Report

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and the Ministry of Jal Shakti, provides financial assistance to the State Government for the conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies. (www.nrcd.nic.in)

Centers for Narmada River Basin Management Studies (cNarmada)

The Centres for Narmada River Basin Management Studies (cNarmada) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Gandhinagar and IIT Indore, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cNarmada is committed to restoring and conserving the Narmada River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement. (www.cnarmada.org)

Center for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as a think-tank in the implementation and dynamic evolution of the Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India. (www.cganga.org)

Acknowledgments

This report is a comprehensive outcome of the project jointly executed by IIT Gandhinagar (Lead Institute) and IIT Indore (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2025. We gratefully acknowledge the individuals who provided information for this report.

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PREFACE

The Narmada River, often referred to as the lifeline of central and western India, holds unparalleled significance for the region's water resources, ecosystems, and communities. Its hydrological complexity, combined with its ecological and cultural heritage, underscores the critical need for its preservation and sustainable management.

This report, focusing on physico-chemical and biological analysis studies of the Narmada River Basin, aims to provide an in-depth analysis of surface water, groundwater, rock, and soil parameters of the Narmada River. The collection and compilation of data on these parameters of both the Upper and Middle Basins will provide valuable insights into the water, soil, and rock quality status of the Narmada Basin.

The findings and recommendations presented in this report are intended to serve as a guiding framework for policymakers, researchers, and practitioners committed to sustainable water management in the Narmada Basin. By identifying trends and challenges, it aspires to support the development of policies that balance physico-chemical and biological quality perspectives, which help in ecological preservation with socioeconomic progress.

We are deeply grateful to all individuals, organizations, and institutions that contributed to the preparation of this report. Their dedication, expertise, and support have been instrumental in shaping this study. It is our hope that this report will inspire collaborative efforts and meaningful action toward the long-term health and sustainability of the Narmada River and its Basin.

Centre for Narmada River Basin Management and Studies (cNarmada)
IIT Gandhinagar, IIT Indore

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Abbreviations & Acronyms

BIS	Bureau of Indian Standards
CWC	Central Water Commission
CGWB	Central Ground Water Board
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
GSI	Geological Survey of India
MPPCB	Madhya Pradesh Pollution Control Board
NWIC	National Water Informatics Centre
NRCD	National River Conservation Directorate
I-WRIS	Indian Water Resource Information System
SLUSI	Soil and Land Use Survey of India
TDS	Total Dissolved Solids
T. Col.	Total Coliform
d/s	Downstream
u/s	Upstream

1. Introduction

The Narmada River Basin extends from 21°40'12" to 23°41'24" N latitudes and 72°48'36" to 81°45'36" E longitudes, encompassing a total area of 97,560.80 sq. km, which constitutes about 3% of India's total geographical area (3,297,427.32 sq. km). Bounded by the Vindhyan ranges to the north, the Maikala hills to the east, the Satpura ranges to the south, and the Arabian Sea to the west, the basin lies at the northern extremity of the Deccan Plateau and covers significant portions of Madhya Pradesh and Gujarat, with smaller parts extending into Chhattisgarh and Maharashtra. The basin spans 39 districts, comprising 27 districts of Madhya Pradesh, six districts of Gujarat, four districts of Chhattisgarh, and two districts of Maharashtra. The Narmada Basin exhibits an elongated shape, stretching approximately 915.65 km east to west and about 236 km north to south. The basin experiences a tropical monsoon climate characterized by distinct wet and dry seasons, with an average annual rainfall ranging from 800 to 1,200 mm. The Narmada River, the longest west-flowing river in India, drains into the Arabian Sea near Bharuch in Gujarat and is further subdivided into Upper, Middle, and Lower Narmada River basins. The Narmada River Basin has a total population of 20,799,195 and spans several states and districts. The Upper Narmada Basin has a population of 8,603,425, while the Middle Narmada Basin has a population of 9,126,886. There is an uneven distribution of population in various districts of the Narmada Basin.

Apart from this, there is considerable variation among the various districts within the Narmada Basin in terms of infrastructure, industrial development, and agricultural development. These developments result in multiple types of water resource uses, which can generate various kinds of solid-liquid waste and other pollutants that can impact the physicochemical and biological parameters of ground and surface water, soil, and rock in terms of physicochemical quality. The Basin encompasses river valleys, fertile plains, and hilly regions. Due to these geographical differences, which can ultimately lead to environmental challenges such as pollution, water availability and quality issues, and soil erosion, these issues may affect the physicochemical and biological properties of water, soil, and rock in the Narmada Basin.

The interpretation of physicochemical and biological parameters from the collected data is the primary focus of this report, which analyzes the quality parameters of surface water, groundwater, soil, and rock, aiming to identify the water quality status, potential pollution levels, and the various factors affecting the Narmada River's water quality.

We will also focus on identifying hotspots that require more attention, regular sampling, and further analysis due to poor water quality data in terms of physical, chemical, and biological parameters. The possible reasons for these hotspots may be due to climatic conditions, such as heavy rainfall, which can ultimately increase pollutant runoff and sediments in rivers, as well as anthropogenic activities. In this report, we focused on the major parameters listed in Table 1.

Table 1 Summary of the parameters analyzed in the report.

Types	**Parameters**
Physical parameters	Turbidity, Total Dissolved Solids, Electrical Conductivity, Temperature, Turbidity, Total Suspended Solids.
Chemical Parameters	pH, Total Alkalinity, Total Hardness, Potassium, Sulphate, Chloride, Nitrate Nitrogen, Silicon Dioxide, Dissolved Oxygen, Biochemical Oxygen Demand, Calcium, Magnesium, Fluoride, Sodium, Ammonical Nitrogen, BOD, COD, DO, TKN, Boron, P-Alkalinity, Phosphate, Potassium
Biological Parameters	Fecal Coliform, Total Coliform

The report is divided into four sections: -

- Surface Water Physico-chemical Analysis
- Ground Water Physico-chemical Analysis
- Soil Physico-chemical Analysis
- Rock Physico-chemical Analysis

2. Water Quality Standards and Criteria

Water quality data is compared with the Bureau of Indian Standards (BIS) IS 10500:2012 limits set for drinking purposes. The BIS values of parameters are listed in Table 2.

The classification of Water Quality is based on its designated use. Table 3 provides the five categories (A to E), which are based on the different parameters.

Table 2 Drinking Water quality standards as per Bureau of Indian Standards BIS IS 10500: 2012.

Parameters	Acceptable Limit	Permissible Limit in Absence of an Alternate Source	Unit
pH	6.5-8.5	-	-
Total Dissolved Solids	500	2000	mg/L
Turbidity	1	5	NTU
Chloride	250	1000	mg/L
Sulphate	200	400	mg/L
Total hardness	200	600	mg/L
Total Alkalinity	200	600	mg/L
Nitrate (No3)	45	-	mg/L
Fluoride	1	1.5	mg/L
Calcium	75	200	mg/L
Magnesium	30	100	mg/L

Source: Bureau of Indian Standards IS 10500:2012

Table 3 Water Quality Criteria according to CPCB Guidelines

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment, but after disinfection	A	● Total Coliforms Organism MPN/100ml shall be 50 or less ● pH between 6.5 and 8.5 ● Dissolved Oxygen 6mg/l or more ● Biochemical Oxygen Demand 5 days 20C 2mg/l or less
Outdoor bathing (Organized)	B	● Total Coliforms Organism

Designated-Best-Use	Class of water	Criteria
		MPN/100ml shall be 500 or less, pH between 6.5 and 8.5, Dissolved Oxygen 5mg/l or more ● Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	● Total Coliforms Organism MPN/100ml shall be 5000 or less, pH between 6 and 9, Dissolved Oxygen 4mg/l or more ● Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Propagation of Wildlife and Fisheries	D	● pH between 6.5 and 8.5, Dissolved Oxygen 4mg/l or more ● Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste Disposal	E	● pH between 6.0 and 8.5 ● Electrical Conductivity at 25 °C micro mhos/cm Max 2250 ● Sodium absorption Ratio Max 26 ● Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Source: https://cpcb.nic.in/water-quality-criteria/

3. Surface Water Physico-Chemical and Biological Analysis

Data has been collected from MPPCB for surface water analysis, which includes 50 sampling stations across the 13 districts of the Narmada Basin. Districts and names of sampling stations for both the Upper and Middle Basins are listed in Tables 4 and 5.

Table 4 Districts covered under MPPCB sampling stations in the Upper and Middle Narmada Basin.

S. No.	Districts Covered by MPPCB
1	Anuppur
2	Dindori
3	Mandla
4	Jabalpur
5	Narsinghpur
6	Narmadapuram
7	Sehore
8	Dewas
9	Dhar
10	Khandwa
11	Khargone
12	Badwani
13	Alirajpur

Source: Narmada: River at a Glance, cNarmada (2024) and MPPCB.

Each district of the Upper and Middle Basin has a different set of sampling stations, as shown in Figures 1& 2.

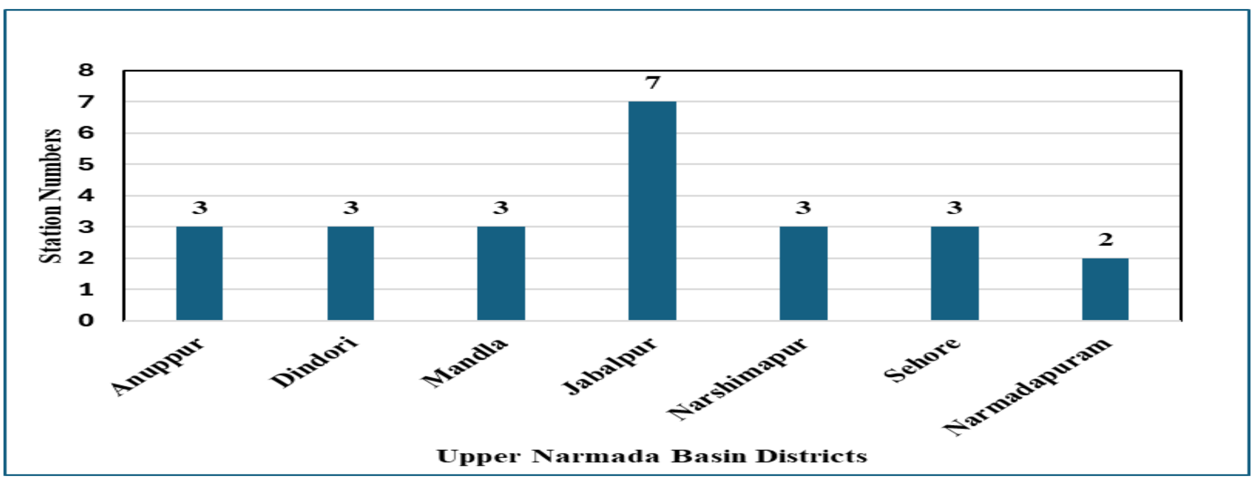


Figure 1 District-wise distribution of sampling station numbers covered in the Upper Narmada Basin.
Source: Narmada: River at a Glance (2024), cNarmada and MPPCB

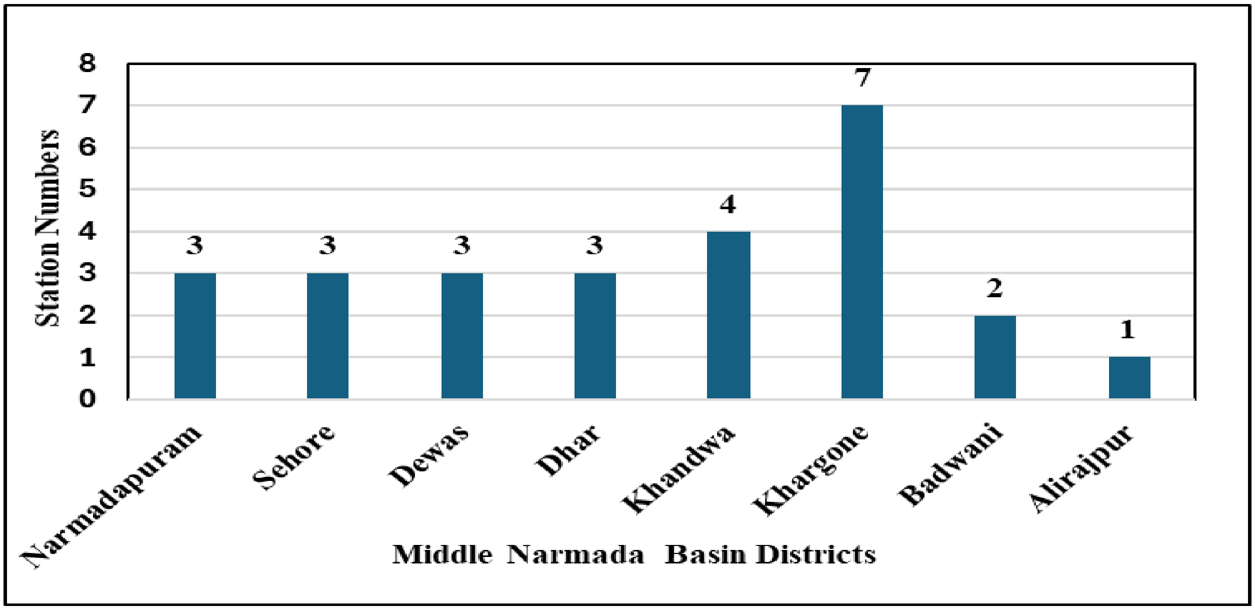


Figure 2 District-wise distribution of sampling station numbers covered in the Middle Narmada Basin.
Source: Narmada: River at a Glance (2024) cNarmada and MPPCB

Table 5 Station codes and Names of sampling stations of Upper and Middle Narmada Basin.

Station code	Station Names of the Upper Narmada Basin
SU1	Narmada at Amarkantak Origin point
SU2	Narmada at Pushkar dam, Amarkantak
SU3	Narmada at Kapildhara, Amarkantak
SU4	Narmada at Chandanghat, Dindori
SU5	Narmada at Dindori u/s, Dindori
SU6	Narmada at Dindori d/s Dindori Jogotikara Ghat
SU7	Narmada at Mandla near Shamshanghat, Mandla
SU8	Narmada at Road bridge, Raftaghat, Mandla
SU9	Narmada at Bhairav temple, Shahastradhara, Mandla
SU10	Narmada at road bridge d/s of Bargi dam
SU11	Narmada at Jamtara Jabalpur
SU12	Narmada at Lalpur, near the water supply intake well point
SU13	Narmada at Tilwaraghat, Jabalpur
SU14	Narmada at Panchawatighat, before mixing with the Bawanganga River
SU15	Narmada at Saraswatighat after mixing with the Bawanganga River
SU16	Narmada near road bridge, Jhansighat, Jabalpur
SU17	Narmada NH-44, Road bridge Barmanghat Narsinghpur
SU18	Narmada at 100 mt d/s Barmanghat, Narsinghpur.
SU19	Narmada SH-44, Jhikoli village, Narsinghpur
SU20	Narmada at the road bridge Sandia, Pipariya
SU21	Narmada u/s of Jait village, Sehore.

Station code	Station Names of the Upper Narmada Basin
SU22	Narmada D/s of Jait village, Sehore.
SU23	Narmada at Shahganj rest house
SU24	Narmada u/s before confluence of Tawa River at Village Bandrabhan
Station Codes and Names of the Middle Narmada Basin	
SM25	Narmada d/s after confluence of the Tawa River at Ramnagar Village, Bandrabhan
SM26	Narmada at Sethanighat
SM27	Narmada near Budhnighat, Budni
SM28	Narmada, d/s textile unit, Village Holipura, Budni
SM29	Narmada at Korighat
SM30	Narmada 100 mts. d/s after confluence of SPM Nallah
SM31	Narmada before the confluence of the river Jammar, Nemawar
SM32	Narmada at Nemawar
SM33	Narmada 500 mts. d/s of Jain Mandir, Nemawar
SM34	Narmada River at Hanuwantia, Khandwa
SM35	Narmada river at Punasa dam
SM36	Narmada at U/s Omkareshwar Dam
SM37	Narmada at D/s Omkareshwar Dam
SM38	Narmada near Mortaka bridge, Badwah, Khargone
SM39	Narmada at Dhareshwar, Khargone
SM40	Narmada at U/s Mandleshwar near Jalood intake well point, Khargone
SM41	Narmada at Mandleshwar d/s Khargone
SM42	Narmada at Maheshwar, Khargone
SM43	Narmada at Shahastradhara, Jalkoti
SM44	Narmada at Khalghat, Khargone
SM45	Narmada at Dharampuri, before mixing the Domestic nalla
SM46	Narmada at Dharampuri d/s
SM47	Narmada at Semalda u/s Badwani
SM48	Narmada at Rajghat, Badwani
SM49	Narmada at Koteshwar, Nisarpur, Dhar
SM50	Narmada at Kakrana, Alirajpur

Source:https://www.mppcb.mp.gov.in/narmada-report16-17-17-18eng.aspx

There are three new stations in the MPPCB data, which we named N1, N2, and N3. N1 is d/s of Mella Area, Near Darogaghat, Jabalpur, added in the Year 2024-2025 with significantly less data, and Stations N2 and N3, Narmada, Barmanghat, Mainghat, Narsinghpur, and Narmada River at Narmada-Kshipra Sangam are the new stations added in the sampling stations. No data is available for these stations. Figures 3 & 4 show the locations of sampling stations in the Upper Narmada Basin (1-24) and Middle Narmada Basin (25-50).

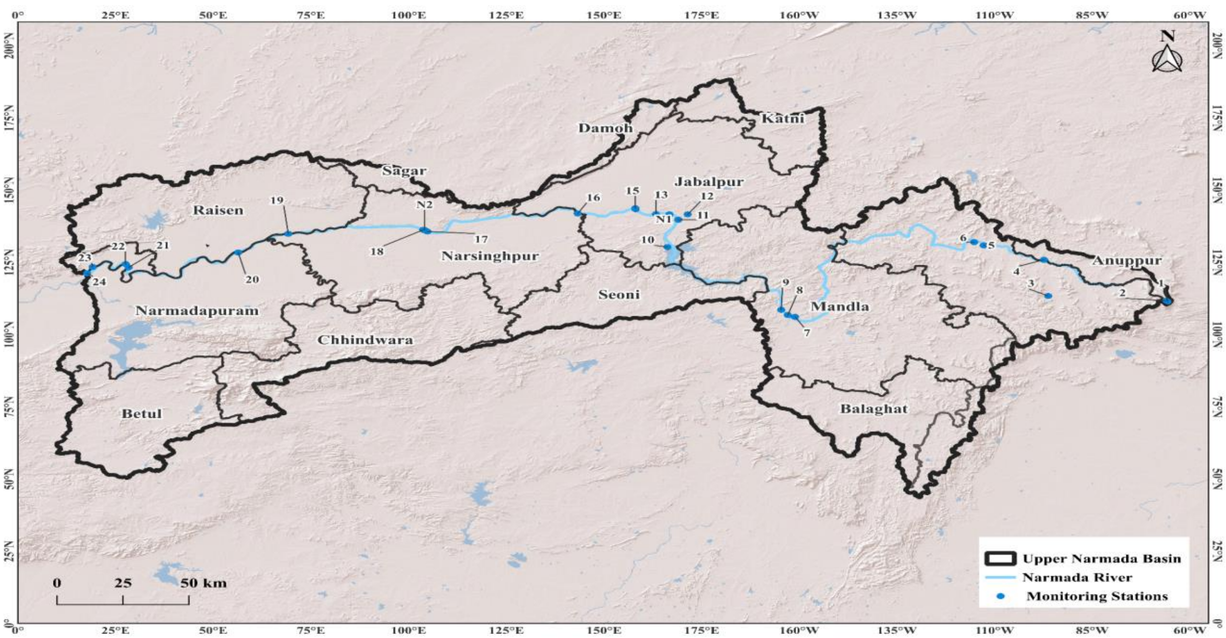


Figure 3 Mapping of different sampling stations (1-24) of districts in the Upper Narmada Basin.

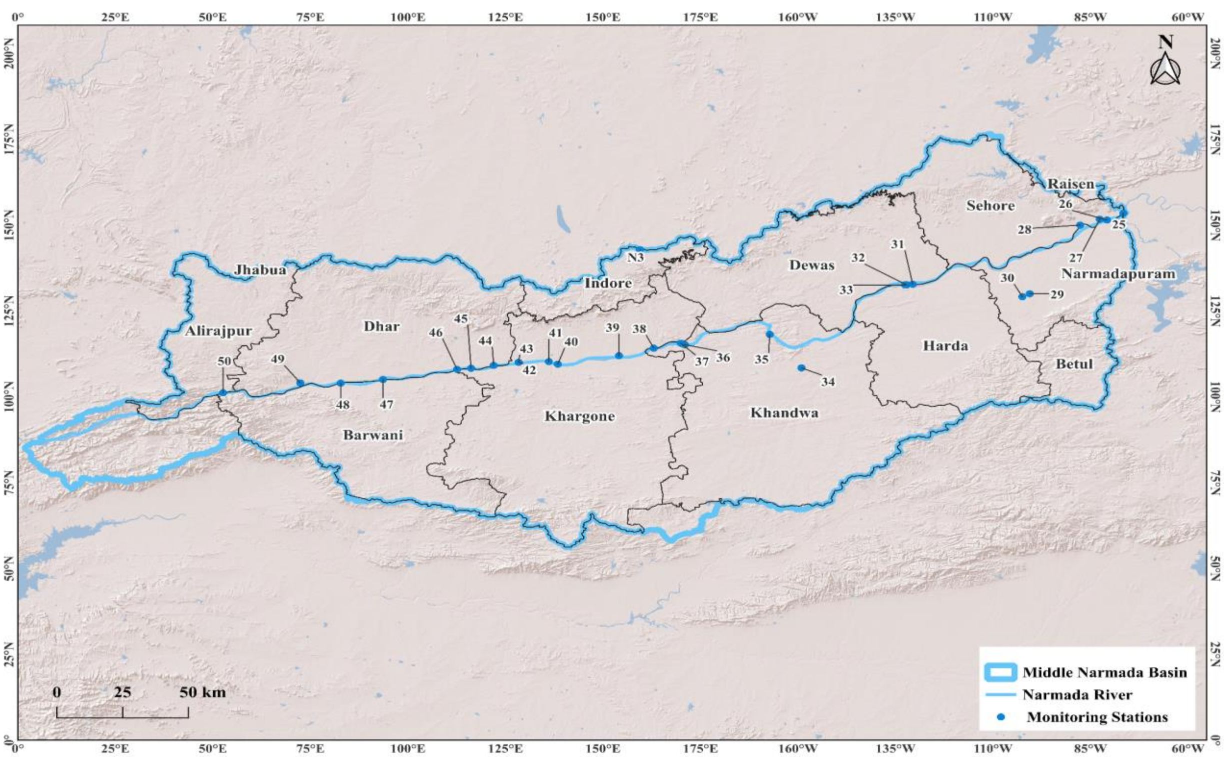


Figure 4 Mapping of different sampling stations (25-50) of districts in the Middle Narmada Basin.

3.1 Upper Narmada Basin

There are a total of 24 stations in the Upper Narmada Basin. The data covers a period of 9 years, from 2016 to 2025 (April – March) for all parameters. The collected data is grouped into three main categories: Physical, Chemical, and Biological Parameters.

3.1.1. Physical Parameters:

Two major physical parameters, Turbidity and Total Dissolved Solids data, are analyzed to assess the water quality of the Upper Narmada Basin.

i) Turbidity

As per the BIS standard, the limit for turbidity is 1-5 NTU. Here, we have analyzed the monthly data for each year (2016-2025) at all stations. According to the values of turbidity, the highest yearly average was observed at 80.74 NTU at station SU24 (Narmada u/s before the confluence of River Tawa near Bandrabhan). At this same station, the maximum values of turbidity observed were 424, 390, and 98 NTU in July, August, and September 2023-2024, which are typically monsoon months. Similar values are observed for station SU22, Narmada River, at the d/s of Jait Village, Sehore, and Station SU23, Narmada River, at Shahganj Guest House, in the same months and year. A similar pattern of extremely high turbidity values was also recorded at other stations during the monsoon season.

The maximum increase in turbidity values during the monsoon season can lead to sediment disturbance and is also correlated with agricultural mechanization and intensive farming in these areas. The figures for the seasonal variation of turbidity are provided for reference in Annexure 3A.

ii) Total Dissolved Solids

Another important parameter, evaluated to assess the water quality of the Narmada Basin, is the total dissolved solids.

According to the standard set by the Bureau of Indian Standards (BIS), the acceptable range of total dissolved solids is 500-2000mg/L. The data showed that the maximum value of total dissolved solids among all years was recorded as 610 mg/L at station SU15 Narmada, at Saraswatighat, after the Bawanganga River.

The average values of all years across all sampling stations fall within the range set by BIS. The highest average value among all stations was observed at 265 mg/L at Station SU17, located on Narmada NH-44, near the Road Bridge Barmanghat, Narsinghpur, as shown in Figure 5.

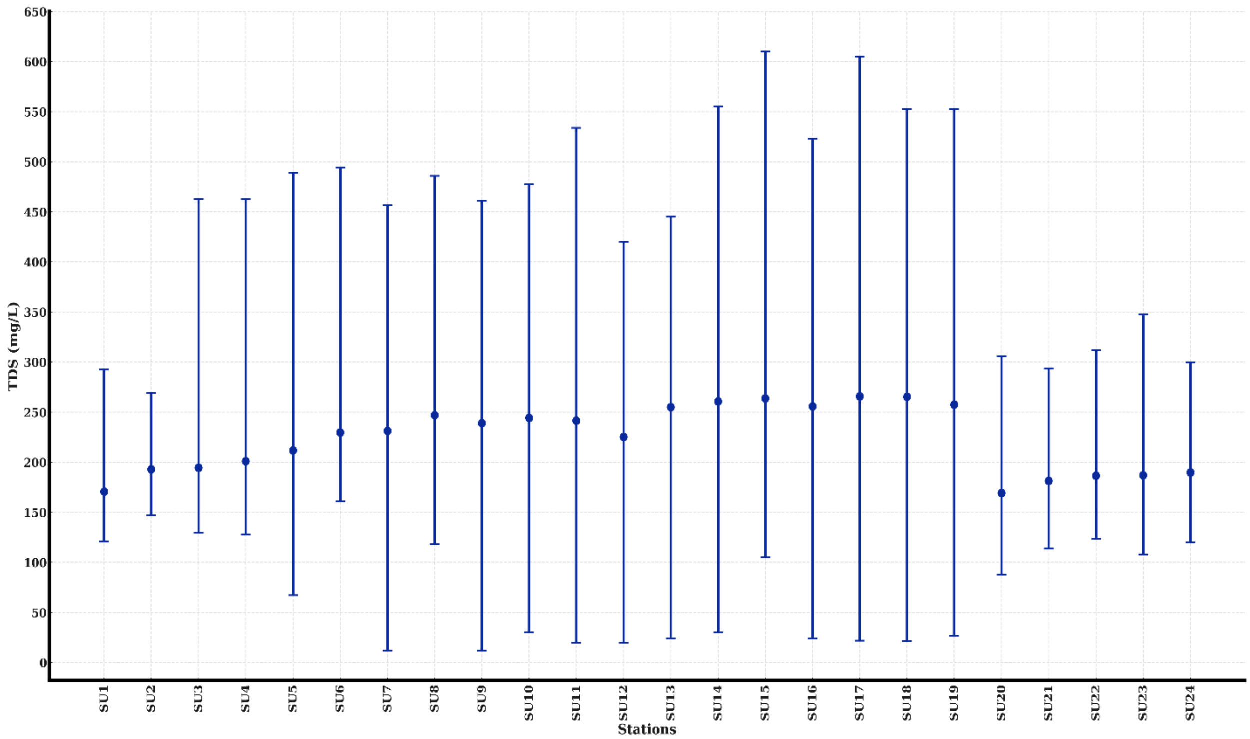


Figure 5 Average, Maximum, and Minimum values over the last 9 years for Total Dissolved Solids in surface water across different sampling stations of Upper Narmada Basin.

3.1.2. Chemical Parameters:

The data analyzed for the chemical parameters include pH, Total Alkalinity, Total Hardness, Potassium, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) across all years and sampling stations.

i) pH

The highest average pH value across all years and stations was observed as 8.3 at Station SU20, located on the Narmada River near Road Bridge Sandhiyaghat, which falls within the BIS permissible limit of 6.5 to 8.5. The pH yearly average values of all years at all sampling stations are shown in Heat Map Figure 6.

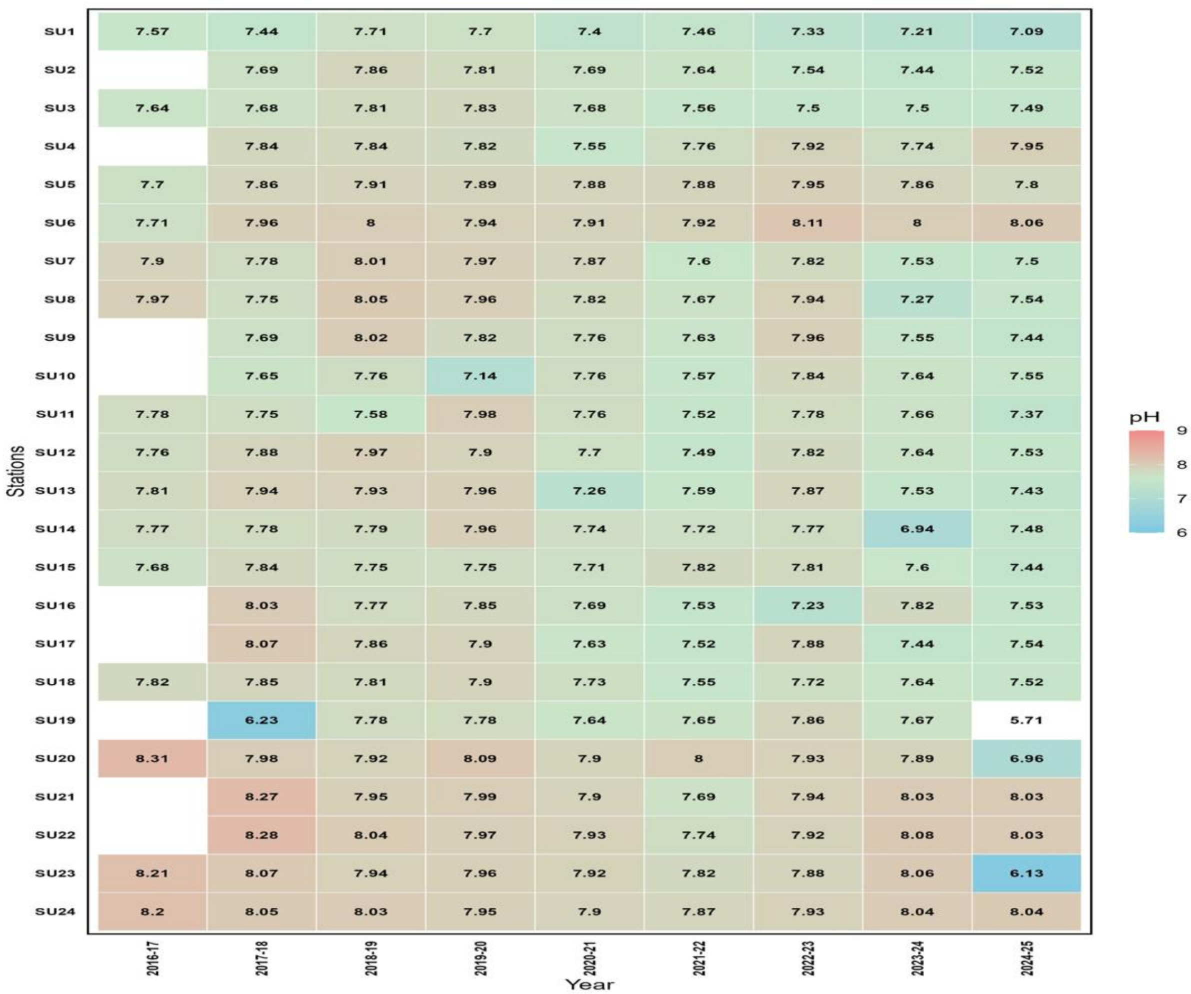


Figure 6 pH yearly average values of surface water across all sampling stations of the Upper Narmada Basin.

ii) Total Alkalinity

The BIS limit set for Total Alkalinity is 200-600mg/L. The highest average value among nine years across all stations was observed at 128 mg/L at Station SU21, located in the Narmada River u/s of the village of Jait, Sehore. At Station 24, the Narmada u/s before the confluence of the Tawa River at Village Bandrabhan, the maximum value of 176 mg/L was recorded. The average values for all years and stations are within the limit, as shown in Figure 7.

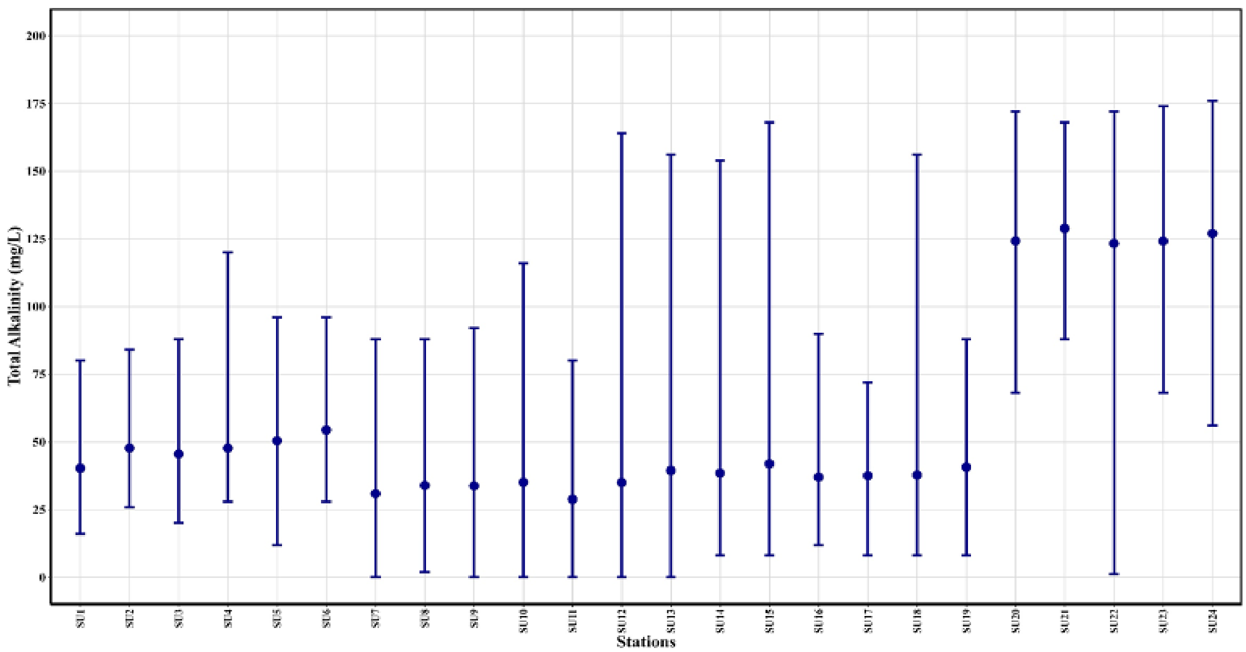


Figure 7 Average, Maximum, and Minimum values over the last 9 years of Total Alkalinity in surface water across different sampling stations of the Upper Narmada Basin.

iii) Total Hardness

The BIS limit of Total hardness is set to 200-600 mg/L. The highest average value among nine years across all stations was observed at 132 mg/L at station SU6, Narmada at Dindori d/s Dindori Jogotikara Ghat. The Maximum Value was observed at 287 mg/L at station SU12, Narmada, at Lalpur, near the water supply intake well point. The average values of all years across all stations for Total Hardness are within the limits, as shown in Figure 8.

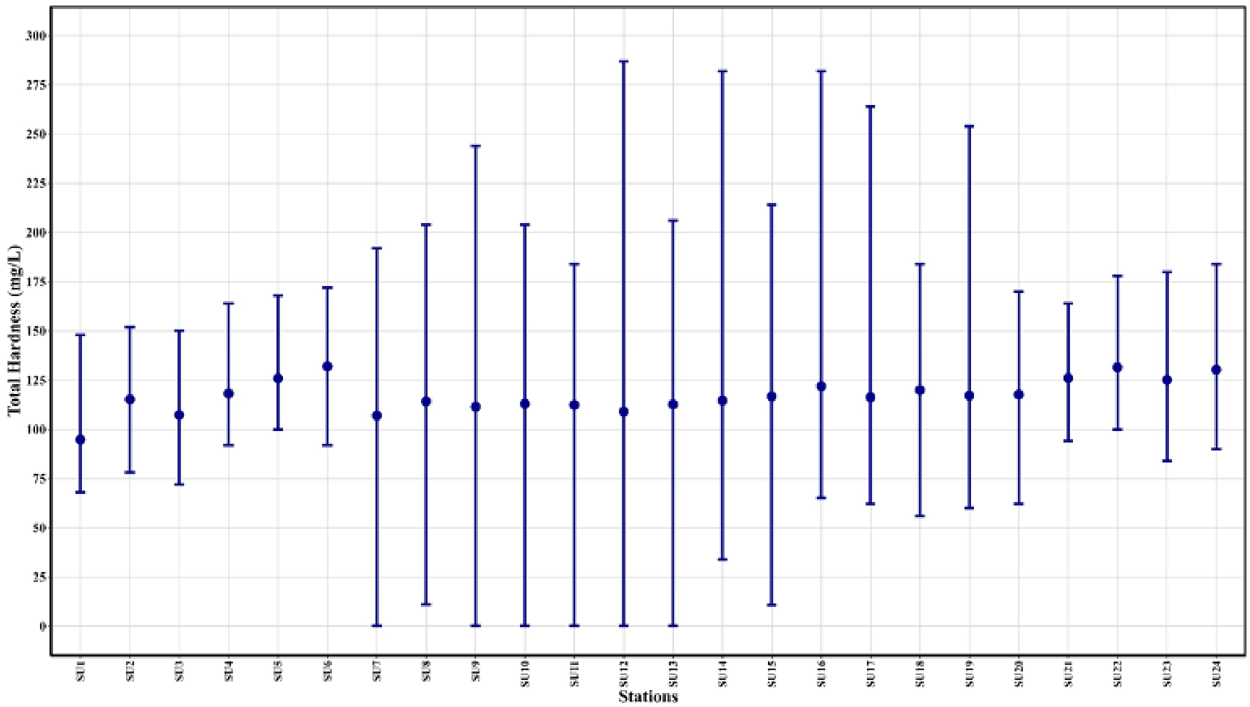


Figure 8 Average, Maximum, and Minimum values over the last 9 years of Total Hardness in surface water across different sampling stations of the Upper Narmada Basin.

iv) Potassium

The highest average values for all nine years at all stations range from 3.52 to 1.69 mg/L. The highest average value for Potassium was observed at 3.52 mg/L at Station 18 Narmada at 100 mt d/s Barmanghat, Narsinghpur, and the maximum value was 18 mg/L at the same station, SU13 Narmada, at Tilwaraghat, Jabalpur. The average values for all nine years at all stations are shown in Figure 9. There is no standard available for Potassium in BIS; however, according to WHO guidelines, a concentration of 10 mg/L is considered safe, with limits varying depending on different conditions (Ref. 7).

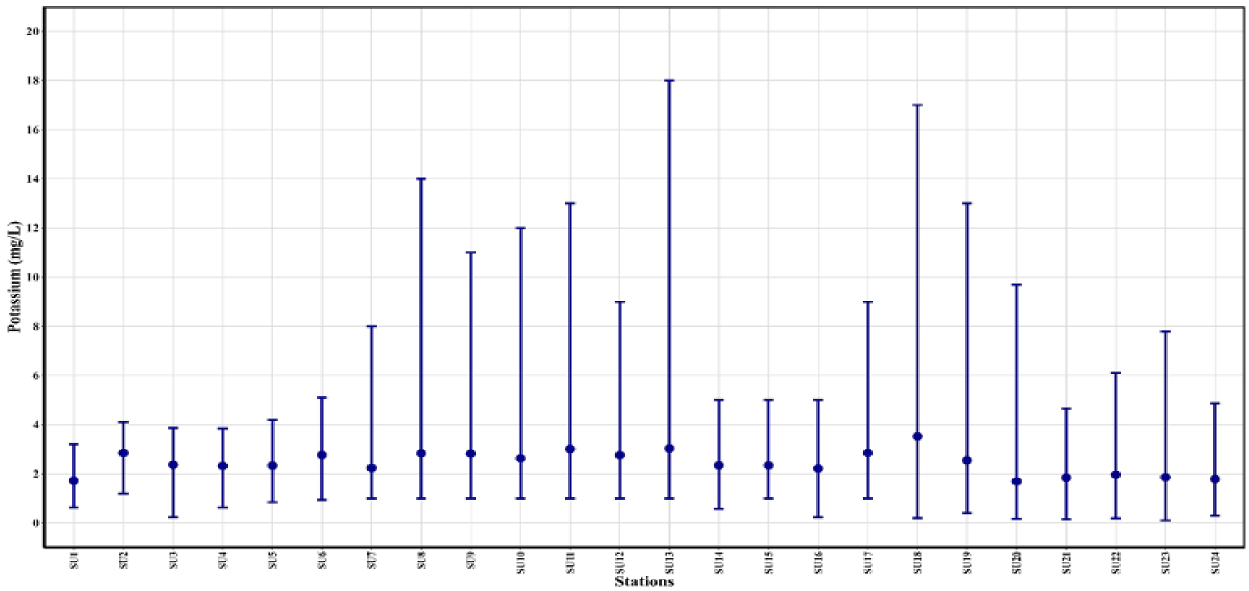


Figure 9 Average, Maximum, and Minimum values over the last 9 years of Potassium in surface water across different sampling stations of the Upper Narmada Basin.

v) Dissolved Oxygen (DO)

The highest average value of dissolved oxygen across all nine years and all sampling stations was recorded as 8.29 mg/L at Station SU 22 Narmada d/s of Jait village, and the maximum value of 14.5 mg/L was observed at the same station. All average values of all years across all stations are within the required limits, i.e., 6 or more, as shown in Figure 10.

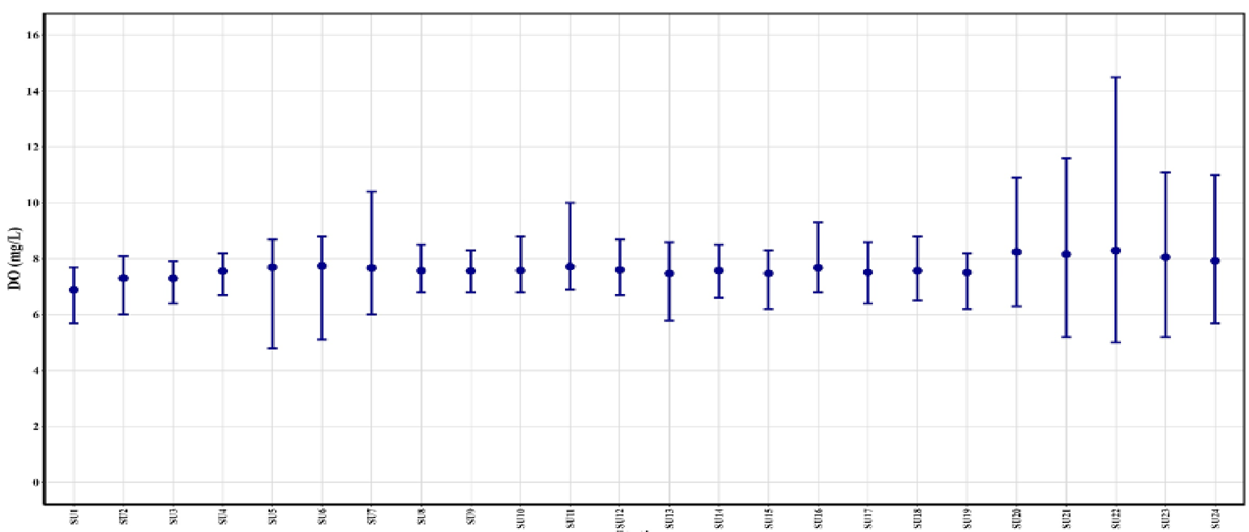


Figure 10 Average, Maximum, and Minimum values over the last 9 years of Dissolved Oxygen in surface water across different sampling stations of the Upper Narmada Basin.

vi) Biochemical Oxygen Demand (BOD)

The analysis indicates that the highest average value across all years and stations observed was 1.84 mg/L at Station SU2 Narmada at Pushkar Dam, Amarkantak, which is within the limits set by BIS, i.e., <3mg/L. The maximum value of 3.1 mg/L was observed at Station SU22 Narmada d/s of Jait village, Sehore. Narmada at the road bridge, Sandia, Pipariya. The average values for all nine years of sampling stations are shown in Figure 11.

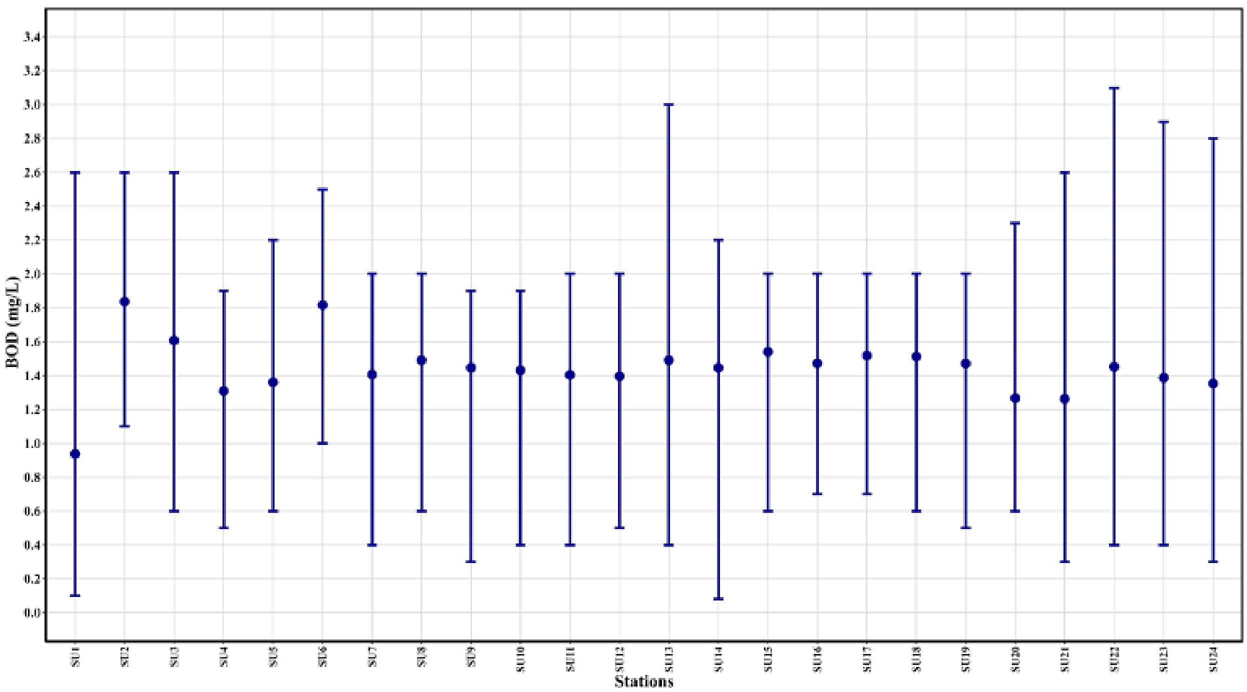


Figure 11 Average, Maximum, and Minimum values over the last 9 years of Biochemical Oxygen Demand in surface water across different sampling stations of the Upper Narmada Basin.

vii) Chemical Oxygen Demand (COD)

The analysis indicates a yearly average value that ranges from 1 to 25 mg/L across all stations over a nine-year period. Details of all stations' yearly averages are provided in Table 6.

Table 6 Summary of COD's yearly average of nine years of all sampling stations in the Upper Narmada Basin

Chemical Oxygen Demand									
Station Codes	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
SU1	7.6	5.3	4.9	4.9	2.7	6.1	5.0	9.8	8.9
SU2	-	12.3	15.5	14.7	10.2	14.1	12.8	17.2	13.5
SU3	11.2	9.0	11.4	9.8	5.2	10.4	14.2	16.0	13.7
SU4	-	8.1	8.2	6.1	3.1	6.5	9.4	13.1	12.4
SU5	20.167	9.4	7.4	6.13	3.13	6.50	10.4	10.2	13.9
SU6	21.0	16.3	15.1	13.88	8.62	13.13	19.1	17.6	17.7
SU7	12.17	12.0	13.7	20.0	13.67	11.8	12.3	16.1	11.6
SU8	12.08333	10.9	16.1	21.0	15.1	12.8	13.0	17.3	10.5
SU9	-	16.0	17.7	20.0	14.8	12.1	13.2	18.9	12.8
SU10	-	5.7	18.4	19.8	12.3	14.3	16.8	14.0	13.1
SU11	12.25	12.3	15.1	23.7	12.5	15.3	11.6	14.4	10.1
SU12	10.75	9.8	14.8	18.92	11.50	14.67	13.6	15.2	10.3
SU13	11.67	10.7	18.3	20.8	14.5	12.8	15.5	14.4	14.3
SU14	13.22	12.4	15.9	19.83	16.42	12.17	14.0	14.6	16.6
SU15	13.5	12.6	16.4	19.17	17.17	13.83	15.3	17.9	18.5
SU16	-	12.8	15.3	15.50	16.08	11.50	14.8	15.5	11.5
SU17	-	8.8	18.8	20.3	14.73	16.7	12.7	18.0	12.3
SU18	13.67	14.3	16.6	18.8	17.0	16.5	12.5	16.3	15.8
SU19	-	8.5	18.3	15.7	19.0	13.2	14.2	16.8	11.8
SU20	13.97	12.94	13.1	13.86	13.50	13.43	13.27	12.71	12.78
SU21	-	16.21	12.3	19.55	13.02	11.56	11.37	16.48	12.84
SU22	-	19.39	18.9	24.50	20.33	15.10	12.17	16.09	12.89
SU23	11.57	12.17	14.7	17.16	17.68	13.50	13.02	17.83	13.17
SU24	14.25	22.6	13.9	17.1	13.8	11.7	13.9	14.13	11.34

3.1.3. Biological Parameter

i) Total Coliform

The range of Total Coliforms in the Upper Narmada Basin, as recorded across nine years and at all sampling stations, varied between 1.8 and 54,000 MPN/100 mL, which is significantly higher than the limits of 50 MPN/100 mL for category A. Many stations (SM20-SM24) across the Upper Narmada Basin have recorded high values of Total Coliforms, primarily in the months of October to February and in the years 2018-2021, that is, post-monsoon months. However, the current year's data (2024-2025) shows a maximum average value of 181 MPN/100 ml at Station SU23, Narmada River, at Shahganj Guest House, which is better than previous years' data, specifically for the above-mentioned stations.

According to the current situation of Total Coliforms in the river water, the water quality is categorized as B, as per the CPCB water quality criteria (Table 5), since the Total Coliform values are above 50 MPN/100ml and less than 500 MPN/100ml. This is an alarm of concern that requires further investigation, regular sampling analysis, and identification of the contamination source to improve the water quality for drinking purposes.

3.2 Middle Narmada Basin

There are a total of 26 stations in the Middle Narmada Basin. The data covers a period of 9 years, from 2016 to 2025 (April – March) for all parameters. The collected data is grouped into three main categories: Physical, Chemical, and Biological Parameters.

3.2.1. Physical Parameters

i) Turbidity

According to the BIS standard, the limit for turbidity is 1-5 NTU. Here, we have analyzed the monthly data for each year at all sampling stations. According to the values, the highest yearly average was observed at 81.94 NTU at Station SM32 Narmada, located at Nemawar, and at Station

SM31 Narmada before the confluence of the River Jammar, also at Nemawar. The maximum values of turbidity observed were 510 NTU at Station SM33 Narmada 500 mts. d/s of Jain Mandir, Nemawar, and 498 NTU at Station SM31 in August 2019-2020, which are typically monsoon months. Similar high turbidity values are observed for many sampling stations and across all nine years from July to September. Graphs for seasonal variation are present in Annexure 3B for reference.

A similar pattern of extremely high turbidity values has been recorded for other sampling stations (SM25-SM33), especially during the monsoon season of the year (2018-2025). The maximum increase in turbidity values that occurs during the monsoon season can lead to sediment disturbance and is also correlated with agricultural mechanization and intensive farming in these areas.

ii) **Total Dissolved Solids**

According to the standard set by the Bureau of Indian Standards (BIS), the acceptable range is 500-2000mg/L for total dissolved solids.

In the analyzed data, the highest average value for nine years across all sampling stations was recorded as 221.2 mg/L at Station SM33, Narmada, 500 meters. d/s of Jain Mandir, Nemawar.

The average maximum value of dissolved solids was recorded as 434mg/L at the same station. Avg. values of 9 years across all sampling stations are within the range and shown in Figure 12.

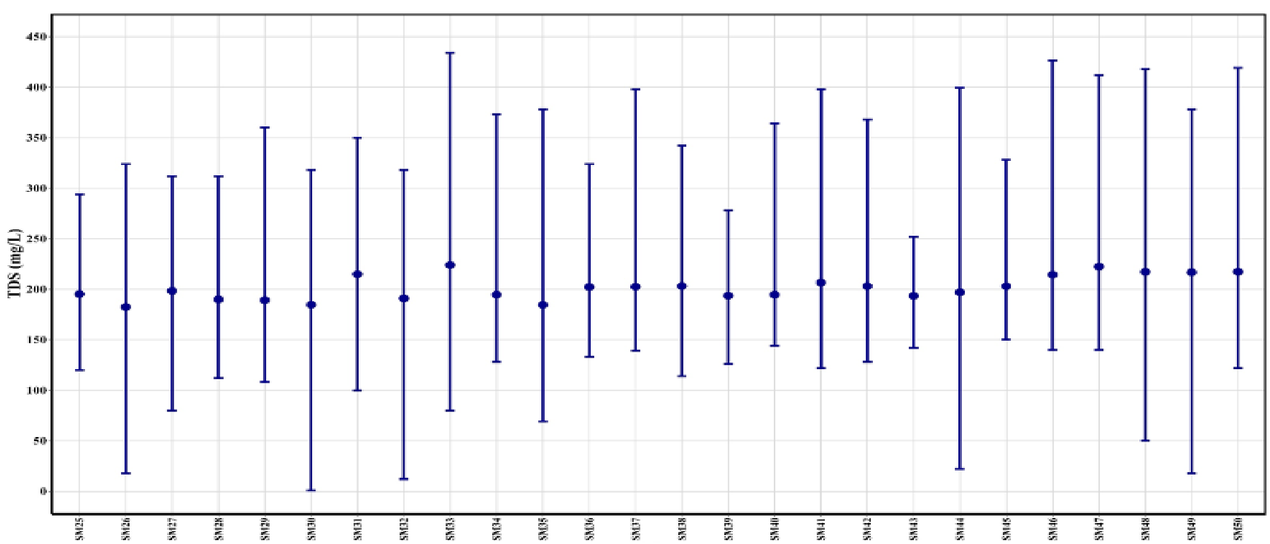


Figure 12 Average, Maximum, and Minimum values over the last 9 years of Total Dissolved Solids in surface water across different sampling stations of the Middle Narmada Basin.

3.2.2. Chemical Parameters

i) pH

The pH values were recorded over a nine-year period at all sampling stations. The maximum yearly average value observed was 8.69 at Station SM34, Narmada River, at Hanumantia, Khandwa, which falls within the BIS permissible limit of 6.5 to 8.5. Variations in pH, with yearly average values from nine years at all sampling stations, are shown in the Heat Map (Figure 13).

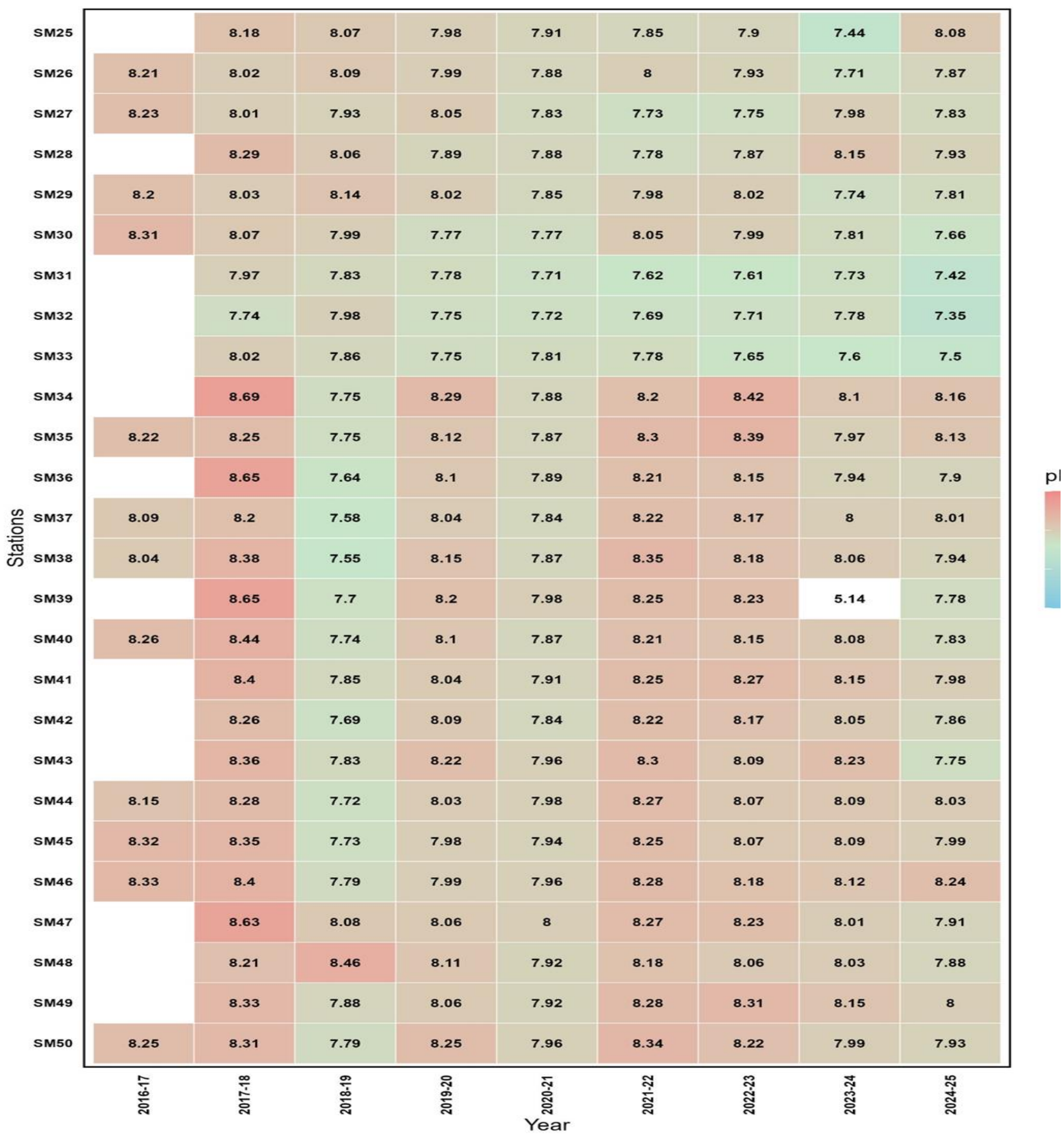


Figure 13 pH of the yearly average at all sampling stations of the Middle Narmada Basin.

ii) Total Hardness

The standard set by BIS for total hardness is 200-600mg/L. The highest average value of nine years across all sampling stations was 168.62 mg/L at Station SM33 Narmada, 500 m. d/s of Jain Mandir, Nemawar. The maximum value of 410 mg/L was recorded at Station SM48 (Narmada at Rajghat). The average values for the nine years across all sampling stations are within the range, as shown in Figure 14.

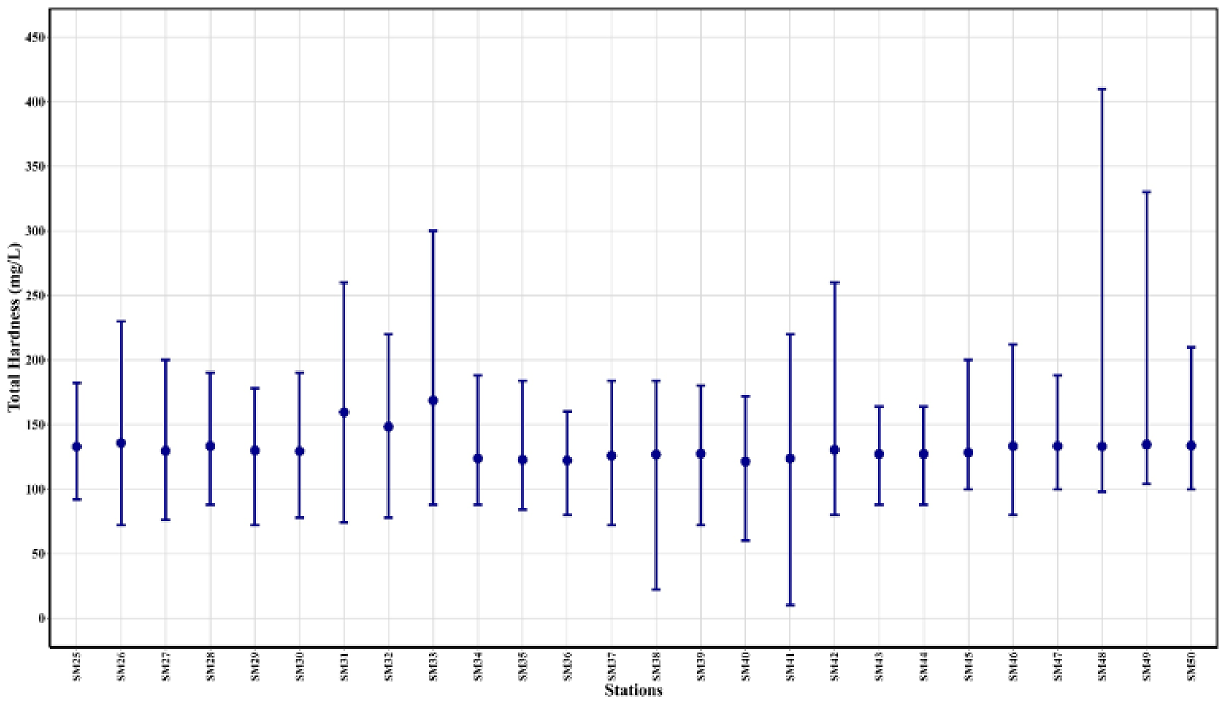


Figure 14 Average, Maximum, and Minimum values over the last 9 years of Total Hardness surface water across different sampling stations of the Middle Narmada Basin.

iii) Total Alkalinity

The standard set by BIS for total alkalinity is 200-600mg/L**.** The highest average value of nine years across all sampling stations was recorded at 149 mg/L at Station SM46 Narmada, d/s of Dharampuri. The maximum value of 238 mg/L was recorded at Station SM26 Narmada at Sethanighat, Narmadapuram. The average values for the nine years at all sampling stations fall within the specified range and are illustrated in Figure 15.

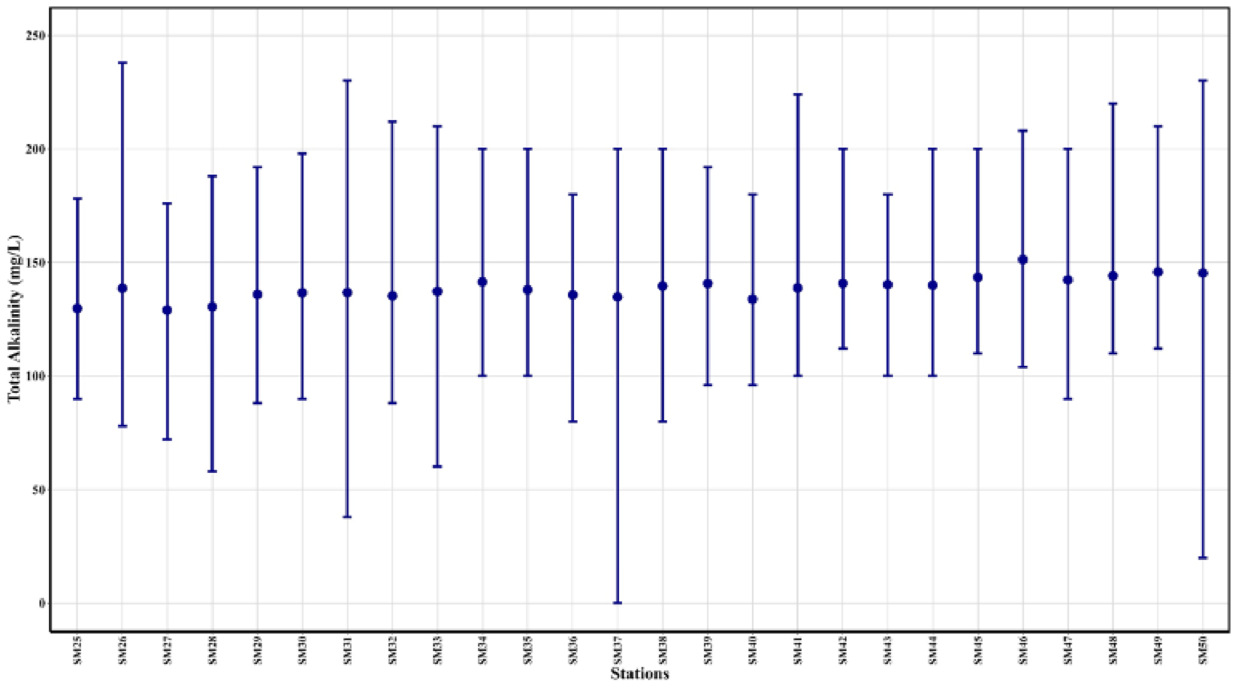


Figure 15 Average, Maximum, and Minimum values over the last 9 years of Total Alkalinity in surface water across different sampling stations of the Middle Narmada Basin.

iv) Potassium

The average values for nine years at all sampling stations range from 2.3 to 1.09 mg/L. The highest average value for Potassium was observed at Station SM25 Narmada d/s after the confluence of the Tawa River at Ramnagar Village. The maximum value of potassium was observed at 7.7 mg/L at Station SM48 Narmada, Rajghat, Barwani. The average values of all 9 years of all stations are shown in Figure 16. There are no standard limits available for Potassium in BIS; however, according to WHO guidelines, a safe limit of up to 10 mg/L is recommended, which varies depending on different conditions (Ref. 7).

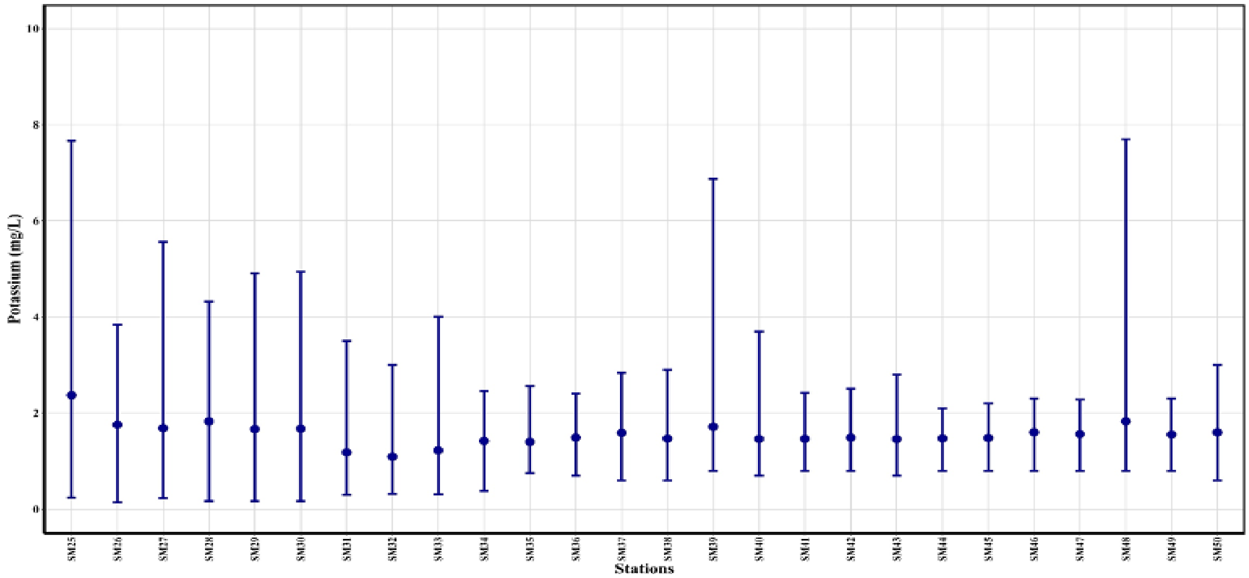


Figure 16 Average, Maximum, and Minimum values over the last 9 years of Potassium in surface water across different sampling stations of the Middle Narmada Basin.

v) Dissolved oxygen

The highest average value of dissolved oxygen across all years and stations was recorded at 8.17 mg/L at Station SM25, Narmada d/s of the confluence of the Tawa River at Ramnagar Village, Bandharban. The same station also recorded a maximum value of 14.10 mg/L. All the nine-year average values are within the limits of 6 or more, as shown in Figure 17.

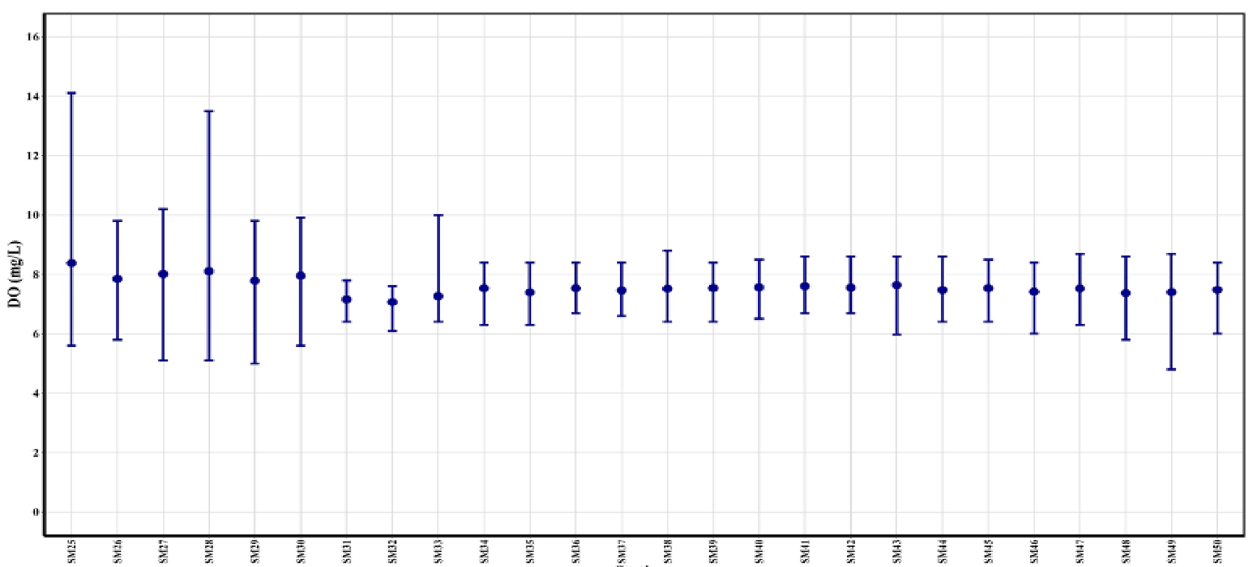


Figure 17 Average, Maximum, and Minimum values over the last 9 years of Dissolved Oxygen in surface water across different sampling stations of the Middle Narmada Basin.

vi) Biochemical Oxygen Demand

As per BIS limits, the Biochemical oxygen demand should not exceed 3 mg or less. Figure 18 shows that the average values for the nine years across all sampling stations fall within this range. The highest average value across all sampling stations was observed at 1.99 mg/L Station SM33, Narmada 500 mts. d/s of Jain Mandir, Nemawar. The maximum value of 3.2 mg/L was observed at Station SM 31, Narmada, before the confluence of the rivers Jammar and Nemawar.

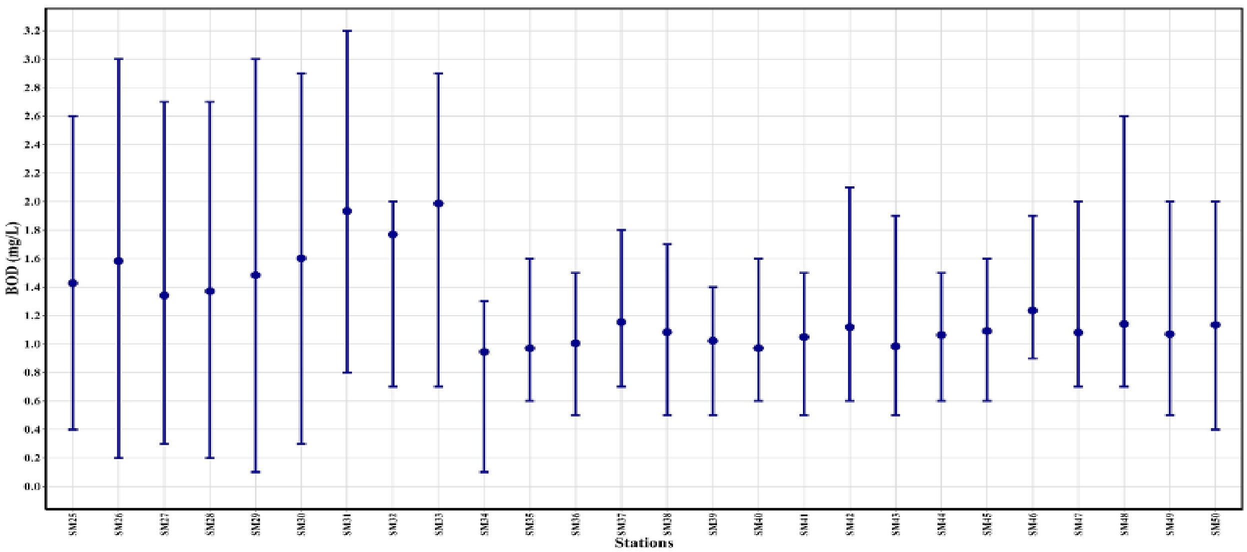


Figure 18 Average, Maximum, and Minimum values over the last 9 years of Biological Oxygen Demand across different sampling stations of the Middle Narmada Basin.

vii) Chemical Oxygen Demand

Chemical Oxygen Demand (COD) analysis indicates a yearly average value for all nine years, ranging from 7 to 23 mg/L across all stations in all years. Details of all stations' yearly averages are provided in Table 7.

Table 7 Summarizes the yearly average of COD of all the Middle Narmada Stations.

Chemical Oxygen Demand									
Station Codes	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
SM25		19.39	15.57	21.19	17.82	17.56	17.16	13.30	14.41
SM26	17.33	15.54	21.33	21.30	19.58	21.68	18.27	18.87	19.73

Chemical Oxygen Demand									
SM27	13.42	12.99	19.53	14.65	15.32	12.73	13.92	18.11	12.02
SM28		22.56	17.25	16.97	19.33	11.78	18.77	17.72	12.03
SM29	14.91	14.73	21.33	19.70	17.76	18.03	15.27	17.12	14.15
SM30	18.96	17.17	21.35	22.99	23.20	18.45	15.10	22.65	19.67
SM31		13.33	11.75	18.42	12.64	14.56	14.17	14.00	11.50
SM32		12.04	10.83	11.26	10.74	13.23	12.33	12.67	10.67
SM33		12.67	10.55	13.00	11.73	14.39	15.50	14.57	13.00
SM34		9.40	11.60	10.60	7.99	8.30	7.68	7.67	9.00
SM35	9.93	11.25	11.55	11.56	8.63	9.15	7.81	7.50	7.83
SM36		12.99	12.49	10.70	8.86	8.48	7.89	7.97	8.24
SM37	14.23	15.53	14.81	12.60	10.18	9.46	10.89	10.12	9.57
SM38	12.37	13.50	10.90	12.19	11.60	10.87	9.58	9.45	10.39
SM39		8.83	8.99	10.72	9.01	10.20	9.55	18.21	10.54
SM40	10.59	11.03	9.64	10.76	8.34	8.06	8.27	8.18	8.63
SM41		12.21	11.89	10.16	8.46	8.72	9.15	8.86	10.87
SM42		14.71	13.60	11.32	10.41	10.45	10.15	13.18	10.13
SM43		10.80	10.32	9.45	8.62	9.07	8.56	7.79	10.40
SM44	11.04	12.41	12.55	11.34	9.76	10.36	8.93	9.37	8.15
SM45	11.61	13.63	13.20	11.86	10.32	9.95	9.27	21.53	9.30
SM46	14.38	15.92	15.92	14.79	11.46	11.26	10.39	11.24	11.13
SM47		14.61	13.41	12.13	8.68	9.86	8.80	8.99	11.31
SM48		16.75	12.63	13.95	10.59	11.10	10.55	10.90	11.09
SM49		12.40	12.13	11.90	9.36	12.97	9.40	9.54	13.29
SM50	9.66	13.12	13.58	11.39	9.93	13.81	9.96	10.70	8.47

3.2.3 Biological Parameter

i) Total Coliforms

The highest value of Total Coliforms in the Middle Narmada Basin, across all years and stations, was recorded at 92000 MPN/100 mL, which is significantly higher than the limit of 50 MPN/100 mL. Many stations (SM25-SM30) across the Middle Narmada Basin have recorded values with this high range of total coliforms, mainly in the months of October to March in years (2018-2024), post-monsoon and monsoon months. Although in the current year data (2024-2025) the maximum average value is 221 MPN/100 ml at Station SM28, Narmada d/s textile unit, Village Holipura, Budni Dhar, which is better than the previous year’s data specifically for these stations but still point of concern and requires further investigations, sample analysis to make the water quality better for drinking purposes.

3.3 Lower Narmada Basin

3.3.1. Station: Garudeshwar

Garudeshwar lies upstream in the lower basin and benefits from relatively lesser human impact compared to downstream stations. **Graph 25 to Graph 50** show the water quality parameters with time from 2015 to 2025 of Garudeshwar Station.

Organic Pollution: BOD and COD show a declining trend over the monitoring period, suggesting effective natural self-purification and reduced organic discharge in the catchment area. BOD levels consistently remain low, indicating minimal sewage or industrial organic load.

Dissolved Oxygen: DO remains consistently high (>5.5 mg/L), showing the river's capacity for self-purification. Slight dips occur during high-flow monsoon months.

Nutrients: Nitrate, phosphate, and TKN levels are moderate, with phosphate increasing slightly during monsoon due to agricultural and surface runoff.

Microbial Load: Moderate coliform contamination occurs year-round, with higher levels during monsoon due to untreated sewage inflows from nearby settlements.

Metals: Most heavy metals remain within safe limits, though occasional iron increases are recorded during rainy season due to sediment disturbance.

Salinity & Hardness: Chloride and TDS levels remain acceptable, though seasonal variations occur.

Overall Condition: Garudeshwar exhibits moderate to good water quality, reflecting transitional influences from upstream clean stretches and local anthropogenic inputs. Continued sewage management and nutrient control are needed.

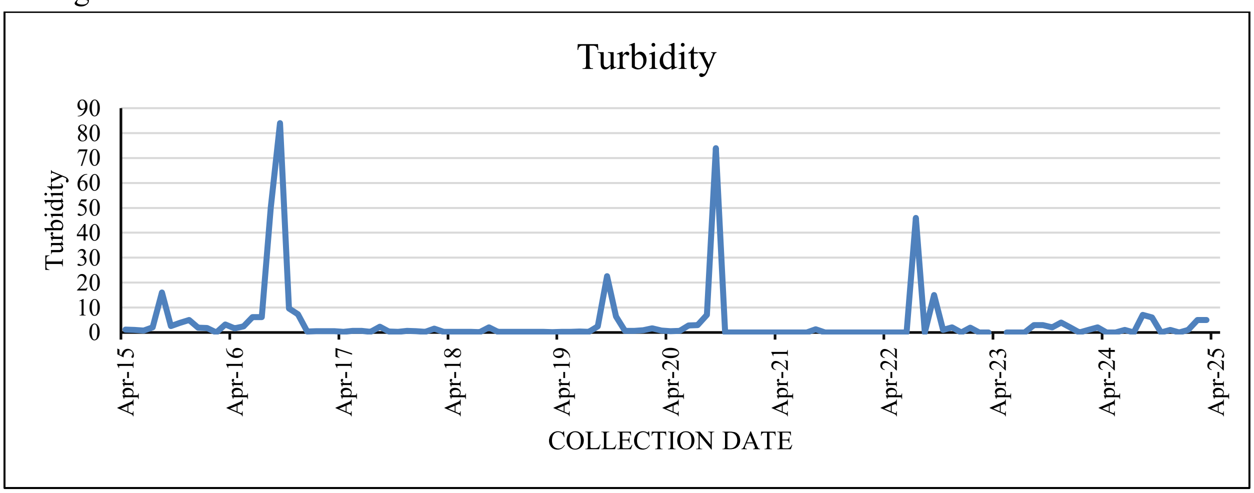


Figure 19 Monthly variation of Turbidity at Garudeshwar Station (2015-2025)

Graph 1: The graph shows the monthly variation of *Turbidity* at Garudeshwar Station from April 2015 to April 2025. Turbidity ranged from 0.1 to 84 (September 2016) , permissible limit (BIS IS10500): 5 NTU, very high maxima (monsoon/episodic spikes) exceeds permissible limit and requires attention.

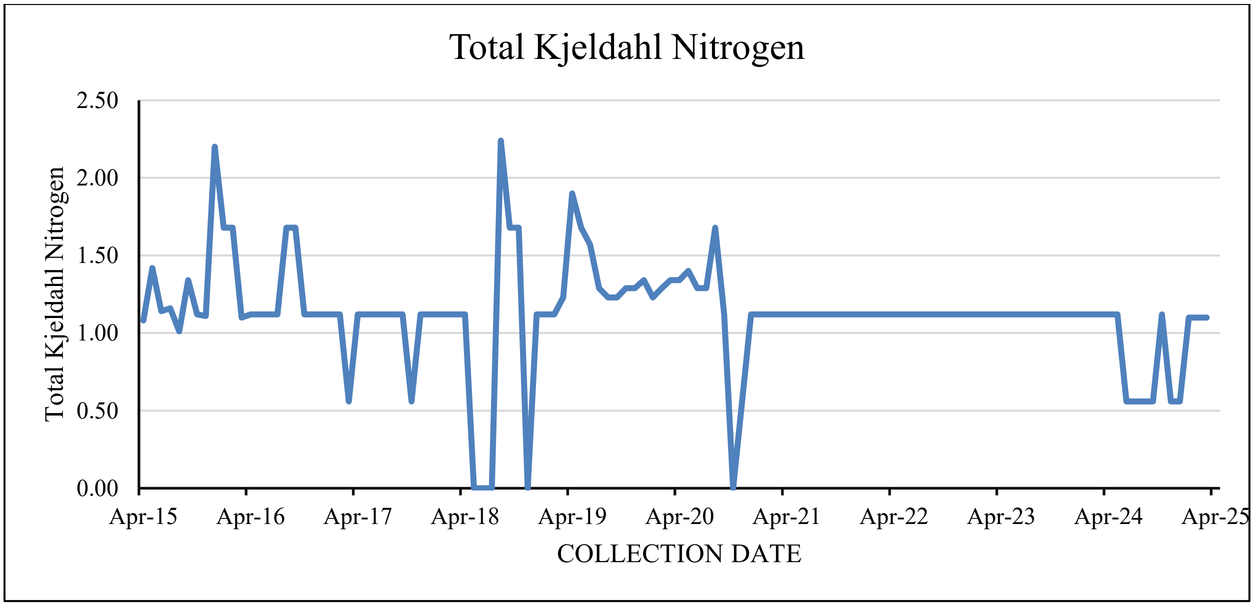


Figure 20 Monthly variation of Total Kjeldahl Nitrogen at Garudeshwar Station (2015-2025)

Graph 26: The graph shows the monthly variation of *Total Kjeldahl Nitrogen* at Garudeshwar Station from April 2015 to April 2025. TKN ranged from 0.56 to 2.24 mg/L (August 2018), no specific BIS drinking limit (reported), within expected environmental ranges.

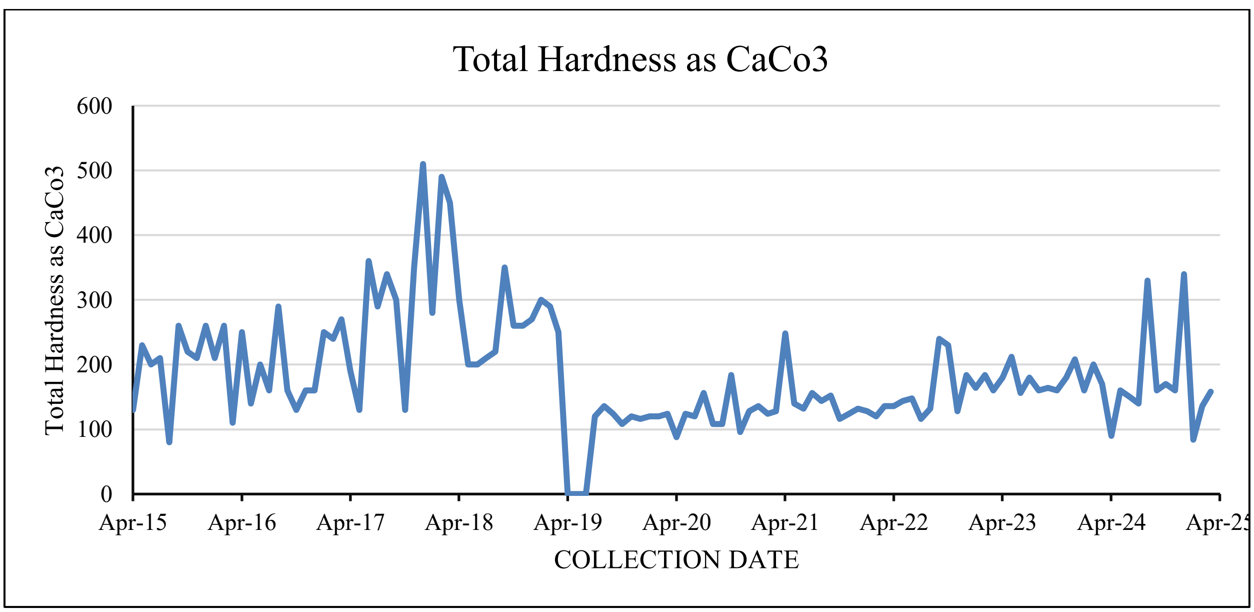


Figure 21 Monthly variation of Total Hardness as CaCo3 at Garudeshwar Station (2015-2025)

Graph 27: The graph shows the monthly variation of *Total Hardness as CaCo3* at Garudeshwar Station from April 2015 to April 2025. Total Hardness ranged from 80 to 510 mg/L(December 2017), permissible limit (BIS IS10500): 600 mg/L, within permissible limit.

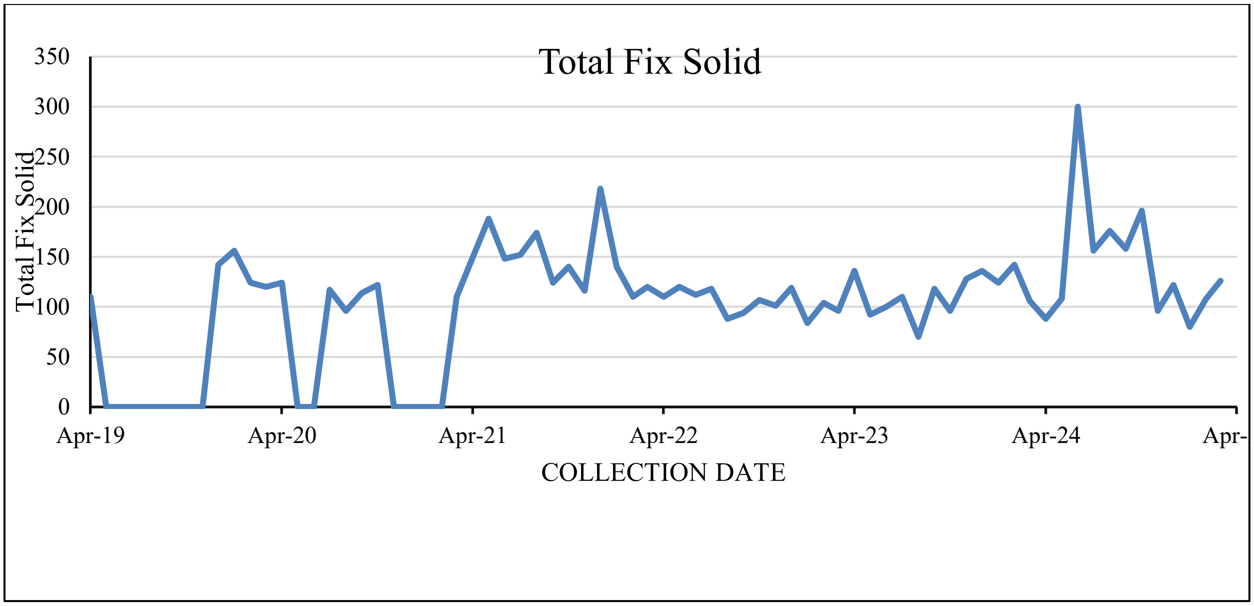


Figure 22 Monthly variation of Total Fix Solid at Garudeshwar Station (2015-2025)

Graph 28: The graph shows the monthly variation of *Total Fix Solid* at Garudeshwar Station from April 2015 to April 2025. Total Fixed Solids (reported similarly to TDS) ranged from 70 to 300 (June 2024), reported as part of TDS.

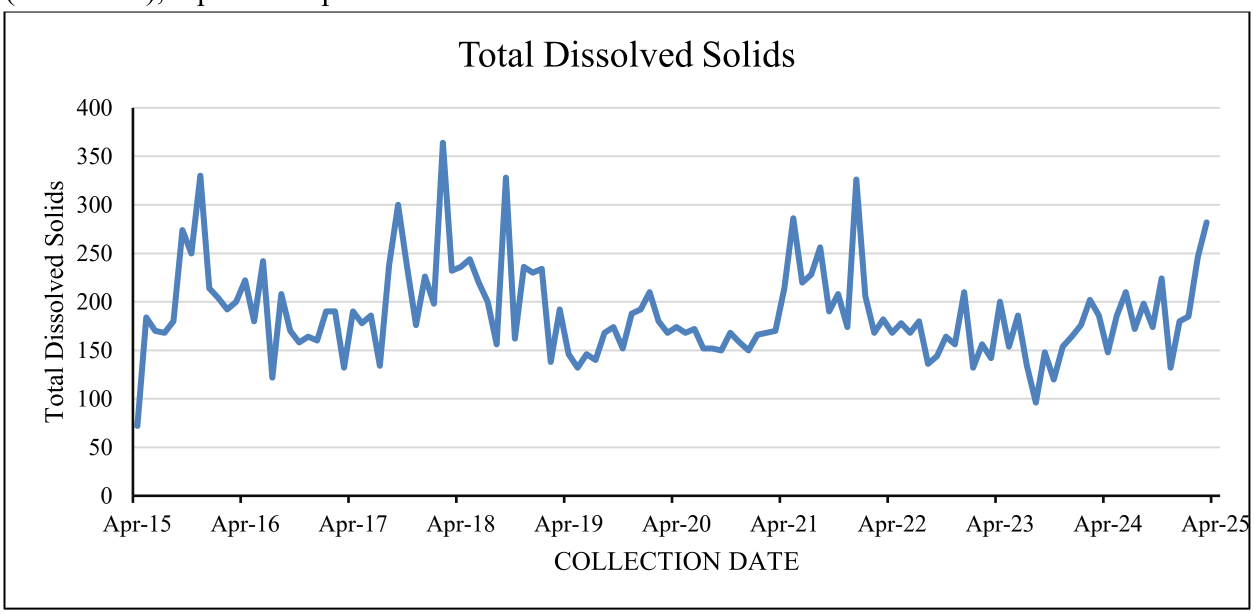


Figure 23 Monthly variation of Total Dissolved Solids at Garudeshwar Station (2015-2025)

Graph 29: The graph shows the monthly variation of *Total Dissolved Solids* at Garudeshwar Station from April 2015 to April 2025. TDS ranged from 72 to 364 mg/L(Feb 2018), permissible limit (BIS IS10500): 2000 mg/L, well within permissible limit (but above desirable 500 mg/L in some months).

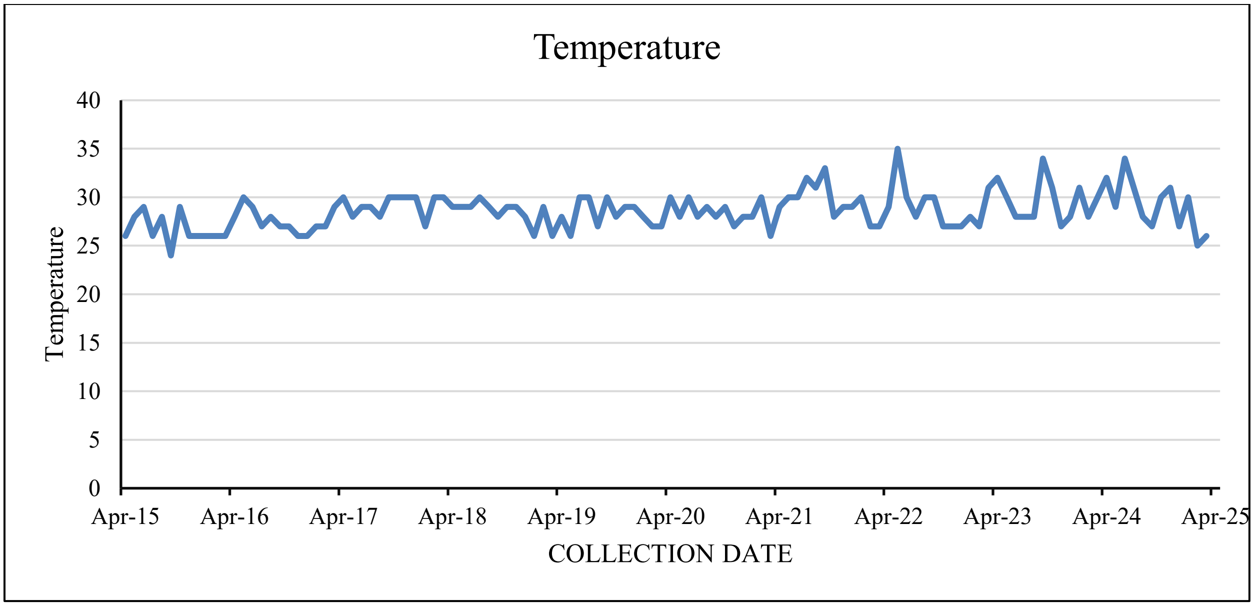


Figure 24 Monthly variation of Temperature at Garudeshwar Station (2015-2025)

Graph 30: The graph shows the monthly variation of *Temperature* at Garudeshwar Station from April 2015 to April 2025. Temperature ranged from 24 to 35 °C(May 2022), seasonal variation expected no drinking-water limit.

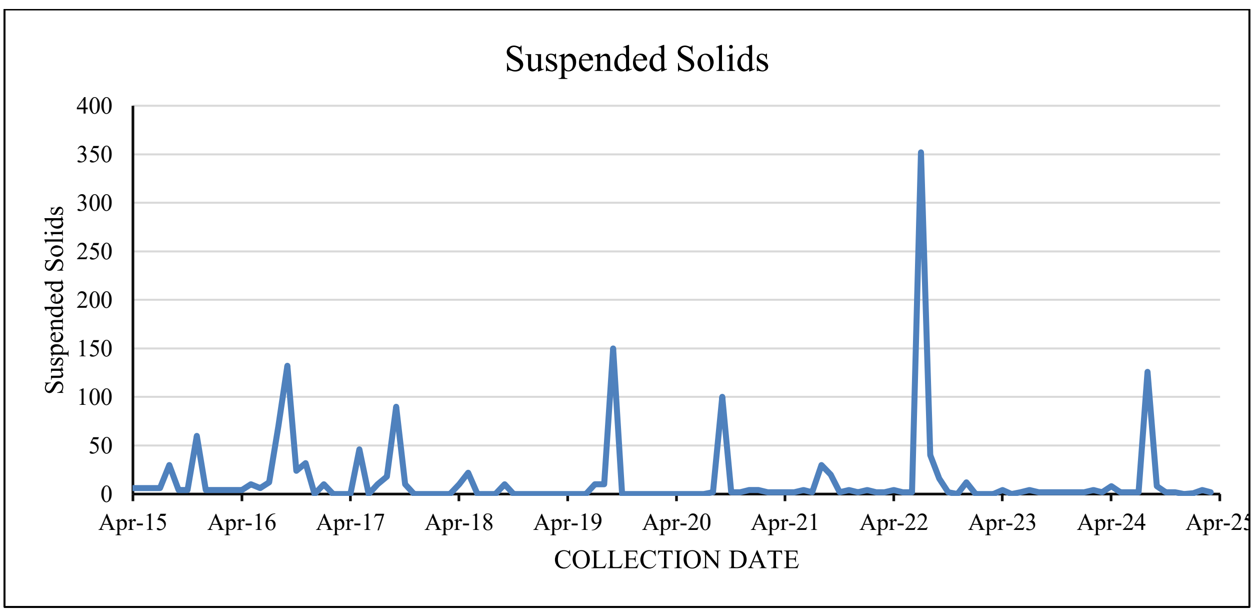


Figure 25 Monthly variation of Suspended Solids at Garudeshwar Station (2015-2025)

Graph 31: The graph shows the monthly variation of *Suspended Solids* at Garudeshwar Station from April 2015 to April 2025. Suspended Solids ranged from 1 to 352 mg/L(July 2022), monsoon spikes; some months above typical STP reuse benchmarks.

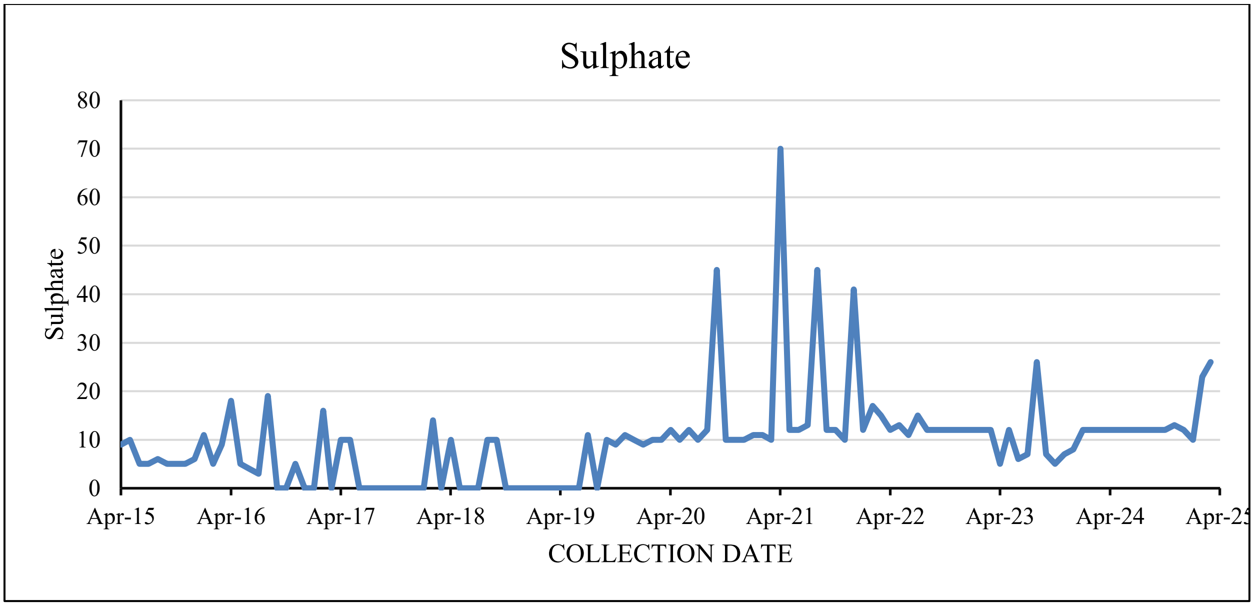


Figure 26 Monthly variation of Sulphate at Garudeshwar Station (2015-2025)

Graph 32: The graph shows the monthly variation of *Sulphate* at Garudeshwar Station from April 2015 to April 2025. Sulphate ranged from 3 to 70 mg/L(April 2021), permissible limit (BIS IS10500): 200 mg/L, within permissible limit.

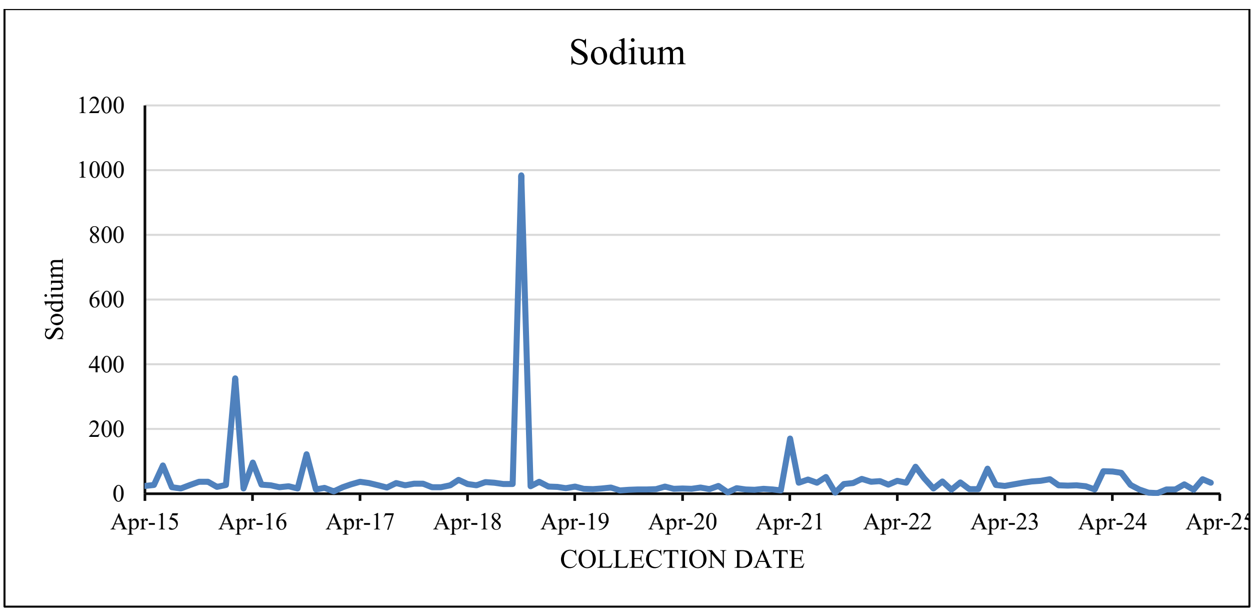


Figure 27 Monthly variation of Sodium at Garudeshwar Station (2015-2025)

Graph 33: The graph shows the monthly variation of *Sodium* at Garudeshwar Station from April 2015 to April 2025. Sodium ranged from 1.93 to 984mg/L (October 2018), within typical guideline ranges some months above typical reuse benchmarks.

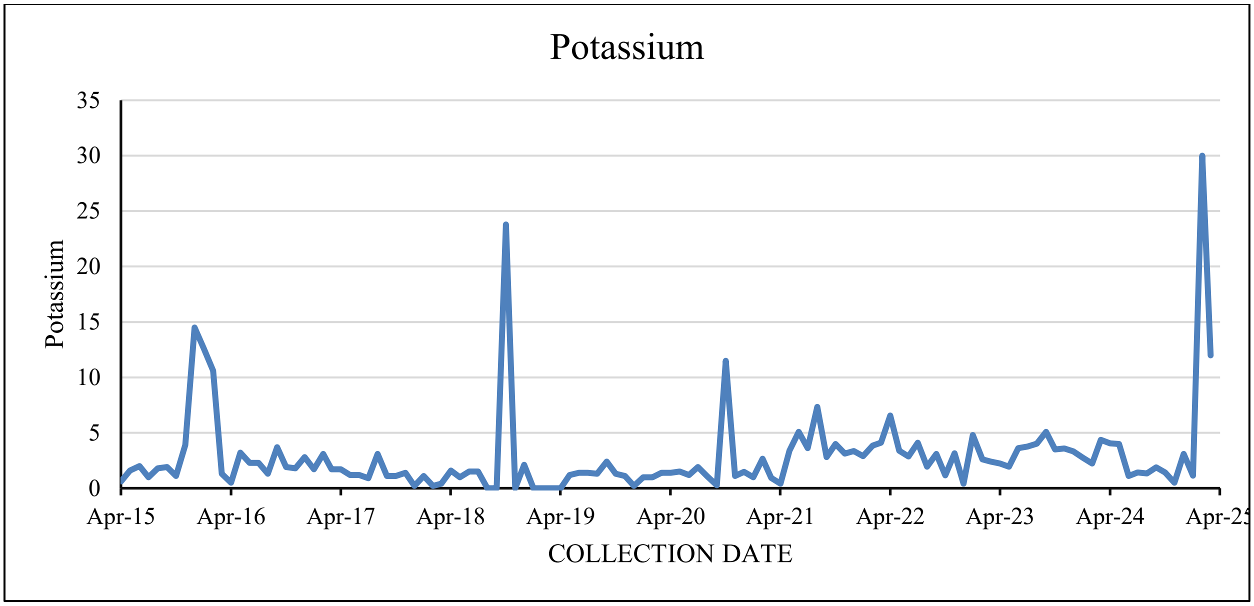


Figure 28 Monthly variation of Potassium at Garudeshwar Station (2015-2025)

Graph 34: The graph shows the monthly variation of *Potassium* at Garudeshwar Station from April 2015 to April 2025. Potassium ranged from 0.2 to 30 mg/L (Febuary 2025), within typical environmental concentrations.

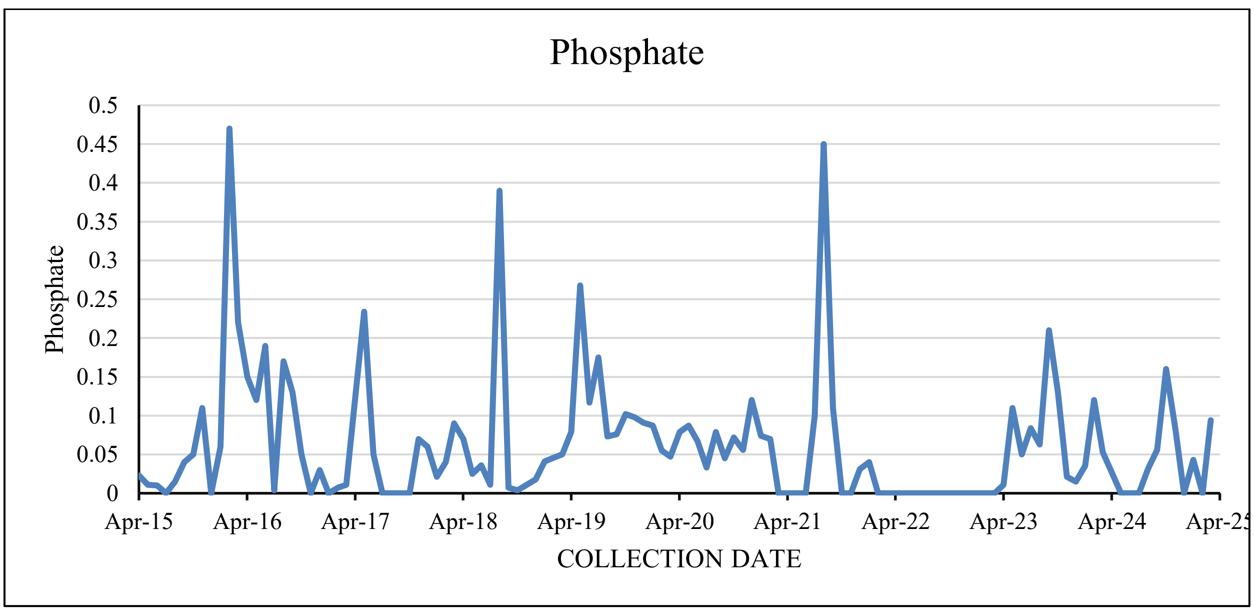


Figure 29 Monthly variation of Phosphate at Garudeshwar Station (2015-2025)

Graph 35: The graph shows the monthly variation of *Phosphate* at Garudeshwar Station from April 2015 to April 2025. Phosphate ranged from 0.004 to 0.47 mg/L(Feb 2016), generally low, with seasonal rises during monsoon.

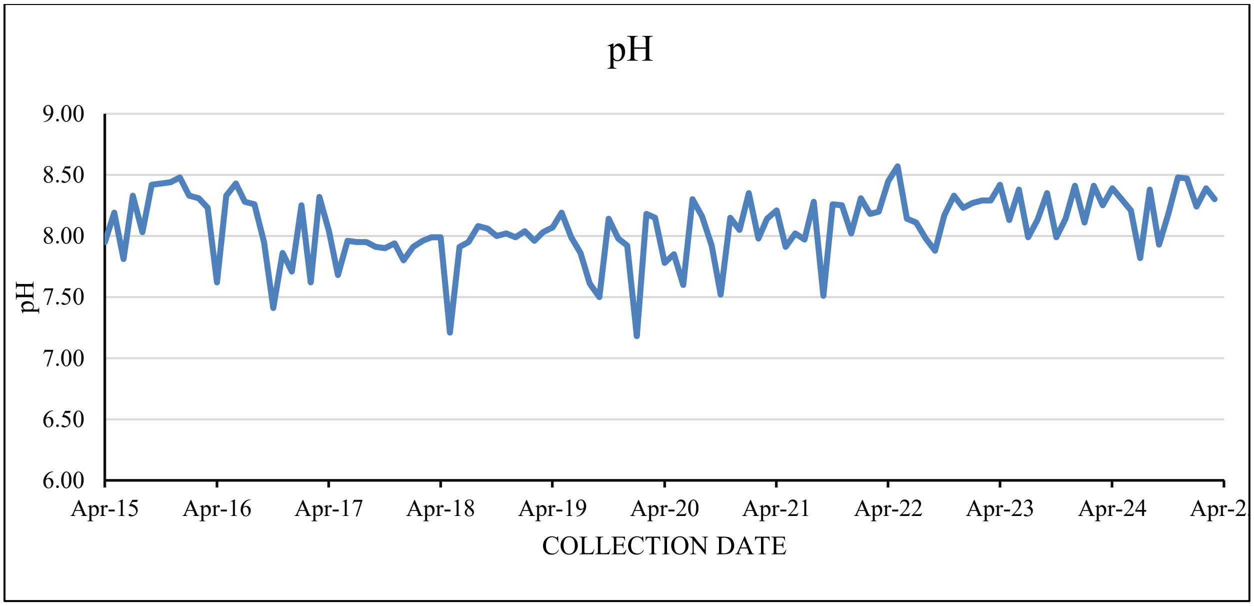


Figure 30 Monthly variation of pH at Garudeshwar Station (2015-2025)

Graph 36: The graph shows the monthly variation of *pH* at Garudeshwar Station from April 2015 to April 2025. pH ranged from 7.18 to 8.57 (May 2022), permissible limit (BIS IS10500): 6.5–8.5, within permissible limits.

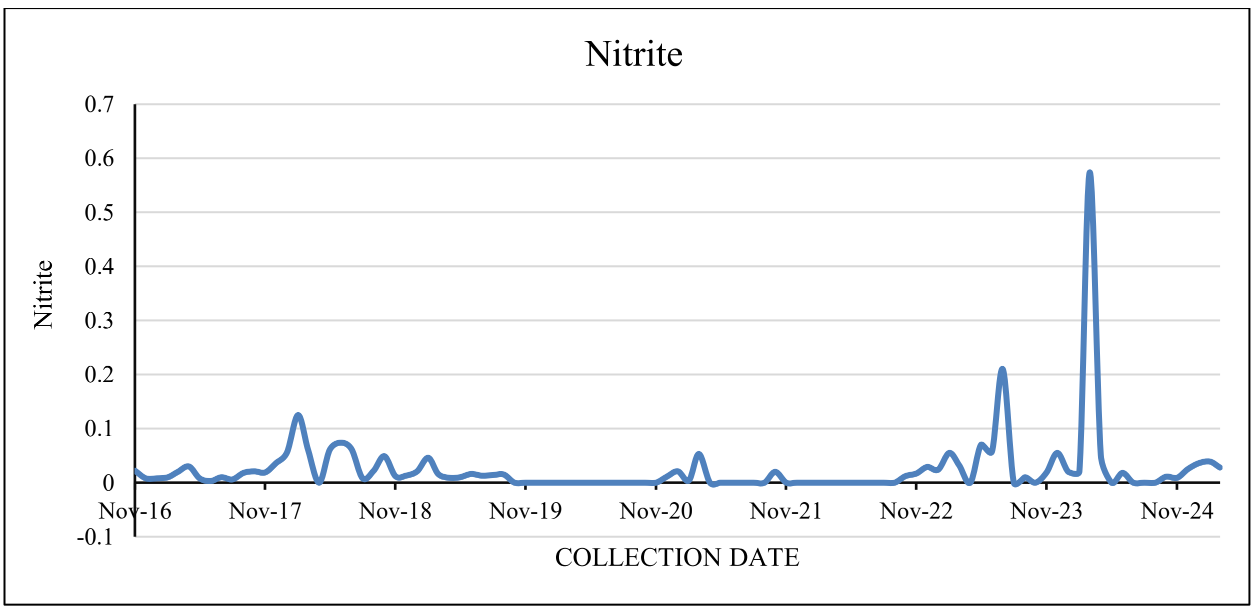


Figure 31 Monthly variation of Nitrite at Garudeshwar Station (2015-2025)

Graph 37: The graph shows the monthly variation of *Nitrite* at Garudeshwar Station from April 2015 to April 2025. Nitrite ranged from 0.01 to 0.574mg/L (March 2024), permissible limit (BIS IS10500): 0.2 mg/L, within permissible limits.

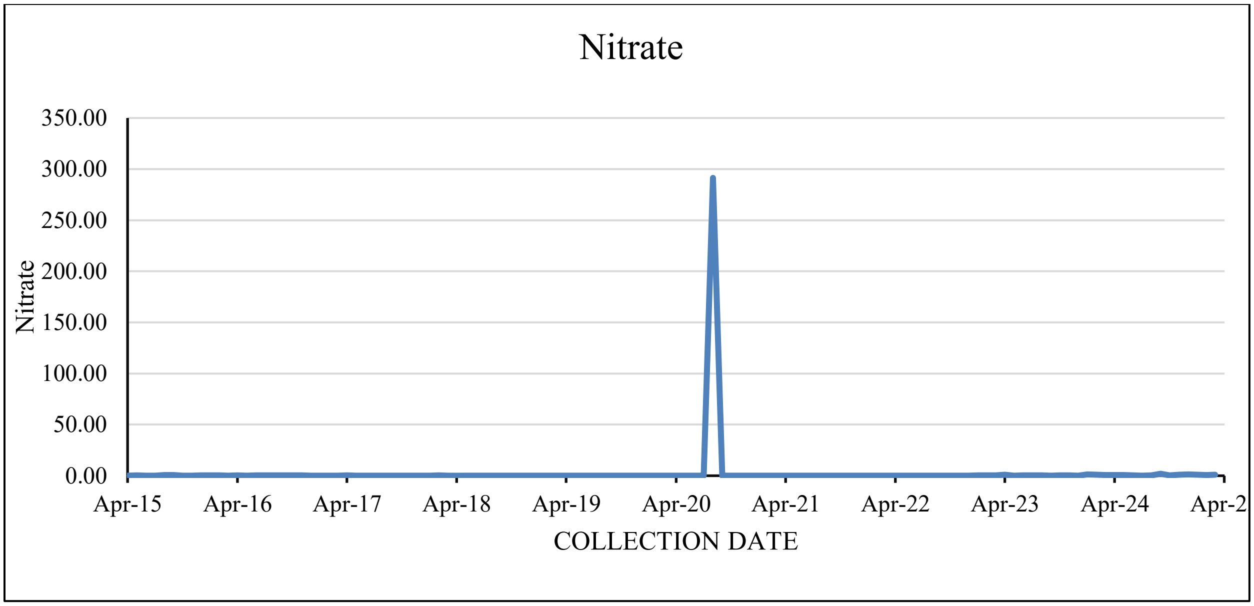


Figure 32 Monthly variation of Nitrate at Garudeshwar Station (2015-2025)

Graph 38: The graph shows the monthly variation of *Nitrate* at Garudeshwar Station from April 2015 to April 2025. Nitrate ranged from 0.6 to 291.4 mg/L (Aug 2020), permissible limit (BIS IS10500): 45 mg/L, mostly within permissible limit though close to the threshold in some months.

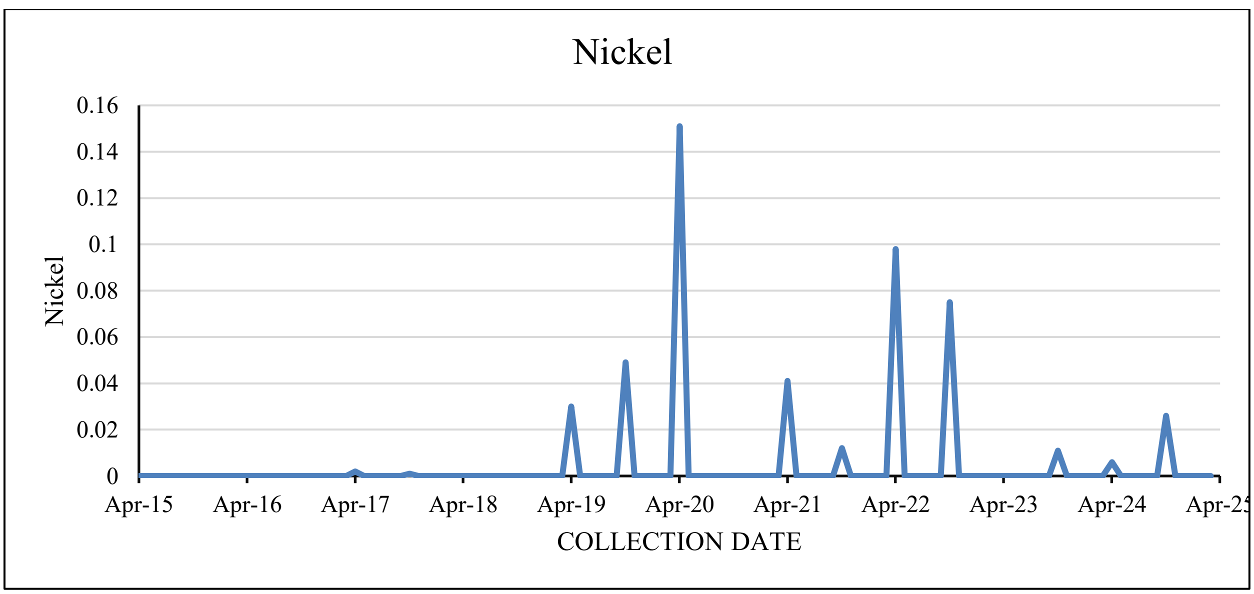


Figure 33 Monthly variation of Nickel at Garudeshwar Station (2015-2025)

Graph 39: The graph shows the monthly variation of *Nickel* at Garudeshwar Station from April 2015 to April 2025. Nickel ranged from 0.00 to 0.151 mg/L(April 2020), permissible limit (BIS IS10500 for heavy metals): 0.02 mg/L, around limit in some months; monitor for heavy inputs.

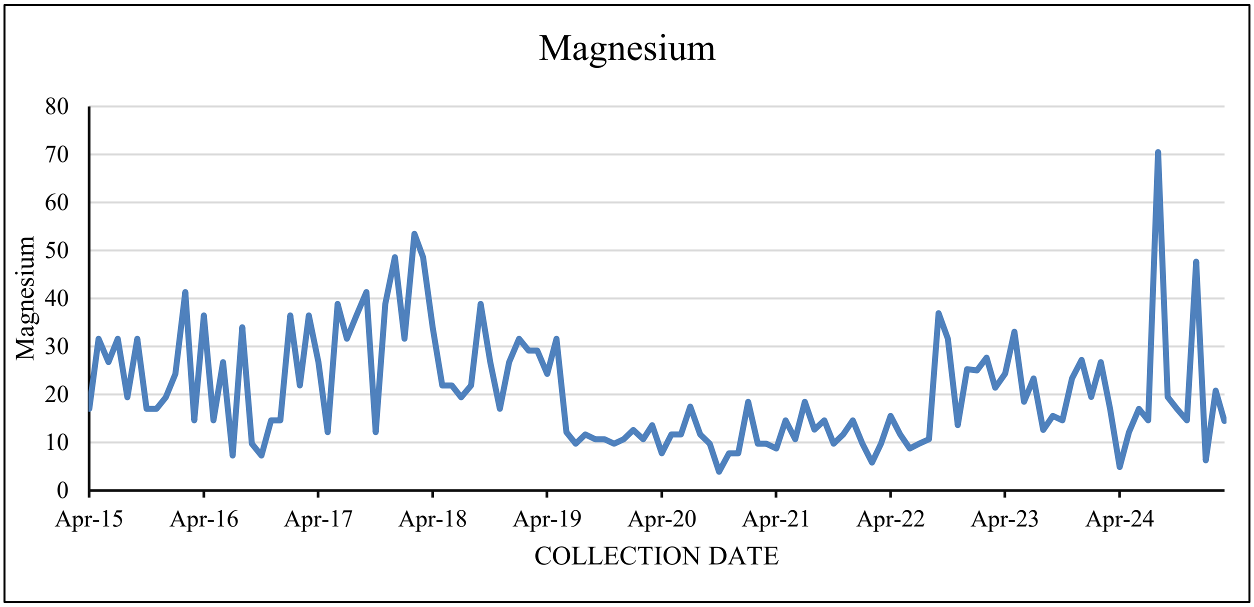


Figure 34 Monthly variation of Magnesiumat Garudeshwar Station (2015-2025)

Graph 40: The graph shows the monthly variation of *Magnesium* at Garudeshwar Station from April 2015 to April 2025. Magnesium ranged from 3.9 to 70.5 mg/L(August 2024), within expected ranges, but some areas need improvement.

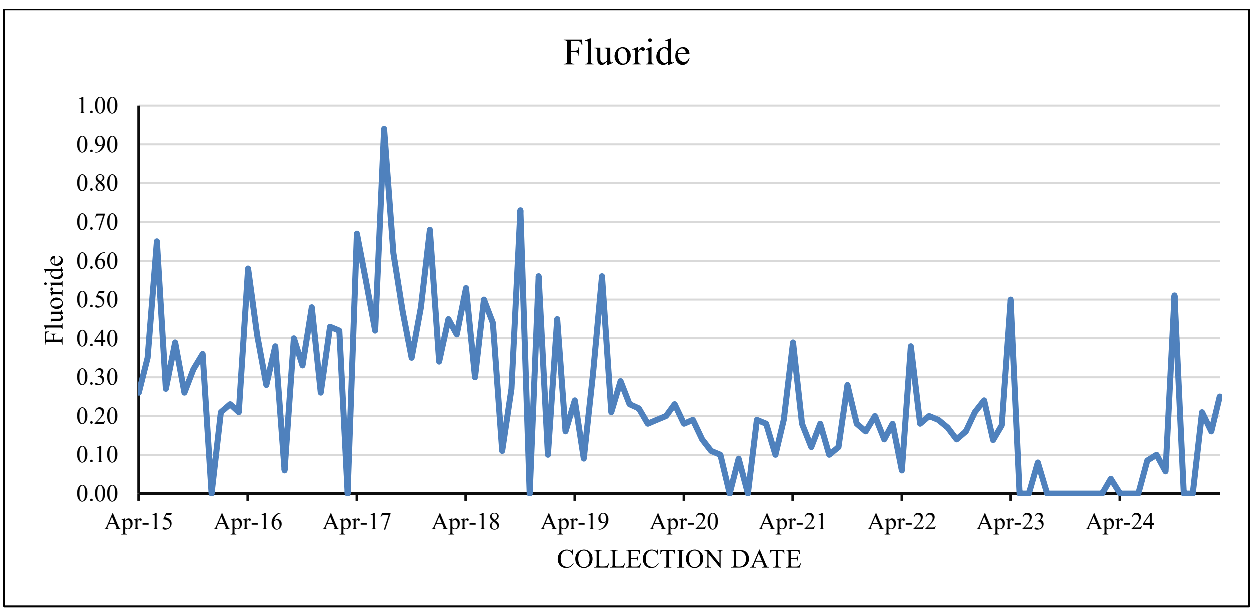


Figure 35 Monthly variation of Fluoride at Garudeshwar Station (2015-2025)

Graph 41: The graph shows the monthly variation of *Fluoride* at Garudeshwar Station from April 2015 to April 2025. Fluoride ranged from 0.04 to 0.94 mg/L(July 2017), permissible limit (BIS IS10500): 1.5 mg/L, within permissible limit.

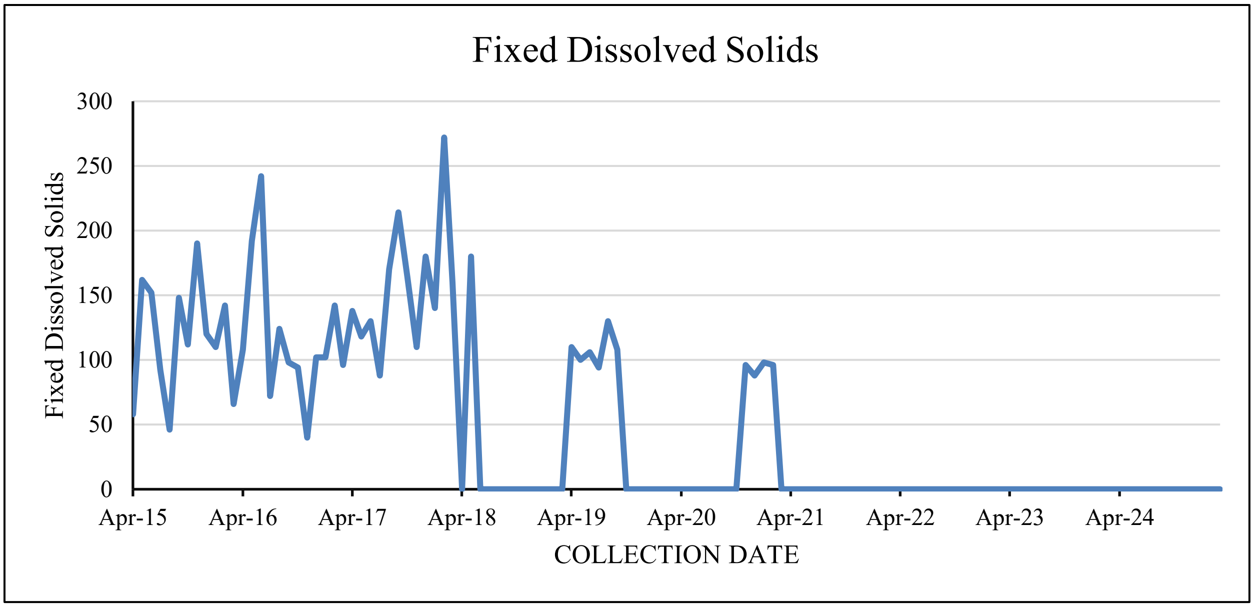


Figure 36 Monthly variation of Fixed Dissolved Solids at Garudeshwar Station (2015-2025)

Graph 42: The graph shows the monthly variation of *Fixed Dissolved Solids* at Garudeshwar Station from April 2015 to April 2025. Fixed Dissolved Solids ranged from 40 to 272 (Feb 2028).

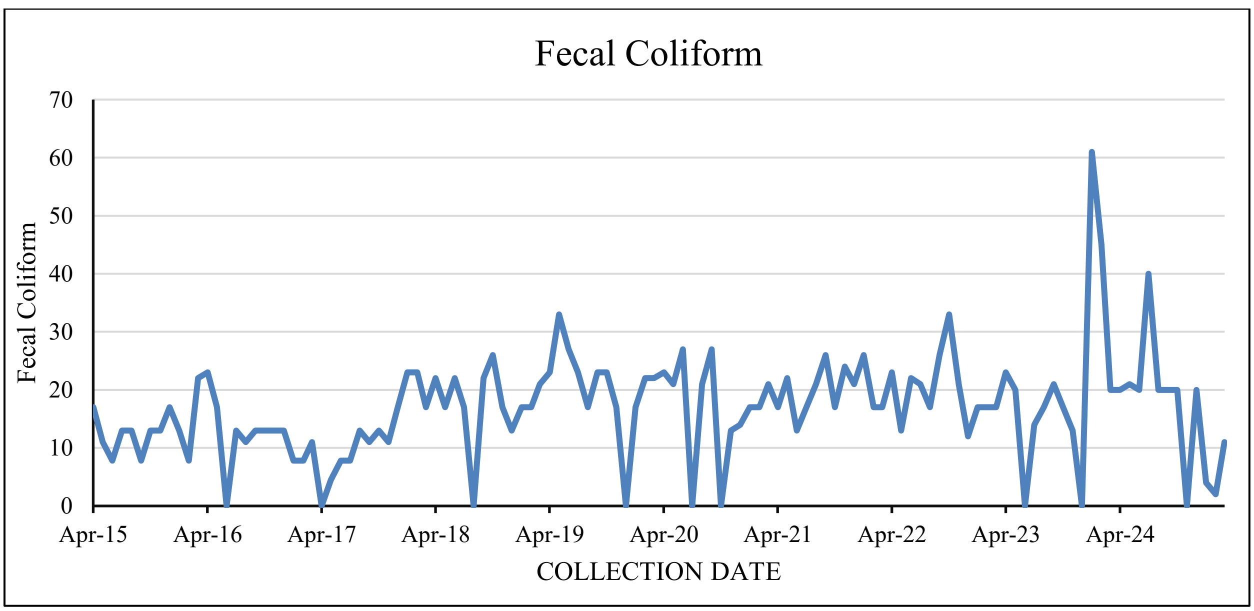


Figure 37 Monthly variation of Fecal Coliform at Garudeshwar Station (2015-2025)

Graph 43: The graph shows the monthly variation of *Fecal Coliform* at Garudeshwar Station from April 2015 to April 2025. Fecal Coliform ranged from 2 to 61 MPN/100mL(Jan 2024), permissible limit for drinking: 0 MPN/100mL, indicates microbial contamination; not acceptable for drinking without treatment.

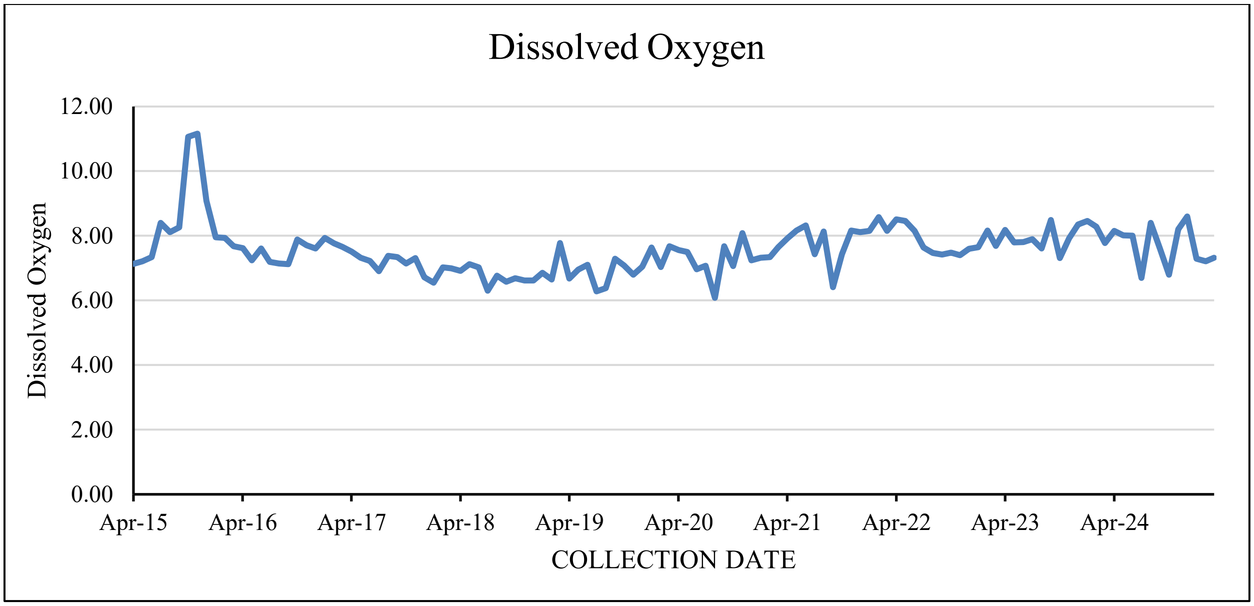


Figure 38 Monthly variation of Dissolved Oxygen at Garudesh warStation (2015-2025)

Graph 44: The graph shows the monthly variation of *Dissolved Oxygen* at Garudeshwar Station from April 2015 to April 2025. DO ranged from 6.08 to 11.16 mg/L(Nov 2015), CPCB ecological guideline: DO ≥ 6 mg/L for good water, often meets ecological guideline but occasional dips noted.

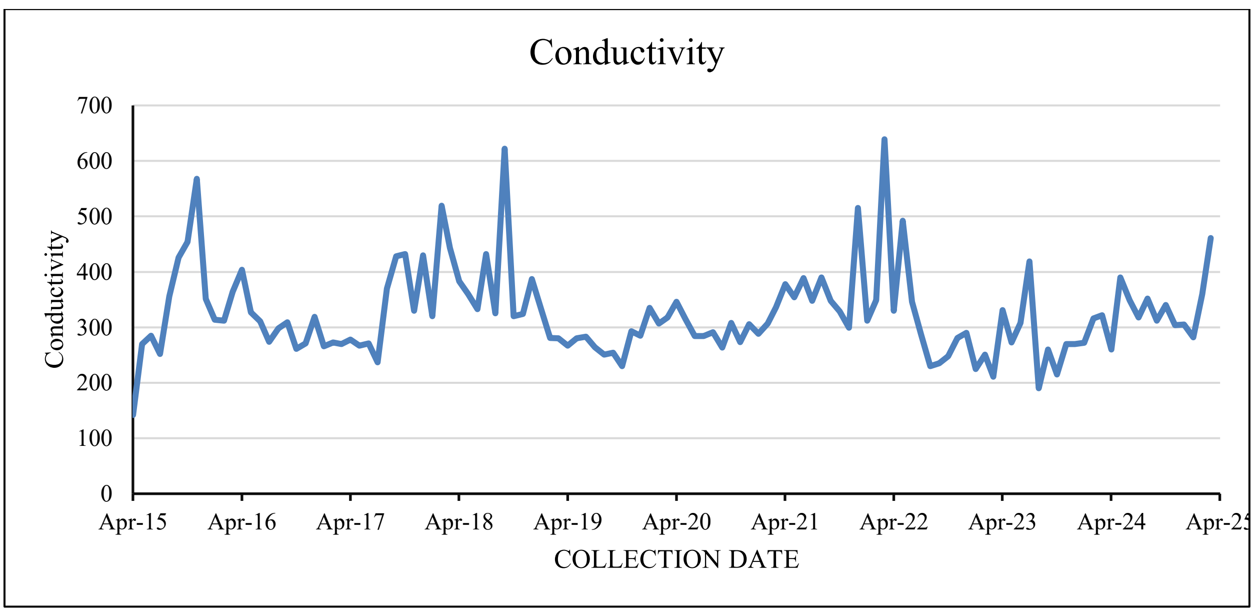


Figure 39 Monthly variation of Conductivity at Garudeshwar Station (2015-2025)

Graph 45: The graph shows the monthly variation of *Conductivity* at Garudeshwar Station from April 2015 to April 2025. Conductivity ranged from 142 to 639 µS/cm(March 2022), within typical freshwater ranges.

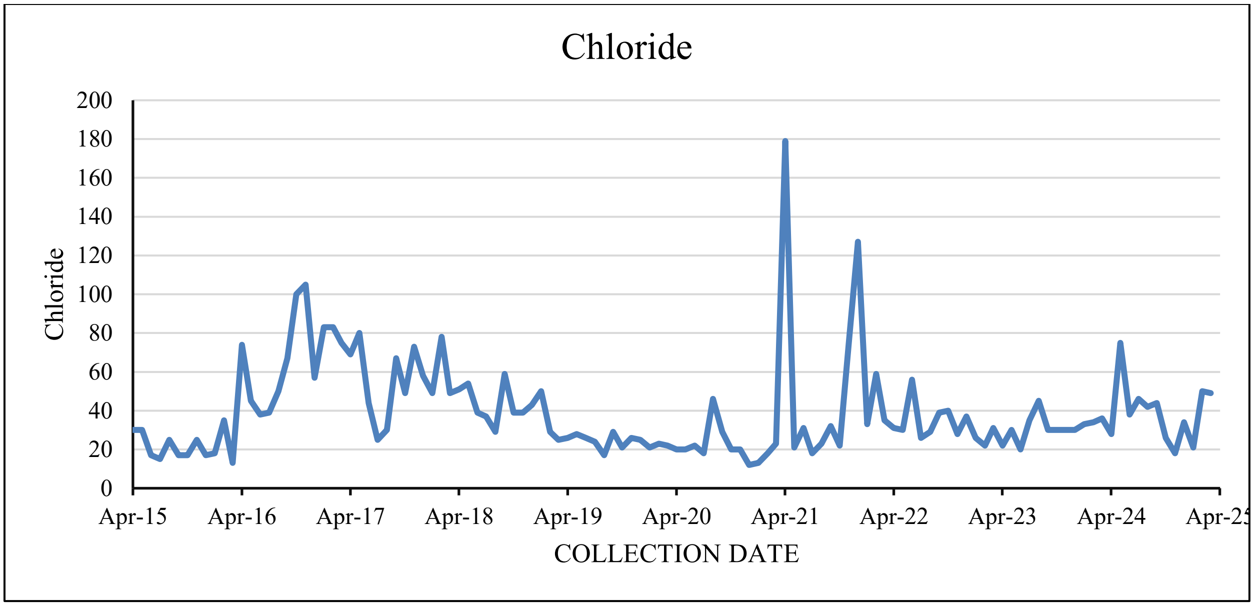


Figure 40 Monthly variation of Chloride at Garudeshwar Station (2015-2025)

Graph 46: The graph shows the monthly variation of *Chloride* at Garudeshwar Station from April 2015 to April 2025. Chloride ranged from 12 to 179 mg/L(Apr 2021), permissible limit (BIS IS10500): 250 mg/L, within permissible limit.

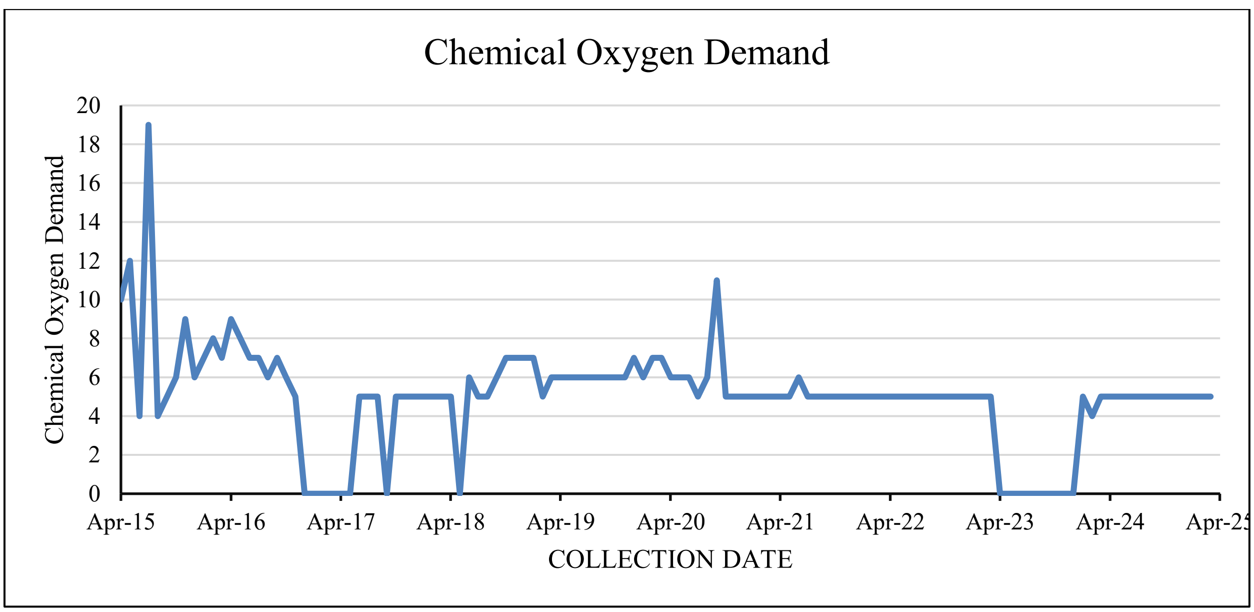


Figure 41 Monthly variation of C.O.D. at Garudeshwar Station (2015-2025)

Graph 47: The graph shows the monthly variation of *C.O.D.* at Garudeshwar Station from April 2015 to April 2025. COD ranged from 4 to 19 mg/L(July 2015), shows periodic organic/chemical loading; some months are elevated.

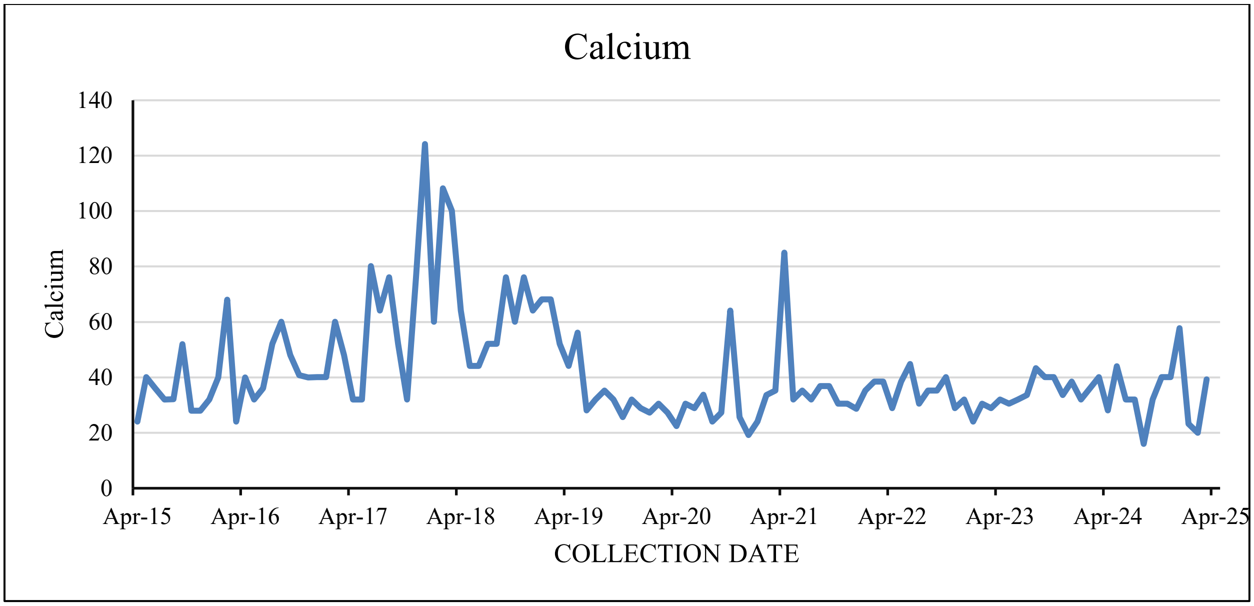


Figure 42 Monthly variation of Calcium at Garudeshwar Station (2015-2025)

Graph 48: The graph shows the monthly variation of *Calcium* at Garudeshwar Station from April 2015 to April 2025. Calcium ranged from 16 to 124.2 mg/L(December 2017), contributes to hardness; within typical ranges while some months are elevated.

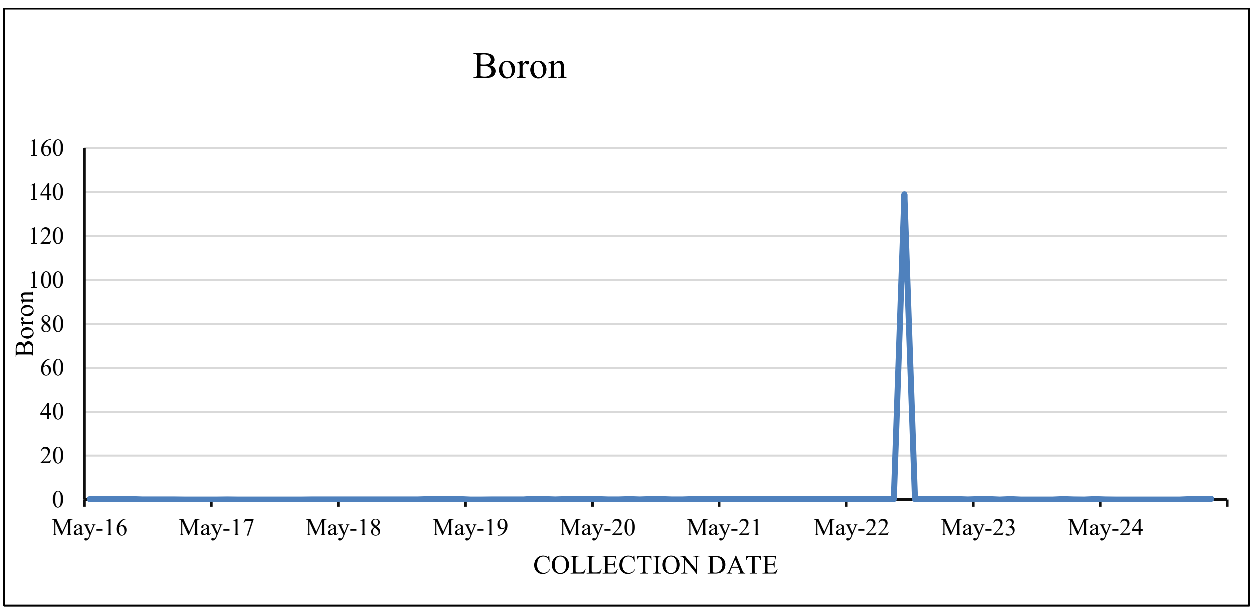


Figure 43 Monthly variation of Boron at Garudeshwar Station (2016-2025)

Graph 49: The graph shows the monthly variation of *Boron* at Garudeshwar Station from April 2016 to April 2025. Boron ranged from 0.03 to 139 mg/L(October 2022), within typical drinking-water guidance.

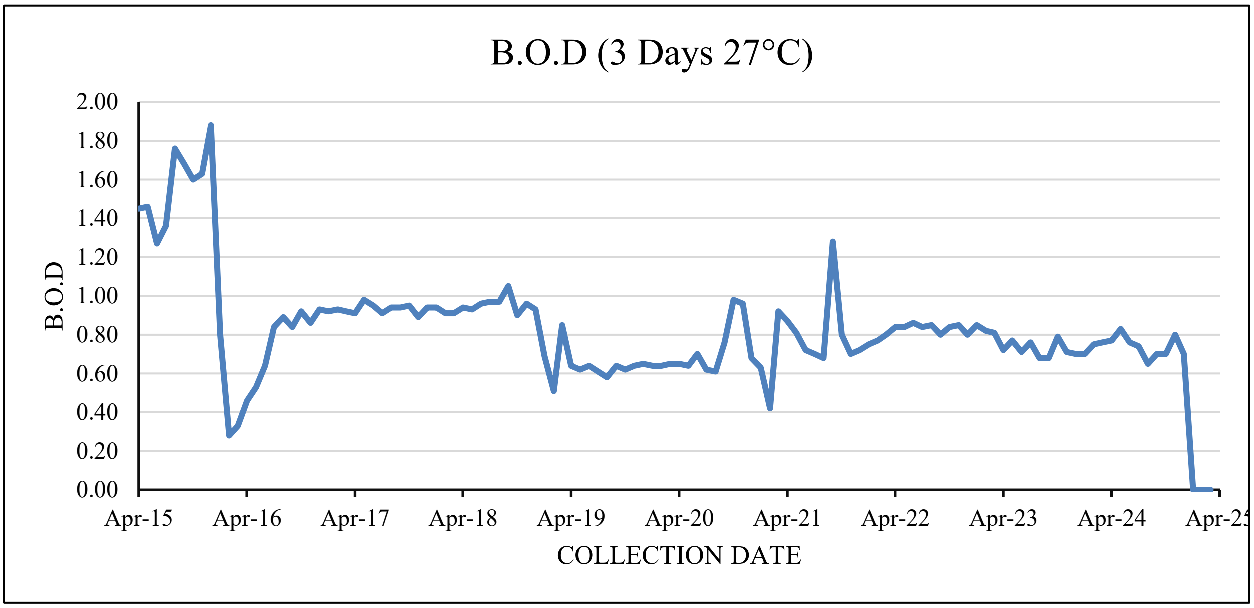


Figure 44 Monthly variation of B.O.D (3 Days 27°C) at Garudeshwar Station (2015-2025)

Graph 50: The graph shows the monthly variation of *B.O.D (3 Days 27°C)* at Garudeshwar Station from April 2015 to April 2025. BOD ranged from 0.28 to 1.88 mg/L(Dec 2015), CPCB bathing criterion: BOD ≤ 3 mg/L, within permissible ranges.

At Garudeshwar water quality is broadly acceptable for many chemical indicators (TDS, total hardness, sulphate, chloride, pH, DO and BOD generally within ecological/permissible ranges), but it shows important episodic and chronic risks that preclude direct potable use without treatment — notable are turbidity spikes up to 84 NTU and persistent faecal coliforms (2–61 MPN/100 mL) which indicate surface runoff/sewage contamination and demand urgent attention (filtration/coagulation and disinfection). Several chemical red flags also appear intermittently: very high reported nitrate peaks (up to 291 mg/L) and nickel (to ~0.15 mg/L) exceed drinking limits and require source-tracing and mitigation, and extreme sodium episodes (to 1000 mg/L) affect usability of the water.

3.3.2. Station: Panetha

Panetha represents the middle-lower transitional stretch of the river and reflects a moderate water quality profile with gradual improvements. **Graph 1 to Graph 24** show the water quality parameters with time from 2015 to 2025 of Panetha Station.

Organic Pollution (BOD, COD): BOD and COD values show a declining trend but remain higher than Garudeshwar, reflecting moderate organic input from tributaries and small-scale anthropogenic sources. Seasonal spikes during monsoon are observed due to stormwater runoff.

Dissolved Oxygen (DO): DO levels remain high and stable throughout the year (above 6 mg/L), ensuring good ecological conditions for aquatic life. Slight seasonal variations are observed during monsoon due to higher organic load and dilution effects.

Nutrients (Nitrate, Phosphate, TKN): Nitrate and TKN remain moderate and stable. Phosphate levels show a seasonal rise during the monsoon, attributed to agricultural runoff, but remain within permissible limits.

Microbial Load: Moderate coliform and E. coli presence during monsoon seasons suggest some influence of surface runoff containing domestic wastewater. However, microbial loads are generally within manageable levels for potential water use.

Metals: Iron occasionally exceeds the desirable limit during high-flow monsoon periods, likely due to natural leaching from sediments. Other metals such as manganese, lead, and cadmium remain well within limits.

Salinity & Hardness: Parameters such as chloride, TDS, and hardness are stable and acceptable, with no indication of salinity stress.

Overall Condition: Panetha reflects good water quality with low organic pollution and high DO. Seasonal nutrient and microbial variations warrant routine monitoring.

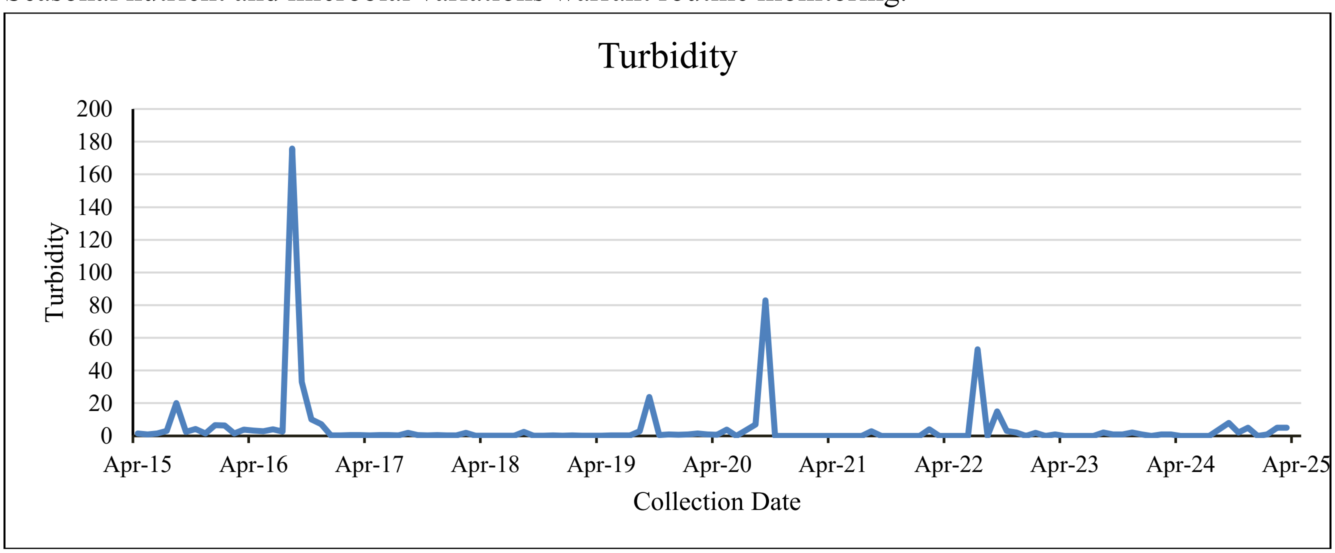


Figure 45 Monthly variation of Turbidity at Panetha Station (2015-2025)

Graph 1: The graph shows the monthly variation of *Turbidity* at Panetha Station from April 2015 to April 2025. Turbidity ranged from 0.2 to 175.8 NTU(August 2016), permissible limit (BIS IS10500): 5 NTU (desirable 1 NTU), exceeds the permissible limit and requires attention.

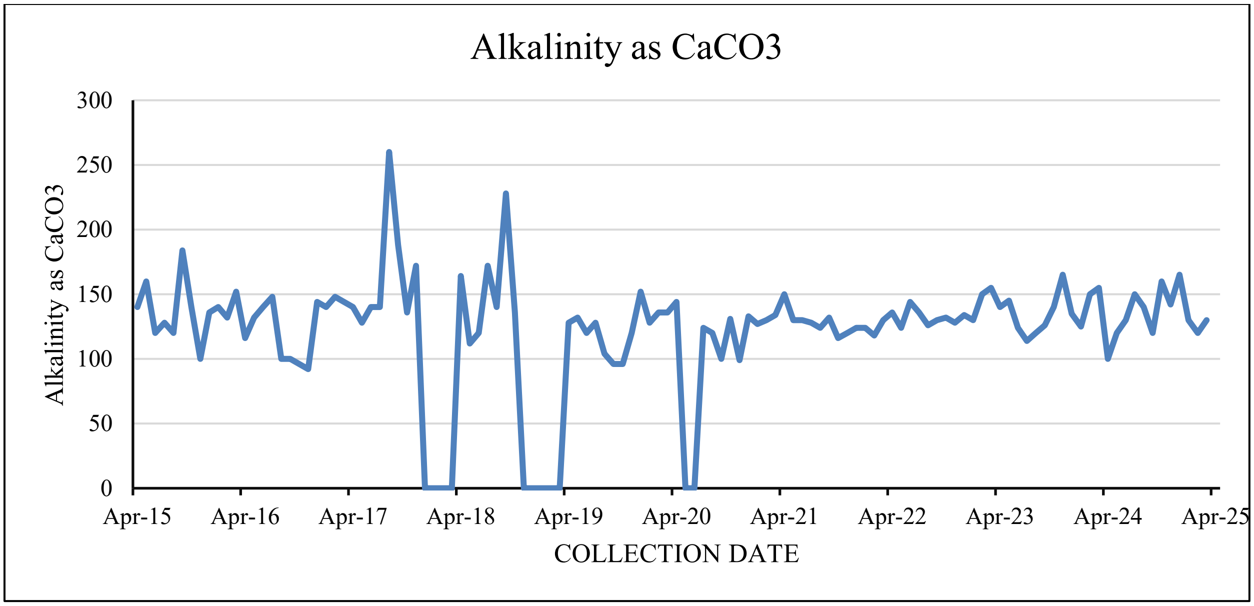


Figure 46 Monthly varation of Alkalinity as Caco3at Panetha Station (2015-2025)

Graph 2: The graph shows the monthly variation of *Alkalinity as CaCO3* at Panetha Station from April 2015 to April 2025. Alkalinity ranged from 92 to 260.0 mg/L(Aug 2017), no strict BIS numeric limit beyond general desirability (often 200 mg/L desirable), mostly within acceptable ranges though occasionally elevated.

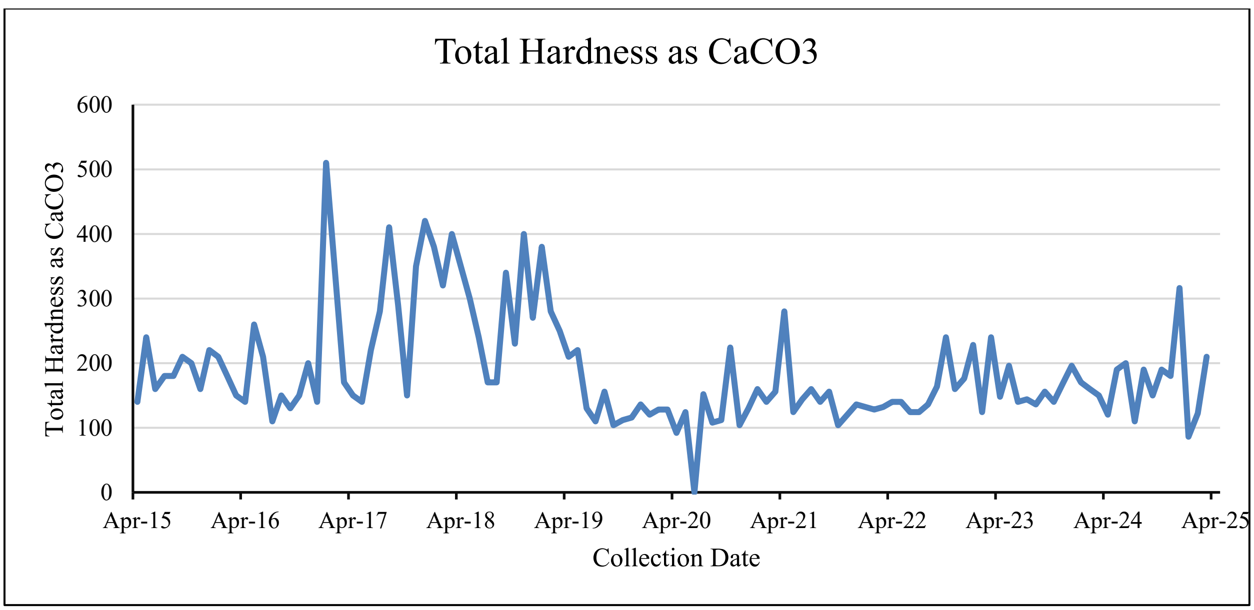


Figure 47 Monthly variation of Total Hardness as CaCo3 at Panetha Station (2015-2025)

Graph 2: The graph shows the monthly variation of *Total Hardness as CaCo3* at Panetha Station from April 2015 to April 2025. Total Hardness ranged from 86.0 to 510.0 mg/L(Jan 2017), permissible limit (BIS IS10500): 600 mg/L (desirable 200 mg/L), within the permissible limit.

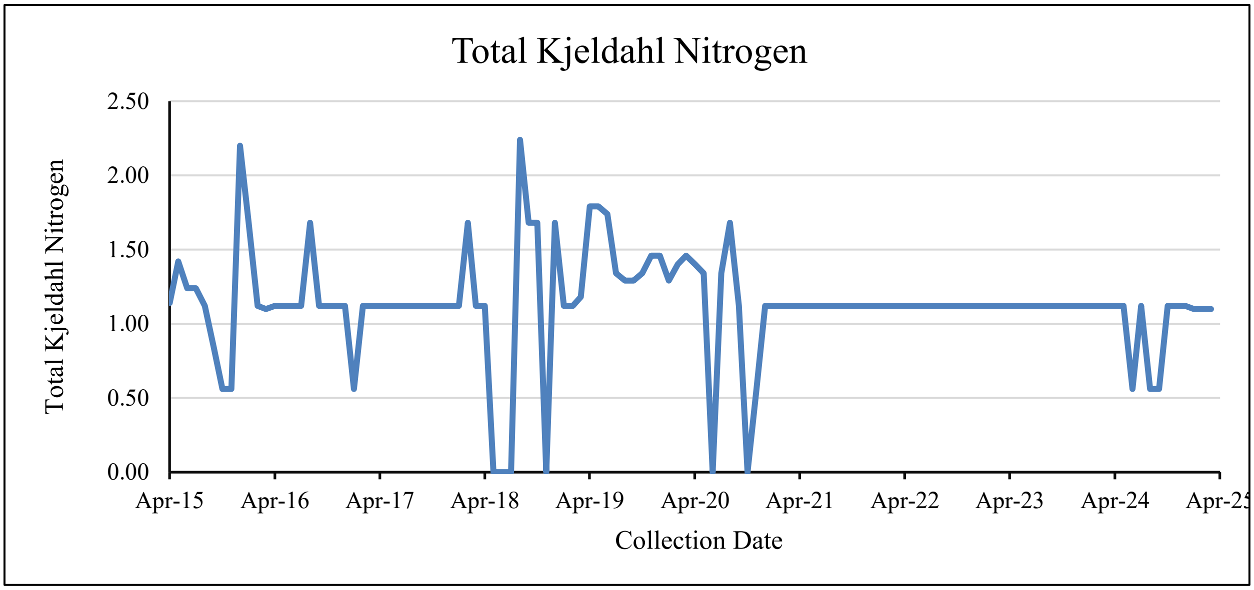


Figure 48 Monthly varation of Total Kjeldahl Nitrogen at Panetha Station (2015-2025)

Graph 3: The graph shows the monthly variation of *Total Kjeldahl Nitrogen* at Panetha Station from April 2015 to April 2025. Total Kjeldahl Nitrogen ranged from 0.56 to 2.24 mg/L(Aug 2018), no specific BIS drinking-water limit (reported as nutrient), reported; within typical environmental ranges.

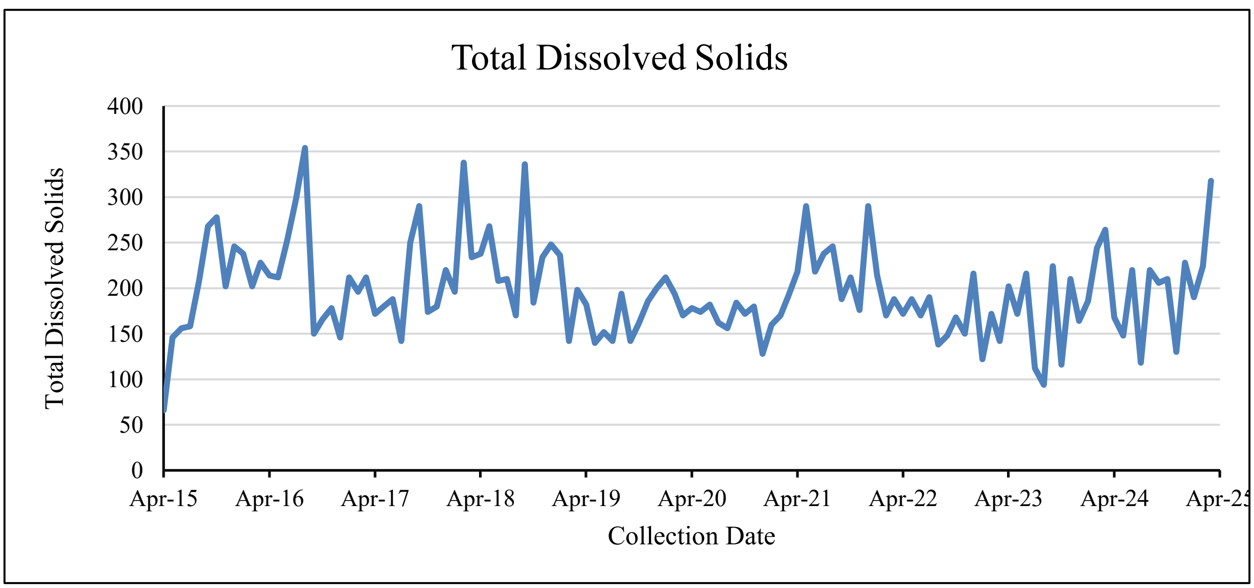


Figure 49 Monthly varation of Total Dissolved Solids at Panetha Station (2015-2025)

Graph 4: The graph shows the monthly variation of *Total Dissolved Solids* at Panetha Station from April 2015 to April 2025. TDS ranged from 66.0 to 354.0 mg/L(Aug 2016), permissible limit (BIS IS10500): 2000 mg/L (desirable 500 mg/L), well within permissible limit (but some values above desirable 500 mg/L).

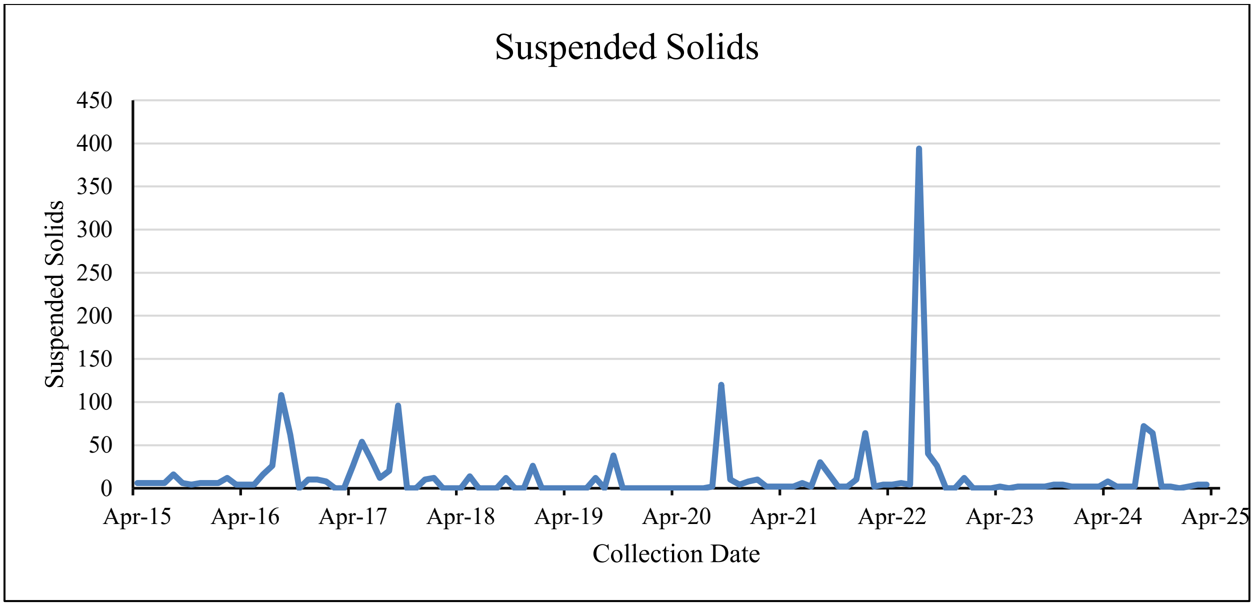


Figure 50 Monthly varation of Suspended Solids Panetha Station (2015-2025)

Graph 6: The graph shows the monthly variation of *Suspended Solids* at Panetha Station from April 2015 to April 2025. Suspended Solids ranged from 2.0 to 394.0 mg/L(July 2022), no direct BIS drinking-water limit (STP reuse norms often use TSS ≤ 20 mg/L), periodic spikes observed (monsoon); some values above common STP reuse benchmarks.

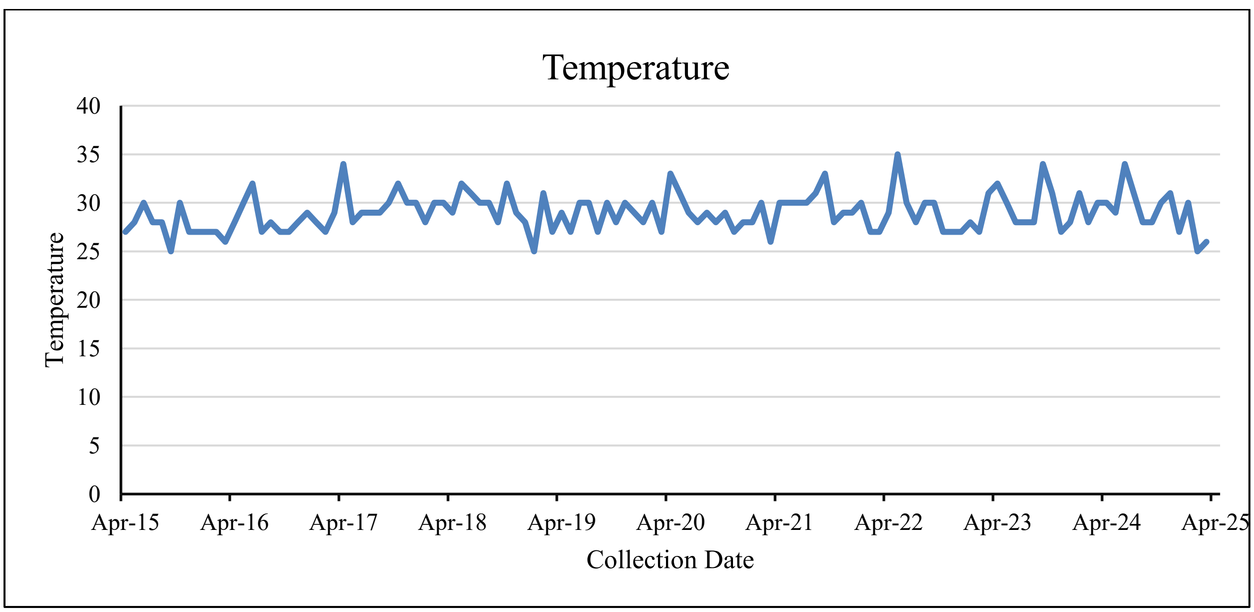


Figure 51 Monthly varation of Temperature at Panetha Station (2015-2025)

Graph 5: The graph shows the monthly variation of *Temperature* at Panetha Station from April 2015 to April 2025. Temperature ranged from 25.0 to 35 °C(May 2022), no fixed BIS drinking limit (reported), reported seasonal variation consistent with climate.

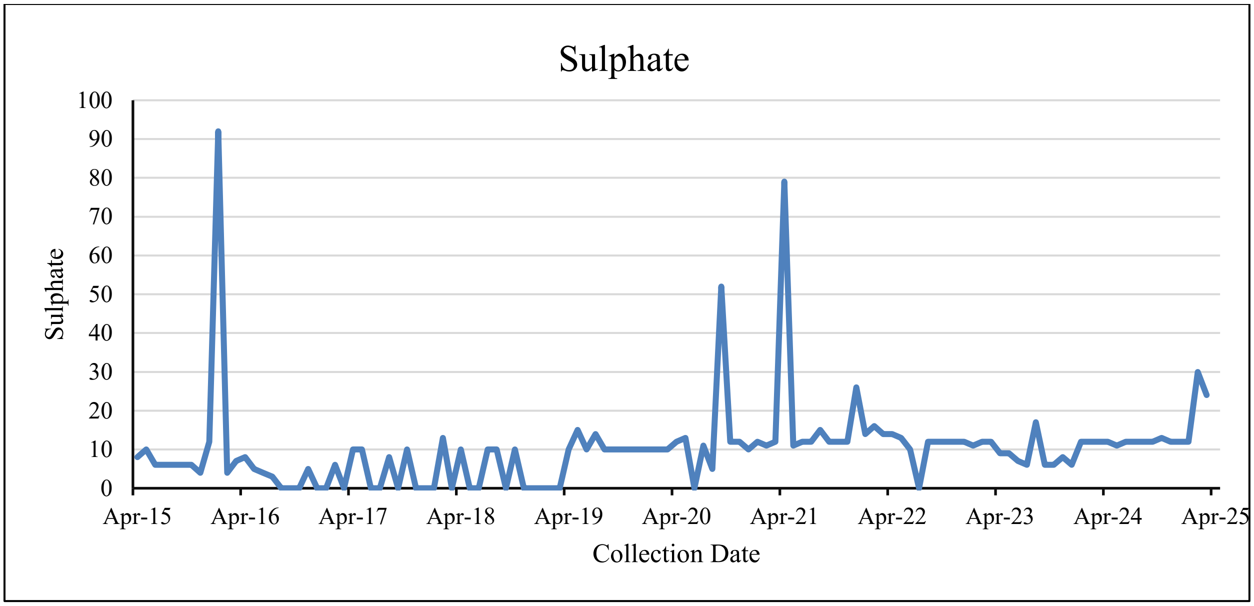


Figure 52 Monthly varation of Sulphate at Panetha Station (2015-2025)

Graph 7: The graph shows the monthly variation of *Sulphate* at Panetha Station from April 2015 to April 2025. Sulphate ranged from 3.0 to 92.0 mg/L(Jan 2016), permissible limit (BIS IS10500): 200 mg/L, within permissible limit.

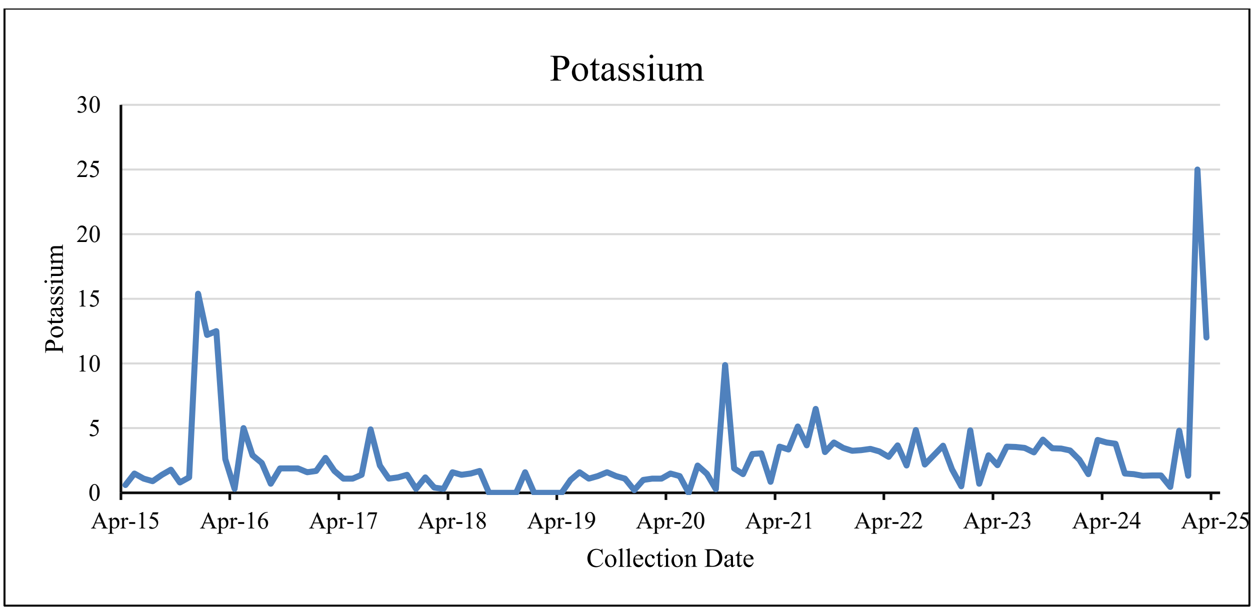


Figure 53 Monthly varation of Sodium at Panetha Station (2015-2025)

Graph 9: The graph shows the monthly variation of *Potassium* at Panetha Station from April 2015 to April 2025. Potassium ranged from 0.2 to 25.0 mg/L(Feb 2025), with no specific BIS limit (reported), within normal environmental concentrations.

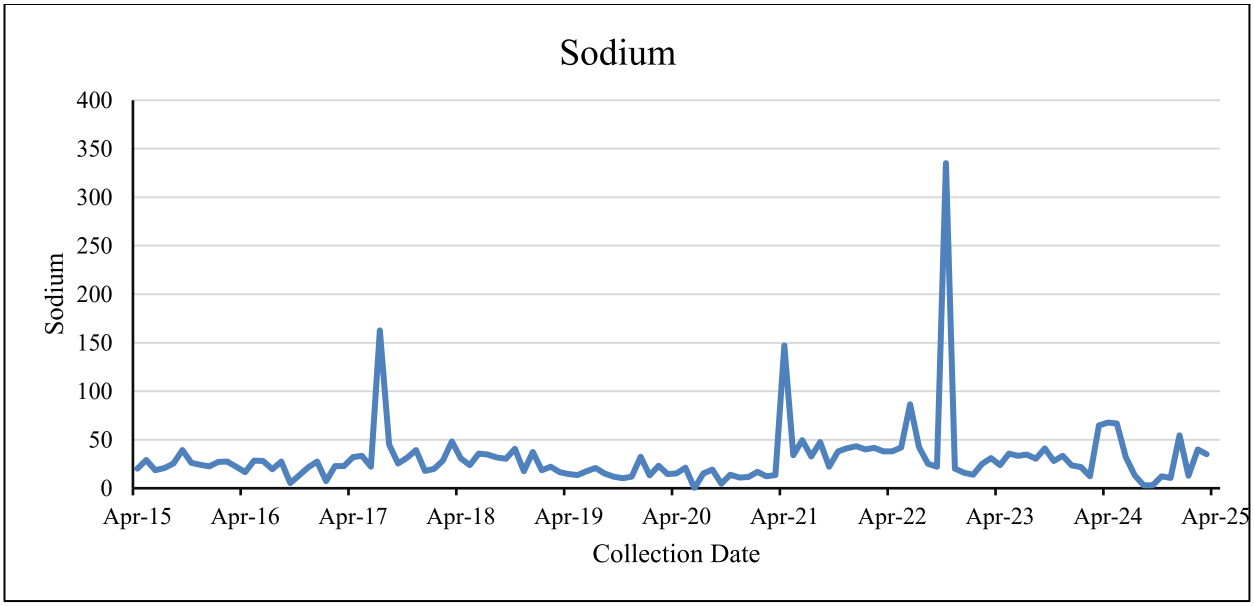


Figure 54 Monthly variation of Sodium at Panetha Station (2015-2025)

Graph 10: The graph shows the monthly variation of *Sodium* at Panetha Station from April 2015 to April 2025. Sodium ranged from 3.0 to 335.15 mg/L(October 2022), no strict BIS numeric limit (reported; guideline values often ~200 mg/L), within typical reporting/guideline ranges.

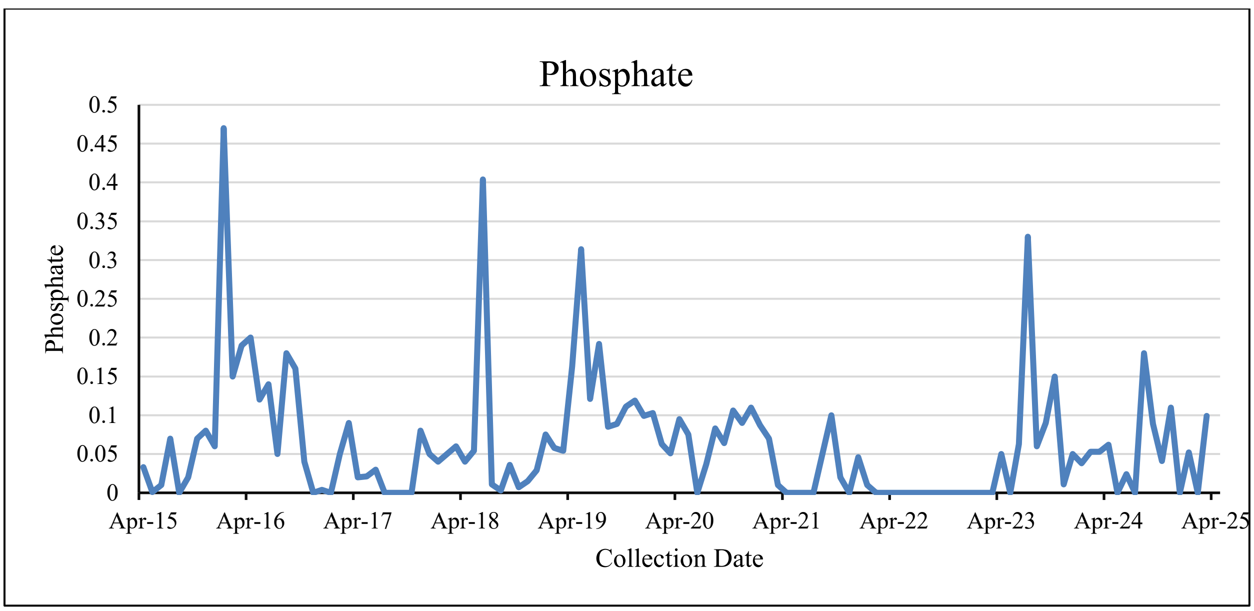


Figure 55 Monthly varation of Phosphate at Panetha Station (2015-2025)

Graph 10: The graph shows the monthly variation of *Phosphate* at Panetha Station from April 2015 to April 2025. Phosphate ranged from 0.01 to 0.47 mg/L(Jan 2016), no specific BIS drinking limit (nutrient environmental concern when elevated), levels mostly low; occasional monsoon rises.

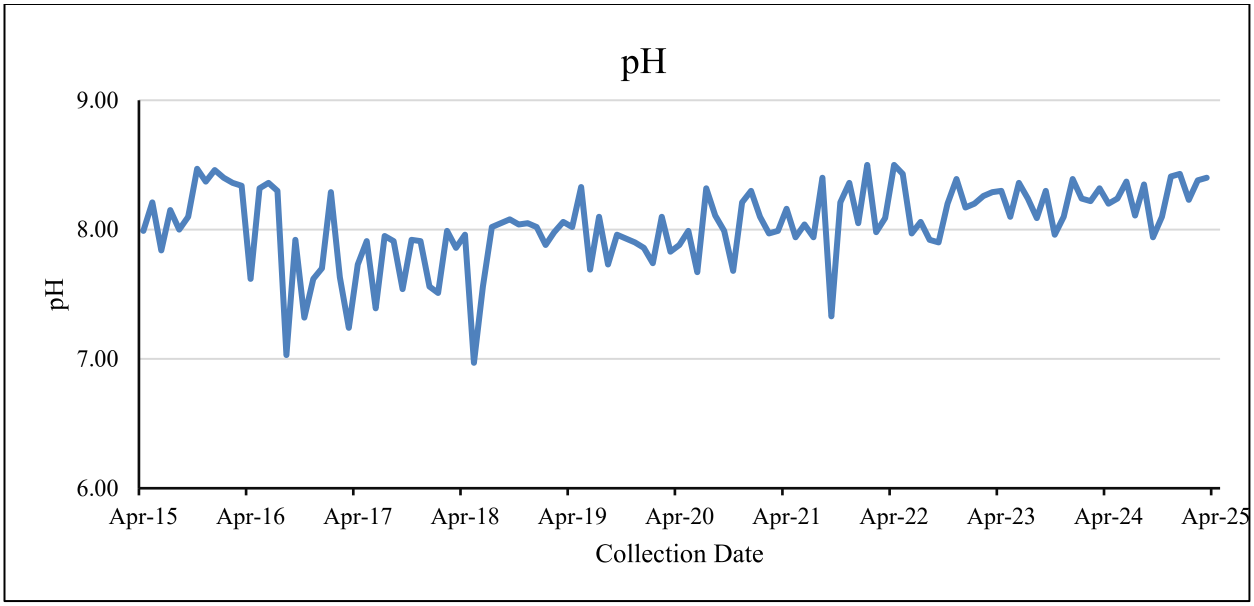


Figure 56 Monthly varation of pH at Panetha Station (2015-2025)

Graph 11: The graph shows the monthly variation of *pH* at Panetha Station from April 2015 to April 2025. pH ranged from 6.97 to 8.5(Jan & April 2022), permissible limit (BIS IS10500): 6.5–8.5 (no relaxation), within permissible limits.

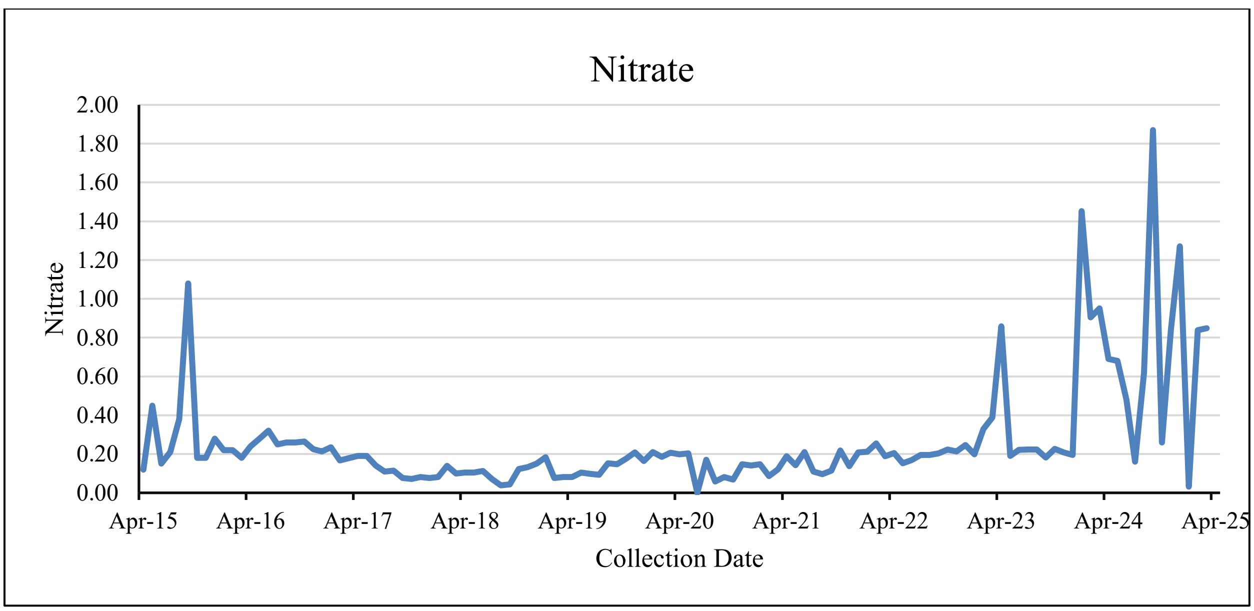


Figure 57 Monthly varation of Nitrate at Panetha Station (2016-2025)

Graph 13: The graph shows the monthly variation of *Nitrate* at Panetha Station from April 2015 to April 2025. Nitrate ranged from 0.03 to 1.87 mg/L(Sep 2024), permissible limit (BIS IS10500): 45 mg/L, exceeds the permissible limit in some months and requires attention.

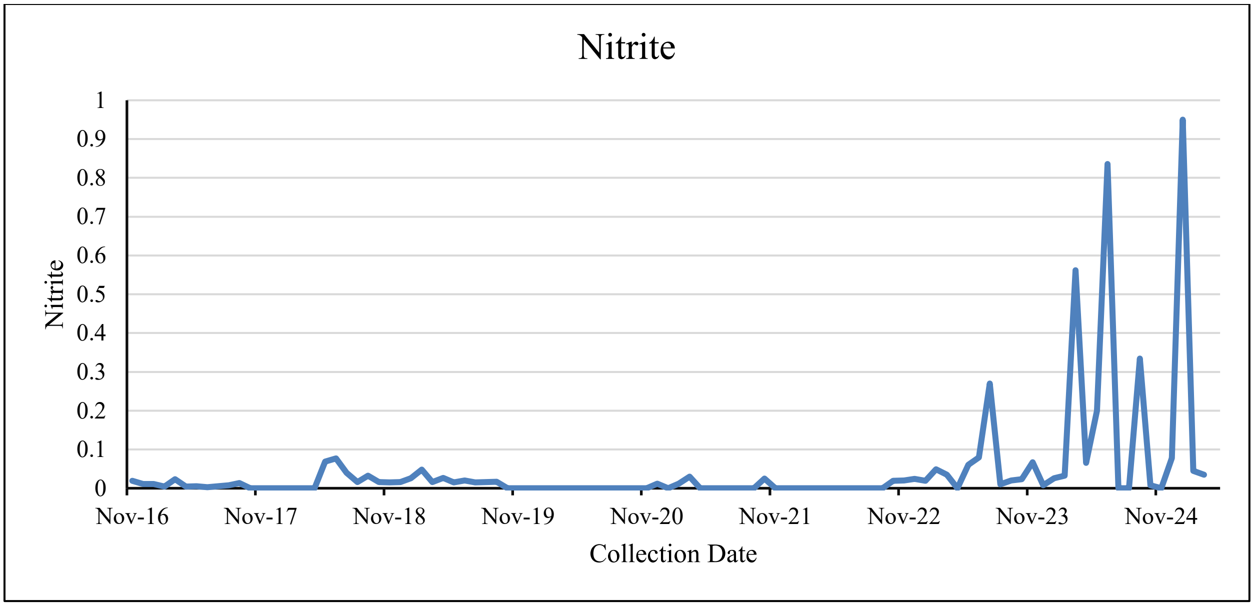


Figure 58 Monthly varation of Nitrite at Panetha Station (2015-2025)

Graph 14: The graph shows the monthly variation of *Nitrite* at Panetha Station from April 2016 to April 2025. Nitrite ranged from 0.01 to 0.95 mg/L(Jan 2025), permissible limit (BIS IS10500): 0.2 mg/L (permissible), at or below permissible limit (close to limit in some months).

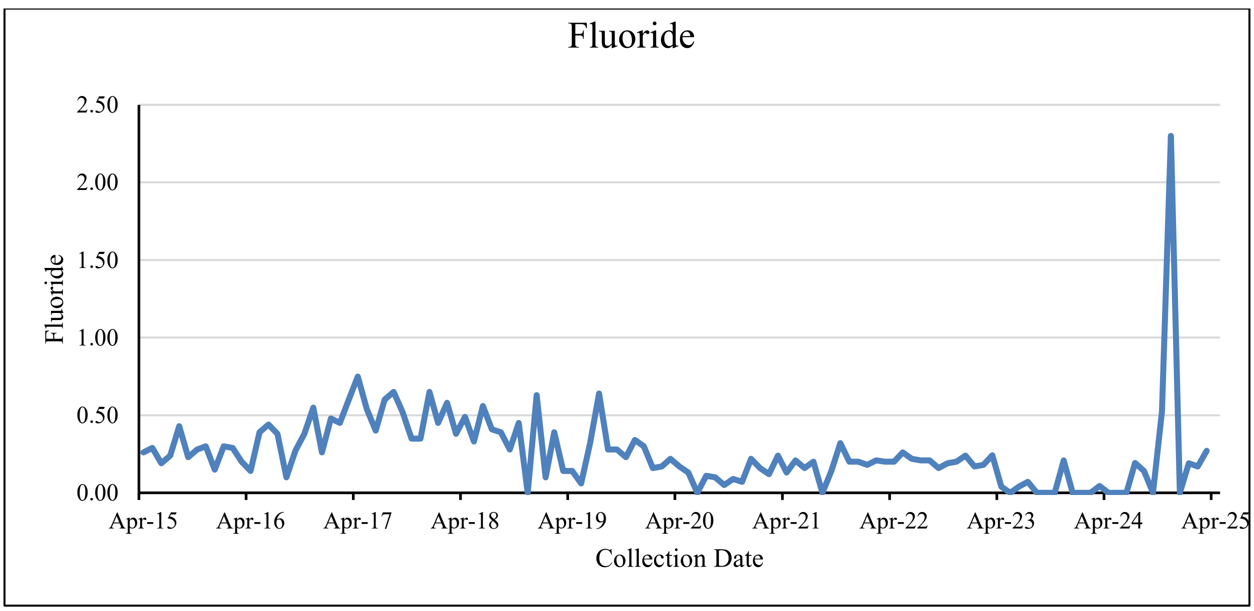


Figure 59 Monthly varation of Magnesium at Panetha Station (2015-2025)

Graph 15: The graph shows the monthly variation of *Fluoride* at Panetha Station from April 2015 to April 2025. Fluoride ranged from 0.06 to 2.30 mg/L, permissible limit (BIS IS10500): 1.5 mg/L (permissible; desirable 1.0 mg/L), within permissible limit.

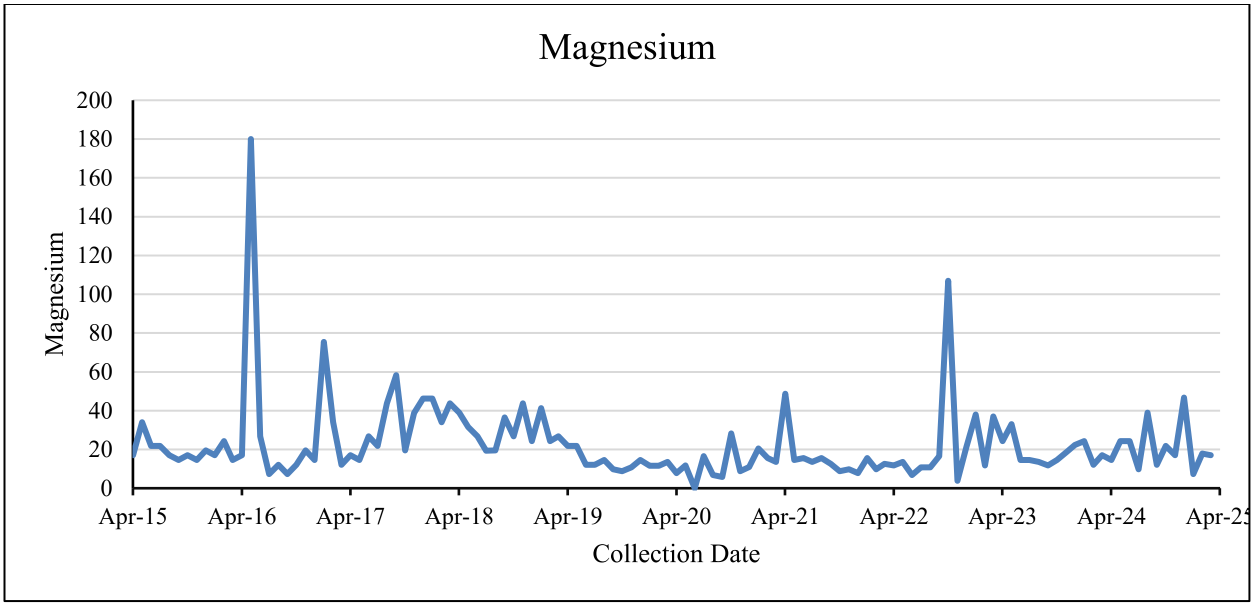


Figure 60 Monthly varation of Fluoride at Panetha Station (2015-2025)

Graph 16: The graph shows the monthly variation of *Magnesium* at Panetha Station from April 2015 to April 2025. Magnesium ranged from 4.0 to 180.0 mg/L(May 2016), no separate BIS numeric limit (contributes to hardness), exceeds permissible limit in some areas.

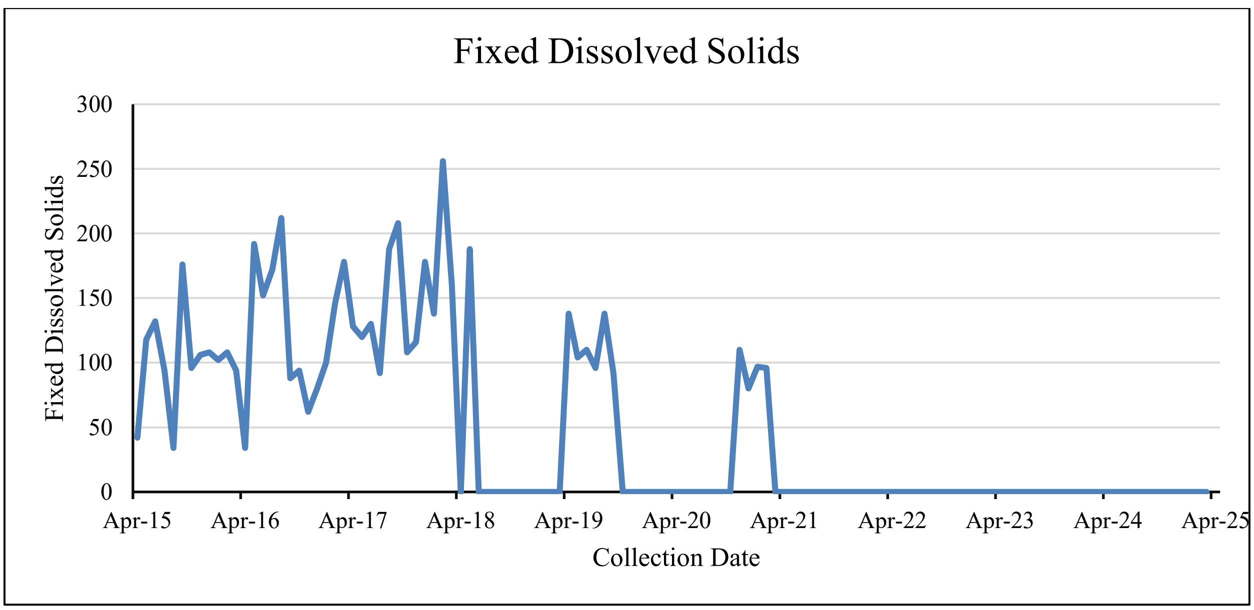


Figure 61 Monthly varation of Fixed Dissolved Solids at Panetha Station (2015-2025)

Graph 17: The graph shows the monthly variation of *Fixed Dissolved Solids* at Panetha Station from April 2015 to April 2025. Fixed Dissolved Solids ranged from 34 to 256(Feb 2018), reported with TDS, within permissible limits.

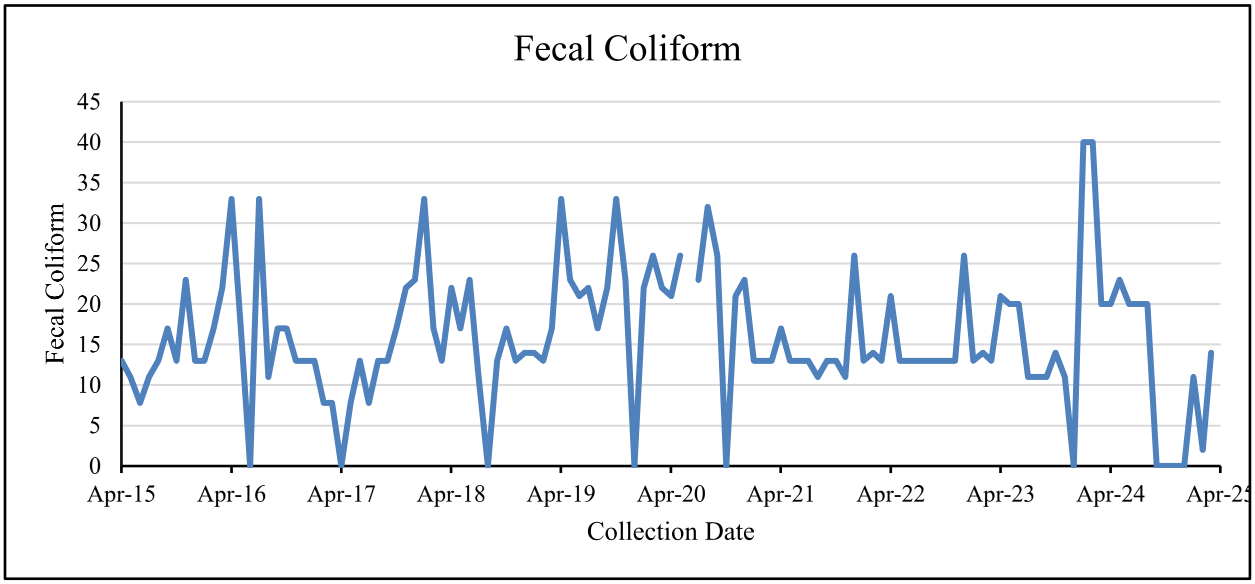


Figure 62 Monthly varation of Fecal Coliform at Panetha Station (2015-2025)

Graph 17: The graph shows the monthly variation of *Fecal Coliform* at Panetha Station from April 2015 to April 2025. Fecal Coliform ranged from 2 to 40 MPN/100mL(Jan & Feb 2024), permissible limit (BIS IS10500 for drinking): 0 MPN/100mL, well above drinking-water limits; indicates microbial contamination (especially monsoon).

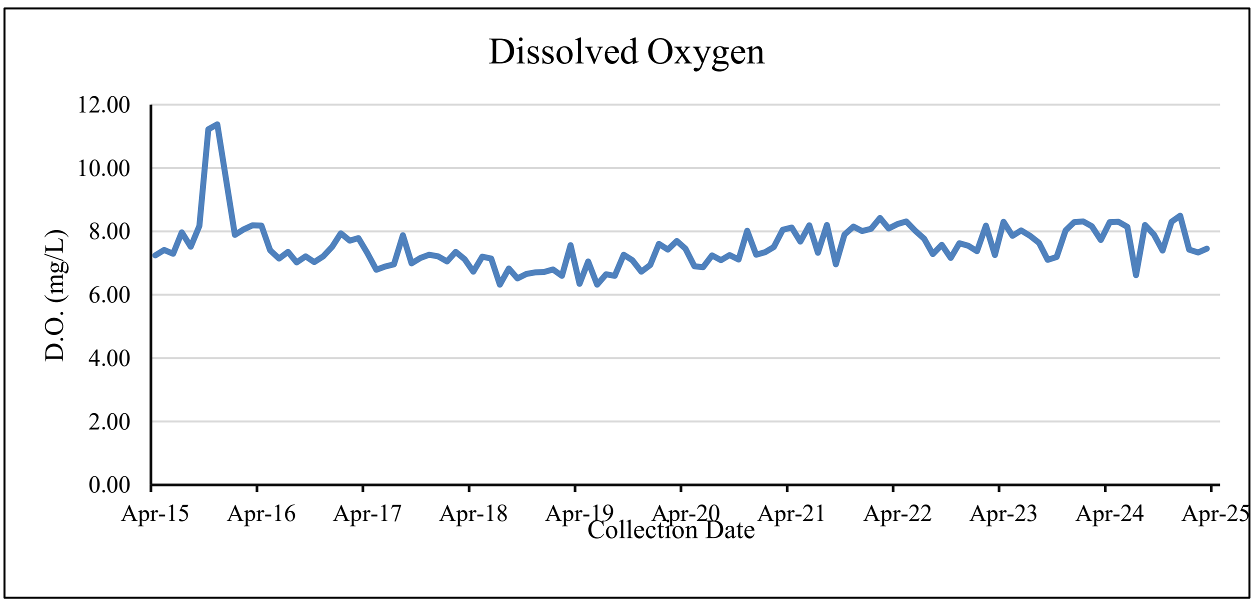


Figure 63 Monthly varation of Dissolved Oxygen at Panetha Station (2015-2025)

Graph 19: The graph shows the monthly variation of *Dissolved Oxygen* at Panetha Station from April 2015 to April 2025. DO ranged from 6.32 to 11.38 mg/L(Nov 2015), CPCB ecological guideline: DO $\geq$ 6 mg/L for good water, mostly meets ecological criteria though some months dip slightly below.

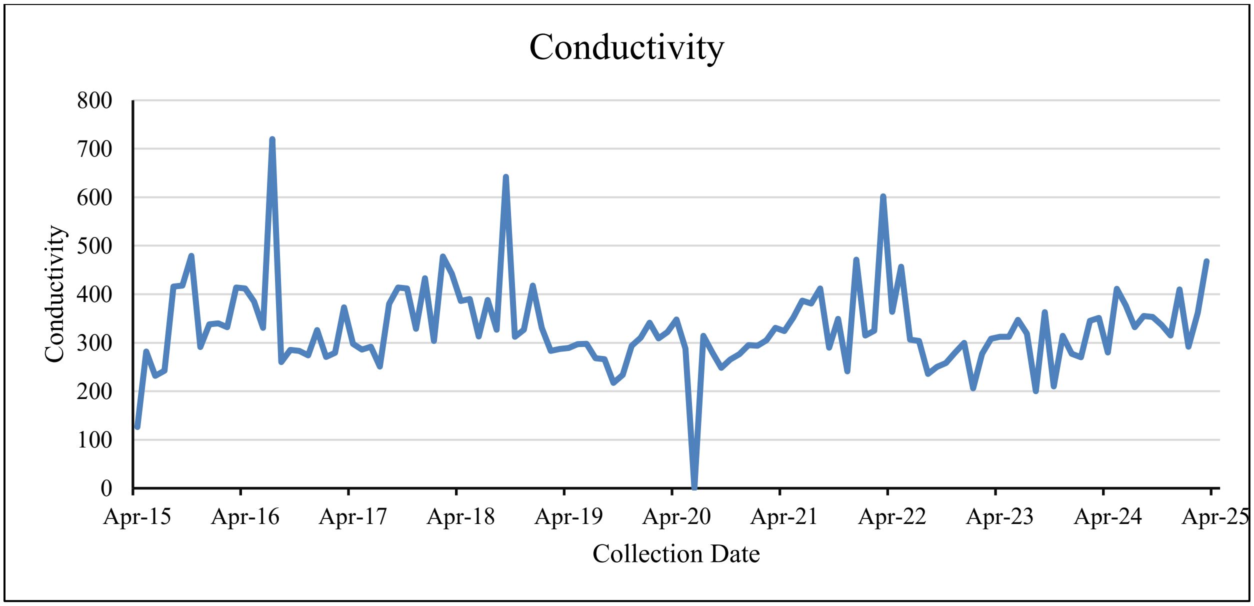


Figure 64 Monthly varation of Conductivity at Panetha Station (2015-2025)

Graph 20: The graph shows the monthly variation of *Conductivity* at Panetha Station from April 2015 to April 2025. Conductivity ranged from 126 to 720 µS/cm(July 2016), no direct BIS limit (reported), shows seasonal/point-source variability; some high values reflect higher ionic load.

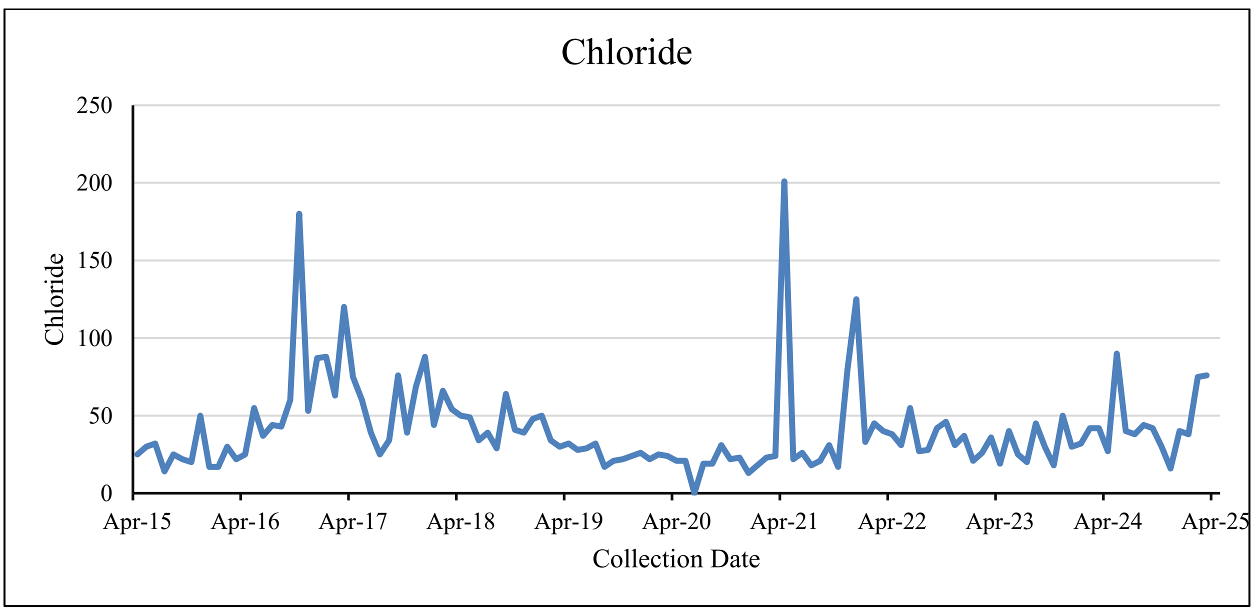


Figure 65 Monthly varation of Chloride at Panetha Station (2015-2025)

Graph 21: The graph shows the monthly variation of *Chloride* at Panetha Station from April 2015 to April 2025. Chloride ranged from 14 to 201 mg/L(April 2021), permissible limit (BIS IS10500): 250 mg/L (desirable ~200 mg/L), within permissible range.

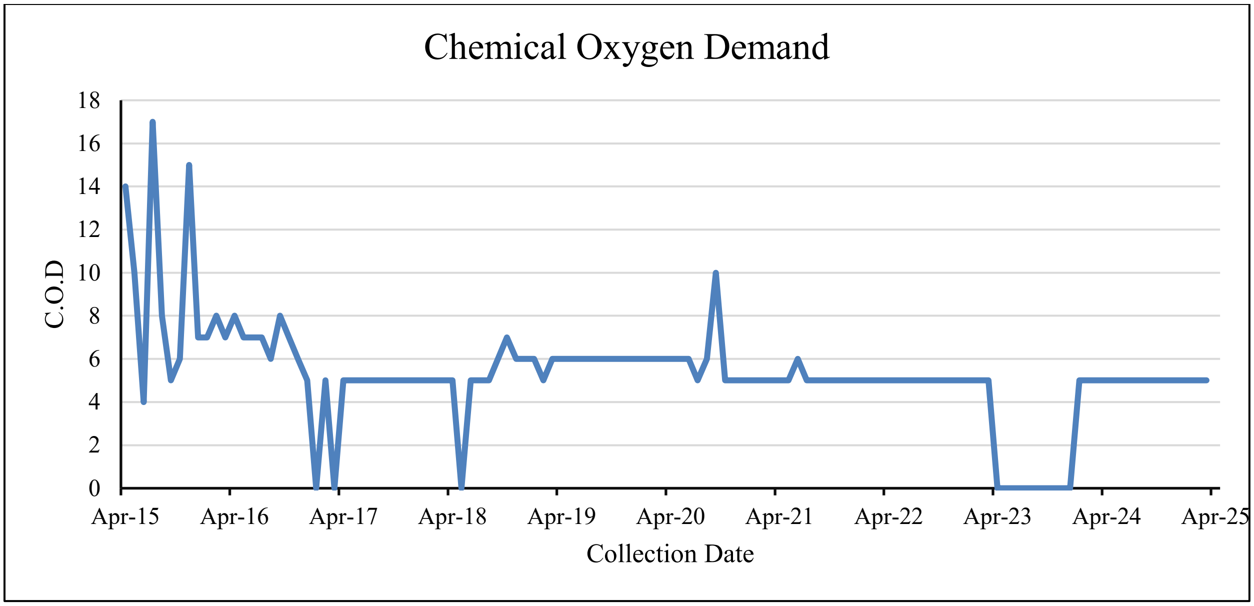


Figure 66 Monthly varation of Chemical Oxygen Demand at Panetha Station (2015-2025)

Graph 22: The graph shows the monthly variation of *Chemical Oxygen Demand (COD)* at Panetha Station from April 2015 to April 2025. COD ranged from 4 to 17.0 mg/L(July 2015), no BIS drinking limit (effluent limits vary), shows periodic organic/chemical loading; some months are elevated.

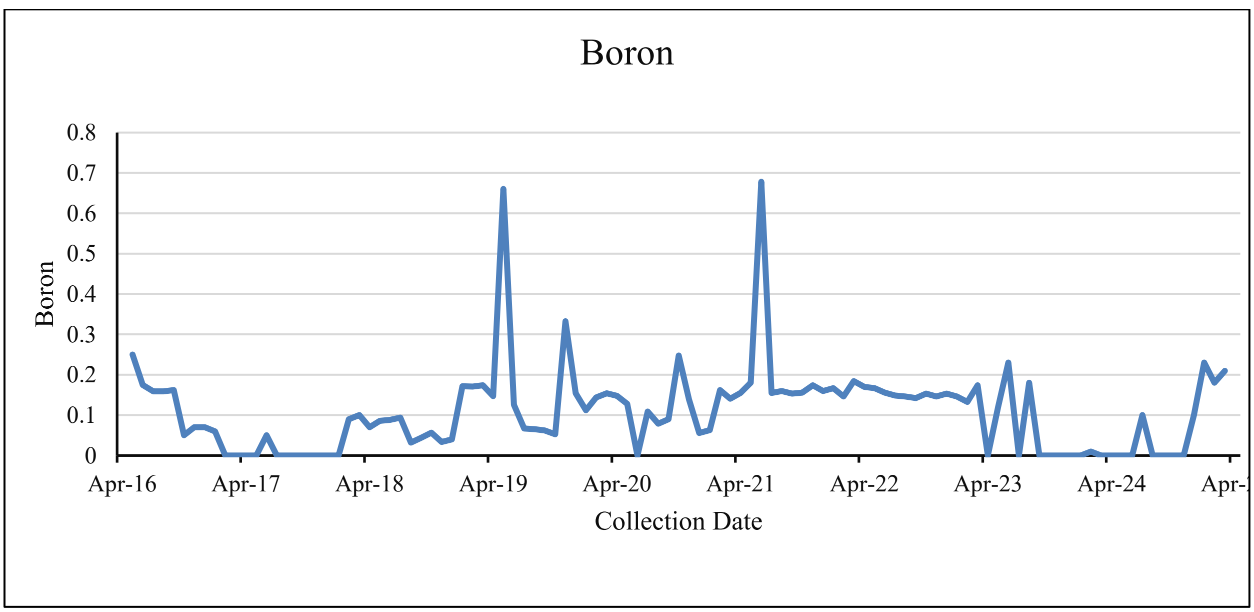


Figure 67 Monthly varation of Boron at Panetha Station (2016-2025)

Graph 23: The graph shows the monthly variation of *Boron* at Panetha Station from April 2016 to April 2025. Boron ranged from 0.02 to 0.678 mg/L(June 2021), typical BIS guidance: desirable ~0.5 mg/L; permissible often 2.0 mg/L, within typical drinking-water guidance.

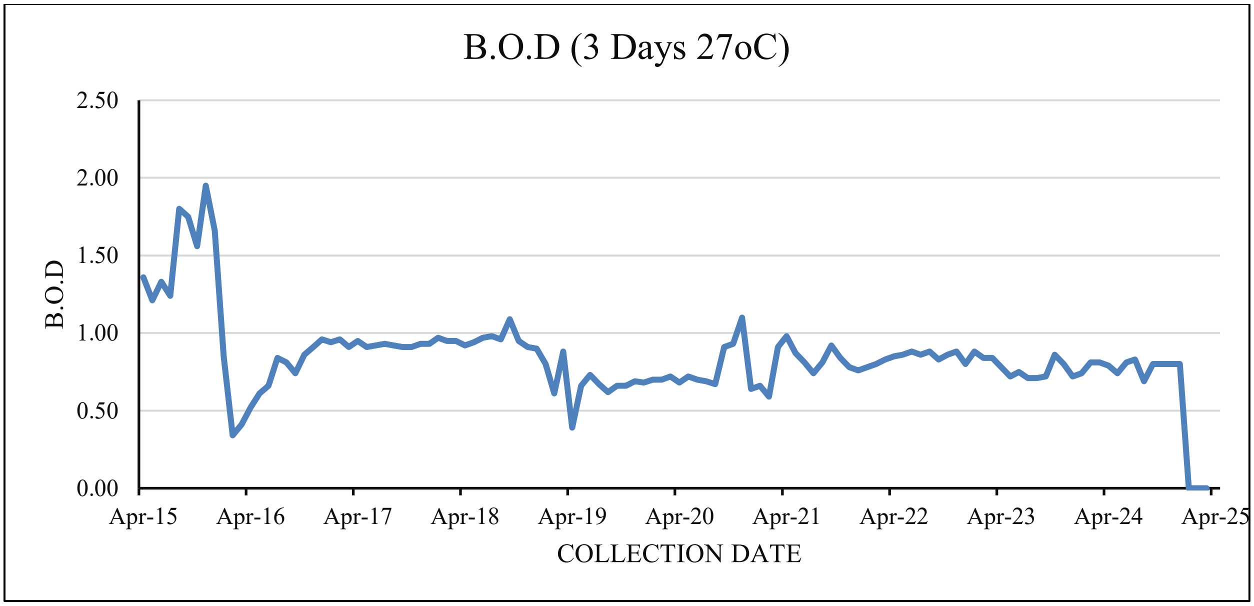


Figure 68 Monthly varation of B.O.D (3 Days 27oC at Panetha Station (2015-2025)

Graph 24: The graph shows the monthly variation of *B.O.D (3 Days 27°C)* at Panetha Station from April 2015 to April 2025. BOD ranged from 0.3 to 1.95 mg/L(Nov 2015), CPCB bathing criterion for Class B (outdoor bathing): BOD ≤ 3 mg/L, some months exceed the bathing standard and indicate organic pollution.

River Narmada at Panetha

The water quality at Panetha station shows moderate variation across parameters during the period April 2015 to April 2025. Panetha Station's water is chemically acceptable for many parameters (TDS, total hardness, sulphate, chloride, boron, pH and generally adequate DO) but shows clear episodic and seasonal problems that compromise safety for direct consumption: large turbidity spikes (up to 175.8 NTU) and persistent faecal coliform counts (2–40 MPN/100 mL vs drinking-water target of 0) are the most serious concerns, while nitrite (to 0.95 mg/L), fluoride (to 2.30 mg/L), elevated suspended solids and occasional high sodium/magnesium values exceed desirable limits in some months.particularly linked to seasonal discharges and runoff.

3.3.3. Station: Zanor

Zanor is located further downstream and benefits from dilution effects but is still influenced by localized activities. **Graph 51 to Graph 77** show the water quality parameters with time from 2015 to 2025 of Zanor Station.

Organic Pollution: BOD and COD are low and improving, reflecting reduced pollution loads. Monsoon periods bring temporary increases due to runoff, but these return to baseline quickly.

Dissolved Oxygen: DO levels remain high and stable (>6 mg/L), sustaining aquatic biodiversity.

Nutrients: Nitrate and TKN are moderate year-round. Seasonal phosphate peaks occur in monsoon, but concentrations remain within acceptable limits.

Microbial Load: Moderate coliform presence is observed, increasing during monsoon due to inflows from nearby agricultural areas and domestic sewage.

Metals: Heavy metals are generally absent or within safe limits; iron occasionally reaches moderate levels during high flow periods.

Salinity & Hardness: Chloride, conductivity, and hardness are stable and acceptable, with no salinity hazards.

Overall Condition: Zanor demonstrates good water quality, showing better conditions than Garudeshwar, with minor seasonal microbial concerns. It benefits from natural purification and reduced direct anthropogenic stress.

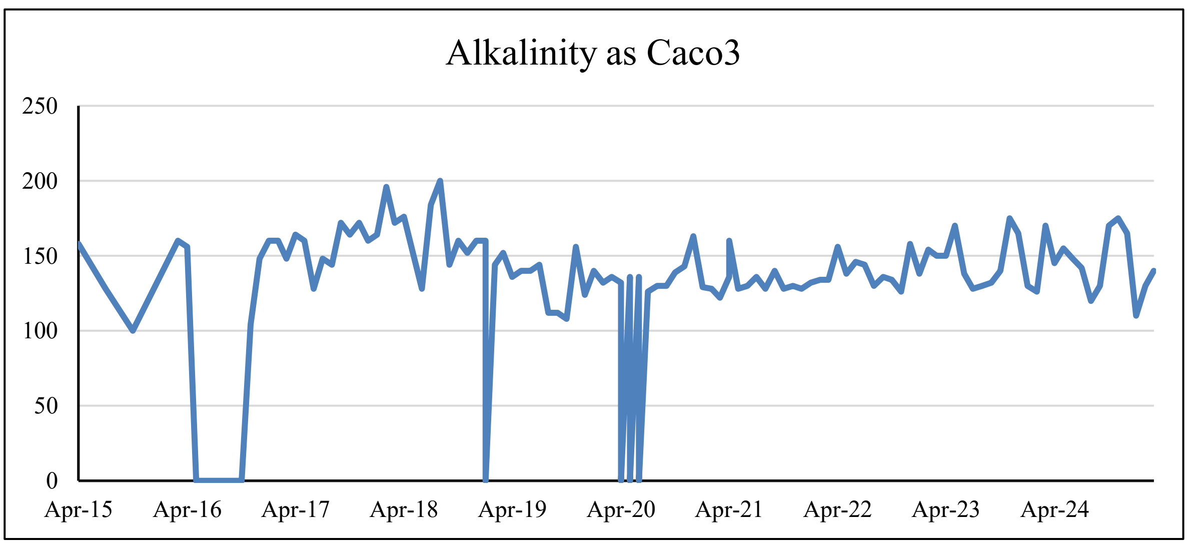


Figure 69 Monthly variation of Alkalinity as CaCo3 at Zanor Station (2015-2025)

The graph shows the monthly variation of *Alkalinity as CaCo3* at Zanor Station from April 2015 to April 2025. Alkalinity ranged from 100 to 200 mg/L(Aug 2018), within typical ranges.

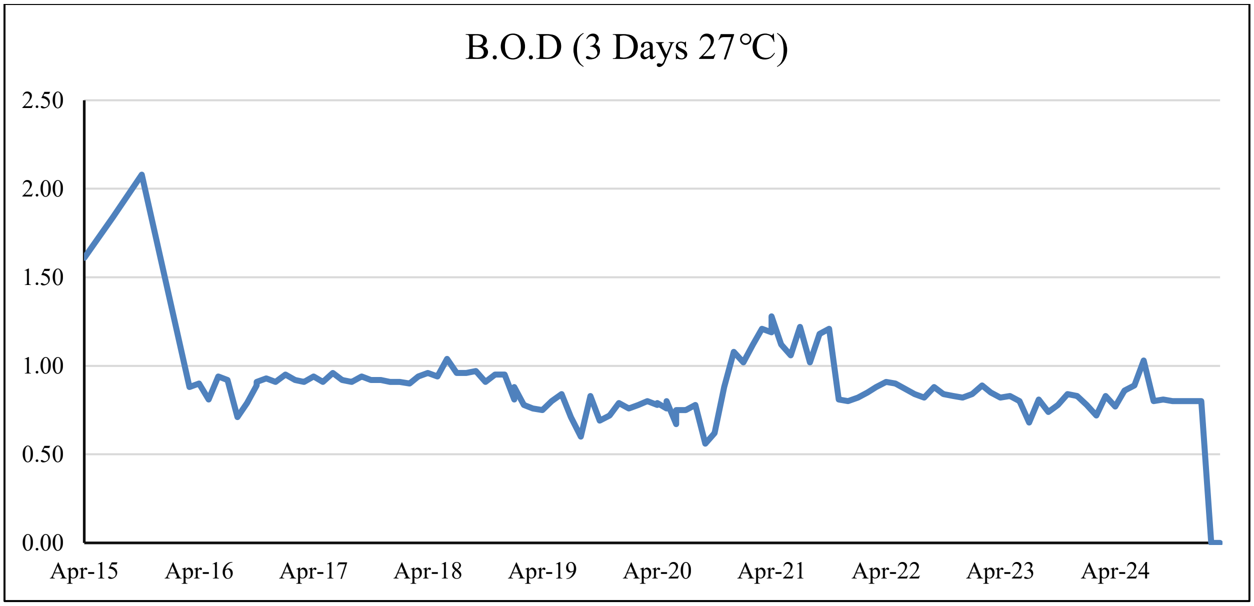


Figure 70 Monthly variation of B.O.D. (3 Days 27 °C at Zanor Station (2015-2025)

Graph 52: The graph shows the monthly variation of *B.O.D. (3 Days 27 °C)* at Zanor Station from April 2015 to April 2025. BOD ranged from 0.56 to 2.08 mg/L(Oct 2015), CPCB bathing criterion: BOD ≤ 3 mg/L, within permissible ranges.

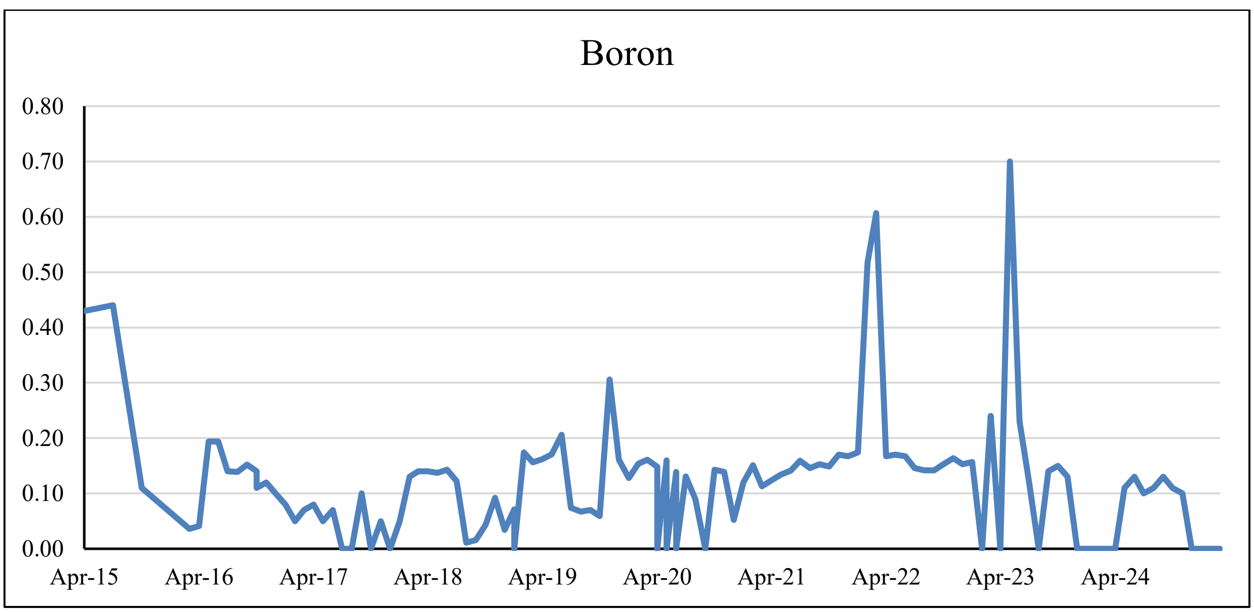


Figure 71 Monthly variation of Boron at Zanor Station (2015-2025)

Graph 53: The graph shows the monthly variation of *Boron* at Zanor Station from April 2015 to April 2025. Boron ranged from 0.01 to 0.7 mg/L(May 2023), within drinking-water guidance.

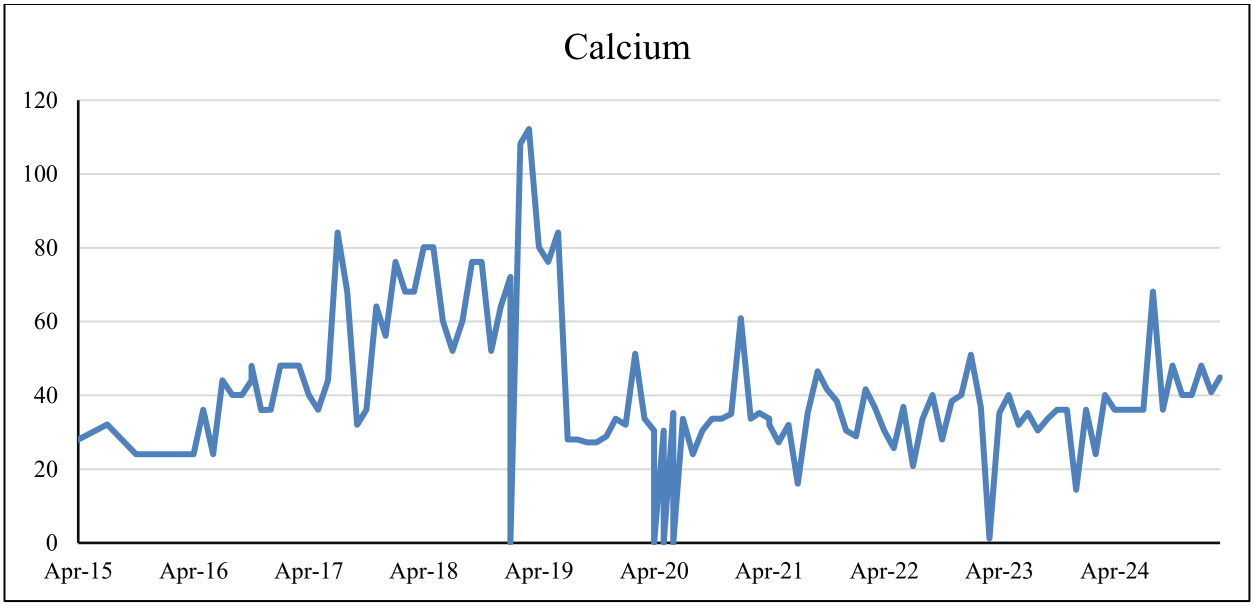


Figure 72 Monthly variation of Calcium at Zanor Station (2015-2025)

Graph 54: The graph shows the monthly variation of *Calcium* at Zanor Station from April 2015 to April 2025. Calcium ranged from 1.18 to 112.2 mg/L(March 2019), some months above typical benchmarks.

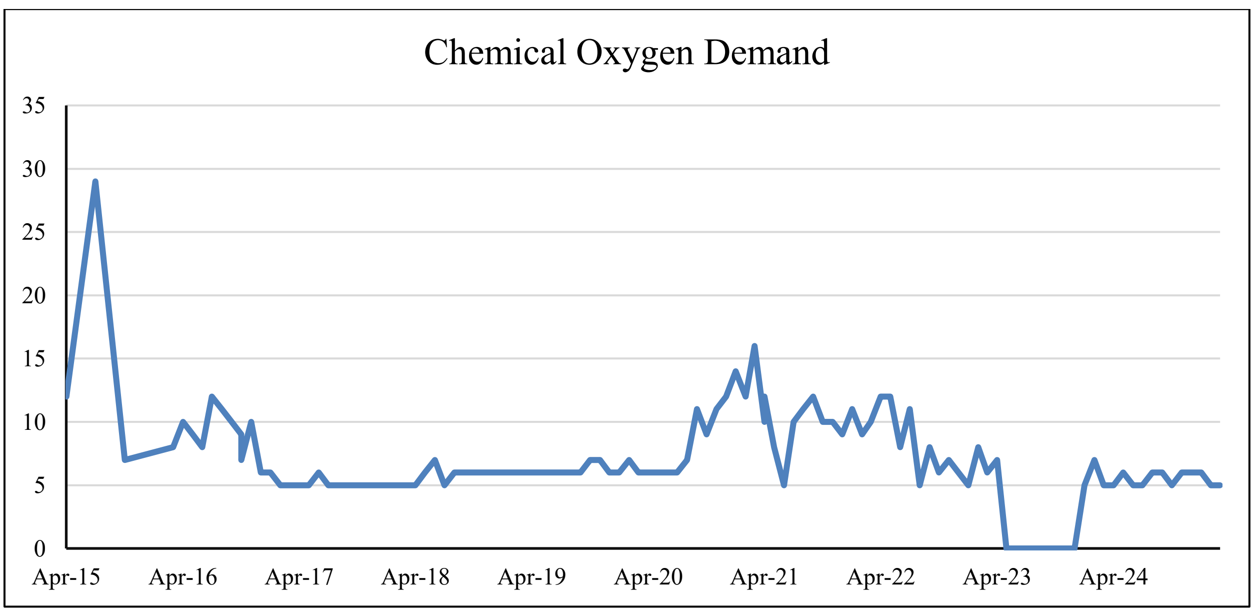


Figure 73 Monthly variation of Chemical Oxygen Demand at Zanor Station (2015-2025)

Graph 55: The graph shows the monthly variation of *Chemical Oxygen Demand* at Zanor Station from April 2015 to April 2025. COD ranged from 6 to 29 mg/L(July 2015), moderate; occasional increases reflect organic inputs.

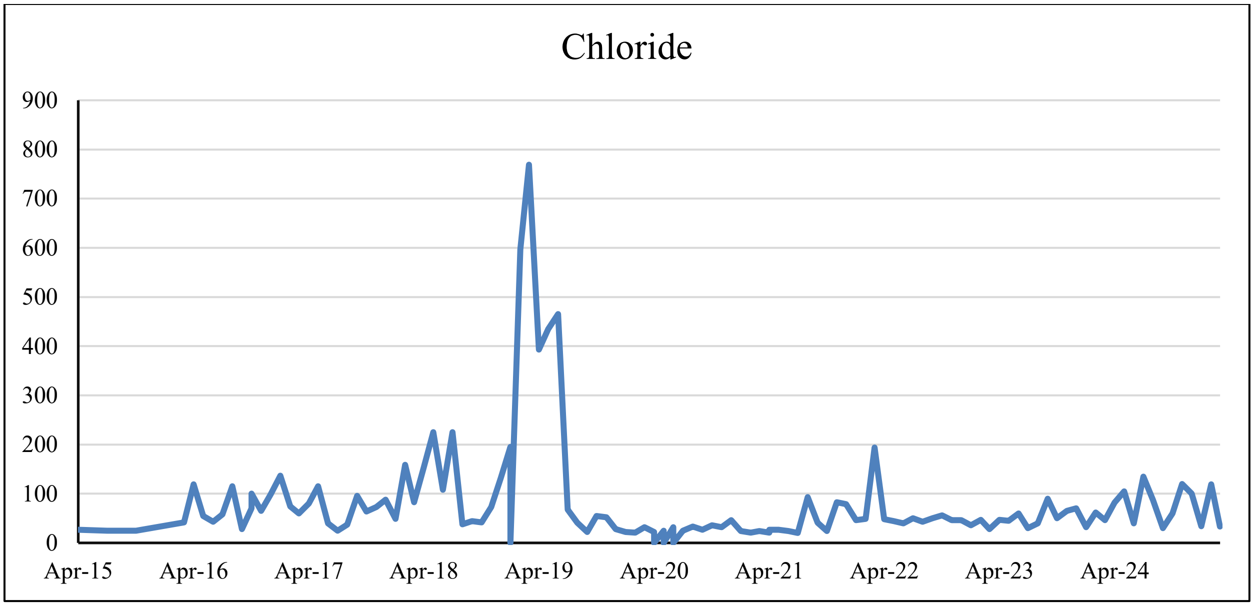


Figure 74 Monthly variation of Chloride at Zanor Station (2015-2025)

Graph 56: The graph shows the monthly variation of *Chloride* at Zanor Station from April 2015 to April 2025. Chloride ranged from 20 to 769 mg/L(March 2019), permissible limit (BIS IS10500): 250 mg/L, exceeds permissible limit in some areas.

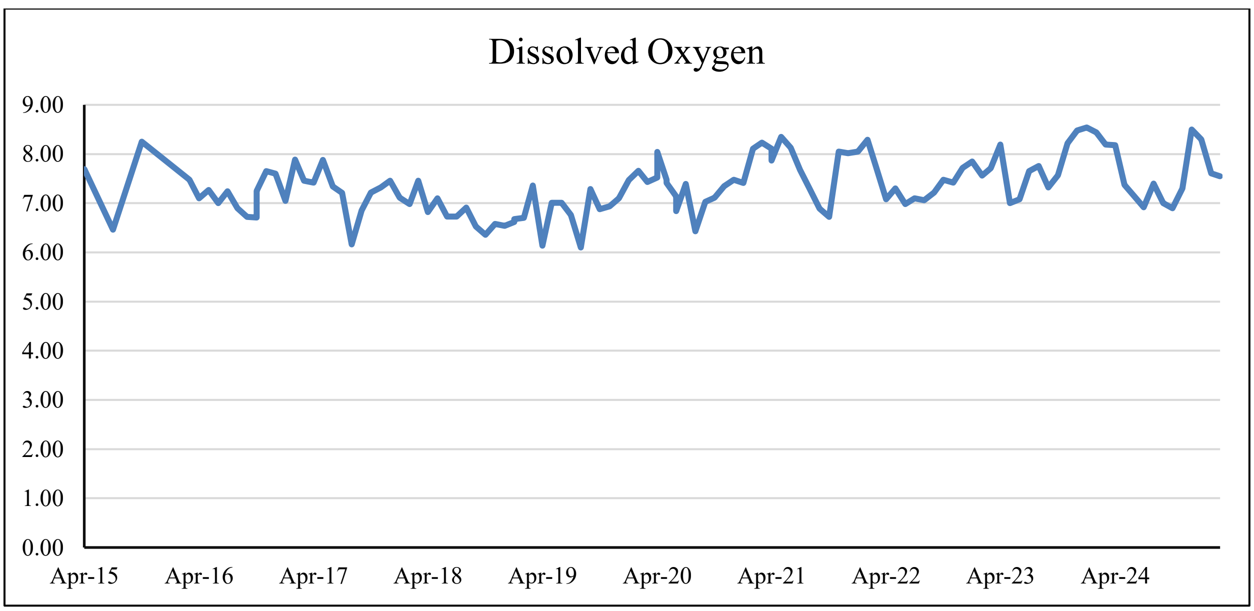


Figure 75 Monthly variation of Dissolved Oxygen at Zanor Station (2015-2025)

Graph 57: The graph shows the monthly variation of *Dissolved Oxygen* at Zanor Station from April 2015 to April 2025. DO ranged from 5.8 to 8.54 mg/L(Jan 2024), CPCB ecological guideline: DO ≥ 6 mg/L, mostly meets ecological criteria, supporting aquatic life.

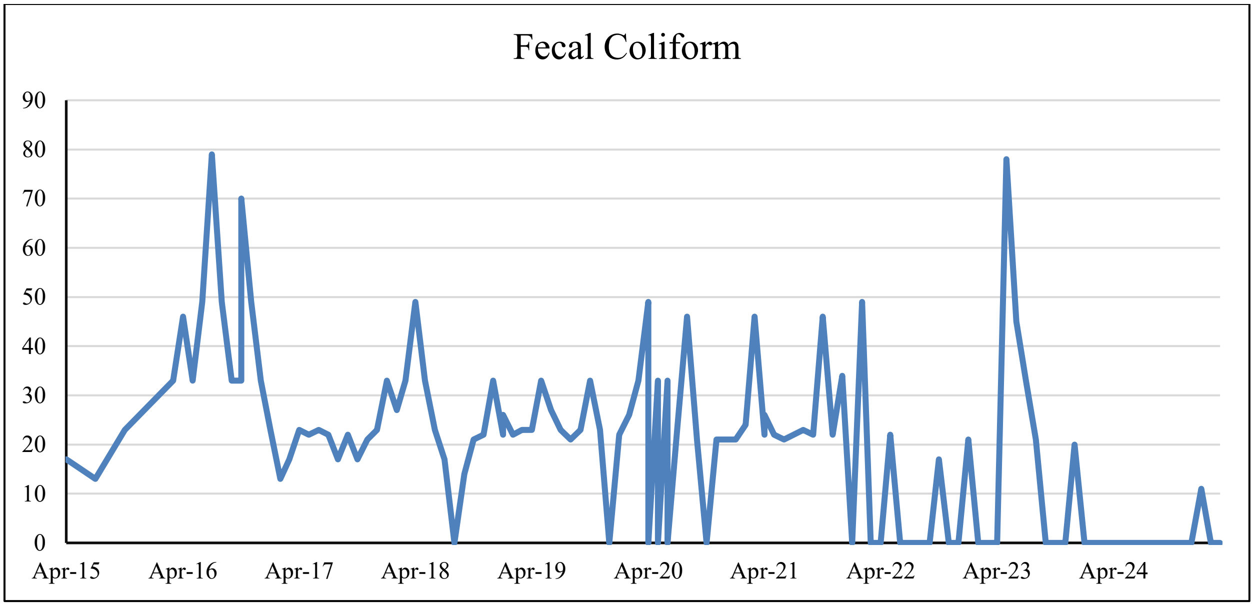


Figure 76 Monthly variation of Fecal Coliform at Zanor Station (2015-2025)

Graph 58: The graph shows the monthly variation of *Fecal Coliform* at Zanor Station from April 2015 to April 2025. Fecal Coliform ranged from 15 to 79 MPN/100mL(July 2016), permissible limit for drinking: 0 MPN/100mL, significant microbial contamination in parts of dataset, needs treatment before use.

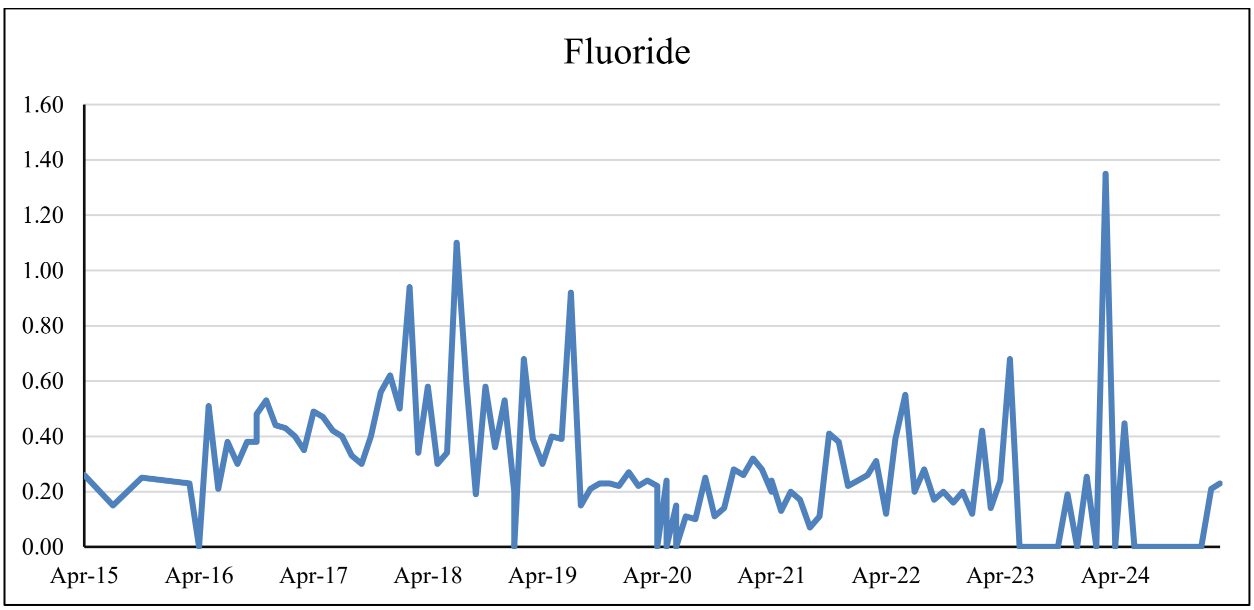


Figure 77 Monthly variation of Fluoride at Zanor Station (2015-2025)

Graph 59: The graph shows the monthly variation of *Fluoride* at Zanor Station from April 2015 to April 2025. Fluoride ranged from 0.06 to 1.35 mg/L, permissible limit (BIS IS10500): 1.35 mg/L(March 2024), within permissible limit.

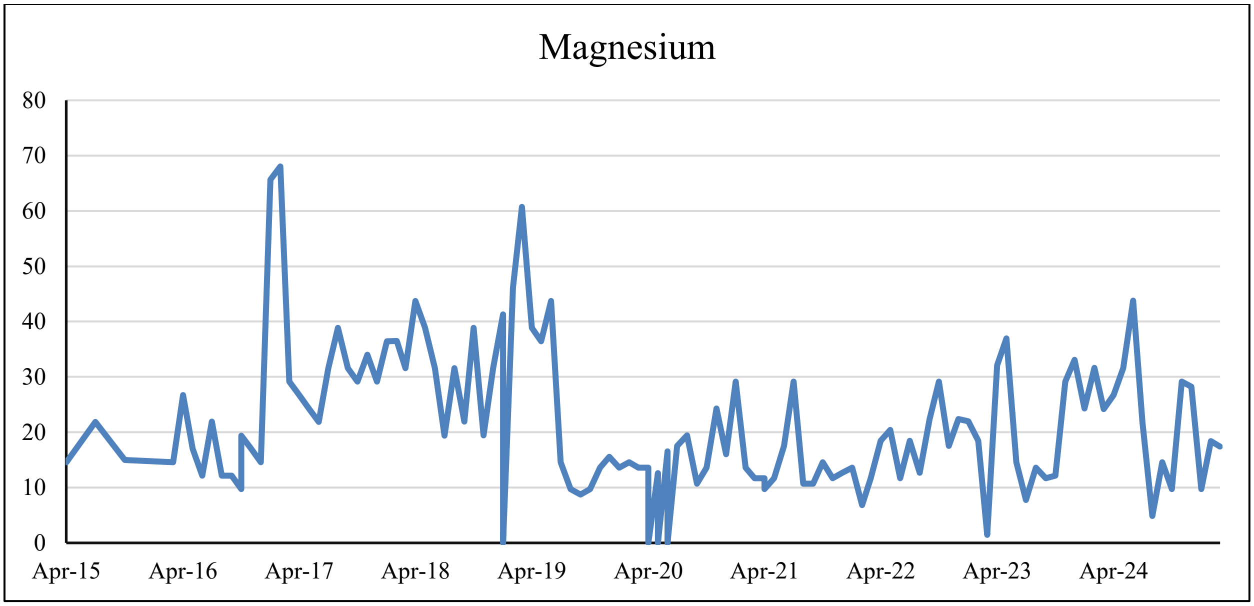


Figure 78 Monthly variation of Magnesium at Zanor Station (2015-2025)

Graph 61: The graph shows the monthly variation of Magnesium at Zanor Station from April 2015 to April 2025. Magnesium ranged from 1.44 to 68.0 mg/L, exceeds permissible limit in some areas.

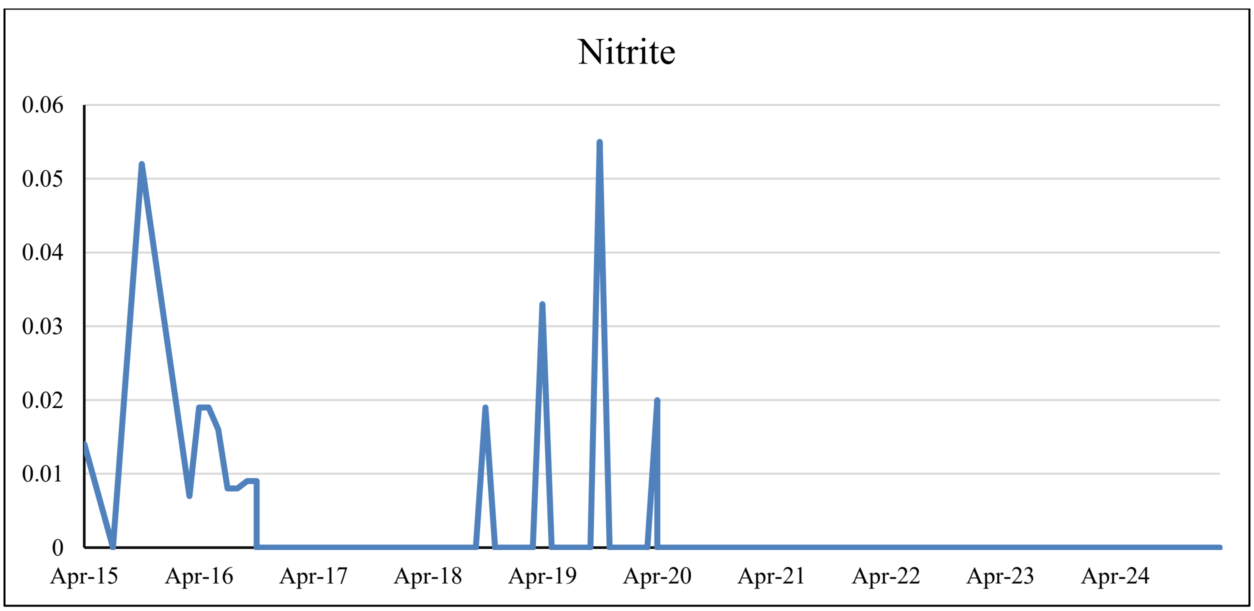


Figure 79 Monthly variation of Nitrite at Zanor Station (2015-2025)

Graph 62: The graph shows the monthly variation of *Nitrite* at Zanor Station from April 2015 to April 2025. Nitrite ranged from 0.01 to 0.055 mg/L(Oct 2019), permissible limit (BIS IS10500): 0.2 mg/L, within permissible limit.

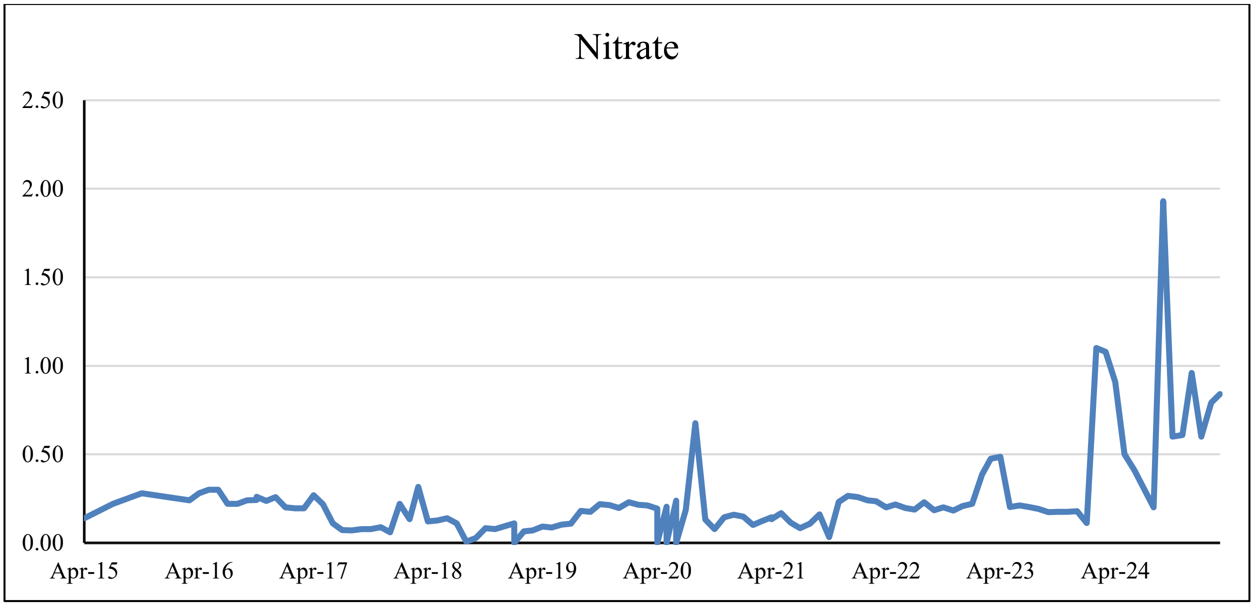


Figure 80 Monthly variation of Nitrate at Zanor Station (2015-2025)

Graph 63: The graph shows the monthly variation of Nitrate at Zanor Station from April 2015 to April 2025. Nitrate ranged from 0.01 to 1.93 mg/L(Sep 2024), permissible limit (BIS IS10500): 45 mg/L, within permissible limit.

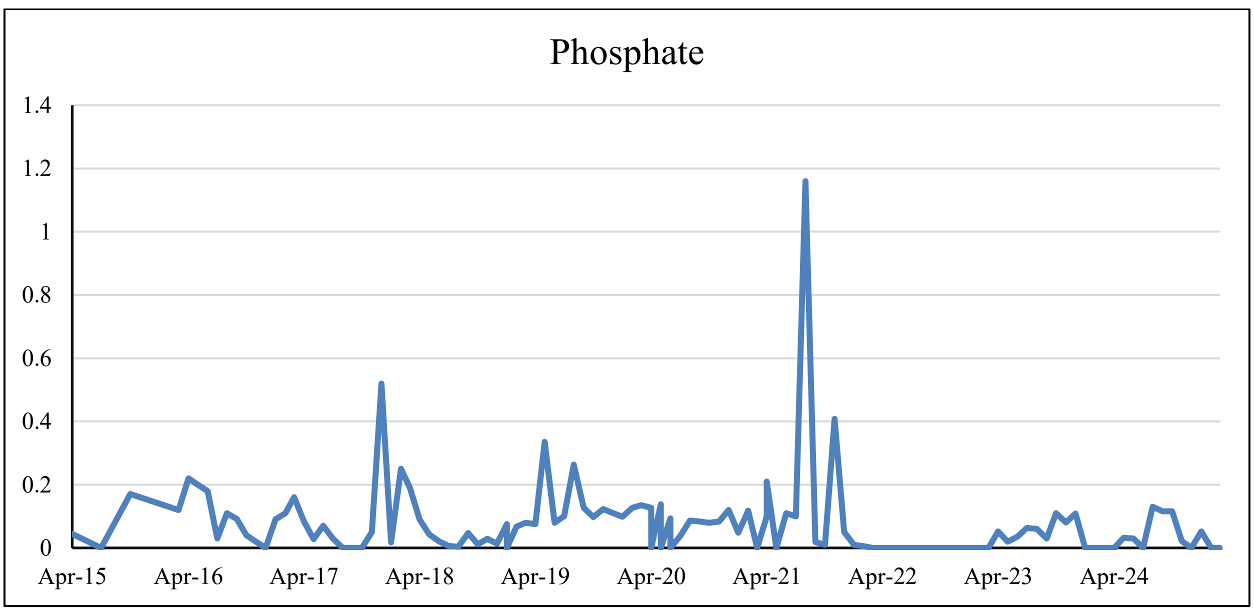


Figure 81 Monthly variation of Phosphate at Zanor Station (2015-2025)

Graph 64: The graph shows the monthly variation of *Phosphate* at Zanor Station from April 2015 to April 2025. Phosphate ranged from 0to 1.16 mg/L(Aug 2021), low to moderate: occasional monsoon peaks.

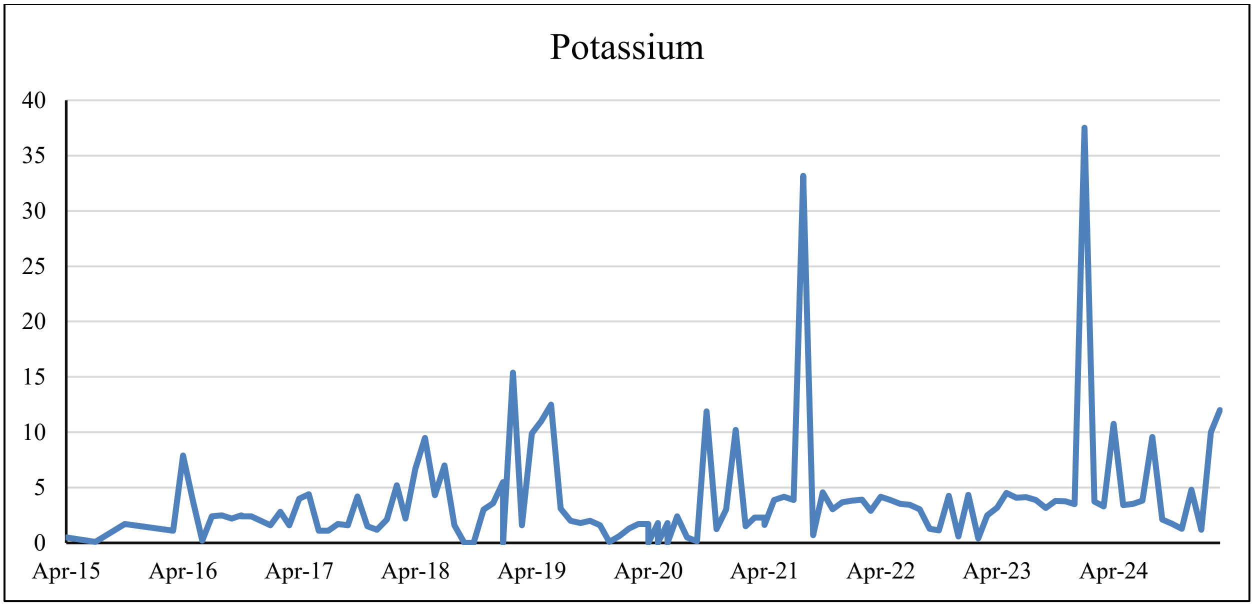


Figure 82 Monthly variation of Potassium at Zanor Station (2015-2025)

Graph 65: The graph shows the monthly variation of *Potassium* at Zanor Station from April 2015 to April 2025. Potassium ranged from 0.1 to 37.51 mg/L(Jan 2024), within normal environmental concentrations.

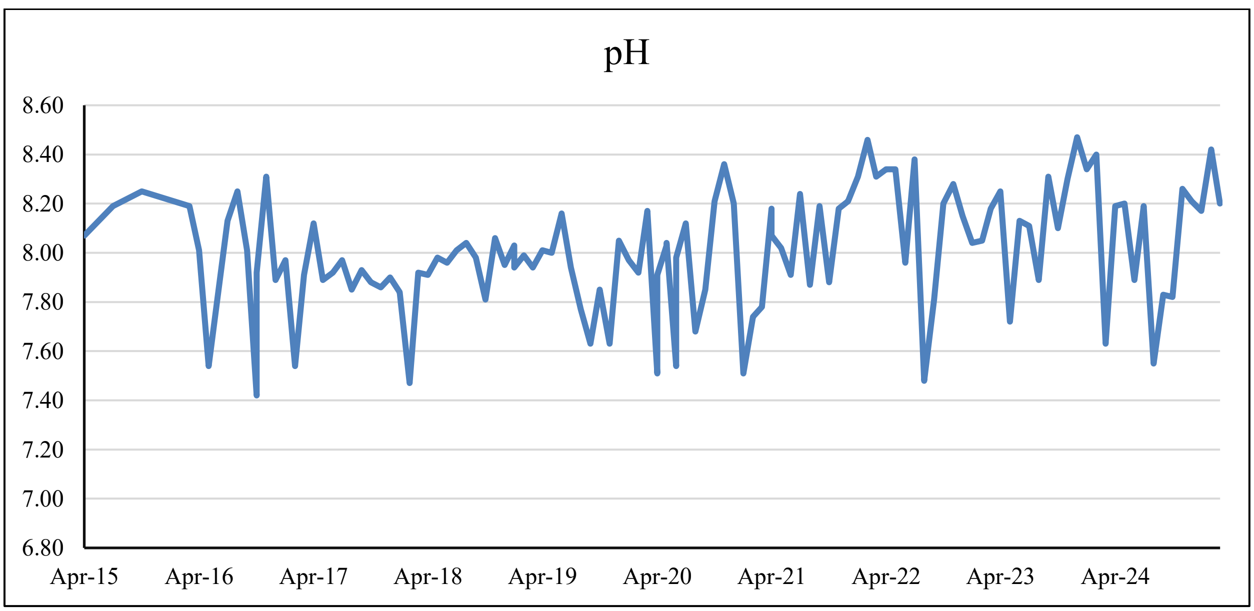


Figure 83 Monthly variation of pH at Zanor Station (2015-2025)

Graph 66: The graph shows the monthly variation of *pH* at Zanor Station from April 2015 to April 2025. pH ranged from 7.42 to 8.47(Dec 2023), permissible limit (BIS IS10500): 6.5–8.5, within permissible limits.

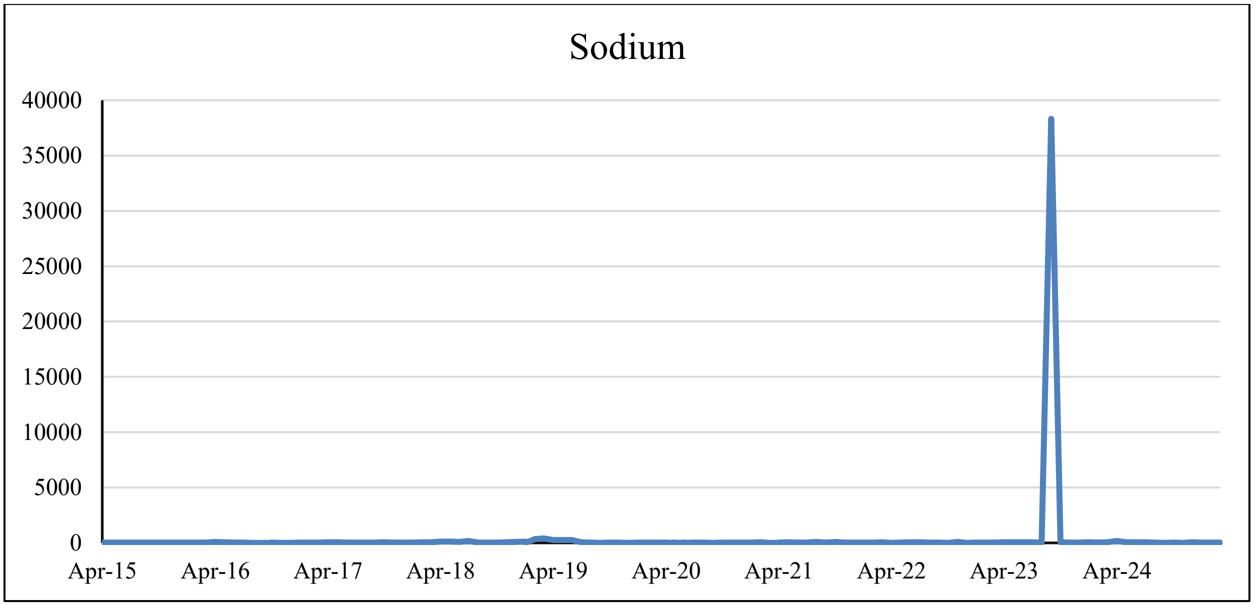
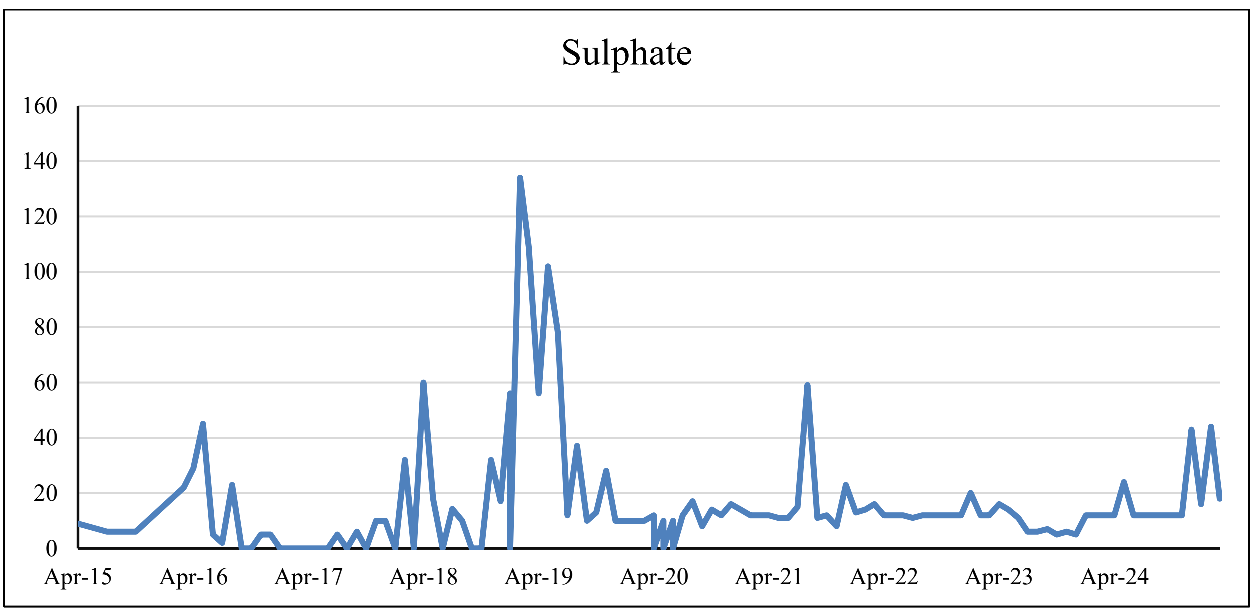


Figure 84 Monthly variation of Sodium at Zanor Station (2015-2025)

Graph 67: The graph shows the monthly variation of Sodium at Zanor Station from April 2015 to April 2025. Sodium ranged from 2.0 to 390.0 mg/L, within typical guideline ranges.



Graph 1** **Figure 85 Monthly variation of Sulphate at Zanor Station (2015-2025)

Graph 68: The graph shows the monthly variation of *Sulphate* at Zanor Station from April 2015 to April 2025. Sulphate ranged from 2 to 134 mg/L(Feb 2019), permissible limit (BIS IS10500): 200 mg/L, within permissible limit.

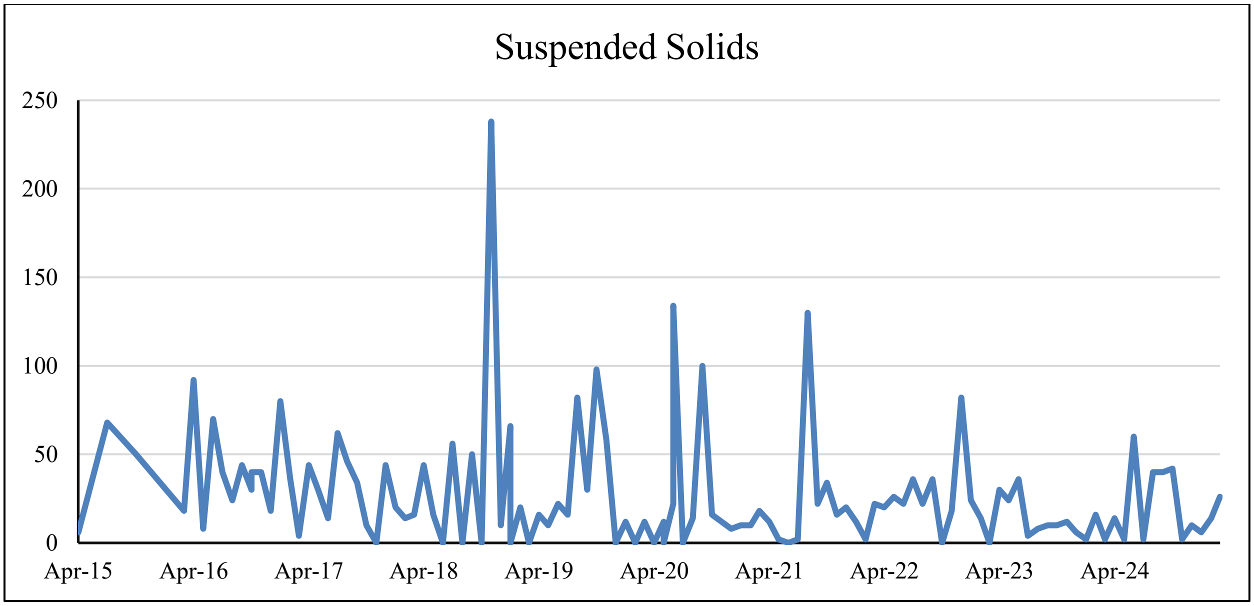


Figure 86 Monthly variation of Suspended Solids at Zanor Station (2015-2025)

Graph 69: The graph shows the monthly variation of *Suspended Solids* at Zanor Station from April 2015 to April 2025. Suspended Solids ranged from 2 to 238 mg/L(Nov 2018), seasonal variability, some monsoon increases.

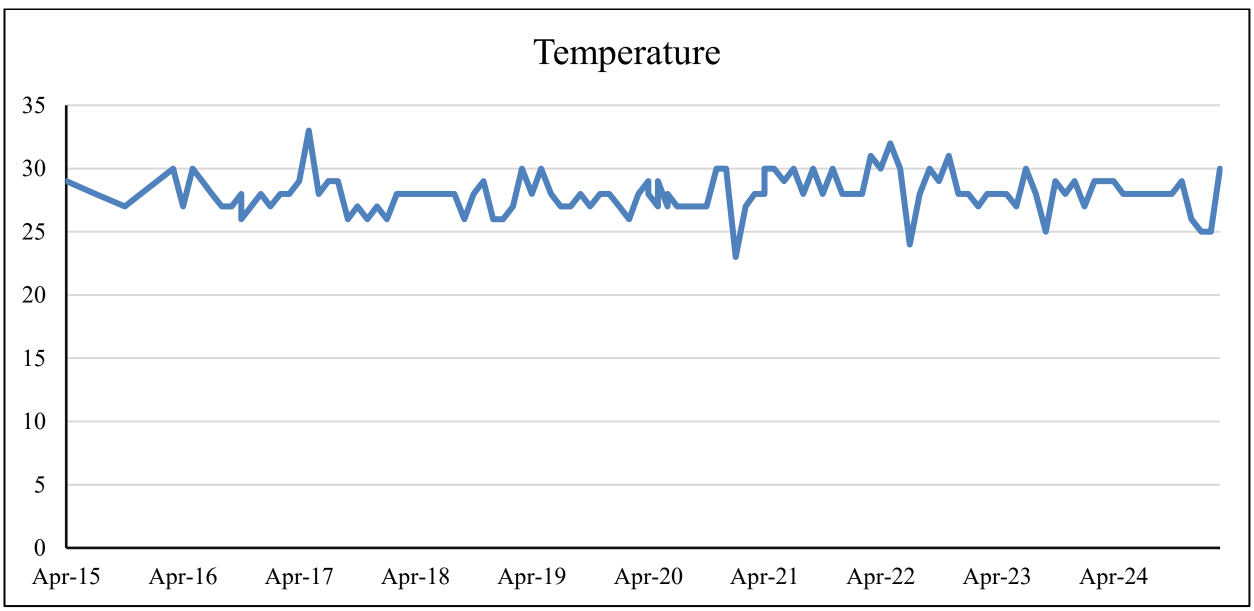


Figure 87 Monthly variation of Temperature at Zanor Station (2015-2025)

Graph 70: The graph shows the monthly variation of *Temperature* at Zanor Station from April 2015 to April 2025. Temperature ranged from 23.0 to 33.0 °C(May 2017), seasonal variation.

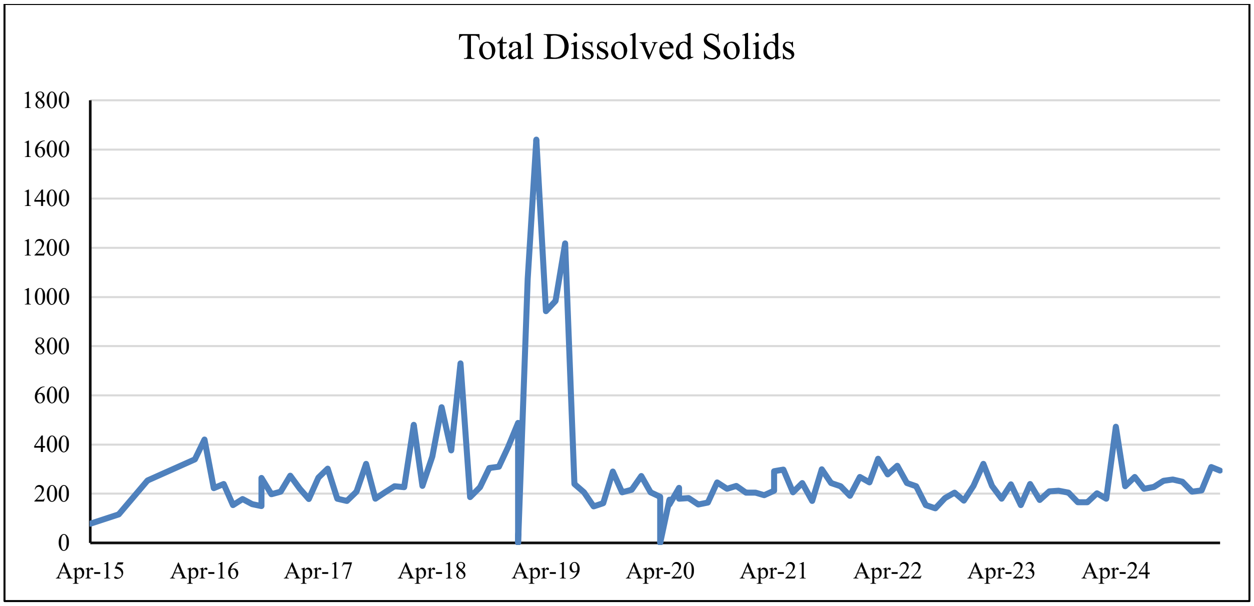


Figure 88 Monthly variation of Total Dissolved Solids at Zanor Station (2015-2025)

Graph 71: The graph shows the monthly variation of *Total Dissolved Solids* at Zanor Station from April 2015 to April 2025. TDS ranged from 78 to 1640 mg/L(March 2019), permissible limit (BIS IS10500): 2000 mg/L, within permissible limit but some months above desirable 500 mg/L.

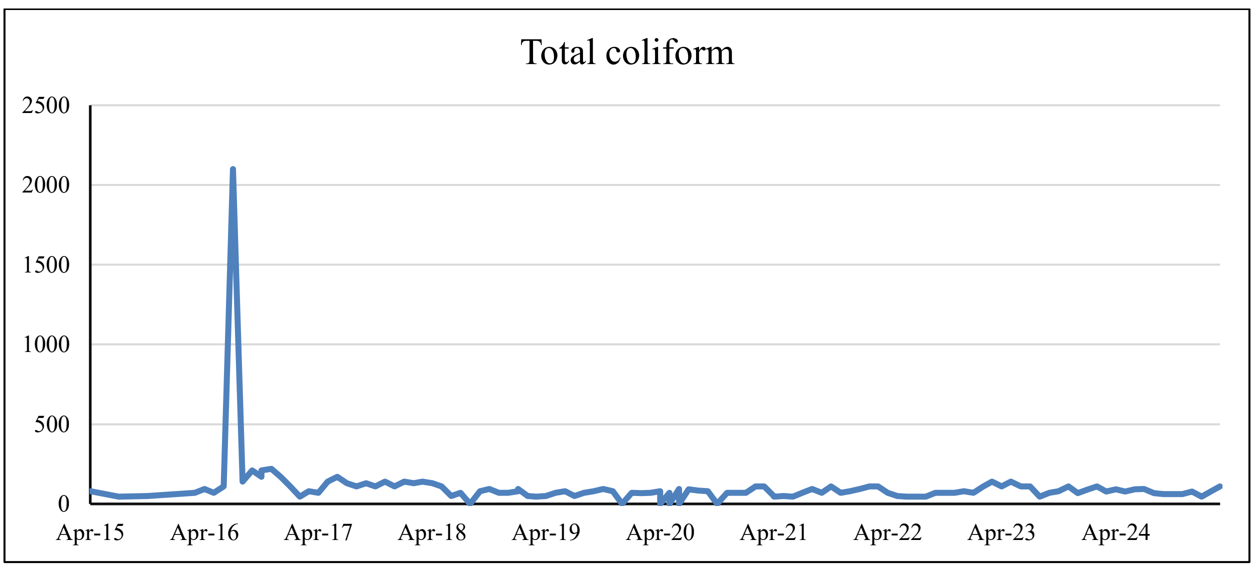


Figure 89 Monthly variation of Total Coliform at Zanor Station (2015-2025)

Graph 72: The graph shows the monthly variation of *Total Coliform* at Zanor Station from April 2015 to April 2025. Total Coliform ranged from 50 to 2100 MPN/100mL(July 2016), permissible limit for drinking: 0 MPN/100mL, CPCB criteria for bathing differ, indicates substantial microbial contamination in parts of the dataset.

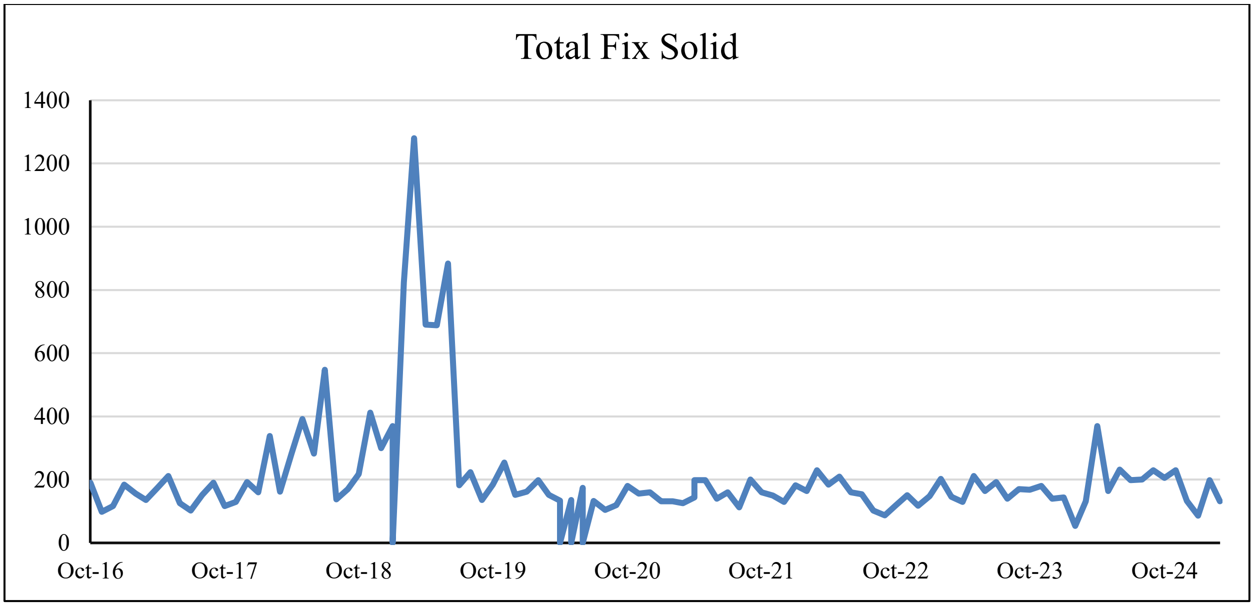


Figure 90 Monthly variation of Total Fix Solid at Zanor Station (2015-2025)

Graph 73: The graph shows the monthly variation of *Total Fix Solid* at Zanor Station from April 2015 to April 2025. Total Fixed Solid (reported with TDS) ranged from 54 to 1280 (March 2019),included in TDS & its within typical ranges.

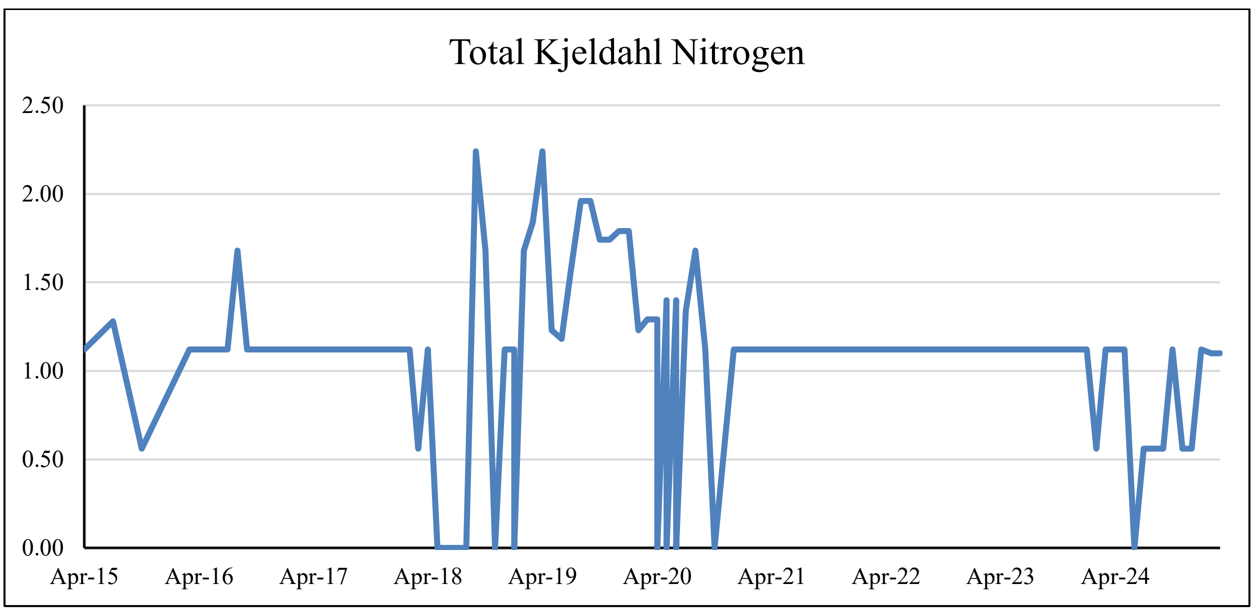


Figure 91 Monthly variation of Total Kjeldahl Nitrogen at Zanor Station (2015-2025)

Graph 74: The graph shows the monthly variation of *Total Kjeldahl Nitrogen* at Zanor Station from April 2015 to April 2025. TKN ranged from 0.6 to 2.24 mg/L(Sep 2018 & April 2019), within expected environmental ranges.

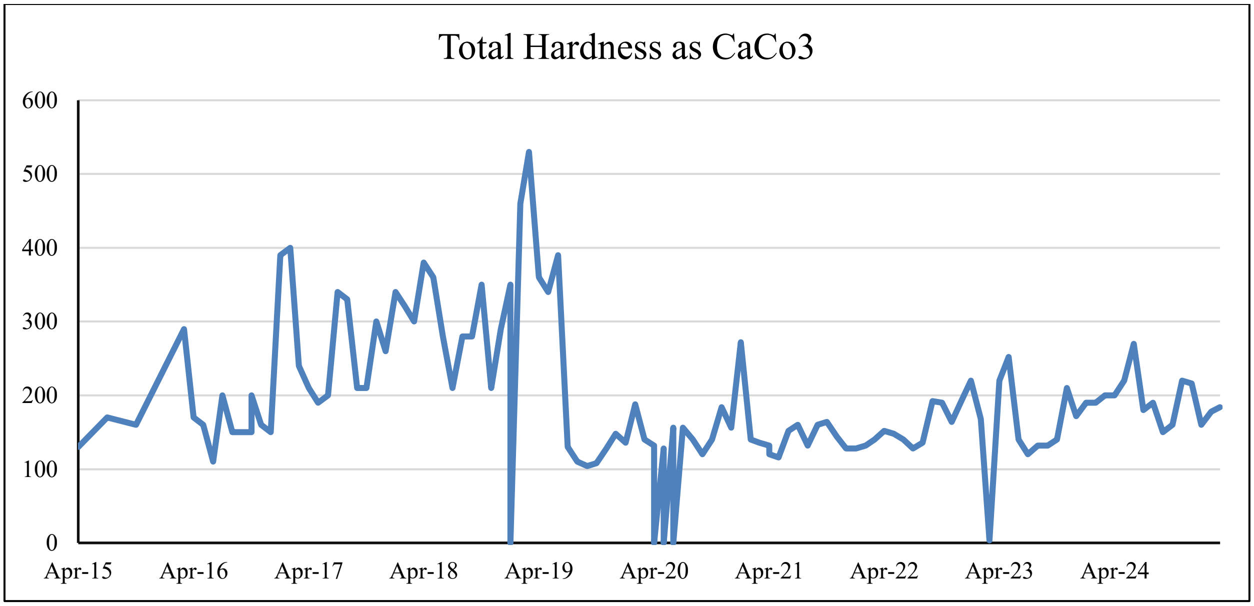


Figure 92 Monthly variation of Total Hardness as CaCo3 at Zanor Station (2015-2025)

Graph 75: The graph shows the monthly variation of *Total Hardness as CaCo3* at Zanor Station from April 2015 to April 2025. Total Hardness ranged from 3.3 to 530 mg/L(March 2019), permissible limit (BIS IS10500): 600 mg/L, within permissible limit.

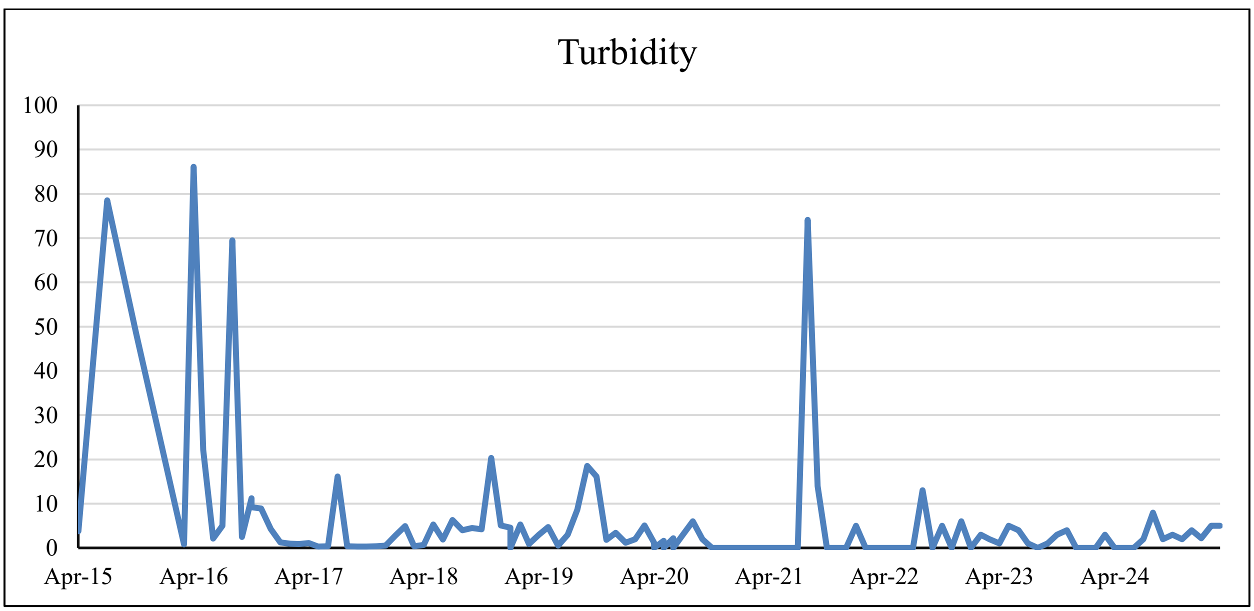


Figure 93 Monthly variation of Conductivity at Zanor Station (2015-2025)

Graph 76: The graph shows the monthly variation of *Turbidity* at Zanor Station from April 2015 to April 2025. Turbidity ranged from 0.3 to 86.1(April 2016), permissible limit (BIS IS10500): 5 NTU, episodic spikes (monsoon/loads) exceed permissible limits and require attention.

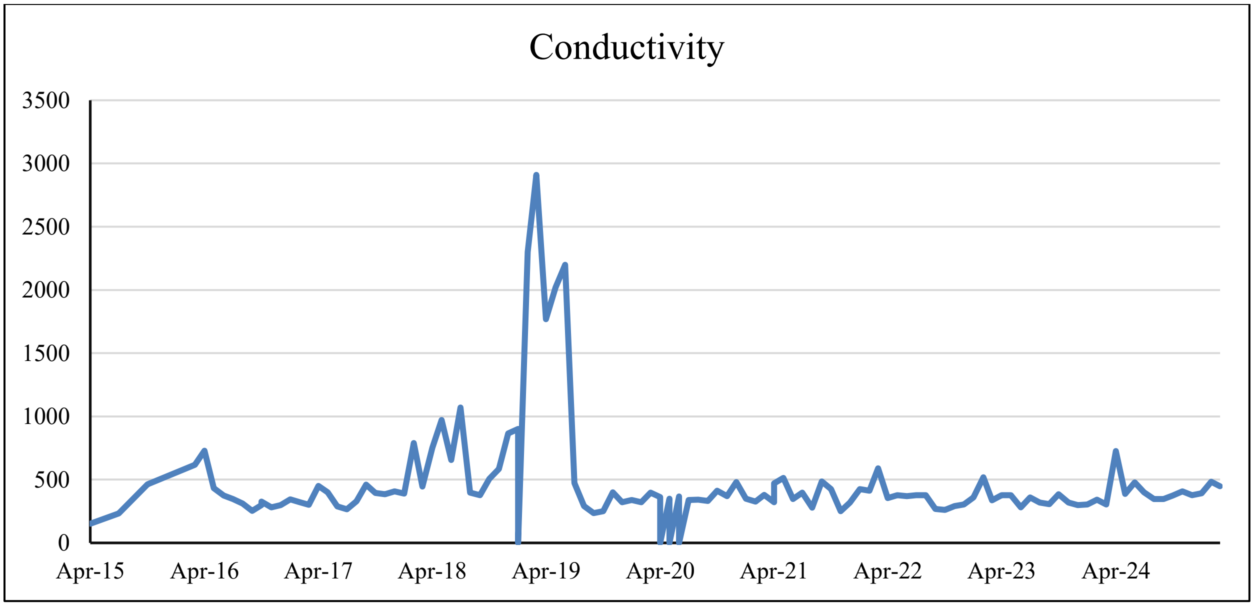


Figure 94 Monthly variation of Turbidity at Zanor Station (2015-2025)

Graph 77: The graph shows the monthly variation of *Conductivity* at Zanor Station from April 2015 to April 2025. Conductivity ranged from 60 to 2910 µS/cm(March 2019), shows ionic variability; some high values reflect elevated dissolved salts in parts of the record.

Zanor's water station parameters show many chemical parameters generally within BIS ecological/permissible ranges (TDS mostly ≤1680 mg/L and below the 2000 mg/L drinking threshold, fluoride within limits, hardness usually acceptable), but show alarmingly large microbial contamination (total coliforms 50–10,000 MPN/100 mL; fecal coliforms 15–80 MPN/100 mL) and turbidity spikes to ~86 NTU (BIS desirable ≤1, permissible 5 NTU), plus occasional high chloride (to ~780 mg/L, above the 250 mg/L desirable/limit) and very high conductivity/TDS episodes (conductivity to 1500 µS/cm, TDS up to 1680 mg/L) and elevated COD (to 30 mg/L) that point to organic and saline/ionic inputs.

3.3.4. Station: Zadeshwar

Zadeshwar lies closer to the estuarine zone and is more influenced by human activity, effluent discharge, and tidal mixing. **Graph 78 to Graph 104** show the water quality parameters with time from 2015 to 2025 of Zadeshwar Station.

Organic Pollution: BOD levels are moderate, and COD shows elevated values compared to upstream stations, indicating higher organic and chemical loading from urban and industrial sources.

Dissolved Oxygen: DO is adequate (>5 mg/L) but slightly lower compared to upstream stations, reflecting the combined effect of organic load and reduced re-aeration.

Nutrients: Nitrate and phosphate are moderate to high, reflecting agricultural runoff and untreated sewage inflows. Seasonal spikes during monsoon are notable.

Microbial Load: Coliform counts are high, particularly during monsoon, pointing to substantial sewage and stormwater inflows. This raises concerns for public health and water usability.

Metals: Iron and manganese occasionally exceed safe limits during monsoon and high tide conditions, likely from industrial discharge and sediment disturbance. Other heavy metals remain within safe ranges.

Salinity & Hardness: Higher chloride and TDS levels are recorded compared to upstream stations, influenced by tidal mixing and estuarine effects.

Overall Condition: Zadeshwar shows moderate water quality with higher anthropogenic stress. Microbial contamination and nutrient enrichment are key concerns requiring targeted interventions.

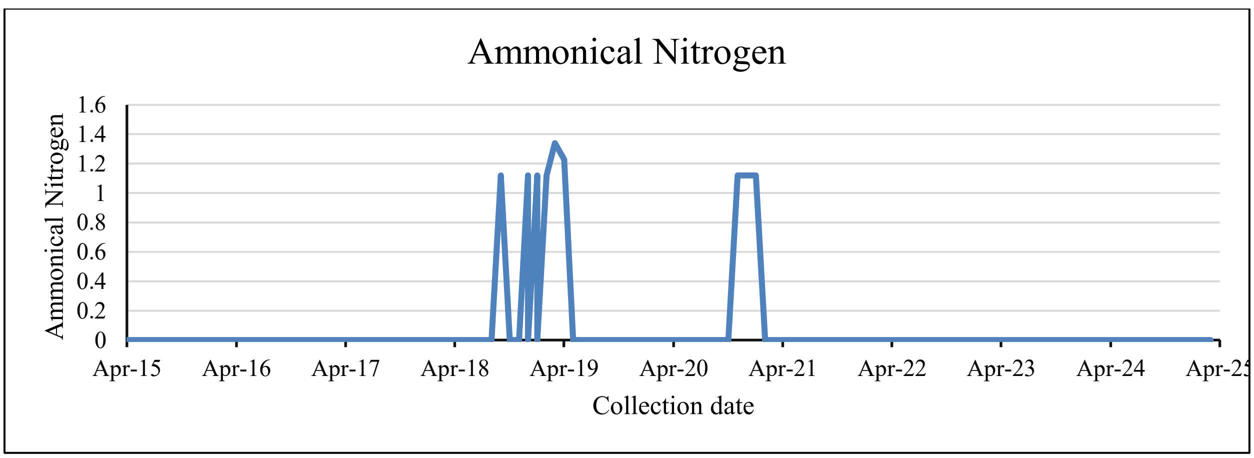


Figure 95 Monthly variation of Ammonical Nitrogen at Zadeshwar Station (2015-2025)

Graph 78: The graph shows the monthly variation of Ammonical Nitrogen at Zadeshwar Station from April 2015 to April 2025. Ammonical Nitrogen ranged from 1.12 to 1.34 mg/L(March 2019), periodic elevations suggest organic inputs/effluent influence; no specific BIS drinking limit for ammonical Nitrogen but environmental concern when elevated.

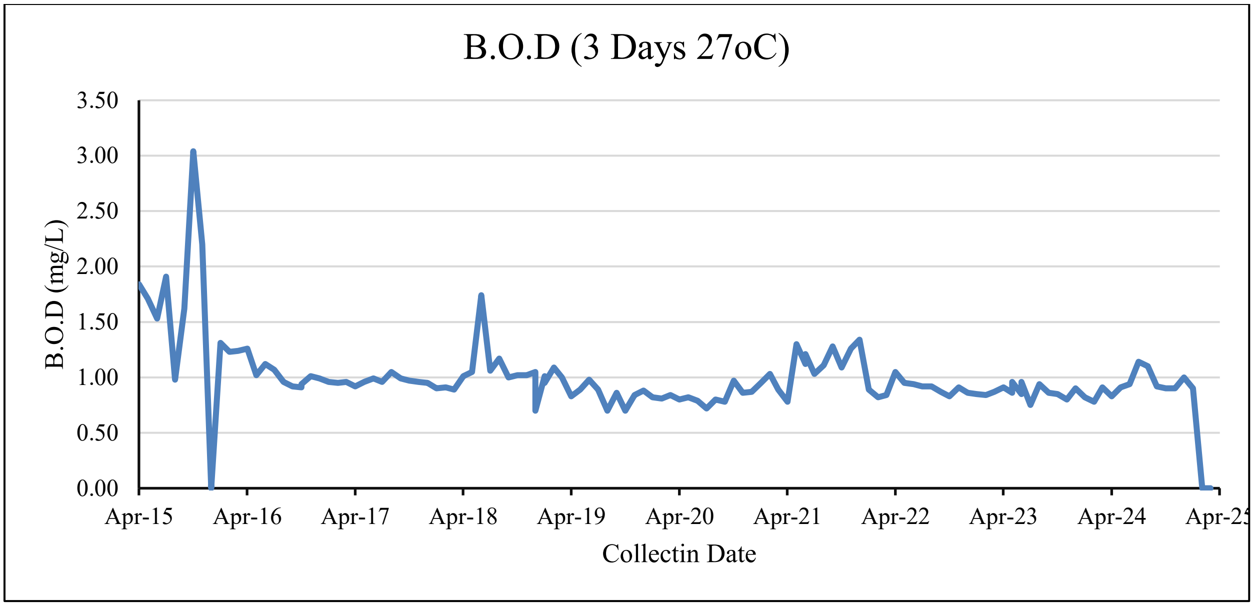


Figure 96 Monthly variation of B.O.D. (3 days 27 °C at Zadeshwar Station (2015-2025)

Graph 79: The graph shows the monthly variation of *B.O.D. (3 days 27 °C)* at Zadeshwar Station from April 2015 to April 2025. BOD ranged from 0.7 to 3.04 mg/L(October 2015), CPCB bathing criterion: BOD ≤ 3 mg/L, within permissible ranges.

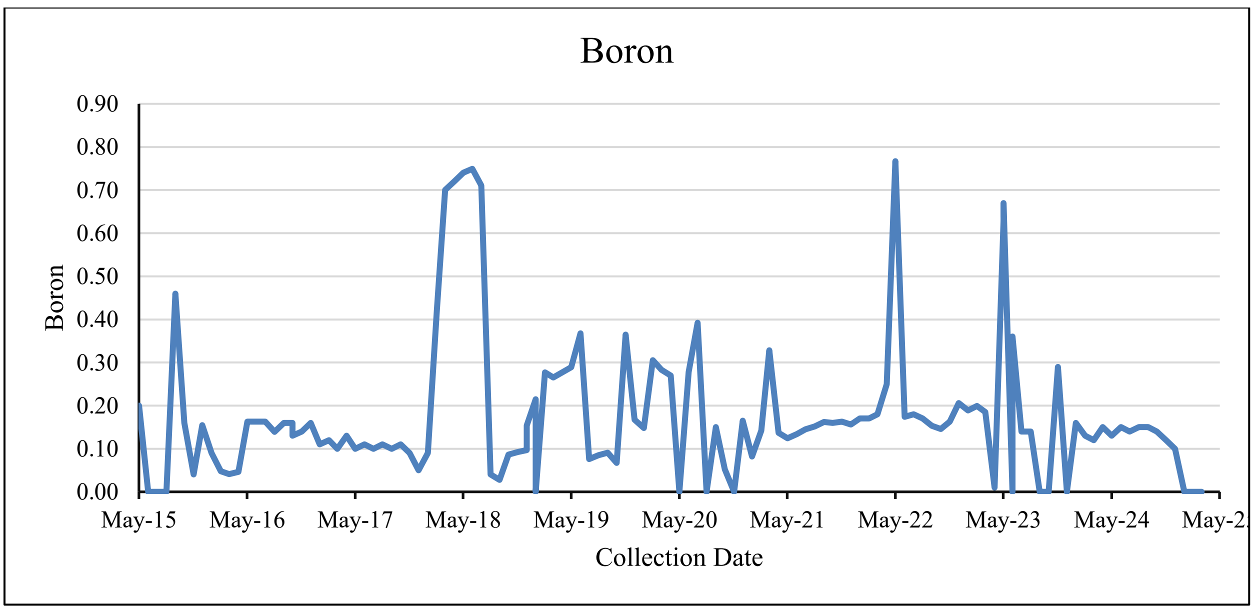


Figure 97 Monthly variation of Boron at Zadeshwar Station (2015-2025)

Graph 80: The graph shows the monthly variation of *Boron* at Zadeshwar Station from April 2015 to April 2025. Boron ranged from 0.01 to 0.77 mg/L(May 2022), typical BIS guidance: desirable ~0.5 mg/L; permissible often ~2.0 mg/L, within permissible ranges.

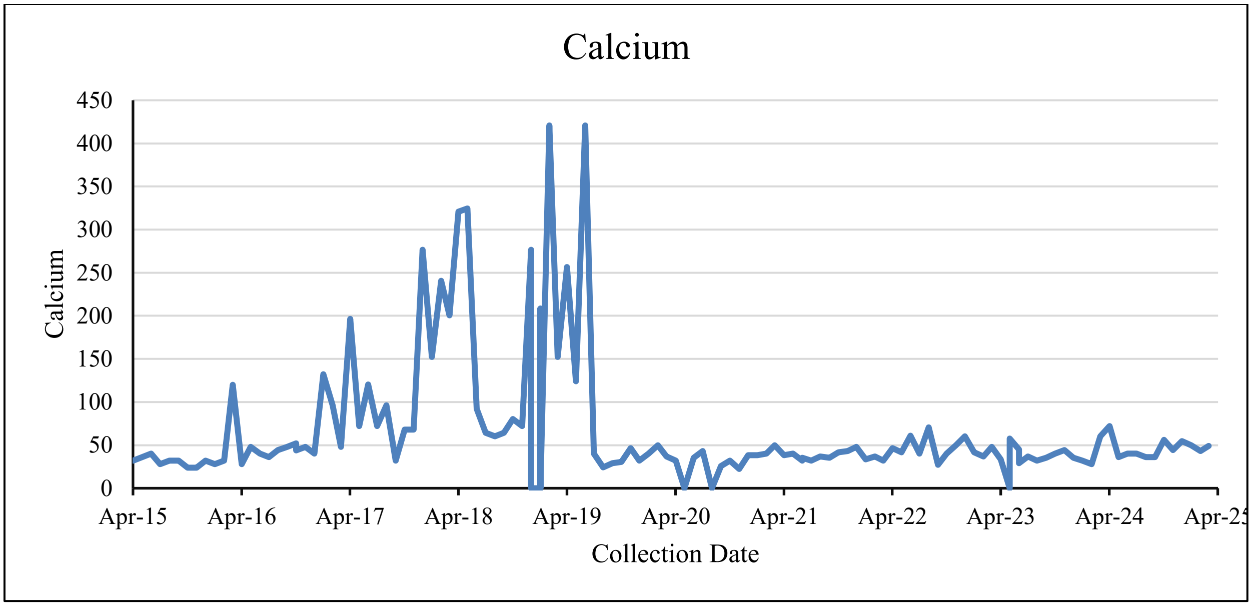


Figure 98 Monthly variation of Calcium at Zadeshwar Station (2015-2025)

Graph 81: The graph shows the monthly variation of *Calcium* at Zadeshwar Station from April 2015 to April 2025. Calcium ranged from 22 to 420.8 mg/L(Feb & June 2019), typical BIS guidance: desirable ~75 mg/L major concern for direct use.

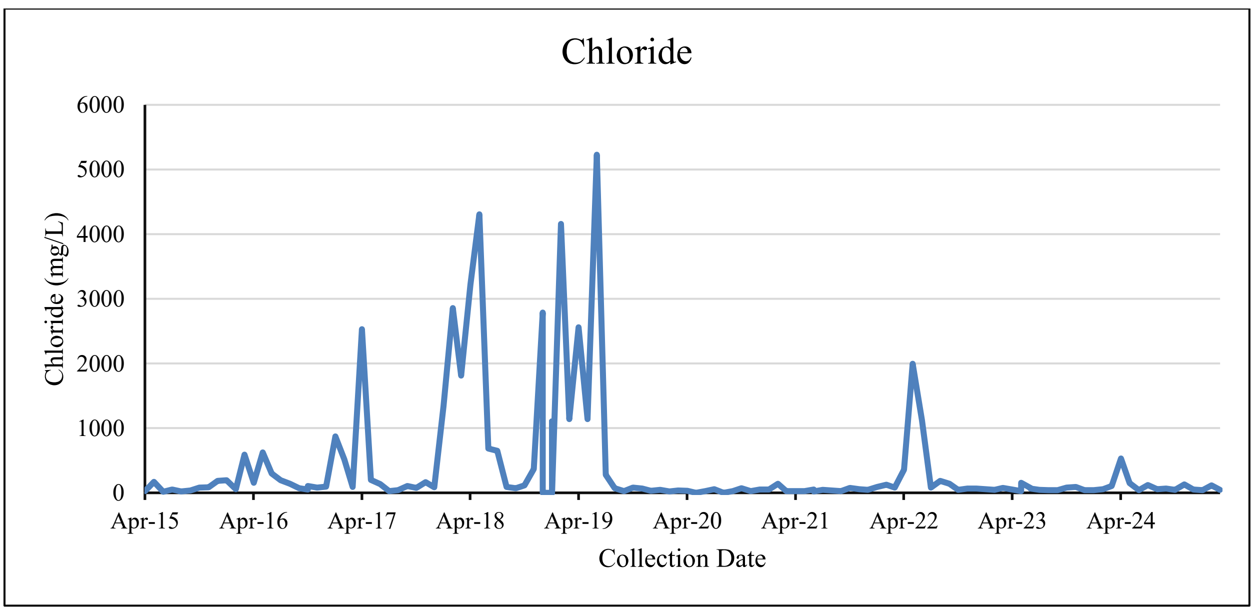


Figure 99 Monthly variation of Chloride at Zadeshwar Station (2015-2025)

Graph 82: The graph shows the monthly variation of *Chloride* at Zadeshwar Station from April 2015 to April 2025. Chloride ranged from 20 to 5229 mg/L(June 2019), permissible limit (BIS IS10500): 250 mg/L, exceeds permissible limit in some months; estuarine/tidal influence likely contributes.

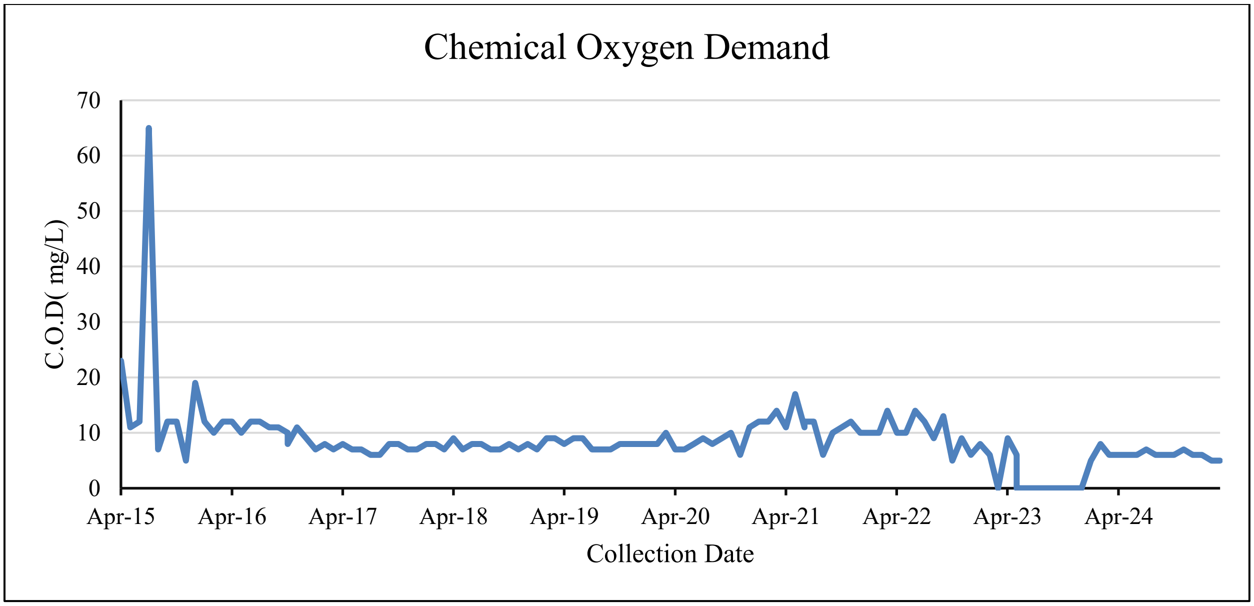


Figure 100 Monthly variation of Chemical Oxygen Demand at Zadeshwar Station (2015-2025)

Graph 83: The graph shows the monthly variation of *Chemical Oxygen Demand* at Zadeshwar Station from April 2015 to April 2025. COD ranged from 5 to 65 mg/L(July 2015), elevated values in some months indicate chemical/organic loading.

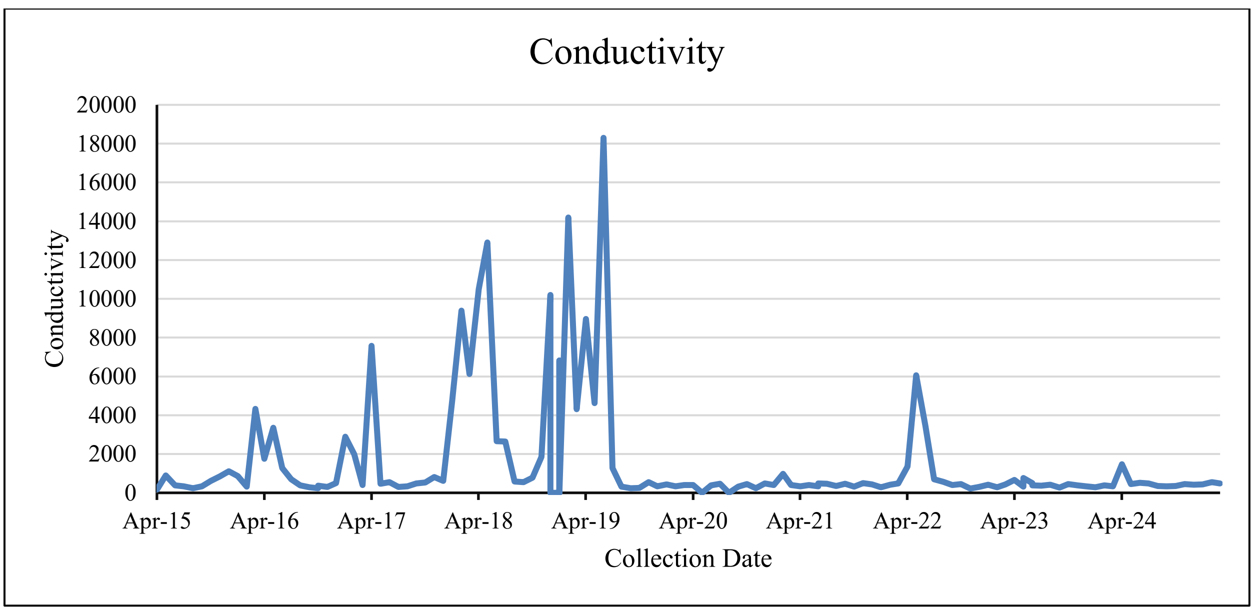


Figure 101 Monthly variation of Conductivity at Zadeshwar Station (2015-2025)

Graph 84: The graph shows the monthly variation of *Conductivity* at Zadeshwar Station from April 2015 to April 2025. Conductivity ranged from 170 to 18300 µS/cm(June 2019), within within permissible ranges. (tidal/reservoir influence).

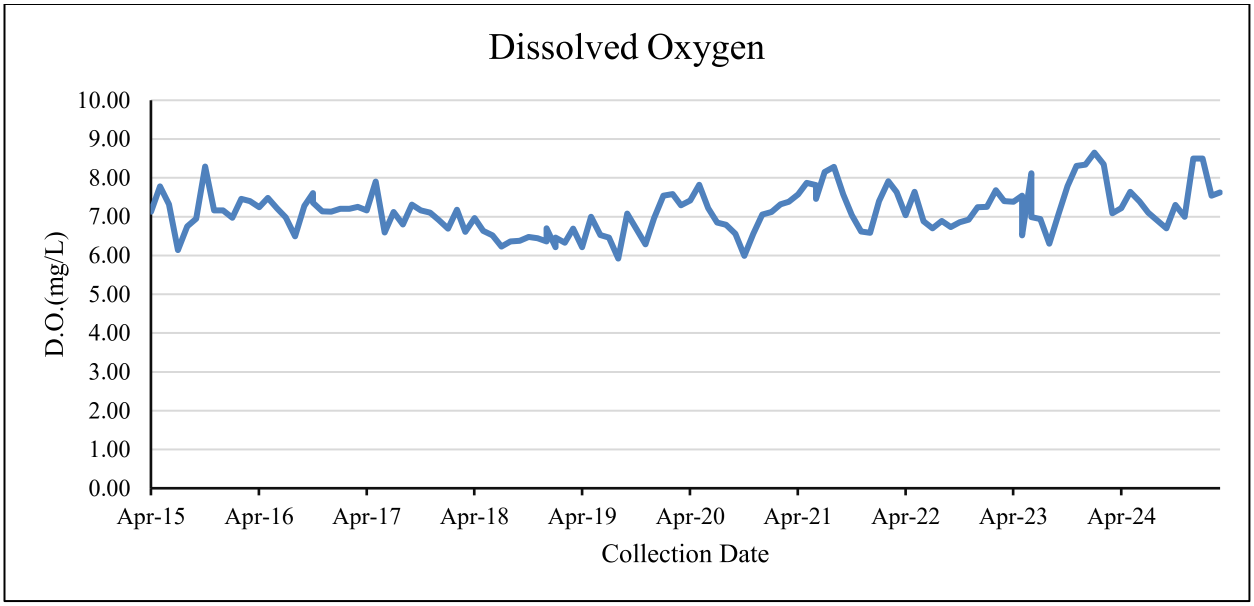


Figure 102 Monthly variation of Dissolved Oxygen at Zadeshwar Station (2015-2025)

Graph 85: The graph shows the monthly variation of *Dissolved Oxygen* at Zadeshwar Station from April 2015 to April 2025. DO ranged from 5.8 to 8.65 mg/L(Jan 2024), CPCB ecological guideline: DO ≥ 6 mg/L for good water, some months fall below ecological threshold, indicating stress.

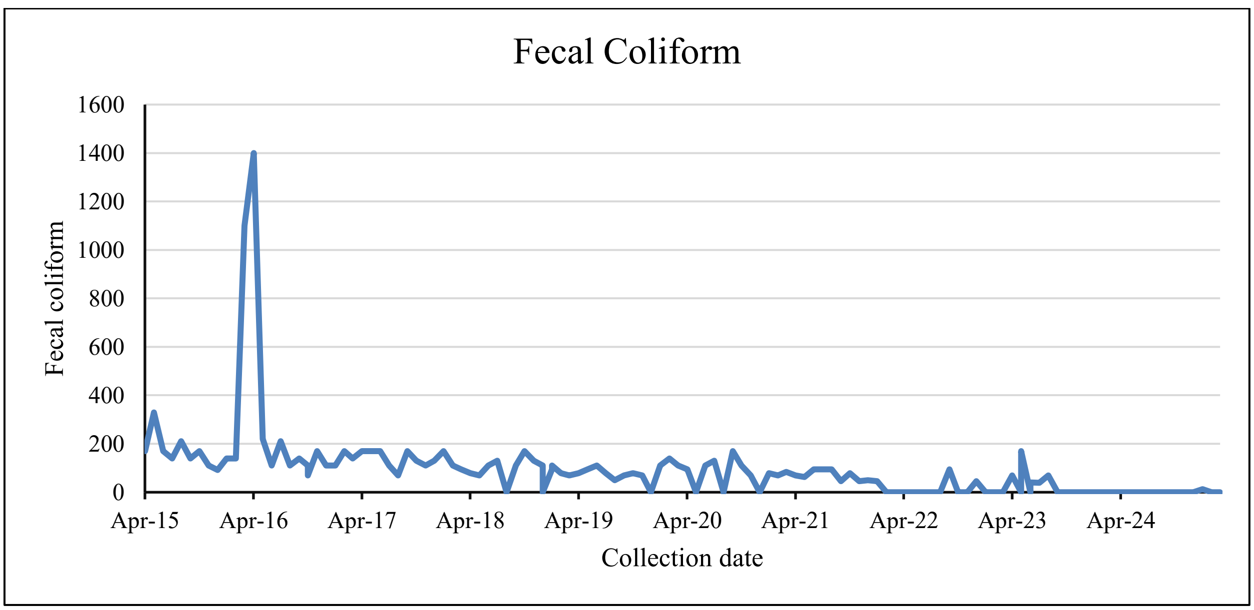


Figure 103 Monthly variation of Fecal Coliform at Zadeshwar Station (2015-2025)

Graph 86: The graph shows the monthly variation of *Fecal Coliform* at Zadeshwar Station from April 2015 to April 2025. Fecal Coliform ranged from 13 to 1400MPN/100mL (April 2016), permissible limit for drinking: 0 MPN/100mL, very high microbial contamination, major health concern for direct use.

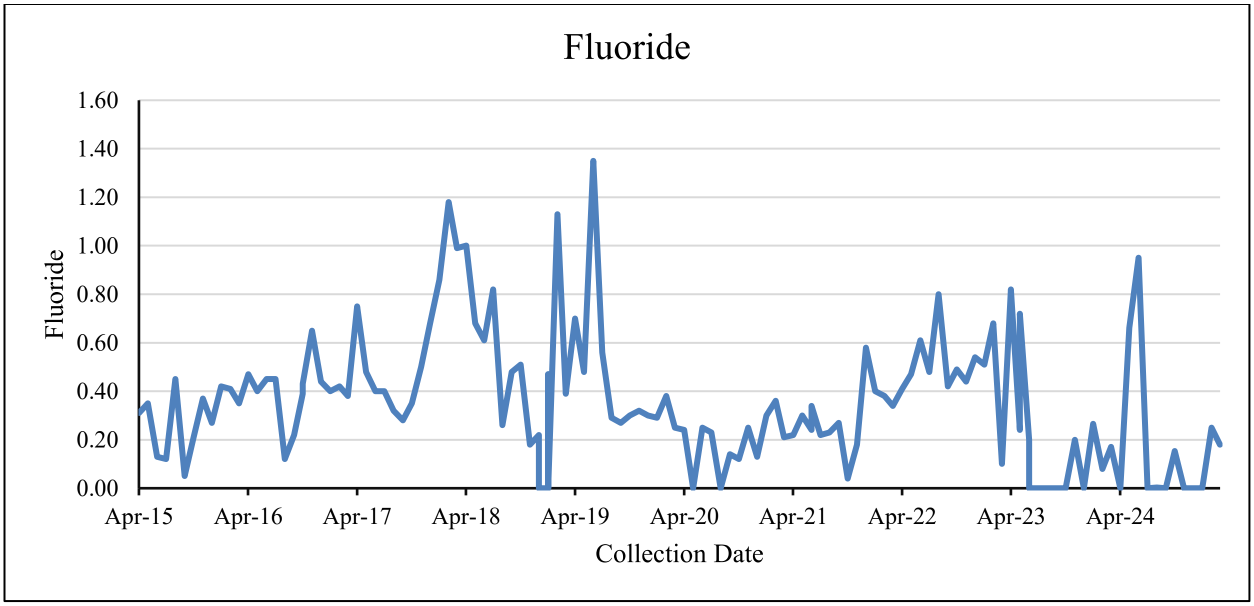


Figure 104 Monthly variation of Fluoride at Zadeshwar Station (2015-2025)

Graph 87: The graph shows the monthly variation of *Fluoride* at Zadeshwar Station from April 2015 to April 2025. Fluoride ranged from 0.0 to 1.35 mg/L(June 2019), permissible limit (BIS IS10500): 1.5 mg/L, - within permissible ranges.

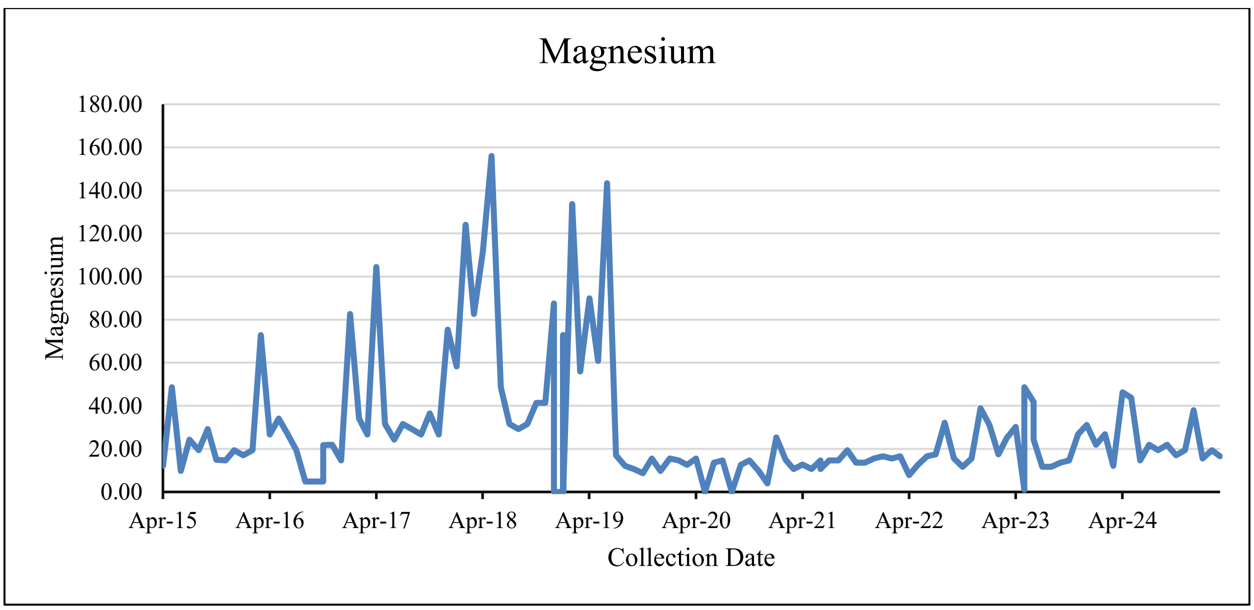


Figure 105 Monthly variation of Magnesium at Zadeshwar Station (2015-2025)

Graph 88: The graph shows the monthly variation of *Magnesium* at Zadeshwar Station from April 2015 to April 2025. Magnesium ranged from 0.96 to 156.0 mg/L (May 2018), contributes to hardness: concerns over some elevated months.

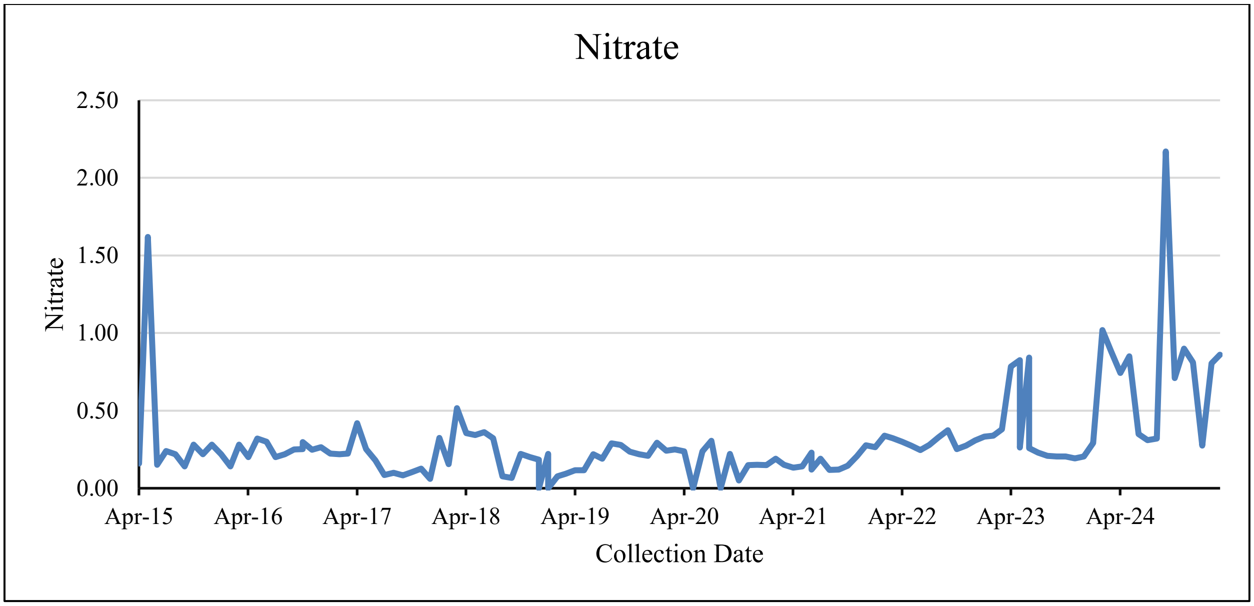


Figure 106 Monthly variation of Nitrate at Zadeshwar Station (2015-2025)

Graph 89: The graph shows the monthly variation of *Nitrate* at Zadeshwar Station from April 2015 to April 2025. Nitrate ranged from 0.0 to 2.17 mg/L(Sep 2024), permissible limit (BIS IS10500): 45 mg/L, within permissible ranges.

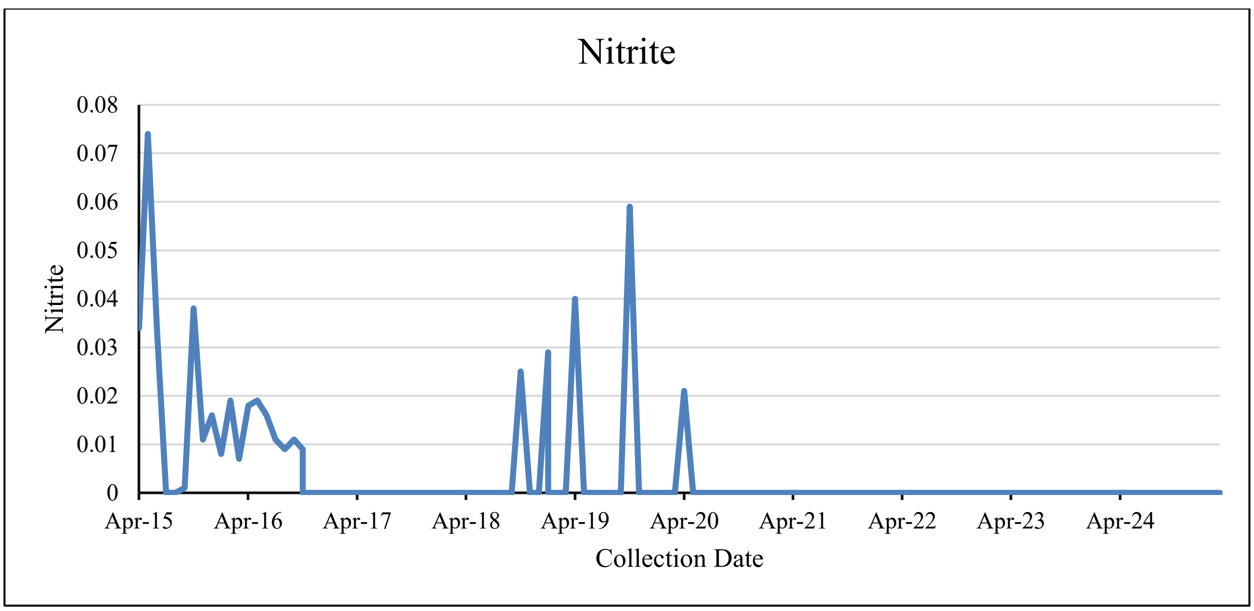


Figure 107 Monthly variation of Nitrite at Zadeshwar Station (2015-2025)

Graph 90: The graph shows the monthly variation of *Nitrite* at Zadeshwar Station from April 2015 to April 2025. Nitrite ranged from 0.01 to 0.074mg/L(May 2015), permissible limit (BIS IS10500): 0.2 mg/L, within permissible ranges.

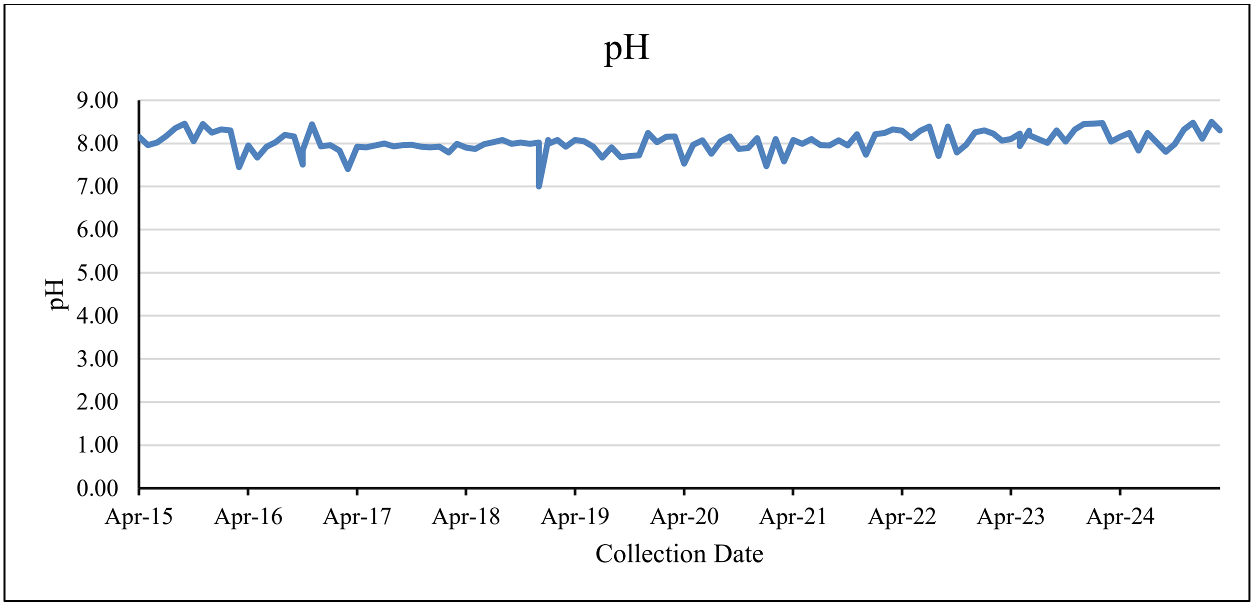


Figure 108 Monthly variation of pH at Zadeshwar Station (2015-2025)

Graph 91: The graph shows the monthly variation of *pH* at Zadeshwar Station from April 2015 to April 2025. pH ranged from 6.2 to 8.5(Feb 2025), permissible limit (BIS IS10500): 6.5–8.5 (no relaxation), within permissible ranges.

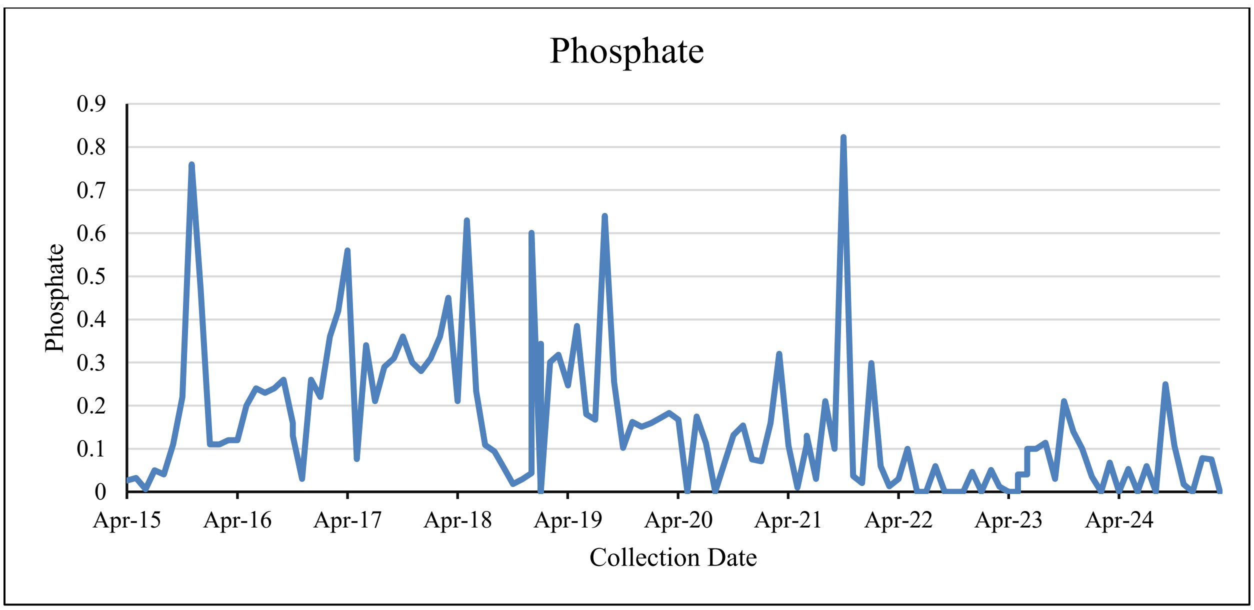


Figure 109 Monthly variation of Phosphate at Zadeshwar Station (2015-2025)

Graph 92: The graph shows the monthly variation of *Phosphate* at Zadeshwar Station from April 2015 to April 2025. Phosphate ranged from 0.02 to .823 mg/L(Oct 2021), higher nutrient peaks in monsoon; potential eutrophication risk locally.

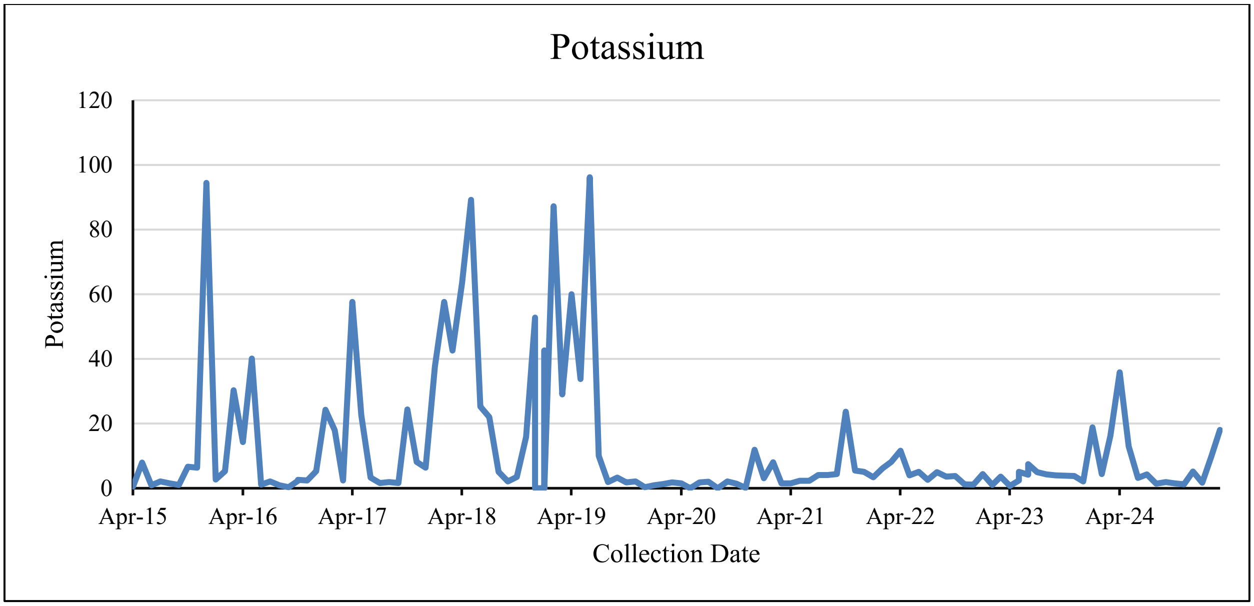


Figure 110 Monthly variation of Potassium at Zadeshwar Station (2015-2025)

Graph 93: The graph shows the monthly variation of *Potassium* at Zadeshwar Station from April 2015 to April 2025. Potassium ranged from 0.2 to 96.2 mg/L(June 2019), within environmental ranges.

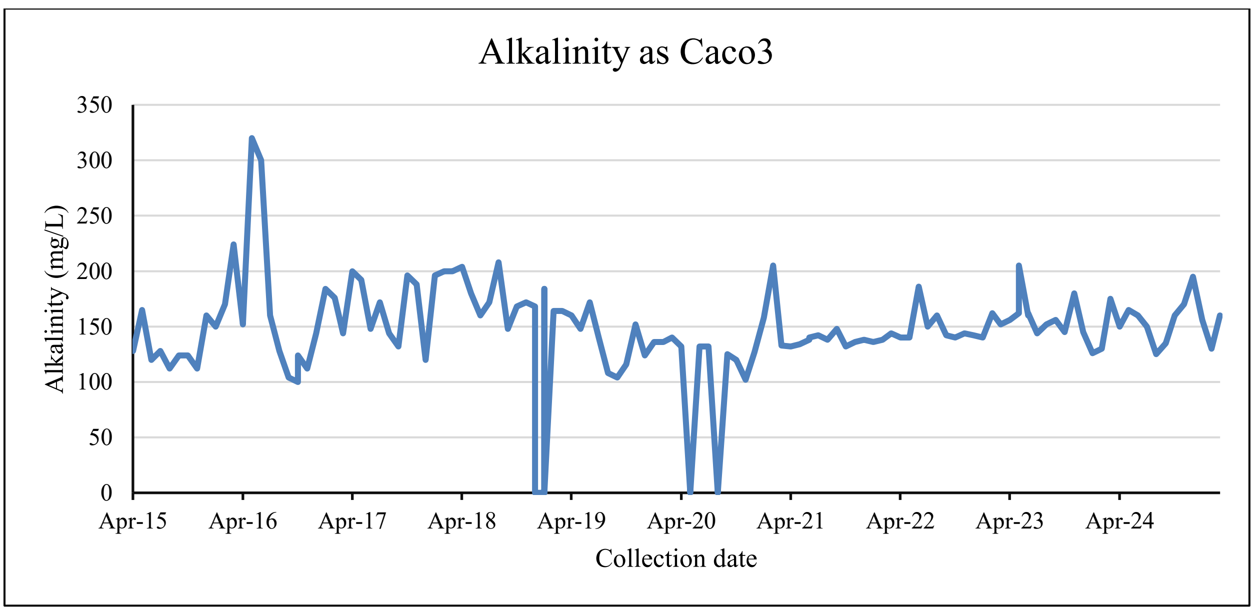


Figure 111 Monthly variation of Alkalinity as CaCo3 at Zadeshwar Station (2015-2025)

Graph 94: The graph shows the monthly variation of *Alkalinity as CaCo3* at Zadeshwar Station from April 2015 to April 2025. Alkalinity ranged from 100 to 320 mg/L(May 2016), occasionally elevated values but generally within operational ranges.

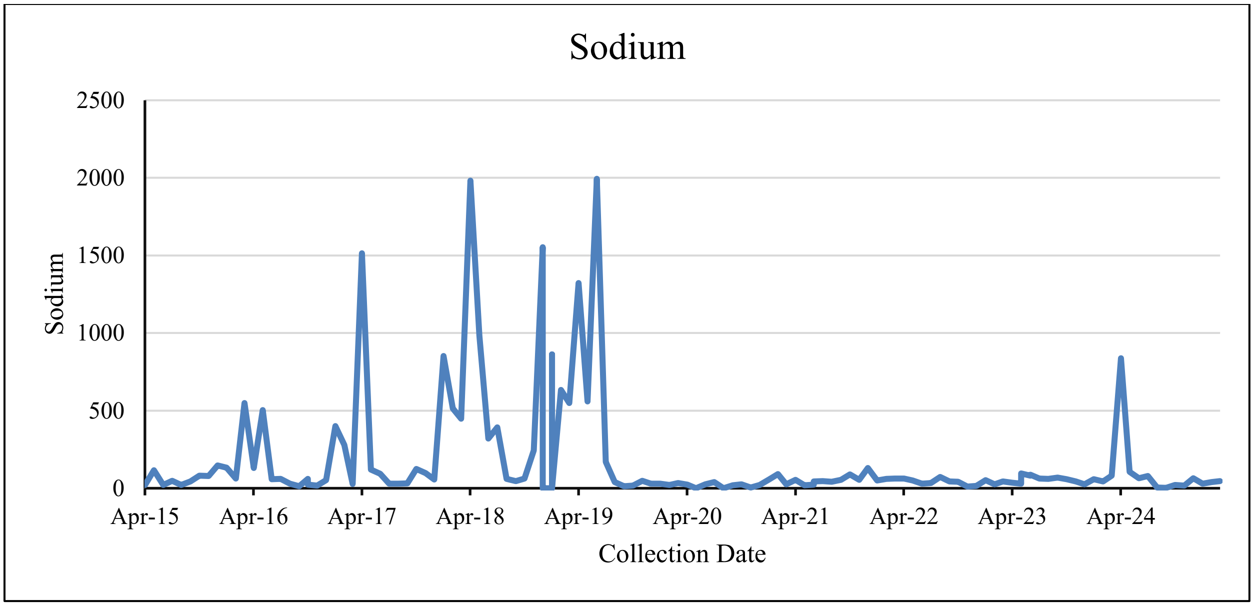


Figure 112 Monthly variation of Sodium at Zadeshwar Station (2015-2025)

Graph 95: The graph shows the monthly variation of *Sodium* at Zadeshwar Station from April 2015 to April 2025. Sodium ranged from 10 to 1994 mg/L(June 2019), high peaks consistent with estuarine/tidal saline influence; some months exceed common guideline levels (200 mg/L), raising concerns.

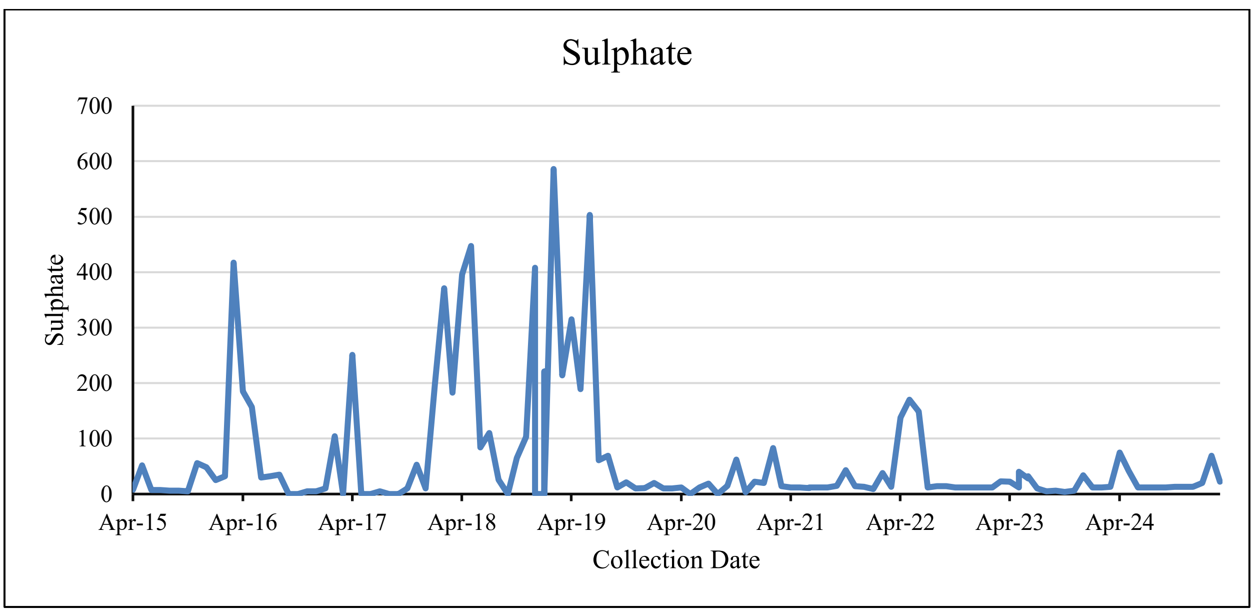


Figure 113 Monthly variation of Sulphate at Zadeshwar Station (2015-2025)

Graph 96: The graph shows the monthly variation of *Sulphate* at Zadeshwar Station from April 2015 to April 2025. Sulphate ranged from 4 to 586 mg/L(Feb 2019), permissible limit (BIS IS10500): 200 mg/L, exceeds permissible limit in some months.

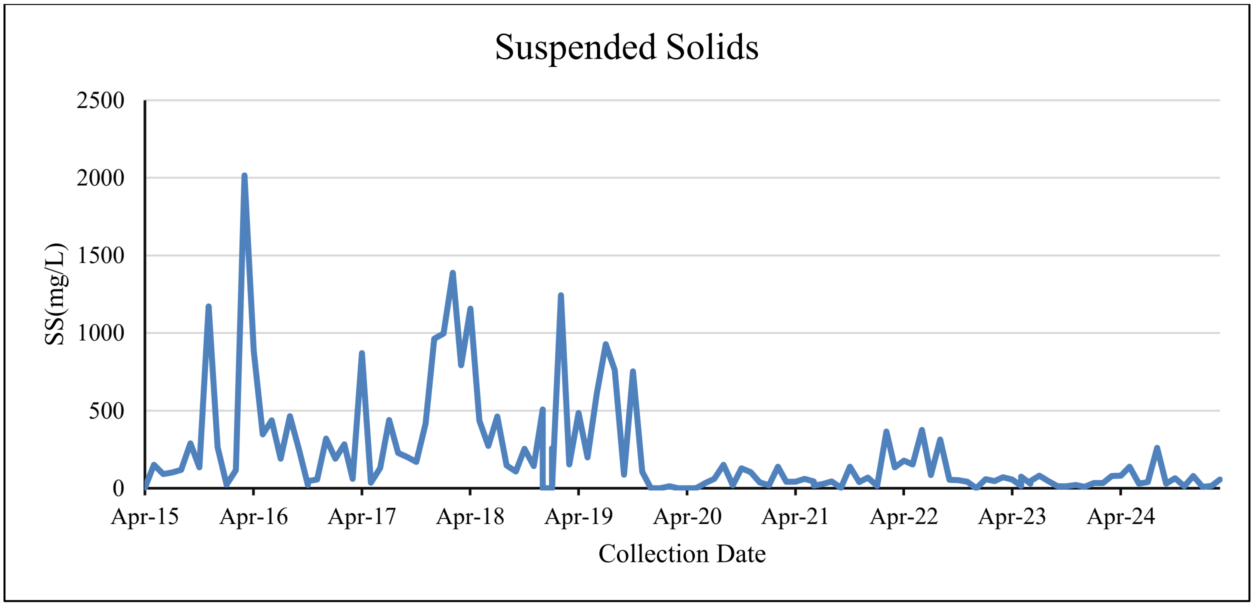


Figure 114 Monthly variation of Suspended Solids at Zadeshwar Station (2015-2025)

Graph 97: The graph shows the monthly variation of *Suspended Solids* at Zadeshwar Station from April 2015 to April 2025. Suspended Solids ranged from 2 to 2016 mg/L(March 2016), considerable variability and high monsoon peaks.

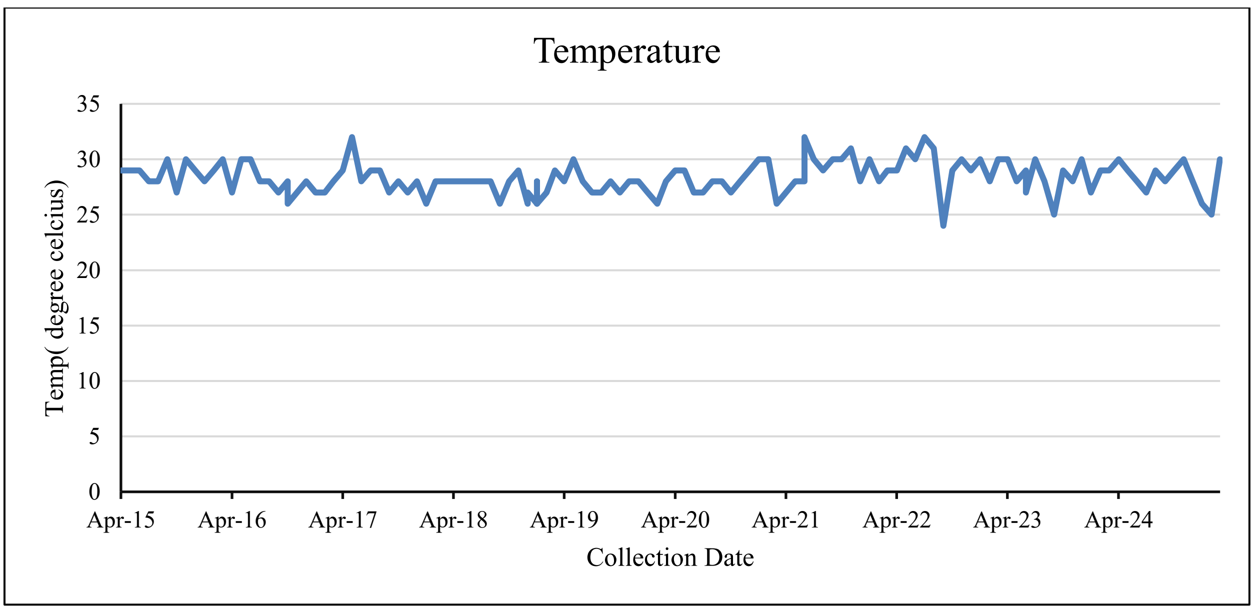


Figure 115 Monthly variation of Temperature at Zadeshwar Station (2015-2025)

Graph 98: The graph shows the monthly variation of *Temperature* at Zadeshwar Station from April 2015 to April 2025. Temperature ranged from 24 to 32 °C(May 2017 & June 2022), seasonal.

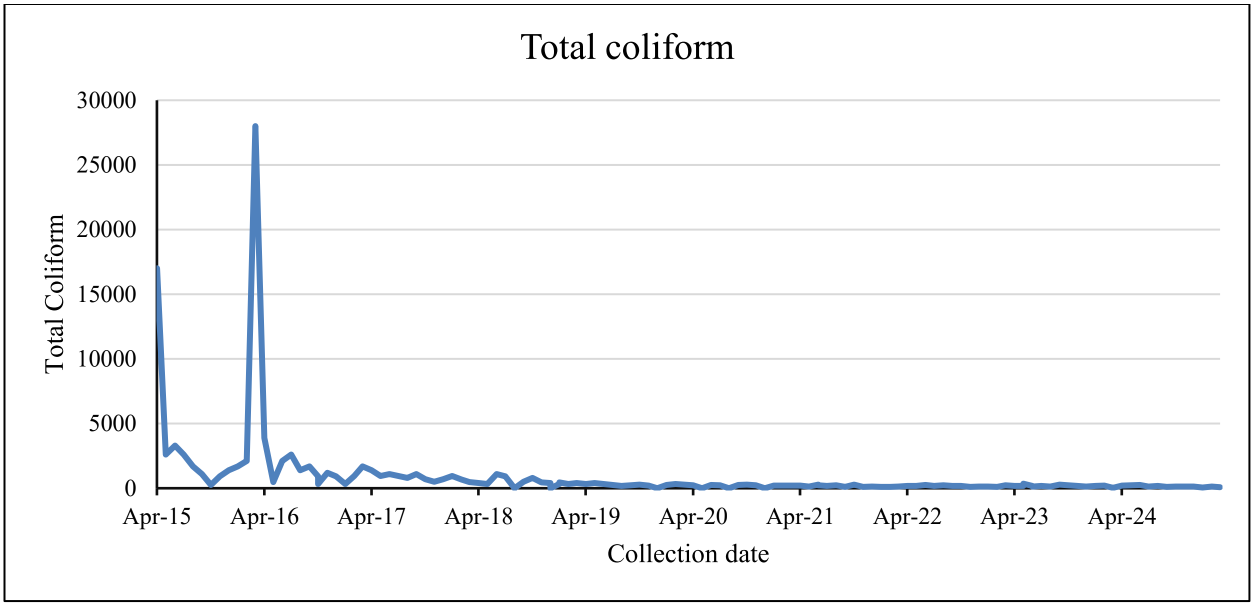


Figure 116 Monthly variation of Total Coliform at Zadeshwar Station (2015-2025)

Graph 99: The graph shows the monthly variation of *Total Coliform* at Zadeshwar Station from April 2015 to April 2025. Total Coliform ranged from 100 to 28000 MPN/100mL(March 2016), permissible limit (drinking): 0 MPN/100mL, very high contamination; public-health risk.

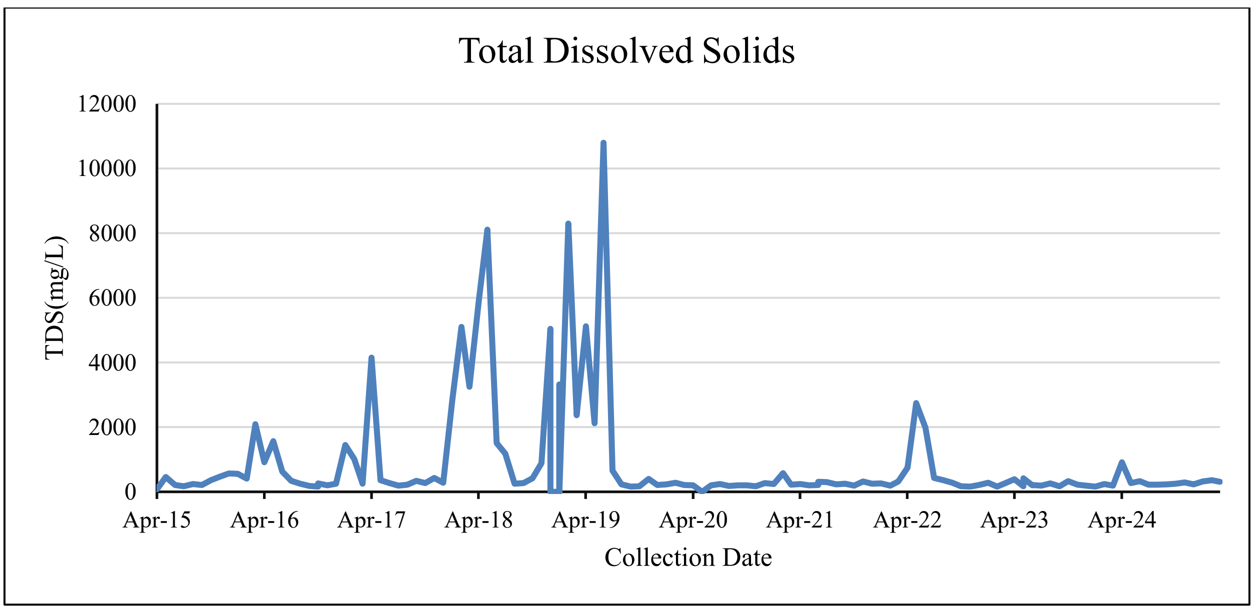


Figure 117 Monthly variation of Total Dissolved Solids at Zadeshwar Station (2015-2025)

Graph 100: The graph shows the monthly variation of *Total Dissolved Solids* at Zadeshwar Station from April 2015 to April 2025. TDS ranged from 60 to 10798 mg/L(June 2019), permissible limit (BIS IS10500): 2000 mg/L, exceeds permissible limit in some months, consistent with estuarine/tidal saline influence.

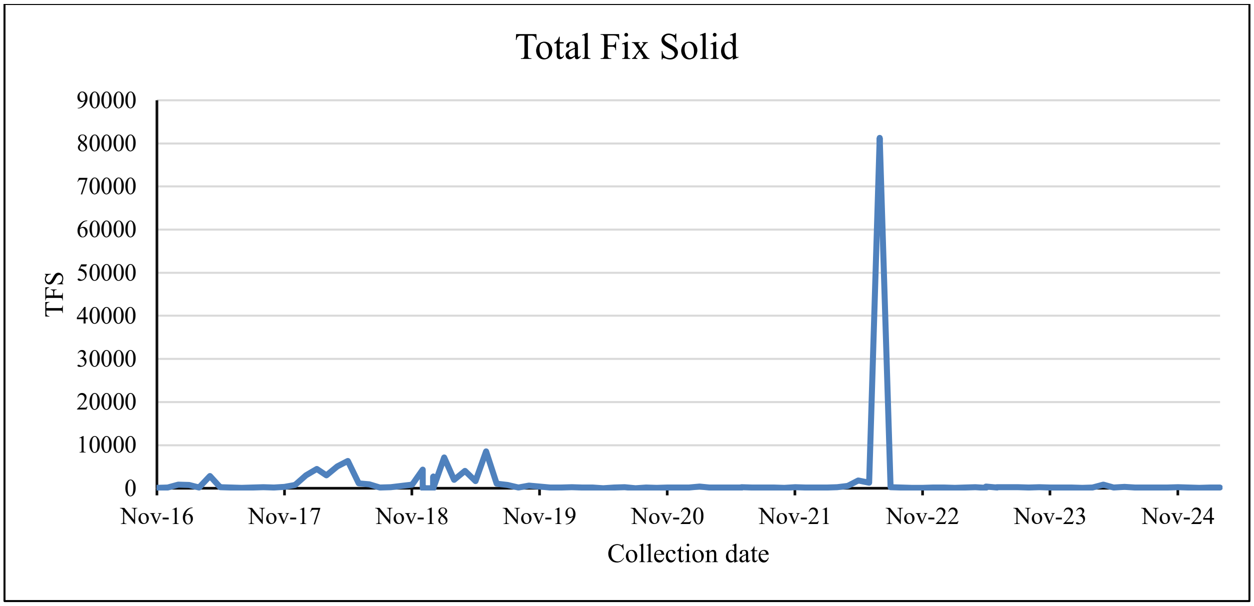


Figure 118 Monthly variation of Total Fix Solid at Zadeshwar Station (2015-2025)

Graph 101: The graph shows the monthly variation of *Total Fix Solid* at Zadeshwar Station from April 2015 to April 2025. With maximum value of 81820 mg/L on July 2022.

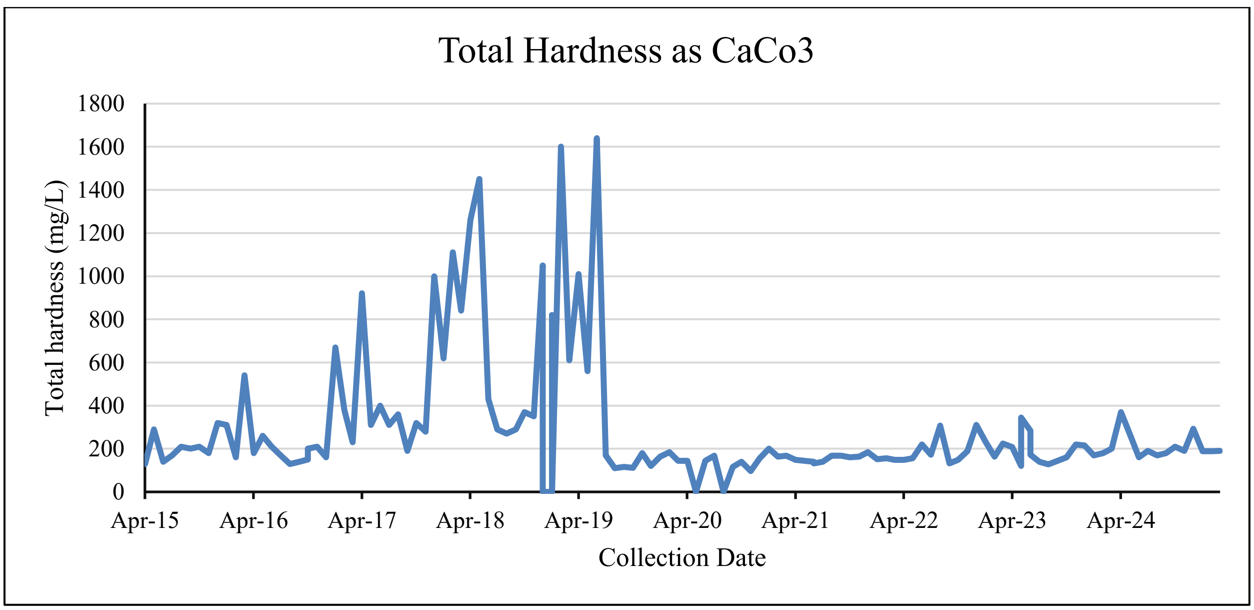


Figure 119 Monthly variation of Total Hardness at Zadeshwar Station (2015-2025)

Graph 102: The graph shows the monthly variation of *Total Hardness* at Zadeshwar Station from April 2015 to April 2025. Total Hardness ranged from 96 to 1640 mg/L(June 2019), permissible limit (BIS IS10500): 600 mg/L, exceeds permissible limit in some months, indicating hard water episodes.

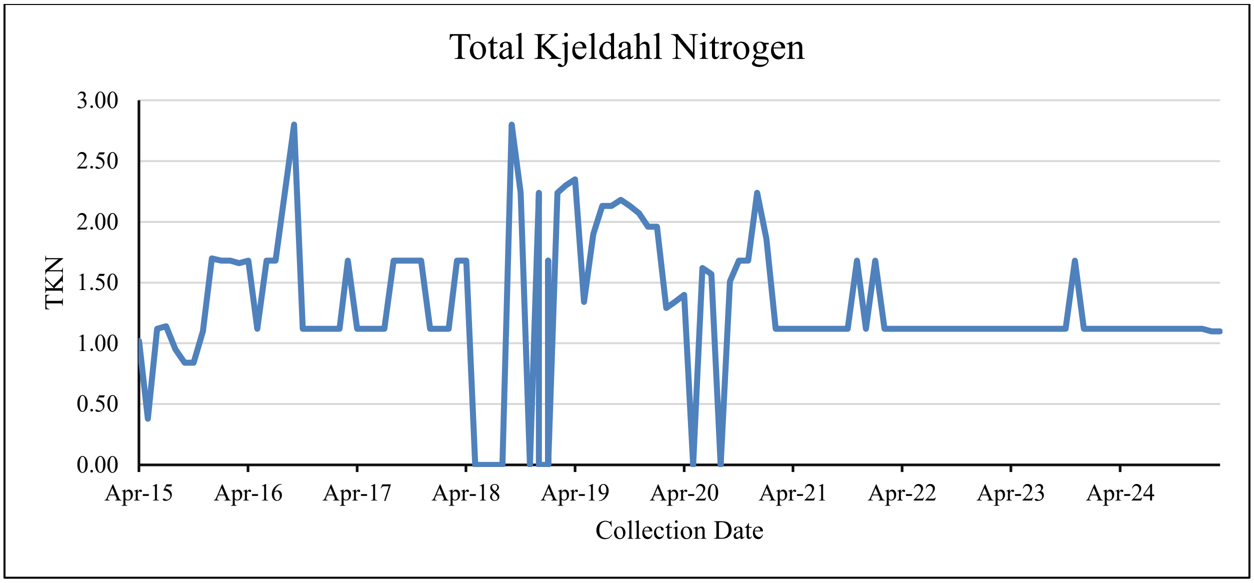


Figure 120 Monthly variation of Total Kjeldahl Nitrogen at Zadeshwar Station (2015-2025)

Graph 103: The graph shows the monthly variation of *Total Kjeldahl Nitrogen* at Zadeshwar Station from April 2015 to April 2025. TKN ranged from 0.38 to 2.8 mg/L(Sep 2016 & Sep 2018), within reported environmental ranges though some months elevated.

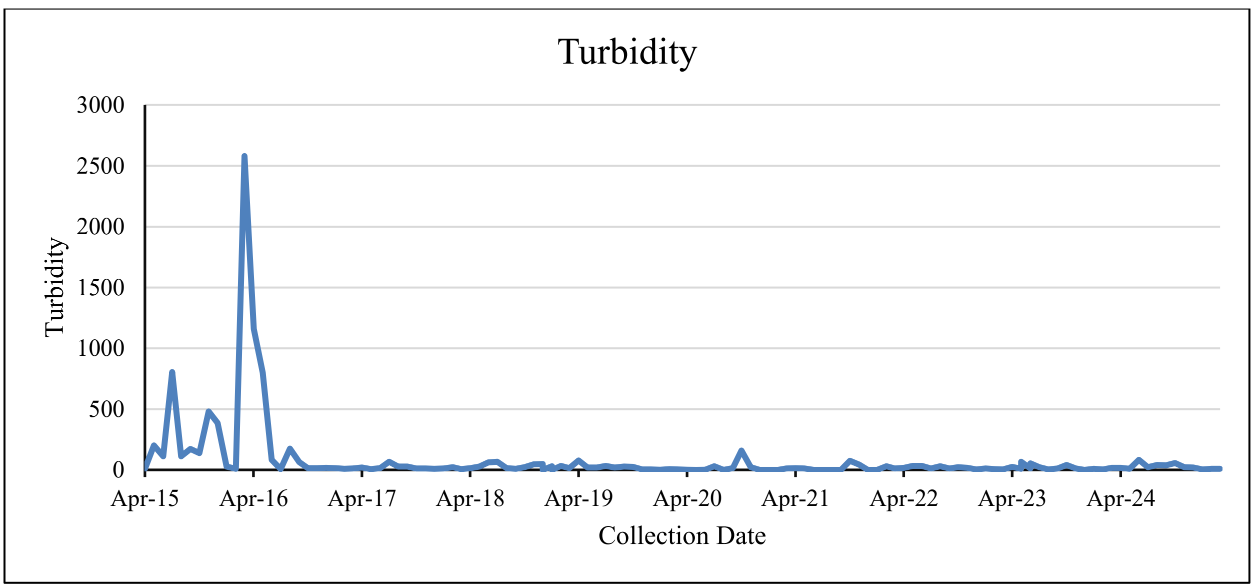


Figure 121 Monthly variation of Turbidity at Zadeshwar Station (2015-2025)

Graph 104: The graph shows the monthly variation of *Turbidity* at Zadeshwar Station from April 2015 to April 2025. Turbidity ranged from 2 to 2580 NTU(March 2016), permissible limit (BIS IS10500): 5 NTU, episodic very high turbidity (monsoon/tidal resuspension); exceeds permissible limit and requires attention.

Downstream at Zadeshwar, the water quality reflects the highest pollution load among all monitored stations. Zadeshwar's April 2015–April 2025 record shows severe and frequent water-quality problems that make the water unsafe for direct human consumption and raise ecological concern — most striking are extreme turbidity spikes (up to ~2,200 NTU) and very high microbial loads (total coliforms 100–100,000 MPN/100 mL; fecal coliforms up to 1,400 MPN/100 mL), accompanied by saline/ionic surges (TDS to ~3,000 mg/L, sodium to ~1,980 mg/L, sulphate to ~586 mg/L), very hard-water episodes (hardness to ~1,720 mg/L), large suspended-solid events (to ~2,000 mg/L) and intermittent elevated COD (to ~65 mg/L) and low DO months — patterns consistent with estuarine/tidal influence, monsoon-driven resuspension and likely sewage/industrial inputs. Zadeshwar experiences considerable anthropogenic pressure, requiring enhanced treatment and pollution-control interventions.

Overall lower Basin Status

Across April 2015–April 2025 the Narmada shows a clear downstream deterioration. Upstream at Garudeshwar and Panetha many chemical parameters remain broadly within permissible limits, but both sites show recurrent seasonal/monsoon-driven turbidity spikes and persistent microbial contamination (faecal/total coliforms) that preclude safe drinking without treatment, while Garudeshwar also records intermittent chemical outliers (nitrate, nickel, high sodium) that need source-tracing. Zanor exhibits higher microbial loads, episodic salinity/ionic excursions and turbidity/COD peaks pointing to sewage and saline/industrial influence. Downstream at Zadeshwar the situation is worst: extreme turbidity and suspended solids, massive microbial contamination, large salinity/TDS and hardness episodes and elevated COD — consistent with estuarine/tidal resuspension plus sewage/industrial inputs.Overall, the trend indicates that water quality remains good upstream and progressively declines downstream.

4. Groundwater Physico-chemical Analysis

This section presents evaluation of groundwater quality across the Narmada Basin, using the Physio-chemical data compiled from various departments responsible for groundwater. The aim is to translate raw laboratory results into a clear picture of water quality showing where parameters exceed guidelines and how water quality varies spatially across the basin. The parameters considered in this section include pH, Electrical Conductivity(E.C.), Total Dissolved Solids(T.D.S.), Total Alkalinity, Chloride, Sulphate, Nitrate, Fluoride, Total Hardness, Calcium, Magnesium, Sodium and Silicon Dioxide. For each parameter, observed values at monitoring locations are summarised and their spatial distribution is illustrated using thematic representations. Areas showing comparatively higher concentrations with referenced to permissible limits are highlighted as potential zones of concern or hotspots, based purely on the observed data patterns. No primary sampling or laboratory analysis was undertaken as part of this study. The results shown in this section therefore reflect the status of groundwater quality as reported by the respective data-providing agencies for the period under consideration. The discussion that follows is arranged by basin sub division into Upper, Middle and Lower Narmada. For each sub-region we review the behaviour of key physico-chemical parameters, highlight hotspots and brief interpretation of the data.

4.1 Upper Narmada Basin

Data for the Upper and Middle Narmada Basin groundwater is collected from the National Water Informatics Centre (NWIC), Department of Water Resources, River Development & Ganga Rejuvenation of the Central Ground Water Board, covering the years 2000-2022, for physicochemical parameters. The Narmada Basin comprises a total of 313 sampling stations, located in the Upper and Middle Basins. Station codes and Names of Sampling stations of the Upper Narmada Basin are in Table 8..

Table 8 Station codes and Names of Sampling stations of the Upper Narmada Basin

Station Codes	Station Names	Station Codes	Station Names	Station Codes	Station Names	Station Code	Station Name
GU1	Amarkantak	GU55	Simariya	GU109	Manegaon2	GU163	Sonkhera
GU2	Karanjiya	GU56	Siloni	GU110	Karakbel New		
GU3	Gorakhpur	GU57	Bargi Pz	GU111	Bauchhar		
GU4	Gadasarai	GU58	Bargi1	GU112	Dangidhana		
GU5	Gadasarai-D	GU59	Manegaon1	GU113	Sundernagar		
GU6	Gadasarai-S	GU60	Bheraghat New	GU114	Bhainsa		
GU7	Sagar Tola	GU61	Jain Dharamshala	GU115	Nandwara		
GU8	Bijhauri	GU62	Panda Ki Madhia	GU116	Ramkhiria		
GU9	Dindori	GU63	Deotal	GU117	Gundrai2		
GU10	Shahpur	GU64	Bedi Nagar	GU118	Tendukhera		
GU11	Vikrampur1	GU65	Madan Mahal	GU119	Dobhi		
GU12	Salaiya	GU66	Saliwada	GU120	Betli		
GU13	Amarpur1	GU67	Barela	GU121	Kareli Basti		
GU14	Harra	GU68	Sadar Bazar	GU122	Koudiya		
GU15	Chabi	GU69	Panchpedi	GU123	Deoribadwani		
GU16	Indira	GU70	Nagar Nigam Complex	GU124	Salichauka		
GU17	Rehgaon	GU71	Datta Mandir	GU125	Kundali		

Station Codes	Station Names	Station Codes	Station Names	Station Codes	Station Names	Station Code	Station Name
GU18	Devgaon	GU72	Cherital	GU126	HarraiDW		
GU19	Mahania patpara	GU73	Bus Stand	GU127	Sathiya		
GU20	Khari	GU74	Raddi Chowki	GU128	Surla		
GU21	Babaliya	GU75	Railway Station	GU129	Chhindi		
GU22	Khamher Kheda	GU76	Kanch Ghar	GU130	Delakhari		
GU23	Kalpi	GU77	Jabalpur	GU131	Renikhera		
GU24	Kudomali New	GU78	Jabalpur(D)	GU132	Mahaljhir		
GU25	Mangalganj	GU79	Jabalpur(S)	GU133	Sarni		
GU26	Gwari	GU80	Adhartal Naka	GU134	Ghoradongri		
GU27	Mandla1	GU81	Gokalpur	GU135	Thapa		
GU28	Mahrajpur	GU82	Ranjhi	GU136	Betul1		
GU29	Pathiri patpara	GU83	Umariya	GU137	Khedi		
GU30	Ramnagar1	GU84	Padaria	GU138	Jogli		
GU31	Padmi choraha	GU85	Bishanpura	GU139	Nimpani		
GU32	Bamhni New	GU86	Kundam Pz	GU140	Bhonra		
GU33	Anjania	GU87	Kundam	GU141	Siarmau		
GU34	Ghughri	GU88	Ghughara	GU142	Deori		
GU35	Mudiya Rijhika	GU89	Sihora1	GU143	Udaipura		
GU36	Bichhia1	GU90	Sihora Pz	GU144	Khiria		
GU37	Sijhora	GU91	Kachupura	GU145	Dhangwan		
GU38	Motinala	GU92	Majholi	GU146	Silwani		
GU39	Mangli	GU93	Patan Pz	GU147	Sultanpur		
GU40	Saletekhri	GU94	Shahpura	GU148	Dam Dongri		
GU41	Damoh(S)	GU95	Banjari	GU149	Hathi palan		

Station Codes	Station Names	Station Codes	Station Names	Station Codes	Station Names	Station Code	Station Name
GU42	Damoh2	GU96	Ghansor1	GU150	Bari		
GU43	Birsa	GU97	Mehta	GU151	Sandia		
GU44	Supkhar	GU98	Khamaria	GU152	Matkuli		
GU45	Jawaditula	GU99	Sahasna	GU153	Pachmarhi		
GU46	Bhaisanghat	GU100	Gharghatia	GU154	Suktawa		
GU47	Mukki	GU101	Makarjhir	GU155	Kesla		
GU48	Parsatola	GU102	Lakhnadon1	GU156	Gurra New		
GU49	Baihar(D)	GU103	Gaurabibi	GU157	BagratawaDW		
GU50	Baihar1	GU104	Dhuma	GU158	Sohagpur		
GU51	Khurmundi	GU105	Nagan Deori	GU159	Semri Harchand		
GU52	Bagholi	GU106	Dargada	GU160	Baharpur		
GU53	Paraswara	GU107	Jhoteshwar	GU161	BabaiDW		
GU54	Umariapan	GU108	Gotegaon	GU162	Nimsadia		

There are a total of 163 groundwater sampling stations that cover 12 districts of the Upper Narmada Basin. A detail of the number of sampling stations is illustrated in Figure 19.

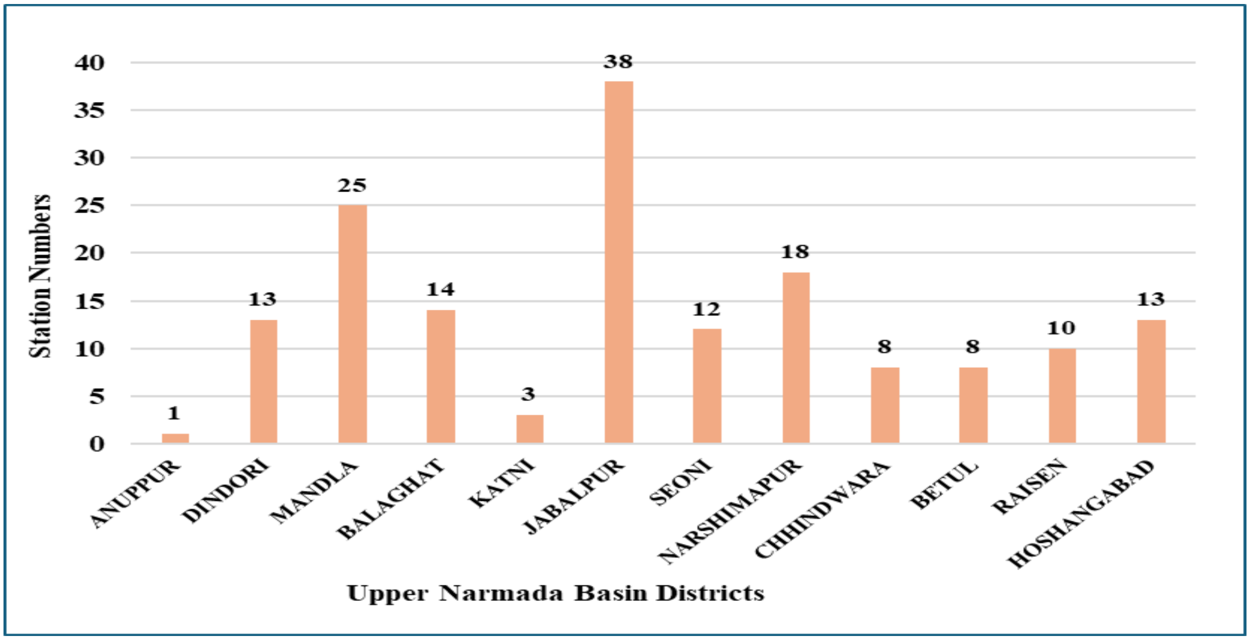


Figure 122 District-wise distribution of groundwater sampling station numbers covered in the Upper Narmada Basin.

The groundwater parameters analyzed in this report are crucial for assessing water quality and health. The following parameters have been measured:

i) pH

The pH data for all sampling stations in the Upper Narmada Basin are available for the period from 2000 to 2022, and yearly average values for all 23 years across different sampling stations are shown in the heatmap (Figure 20).

The highest average value of all 23 years for pH values across these stations ranges from 6.93 to 7.98, which fall within the BIS permissible limit of **6.5 to 8.5**. A noticeable increase in pH values was observed at several stations, exceeding the upper limit of 8.5. The maximum pH values were recorded at stations GU20 (10.86 Khari) and GU34 (10.37 Ghughri), as well as at several other stations, with maximum values ranging from 8.6 to 9.81 during the period. Apart from these values, the pH levels at all stations remained within the acceptable range, indicating overall stable quality conditions in the basin.

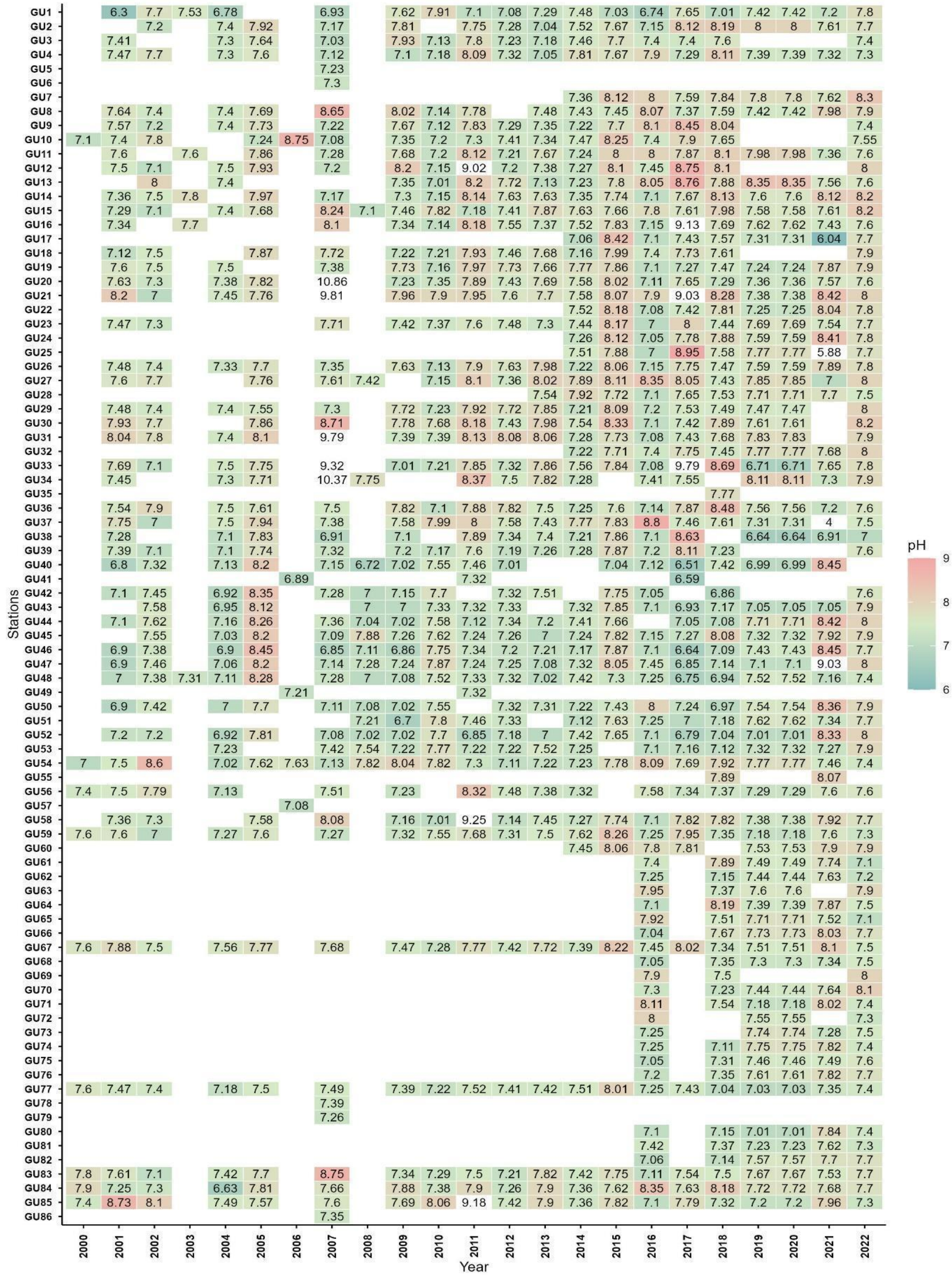


Figure 123 pH yearly average values of groundwater of all sampling stations of 23 years of the Upper Narmada Basin.(1)

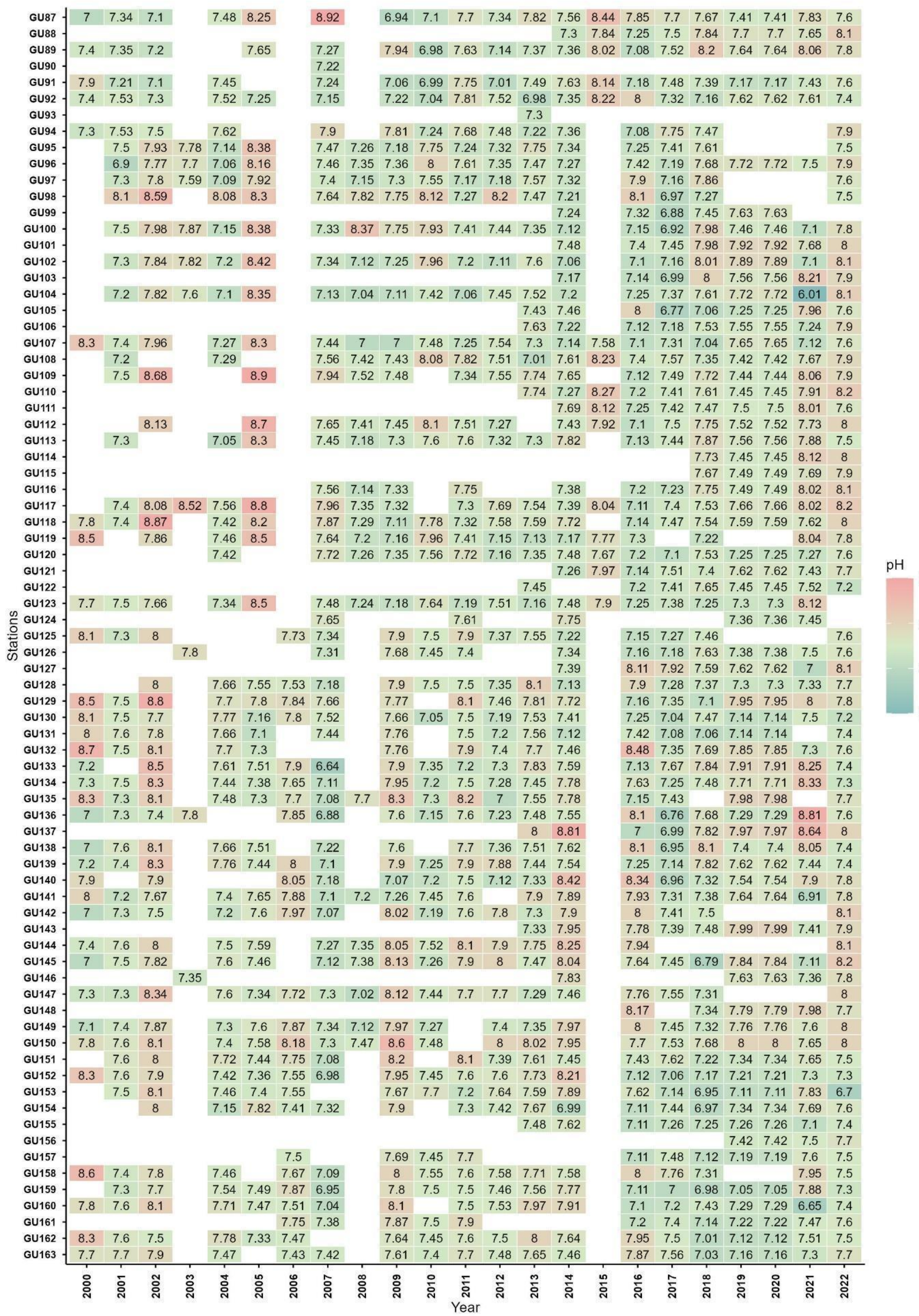


Figure 124 pH yearly average values of groundwater of all sampling stations of 23 years of the Upper Narmada Basin.(2)

ii) Chloride

The BIS standard limit for Chloride is between 250 and 1000mg/L. Data collected over the years 2000-2022 for all 163 sampling stations show that the highest average value for all years for chloride is 236.27 mg/L, recorded at Station GU156 (Gurra New), and 216.56 mg/L at Station GU50 (Baihar 1). The maximum chloride value, 849.7 mg/L, was observed at Station 56 (Siloni). All the chloride values for all years and stations are within the permissible limits for the Upper Narmada Basin, as shown in Figure 125.

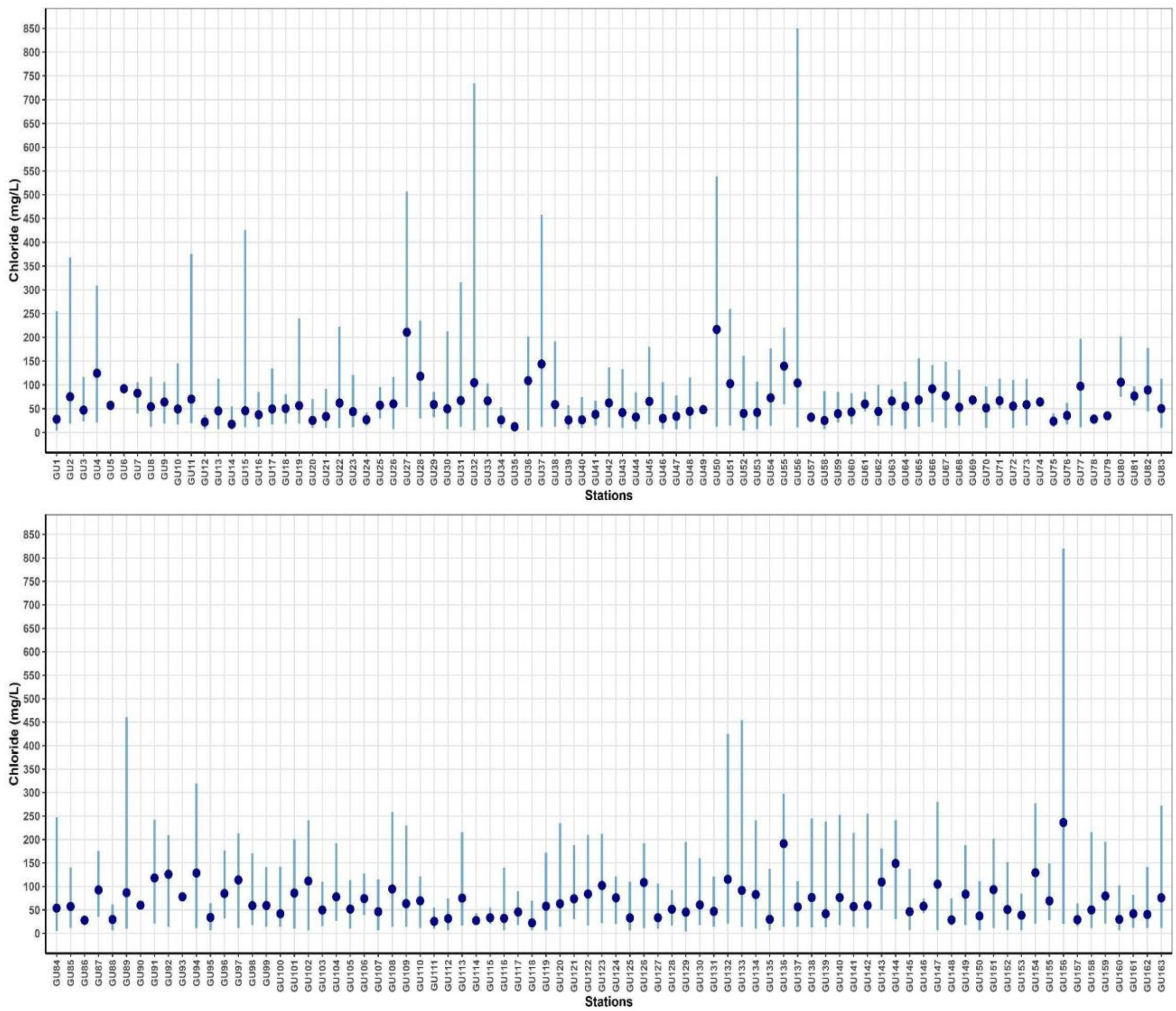


Figure 125 Average, Maximum, and Minimum values of the 22 years of Chloride in groundwater across different sampling stations of the Upper Narmada Basin.

iii) Sulphate

The BIS standard limit for sulphate is 200-400 mg/L. Data collected over the years (2000-2022) for all 163 sampling stations show that the highest average value for all years of sulphate, at 199.53 mg/L, was recorded at Station GU144 (Khiria). Additionally, at this same station, the maximum sulphate values reached 575 mg/L and 500 mg/L. In all other years and stations, the all-year average values of sulphate levels did not exceed the upper limit, as shown in Figure 126.

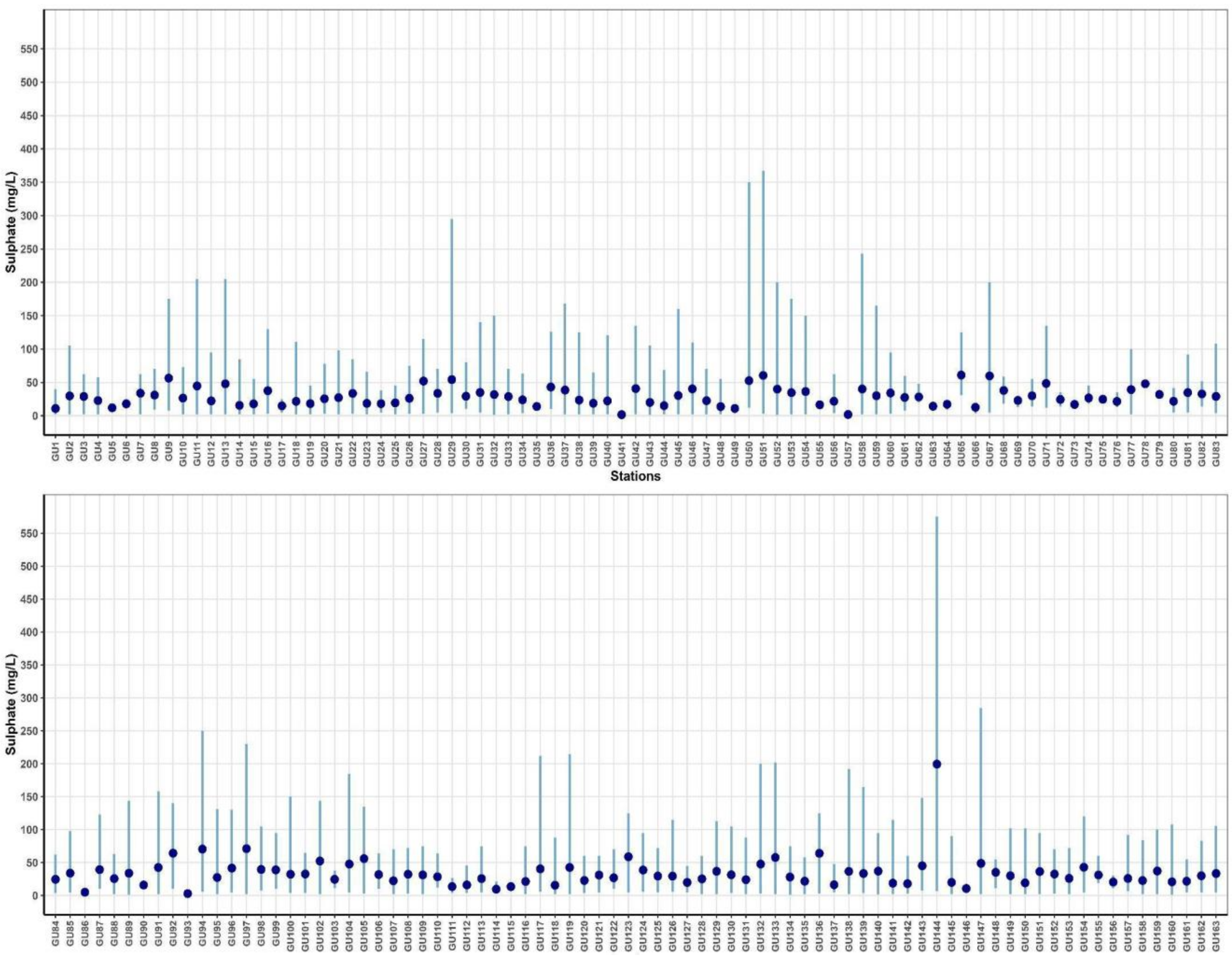


Figure 126 Average, Maximum, and Minimum values of the 20 years of Sulphate in groundwater across different sampling stations of the Upper Narmada Basin.

iv) Fluoride

The BIS standard limit for fluoride is 1-1.5 mg/L. The data for fluoride collected over (2000-2022) for all sampling stations. The highest average fluoride value for all years was observed at 1.31 mg/L at Station GU74 (Raddi Chowki), which falls within the standard limits. A maximum value of 2.8 mg/L was recorded at Station GU36 (Bicchai1). The overall average for all years across all stations is within the permissible limit, as shown in Figure 127.

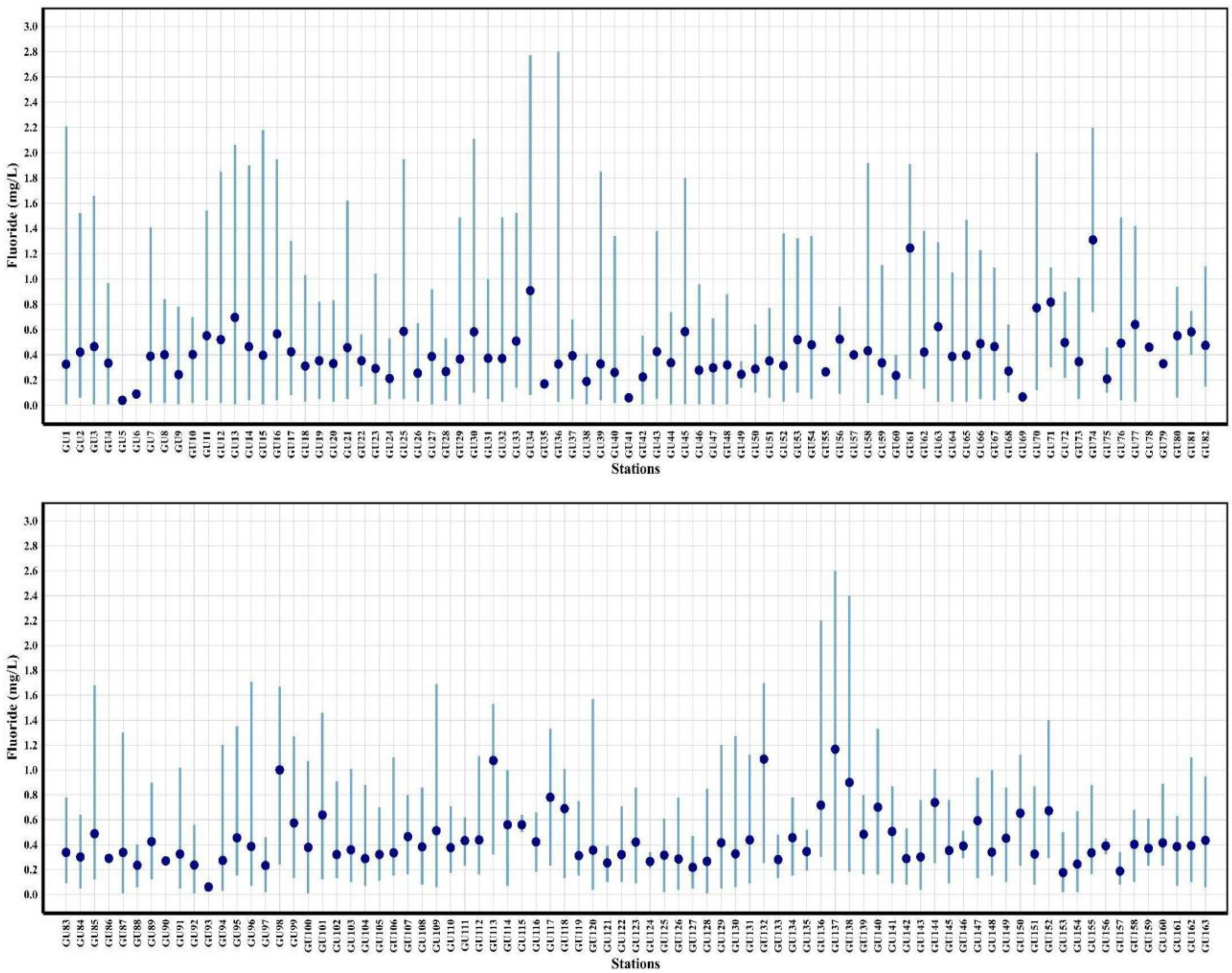


Figure 127 Average, Maximum, and Minimum values of 23 years of Fluoride in groundwater across different sampling stations of the Upper Narmada Basin.

v) Total Hardness

The BIS standard limit for Total Hardness is between 200 and 600mg/L. We have collected and analysed data over the years 2000-2022 for all stations, which shows that the highest overall average value of all years for total hardness is 536.67 mg/L, recorded at Station GU156 (Gurra New), and also 507 mg/L, recorded at Station GU94 (Shahpura), which are within the limits.

The maximum total hardness value, 1,250 mg/L, was observed at Station GU56 (Siloni) in 2021. Additionally, three other stations reported significant hardness values: Station GU94 (Shahpura) with 1015 mg/L in 2004, Station GU144 (Khiria) with 1000 mg/L in 2008, and Station GU156 (Gurra New) with 1040 mg/L in 2022. Numerous sampling stations recorded total hardness values ranging from 610 mg/L to 955 mg/L, as shown in Figure 128, which exceeds the permissible limit. However, it is important to note that each of these stations exhibited high values only once or twice during the study period, while the total hardness values for all other years remained within the acceptable range.

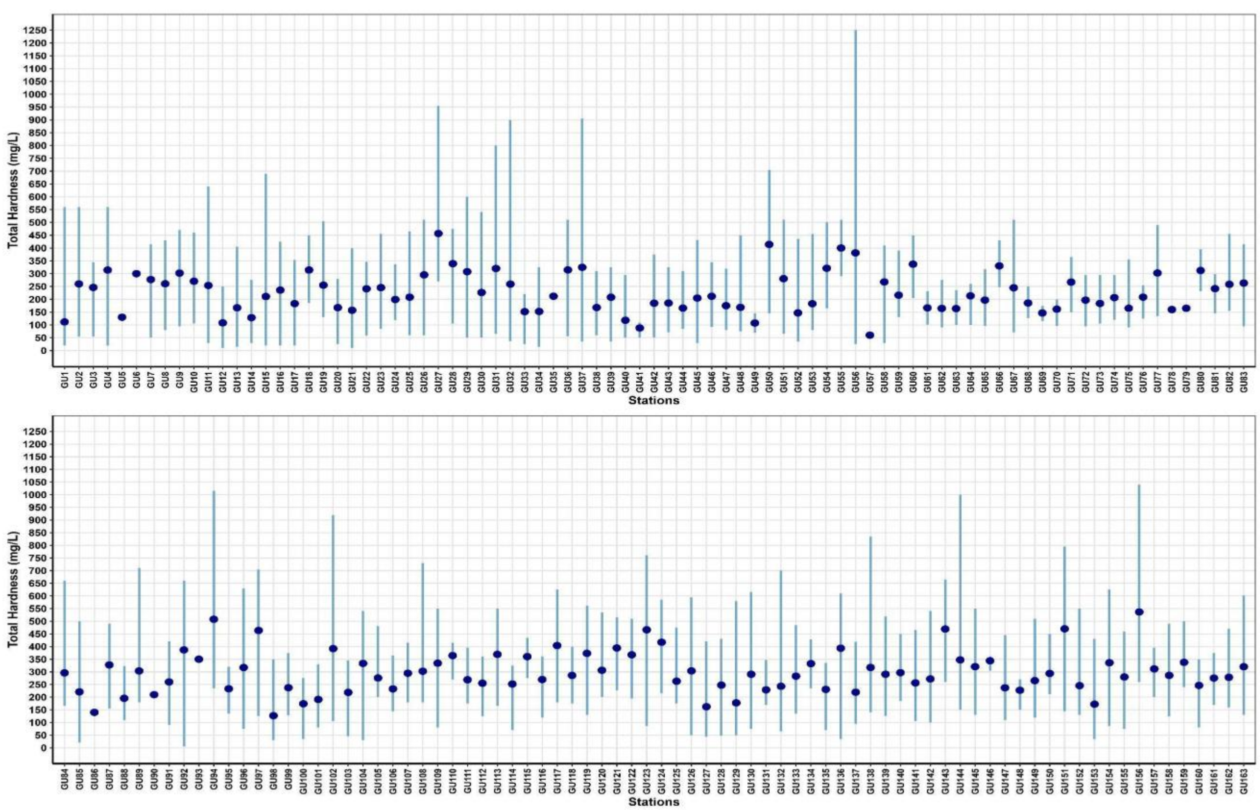


Figure 128 Average, Maximum, and Minimum values of 21 years of Total Hardness in groundwater across different sampling stations of the Upper Narmada Basin.

vi) Total Alkalinity

The BIS standard limit for Total Alkalinity is between 200 and 600mg/L. We have collected and analyzed data from 2004 to 2015 for all stations, which shows that the highest overall average value for total alkalinity across all years is 505 mg/L, recorded at Station GU144 (Khiria). The maximum total alkalinity value observed at this station was 665 mg/L. All other stations remained within the permissible limit during the entire period, as shown in Figure 129.

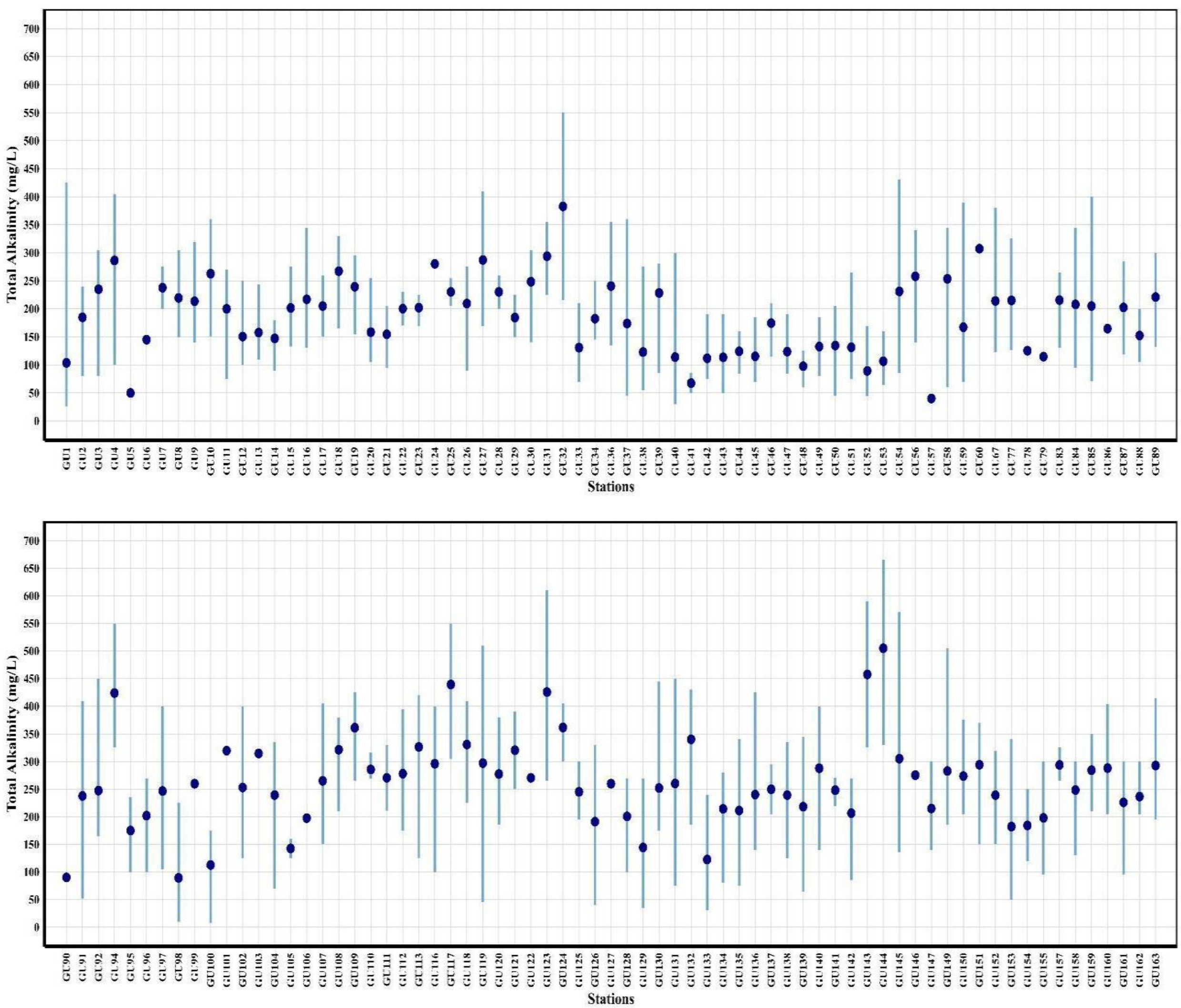


Figure 129 Average, Maximum, and Minimum values of all 12 years of Total Alkalinity in groundwater across different sampling stations of the Upper Narmada Basin.

vii) Silicon dioxide and Total Dissolved Solids

The SiO2 maximum value limit is 210mg/L(Ref.9), considered safe for drinking water, and the data collected from 2016 to 2022 for all sampling stations lie within these limits. The maximum value was observed at 93 mg/L at Station GU56 (Siloni). Similarly, TDS values across all stations for all years are within the limit, i.e., 500-2000mg/L.

viii) Nitrate

The BIS standard limit for Nitrate Nitrogen is set at < 45mg/L. The data collected and analysed over (2000-2022) for all sampling stations. The highest average value of all years was observed at 124 mg/L at Station GU97 (Mehta). The maximum Value of Nitrate was observed at 424 mg/L at Station GU84, Padaria. Many of the stations located in the Upper Narmada Basin exhibited nitrate levels that were significantly elevated and exceeded the established limits.

4.2 Middle Narmada Basin

There are a total of 150 sampling stations for groundwater (164-313) that cover 12 districts of the Middle Narmada Basin. . Station codes and Names of Sampling stations of the Middle Narmada Basin are stated in Table 9. Details of the number of stations per districts are illustrated in Figure 26.

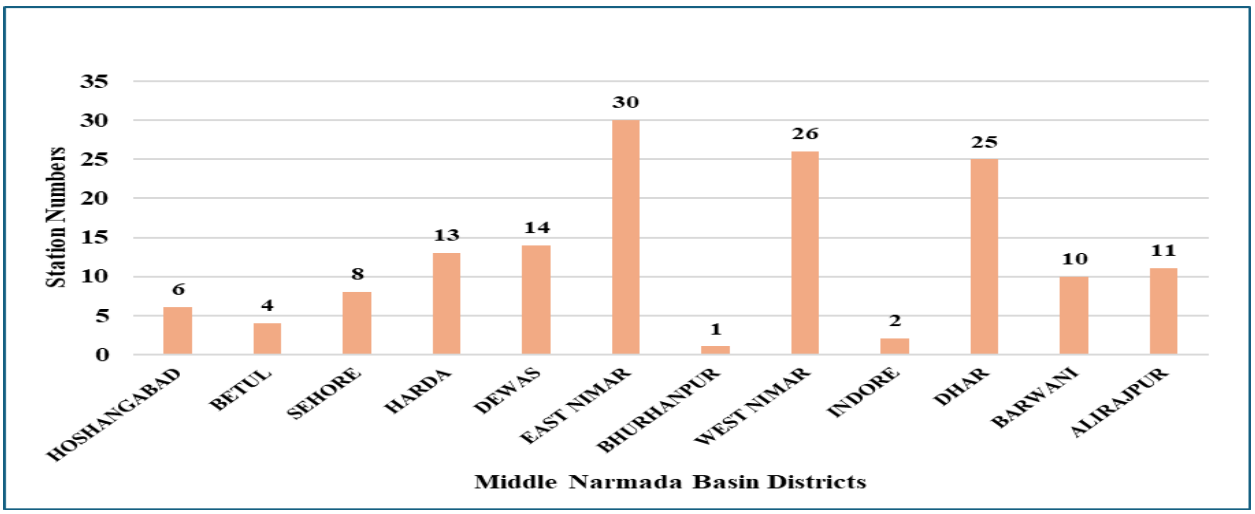


Figure 130 District-wise distribution of sampling stations in the Middle Narmada Basin.

Table 9 Station codes and Names of sampling stations of the Middle Narmada Basin.

Station Codes	Station Names	Station Codes	Station Names	Station Codes	Station Names
GM164	PathrautaDW	GM216	Udaipur	GM268	Lunera
GM165	Raisalpur	GM217	Bangarda	GM269	Dhar
GM166	Sanwalkhera	GM218	Mundi	GM270	Dhar (D)
GM167	DolariaDW	GM219	Dagad Khedi	GM271	Dhar (S)
GM168	Bhilatdeo	GM220	Bori saray	GM272	Amjhira
GM169	Seonimalwa	GM221	Bedia	GM273	Amjhera(D)
GM170	Chincholi(S)	GM222	Chanera	GM274	Tanda
GM171	Pathakhera	GM223	Kahlari	GM275	Bagh New
GM172	Chirapatala	GM224	Jawar	GM276	Bagh(D)
GM173	Khokharkheda	GM225	Roshiya	GM277	Bagh(S)
GM174	Budhni	GM226	Deshgaon New	GM278	Palasi
GM175	Bayan	GM227	Chhegaonmakhan	GM279	Kukshi1
GM176	Neelkachar	GM228	Khandwa	GM280	Pipalya
GM177	Malibayan	GM229	Jaswadi1	GM281	Dhulsar
GM178	Bordi	GM230	Rudhy Bhata	GM282	Singhana
GM179	Nadan	GM231	Khedi New	GM283	Dehari
GM180	Larkui New	GM232	Kalamkalan	GM284	Gandhwani
GM181	Rala	GM233	Khalwa1	GM285	Zeerabad
GM182	Chhidgaon	GM234	Gurhi	GM286	Manawar1
GM183	Timarni	GM235	Balwara1	GM287	Manawar(D)
GM184	Temagaon	GM236	Pandhana	GM288	Mandu
GM185	Mohanpur1	GM237	Kusumbiya	GM289	Gujri1
GM186	Chhuri Khal	GM238	Borgaon Buzurg	GM290	Dhamnod
GM187	Sonpura Colony	GM239	Jhiri	GM291	Tawlai
GM188	Chhipawad	GM240	Bhulwani	GM292	Dharampuri1
GM189	Khirkiya(D)	GM241	Dhulkot	GM293	Chachariya
GM190	Mandla	GM242	Bhagwanpura(D)	GM294	Sendhwa
GM191	Masangaon	GM243	Ghatti	GM295	Niwali1
GM192	HardaDW	GM244	Segaon	GM296	Palsud
GM193	Handia	GM245	Un	GM297	Balsamund
GM194	Handia(S)	GM246	Khargone	GM298	Julwania
GM195	Pipilianankar	GM247	Divalgaon	GM299	Baruphatak
GM196	Khategaon(S)	GM248	Bamnala New	GM300	Rajpur(D)
GM197	Khategaon(D)	GM249	Bhikangaon1	GM301	Rajpur
GM198	Dhayali	GM250	Bhikangaon(D)	GM302	Borlai
GM199	Satwas New	GM251	Daudwa	GM303	Fatta
GM200	Kantaphor	GM252	Sanawad New	GM304	Nanpur
GM201	Kannod	GM253	Sanawad(D)	GM305	Borkua
GM202	Kusumania	GM254	Amba	GM306	Aalirajpur(S)
GM203	Bijawad	GM255	Gogaon	GM307	Alirajpur

Station Codes	Station Names	Station Codes	Station Names	Station Codes	Station Names
GM204	Bijawad(D)	GM256	Sawda	GM308	Khattali
GM205	Punjapura	GM257	Kasrawad1	GM309	Jobat New
GM206	Bhikupura	GM258	Kasrawad(S)	GM310	Jobat(D)
GM207	Udainagar	GM259	Maheshwar	GM311	Badaguda
GM208	Pipri	GM260	Maheswar(S)	GM312	Ambua
GM209	Thapana	GM261	Dhargaon	GM313	Bhabra New
GM210	Ghosali	GM262	Piplyabuzrug		
GM211	Dhangaon	GM263	Baddiya		
GM212	Karoli	GM264	Barwah		
GM213	Gujar Khedi	GM265	Balwara		
GM214	Kelwa kalan	GM266	Nandpura		
GM215	Daulatpur	GM267	Manpur(D)		

i) pH

The pH data for all sampling stations in the Middle Narmada Basin are available for the period from 2000 to 2022, and yearly average values of all 23 years across different sampling stations are shown in the heat map.

The highest average value of all 22 years for pH values across these stations ranges from 6.92 to 8.12, which falls within the BIS permissible limit of **6.5 to 8.5**. A noticeable increase in pH values was observed at several stations, exceeding the upper limit of 8.5. The maximum pH values were recorded at Stations GM208 (9.5, Pipri) and GM256 (9.43, Sawda), as well as at several other stations, with maximum values ranging from 8.89 to 9.5 during the period. The pH yearly average values are shown in the Heat map Figure 27.

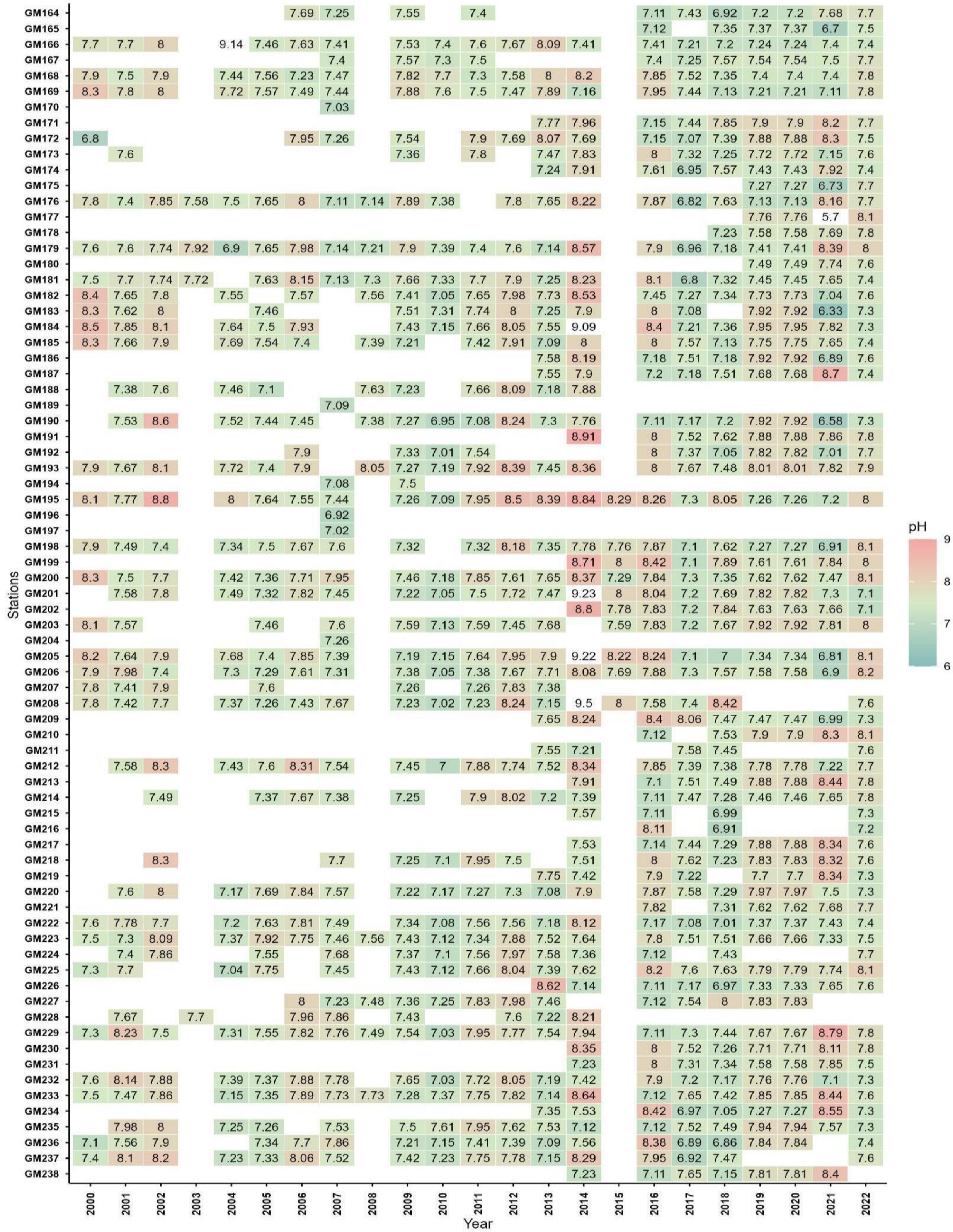


Figure 131 pH yearly average of groundwater across all sampling stations of 23 years of the Middle Narmada Basin.(1)

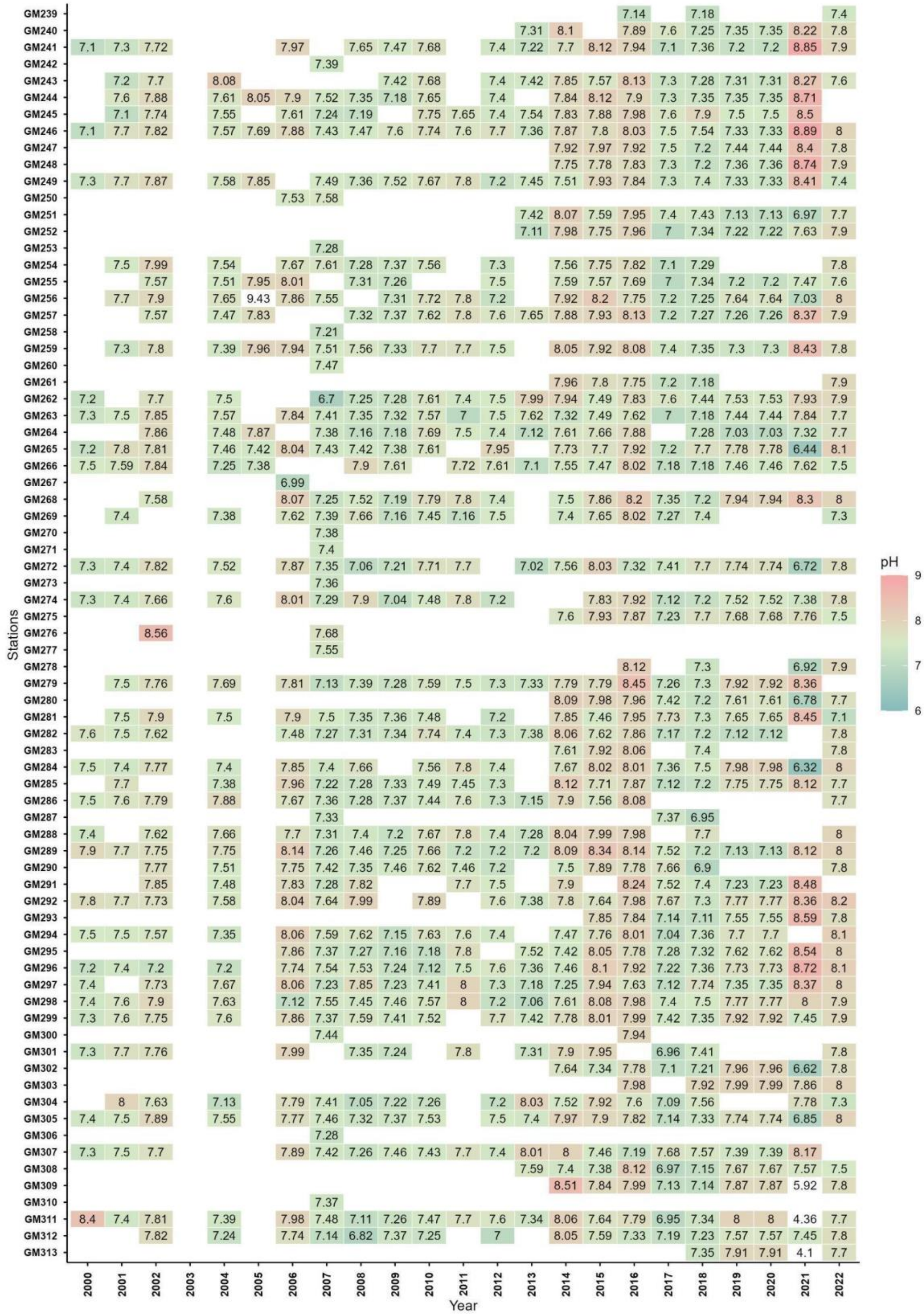


Figure 132 pH yearly average of groundwater across all sampling stations of 23 years of the Middle Narmada Basin.(2)

ii) Chloride

The BIS standard limit for chloride is between 250 and 1000mg/L. We have collected and analyzed data over the years (2001-2022) for all sampling stations, showing that the highest average value for all years for chloride is 500 mg/L, which was recorded at Station GM304 (Nanpur). The maximum chloride value, 1026 mg//L, was observed at Station GM238 (Borgaon Buzurg). All the chloride average values for all years and stations are within the permissible limits for the Middle Narmada Basin, as shown in Figure 28.

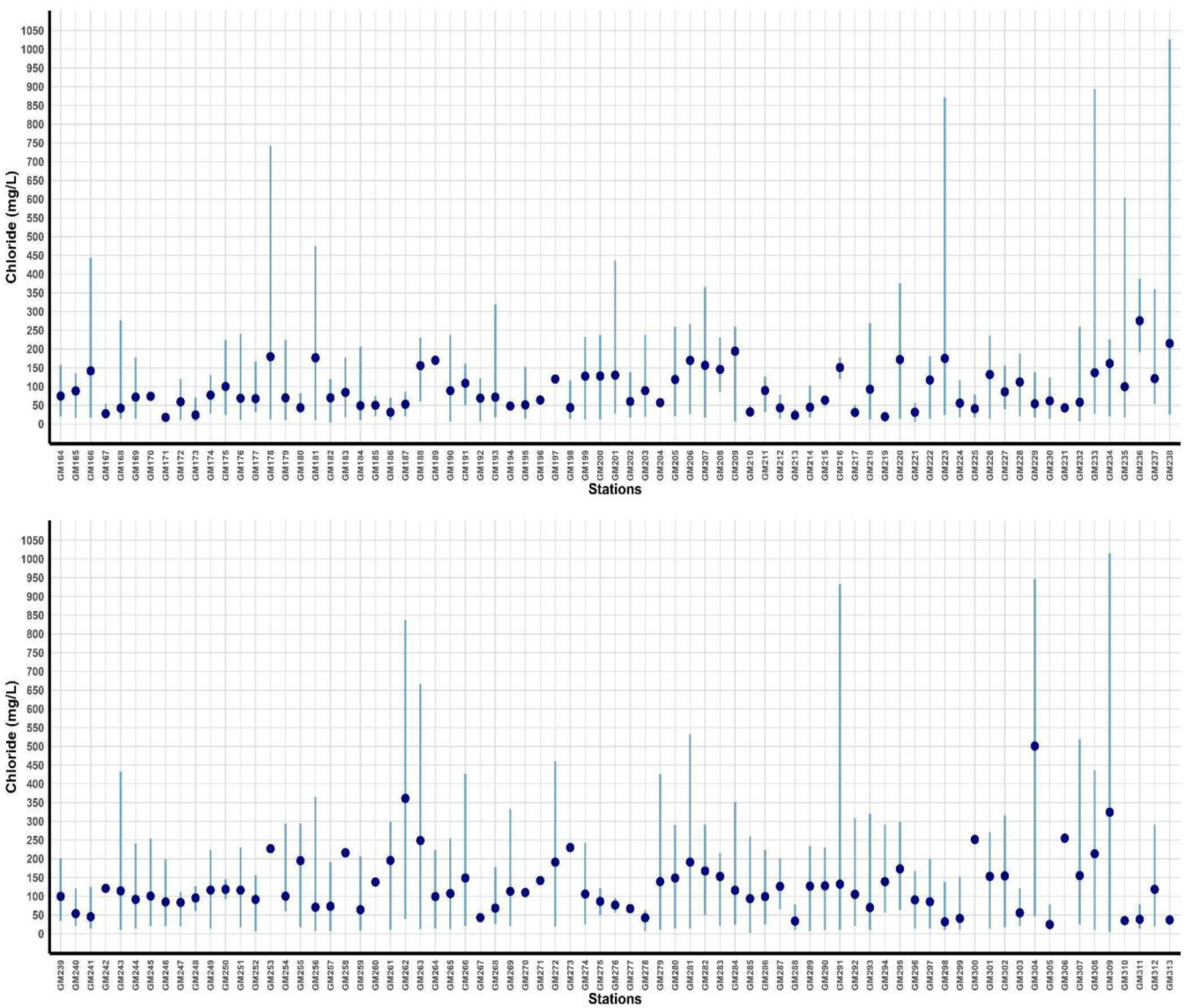


Figure 133 Average, Maximum, and Minimum values of 22 years of Chloride in groundwater across different sampling stations of the Middle Narmada Basin.

iii) Sulphate

The BIS standard limit for sulphate is 200-400mg/L. We have collected data and analyzed it from 2000 to 2022 across all sampling stations, showing that the highest average sulfate value of all years, recorded at Station GM304 (Nanpur), was 183.9 mg/L. The maximum sulphate value observed was 650 mg/L at Station GM166 (Sanwalkhera) and 541 mg/L at Station GM243 (Ghatti). In all other years and stations, the sulphate average value of all years did not exceed the upper limit, as shown in Figure 29.

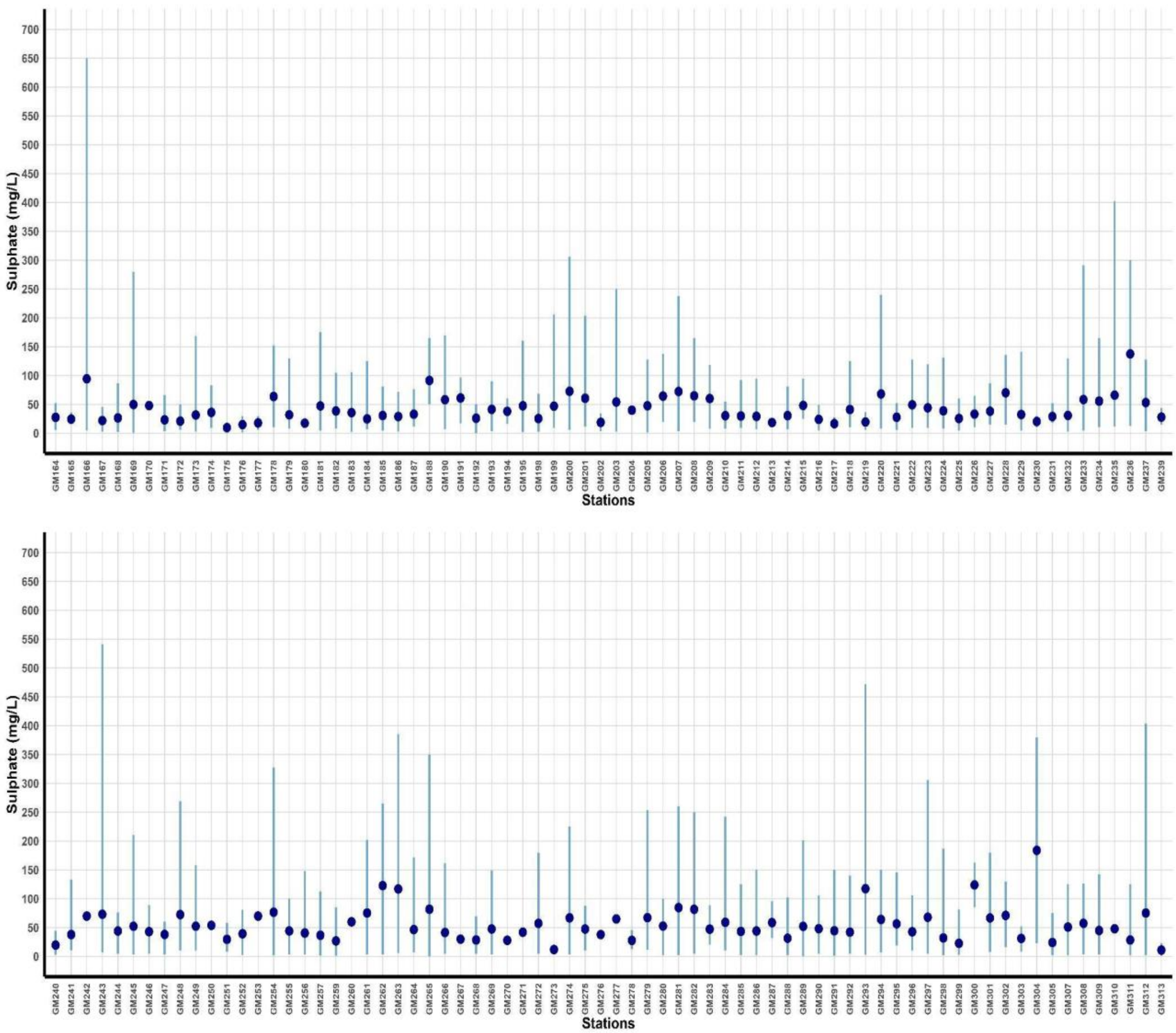


Figure 134 Average, Maximum, and Minimum values of all 20 years of Sulphate in groundwater across different sampling stations of the Middle Narmada Basin.

iv) Fluoride

The BIS standard limit for fluoride is 1-1.5 mg/L. The data for fluoride was collected over (2000-2022) for all sampling stations. The highest average fluoride value of all years was observed at 1.55 mg/L at Station GM193 (Handia), which falls within the standard limits. A maximum value of 2.8 mg/L was recorded at station GM249 (Bhikangaon). The average of all years across all sampling stations is within the permissible limit, as shown in the Figure 30.

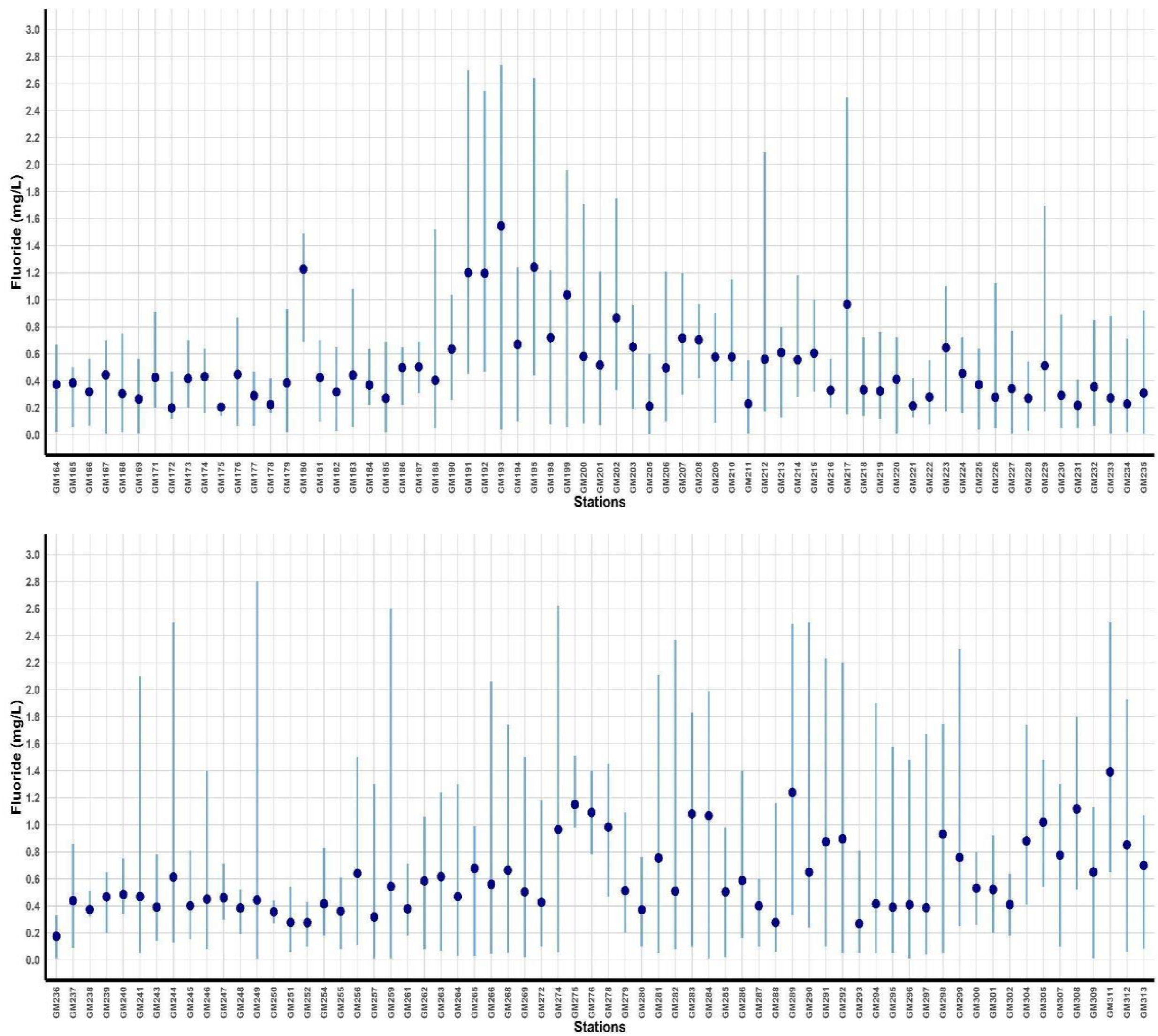


Figure 135 Average, Maximum, and Minimum values of all 23 years of fluoride in groundwater across different sampling stations of the Middle Narmada Basin.

v) Total Hardness

The BIS standard limit for Total hardness is between 200 and 600mg/L. We have collected and analysed data over the years 2000-2022) years for all stations, which shows that the highest average value of all years for total hardness is 768 mg/L, recorded at Station GM262 (Pipliyabuzrug), and also Stations GM236 (Pandhana), GM304 (Nanpur) also show high average values in the same range as shown in Figure 31.

The maximum total hardness value ranges between 1800 and 700 mg/L. The highest value of 1800 mg/L was observed at Station GM291 (Tawlal) in 2004 and at Station GM262 (Pipliyabuzrug) in 2010.

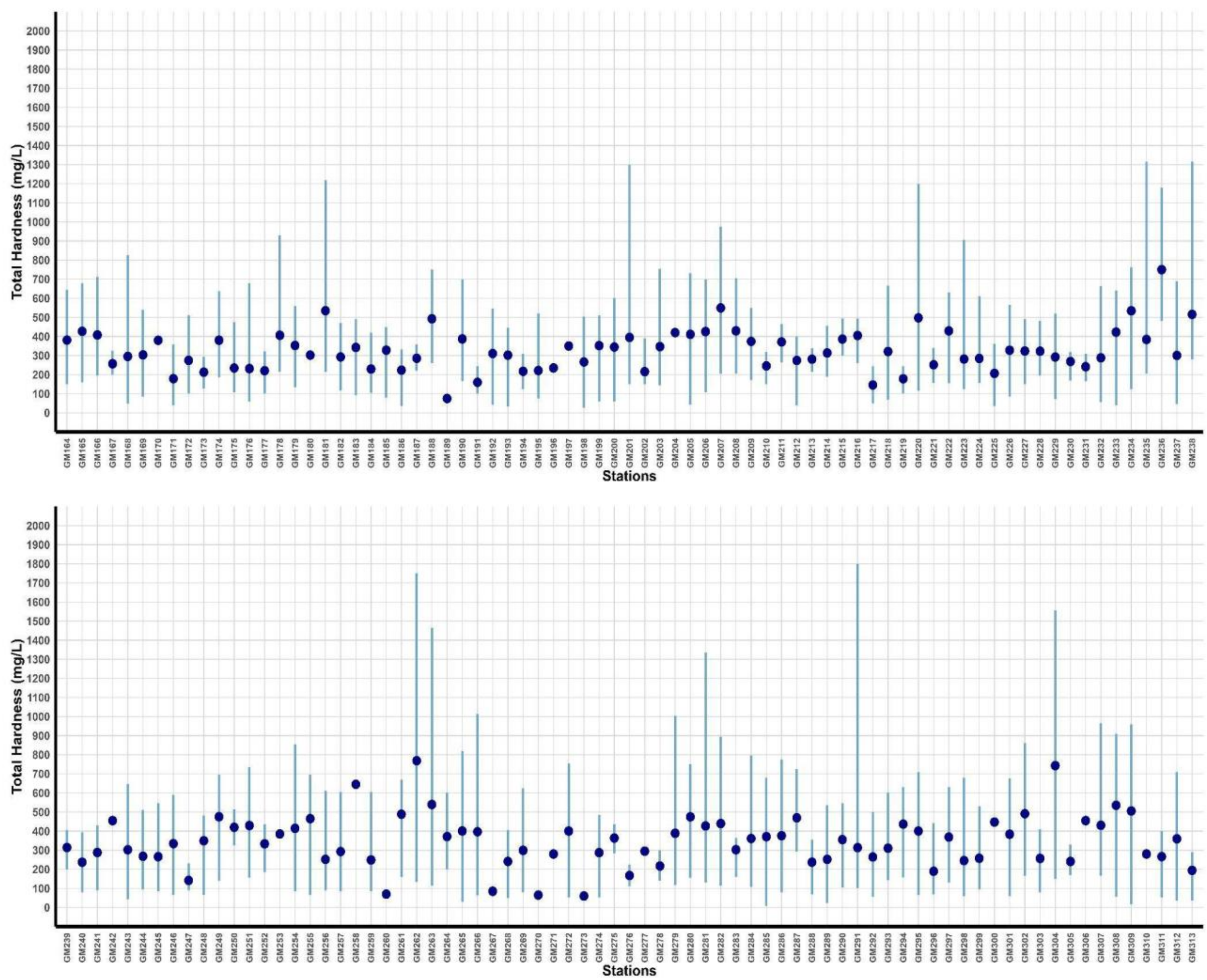


Figure 136 Average, Maximum, and Minimum values of all 21 years of Total Hardness in groundwater across different sampling stations of the Middle Narmada Basin.

vi) Total Alkalinity

The BIS standard limit for Total Alkalinity is between 200 and 600mg/L. We analyzed data from 2002 to 2015 for all stations, which shows that the highest average value for total alkalinity across all years was 457.87 mg/L, recorded at Station GM199 (Satwas New). The maximum total alkalinity value observed at Station GM166 (Sanwalkhera) was 600 mg/L and remained within the permissible limit during the entire period. The overall average values are shown in Figure 32.

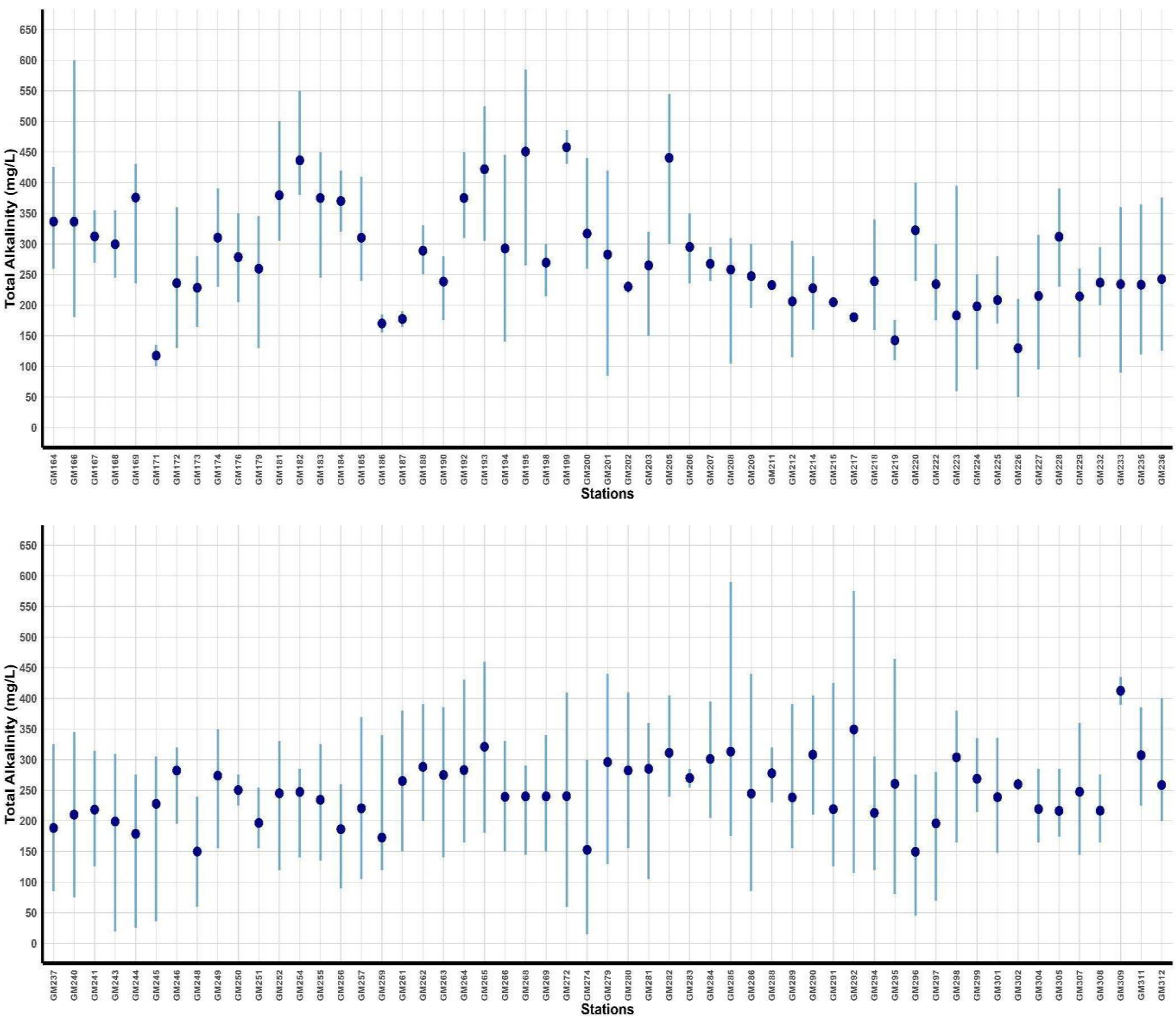


Figure 137 Average, Maximum, and Minimum values of all 12 years of Total Alkalinity in groundwater across different sampling stations of the Middle Narmada Basin.

vii) Silicon dioxide and Total Dissolved Solids

The SiO_2 maximum value limit is 210 mg/L(Ref . 9), considered safe for drinking water, and the data collected from 2016 to 2022 for all stations lie within these limits. The maximum value was observed at 62 mg/L at Station GM179 (Nadan).

Another parameter, Total Dissolved Solids, was also analyzed and shows that the highest value of the overall average across all years and stations was recorded at 1571 mg/L at Station GM178 (Bordi), which is within the range of the BIS standard, i.e., 500-2000 mg/L. The maximum value of 2471 was also observed at the same station. TDS values across all sampling stations for all years are within the limits, i.e. 500-2000mg/L.

viii) Nitrate

The BIS standard limit for Nitrate Nitrogen is set at < 45mg/L. The data collected and analysed over (2000-2022) across the stations. The highest average Nitrate value of all the years was observed at 198 mg/L at Station GM262 (Pipliyabuzrug), with a maximum value of 645 mg/L. Many of the stations located in the Middle Narmada Basin exhibited nitrate levels that are significantly elevated and exceeded the established limits.

Data Interpretation and Discussion

In this report, 9 years of data (2016-2025) have been analyzed, showing that most parameters are within the standard limits for drinking water.

After analysing the physical parameters, it can be considered that water is safe for drinking except for the stations which have extremely high turbidity values and most of them lies in the district of Sehore and Narmadapuram, which requires more ground- truthing and detail water sample analysis, so that exact reason can be identified for the high turbidity values during monsoon season in these areas.

All the chemical parameters of the Narmada River are within acceptable ranges, indicating good river health for both safe drinking water and aquatic life, which is essential for maintaining the overall health of the river. As we can see, there is a consistent concentration of dissolved oxygen, which further indicates the healthy river and thriving aquatic life, as adequate oxygen levels are essential for maintaining the ecological balance of the river. This indicates that the river water quality is safe and satisfactory, and is classified as A.

Overall, the basic condition of the river water is good and stable in the Upper and Middle Narmada Basin. However, two parameters stand out as major concerns: turbidity and total coliforms. The values for both are very high and exceed the permissible limits. These values are from the maximum stations located in the districts of Sehore and Narmadapuram, which exhibit a seasonal pattern. Turbidity values shoot high in the monsoon season, and Total coliforms in the post-monsoon season. These seasonal peaks may be due to natural processes, such as heavy rainfall, sediment, and agricultural runoff, as well as human influences, especially in the case of Total coliforms, which affect the river's health.

To understand and to solve the issues, more ground-truthing, regular sampling and analysis, and field visits should be done to identify the source of pollution. These stations can be considered Hotspots and require attention to improve river water quality through proper management practices, community awareness, and regular monitoring.

The analysis of groundwater data for both the Upper and Middle stations of the Narmada Basin reveals that most of the assessed physico-chemical parameters, such as TDS, SiO_2, chloride, sulphate, and fluoride, as well as pH, remain within the permissible limits across the periods. This indicated that the groundwater generally maintains stable water quality conditions for these parameters. contributions. Overall, the river remains within safe limits for most parameters.

However, the analysis also identifies that nitrate and hardness levels show an increase in the values at some sampling stations. These elevations raise concerns that there may be a potential influence from agricultural runoff, as well as organic and inorganic pollutants.

Additionally, natural geological factors could also play a role in altering these concentrations.

Overall, despite increases in these values at some stations, groundwater quality remains within safe limits for most parameters. These analyses underscore the importance of regular monitoring and assessment in safeguarding groundwater resources in the Narmada Basin.

There are various factors influence the quality of groundwater in the Middle Narmada Basin, Dhar district, with particular concern over high levels of Nitrates, Total hardness, Iron, and pH in the region. Furthermore, it has been noted that approximately 70.51% of the area in Dhar district has been affected in terms of groundwater quality. (Ref .1)

Another study indicated that the groundwater in the region is significantly affected by elevated concentrations of nitrate and hardness, attributed to a rise in multivalent cations. The study also noted that the water is categorized from hard to very hard, and approximately 25.49% of the state's groundwater contains nitrate levels that exceeded the acceptable limit. (Ref 2)

4.3 Lower Narmada Basin

The data for the Lower Narmada Basin groundwater was collected from the Gujarat Water Resources Development Corporation Ltd. (GWRDC), covering the years 2015-2024, for physicochemical parameters. The data was distributed across 143 sampling sites. Well Id's and Names of Sampling stations of the Lower Narmada Basin are stated in Table 10. Details of the number of stations per districts are illustrated in Figure and their spatial representation is given in figure.

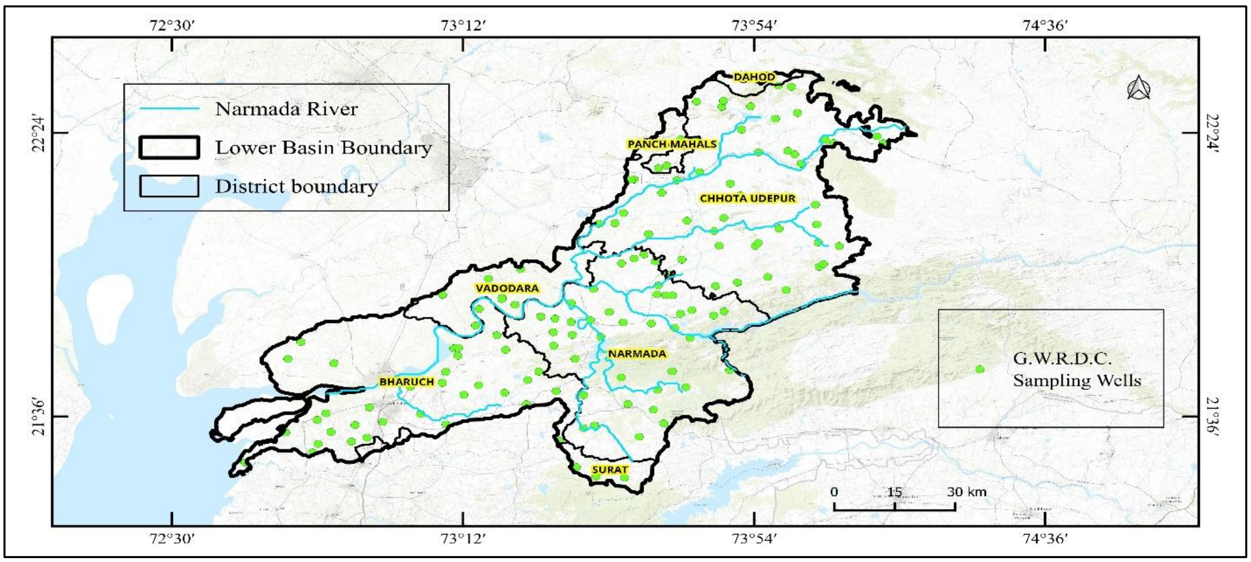


Figure 138 Distribution of sampling wells of GWRDC across lower Narmada basin

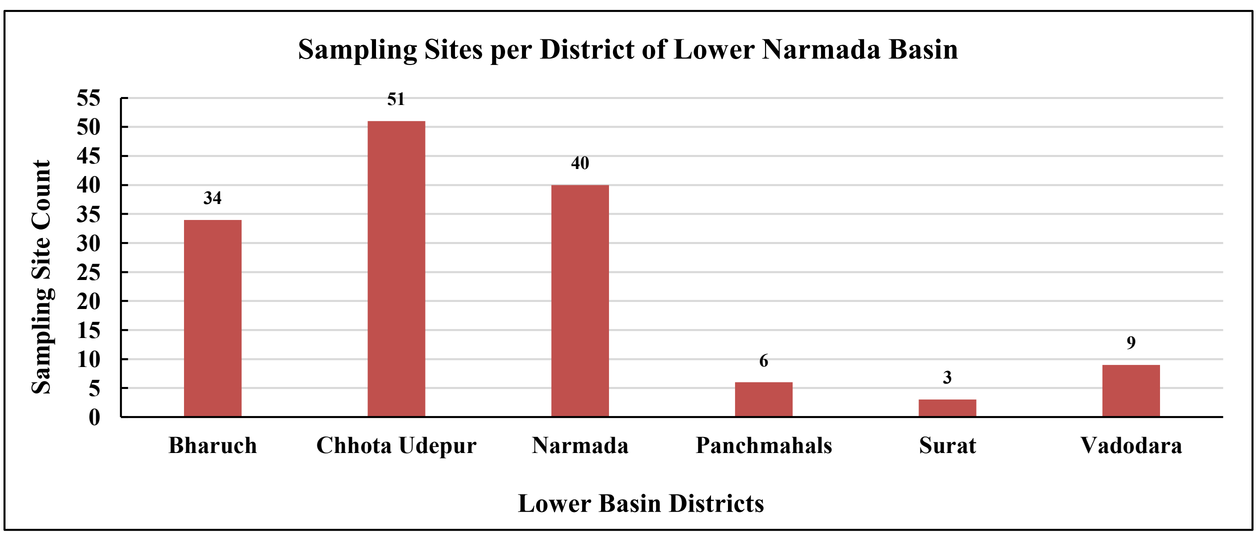


Figure 139 District wise distribution of groundwater sampling station wells covered in the Lower Narmada Basin.

Table 10 Well Ids' and metadata of sampling wells of the Lower Narmada Basin.

Sr.No.	Well ID	District Name	Block Name	Village	Long	Lat
1	HPII_BRH_004	Bharuch	Anklesvar	Adol	72.9402771	21.5755558
2	SBRHPz-22	Bharuch	Anklesvar	Anklesvar	72.9749985	21.6250000
3	G_1_BRH_004	Bharuch	Anklesvar	Kapodara	73.0074997	21.5847225
4	HPII_BRH_005	Bharuch	Anklesvar	Karmali	72.9316635	21.5288887
5	G_1_BRH_005	Bharuch	Anklesvar	Matied	72.8708344	21.6086121
6	G_1_BRH_006	Bharuch	Anklesvar	Motwan	72.8824997	21.5558338
7	HPII_BRH_006	Bharuch	Anklesvar	Panoli	72.9691696	21.5397224
8	G_1_BRH_007	Bharuch	Anklesvar	Piprod	73.0983353	21.6069450
9	BR-12	Bharuch	Hansot	Kantiajal	72.6755524	21.4699993
10	G_1_BRH_009	Bharuch	Hansot	Shera	72.8491669	21.5902786
11	SBRHPz-04	Bharuch	Hansot	Sunevkalla	72.8380585	21.4986115
12	G_1_BRH_011	Bharuch	Hansot	Valner	72.8511124	21.5222225
13	G_1_BRH_010	Bharuch	Hansot	Vansnoli	72.7730560	21.5547218
14	BR-16	Bharuch	Jhagadia	Avidha	73.1877747	21.7711105
15	SBRHPz-09	Bharuch	Jhagadia	Indor	73.2388916	21.9033337
16	NHP_BRH_005	Bharuch	Jhagadia	Jarsad	73.1888885	21.7933331
17	SBRHPz-10	Bharuch	Jhagadia	Jhagadia	73.1588898	21.7252769
18	G_2_BHR_001	Bharuch	Jhagadia	Kochbar	73.4238892	21.6711121
19	BR-20	Bharuch	Jhagadia	Mulad	73.0736084	21.6838894
20	BR-23A	Bharuch	Jhagadia	Padvania	73.2383347	21.6877785
21	BR-24	Bharuch	Jhagadia	Prakhad	73.1777802	21.7922230
22	NHP_BRH_007	Bharuch	Jhagadia	Rajpor	73.2016678	21.6611118
23	NHP_BRH_006	Bharuch	Jhagadia	Rumalpura	73.2813873	21.8291664
24	BR-60	Bharuch	Jhagadia	Valia	73.1591644	21.5772228
25	BR-27A	Bharuch	Jhagadia	Wadkhunta	73.3552780	21.7024994
26	BR-28	Bharuch	Jhagadia	Waghpura	73.3022232	21.7877769
27	BR-29	Bharuch	Jhagadia	Wanthewad	73.1500015	21.6944447
28	SBRHPz-12	Bharuch	Netrang	Kolivada	73.3002777	21.6666660
29	NHP_BRH_008	Bharuch	Netrang	Vankol	73.3824997	21.7263889
30	G_2_BHR_005	Bharuch	Vagra	Sadathala	72.7788925	21.7622223
31	G_2_BHR_006	Bharuch	Vagra	Sutrel	72.8099976	21.8099995
32	G_2_BHR_007	Bharuch	Vagra	Vilayat	72.8899994	21.7500000
33	NHP_BRH_011	Bharuch	Valia	Bilothi	73.4330521	21.5308342
34	BR-58	Bharuch	Valia	Netrang	73.3522186	21.6347218
35	G_2_VAD_008	Chhota Udepur	Bodeli	Ferkuva	73.8272247	22.1605549
36	SVADPz-35	Chhota Udepur	Bodeli	Jabugam	73.7691650	22.2891674
37	SVADPz-34	Chhota Udepur	Bodeli	Laved	73.6050034	22.2674999
38	BD-10	Chhota Udepur	Chhota udepur	Ambala	74.0916672	22.3716660
39	BD-09	Chhota Udepur	Chhota udepur	Chhota Udaipur	74.0133362	22.3133335

Sr.No.	Well ID	District Name	Block Name	Village	Long	Lat
40	BD-12	Chhota Udepur	Chhota udepur	Ferkuwa	74.2108307	22.3713894
41	BD-14	Chhota Udepur	Chhota udepur	Kevdi	73.9583359	22.5333328
42	G_2_VAD_001	Chhota Udepur	Chhota udepur	Khadakvada	74.1961136	22.3905563
43	SVADPz-06	Chhota Udepur	Chhota udepur	Lagami	74.0044479	22.4563885
44	SVADPz-37	Chhota Udepur	Chhota udepur	Malaja	73.9813919	22.3494453
45	G_2_VAD_003	Chhota Udepur	Chhota udepur	Mithi Bore	73.9899979	22.5300007
46	G_2_VAD_002	Chhota Udepur	Chhota udepur	Padaliya	74.0722198	22.3802776
47	BD-19	Chhota Udepur	Chhota udepur	Zoz	73.9513855	22.4400005
48	BD-36	Chhota Udepur	Jetpur-pavi	Bar	73.8222198	22.4733334
49	G_2_VAD_007	Chhota Udepur	Jetpur-pavi	Chhotanagar	73.8427811	22.2566662
50	BD-38	Chhota Udepur	Jetpur-pavi	Gutanwad	73.8700027	22.4091663
51	SVADPz-05	Chhota Udepur	Jetpur-pavi	Kadval	73.7616653	22.4880562
52	BD-40	Chhota Udepur	Jetpur-pavi	Kalarani	73.8675003	22.2236118
53	SVADPz-32	Chhota Udepur	Jetpur-pavi	Kashipura	73.8038864	22.1230564
54	G_2_VAD_009	Chhota Udepur	Jetpur-pavi	Kheda	73.8266678	22.4905548
55	NHP_CHU_001	Chhota Udepur	Jetpur-pavi	Kundal	73.8919449	22.4750004
56	G_2_VAD_011	Chhota Udepur	Jetpur-pavi	Nani Amrol	73.9400024	22.2199993
57	NHP_CHU_002	Chhota Udepur	Kavant	Ambadungar	73.6697235	21.9697227
58	BD-11	Chhota Udepur	Kavant	Dungargam	74.0513916	22.1416664
59	G_2_VAD_013	Chhota Udepur	Kavant	Gajalavant	73.9100037	22.0900002
60	SVADPz-36	Chhota Udepur	Kavant	Kavant	74.0544434	22.0911102
61	G_2_VAD_014	Chhota Udepur	Kavant	Mankodi	73.9599991	22.1299992
62	BD-15	Chhota Udepur	Kavant	Nalvant	73.9030533	22.0811119
63	BD-16	Chhota Udepur	Kavant	Navalja	74.1050034	22.0805550
64	BD-18	Chhota Udepur	Kavant	Raisingpura	74.0569458	22.0222225
65	SVADPz-07	Chhota Udepur	Kavant	Raisingpura	74.0669479	22.0294437
66	G_2_VAD_015	Chhota Udepur	Kavant	Raypur	74.0477753	22.1977787
67	NHP_CHU_003	Chhota Udepur	Kavant	Saidivasan	73.9974976	22.3397217
68	G_2_VAD_016	Chhota Udepur	Nasvadi	Damoli	73.8163910	22.0819435
69	NHP_CHU_004	Chhota Udepur	Nasvadi	Dhaniya Umarva	73.9102783	22.3449993
70	G_2_VAD_017	Chhota Udepur	Nasvadi	Dhar Simal	73.9769440	21.9569435
71	BD-26	Chhota Udepur	Nasvadi	Dugdha	73.9330521	21.9938889
72	BD-27	Chhota Udepur	Nasvadi	Goyavant	73.8600006	21.9777775
73	SVADPz-08	Chhota Udepur	Nasvadi	Nakhalpur	73.8077774	21.9680557
74	SVADPz-30	Chhota Udepur	Nasvadi	Nasvadi	73.7263870	22.0422230
75	BD-31	Chhota Udepur	Nasvadi	Vadiya	73.6944427	21.9983330
76	SVADPz-31	Chhota Udepur	Nasvadi	Vadiya	73.6961136	21.9997215
77	BD-45	Chhota Udepur	Sankheda	Bodeli	73.7144470	22.2661114
78	NCCA-025A	Chhota Udepur	Sankheda	Desan	73.7388916	22.1522217
79	NCCA-026	Chhota Udepur	Sankheda	Handod	73.5652771	22.1452770
80	NCCA-030A	Chhota Udepur	Sankheda	Indral	73.6463852	22.1147213

Sr.No.	Well ID	District Name	Block Name	Village	Long	Lat
81	NHP_CHU_008	Chhota Udepur	Sankheda	Ladhod	73.6780548	22.2313881
82	NCCA-028A	Chhota Udepur	Sankheda	Laved	73.6116638	22.2688885
83	SVADPz-33	Chhota Udepur	Sankheda	Sankheda	73.5858307	22.1738892
84	NHP_CHU_009	Chhota Udepur	Sankheda	Vadadli	73.5263901	22.1433334
85	NHP_CHU_010	Chhota Udepur	Sankheda	Vaghetha	73.6780548	22.2313881
86	BR-06	Narmada	Dediapada	Chuli	73.5163879	21.5744438
87	SBRHPz-17	Narmada	Dediapada	Dediapada	73.5966644	21.6350002
88	NHP_NMR_001	Narmada	Dediapada	Dumkhal	73.8413925	21.7308331
89	G_2_NMR_003	Narmada	Dediapada	Fulsar	73.5800018	21.7099991
90	BR-08	Narmada	Dediapada	Gangpur	73.6827774	21.5802784
91	G_2_NMR_001	Narmada	Dediapada	Kanbudi	73.6583328	21.6191673
92	G_2_NMR_005	Narmada	Dediapada	Kharchipada	73.4902802	21.5666676
93	G_2_NMR_006	Narmada	Dediapada	Kundi Amba	73.6236115	21.5424995
94	BR-09	Narmada	Dediapada	Motisingloti	73.6677780	21.6752777
95	G_2_NMR_004	Narmada	Dediapada	Namgir	73.7033310	21.7272224
96	SBRHPz-19	Narmada	Dediapada	Patvali	73.7361145	21.6825008
97	G_2_NMR_007	Narmada	Dediapada	Solia	73.4899979	21.6599998
98	G_2_NMR_008	Narmada	Garudeshwar	Bhumalia	73.7227783	21.8894444
99	BR-32	Narmada	Garudeshwar	Chhindiapura	73.7038879	21.9422226
100	SBRHPz-08	Narmada	Garudeshwar	Gulvani	73.8274994	21.8961105
101	SBRHPz-05	Narmada	Garudeshwar	Indravarna	73.6527786	21.8622227
102	G_2_NMR_012	Narmada	Garudeshwar	Naghatpor	73.7500000	21.8999996
103	BR-37	Narmada	Garudeshwar	Nana zunda	73.5852814	21.8652782
104	BR-38	Narmada	Garudeshwar	Navapara	73.3872223	21.8816662
105	BR-44A	Narmada	Garudeshwar	Survani	73.8030548	21.8844452
106	NHP_NMR_002	Narmada	Garudeshwar	Thavadiya	73.7091675	21.8500004
107	G_2_NMR_013	Narmada	Garudeshwar	Vaviala	73.6877747	21.9419441
108	NHP_NMR_003	Narmada	Garudeshwar	Zer	73.7466660	21.8211117
109	BR-30	Narmada	Nandod	Amletha	73.4172211	21.8377781
110	G_2_NMR_009	Narmada	Nandod	Amli	73.4697189	21.7622223
111	G_2_NMR_010	Narmada	Nandod	Dhanpur	73.4599991	21.9200001
112	SBRHPZ-07	Narmada	Nandod	Ghanta	73.4180527	21.7994442
113	G_2_NMR_011	Narmada	Nandod	Jitgadh	73.5313873	21.8244438
114	SBRHPz-06	Narmada	Nandod	Jiyor	73.5141678	21.9594440
115	BR-36	Narmada	Nandod	Nana haidwa	73.4627762	21.8299999
116	SBRHPz-25	Narmada	Nandod	Navapura	73.3872223	21.8816662
117	BR-40	Narmada	Nandod	Pratapnagar	73.4213867	21.8761120
118	BR-41	Narmada	Nandod	Rajpipla	73.5061111	21.8713894
119	BR-45	Narmada	Nandod	Thari	73.5519409	21.8947220
120	BR-48	Narmada	Nandod	Virpur	73.4599991	21.8661118
121	G_2_NMR_018	Narmada	Tilakwada	Agar	73.6616669	22.0377769

Sr.No.	Well ID	District Name	Block Name	Village	Long	Lat
122	HPII_NMR_001	Narmada	Tilakwada	Katkoi	73.6661148	21.9444447
123	BD-58	Narmada	Tilakwada	Namaria	73.6119461	22.0452785
124	G_2_NMR_019	Narmada	Tilakwada	Soikuva	73.6352768	22.0569439
125	SVADPz-29	Narmada	Tilakwada	Vajeria	73.5813904	22.0319443
126	G_2_PMS_004	Panchmahals	Jambughoda	Duma	73.6699982	22.2999992
127	PM-045	Panchmahals	Jambughoda	Duma	73.6900024	22.3077774
128	G_2_PMS_006	Panchmahals	Jambughoda	Jambughoda	73.7341690	22.3641663
129	PM-047	Panchmahals	Jambughoda	Jotwad	73.7238922	22.3819447
130	G_2_PMS_005	Panchmahals	Jambughoda	Kanjipani	73.7569427	22.3775005
131	PM-046	Panchmahals	Jambughoda	Kanjipani	73.7574997	22.3811111
132	SRT-31	Surat	Umarpada	Bilvan	73.5888901	21.4269447
133	SSRTPz-14	Surat	Umarpada	Ghanawad	73.5199966	21.4302769
134	SRT-36	Surat	Umarpada	Umarpada	73.4727783	21.4569435
135	SVADPZ-28	Vadodara	Sinor	Chhanbhoi	73.3388901	22.0158329
136	G_2_VAD_018	Vadodara	Sinor	Mota Fofaliya	73.3711090	21.9599991
137	SVADPz-17	Vadodara	Karjan	Sayar(Nareshwar)	73.2302780	21.8566666
138	BD-55	Vadodara	Sinor	Sinor	73.3249969	21.9150009
139	NCCA-041A	Vadodara	Sinor	Surasamal	73.2938919	21.9347229
140	SVADPz-27	Vadodara	Sinor	Surasamal	73.2938919	21.9313889
141	NCCA-019A	Vadodara	Karjan	Urad	73.1508331	21.9430561
142	SVADPz-16	Vadodara	Karjan	Urad	73.1505585	21.9438896
143	NHP_VAD_007	Vadodara	Sinor	Utaraj	73.2608337	21.9886112

i.) pH

The BIS standard limit value for pH is between 6.5 and 8.5 and the ideal is usually considered 7. Across the network of 143 monitoring stations, the highest average pH for 2022–2024 was 9.4 at station G_2_VAD_001, while the single highest observed value in 2024 was 11.1 at station BR-12. The pre monsoon average pH was 8.89, with a standard deviation of 0.78, while the average post monsoon pH was 8.43 with a standard variation of 0.38. It was seen that on an average the values of pH dropped by 3.33% in the post monsoon season. In the 2024 seasonal samples, 85(60%) stations recorded pH values above the limit in the pre-monsoon sampling, of which 57 (40%) stations remained above the limit even after the post monsoon recharge. 29 (20%) stations show persistent exceedance as their 2022–2024 average as well as post-monsoon 2024 values are above the BIS limit, and are represented in Table 4.3.A and wells having values higher than limit in post monsoon 2024 are mentioned in Table 4.3.B.

The pre-monsoon pH map shows groundwater pH values across the Lower Narmada Basin prior to the monsoon; green areas are pH ≤ 8.5 (within BIS limit) while red areas exceed the BIS upper limit (pH > 8.5).

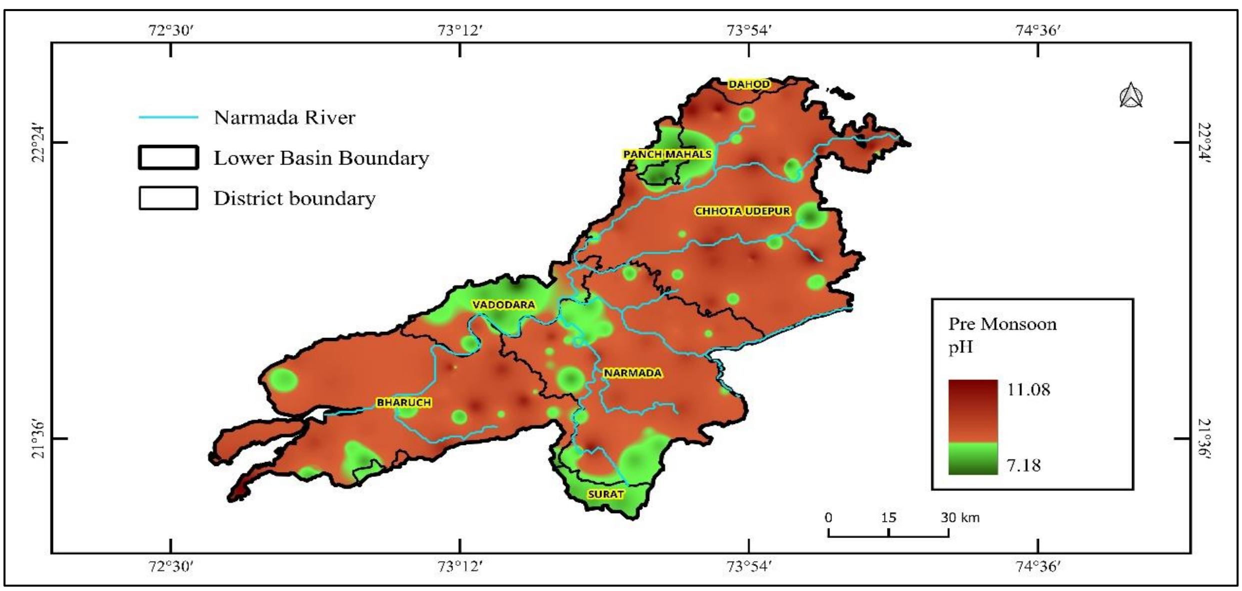


Figure 140 Spatial representation of pH values across the lower narmada basin in the 2024 pre monsoon period.

Compared to pre-monsoon, the post-monsoon map shows noticeably fewer high-pH (red) zones and more widespread green, suggesting a basin-scale reduction in alkaline conditions following monsoon recharge, while still persisting unpotable conditions in much area of the basin.

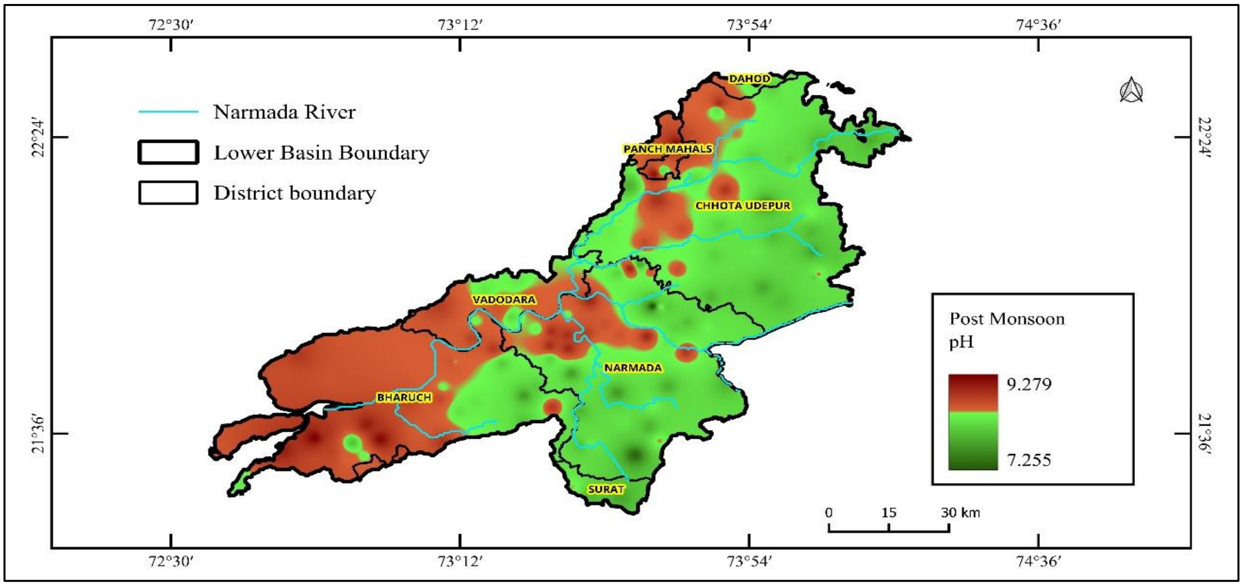


Figure 141 Spatial representation of pH values across the lower narmada basin in the 2024 post monsoon period.

ii.) Electrical Conductivity

The BIS IS 10500:2012 does not describe any specific drinking water limit for Electrical Conductivity and so does the 'Guidelines for drinking-water quality Fourth edition' by World Health Organisation. Hence reference value for standard limit for electrical conductivity is taken from 'European Union (Drinking Water) Regulations 2023' which states the limit at 2500 µS/cm at 20 ºC which converted in accordance for the dataset at 25 ºC amounts to 2750 µS/cm at 20 ºC.

Across the network of 143 monitoring stations, the highest average electrical conductivity for 2022–2024 was 11970 at station G_2_BHR_005, while the single highest observed value was 21740 at station SBRHPz-04. 13(9%) stations show persistent exceedance as their 2022–2024 average as well as post-monsoon 2024 values are above the BIS limit, which are represented in table 4.3.C. The pre monsoon average E.C. was 1520µS/cm, with a standard deviation of 1930 µS/cm, while the average post monsoon E.C. was 1314 µS/cm with a standard variation of 1918 µS/cm. It was seen that on a average the values of E.C. dropped by 14.33% in the post monsoon season.

The pre-monsoon E.C. map shows groundwater E.C. values across the Lower Narmada Basin prior to the monsoon; green areas are E.C. ≤ 2750 µS/cm (within E.U. limit) while red areas exceed the E.U. limit (E.C. > 2750 µS/cm).

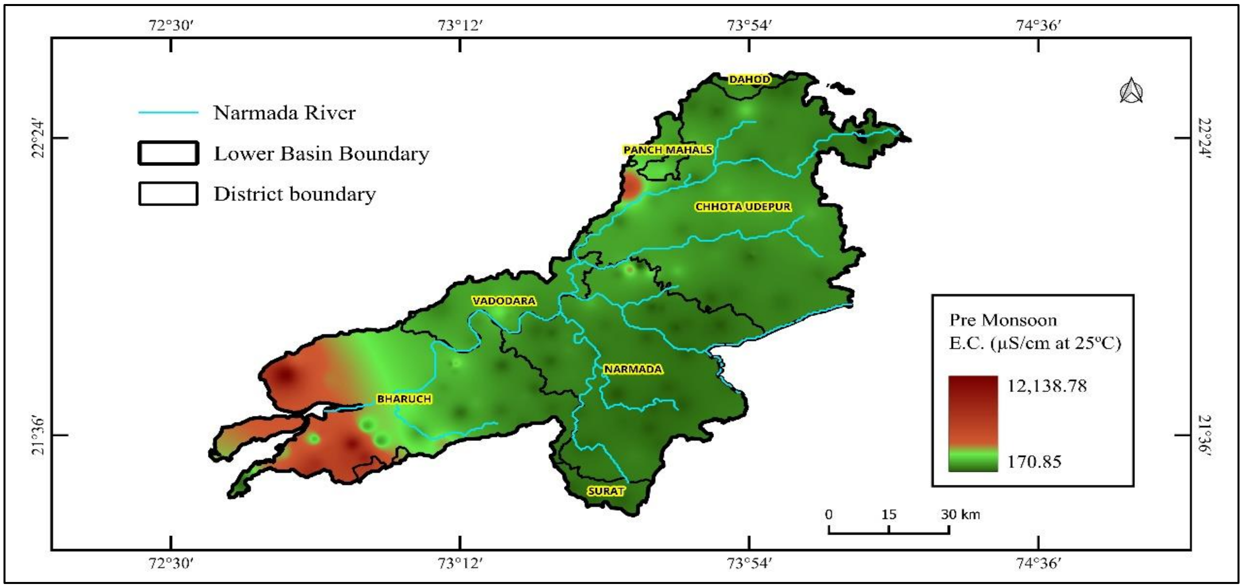


Figure 142 Spatial representation of E.C. values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map does not noticeably represent fewer high-E.C. (red) zones, but it is observed that locations within the limit have decreased in value and stayed under the limit while most of the locations have decreased in value but not enough to be below the limit. Most of the hotspots are located in the comparatively downstream region of the basin along with some region of Chhota Udepur in upstream.

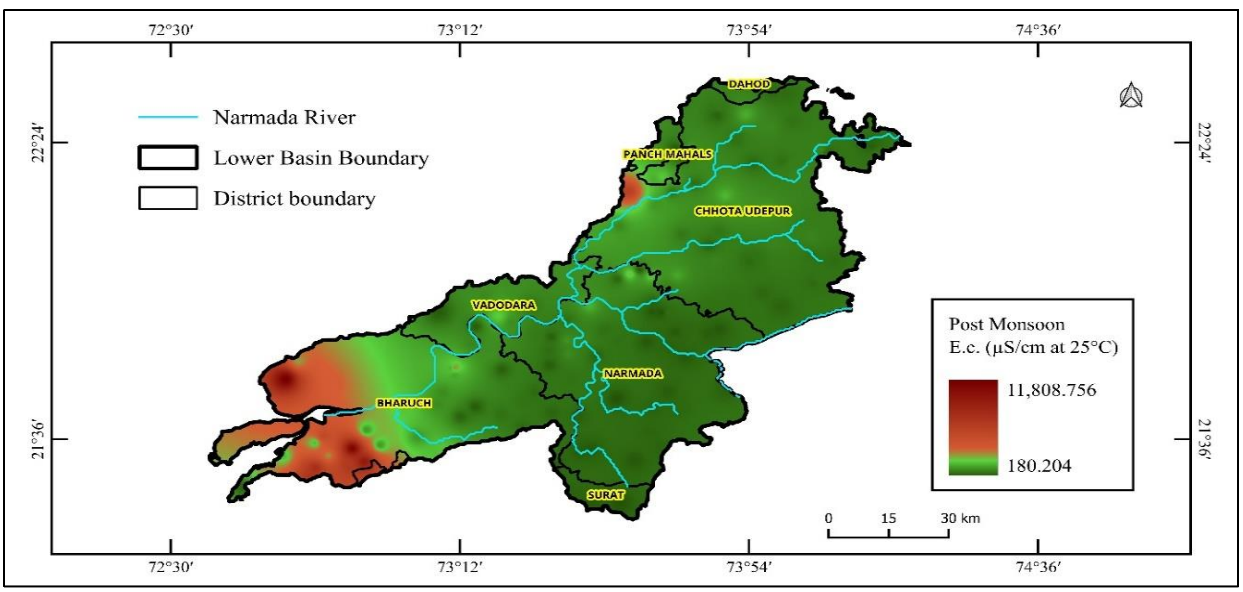


Figure 143 Spatial representation of E.C. values across the lower narmada basin in the 2024 post monsoon period.

iii.) Total Dissolved Solids (T.D.S.)

The BIS requirement (Acceptable Limit) for T.D.S. is 500 mg/L and the Permissible Limit in Absence of Alternate Source is 2000 mg/L. Across the network of 143 monitoring stations, the highest average T.D.S. value for 2022–2024 was 7196 mg/L at station G_2_BHR_005, while the single highest observed value was 13880 at station SBRHPz-04. 12(8%) stations show persistent exceedance as their 2022–2024 average as well as post-monsoon 2024 values are above the BIS limit of 2000 mg/L and are represented in table 4.3.D. 42(30%) sites have values above the 500 mg/L limit in both 2022-2024 average as well as in post-monsoon 2024 and are represented in table.4.3.E. The pre monsoon average T.D.S. value was 932 mg/L, with a standard deviation of 1187 mg/L, while the average post monsoon T.D.S. was 763 mg/L with a standard variation of 1114 mg/L.

The pre-monsoon T.D.S. map shows groundwater T.D.S. values across the Lower Narmada Basin prior to the monsoon. Green areas are T.D.S. ≤ 500 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 500 mg/L (acceptable limit) and 2000 mg/L (permissible limit) while red areas exceed the permissible limit of 2000 mg/L.

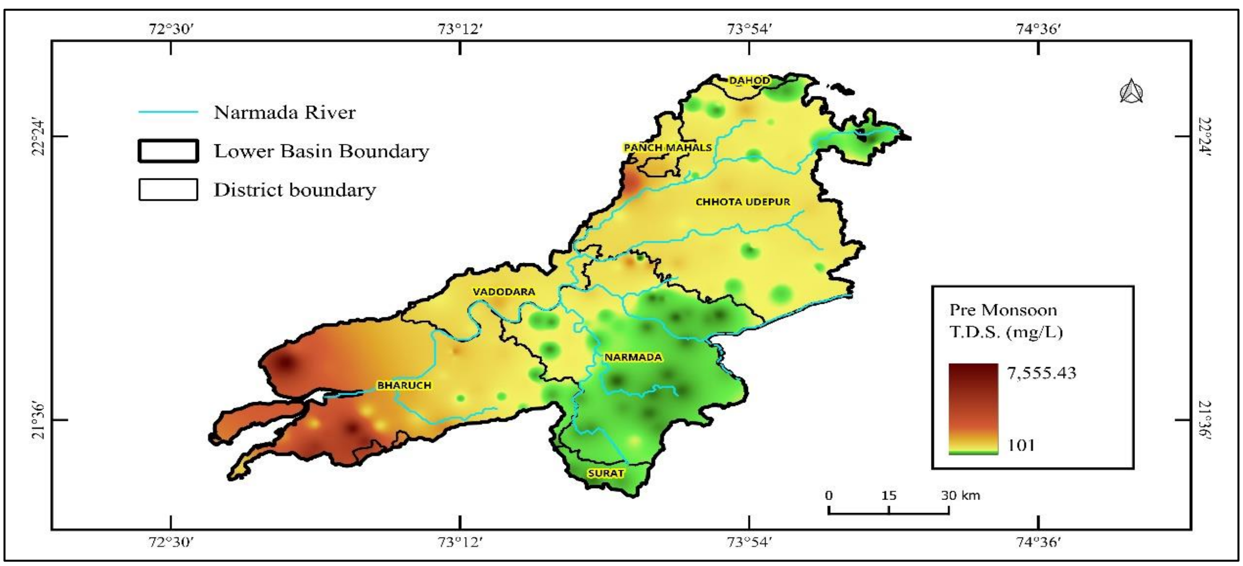


Figure 144 Spatial representation of TDS values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high-T.D.S. (yellow) zones and more widespread green, suggesting a basin-scale reduction in T.D.S. conditions following monsoon recharge. It is also observed that locations within the limit have decreased in value and stayed under the limit while some of the locations have decreased in value but not enough to be below the limit. Most of the hotspots are located in the comparatively downstream region of the basin.

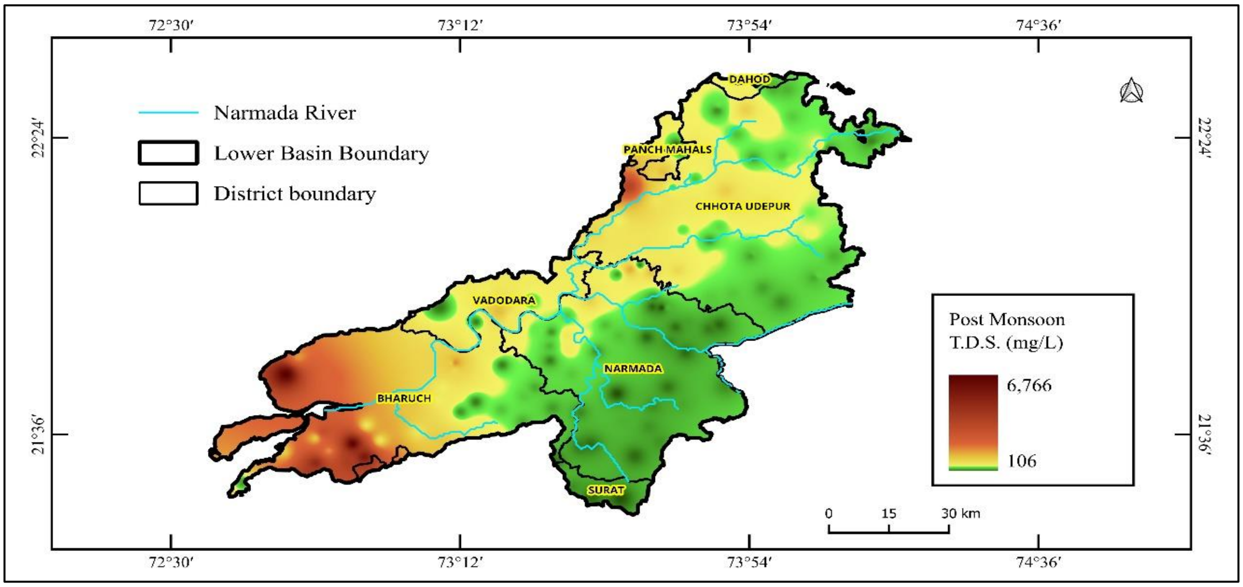


Figure 145 Spatial representation of TDS values across the lower narmada basin in the 2024 post monsoon period.

iv.) Total Alkalinity

The BIS requirement (Acceptable Limit) for Total Alkalinity is 200 mg/L and the Permissible Limit in Absence of Alternate Source is 600 mg/L. Across the network of 143 monitoring stations, the highest average Total alkalinity for 2022–2024 was 540 mg/L at station NHP_BRH_005, while the single highest observed value was 747 mg/L at station G_1_BRH_009. 5(3%) stations show exceedance of permissible limit of 600 mg/L in terms of either pre or post-monsoon 2024 values and are represented in table 4.3.F. 53(37%) sites have values above the 200 mg/L limit in both 2022-2024 average as well as in post-monsoon 2024 and are represented in table 4.3.G. The pre monsoon average Total Alkalinity value was 246 mg/L, with a standard deviation of 158 mg/L, while the average post monsoon alkalinity was 200 mg/L with a standard variation of 109 mg/L. It was seen that on a average the values of Alkalinity increased by 8% in the post monsoon season.

The pre-monsoon Total Alkalinity map shows groundwater Total Alkalinity values across the Lower Narmada Basin prior to the monsoon. Green areas reflect Total Alkalinity ≤ 200 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 200 mg/L (acceptable limit) and 600 mg/L (permissible limit) while red areas exceed the permissible limit of 600 mg/L.

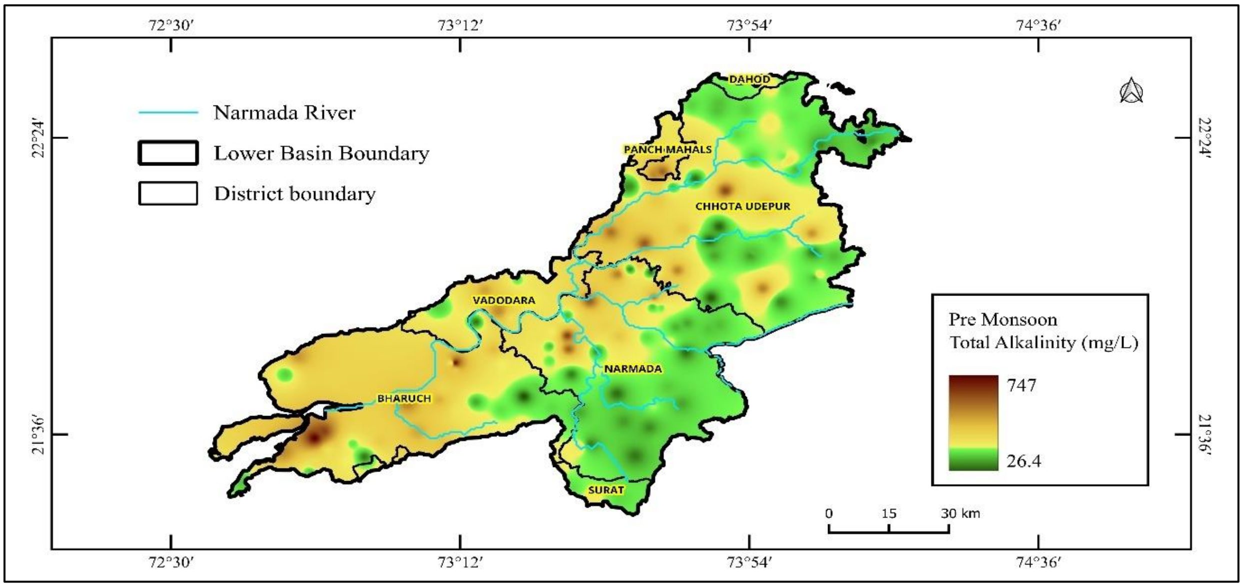


Figure 146 Spatial representation of Total Alkalinity values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows fewer high-Total Alkalinity (red and yellow) zones and more widespread green, suggesting reduction in Total Alkalinity conditions following monsoon recharge. It is also observed that locations within the limit have decreased in value and stayed under the limit while some of the locations have decreased in value but not enough to be below the permissible limit. But it was seen that on an average the values of alkalinity increased by 8% in the post monsoon season. Most of the hotspots are located in the comparatively downstream region of the basin.

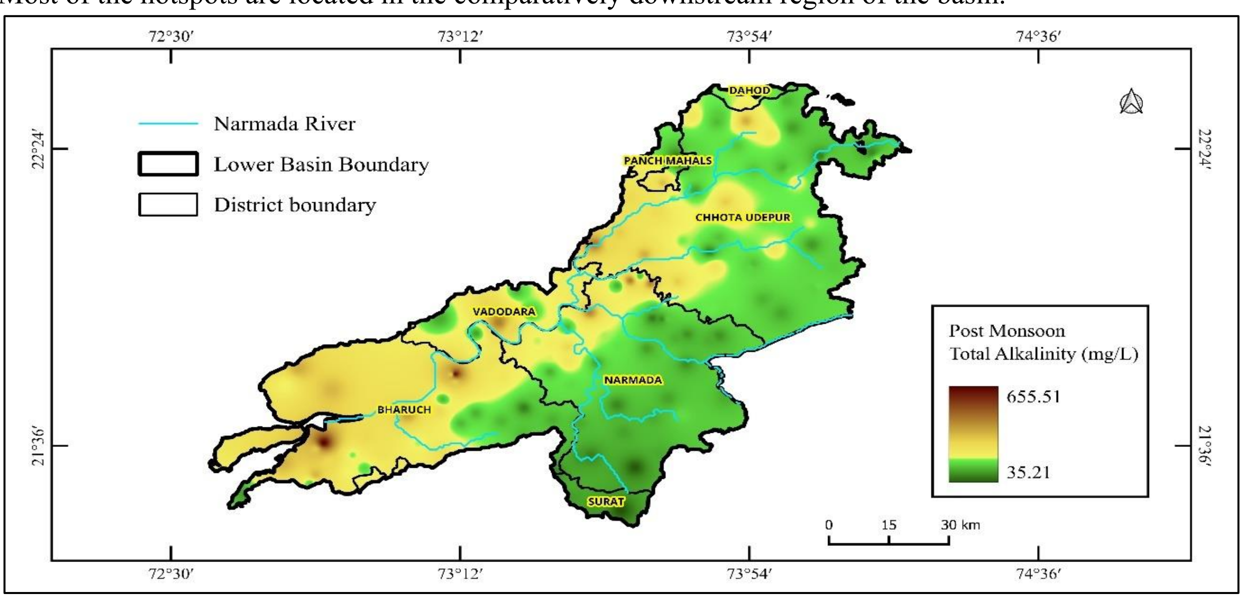


Figure 147 Spatial representation of Total Alkalinity values across the lower narmada basin in the 2024 post monsoon period.

v.) Chloride

The BIS requirement (Acceptable Limit) for Chlorides is 250 mg/L and the Permissible Limit in Absence of Alternate Source is 1000 mg/L. Across the network of 143 monitoring stations, the highest average Chloride value for 2022–2024 was 2803 mg/L at station HPII_BRH_004, while the single highest observed value was 4797 at station G_2_BHR_005. 12(8%) stations show exceedance of permissible limit in terms of either pre or post-monsoon 2024 values which are represented in table 4.3.H . 9(6%) sites have values above the 250 limit in both 2022-2024 average as well as in post-monsoon 2024 and are represented in table 4.3.I . The pre monsoon average Chloride value was 332 mg/L , with a standard deviation of 713 mg/L, while the average post monsoon Chloride value was 305 mg/L with a standard variation of 745 mg/L. It was seen that on an average the values of Chloride dropped by 3.55% in the post monsoon season.

The pre-monsoon Chloride map shows groundwater Chloride values across the Lower Narmada Basin prior to the monsoon. Green areas are E.C. ≤ 250 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 250 mg/L (acceptable limit) and 1000 mg/L (permissible limit) while red areas exceed the permissible limit of 1000 mg/L.

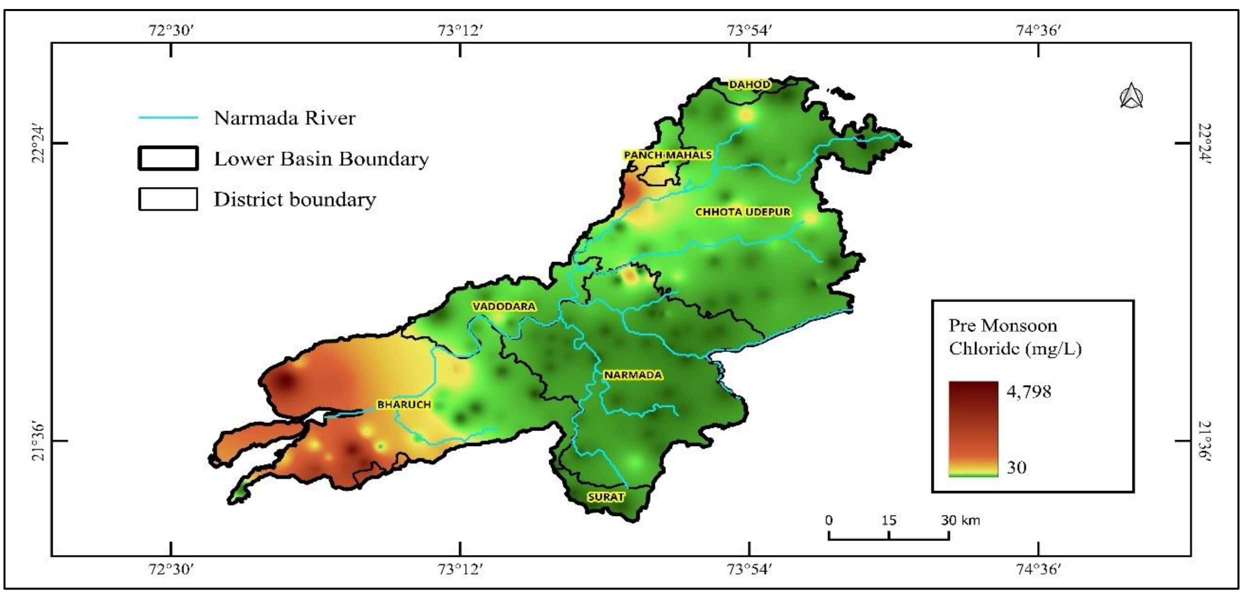


Figure 148 Spatial representation of Chloride values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map does not noticeably represent fewer high-Chloride (red or yellow) zones and it is observed that values of much locations within the limit have decreased in value and stayed under the limit. While most of the locations above or below the limit have not decreased significantly in value but also there is seen an increase in value of chloride in few locations. Most of the hotspots are located in the comparatively downstream region of the basin along with some regions of Chhota Udepur in upstream.

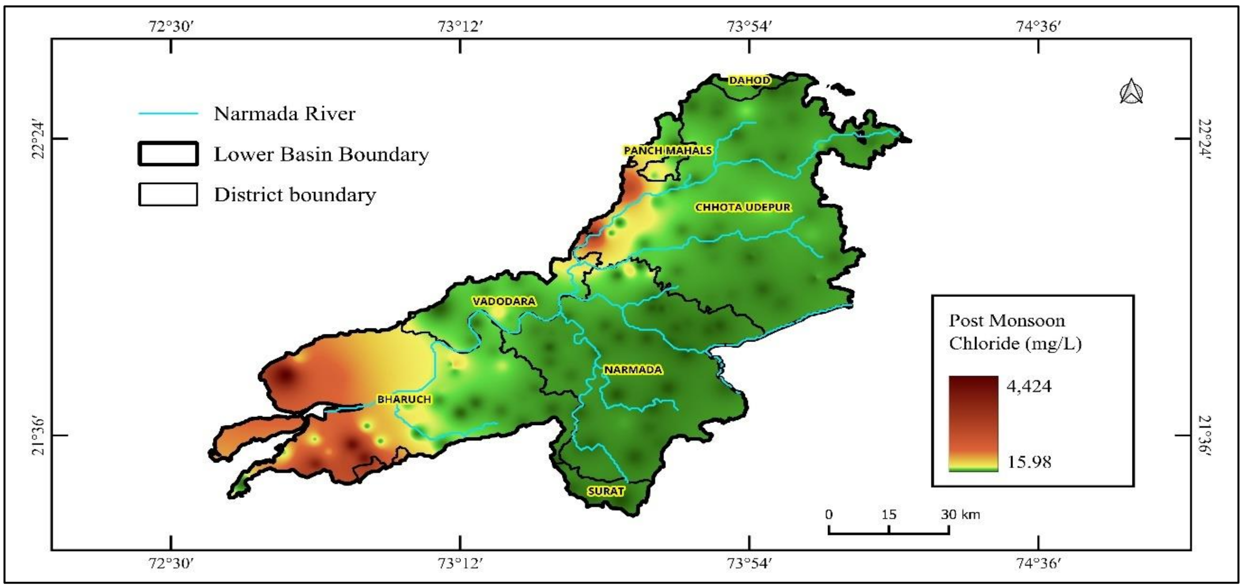


Figure 149 Spatial representation of Chloride values across the lower narmada basin in the 2024 post monsoon period.

vi.) Nitrate (No_3)

The BIS standard limit value for Nitrate is 45 mg/L. Across the network of 143 monitoring stations, the highest average Nitrate value for 2022–2024 was 10.6 mg/L at station NHP_CHU_009, while the single highest observed value was 14.2 mg/L at station SBRHPz-04. All of the wells are well below the permissible limit of 45mg/L. The pre monsoon average Nitrate value was 3.93 mg/L, with a standard deviation of 3.75 mg/L, while the average post monsoon Nitrate value was 5.07 mg/L with a standard variation of 4.51 mg/L.

The pre-monsoon Nitrate map shows groundwater Nitrate values across the Lower Narmada Basin prior to the monsoon in a spectrum of green (Nitrate < 45 within BIS limit).

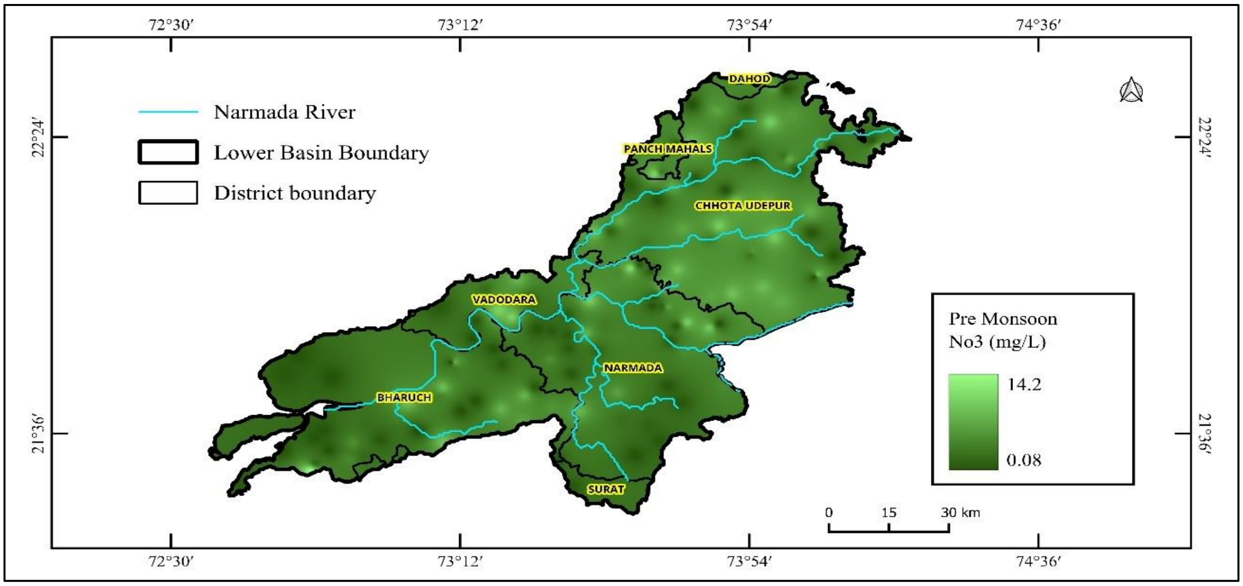


Figure 150 Spatial representation of Nitrate as No3 values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows lesser lower nitrate (greener) zones, suggesting a massive increase in nitrate conditions following post monsoon. Most of the hotspots are located in the comparatively upstream region of the basin.

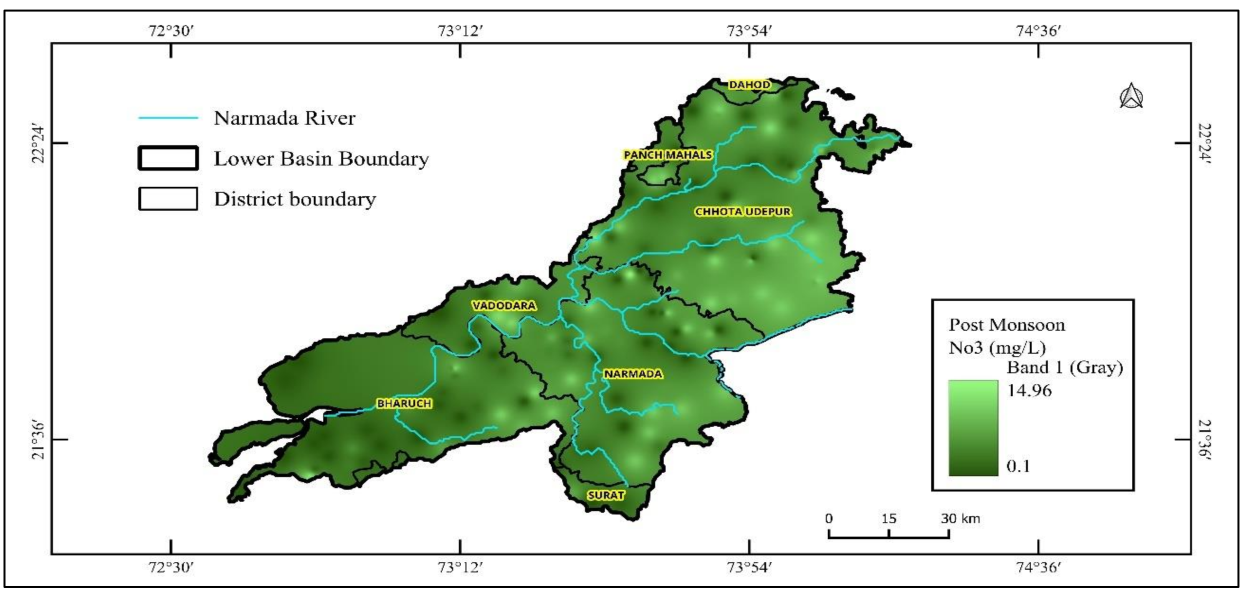


Figure 151 Spatial representation of Nitrate as No3 values across the lower narmada basin in the 2024 post monsoon period.

vii.) Sulphate (so4)

The BIS requirement (Acceptable Limit) for Sulphate is 200 mg/L and the Permissible Limit in Absence of Alternate Source is 400 mg/L. Across the network of 143 monitoring stations, the highest average Sulphate value for 2022–2024 was 648 mg/L at station SBRHPz-04, while the single highest observed value was 262 at station SBRHPz-04. Only 1 station (SBRHPz-04) went above the bis acceptable limit of 200 mg/L in 2024 pre monsoon and eventually reduced to 162 mg/L in 2024 post monsoon, indicating that all of the basin in well below the acceptable limit. The pre monsoon average sulphate value was 36.9 mg/L, with a standard deviation of 39.23 mg/L, while the average post monsoon Chloride value was 40.5 mg/L with a standard variation of 32.3 mg/L. It was seen that on an average the values of Sulphate increased by 86% in the post monsoon season.

The pre-monsoon map shows groundwater Sulphate values across the Lower Narmada Basin prior to the monsoon in a spectrum of green (within BIS acceptable limit of 200) and yellow spectrum represents area with values between 200 (acceptable limit) and 400 (permissible limit).

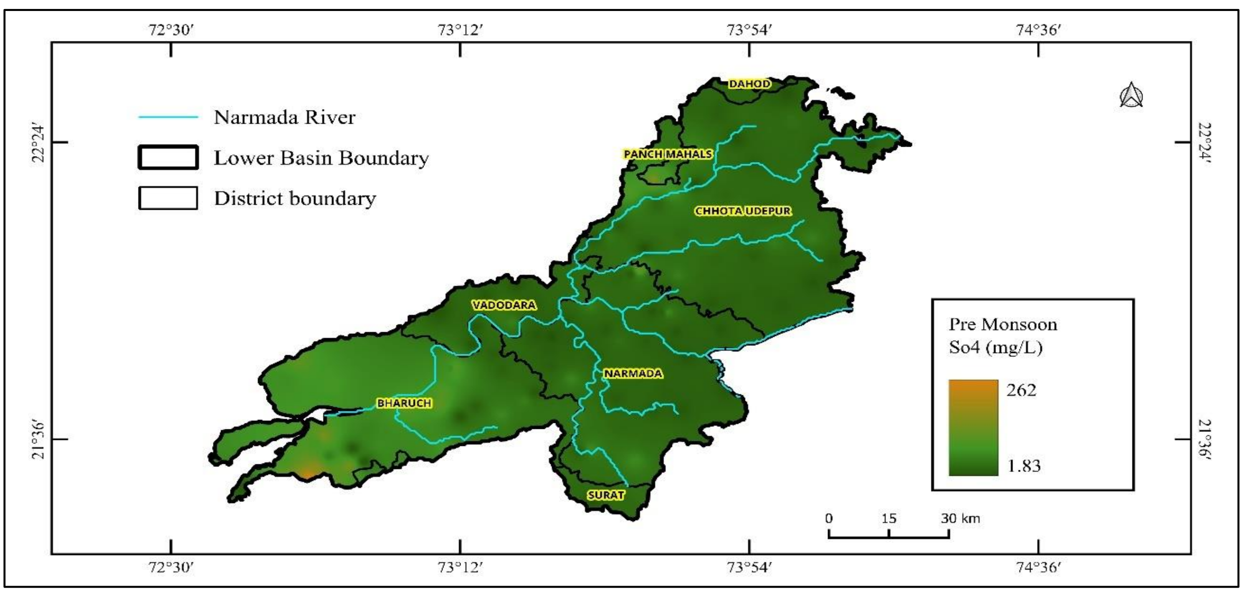


Figure 152 Spatial representation of Sulphate values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows lesser lower sulphate (greener) zones, suggesting a overall increase in sulphate conditions following post monsoon.

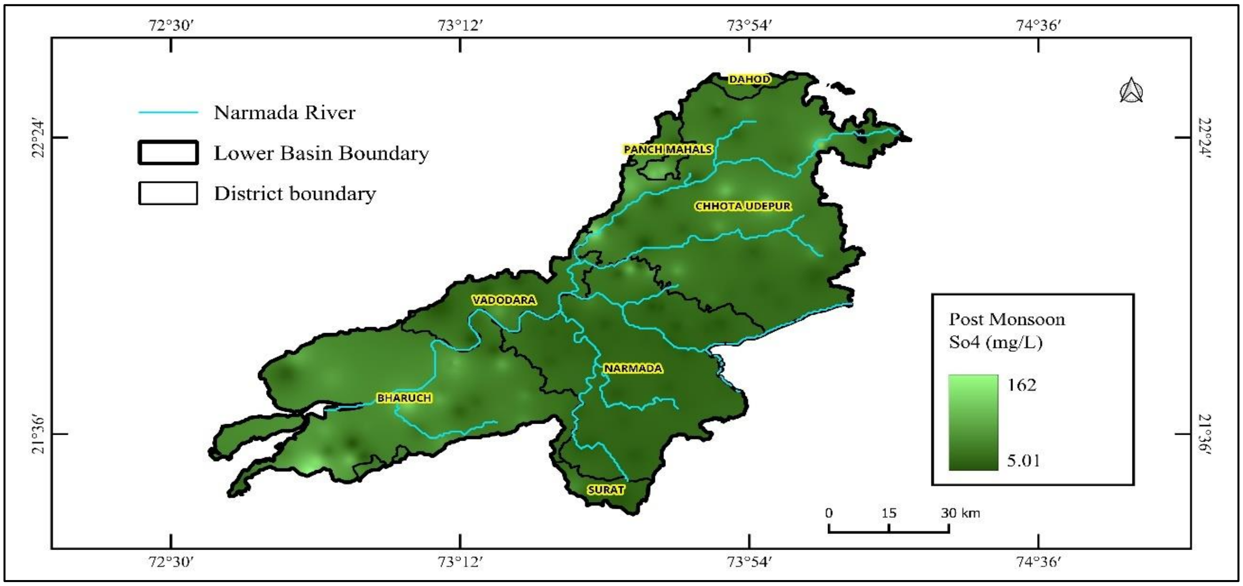


Figure 153 Spatial representation of Sulphate values across the lower narmada basin in the 2024 pre monsoon period.

viii.) Fluoride

The BIS requirement (Acceptable Limit) for Fluoride is 1 mg/L and the Permissible Limit in Absence of Alternate Source is 1.5 mg/L. Across the network of 143 monitoring stations, the highest average Fluoride value for 2022–2024 was 1.76 mg/L at station SVADPz-07, while the single highest observed value was 1.97 at station SVADPz-07. In the 2024 seasonal samples, 37(26%) stations recorded Fluoride values above the acceptable 1 limit in the pre-monsoon sampling, of which 10 (7%) stations remained above the limit even after the post monsoon recharge, but there were total of 34(24%) stations which were above the acceptable limit and are represented in table 4.3.J . This shows additional 24 stations jumped from below limit to above acceptable limit. The pre monsoon average Fluoride value was 0.87 mg/L, with a standard deviation of 0.47 mg/L, while the average post monsoon Fluoride value was 0.65 mg/L with a standard variation of 0.43 mg/L. It was seen that on a average the values of Fluoride increased by 22% in the post monsoon season.

The pre-monsoon Fluoride map shows groundwater Fluoride values across the Lower Narmada Basin prior to the monsoon. Green areas are Fluoride ≤ 1 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 1 mg/L (acceptable limit) and 1.5 mg/L (permissible limit) while red areas exceed the permissible limit of 1.5 mg/L. Most of the hotspots are located in the comparatively upstream region of the basin.

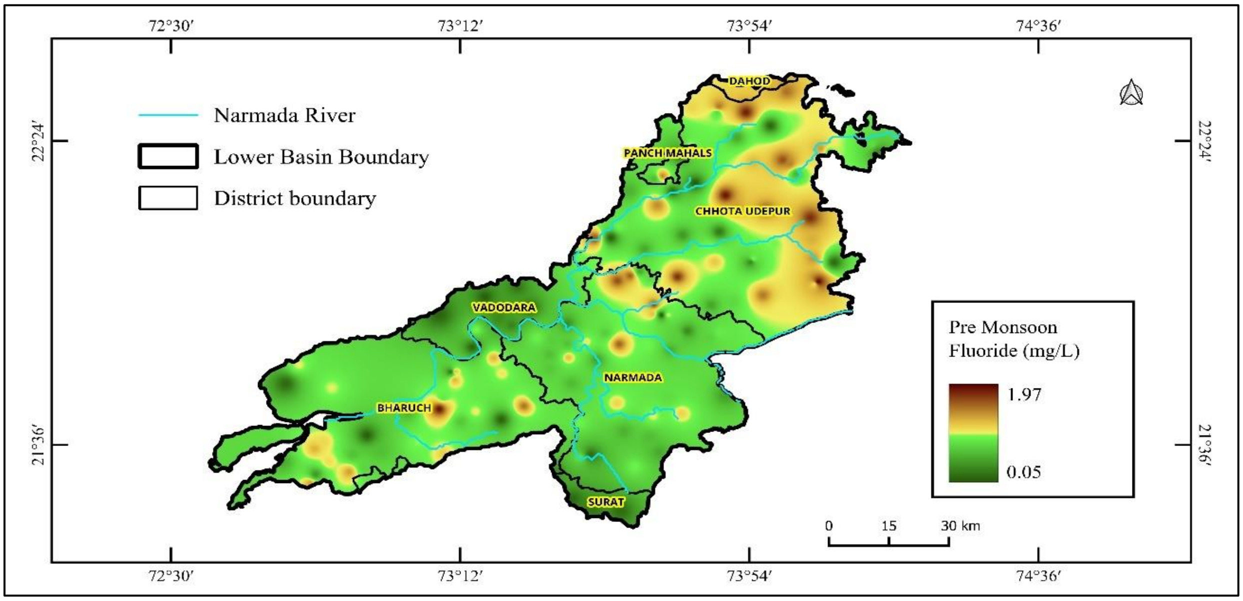


Figure 154 Spatial representation of Fluoride values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high-Fluoride (yellow) zones, eliminating the red zones as there are no locations above the permissible limit and more widespread green areas. But statistically it is also observed that some locations within the limit have decreased in value and some have increased and exceeded the acceptable limit, while some of the locations have decreased in value but not enough to be below the limit.

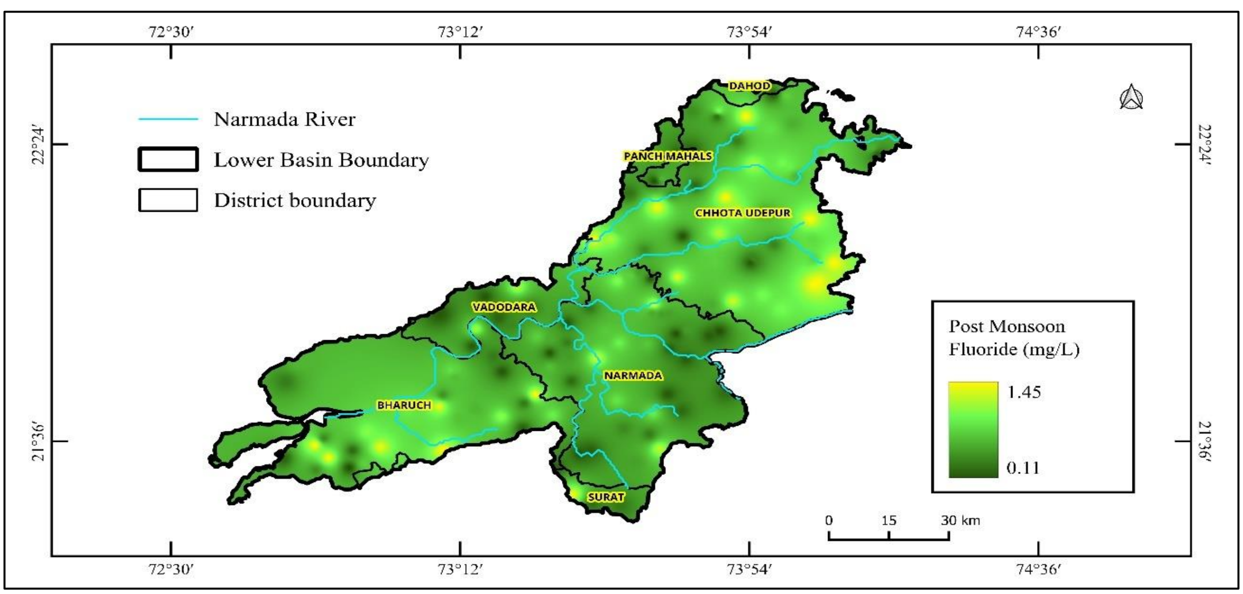


Figure 155 Spatial representation of Fluoride values across the lower narmada basin in the 2024 post monsoon period.

ix.) Total Hardness

The BIS requirement (Acceptable Limit) for Total Hardness is 200 mg/L and the Permissible Limit in Absence of Alternate Source is 600 mg/L. Across the network of 143 monitoring stations, the highest average electrical conductivity for 2022–2024 was 943 mg/L at station SVADPz-34, while the single highest observed value was 1586 at station SVADPz-34. 14(10%) stations show exceedance of permissible limit in terms of either post-monsoon 2024 or average of 2022-2024 values and are represented in table 4.3.K . In the 2024 seasonal samples, 87(60%) stations recorded Hardness values above the limit in the pre-monsoon sampling, of which 39 (27%) stations remained above the limit even after the post monsoon recharge, but there were total of 47(33%) stations which were above the acceptable limit and are represented in table 4.3.L . This shows additional 8 stations jumped from below limit to above acceptable limit. The pre monsoon average Hardness value was 354 mg/L, with a standard deviation of 279 mg/L, while the average post monsoon Hardness value was 248 mg/L with a standard deviation of 232 mg/L. It was seen that on an average the values of Hardness dropped by 18% in the post monsoon season.

The pre-monsoon total hardness map shows groundwater hardness values across the Lower Narmada Basin prior to the monsoon. Green areas are hardness ≤ 200 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 200 mg/L (acceptable limit) and 600 mg/L (permissible limit) while red areas exceed the permissible limit of 600 mg/L.

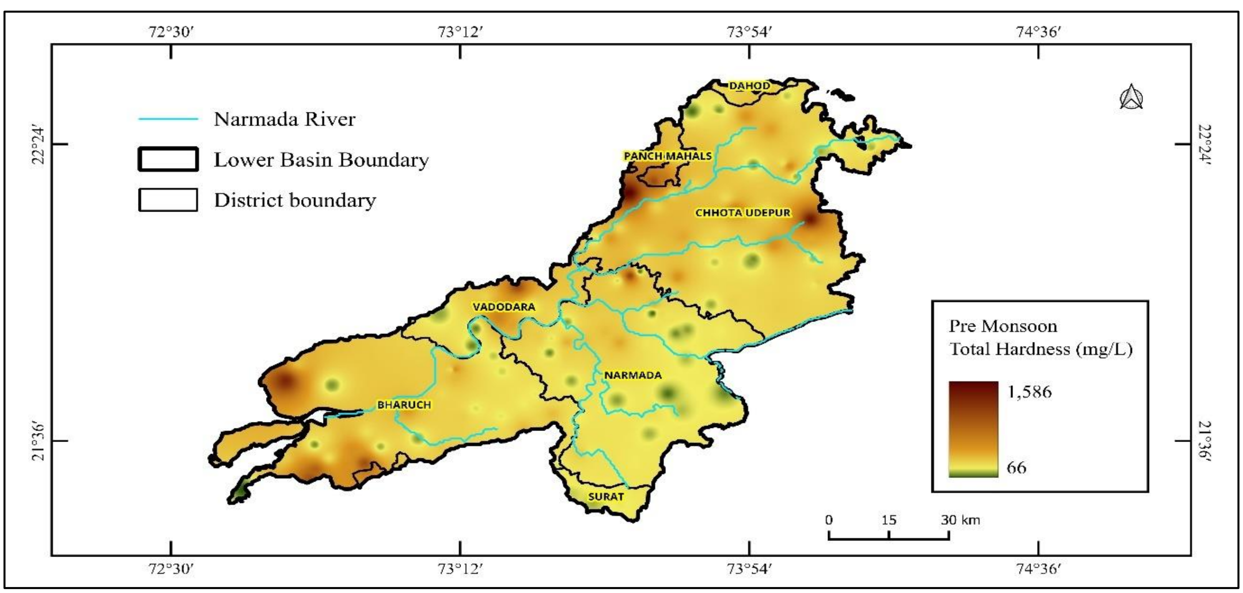


Figure 156 Spatial representation of Total Hardness values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high Hardness (yellow) zones and more widespread green, suggesting a basin-scale reduction in Total Hardness conditions following monsoon recharge. It is also observed that locations within the limit have decreased in value and stayed under the limit while some locations have increased and exceeded the acceptable limit and some of the locations have decreased in value but not enough to be below the limit.

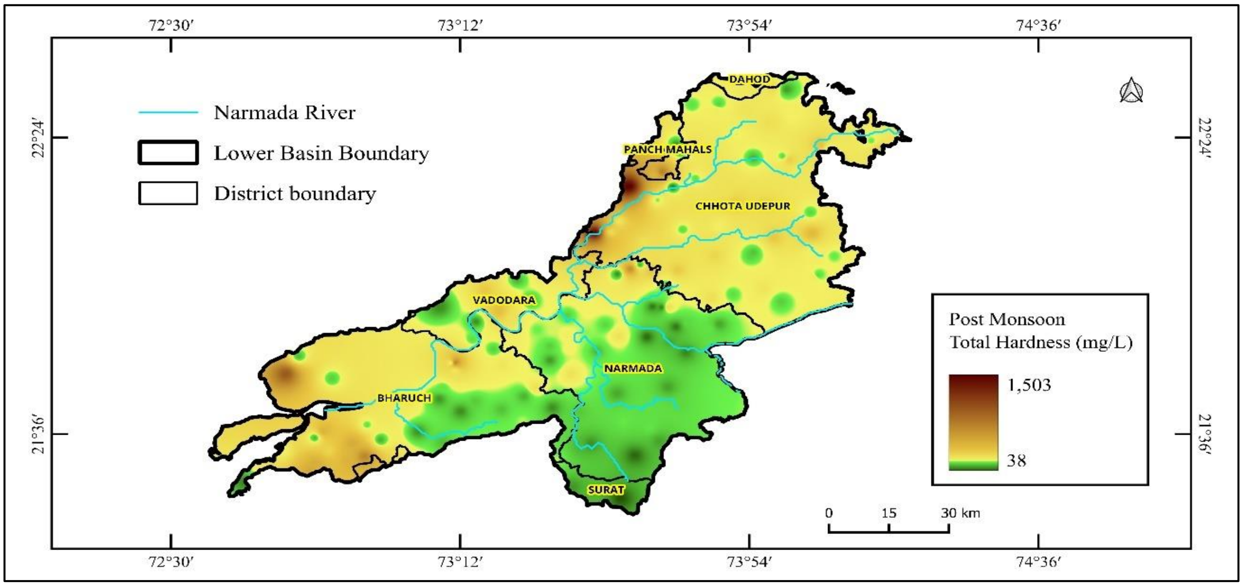


Figure 157 Spatial representation of Total Hardness values across the lower narmada basin in the 2024 post monsoon period.

x.) Calcium

The BIS requirement (Acceptable Limit) for Calcium is 75 mg/L and the Permissible Limit in Absence of Alternate Source is 200 mg/L. Across the network of 143 monitoring stations, the highest average Calcium for 2022–2024 was 149 mg/L at station NHP_CHU_009, while the single highest observed value was 379 at station NHP_CHU_009. 3 stations (G_2_BHR_005 – Avg. is 233 mg/L, NHP_CHU_009 – Post monsoon 24 value is 379 mg/L, SBRHPz-04 – Avg. is 230 mg/L) show exceedance of permissible limit values. In the 2024 seasonal samples, 31(21%) stations recorded Calcium values above the limit in the pre-monsoon sampling, of which 5 (40%) stations remained above the limit even after the post monsoon recharge, but there were total of 15(10%) stations which were above the acceptable limit and are represented in table 4.3.M . This shows additional 10 stations jumped from below limit to above acceptable limit. The pre monsoon average Calcium value was 50.32 mg/L, with a standard deviation of 38.61 mg/L, while the average post monsoon Calcium value was 43.25 mg/L with a standard deviation of 38.78 mg/L.

The pre-monsoon Calcium map shows groundwater Calcium values across the Lower Narmada Basin prior to the monsoon. green areas are Calcium ≤ 75 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 75 mg/L (acceptable limit) and 200 mg/L (permissible limit) while red areas exceed the permissible limit of 200 mg/L.

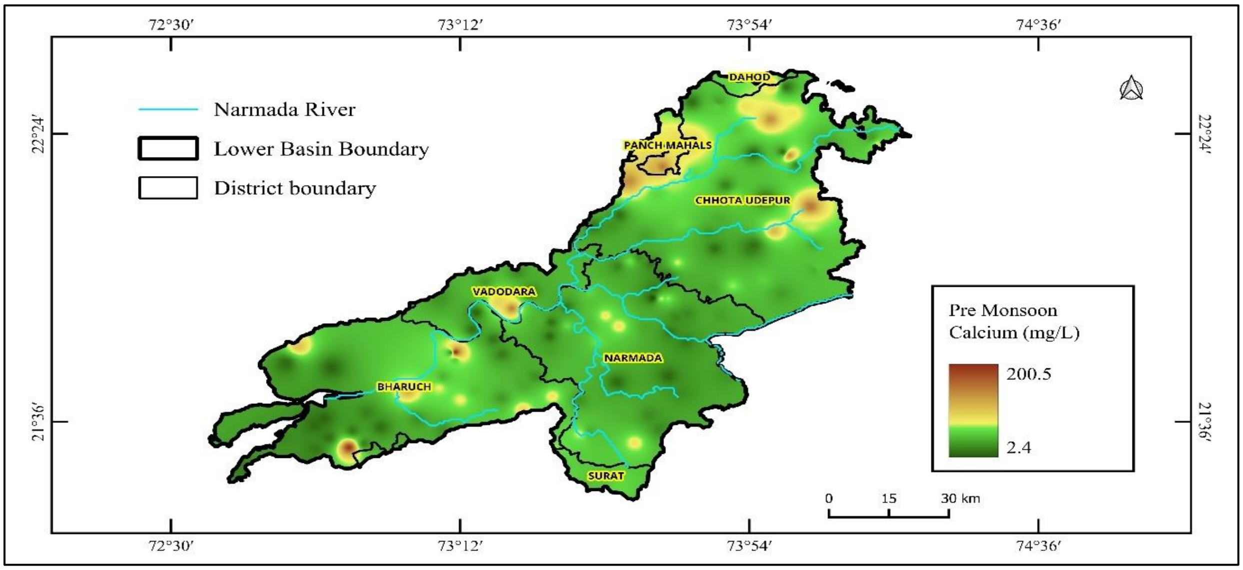


Figure 158 Spatial representation of Calcium values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high Calcium (yellow) zones but also less darker green, suggesting a basin-scale increase in Calcium conditions following monsoon recharge. It is also observed that locations within the limit have decreased in value and stayed under the limit while many of the locations increased in value but remained below the acceptable limit and some have decreased in value but not enough to be below the limit.

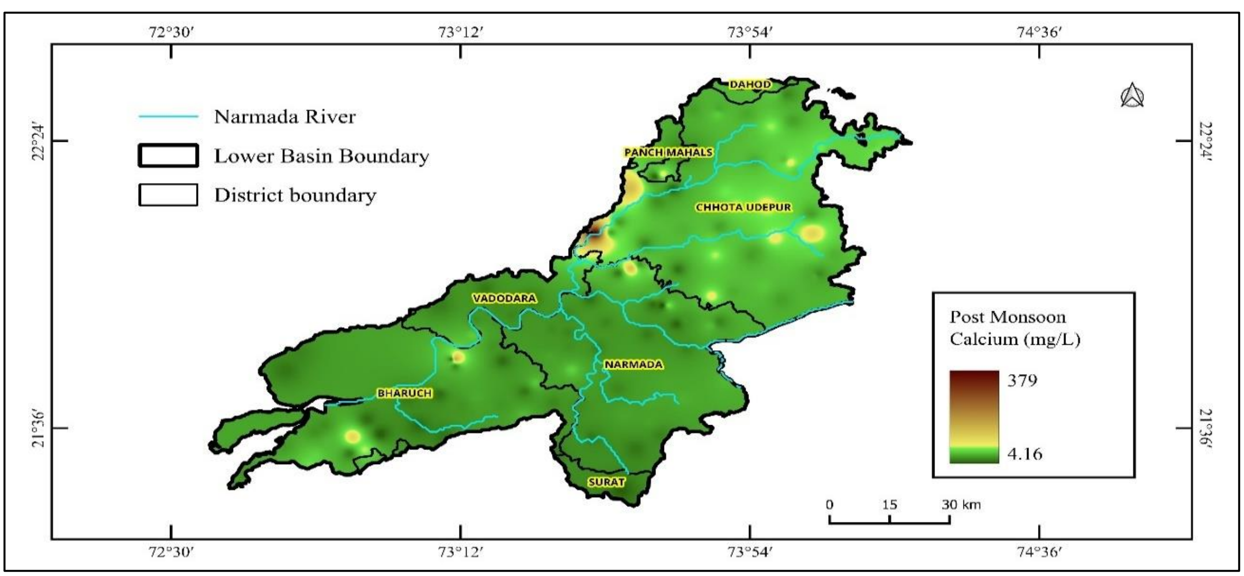


Figure 159 Spatial representation of Calcium values across the lower narmada basin in the 2024 post monsoon period.

xi.) Magnesium

The BIS requirement (Acceptable Limit) for Magnesium is 30 mg/L and the Permissible Limit in Absence of Alternate Source is 100 mg/L. Across the network of 143 monitoring stations, the highest average Magnesium value for 2022–2024 was 230 mg/L at station G_2_BHR_005, while the single highest observed value was 312 mg/L at station G_2_BHR_005. 8(6%) stations show exceedance of permissible limit in terms of either pre or post monsoon 2024 or average of 2022-2024 values and are represented in table 4.3.N . In the 2024 seasonal samples, 80(56%) wells recorded magnesium values above the acceptable 30 mg/L limit in the pre-monsoon sampling, of which 29 (20%) stations remained above the limit even after the post monsoon recharge, but there were total of 37(26%) stations which were above the acceptable limit and are represented in table 4.3.O . This shows additional 8 stations jumped from below limit to above acceptable limit. The pre monsoon average Magnesium value was 55.6 mg/L , with a standard deviation of 59.5 mg/L, while the average post monsoon Magnesium value was 34.12 mg/L with a standard deviation of 42 mg/L. It was seen that on an average the values of Magnesium decreased by 22% in the post monsoon season.

The pre-monsoon Magnesium map shows groundwater Magnesium values across the Lower Narmada Basin prior to the monsoon; green areas are Magnesium ≤ 30 mg/L (within BIS acceptable limit), yellow spectrum represents areas with values between 30 mg/L (acceptable limit) and 100 mg/L (permissible limit) while red areas exceed the permissible limit of 100 mg/L.

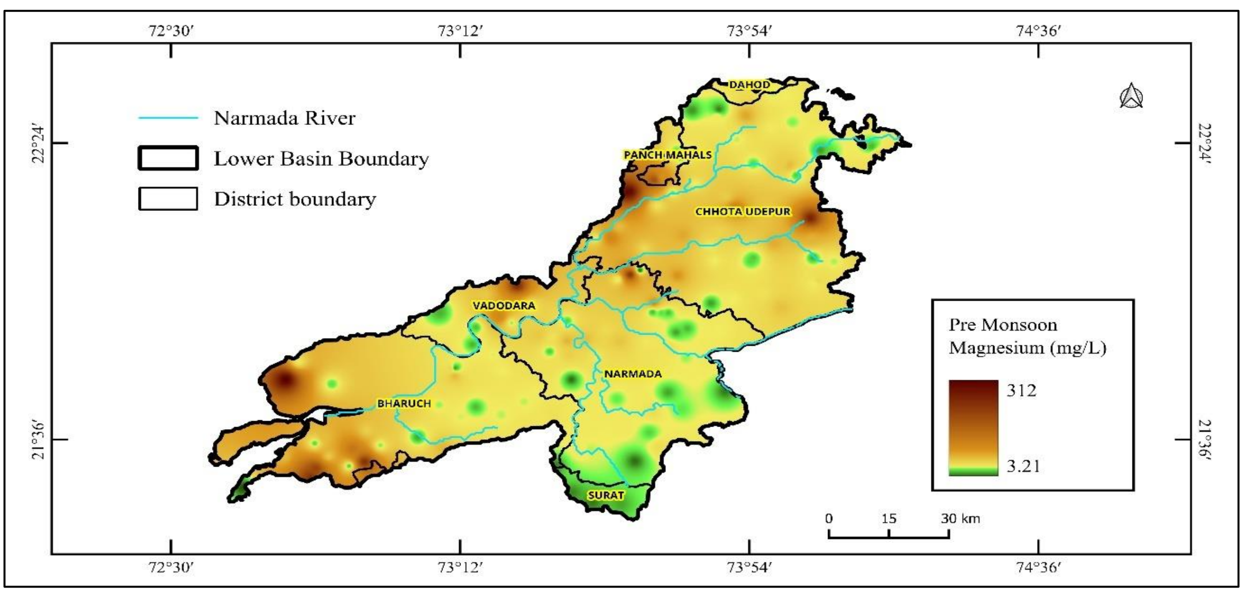


Figure 160 Spatial representation of Magnesium values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high-T.D.S. (red and yellow) zones and more widespread green. It is also observed that locations within the limit have decreased in value and stayed under the limit. While some of the locations have increased in value, some have decreased in value but not enough to be below the limit.

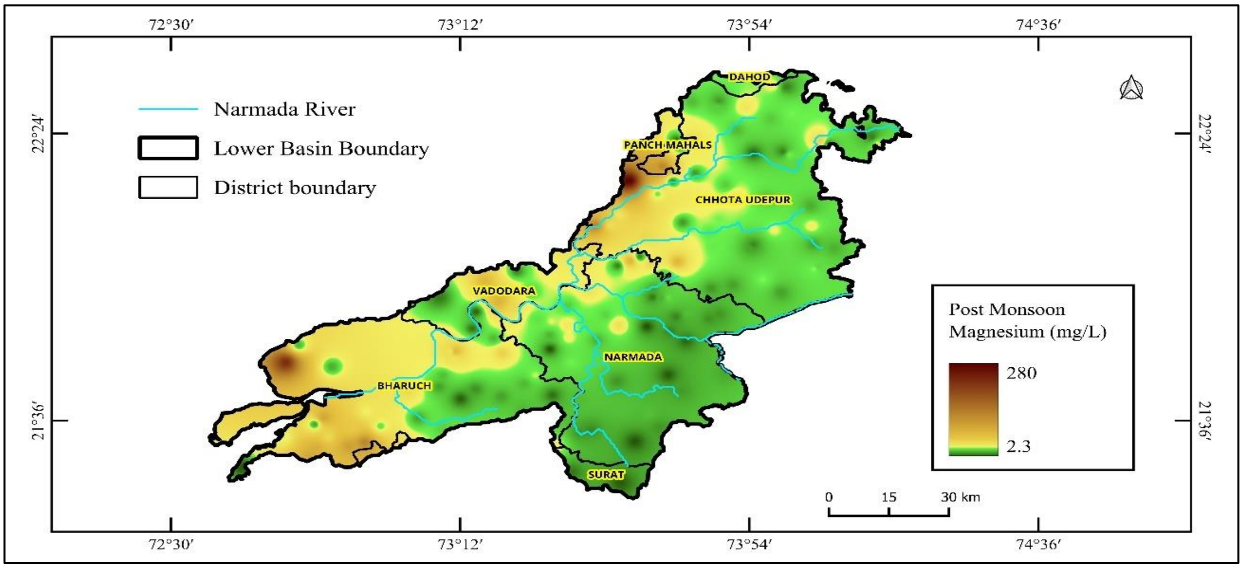


Figure 161 Spatial representation of Magnesium values across the lower narmada basin in the 2024 post monsoon period.

xii.) Sodium

The BIS IS 10500:2012 does not describe any specific drinking water limit for Sodium and so does the 'Guidelines for drinking-water quality Fourth edition' by World Health Organisation. Hence reference value for standard limit for Sodium is taken from 'European Union (Drinking Water) Regulations 2023' which states the limit at 200 mg/L. Across the network of 143 monitoring stations, the highest average sodium level for 2022–2024 was 1919 mg/L at station HPII_BRH_004, while the single highest observed value was 3288 at station NHP_BRH_008. In the 2024 seasonal samples, 42 stations (29%) recorded sodium values above the limit in the pre-monsoon sampling, of which 24 (17%) stations remained above the limit even after the post monsoon recharge which show persistent exceedance as their 2022–2024 average as well as post-monsoon 2024 values are above the BIS limit. But there were total of 34(24%) stations which were above the acceptable limit and are represented in table 4.3.P . This shows additional 10 stations jumped from below limit to above acceptable limit. The pre monsoon average Sodium value was 232 mg/L, with a standard deviation of 472 mg/L, while the average post monsoon Sodium value was 179 mg/L with a standard deviation of 334 mg/L. It was seen that on an average the values of Sodium dropped by 7% in the post monsoon season.

The pre-monsoon sodium map shows groundwater sodium values across the Lower Narmada Basin prior to the monsoon; green areas are Sodium ≤ 200 (within E.U. limit), while red areas exceed the permissible limit.

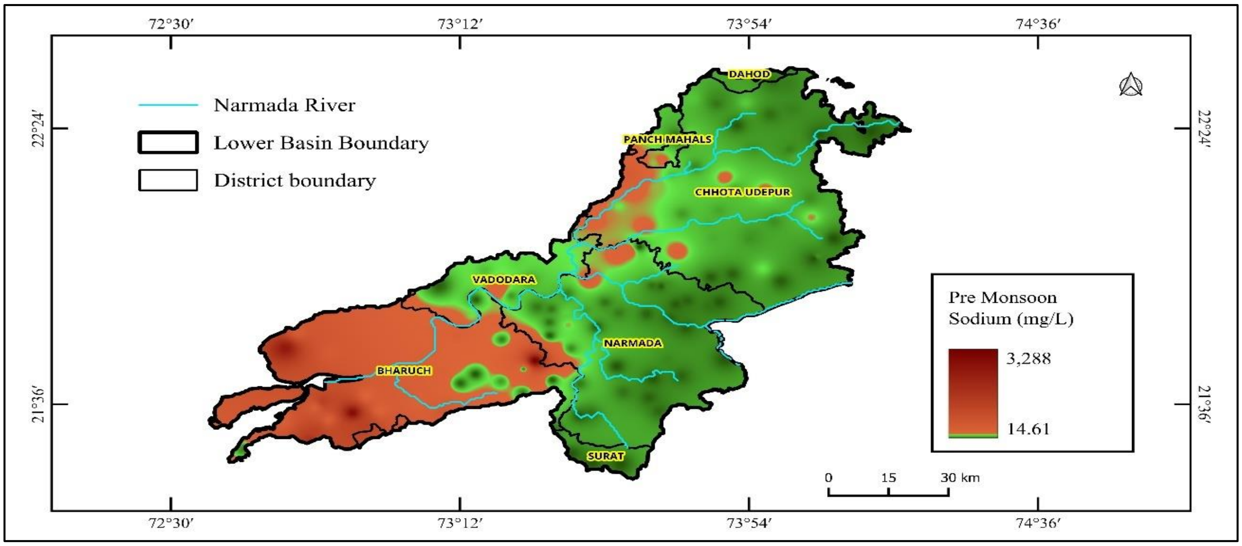


Figure 162 Spatial representation of Sodium values across the lower narmada basin in the 2024 pre monsoon period.

Compared with pre-monsoon, the post-monsoon map shows noticeably fewer high sodium (red) zones and more widespread green, suggesting a basin-scale reduction in sodium conditions following monsoon recharge. It is also observed that locations within the limit have decreased in value and stayed under the limit, many locations decreases below the limit, while some of the locations have decreased in value but not enough to be below the limit. Most of the hotspots are located in the comparatively downstream region of the basin.

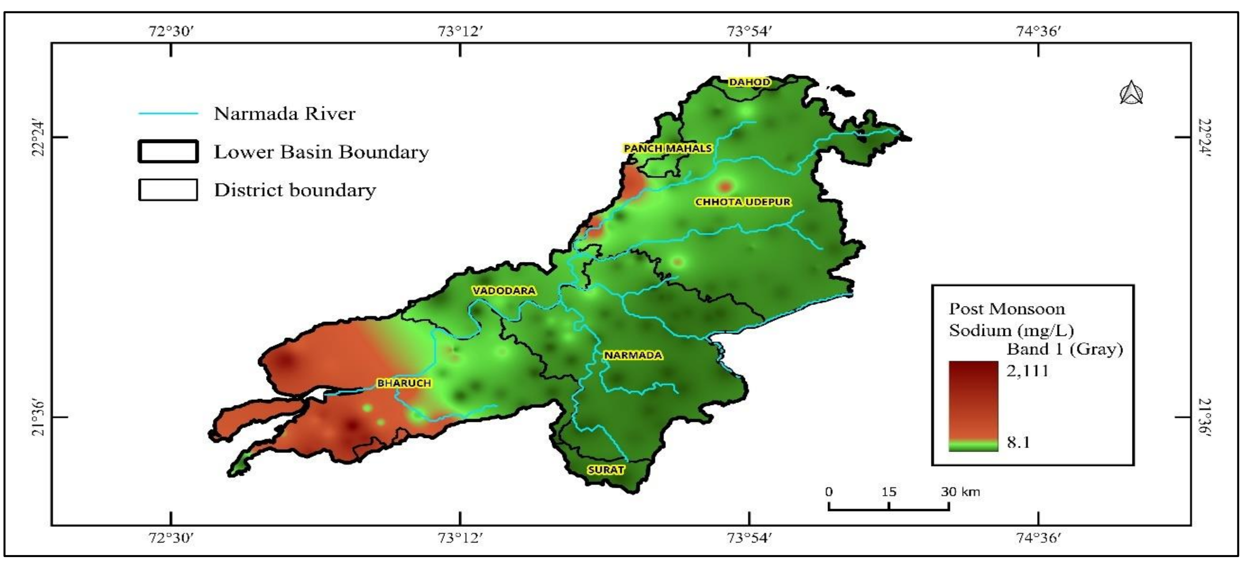


Figure 163 Spatial representation of Sodium values across the lower narmada basin in the 2024 post monsoon period.

Overall characteristic condition of Lower Narmada basin

The Characteristic Number (CN) for each station was computed by normalizing the measured value of 12 parameters (pH, EC, TDS, Total Alkalinity, Chloride, NO_3, SO_4, Fluoride, Total Hardness, Ca, Mg, Na) against the BIS 10500 acceptable limits, giving equal weight to each parameter. Pre and post-monsoon Characteristic Number were interpolated using IDW to produce spatial rasters, and a per well average CN was calculated from the two seasons. Higher CN values indicate a greater cumulative exceedance of acceptable limits and therefore higher priority for remedial action.

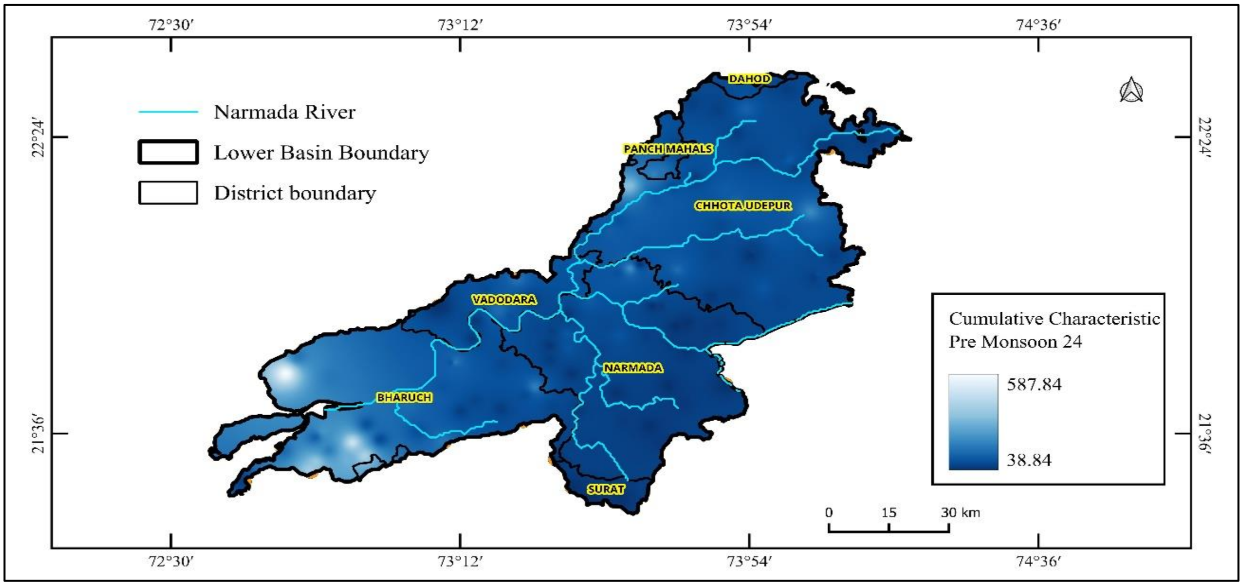


Figure 164 Spatial representation of Cumulative Characteristic Number values across the lower narmada basin in the 2024 pre monsoon period.

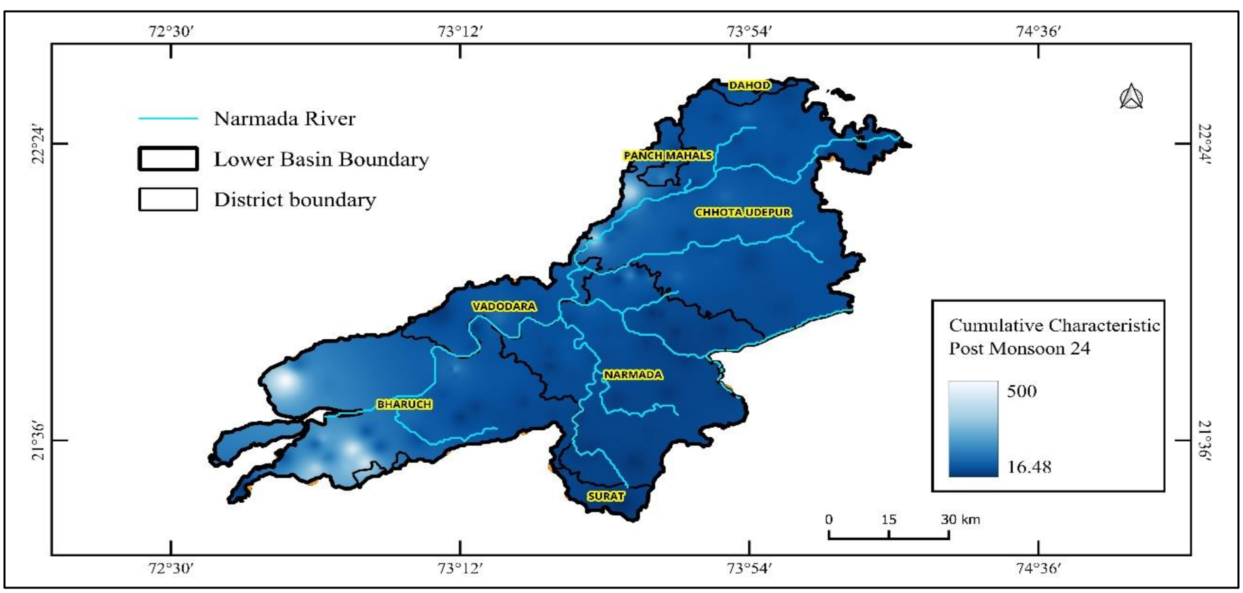


Figure 165 Spatial representation of Cumulative Characteristic Number values across the lower narmada basin in the 2024 post monsoon period.

The pre-monsoon CN map illustrates the spatial distribution of cumulative characteristic water quality over the year 2024. Areas with high CN represent wells where multiple parameters most strongly exceed BIS acceptable limits and therefore demand urgent attention. Well wise ranking table is represented in table.

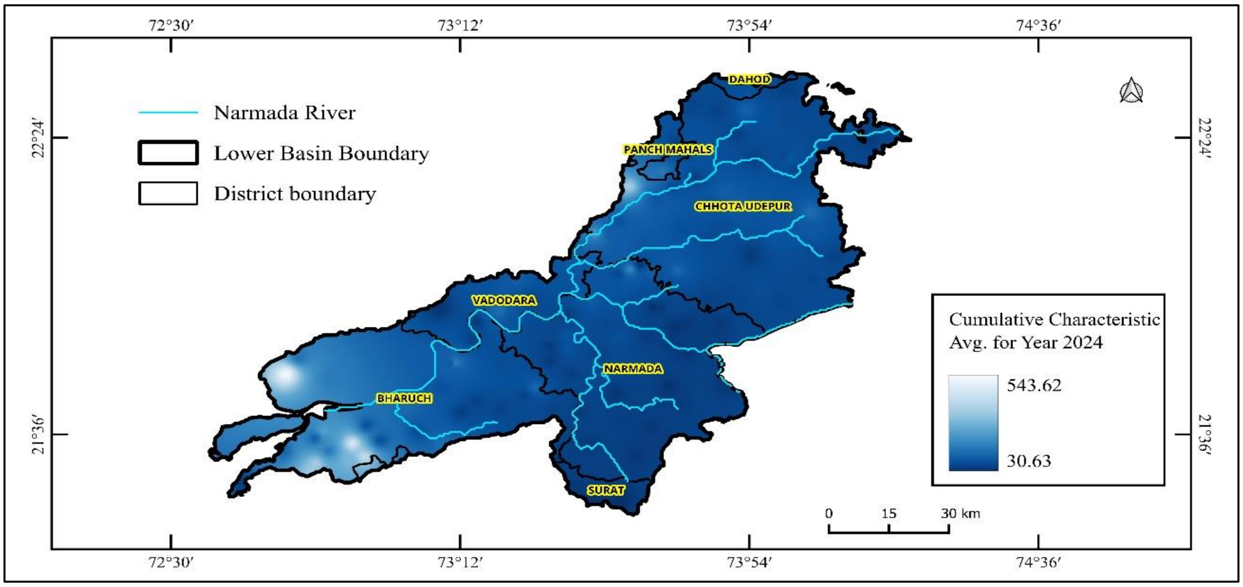


Figure 166 Spatial representation of Average Cumulative Charateristic Number values across the lower narmada basin for the year 2024.

Table 11 represents the wells in order of unacceptable characteristic parameters to acceptable characteristic parameters, by assigning equal weightage to each parameter present in the well.

Table 11 Ranking of wells on the basis of increasing water qualiyt characteristic number.

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
1	G_2_BHR_005	Bharuch	Vagra	Sadathala	72.77889	21.76222	Alluvium	42.18	543.51
2	HPII_BRH_004	Bharuch	Anklesvar	Adol	72.94028	21.57556	Alluvium	57.17	463.39
3	HPII_BRH_006	Bharuch	Anklesvar	Panoli	72.96917	21.53972	Alluvium	56.93	413.58
4	G_1_BRH_011	Bharuch	Hansot	Valner	72.85111	21.52222	Alluvium	27	360.30
5	SBRHPz-04	Bharuch	Hansot	Sunevkalla	72.83806	21.49861	Alluvium	23.75	355.54

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
6	NCCA-028A	Chhota Udepur	Sankheda	Laved	73.61166	22.26889	Basalt	60	349.62
7	SVADPz-34	Chhota Udepur	Bodeli	Laved	73.605	22.2675	Basalt	60	349.62
8	HPII_BRH_005	Bharuch	Anklesvar	Karmali	72.93166	21.52889	Alluvium	59.06	298.82
9	G_1_BRH_005	Bharuch	Anklesvar	Matied	72.87083	21.60861	Alluvium	40.19	240.48
10	NHP_CHU_009	Chhota Udepur	Sankheda	Vadadli	73.52639	22.14333	Basalt	45	216.77
11	BD-58	Narmada	Tilakwada	Namaria	73.61195	22.04528	Basalt	18.58	187.70
12	NHP_BRH_005	Bharuch	Jhagadia	Jarsad	73.18889	21.79333	Alluvium	45	175.76
13	G_1_BRH_006	Bharuch	Anklesvar	Motwan	72.8825	21.55583	Alluvium	32.1	162.40
14	G_2_BHR_007	Bharuch	Vagra	Vilayat	72.89	21.75	Alluvium	42.19	162.38
15	PM-045	Panchmahals	Jambughoda	Duma	73.69	22.30778	Phyllite Schist	10	158.98
16	G_2_PMS_004	Panchmahals	Jambughoda	Duma	73.67	22.3	Phyllite Schist	60	155.72
17	G_2_BHR_006	Bharuch	Vagra	Sutrel	72.81	21.81	Alluvium	42.14	145.98
18	G_2_VAD_015	Chhota Udepur	Kavant	Raypur	74.04778	22.19778	Basalt	60	137.56
19	BR-60	Bharuch	Jhagadia	Valia	73.15916	21.57722	Basalt	15.53	135.61
20	NCCA-041A	Vadodara	Sinor	Surasamal	73.29389	21.93472	Alluvium	76.22	135.33
21	SVADPz-27	Vadodara	Sinor	Surasamal	73.29389	21.93139	Alluvium	76.22	135.33
22	BR-20	Bharuch	Jhagadia	Mulad	73.07361	21.68389	Alluvium	15	132.68
23	SVADPz-30	Chhota Udepur	Nasvadi	Nasvadi	73.72639	22.04222	Sandstone	90	128.78
24	NHP_BRH_008	Bharuch	Netrang	Vankol	73.3825	21.72639	Basalt	45	126.57
25	G_1_BRH_010	Bharuch	Hansot	Vansnoli	72.77306	21.55472	Alluvium	32.08	119.86
26	BD-40	Chhota Udepur	Jetpur-pavi	Kalarani	73.8675	22.22361	Alluvium	11.15	116.22

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
27	NHP_CHU_001	Chhota Udepur	Jetpur-pavi	Kundal	73.89194	22.475	Basalt	60	115.80
28	G_1_BRH_009	Bharuch	Hansot	Shera	72.84917	21.59028	Alluvium	33.02	113.68
29	G_2_NMR_018	Narmada	Tilakwada	Agar	73.66167	22.03778	Basalt	60	112.06
30	G_2_VAD_007	Chhota Udepur	Jetpur-pavi	Chhotanagar	73.84278	22.25667	Granite	60	111.58
31	SVADPZ-28	Vadodara	Sinor	Chhanbhoi	73.33889	22.01583	Alluvium	65.8	109.77
32	BR-16	Bharuch	Jhagadia	Avidha	73.18777	21.77111	Alluvium	21.05	105.29
33	SBRHPz-06	Narmada	Nandod	Jiyor	73.51417	21.95944	Alluvium	39.8	104.02
34	NCCA-026	Chhota Udepur	Sankheda	Handod	73.56528	22.14528	Alluvium	26.47	103.33
35	PM-046	Panchmahals	Jambughoda	Kanjipani	73.7575	22.38111	Phyllite Schist	10.55	100.15
36	NHP_CHU_008	Chhota Udepur	Sankheda	Ladhod	73.67805	22.23139	Basalt	45	99.00
37	BD-11	Chhota Udepur	Kavant	Dungargam	74.05139	22.14167	Basalt	14.95	98.18
38	G_2_VAD_011	Chhota Udepur	Jetpur-pavi	Nani Amrol	73.94	22.22	Basalt	60	97.19
39	BR-24	Bharuch	Jhagadia	Prakhad	73.17778	21.79222	Alluvium	18.3	96.80
40	BR-29	Bharuch	Jhagadia	Wanthewad	73.15	21.69444	Basalt	11.25	95.25
41	NCCA-030A	Chhota Udepur	Sankheda	Indral	73.64639	22.11472	Sandstone	36.88	92.00
42	NHP_CHU_003	Chhota Udepur	Kavant	Saidivasan	73.9975	22.33972	Basalt	60	91.41
43	G_2_VAD_014	Chhota Udepur	Kavant	Mankodi	73.96	22.13	Basalt	60	91.37
44	BR-48	Narmada	Nandod	Virpur	73.46	21.86611	Basalt	10.57	89.82
45	BD-31	Chhota Udepur	Nasvadi	Vadiya	73.69444	21.99833	Basalt	13	88.99
46	SBRHPz-22	Bharuch	Anklesvar	Anklesvar	72.975	21.625	Alluvium	41.46	88.99
47	NHP_CHU_010	Chhota Udepur	Sankheda	Vaghetha	73.67805	22.23139	Basalt	45	87.96

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
48	BR-36	Narmada	Nandod	Nana haidwa	73.46278	21.83	Basalt	9.35	87.21
49	BD-55	Vadodara	Sinor	Sinor	73.325	21.915	Alluvium	26.13	85.20
50	SVADPz-33	Chhota Udepur	Sankheda	Sankheda	73.58583	22.17389	Alluvium	38.39	82.99
51	G_1_BRH_004	Bharuch	Anklesvar	Kapodara	73.0075	21.58472	Alluvium	40.01	82.45
52	BR-37	Narmada	Garudeshwar	Nana zunda	73.58528	21.86528	Basalt	17.83	81.16
53	SBRHPz-10	Bharuch	Jhagadia	Jhagadia	73.15889	21.72528	Alluvium	36.41	80.93
54	BD-19	Chhota Udepur	Chhota udepur	Zoz	73.95139	22.44	Basalt	15	80.36
55	NHP_VAD_007	Vadodara	Sinor	Utaraj	73.26083	21.98861	Alluvium	60	80.18
56	NHP_CHU_002	Chhota Udepur	Kavant	Ambadungar	73.66972	21.96972	Basalt	75	80.15
57	BD-26	Chhota Udepur	Nasvadi	Dugdha	73.93305	21.99389	Basalt	9.32	77.99
58	NHP_BRH_006	Bharuch	Jhagadia	Rumalpura	73.28139	21.82917	Alluvium	45	77.63
59	SVADPz-07	Chhota Udepur	Kavant	Raisingpura	74.06695	22.02944	Basalt	30	75.73
60	G_2_PMS_005	Panchmahals	Jambughoda	Kanjipani	73.75694	22.3775	Phyllite Schist	60	75.73
61	NCCA-025A	Chhota Udepur	Sankheda	Desan	73.73889	22.15222	Phyllite Schist	60.97	75.56
62	BR-41	Narmada	Nandod	Rajpipla	73.50611	21.87139	Basalt	30.5	75.25
63	G_2_VAD_016	Chhota Udepur	Nasvadi	Damoli	73.81639	22.08194	Basalt	60	74.86
64	G_1_BRH_007	Bharuch	Anklesvar	Piprod	73.09834	21.60695	Alluvium	25.24	74.80
65	BR-28	Bharuch	Jhagadia	Waghpura	73.30222	21.78778	Alluvium	18.95	74.44
66	G_2_VAD_008	Chhota Udepur	Bodeli	Ferkuva	73.82722	22.16055	Basalt	60	71.09
67	G_2_VAD_002	Chhota Udepur	Chhota udepur	Padaliya	74.07222	22.38028	Granite	60	70.72
68	BR-38	Narmada	Garudeshwar	Navapara	73.38722	21.88167	Alluvium	10.82	70.66

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
69	SVADPz-36	Chhota Udepur	Kavant	Kavant	74.05444	22.09111	Basalt	60	69.03
70	BD-12	Chhota Udepur	Chhota udepur	Ferkuwa	74.21083	22.37139	Basalt	12.1	68.30
71	SVADPz-37	Chhota Udepur	Chhota udepur	Malaja	73.98139	22.34945	Granite	60	68.20
72	SVADPz-06	Chhota Udepur	Chhota udepur	Lagami	74.00445	22.45639	Phyllite Schist	30	68.08
73	SVADPz-29	Narmada	Tilakwada	Vajeria	73.58139	22.03194	Granite	90	67.94
74	BR-58	Bharuch	Valia	Netrang	73.35222	21.63472	Basalt	10.5	67.85
75	G_2_VAD_009	Chhota Udepur	Jetpur-pavi	Kheda	73.82667	22.49055	Granite	60	66.52
76	BD-14	Chhota Udepur	Chhota udepur	Kevdi	73.95834	22.53333	Basalt	11.6	66.28
77	SVADPz-31	Chhota Udepur	Nasvadi	Vadiya	73.69611	21.99972	Basalt	60	66.14
78	BR-32	Narmada	Garudeshwar	Chhindiapura	73.70389	21.94222	Basalt	8.3	65.79
79	BR-45	Narmada	Nandod	Thari	73.55194	21.89472	Alluvium	30.88	65.69
80	SBRHPz-25	Narmada	Nandod	Navapura	73.38722	21.88167	Alluvium	58.77	65.69
81	SVADPz-32	Chhota Udepur	Jetpur-pavi	Kashipura	73.80389	22.12306	Basalt	90	65.62
82	BD-09	Chhota Udepur	Chhota udepur	Chhota Udaipur	74.01334	22.31333	Basalt	11.73	64.71
83	BR-40	Narmada	Nandod	Pratapnagar	73.42139	21.87611	Alluvium	16.03	62.88
84	SVADPz-05	Chhota Udepur	Jetpur-pavi	Kadval	73.76167	22.48806	Phyllite Schist	20.5	62.17
85	BD-27	Chhota Udepur	Nasvadi	Goyavant	73.86	21.97778	Basalt	15.1	61.62
86	BR-27A	Bharuch	Jhagadia	Wadkhunta	73.35528	21.7025	Basalt	8.3	61.38
87	G_2_VAD_017	Chhota Udepur	Nasvadi	Dhar Simal	73.97694	21.95694	Basalt	60	60.98
88	BD-18	Chhota Udepur	Kavant	Raisingpura	74.05695	22.02222	Basalt	14	60.85
89	BD-45	Chhota Udepur	Sankheda	Bodeli	73.71445	22.26611	Alluvium	13.6	59.99

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
90	G_2_BHR_001	Bharuch	Jhagadia	Kochbar	73.42389	21.67111	Basalt	48.6	59.46
91	BR-23A	Bharuch	Jhagadia	Padvania	73.23833	21.68778	Basalt	10.8	58.53
92	BD-16	Chhota Udepur	Kavant	Navalja	74.105	22.08055	Basalt	16.1	58.14
93	SBRHPz-12	Bharuch	Netrang	Kolivada	73.30028	21.66667	Basalt	30	57.07
94	G_2_VAD_013	Chhota Udepur	Kavant	Gajalavant	73.91	22.09	Basalt	60	56.63
95	SVADPz-17	Vadodara	Karjan	Sayar(Nareshwar)	73.23028	21.85667	Alluvium	55.99	56.41
96	NHP_CHU_004	Chhota Udepur	Nasvadi	Dhaniya Umarva	73.91028	22.345	Basalt	60	56.28
97	SVADPz-08	Chhota Udepur	Nasvadi	Nakhalpur	73.80778	21.96806	Basalt	30	56.17
98	BD-36	Chhota Udepur	Jetpur-pavi	Bar	73.82222	22.47333	Basalt	15	56.11
99	BR-09	Narmada	Dediapada	Motisingloti	73.66778	21.67528	Basalt	12.4	55.61
100	BD-38	Chhota Udepur	Jetpur-pavi	Gutanwad	73.87	22.40917	Basalt	8.25	55.40
101	G_2_NMR_011	Narmada	Nandod	Jitgadh	73.53139	21.82444	Basalt	60	55.38
102	G_2_VAD_003	Chhota Udepur	Chhota udepur	Mithi Bore	73.99	22.53	Granite	60	53.34
103	SVADPz-35	Chhota Udepur	Bodeli	Jabugam	73.76917	22.28917	Granite	60	53.16
104	SBRHPz-17	Narmada	Dediapada	Dediapada	73.59666	21.635	Basalt	53	52.89
105	BD-10	Chhota Udepur	Chhota udepur	Ambala	74.09167	22.37167	Basalt	9.35	52.12
106	G_2_NMR_009	Narmada	Nandod	Amli	73.46972	21.76222	Basalt	60	51.69
107	NHP_BRH_007	Bharuch	Jhagadia	Rajpor	73.20167	21.66111	Alluvium	43	51.18
108	PM-047	Panchmahals	Jambughoda	Jotwad	73.72389	22.38194	Phyllite Schist	8.2	50.78
109	BR-12	Bharuch	Hansot	Kantiajal	72.67555	21.47	Alluvium	9.25	50.19
110	BR-08	Narmada	Dediapada	Gangpur	73.68278	21.58028	Basalt	5.52	50.12
111	G_2_NMR_005	Narmada	Dediapada	Kharchipada	73.49028	21.56667	Basalt	60	49.03

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geology	Well depth	Characteristic Quality
112	SBRHPz-19	Narmada	Dediapada	Patvali	73.73611	21.6825	Basalt	30	48.90
113	G_2_NMR_007	Narmada	Dediapada	Solia	73.49	21.66	Basalt	60	48.75
114	BR-30	Narmada	Nandod	Amletha	73.41722	21.83778	Alluvium	12.6	48.49
115	SBRHPz-09	Bharuch	Jhagadia	Indor	73.23889	21.90333	Alluvium	35.55	48.45
116	BR-44A	Narmada	Garudeshwar	Survani	73.80305	21.88445	Basalt	10.3	48.36
117	SBRHPz-05	Narmada	Garudeshwar	Indravarna	73.65278	21.86222	Basalt	30	48.30
118	G_2_VAD_018	Vadodara	Sinor	Mota Fofaliya	73.37111	21.96	Alluvium	63.16	47.85
119	SBRHPZ-07	Narmada	Nandod	Ghanta	73.41805	21.79944	Basalt	44	47.52
120	G_2_NMR_010	Narmada	Nandod	Dhanpur	73.46	21.92	Alluvium	57.26	46.94
121	G_2_VAD_001	Chhota Udepur	Chhota udepur	Khadakvada	74.19611	22.39056	Basalt	60	46.25
122	NHP_NMR_002	Narmada	Garudeshwar	Thavadiya	73.70917	21.85	Basalt	60	46.21
123	G_2_PMS_006	Panchmahals	Jambughoda	Jambughoda	73.73417	22.36417	Phyllite Schist	60	45.71
124	BR-06	Narmada	Dediapada	Chuli	73.51639	21.57444	Basalt	11.2	45.45
125	BD-15	Chhota Udepur	Kavant	Nalvant	73.90305	22.08111	Basalt	10.7	45.08
126	NHP_BRH_011	Bharuch	Valia	Bilothi	73.43305	21.53083	Basalt	60	44.82
127	G_2_NMR_012	Narmada	Garudeshwar	Naghatpor	73.75	21.9	Basalt	60	43.72
128	SRT-36	Surat	Umarpada	Umarpada	73.47278	21.45694	Basalt	13.7	43.63
129	G_2_NMR_006	Narmada	Dediapada	Kundi Amba	73.62361	21.5425	Basalt	60	43.25
130	G_2_NMR_013	Narmada	Garudeshwar	Vaviala	73.68777	21.94194	Basalt	60	42.99
131	G_2_NMR_001	Narmada	Dediapada	Kanbudi	73.65833	21.61917	Basalt	60	42.00
132	G_2_NMR_019	Narmada	Tilakwada	Soikuva	73.63528	22.05694	Basalt	60	41.58

Sr. No.	Well ID	District Name	Block Name	Village	Long	Lat	Geolo gy	Well depth	Charact eristic Quality
133	NHP_NMR _001	Narmada	Dediapa da	Dumkhal	73.84139	21.73083	Basalt	40	41.57
134	SBRHPz-08	Narmada	Garudes hwar	Gulvani	73.8275	21.89611	Basalt	40	41.49
135	NHP_NMR _003	Narmada	Garudes hwar	Zer	73.74667	21.82111	Basalt	60	39.23
136	G_2_NMR _003	Narmada	Dediapa da	Fulsar	73.58	21.71	Basalt	60	39.19
137	NCCA-019A	Vadodara	Karjan	Urad	73.15083	21.94306	Alluvi um	72.62	39.02
138	SVADPz-16	Vadodara	Karjan	Urad	73.15056	21.94389	Alluvi um	72.62	39.02
139	G_2_NMR _004	Narmada	Dediapa da	Namgir	73.70333	21.72722	Basalt	60	36.04
140	SSRTPz-14	Surat	Umarpa da	Ghanawa d	73.52	21.43028	Basalt	90	34.97
141	HPII_NMR _001	Narmada	Tilakwa da	Katkoi	73.66611	21.94444	Basalt	60	33.17
142	G_2_NMR _008	Narmada	Garudes hwar	Bhumalia	73.72278	21.88944	Basalt	60	32.70
143	SRT-31	Surat	Umarpa da	Bilvan	73.58889	21.42694	Basalt	6.7	30.63

The below presented Correlation Matrix of 12 parameters according to the G.W.R.D.C. data of year 2024Below is a correlation matrix developed from the 2024 data of the 143 sampling wells which indicate the inter-relationship among the water parameters. The matrix shows pairwise Pearson correlation coefficients between the 12 measured water-quality variables (pH, EC, TDS, Total Alkalinity, Chloride, NO_3, SO_4, Fluoride, Total Hardness, Ca, Mg, Na). Cell shading highlights the strength and sign of correlations. Values close to +1 (deep green) indicate very strong positive relationships, values near 0 indicate little or no relationship, and negative values (orange/red) indicate inverse relationships.

	pH	EC (µ S-cm at 25 ° C)	TDS (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Total Alkalinity (mg/L)	Cl (mg/L)	NO3 (mg/L)	SO4 (mg/L)	F (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
pH	1														
EC (µ S-cm at 25 ° C)	-0.01942	1													
TDS (mg/L)	0.000407	0.997261	1												
CO3 (mg/L)	0.60025	0.08782	0.095432	1											
HCO3 (mg/L)	-0.33007	0.187023	0.178579	0.135159	1										
Total Alkalinity (mg/L)	-0.0236	0.196162	0.192251	0.541809	0.90602	1									
Cl (mg/L)	-0.04618	0.942826	0.942812	0.017191	0.088724	0.082606	1								
NO3 (mg/L)	-0.21491	-0.03134	-0.04033	-0.10621	0.135344	0.069444	-0.02942	1							
SO4 (mg/L)	-0.05408	0.437625	0.43667	0.176177	0.328335	0.353777	0.382828	0.211508	1						
F (mg/L)	0.207233	-0.02434	-0.01694	0.238001	0.129572	0.211577	-0.04548	0.066661	0.063864	1					
Total Hardness (mg/L)	-0.1628	0.62028	0.613043	-0.02512	0.304295	0.2474	0.62137	0.187775	0.43373	0.053662	1				
Ca (mg/L)	-0.25605	0.173348	0.162161	-0.11395	0.34741	0.246029	0.248049	0.301173	0.340648	0.103425	0.614936	1			
Mg (mg/L)	-0.08188	0.674266	0.670596	0.021194	0.213418	0.190093	0.641607	0.091638	0.373535	0.018872	0.935459	0.296632	1		
Na (mg/L)	-0.01365	0.829696	0.831275	0.096368	0.148018	0.166726	0.81101	-0.06076	0.35189	0.004834	0.434389	0.061126	0.499163	1	
K (mg/L)	0.108343	0.300811	0.30205	0.133871	0.029444	0.08216	0.23684	-0.05925	0.265697	-0.03352	0.161963	-0.02249	0.206211	0.22818	1

Figure 167 Correlation Matrix of water quality parameters

- EC and TDS are almost perfectly correlated ($r \approx 0.997$), confirming they convey essentially the same conductivity/salinity information in this dataset.
- Major-ion chemistry (Total Hardness, Ca, Mg, Na, Cl, SO_4) shows consistently strong positive correlations with each other (many r values well above 0.7–0.9), indicating a common control such as mineral dissolution, evaporation, or saline inputs.
- pH has weak or slightly negative correlations with many ionic parameters (small negative r in several cells), suggesting pH is governed by different processes and does not covary strongly with salinity/ion load here.
- Nitrate and Fluoride show weaker and more variable correlations with the major ions, implying partly different sources or controls (e.g., nitrate from surface/anthropogenic inputs; fluoride from local lithology).
- Several off - diagonal cells with moderate positive coefficients (0.2–0.6) suggest secondary relationships seasonal mobilization or localized mixing rather than dataset-wide covariance.

5. Soil Profile of the Narmada Basin

In the Upper Narmada basin, soils are predominantly shallow black soils formed through the erosion of trap basalts. These soils contain smectite-rich clay minerals with high water-holding capacity; their expandable clay structure swells upon wetting, which restricts drainage. Organic matter content is typically below 5%. The black soil here is primarily in-situ or colluvial deposits and is often interspersed with patches of red, sandy, or lateritic soils. The soil profile is generally shallow, covering hilltops and plateau surfaces.

Red soil in this region originates from the intense chemical weathering of basalts, during which most minerals are leached out, except for oxides of silica, iron, and aluminum. Due to this strong leaching, these soils exhibit good drainage but are deficient in plant-nutrients essential for growth.

In the Middle Narmada basin, particularly across the Vindhyan and Satpura plateau, soils range from shallow to medium black types. Near Hoshangabad, thick layers of recent alluvium occur, producing highly fertile soils that support crops such as cotton, jowar, and wheat.

Toward the Lower Narmada basin, valley areas, and the southern plateau are dominated by medium-deep black soils, while the northern plateau features mixed red and black soil types. At the Narmada estuary, Pliocene formations occur alongside recent alluvium. These alluvial soils are largely sandy loams, well-drained, highly fertile, and capable of sustaining productive agriculture. (Ref.3).

5.1Soil series classification

The compiled datasets present a comprehensive, multi-decadal soil-series classification for the Narmada basin, retrived from detailed field surveys (1990–2025) done by Soil and Land Use Survey of India (SLUSI) across hundreds of micro- and sub-watersheds in the Narmada Basin (Ref.4). Surveys combined traditional topographic maps, cadastral plans, aerial/satellite imagery and high-resolution remote sensing to map soil types, extent and landscape features at scales suitable for watershed planning. The classifications capture the basin's major physiographic zones (western plateau, central plateau, and hill regions), diverse agro-climatic regimes, and fine-scale variability in series distribution information, which directly supports land-use planning, irrigation suitability, resource conservation, and targeted soil- and water-management interventions. Overall, the dataset forms a spatially explicit, policy-relevant foundation for integrated river-basin management and agricultural decision-making in the Narmada catchment. Annexure 5 A shows the dataset for each surveyed area, and Figure 33(Page1-4) shows the soil series classification of different surveyed areas.

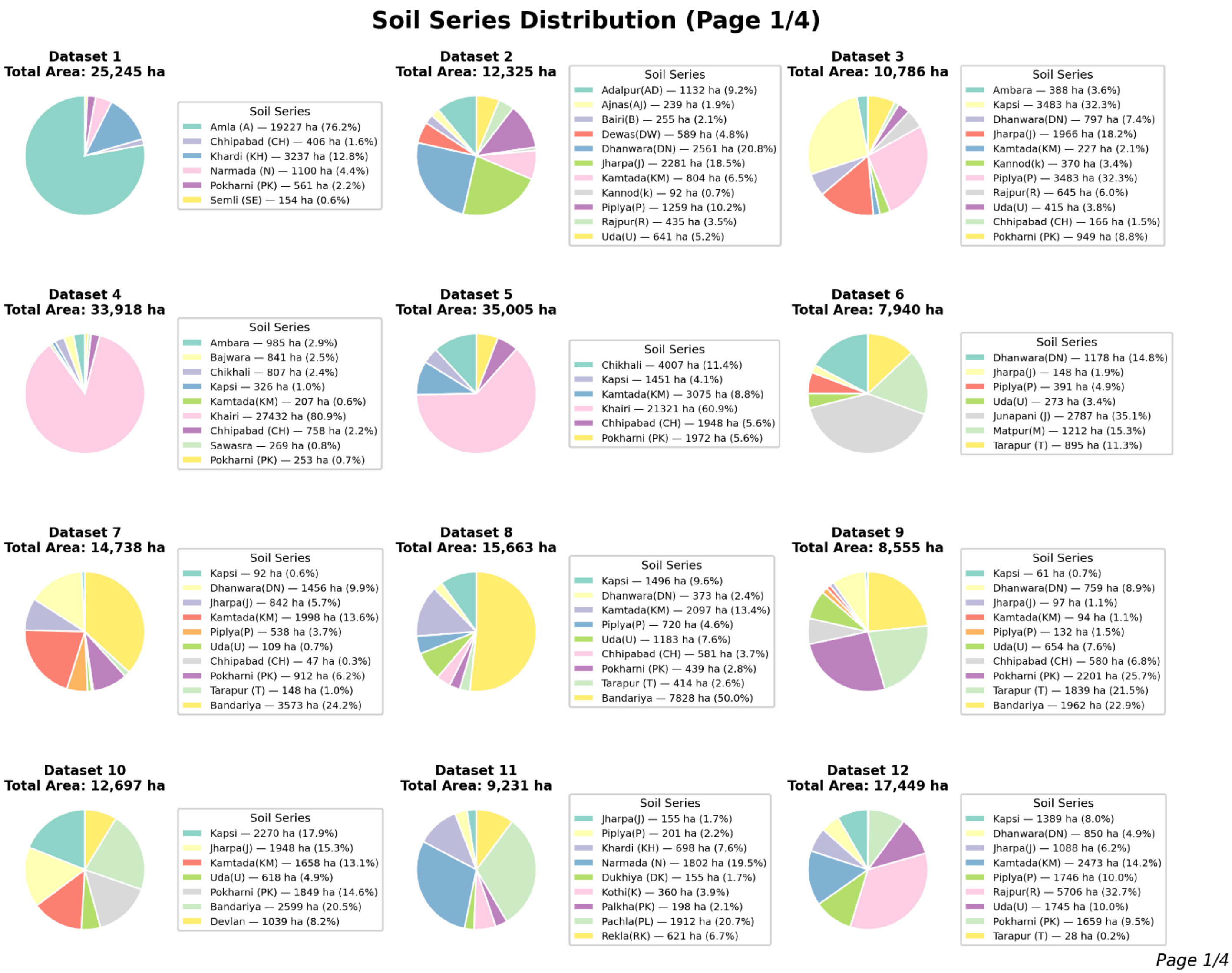


Figure 168 Soil Series distribution for the different surveyed areas in the Basin.(1/4)

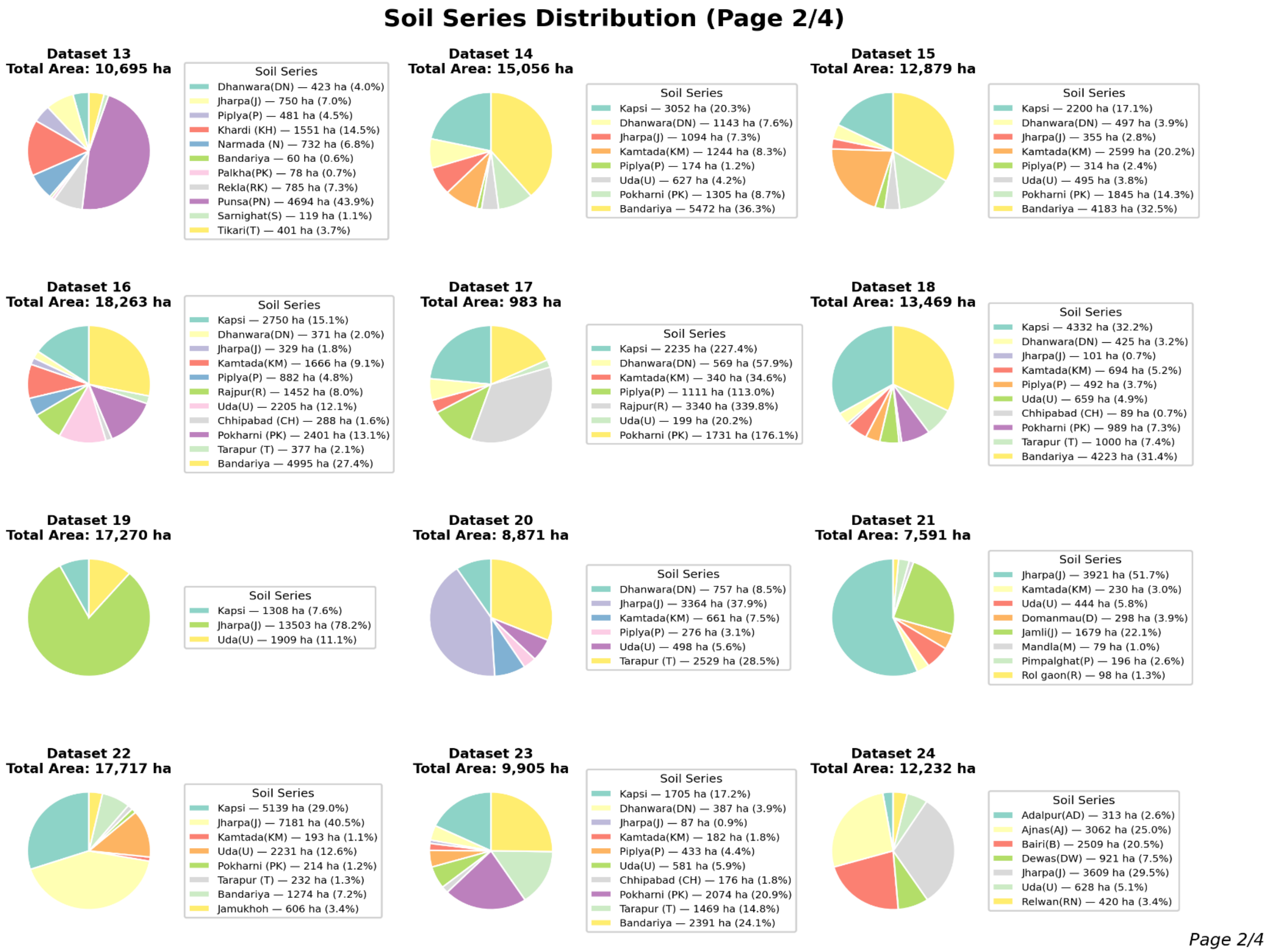


Figure 169 Soil Series distribution for the different surveyed areas in the Basin.(2/4)

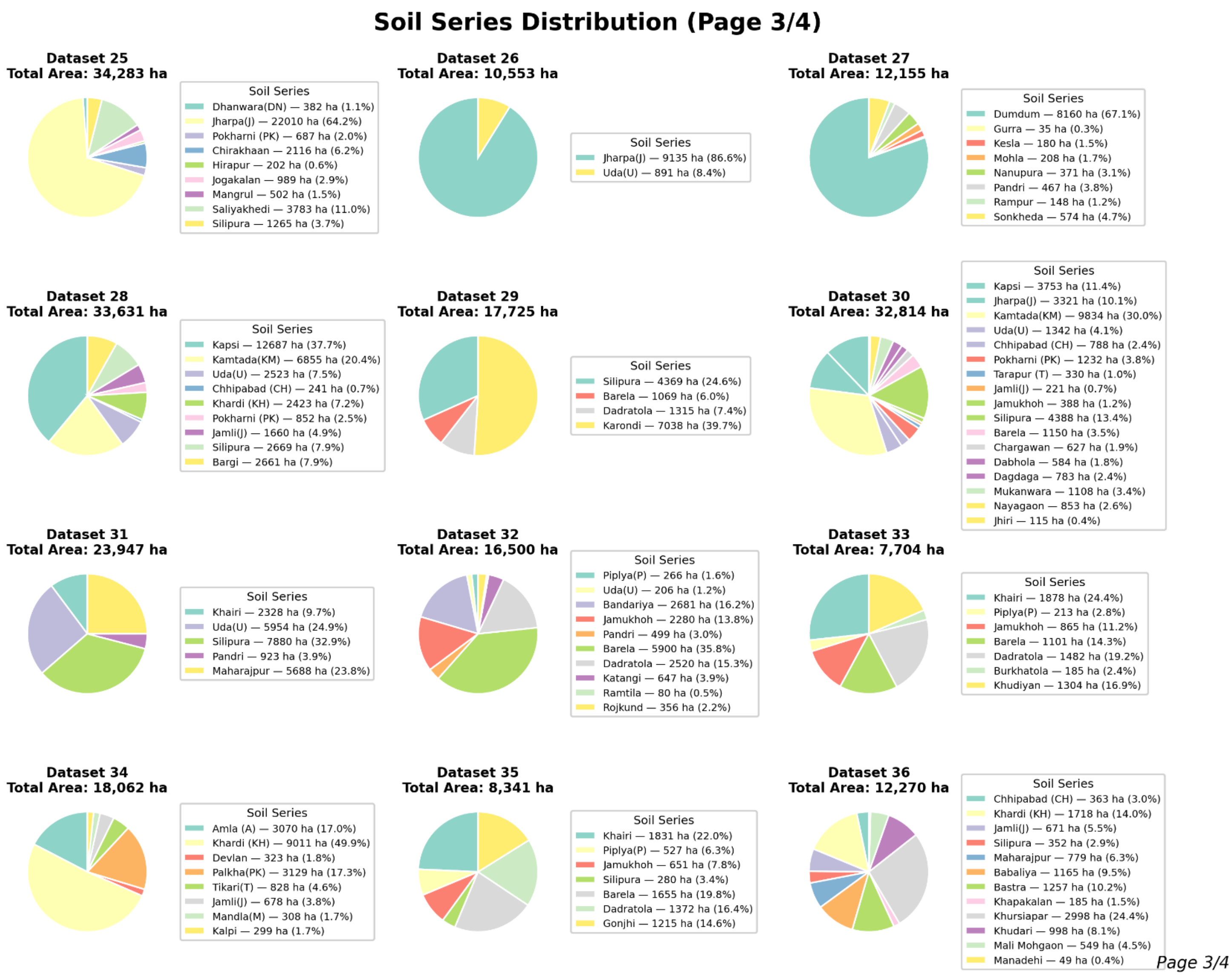


Figure 170 Soil Series distribution for the different surveyed areas in the Basin.(3/4)

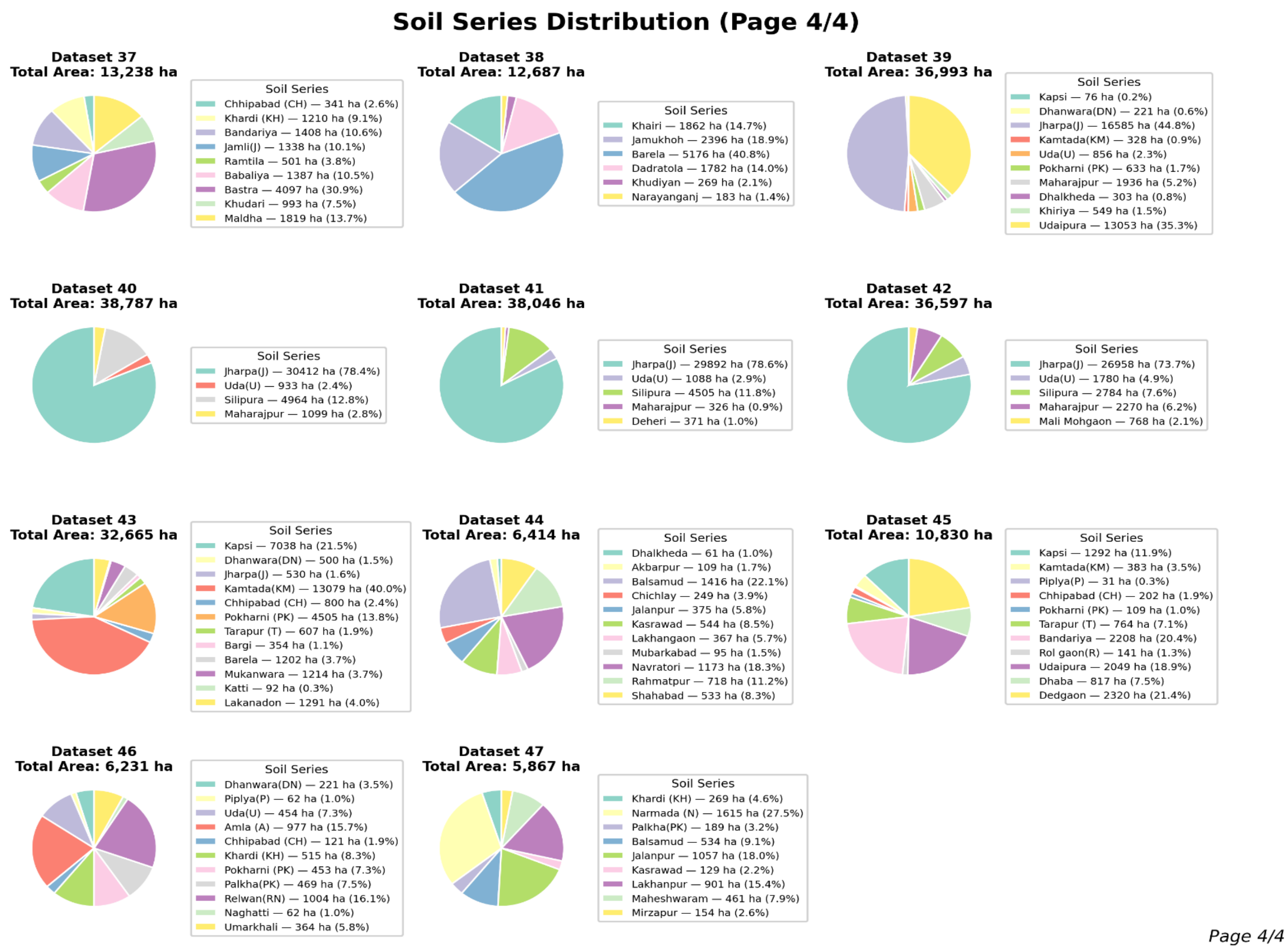


Figure 171 Soil Series distribution for the different surveyed areas in the Basin.(4/4)

Source - https://slusi.da.gov.in/dss/searchdss.html

5.2 Land Capability Classification

The land capability sub-class analysis of Datasets 1 to 47 as shown in Figure 34, which cover extensive micro- and sub-watersheds across the Narmada River basin, reveals a landscape shaped by diverse physiography, variations in soil depth, drainage conditions, and erosion intensities. Across the basin, Class III and Class IV lands dominate, especially the subclasses *IIIe, IIIs, IIIes, IVe,* and *IVes*, indicating widespread moderate to severe limitations due to erosion hazards, soil shallowness, and topographic constraints. These classes collectively represent the transitional agricultural zone of the basin, where cultivation is possible but requires significant soil and water conservation measures, contour farming, organic amendments, and erosion-control interventions. Class II soils, although present, are limited to relatively small pockets with deeper soil, gentler slopes, and lower erosion risks, reflecting more productive agro-zones in parts of Dewas, Harda, Sehore, and Barwani districts. Class V–VII soils appear intermittently, representing severely constrained lands that are often unsuitable for regular cropping. These areas are typically associated with stony outcrops, steep gradients, excessive runoff, or waterlogging tendencies, which tend to limit their utilization to forestry, grazing, watershed recharge interventions, or ecological restoration. The dataset also highlights substantial tracts of forest land and miscellaneous land, particularly in Mandla, Seoni, Jabalpur, Raisen, and Satpura-fringe regions, underscoring the basin's ecological richness and the presence of natural vegetation on fragile terrains. Together, the classification patterns across all 47 datasets illustrate a spatially heterogeneous basin in terms of agricultural capability, necessitating location-specific, conservation-oriented land-use planning. The results underscore the need to integrate land capability constraints into soil conservation strategies, watershed development programs, and sustainable river basin management frameworks for the Narmada catchment.

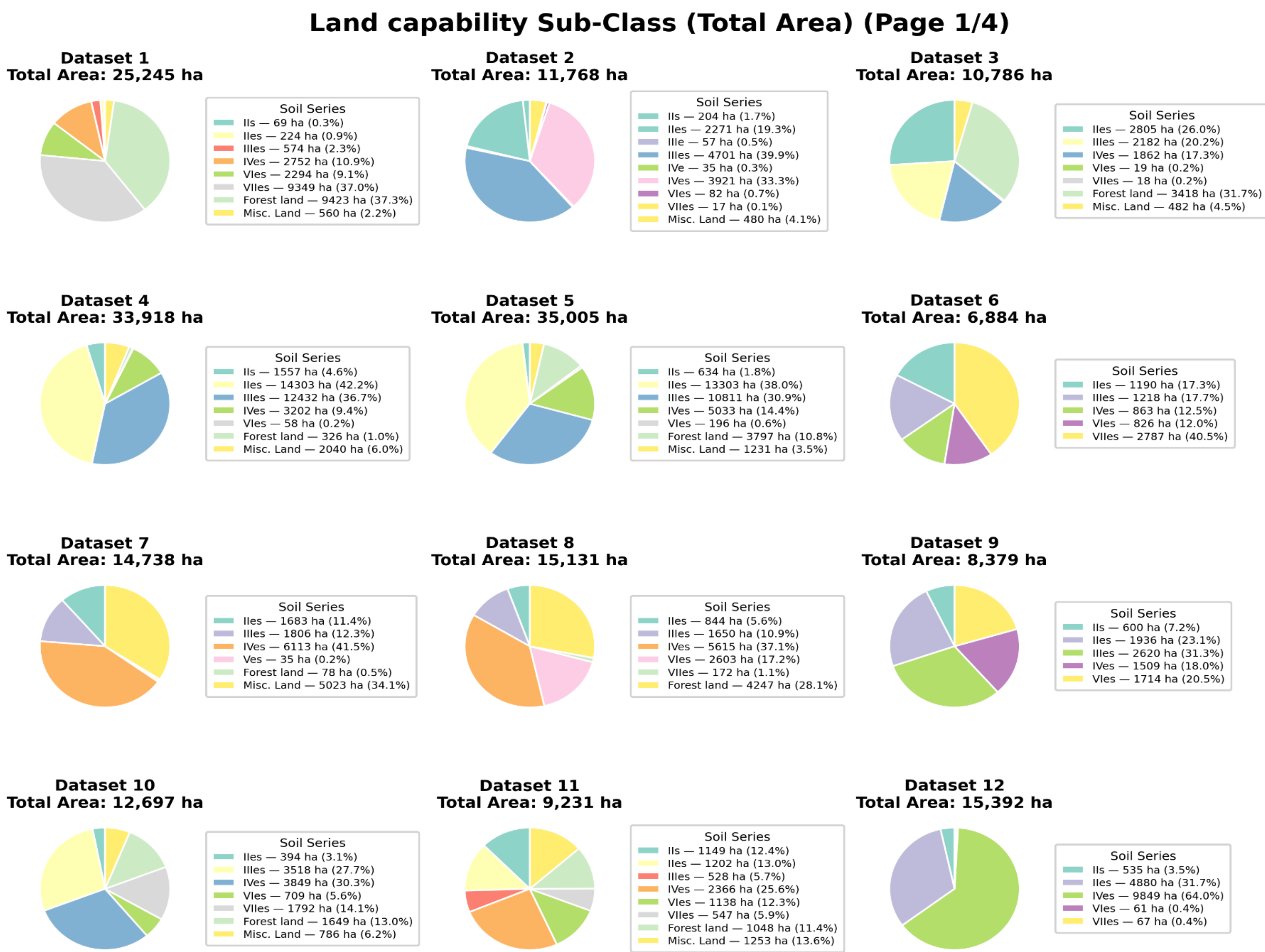


Figure 172 Land capability class of the surveyed area.(1/4)

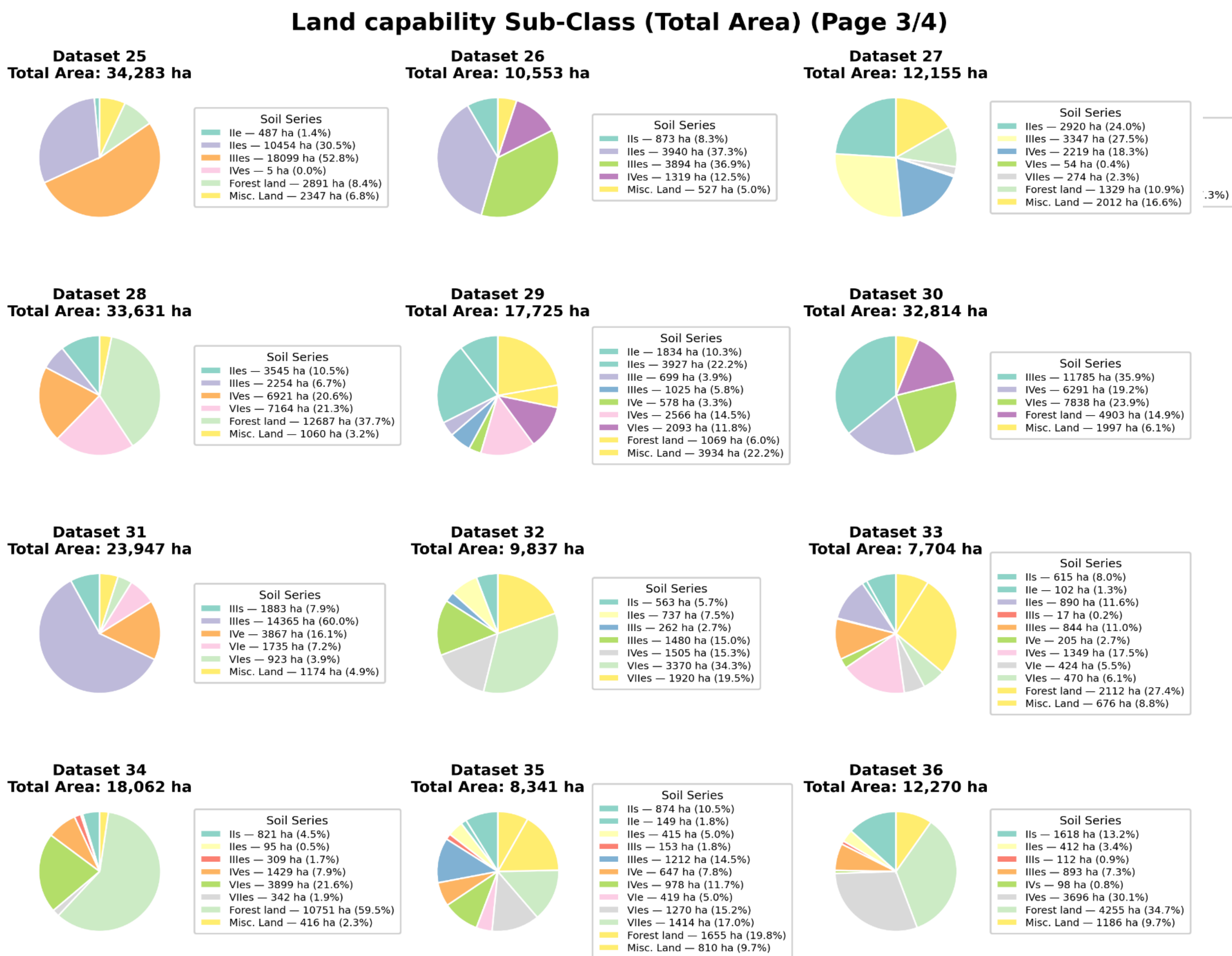


Figure 173 Land capability class of the surveyed area.(3/4)

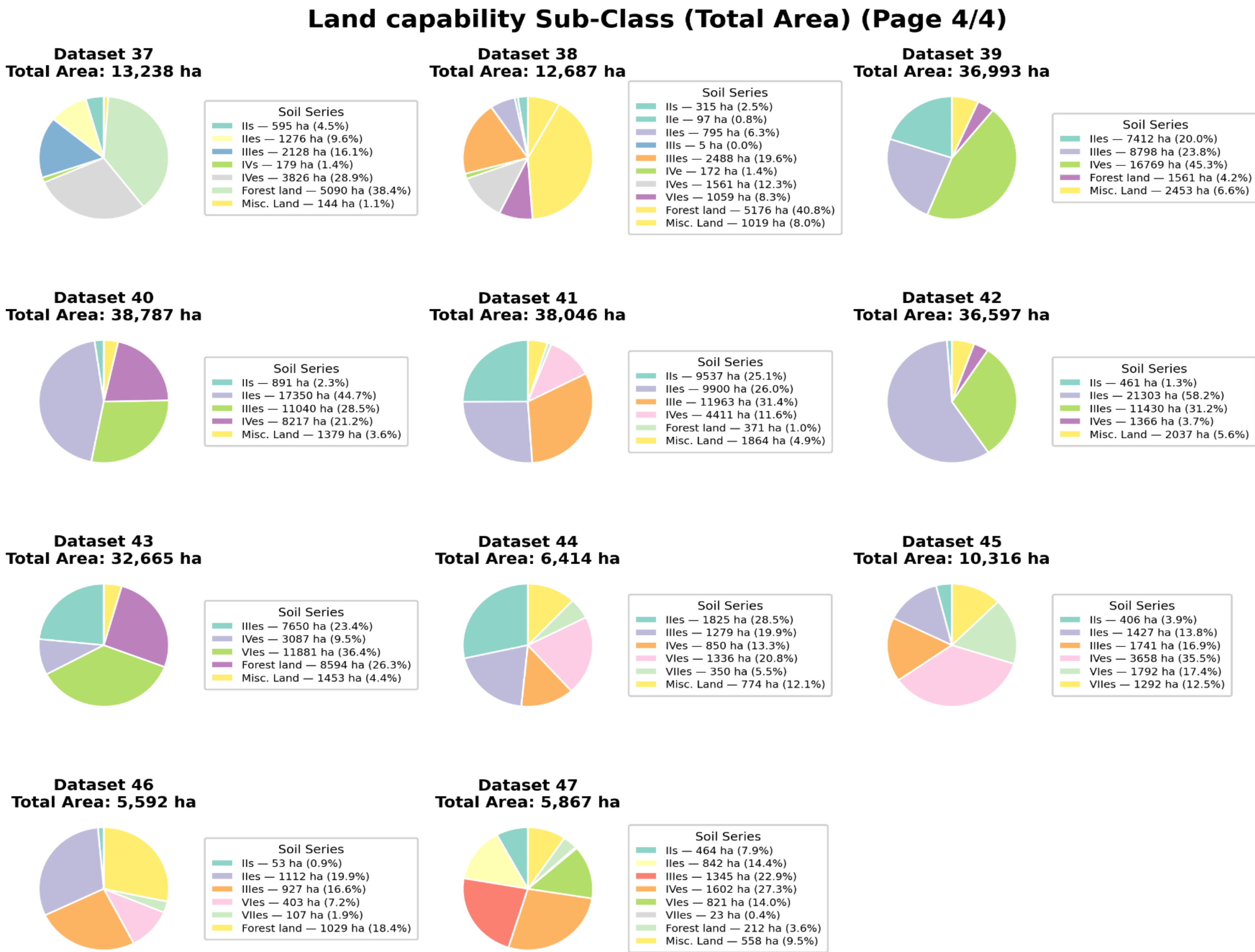


Figure 174 Land capability class of the surveyed area.(4/4)

(Sourcehttps://slusi.da.gov.in/dss/searchdss.html)

5.3 Chemical Composition of Soils in the Narmada River Basin

The geochemical composition of soils across the Narmada River Basin reflects the dominance of Deccan basalt, with local contributions from alluvium and sedimentary formations. Data collected from The Geological Survey of India (GSI), OCBIS Portal (Ref.11) Four geochemical toposheets (55N/10, 55N/13, 54L/08, 55F/15–55J/03–55J/02) covering Narsinghpur, Seoni, Mandla, Jabalpur, Sagar, Vidisha, Betul, and Hoshangabad indicates consistent spatial trends in major oxides, trace metals, and rare earth elements (REEs). Data obtained from geochemical mapping sheets covering districts such as Narsinghpur, Seoni, Mandla, Jabalpur, Sagar, Vidisha, Betul, and Hoshangabad demonstrate consistent trends in major oxides, trace metals, and rare earth elements. These patterns reflect both the lithological diversity of the basin and the progressive weathering processes that shape its soil chemistry. The substantial variations in silica, iron, magnesium, and calcium oxides highlight the contrasting geological settings between the upper and middle basin regions, thereby providing crucial insight into the pedogenic evolution of Narmada soils.

i) Major Oxides

The major oxide composition of soils in the Narmada River Basin reflects the combined influence of Deccan basalt geology, weathering intensity, and d/s sediment dynamics. Silicon dioxide (SiO_2) shows substantial spatial variation, ranging from 40.13–50.31% in the upper basin districts of Narsinghpur, Seoni, Mandla, and Jabalpur, where basalt-derived soils dominate, and the silica content remains moderate due to limited quartz presence. Moving d/s into Betul and Hoshangabad, SiO_2 increases markedly to 57–67%, a trend that indicates stronger contributions from alluvial inputs, reworked sediments, and quartz-rich lithologies. This d/s enrichment in silica is typical of river basins where sediment sorting and mixing modify the original basaltic signature. Aluminium oxide (Al_2O_3) values consistently fall within 13.7–21.04%, reflecting the widespread formation of secondary clay minerals such as kaolinite and illite, produced through prolonged chemical weathering of feldspar-rich basalts.

A defining feature of the basin's soil chemistry is the abundance of iron oxide (Fe_2O_3), which occurs in high concentrations across all surveyed districts 14.69–21.22% in the upper basin and 5–9% in the Betul–Hoshangabad region. These elevated Fe levels strongly affirm the basaltic parent material, as iron-bearing minerals like magnetite and hematite are abundant in Deccan trap rocks. The high Fe_2O_3 content is also responsible for the reddish to dark brown coloration commonly observed in these soils. Other oxides such as manganese (MnO: 0.20–0.34%), magnesium (MgO: 1.19–2.71%), and calcium (CaO: 1.26–5.20%) further underscore the mafic nature of the soil, indicating the presence of minerals like augite, olivine, and calcic plagioclase, which weather to release these oxides.

The concentrations of sodium oxide (Na_2O) and potassium oxide (K_2O), ranging from 0.15–2.07% and 0.19–1.31% respectively, signify the gradual breakdown of feldspar minerals, contributing important macro-nutrients that enhance soil fertility. Titanium oxide (TiO_2) occurs in notable quantities (1.52–4.25%), which is characteristic of Deccan basalts due to the presence of titanomagnetite and ilmenite. In contrast, phosphorus pentoxide (P_2O_5) remains very low (0.09–0.25%) across all locations, reflecting the limited availability of phosphate minerals within basaltic terrains and explaining the inherently low phosphorus fertility that often constrains agricultural productivity in these regions. Collectively, the major oxide profile of the Narmada Basin soils provides strong evidence of their basaltic heritage while also highlighting the d/smodifications introduced by sedimentary inputs and weathering processes.

ii) Trace Metals and Heavy Elements (ppm)

The distribution of trace metals and heavy elements across the Narmada River Basin provides strong evidence of the underlying basaltic and mafic geological framework, while also revealing subtle influences of sedimentary mixing in certain regions. Among the most diagnostic elements are chromium (Cr), nickel (Ni), and cobalt (Co), which occur in distinctly elevated concentrations Cr ranging from 266 to 699 ppm, Ni from 48 to 73 ppm, and Co from 6.1 to 26.83 ppm. Such elevated levels are typical of soils derived from ultramafic and mafic rock weathering, as these metals are commonly hosted in primary minerals like pyroxenes, olivine, and spinels. Their persistence in high concentrations across the basin reflects the chemical robustness of basalt-derived soils and confirms the strong geochemical imprint of the Deccan Traps, even in areas where weathering and sediment transport have modified the surface material.

Metals such as copper (Cu) and zinc (Zn) are present at concentrations typical of natural basalt-derived soils, with Cu ranging from 20 to 31 ppm and Zn from 160 to 322 ppm. These micronutrients play an essential role in soil fertility and plant nutrition, and their moderate to high presence indicates a healthy supply of geogenic micronutrients in most districts. Meanwhile, the concentrations of barium (Ba), strontium (Sr), and rubidium (Rb) show significant spatial variability, with Ba ranging widely from 25 to 708 ppm, Sr from 59 to 196 ppm, and Rb from 30 to 40 ppm. The high values of Ba and Sr are indicative of plagioclase-rich lithology, as these elements commonly substitute for calcium in feldspar lattices. Their enhanced abundance in districts such as Sagar and Vidisha suggests the influence of sedimentary formations, particularly from the Vindhyan Supergroup, which contains carbonate-rich and feldspathic sequences. In contrast, the moderate Rb concentrations reflect minor inputs from felsic minerals, which may be introduced through alluvial processes or reworked sediments.

The basin also exhibits notable concentrations of High Field Strength Elements (HFSEs) such as yttrium (Y), zirconium (Zr), niobium (Nb), and hafnium (Hf). These elements occur at ranges typical of basaltic terrains, with Zr between 125 and 366 ppm, Nb between 214 and 414 ppm, Y between 14 and 31 ppm, and Hf between 4.86 and 8.29 ppm. HFSEs are highly resistant to weathering and are usually associated with accessory minerals like zircon, rutile, and titanite, which persist even in strongly weathered soils. Their distribution patterns across the Narmada basin indicate a dominant volcanic source, but the slightly elevated values in some middle-basin districts suggest a mixed volcanic–sedimentary signature, likely resulting from the incorporation of eroded sediments derived from non-basaltic formations. Overall, the trace metal and HFSE profiles reinforce the predominantly basaltic nature of the basin's soils while also highlighting localized lithological diversity arising from sedimentary contributions and alluvial reworking.

iii) Rare Earth Elements (REEs)

The Rare Earth Element (REE) composition of the Narmada River Basin soils provides an important geochemical fingerprint that further reinforces the dominant influence of Deccan basalt geology, while also revealing subtle variations associated with weathering intensity and sedimentary mixing. The concentrations of light REEs (LREEs) such as lanthanum (La: 10.54–24.96 ppm), cerium (Ce: 25.07–55.41 ppm), praseodymium (Pr: 3.12–7.02 ppm), and neodymium (Nd: 14.54–31.72 ppm) are consistently higher than those of heavy REEs (HREEs), which include elements such as ytterbium (Yb), lutetium (Lu), and trace quantities of samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), and erbium (Er). This LREE-enriched pattern is a defining characteristic of basalt-derived soils worldwide and is consistent with the behavior of REEs during magmatic differentiation, where LREEs tend to be concentrated in incompatible mineral phases. The presence of these elements in stable concentrations across multiple districts underscores the uniform basaltic parentage of the basin's soils. Furthermore, the persistence of REEs in comparable proportions across the region indicates that these elements are largely housed within resistant accessory minerals such as zircon, apatite, allanite, and titanite, which do not readily break down during chemical weathering. Their stability allows them to retain the original geochemical signature of the parent rock even in areas where the soils have been subjected to intense tropical weathering or episodic alluvial reworking. Notably, the middle basin districts where mixed volcanic and sedimentary materials occur show only mild deviation in REE patterns, suggesting that sedimentary contributions, while present, do not significantly disturb the inherent basaltic REE profile. The preservation of Eu and Sm anomalies further supports the predominance of basalt-derived mineral phases, as these anomalies are characteristic of plagioclase-bearing mafic rocks.

Overall, the REE distribution across the Narmada Basin not only reaffirms the basaltic geochemical dominance but also highlights the capacity of REEs to serve as robust tracers of lithology and sediment provenance. Their relatively uniform concentration ranges limited anthropogenic influence, and enrichment in LREEs collectively validate the geological consistency of the basin while reflecting subtle spatial variations linked to weathering intensity and sedimentary admixture. This stable REE signature, when interpreted alongside major oxides and trace metals, provides a comprehensive understanding of the soil evolution and geochemical identity of the Narmada River Basin.

5.4 Chemical Composition of Soil in Lower Basin

5.4.1. Soil Geochemistry of Panchmahals District

The soil geochemistry of Jambughoda taluka in Panchmahals district is evaluated using pH, electrical conductivity (EC), available sulphur, and organic carbon content. A total of 24 soil samples were collected and analyzed to understand the chemical nature and fertility status of the soils.

Soil Reaction (pH)

The soil pH of Jambughoda taluka ranges from 6.66 to 8.88, with a mean pH value of 8.09. This indicates that the soils are dominantly alkaline in nature. Out of the total samples, 75.0% soils are alkaline, while 25.0% soils are neutral. No acidic soils were recorded (0.0% acidic). The alkaline reaction of soil may influence nutrient availability, especially micronutrients, and reflects the presence of base-rich parent material and semi-arid climatic conditions.

Electrical Conductivity (EC)

Electrical conductivity values vary from 0.10 to 0.76 dS/m, with a mean value of 0.26 dS/m. All soil samples (100.0%) fall under the low EC category, indicating that the soils are non-saline in nature. Medium and high EC classes are completely absent (0.0% each). Low EC values suggest that salt accumulation is not a problem and soils are suitable for most crops.

Available Sulphur Status

The available sulphur content ranges from 6.48 to 19.1 mg/kg, with a mean value of 9.8 mg/kg. Based on fertility classification, 66.7% of the samples are low in sulphur, while 33.3% fall under the medium category. No soil sample shows high sulphur content (0.0% high). This indicates that sulphur deficiency is common in the soils of Jambughoda taluka and sulphur supplementation may be required for better crop productivity.

Organic Carbon Content

Organic carbon content in the soils varies from 0.19% to 0.51%, with a mean value of 0.38%. A large majority of samples (95.8%) fall under the low organic carbon category, while only 4.2% soils are medium. High organic carbon content is completely absent (0.0% high). Low organic carbon reflects poor organic matter status, which can affect soil structure, water-holding capacity, and nutrient availability.

Overall Soil Geochemical Characteristics

Overall, the soils of Jambughoda taluka are alkaline, non-saline, low in organic carbon, and deficient to moderately sufficient in sulphur. The chemical properties indicate the need for proper soil management practices such as the application of organic manures, green manuring, and sulphur-containing fertilizers to improve soil fertility and sustain agricultural productivity.

Table 12 Summary of Soil Geochemical Properties of Jambughoda Taluka

Parameter	No. of Samples	Minimum	Maximum	Mean	Classification Details
pH	24	6.66	8.88	8.09	Acidic: 0.0%, Neutral: 25.0%, Alkaline: 75.0%
EC (dS/m)	24	0.10	0.76	0.26	Low: 100.0%, Medium: 0.0%, High: 0.0%
Sulphur (mg/kg)	24	6.48	19.1	9.8	Low: 66.7%, Medium: 33.3%, High: 0.0%
Organic Carbon (%)	24	0.19	0.51	0.38	Low: 95.8%, Medium: 4.2%, High: 0.0%

Source:- Characterization and Evaluation of Land Resources of Valia Block, Bharuch District, Gujarat. Tiwari, G., Jangir, A., Sharma, R. P., Dash, B., Naitam, R. K., Malav, L. C., Paul, R., Chandran, P., and Singh, S. K.

5.4.2. Soil Geochemical Parameters of Narmada District

Soil pH

Soil pH in Narmada district ranges from 5.70 to 8.17, showing acidic to alkaline soils. In Tilakwada, pH varies from 7.44 to 8.12 with a mean of 7.78, indicating alkaline soil. Garudeshwar soils show pH values between 6.49 and 8.04 (mean 7.42). In Nandod, pH ranges from 6.78 to 8.17

with a mean of 7.53. Dediyapada soils have pH values from 6.34 to 7.93 (mean 7.18). Sagbara shows lower pH values ranging from 5.70 to 7.05 with a mean of 6.24, indicating slightly acidic to neutral soil. Overall mean pH of the district is 7.23 with a standard deviation of 0.63.

Electrical Conductivity (EC)

Electrical conductivity values are low in all talukas, indicating non-saline soils. In Tilakwada, EC ranges from 0.11 to 0.35 dS m^{-1} with a mean of 0.21 dS m^{-1}. Garudeshwar shows EC values between 0.08 and 0.47 dS m^{-1} (mean 0.27 dS m^{-1}). In Nandod, EC varies from 0.11 to 0.74 dS m^{-1} with a mean of 0.25 dS m^{-1}. Dediyapada has EC values from 0.04 to 0.51 dS m^{-1} (mean 0.24 dS m^{-1}). Sagbara shows the lowest EC ranging from 0.05 to 0.27 dS m^{-1} with a mean of 0.13 dS m^{-1}. Overall EC ranges from 0.04 to 0.74 dS m^{-1} with a mean of 0.22 dS m^{-1} and SD of 0.11.

Soil Organic Carbon (SOC)

Soil organic carbon content varies widely across the district. In Tilakwada, SOC ranges from 0.40 to 1.03% with a mean of 0.75%. Garudeshwar shows SOC values from 0.46 to 1.80% (mean 0.88%). In Nandod, SOC ranges between 0.40 and 1.62% with a mean of 0.79%. Dediyapada soils have SOC values from 0.27 to 1.08% (mean 0.63%). Sagbara shows higher SOC ranging from 0.73 to 2.83% with a mean of 1.27%. Overall SOC ranges from 0.27 to 2.83% with a mean of 0.86% and SD of 0.37.

Available Nitrogen (N)

Available nitrogen content is generally low to medium across the district. In Tilakwada, available N ranges from 62.72 to 172.48 kg ha^{-1} with a mean of 116.45 kg ha^{-1}. Garudeshwar soils show values from 77.26 to 152.40 kg ha^{-1} (mean 116.14 kg ha^{-1}). In Nandod, available N ranges from 45.27 to 133.26 kg ha^{-1} with a mean of 97.92 kg ha^{-1}. Dediyapada shows higher values ranging from 92.82 to 225.71 kg ha^{-1} (mean 131.86 kg ha^{-1}). Sagbara soils range from 62.72 to 209.48 kg ha^{-1} with a mean of 141.44 kg ha^{-1}. Overall available N ranges from 45.27 to 225.71 kg ha^{-1}, mean 120.76 kg ha^{-1}, and SD 34.06.

Available Phosphorus (P_2O_5)

Available phosphorus content varies from low to medium. In Tilakwada, P_2O_5 ranges from 6.03 to 66.35 kg ha^{-1} with a mean of 29.27 kg ha^{-1}. Garudeshwar shows the same range and mean (6.03–66.35 kg ha^{-1}, mean 29.27 kg ha^{-1}). In Nandod, available P_2O_5 ranges from 2.01 to 43.23 kg ha^{-1}

with a mean of 21.56 kg ha^{-1}. Dediyapada shows values from 2.01 to 59.31 kg ha^{-1} (mean 20.28 kg ha^{-1}). Sagbara soils range from 2.01 to 39.21 kg ha^{-1} with a mean of 16.28 kg ha^{-1}. Overall P_2O_5 ranges from 2.01 to 30.16 kg ha^{-1}, mean 12.24 kg ha^{-1}, and SD 13.57.

Available Potassium (K_2O)

Available potassium content is high in most talukas. In Tilakwada, K_2O ranges from 260.87 to 495.19 kg ha^{-1} with a mean of 370.51 kg ha^{-1}. Garudeshwar shows similar values (260.87–495.19 kg ha^{-1}, mean 370.51 kg ha^{-1}). In Nandod, K_2O ranges from 217.60 to 498.40 kg ha^{-1} with a mean of 377.20 kg ha^{-1}. Dediyapada soils show values from 207.21 to 471.88 kg ha^{-1} (mean 326.32 kg ha^{-1}). Sagbara ranges from 216.83 to 518.63 kg ha^{-1} with a mean of 321.97 kg ha^{-1}. Overall K_2O ranges from 237.83 to 428.51 kg ha^{-1}, mean 333.56 kg ha^{-1}, and SD 74.13.

Available Sulphur (S)

Available sulphur content shows wide variation. In Tilakwada, S ranges from 2.52 to 24.49 mg kg^{-1} with a mean of 11.77 mg kg^{-1}. Garudeshwar shows the same range and mean (2.52–24.49 mg kg^{-1}, mean 11.77 mg kg^{-1}). In Nandod, S ranges from 2.50 to 25.20 mg kg^{-1} with a mean of 12.00 mg kg^{-1}. Dediyapada soils range from 3.28 to 20.95 mg kg^{-1} (mean 10.52 mg kg^{-1}). Sagbara shows S values from 1.26 to 21.46 mg kg^{-1} with a mean of 11.18 mg kg^{-1}. Overall sulphur content ranges from 3.78 to 25.50 mg kg^{-1}, mean 12.43 mg kg^{-1}, and SD 5.61.

Table 13 Macronutrient (N, P_2O_5, K_2O and S) status and other soil properties in different talukas of Narmada district

Taluka	pH (1:2.5)	EC (1:2.5) (dS m^{-1})	SOC (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available S (mg kg^{-1})
Tilakwada	7.44–8.12 (7.78)	0.11–0.35 (0.21)	0.40–1.03 (0.75)	62.72–172.48 (116.45)	6.03–66.35 (29.27)	260.87–495.19 (370.51)	2.52–24.49 (11.77)

Garudeshwar	6.49–8.04 (7.42)	0.08–0.47 (0.27)	0.46–1.80 (0.88)	77.26–152.40 (116.14)	6.03–66.35 (29.27)	260.87–495.19 (370.51)	2.52–24.49 (11.77)
Nandod	6.78–8.17 (7.53)	0.11–0.74 (0.25)	0.40–1.62 (0.79)	45.27–133.26 (97.92)	2.01–43.23 (21.56)	217.60–498.40 (377.20)	2.50–25.20 (12.00)
Dediyapada	6.34–7.93 (7.18)	0.04–0.51 (0.24)	0.27–1.08 (0.63)	92.82–225.71 (131.86)	2.01–59.31 (20.28)	207.21–471.88 (326.32)	3.28–20.95 (10.52)
Sagbara	5.70–7.05 (6.24)	0.05–0.27 (0.13)	0.73–2.83 (1.27)	62.72–209.48 (141.44)	2.01–39.21 (16.28)	216.83–518.63 (321.97)	1.26–21.46 (11.18)
Overall	5.70–8.17 (7.23)	0.04–0.74 (0.22)	0.27–2.83 (0.86)	45.27–225.71 (120.76)	2.01–30.16 (12.24)	237.83–428.51 (333.56)	3.78–25.50 (12.43)
SD	0.63	0.11	0.37	34.06	13.57	74.13	5.61

Source:- Assessment of Available Macronutrient Status and Their Correlation Studies with Important Soil Properties in Soils of Narmada District. Kachhiyapatel, K. A., Kumawat, L., Patel, K. H., Singh, N., Kotadiya, R. H., and Patel, P. H.

5.4.3. Soil Geochemistry of Vadodara District

Soil pH

In Karjan taluka, soil pH ranges from 7.44 to 7.47, showing slightly alkaline soil conditions. In Sinor taluka, pH varies from 7.26 to 7.60, which also indicates neutral to slightly alkaline soils. Overall, soils of both talukas are suitable for most crops.

Organic Carbon

Organic carbon content in Karjan ranges from 0.55 to 4.01%, showing low to high organic matter in different villages. In Sinor, organic carbon varies from 0.47 to 0.68%, which indicates generally low organic matter compared to Karjan.

Available Phosphorus

Available phosphorus in Karjan taluka ranges from 32.59 to 49.26 kg ha^{-1}, indicating medium phosphorus status. In Sinor taluka, available phosphorus ranges from 40.35 to 81.05 kg ha^{-1}, showing medium to high phosphorus availability.

Available Potassium

Available potassium content in Karjan ranges from 212.43 to 372.39 kg ha^{-1}, which indicates medium to high potassium status. In Sinor, potassium ranges from 342.30 to 402.75 kg ha^{-1}, showing generally high potassium availability.

Table 1 presents the range and mean values of major soil chemical parameters of Vadodara district based on cluster-wise analysis.

Table 14 Soil Geochemical Characteristics of Vadodara District (Cluster-wise Summary, Village IDs Omitted)

Taluka	**No. of Villages Sampled**	**pH (Range)**	**Organic Carbon (Range)**	**Available Phosphorus (Range)**	**Available Potassium (Range)**
Karjan	17	7.44 – 7.47	0.55 – 4.01	32.59 – 49.26	212.43 – 372.39
Sinor	10	7.26 – 7.60	0.47 – 0.68	40.35 – 81.05	342.30 – 402.75

Source:- Analysis of Soil Parameter Variability in Vadodara District Using Clustering Techniques Bhagirath Prajapati, Priyanka Puvar***

5.4.4. Soil geochemistry Bharuch district

The soils of Valia Taluka show clear variation in chemical properties with depth and soil type. Six pedons representing different soil series and soil orders were studied. The main soil properties include pH, electrical conductivity (EC), organic carbon (OC), calcium carbonate ($CaCO_3$), exchangeable cations, exchangeable sodium percentage (ESP), and Ca:Mg ratio.

Soil reaction (pH)

Soil pH shows clear variation with soil series and depth, and all values indicate neutral to strongly alkaline conditions. In the **Pansoli series**, the surface horizon Ap (0–11 cm) has a pH of **8.3**, which increases to **8.5** in Bw1 (11–42 cm), remains same 8.5 in Bw2 (42–80 cm), BC horizon (80–120 cm). In the **Dodwada series**, pH is **8.1** in the Ap horizon (0–15 cm), increases to **8.4** in Bw1 (15–65 cm), then decreases to **8.0** in Bss1 (65–95 cm) and further to **7.9** in the BC horizon (95–150 cm). The **Tuna series** shows consistently alkaline pH throughout the profile, with values of **8.2** in Ap (0–15 cm), **8.3** in Bk1 (15–53 cm), **8.4** in Bk2 (53–70 cm), and **8.4** in BC (70–95 cm). In the **Sodam series**, pH is near neutral at the surface with **6.8** in Ap (0–15 cm), increases slightly to **6.9** in Bw1 (15–40 cm), rises to **7.1** in Bw2 (40–70 cm), and reaches **7.3** in the BC horizon (70–110 cm). The **Sevad series** shows the highest pH values, with **9.3** in Ap (0–15 cm) and Bw1 (15–35 cm), increasing to **9.5** in Bss1 (35–65 cm), **9.6** in Bss2 (65–96 cm), and reaching **9.7** in the BC horizon (96–150 cm). In the **Vatariya series**, pH is **8.6** in the Ap horizon (0–15 cm) and slightly decreases to **8.5** in the BC horizon (15–49 cm). Overall, soil pH ranges from **6.8 to 9.7**, with most soils showing alkaline reaction and a general tendency for pH to increase or remain stable with depth, especially in sodic and calcareous soil series.

Electrical Conductivity (EC)

Electrical conductivity of the soils shows variation with soil series and depth, with values ranging from 0.08 to 1.60 dS m^{-1}, indicating non-saline to moderately saline conditions. In the Pansoli series, EC remains constant at 0.15 dS m^{-1} in all horizons, including Ap (0–11 cm), Bw1 (11–42 cm), Bw2 (42–80 cm), and BC (80–120 cm), showing uniform non-saline conditions throughout the profile. In the Dodwada series, EC is 0.11 dS m^{-1} in the Ap horizon (0–15 cm), increases to 0.23 dS m^{-1} in Bw1 (15–65 cm), rises sharply to 1.16 dS m^{-1} in Bss1 (65–95 cm), and then slightly decreases to 0.87 dS m^{-1} in the BC horizon (95–150 cm), indicating salt accumulation in the subsurface layers. The Tuna series shows consistently low EC values, with 0.14 dS m^{-1} in Ap (0–15 cm) and Bk1 (15–53 cm), 0.13 dS m^{-1} in Bk2 (53–70 cm), and 0.12 dS m^{-1} in BC (70–95 cm), reflecting non-saline conditions at all depths. In the Sodam series, EC decreases gradually with depth from 0.15 dS m^{-1} in Ap (0–15 cm) to 0.10 dS m^{-1} in Bw1 (15–40 cm), slightly increases to

0.11 dS m^{-1} in Bw2 (40–70 cm), and reaches the lowest value of 0.08 dS m^{-1} in the BC horizon (70–110 cm). The Sevad series records the highest EC values among all soils, with 0.31 dS m^{-1} in Ap (0–15 cm), 0.33 dS m^{-1} in Bw1 (15–35 cm), a sharp increase to 1.60 dS m^{-1} in Bss1 (35–65 cm), followed by 1.50 dS m^{-1} in Bss2 (65–96 cm), and 1.30 dS m^{-1} in the BC horizon (96–150 cm), showing moderate salinity in the subsurface horizons. In the Vatariya series, EC decreases from 0.26 dS m^{-1} in the Ap horizon (0–15 cm) to 0.18 dS m^{-1} in the BC horizon (15–49 cm). Overall, EC values indicate that most soils are non-saline, except the deeper horizons of the Sevad and Dodwada series, where moderate salt accumulation is observed.

Organic Carbon (OC)

Organic carbon content of the soils shows clear variation with soil series and depth, with values ranging from 0.18 to 1.20%. In the Pansoli series, organic carbon is very low and nearly uniform, with 0.18% in the Ap horizon (0–11 cm), 0.18% in Bw1 (11–42 cm), 0.20% in Bw2 (42–80 cm), and 0.20% in the BC horizon (80–120 cm). In the Dodwada series, organic carbon is higher in the surface soil and decreases with depth, recording 0.77% in Ap (0–15 cm), 0.62% in Bw1 (15–65 cm), 0.63% in Bss1 (65–95 cm), and 0.51% in the BC horizon (95–150 cm). The Tuna series shows relatively high organic carbon at the surface with 0.92% in Ap (0–15 cm), followed by a sharp decline to 0.39% in Bk1 (15–53 cm), 0.29% in Bk2 (53–70 cm), and 0.25% in BC (70–95 cm). In the Sodam series, organic carbon is highest in the surface horizon with 1.20% in Ap (0–15 cm), then decreases to 0.84% in Bw1 (15–40 cm), 0.72% in Bw2 (40–70 cm), and further to 0.35% in the BC horizon (70–110 cm). The Sevad series shows low organic carbon in the surface soil with 0.27% in Ap (0–15 cm), increases to 0.57% in Bw1 (15–35 cm), decreases to 0.32% in Bss1 (35–65 cm) and 0.28% in Bss2 (65–96 cm), and then increases again to 0.81% in the BC horizon (96–150 cm). In the Vatariya series, organic carbon shows a slight increase with depth, from 0.52% in the Ap horizon (0–15 cm) to 0.58% in the BC horizon (15–49 cm). Overall, organic carbon is generally higher in surface horizons and decreases with depth in most soil series, reflecting the influence of plant residues and organic matter accumulation near the surface.

Calcium Carbonate ($CaCO_3$)

Calcium carbonate content in the soils shows wide variation with soil series and depth, with values ranging from 5.1 to 26.6%. In the Pansoli series, $CaCO_3$ is relatively high and fairly uniform, recording 11.9% in the Ap horizon (0–11 cm) and Bw1 (11–42 cm), and slightly lower values of

10.4% in Bw2 (42–80 cm) and the BC horizon (80–120 cm). In the Dodwada series, $CaCO_3$ is lower in the surface soil and increases with depth, with 6.0% in Ap (0–15 cm), 5.9% in Bw1 (15–65 cm), 6.2% in Bss1 (65–95 cm), and 7.3% in the BC horizon (95–150 cm). The Tuna series shows strong accumulation of calcium carbonate in the subsoil, with 11.3% in the Ap horizon (0–15 cm), increasing sharply to 26.6% in Bk1 (15–53 cm), remaining high at 24.4% in Bk2 (53–70 cm), and slightly decreasing to 22.5% in the BC horizon (70–95 cm). In the Sodam series, $CaCO_3$ content is low throughout the profile, with 5.4% in Ap (0–15 cm), 5.9% in Bw1 (15–40 cm), 5.2% in Bw2 (40–70 cm), and 5.1% in the BC horizon (70–110 cm). The Sevad series contains moderately high calcium carbonate at all depths, with 13.3% in Ap (0–15 cm), 14.3% in Bw1 (15–35 cm), 12.2% in Bss1 (35–65 cm), 14.8% in Bss2 (65–96 cm), and 14.1% in the BC horizon (96–150 cm). In the Vatariya series, $CaCO_3$ content remains almost constant, with 13.9% in the Ap horizon (0–15 cm) and 13.8% in the BC horizon (15–49 cm). Overall, calcium carbonate shows clear depth-wise accumulation in calcic soils like the Tuna and Sevad series, while remaining low and uniform in the Sodam series.

Calcium (Ca^{2+})

Calcium content shows clear variation with soil series and depth, with values ranging from 15.0 to 33.6 cmol(p^+) kg^{-1}. In the Pansoli series, calcium is high and fairly stable throughout the profile, measuring 31.6 cmol(p^+) kg^{-1} in the Ap horizon (0–11 cm), remaining 31.6 cmol(p^+) kg^{-1} in Bw1 (11–42 cm), increasing slightly to 32.4 cmol(p^+) kg^{-1} in Bw2 (42–80 cm), and then decreasing to 31.2 cmol(p^+) kg^{-1} in the BC horizon (80–120 cm). In the Dodwada series, calcium increases with depth, with 27.2 cmol(p^+) kg^{-1} in Ap (0–15 cm), 27.6 cmol(p^+) kg^{-1} in Bw1 (15–65 cm), 28.8 cmol(p^+) kg^{-1} in Bss1 (65–95 cm), and 28.7 cmol(p^+) kg^{-1} in the BC horizon (95–150 cm). The Tuna series shows moderately high calcium values, recording 30.4 cmol(p^+) kg^{-1} in the Ap horizon (0–15 cm), decreasing to 28.8 cmol(p^+) kg^{-1} in Bk1 (15–53 cm), further to 27.6 cmol(p^+) kg^{-1} in Bk2 (53–70 cm), and increasing again to 28.0 cmol(p^+) kg^{-1} in the BC horizon (70–95 cm). In the Sodam series, calcium content increases steadily with depth, with 27.6 cmol(p^+) kg^{-1} in Ap (0–15 cm), 29.2 cmol(p^+) kg^{-1} in Bw1 (15–40 cm), 30.4 cmol(p^+) kg^{-1} in Bw2 (40–70 cm), and 31.6 cmol(p^+) kg^{-1} in the BC horizon (70–110 cm). The Sevad series shows high calcium in surface horizons but a clear decline in sodic subsoil layers, with 28.4 cmol(p^+) kg^{-1} in Ap (0–15 cm), 28.2 cmol(p^+) kg^{-1} in Bw1 (15–35 cm), dropping sharply to 15.6 cmol(p^+) kg^{-1} in Bss1 (35–65 cm), 15.0 cmol(p^+) kg^{-1} in Bss2 (65–96 cm), and slightly increasing to 18.4 cmol(p^+) kg^{-1} in the BC horizon (96–150 cm). In the Vatariya series, calcium is the highest among all soils, remaining constant at 33.6 cmol(p^+) kg^{-1} in both the Ap horizon (0–15 cm) and the BC horizon (15–49 cm). Overall, calcium is generally high in all soil series, but shows a marked reduction in the sodic horizons of the Sevad series due to increased sodium dominance.

Magnesium (Mg^{2+})

magnesium content varies with soil series and depth, with values ranging from 3.6 to 32.6 cmol(p^+) kg^{-1}. In the Pansoli series, magnesium is low to moderate and shows some fluctuation with depth, measuring 6.4 cmol(p^+) kg^{-1} in the Ap horizon (0–11 cm), decreasing to 3.6 cmol(p^+) kg^{-1} in Bw1 (11–42 cm), and then increasing to 4.8 cmol(p^+) kg^{-1} in Bw2 (42–80 cm) and remaining 4.8 cmol(p^+) kg^{-1} in the BC horizon (80–120 cm). In the Dodwada series, magnesium content is moderate and increases in the subsurface, with 7.2 cmol(p^+) kg^{-1} in Ap (0–15 cm), remaining 7.2 cmol(p^+) kg^{-1} in Bw1 (15–65 cm), increasing to 9.2 cmol(p^+) kg^{-1} in Bss1 (65–95 cm), and decreasing slightly to 7.6 cmol(p^+) kg^{-1} in the BC horizon (95–150 cm). The Tuna series shows moderate magnesium levels with depth, recording 7.6 cmol(p^+) kg^{-1} in Ap (0–15 cm), decreasing to 6.4 cmol(p^+) kg^{-1} in Bk1 (15–53 cm), further to 4.4 cmol(p^+) kg^{-1} in Bk2 (53–70 cm), and increasing again to 7.2 cmol(p^+) kg^{-1} in the BC horizon (70–95 cm). In the Sodam series, magnesium is high and increases steadily with depth, with 14.8 cmol(p^+) kg^{-1} in Ap (0–15 cm), 16.4 cmol(p^+) kg^{-1} in Bw1 (15–40 cm), 16.8 cmol(p^+) kg^{-1} in Bw2 (40–70 cm), and reaching 18.4 cmol(p^+) kg^{-1} in the BC horizon (70–110 cm). The Sevad series shows very high magnesium content, especially in sodic horizons, with 18.4 cmol(p^+) kg^{-1} in Ap (0–15 cm), 17.4 cmol(p^+) kg^{-1} in Bw1 (15–35 cm), increasing sharply to 31.0 cmol(p^+) kg^{-1} in Bss1 (35–65 cm), 30.4 cmol(p^+) kg^{-1} in Bss2 (65–96 cm), and reaching the highest value of 32.6 cmol(p^+) kg^{-1} in the BC horizon (96–150 cm). In the Vatariya series, magnesium content is moderate and slightly decreases with depth, recording 10.8 cmol(p^+) kg^{-1} in the Ap horizon (0–15 cm) and 10.4 cmol(p^+) kg^{-1} in the BC horizon (15–49 cm). Overall, magnesium increases in deeper horizons of sodic and fine-textured soils, particularly in the Sevad and Sodam series, while remaining moderate in the other soil series.

Sodium (Na^+)

sodium shows clear variation among soil series and also changes with depth in each profile. In the Pansoli series, sodium content is low throughout the profile, with 1.2 cmol(p^+) kg^{-1} in the Ap horizon (0–11 cm), increasing slightly to 1.6 cmol(p^+) kg^{-1} in Bw1 (11–42 cm), 2.0 cmol(p^+) kg^{-1}

in Bw2 (42–80 cm), and reaching 2.4 cmol(p^+) kg^{-1} in the BC horizon (80–120 cm). The Dodwada series also shows low to moderate sodium levels, recording 1.6 cmol(p^+) kg^{-1} in Ap (0–15 cm), 2.0 cmol(p^+) kg^{-1} in Bw1 (15–65 cm), increasing to 3.2 cmol(p^+) kg^{-1} in Bss1 (65–95 cm), and slightly decreasing to 2.8 cmol(p^+) kg^{-1} in the BC horizon (95–150 cm). In the Tuna series, sodium remains moderate, with 2.4 cmol(p^+) kg^{-1} in Ap (0–15 cm), 2.8 cmol(p^+) kg^{-1} in Bk1 (15–53 cm), 3.6 cmol(p^+) kg^{-1} in Bk2 (53–70 cm), and 3.2 cmol(p^+) kg^{-1} in the BC horizon (70–95 cm). The Sodam series shows distinctly higher sodium content, starting with 6.8 cmol(p^+) kg^{-1} in Ap (0–15 cm), increasing to 8.4 cmol(p^+) kg^{-1} in Bw1 (15–40 cm), 9.2 cmol(p^+) kg^{-1} in Bw2 (40–70 cm), and reaching 10.4 cmol(p^+) kg^{-1} in the BC horizon (70–110 cm). In the Sevad series, sodium is very high and increases sharply with depth, measuring 8.8 cmol(p^+) kg^{-1} in Ap (0–15 cm), 10.6 cmol(p^+) kg^{-1} in Bw1 (15–35 cm), 18.4 cmol(p^+) kg^{-1} in Bss1 (35–65 cm), 19.6 cmol(p^+) kg^{-1} in Bss2 (65–96 cm), and reaching 21.2 cmol(p^+) kg^{-1} in the BC horizon (96–150 cm). The Vatariya series shows moderate sodium content, with 3.6 cmol(p^+) kg^{-1} in the Ap horizon (0–15 cm) and a slight increase to 4.0 cmol(p^+) kg^{-1} in the BC horizon (15–49 cm). Overall, sodium is low in Pansoli, Dodwada, and Tuna series, moderate in Vatariya, and very high in Sodam and especially Sevad series, indicating sodicity increases with depth in these soils.

Potassium (K^+)

Potassium content shows variation with soil series and depth across all profiles. In the Pansoli series, potassium values are low and slightly variable with depth, measuring 0.8 cmol(p^+) kg^{-1} in the Ap horizon (0–11 cm), decreasing to 0.6 cmol(p^+) kg^{-1} in Bw1 (11–42 cm), increasing again to 0.8 cmol(p^+) kg^{-1} in Bw2 (42–80 cm), and remaining 0.8 cmol(p^+) kg^{-1} in the BC horizon (80–120 cm). The Dodwada series shows moderate potassium content, with 0.8 cmol(p^+) kg^{-1} in Ap (0–15 cm), increasing to 1.0 cmol(p^+) kg^{-1} in Bw1 (15–65 cm), reaching 1.2 cmol(p^+) kg^{-1} in Bss1 (65–95 cm), and slightly decreasing to 1.0 cmol(p^+) kg^{-1} in the BC horizon (95–150 cm). In the Tuna series, potassium remains moderate throughout the profile, recording 1.0 cmol(p^+) kg^{-1} in Ap (0–15 cm), 1.0 cmol(p^+) kg^{-1} in Bk1 (15–53 cm), 0.8 cmol(p^+) kg^{-1} in Bk2 (53–70 cm), and 1.0 cmol(p^+) kg^{-1} in the BC horizon (70–95 cm). The Sodam series shows comparatively higher potassium levels, starting at 1.2 cmol(p^+) kg^{-1} in Ap (0–15 cm), increasing to 1.4 cmol(p^+) kg^{-1} in Bw1 (15–40 cm), remaining 1.4 cmol(p^+) kg^{-1} in Bw2 (40–70 cm), and slightly increasing to 1.6 cmol(p^+) kg^{-1} in the BC horizon (70–110 cm). In the Sevad series, potassium content is moderate to high and increases with depth, with 1.2 cmol(p^+) kg^{-1} in Ap (0–15 cm), 1.4 cmol(p^+) kg^{-1} in Bw1

(15–35 cm), 1.6 cmol(p^+) kg^{-1} in Bss1 (35–65 cm), 1.6 cmol(p^+) kg^{-1} in Bss2 (65–96 cm), and 1.8 cmol(p^+) kg^{-1} in the BC horizon (96–150 cm). The Vatariya series shows moderate potassium values, recording 1.0 cmol(p^+) kg^{-1} in the Ap horizon (0–15 cm) and 1.0 cmol(p^+) kg^{-1} in the BC horizon (15–49 cm). Overall, potassium is low in Pansoli, moderate in Dodwada, Tuna, and Vatariya, and relatively higher in Sodam and Sevad series, with a general tendency to increase slightly in deeper horizons.

Ca:Mg Ratio

The calcium to magnesium (Ca:Mg) ratio shows clear differences among soil series and also changes with depth in each profile. In the Pansoli series, the Ca:Mg ratio is 15.0 in the Ap horizon (0–11 cm). It decreases to 8.6 in Bw1 (11–42 cm), then increases to 10.7 in Bw2 (42–80 cm), and remains 10.7 in the BC horizon (80–120 cm). In the Dodwada series, the ratio is 14.4 in the Ap horizon (0–15 cm). It increases to 15.7 in Bw1 (15–65 cm), reaches a higher value of 20.4 in Bss1 (65–95 cm), and slightly decreases to 18.6 in the BC horizon (95–150 cm). The Tuna series shows a Ca:Mg ratio of 16.9 in the Ap horizon (0–15 cm). It slightly increases to 17.1 in Bk1 (15–53 cm), decreases to 12.9 in Bk2 (53–70 cm), and again increases to 18.4 in the BC horizon (70–95 cm). In the Sodam series, the Ca:Mg ratio is consistently high. It is 26.5 in the Ap horizon (0–15 cm), slightly decreases to 26.2 in Bw1 (15–40 cm), further decreases to 25.5 in Bw2 (40–70 cm), and increases to 27.6 in the BC horizon (70–110 cm). The Sevad series shows very high Ca:Mg ratios throughout the profile. The ratio is 32.0 in Ap (0–15 cm), decreases slightly to 30.7 in Bw1 (15–35 cm), increases sharply to 40.0 in Bss1 (35–65 cm), remains 39.6 in Bss2 (65–96 cm), and is 39.1 in the BC horizon (96–150 cm). In the Vatariya series, the Ca:Mg ratio is 21.2 in the Ap horizon (0–15 cm) and decreases to 18.6 in the BC horizon (15–49 cm). Overall, the Ca:Mg ratio is lowest in the Pansoli series, moderate in the Dodwada and Tuna series, high in the Sodam series, and very high in the Sevad series, showing strong dominance of calcium over magnesium, especially in deeper horizons.

Pedon	**Series**	**Horizon**	**Depth (cm)**	**pH (1:2.5)**	**EC (dS m^{-1})**	**OC (%)**	**$CaCO_3$ (%)**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**Ca:Mg**

1	Pansoli	Ap	0–11	8.3	0.15	0.18	11.9	31.6	6.4	1.3	0.2	4.9
		Bw1	11–42	8.5	0.15	0.18	11.9	31.6	3.6	1.5	0.2	8.8
		Bw2	42–80	8.5	0.15	0.20	10.4	32.4	4.8	1.8	0.2	6.7
		BC	80–120	8.5	0.15	0.20	10.4	31.2	4.8	1.7	0.2	6.5
2	Dodwada	Ap	0–15	8.1	0.11	0.77	6.0	27.2	7.2	1.0	0.1	3.8
		Bw1	15–65	8.4	0.23	0.62	5.9	27.6	7.2	2.1	0.1	3.8
		Bss1	65–95	8.0	1.16	0.63	6.2	28.8	9.2	3.2	0.1	3.1
		BC	95–150	7.9	0.87	0.51	7.3	28.7	7.6	2.3	0.1	3.8
3	Tuna	Ap	0–15	8.2	0.14	0.92	11.3	30.4	7.6	0.3	0.3	4.0
		Bk1	15–53	8.3	0.14	0.39	26.6	28.8	6.4	0.3	0.3	4.5
		Bk2	53–70	8.4	0.13	0.29	24.4	27.6	4.4	0.3	0.2	6.3
		BC	70–95	8.4	0.12	0.25	22.5	28.0	7.2	0.4	0.2	3.9
4	Sodam	Ap	0–15	6.8	0.15	1.20	5.4	27.6	14.8	0.6	0.3	1.9
		Bw1	15–40	6.9	0.10	0.84	5.9	29.2	16.4	0.4	0.3	1.8
		Bw2	40–70	7.1	0.11	0.72	5.2	30.4	16.8	0.5	0.3	1.8

		BC	70–110	7.3	0.08	0.35	5.1	31.6	18.4	0.7	0.3	1.7
5	Sevad	Ap	0–15	9.3	0.31	0.27	13.3	28.4	18.4	9.0	0.3	1.5
		Bw1	15–35	9.3	0.33	0.57	14.3	28.2	17.4	8.3	0.3	1.6
		Bss1	35–65	9.5	1.60	0.32	12.2	15.6	31.0	28.7	0.5	0.5
		Bss2	65–96	9.6	1.50	0.28	14.8	15.0	30.4	30.4	0.5	0.5
		BC	96–150	9.7	1.30	0.81	14.1	18.4	32.6	30.9	0.5	0.6
6	Vatariya	Ap	0–15	8.6	0.26	0.52	13.9	33.6	10.8	1.8	0.3	3.1
		BC	15–49	8.5	0.18	0.58	13.8	33.6	10.4	1.1	0.3	3.2

Source:- Characterization and Evaluation of Land Resources of Valia Block, Bharuch District, Gujarat G. Tiwari, A. Jangir, R. P. Sharma, B. Dash, R. K. Naitam, L. C. Malav, R. Paul, P. Chandran and S. K. Singh*

5.4.5. Soil Geochemical Parameters of Chhota Udaipur District

The soil geochemical characteristics of Chhota Udaipur district were studied using soil samples collected from different talukas and villages, namely Jetpur Pavi, Chhota Udaipur, Sankheda, Kawant and Naswadi. The parameters analysed include available nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn), iron (Fe) and manganese (Mn) for the years 2012 and 2017.

Nitrogen (N)

The available nitrogen content in the soils of Chhota Udaipur district shows clear variation among different talukas and villages and also between the years 2012 and 2017. In Jetpur Pavi taluka, nitrogen values in 2012 ranged from 326.59 to 352.69 kg/ha. Moti Rasli recorded 352.16 kg/ha, Paliya villages showed 342.67, 326.59 and 335.28 kg/ha, and Tarapur recorded 342.69 kg/ha. In 2017, nitrogen levels in Jetpur Pavi decreased and ranged from 227.6 to 275.2 kg/ha, with Moti Rasli showing 227.6 kg/ha, Paliya recording 236.6, 275.2 and 269.3 kg/ha, and Tarapur having 242.8 kg/ha. In Chhota Udaipur taluka, nitrogen content in 2012 ranged from 289.12 to 304.87 kg/ha, where Rangpur recorded 289.12 kg/ha, Puniyavant 293.41 kg/ha, and Gabadiya 304.87 kg/ha. In 2017, a strong decline was observed, and nitrogen values ranged from 154.6 to 215.0 kg/ha, with Gabadiya showing the lowest value of 154.6 kg/ha, Rangpur 178.1 kg/ha, and Puniyavant 215.0 kg/ha. In Sankheda taluka, nitrogen content in 2012 was relatively high, ranging from 359.73 to 381.24 kg/ha, with 381.24 kg/ha at Akakheda and 359.73 kg/ha at Ambapura. In 2017, nitrogen decreased to 255.6 kg/ha at Akakheda and 226.5 kg/ha at Ambapura. In Kawant taluka, nitrogen values in 2012 at Borchapda village were 329.21, 295.37 and 314.03 kg/ha, while nitrogen data for 2017 were not available. In Naswadi taluka, Thakdwani village recorded the highest nitrogen values in the district during 2012, with 408.35 and 387.64 kg/ha, but nitrogen data for 2017 were also not available. Overall, the nitrogen status of Chhota Udaipur district shows a general decline from 2012 to 2017 in talukas where data are available, indicating continuous removal of nitrogen due to cropping and the need for improved nitrogen management practices.

Sulphur(S)

The available Sulphur content in the soils of Chhota Udaipur district shows wide variation among talukas, villages and between the years 2012 and 2017. In Jetpur Pavi taluka, sulphur values in 2012 were low and ranged from 4.29 to 6.21 ppm. Moti Rasli recorded 6.21 ppm, Paliya villages showed 4.52, 4.63 and 4.38 ppm, and Tarapur recorded 4.29 ppm. In 2017, sulphur content in Jetpur Pavi increased and ranged from 6.88 to 23.00 ppm, where Moti Rasli had 6.88 ppm, Paliya villages recorded 10.00, 23.00 and 12.38 ppm, and Tarapur showed 11.00 ppm. In Chhota Udaipur taluka, sulphur values in 2012 were comparatively high and ranged from 22.43 to 29.84 ppm, with Rangpur recording 26.52 ppm, Puniyavant 29.84 ppm, and Gabadiya 22.43 ppm. In 2017, sulphur content in this taluka decreased sharply and ranged from 5.53 to 8.09 ppm, where Puniyavant recorded 5.53 ppm, and both Rangpur and Gabadiya recorded 8.09 ppm. In Sankheda taluka, sulphur values in 2012 ranged from 13.66 to 15.00 ppm, with 13.66 ppm at Akakheda and 15.00 ppm at Ambapura. In 2017, sulphur decreased and ranged from 5.20 ppm at Akakheda to 7.28 ppm at Ambapura. In Kawant taluka, sulphur content at Borchapda village in 2012 ranged from 20.31 to 22.57 ppm, while in 2017 sulphur values showed wide variation, ranging from 10.58 to 31.74

ppm. In Naswadi taluka, Thakdwani village recorded sulphur values of 17.82 and 13.00 ppm in 2012, while in 2017 sulphur ranged from 11.04 to 15.64 ppm. Overall, the sulphur status of Chhota Udaipur district shows both deficiency and adequacy depending on location and year, indicating uneven sulphur availability across the district.

Zinc(Zn)

The available zinc content in the soils of Chhota Udaipur district shows clear variation among talukas, villages and between the years 2012 and 2017. In Jetpur Pavi taluka, zinc values in 2012 ranged from 1.06 to 3.42 ppm. Moti Rasli recorded the highest value of 3.42 ppm, Paliya villages showed 1.41, 1.38 and 1.25 ppm, and Tarapur recorded 1.06 ppm. In 2017, zinc content in Jetpur Pavi declined sharply and ranged from 0.46 to 1.16 ppm, where Moti Rasli recorded 0.48 ppm, Paliya villages showed 1.16, 0.46 and 0.67 ppm, and Tarapur had 0.55 ppm. In Chhota Udaipur taluka, zinc values in 2012 ranged from 1.37 to 1.59 ppm, with Rangpur recording 1.37 ppm, Puniyavant 1.44 ppm, and Gabadiya 1.59 ppm. In 2017, zinc levels in this taluka further declined and ranged from 0.38 to 0.55 ppm, where Gabadiya recorded the lowest value of 0.38 ppm, Rangpur 0.48 ppm, and Puniyavant 0.55 ppm. In Sankheda taluka, zinc content in 2012 was comparatively high, ranging from 2.97 to 3.95 ppm, with 3.95 ppm at Akakheda and 2.97 ppm at Ambapura. In 2017, zinc values in Sankheda dropped to 0.48 to 0.56 ppm. In Kawant taluka, zinc values at Borchapda village in 2012 ranged from 1.13 to 1.42 ppm, while in 2017 they decreased and ranged from 0.74 to 0.94 ppm. In Naswadi taluka, zinc content at Thakdwani village in 2012 ranged from 1.22 to 1.46 ppm, and in 2017 it ranged from 0.74 to 0.98 ppm. Overall, zinc levels in Chhota Udaipur district showed a general decline from 2012 to 2017 across all talukas, indicating widespread zinc deficiency and the need for zinc management in soils.

Iron(Fe)

The available iron content in the soils of Chhota Udaipur district varies across talukas, villages and between the years 2012 and 2017. In Jetpur Pavi taluka, iron values in 2012 ranged from 10.45 to 11.42 ppm. Moti Rasli recorded 10.45 ppm, Paliya villages showed 11.42, 10.63 and 10.83 ppm, and Tarapur recorded 11.21 ppm. In 2017, iron content in Jetpur Pavi ranged from 4.26 to 13.52 ppm, where Paliya recorded the lowest value of 4.26 ppm and the highest value of 13.52 ppm, while Moti Rasli had 6.08 ppm and Tarapur 6.40 ppm. In Chhota Udaipur taluka, iron values in 2012 ranged from 11.65 to 14.27 ppm, with Rangpur recording 13.58 ppm, Puniyavant 14.27 ppm, and Gabadiya 11.65 ppm. In 2017, iron content in this taluka decreased and ranged from 4.50 to 7.20 ppm, where Gabadiya recorded 4.50 ppm, Rangpur 5.50 ppm, and Puniyavant 7.20 ppm. In Sankheda taluka, iron values in 2012 ranged from 12.08 to 12.34 ppm, with 12.08 ppm at Akakheda and 12.34 ppm at Ambapura. In 2017, iron content in Sankheda ranged from 10.20 to 12.22 ppm. In Kawant taluka, iron content at Borchapda village in 2012 ranged from 10.52 to 11.62 ppm, while in 2017 iron values ranged from 8.96 to 10.00 ppm. In Naswadi taluka, Thakdwani village recorded iron values of 12.09 and 11.80 ppm in 2012, while in 2017 iron ranged from 7.74 to 10.00 ppm. Overall, iron content in Chhota Udaipur district was adequate in 2012 but showed a declining trend in many villages by 2017, especially in Chhota Udaipur and Jetpur Pavi talukas.

Manganese(Mn)

The available manganese (Mn) content in the soils of Chhota Udaipur district shows clear variation among talukas, villages and between the years 2012 and 2017. In Jetpur Pavi taluka, manganese values in 2012 ranged from 6.32 to 10.27 ppm. Moti Rasli recorded 10.27 ppm, Paliya villages showed 6.32, 7.24 and 8.20 ppm, while Tarapur had 7.63 ppm. In 2017, manganese content in Jetpur Pavi ranged from 5.08 to 7.45 ppm, with Moti Rasli recording 5.33 ppm, Paliya villages showing 5.08, 7.18 and 7.45 ppm, and Tarapur recording 7.35 ppm. In Chhota Udaipur taluka, manganese values in 2012 ranged from 10.81 to 11.56 ppm, where Rangpur had 11.56 ppm, Puniyavant 11.29 ppm, and Gabadiya 10.81 ppm. In 2017, manganese content in this taluka declined and ranged from 5.15 to 7.66 ppm, with Puniyavant recording 5.15 ppm, Rangpur 6.16 ppm, and Gabadiya 7.66 ppm. In Sankheda taluka, manganese values in 2012 were very low and ranged from 1.59 to 2.04 ppm, with 1.59 ppm at Akakheda and 2.04 ppm at Ambapura. In 2017, manganese in Sankheda showed an increase at Akakheda to 16.04 ppm, while Ambapura recorded 2.08 ppm. In Kawant taluka, Borchapda village showed manganese values between 10.36 and 10.80 ppm in 2012, while in 2017 manganese ranged from 9.10 to 10.00 ppm. In Naswadi taluka, Thakdwani village recorded manganese values of 11.47 and 10.90 ppm in 2012, and in 2017 manganese ranged from 10.00 to 10.00 ppm. Overall, manganese content in Chhota Udaipur district was moderate to high in most talukas, with very low values in Sankheda in 2012 and a sharp increase at Akakheda in 2017.

Sr. No.	Taluka – Village	2012 Nitrogen (kg/ha)	2012 Sulphur (ppm)	2012 Zn (ppm)	2012 Fe (ppm)	2012 Mn (ppm)	2017 Nitrogen (kg/ha)	2017 Sulphur (ppm)	2017 Zn (ppm)	2017 Fe (ppm)	2017 Mn (ppm)
1	Jetpur Pavi – Moti Rasli	352.16	6.21	3.42	10.45	10.27	227.6	6.88	0.48	6.08	5.33
2	Jetpur Pavi – Paliya	342.67	4.52	1.41	11.42	6.32	236.6	10.00	1.16	13.52	5.08
3	Jetpur Pavi – Paliya	326.59	4.63	1.38	10.63	7.24	275.2	23.00	0.46	4.26	7.18
4	Jetpur Pavi – Paliya	335.28	4.38	1.25	10.83	8.20	269.3	12.38	0.67	8.30	7.45
5	Jetpur Pavi – Tarapur	342.69	4.29	1.06	11.21	7.63	242.8	11.00	0.55	6.40	7.35
6	Chhota Udaipur – Rangpur	289.12	26.52	1.37	13.58	11.56	178.1	8.09	0.48	5.50	6.16
7	Chhota Udaipur – Puniyavant	293.41	29.84	1.44	14.27	11.29	215.0	5.53	0.55	7.20	5.15
8	Chhota Udaipur – Gabadiya	304.87	22.43	1.59	11.65	10.81	154.6	8.09	0.38	4.50	7.66

9	Sankheda – Akakheda	381.24	13.66	3.95	12.08	1.59	255.6	5.20	0.56	10.20	16.04
10	Sankheda – Ambapura	359.73	15.00	2.97	12.34	2.04	226.5	7.28	0.48	12.22	2.08
11	Kawant – Borchapda	329.21	20.31	1.13	10.52	10.52	NA	31.74	0.94	9.14	9.14
12	Kawant – Borchapda	295.37	22.57	1.31	11.04	10.80	NA	18.52	0.74	10.00	10.00
13	Kawant – Borchapda	314.03	20.49	1.42	11.62	10.36	NA	10.58	0.88	8.96	9.10
14	Naswadi – Thakdwani	408.35	17.82	1.46	12.09	11.47	NA	11.04	0.98	7.74	10.00
15	Naswadi – Thakdwani	387.64	13.00	1.22	11.80	10.90	NA	15.64	0.74	10.00	10.00

Source:-CHARACTERISTICS OF GEOCHEMICAL PARAMETERS OF THE SOIL IN CHHOTA UDEPUR DISTRICT, GUJARAT. Axesh Vamja1, Mukesh Modi2,

pH

The soil pH in different talukas of the study area shows mostly neutral to slightly alkaline conditions. In Chhota Udaipur, 42 samples were taken, and the average pH is 7.38, slightly alkaline. Dabhoi taluka shows a slightly lower mean pH of 7.04, suggesting near-neutral soil conditions. Jetpur Pavi, with 54 samples, has the lowest pH of 6.76, which is closer to neutral but slightly acidic. Kawant has 30 samples with pH 7.38, slightly alkaline. Naswadi, with 41 samples, has pH 7.35, also slightly alkaline. Sankheda has 47 samples with pH 7.25, slightly alkaline.

Organic Carbon (%)

The organic carbon (OC) in soil of different talukas shows variation from low to moderate levels. In Chhota Udaipur, 42 samples were taken and the average OC is 0.48% which is low. Dabhoi with 29 samples has .54%, Jetpur Pavi with 54 samples has 0.58% OC and Kawant, with 30 samples, has OC of 0.57% are showing moderate organic matter in the soil. Naswadi, with 41 samples, shows the highest OC of 0.79%, indicating better organic content in the soil. Sankheda, with 47 samples, has 0.52% OC, slightly lower than moderate.

Phosphorus

The available phosphorus in soil of different talukas shows moderate variation. In Chhota Udaipur, 42 samples were taken, and the average phosphorus is 75.77 kg/ha, which is moderate. Dabhoi has 29 samples with 60.80 kg/ha, slightly lower than Chhota Udaipur. Jetpur Pavi, with 54 samples, has the lowest phosphorus of 33.50 kg/ha, showing poor phosphorus content in the soil. Kawant, with 30 samples, has 60.51 kg/ha, moderate level. Naswadi, with 41 samples, has 48.16 kg/ha, low to moderate. Sankheda, with 47 samples, has 62.66 kg/ha, moderate level.

Overall, the phosphorus content in these soils is mostly low to moderate. Talukas like Chhota Udaipur have better phosphorus, while Jetpur Pavi is low.

Potassium

The available potassium in soil of different talukas shows noticeable variation. In Chhota Udaipur, 42 samples were taken, and the average potassium is 318.67 kg/ha, which is moderate. Dabhoi has 29 samples with 285.84 kg/ha, slightly lower than Chhota Udaipur. Jetpur Pavi, with 54 samples, has the lowest potassium of 252.42 kg/ha, showing poor potassium content. Kawant, with 30 samples, has 388.40 kg/ha, which is high and good for crops. Naswadi, with 41 samples, has 326.26 kg/ha, moderate to high. Sankheda, with 47 samples, has 290.82 kg/ha, moderate level.

Overall, potassium content in these soils ranges from low to high. Talukas like Kawant and Naswadi have high potassium, suitable for crop growth, while Jetpur Pavi has low potassium.

Taluka	Number of samples	pH	Organic Carbon (%)	Phosphorus (kg/ha)	Potassium (kg/ha)
Chhota Udaipur	42	7.38	0.48	75.77	318.67
Dabhoi	29	7.04	0.54	60.80	285.84
Jetpur Pavi	54	6.76	0.58	33.50	252.42
Kavvat	30	7.38	0.57	60.51	388.40
Nasvadi	41	7.35	0.79	48.16	326.26
Padra	20	7.75	0.61	56.34	457.69
Sankheda	47	7.25	0.52	62.66	290.82

Source:- Analysis of Soil Parameter Variability in Vadodara District Using Clustering Techniques Bhagirath Prajapati, Priyanka Puvar***

Electrical conductivity (EC)

The electrical conductivity (EC) of soils in different talukas shows that the soils are mostly non-saline. In **Chhota Udaipur**, 60 soil samples were analyzed. The EC values range from 0.07 to 0.48 dS m^{-1}, with a mean value of 0.16 dS m^{-1}. All the soils fall under the low EC category.

In **Dabhoi**, 54 samples were studied. The EC varies from 0.10 to 1.31 dS m^{-1}, and the average EC is 0.35 dS m^{-1}. Most soils (96.3%) have low EC, while a small portion (3.7%) falls in the medium EC category. No high EC soils were recorded.

In **Jetpur Pavi** 84 soil samples were studied. The EC ranges from 0.08 to 1.25 dS m^{-1}, with a mean value of 0.24 dS m^{-1}. Majority of soils (98.8%) show low EC, and only 1.2% are in the medium EC group.

In **Kapwant**, 54 samples were collected. The EC values range from 0.08 to 0.58 dS m^{-1}, and the mean EC is 0.20 dS m^{-1}. All soils belong to the low EC category.

In **Naswadi** 72 samples were collected. The EC ranges from 0.08 to 0.66 dS m^{-1}, with an average of 0.23 dS m^{-1}. All soils show low EC.

In **Sankheda**, 84 soil samples were analyzed. The EC values range from 0.07 to 0.88 dS m^{-1}, and the mean EC is 0.18 dS m^{-1}. All soils fall under the low EC class.

Overall, the EC values of soils in all talukas are low, indicating non-saline conditions. Medium EC soils are found only in small amounts, while high EC soils are completely absent. These low EC values suggest that the soils are suitable for most crops and do not have salinity problems.

Parameter	**Chhota Udepur**	**Dabhoi**	**Jetpur Pavi**	**Kavant**	**Nasvadi**	**Sankheda**
Number of samples	60	54	84	54	72	84
EC Min (dS m^{-1})	0.07	0.10	0.08	0.08	0.08	0.07
EC Max (dS m^{-1})	0.48	1.31	1.25	0.58	0.66	0.88
EC Mean (dS m^{-1})	0.16	0.35	0.24	0.20	0.23	0.18
Low EC soils (%)	100.0	96.3	98.8	100.0	100.0	100.0
Medium EC soils (%)	0.0	3.7	1.2	0.0	0.0	0.0
High EC soils (%)	0.0	0.0	0.0	0.0	0.0	0.0

Source:- Assessment of Sulphur Status and Other Selected Parameters in Soils of Kheda, Anand, Vadodara and Panchamahals Districts of Central Gujarat, India J. K. MALAV1, K. P. PATEL2, V. P. RAMANI3, S.B. PATEL3 AND R.A. PATEL3

6. Lithological Profile of the Narmada River Basin

The lithological data is collected from the Geological Survey of India (GSI), OCBIS Portal for the Upper and Middle Narmada Basin. (Ref 11)

The Narmada River basin exhibits a highly diverse geological architecture shaped by multiple tectono-sedimentary cycles, making it one of India's most complex litho-physiographic regions. The upper and central basin is dominated by extensive exposures of the Gondwana Supergroup, represented by the Barakar, Motur, Bijori, Pachmarhi, Denwa, and Bagra formations. These formations consist primarily of medium- to coarse-grained feldspathic sandstones, conglomerates, red–green mudstones, clay lenses, and calcareous bands, reflecting repeated cycles of fluvial deposition within a braided to meandering river system developed in a tectonically active pull-apart basin setting. The northern parts display thick, white, quartz-pebble-bearing sandstones of the Pachmarhi Formation, while the northwestern areas include the soft sandstones, clay-rich red beds, and calcareous mudstones of the Denwa Formation, overlain by the coarse, conglomeratic Bagra Formation interpreted to be alluvial-fan deposits formed due to rift-margin uplift and fault reactivation.

In the structural framework of the basin, the Narmada–Son Trough forms the principal tectonic lineament separating the Archaean and Bijawar crystalline basement from younger Vindhyan sedimentary sequences. The Vindhyan Supergroup contributes hard, horizontally bedded sandstones and shales, which form prominent escarpments and gorges along the valley, including the well-known marble gorge at Bheraghat. Further south, the basin is characterized by the Deccan Trap volcanic province, consisting of massive to vesicular basaltic lava flows with intertrappean limestone, sandstone, and clay horizons, commonly encountered in drilling records across Mandla, Betul, Hoshangabad, and Jhabua districts. These basalt flows form extensive flat-topped plateaus and ridges that dominate the Malwa and Satpura regions, frequently appearing at depths ranging from a few meters to over 200 m, depending on Quaternary cover thickness.

Large portions of the middle and lower basin are mantled by unconsolidated Quaternary alluvium, including sand, silt, clay, kankar, and gravel, deposited by the Narmada and its tributaries. Borehole lithologs consistently show alluvium extending to depths of 30–150 m before encountering underlying Gondwana, Vindhyan, Proterozoic, or Deccan Trap units. In several locations such as Mandla, Hoshangabad, Barwani, Jabalpur, and Narmadapuram the sub-alluvial lithology includes slates, phyllites, quartzites, dolomites, and granitic gneisses, indicating the presence of Archaean to Proterozoic crystalline basement beneath sedimentary and trap sequences. This diversity of lithologies reflects the long and complex evolutionary history of the basin, influenced by flexural subsidence, volcanic activity, basement faulting, and sustained fluvial processes, making the Narmada basin a geologically heterogeneous terrain with a distinct combination of volcanic, sedimentary, and crystalline rock assemblages.

6.1. Chemical composition of the Rocks of the Upper Narmada Basin

The chemical composition of rocks in the Upper Narmada Basin interpreted from NGCM geochemical datasets across geochemical toposheets 55N/10, 55N/13, 55N/01, 55N/11, 64B/07, and 64F/10 reveals a predominantly mafic to intermediate volcanic signature, shaped by the extensive spread of Deccan Trap basalts and interlayered Gondwana sedimentary formations. These toposheets cover the key upper-basin districts of Narsinghpur, Seoni, Mandla, Jabalpur, Chhindwara, Balaghat, and Dindori, providing a comprehensive geochemical picture of the region. The dataset shows that these rocks are consistently enriched in iron, magnesium, calcium, titanium, chromium, nickel, and cobalt, highlighting their basaltic lineage. At the same time, the presence of silica-rich and alkali-bearing samples in specific locations reflects the influence of Gondwana sandstones, intertrappean sediments, and weathered Proterozoic units, producing a geochemically diverse yet volcanically dominated upper basin. High Field Strength Elements (HFSEs) and Rare Earth Element (REE) systematics further confirm a strong Deccan volcanic foundation with localized sedimentary overprints.

i) Major Oxides

The major oxide chemistry strongly supports the mafic volcanic origin of upper Narmada rocks. Silicon dioxide (SiO_2) varies widely from 39.67% to as high as 72.8% indicating both classic basaltic compositions (45–52%) and areas where weathered quartz-rich sediments or Gondwana formations elevate silica content above 60%. Mean SiO_2 values across Narsinghpur, Seoni, Mandla, and Jabalpur stabilize between 46–50%, while Mandla–Balaghat and Dindori include silica-rich samples up to 72%, representing sandstone intercalations or intense silica mobilisation. Aluminium oxide (Al_2O_3) ranges between 10–27%, with most values clustering around 14–17%, consistent with abundant feldspar and clay mineral presence. Iron oxide (Fe_2O_3) remains notably high 8–21% in most districts, with some samples exceeding 26%, reflecting the high Fe content of Deccan basalt and its derivative soils.

Magnesium oxide (MgO) exhibits broad variability, ranging from 0.7–8.8%, while Calcium oxide (CaO) spans 0.4–8.8%, highlighting the presence of augite, olivine, and plagioclase in fresh or moderately altered basalt flows. Even highly weathered rocks retain MgO–CaO signatures due to resistant mafic mineral remnants. Manganese oxide (MnO) remains low (0.2–0.6%) but stable across districts. Sodium (Na_2O, 0.13–1.89%) and Potassium oxides (K_2O, 0.17–1.89%) reflect feldspar weathering and are locally enriched in Mandla–Balaghat where Gondwana sandstones contribute to alkali release. Titanium dioxide (TiO_2) is strikingly high 1.5–4.5% a unique basaltic signature derived from titanomagnetite and ilmenite. Conversely, Phosphorus pentoxide (P_2O_5) remains consistently low (0.06–0.68%) across all districts, confirming the low natural apatite content typical of Deccan basalt terrains and explaining the poor intrinsic phosphorus fertility of these rocks.

ii) Trace Metals & Heavy Elements

Trace metal concentrations across upper Narmada rocks exhibit a deeply basaltic affinity. Chromium (Cr) displays extremely high levels 120–1281 ppm with Mandla, Balaghat, and Dindori presenting the highest values, often exceeding 1000 ppm, consistent with chromite-bearing basaltic minerals and less-altered mafic units. Nickel (Ni) ranges between 12–107 ppm, and Cobalt (Co) between 6–93 ppm, both diagnostic of olivine–pyroxene–rich basaltic rocks. These three transition metals together confirm the strong ultramafic–mafic influence in the upper basin geochemistry. Vanadium (V) also spans a wide range (14–169 ppm, occasionally up to 214 ppm), further characterising the mafic volcanic provenance.

Copper (Cu) (14–49 ppm) and Zinc (Zn) (60–322 ppm) fall within natural geogenic ranges, though some higher Zn values in Jabalpur and Dindori imply localized concentration due to secondary enrichment. Barium (Ba) shows substantial variability (25–1232 ppm), particularly high in Mandla–Balaghat and Dindori, suggesting inputs from feldspar-rich Gondwana sandstones or intertrappean calcareous beds. Strontium (Sr) (54–420 ppm) is persistently elevated, consistent with plagioclase-rich basaltic fabrics and carbonate-bearing intertrappean sediments. Rubidium (Rb) is moderate (12–106 ppm), indicating minor felsic or sedimentary input.

High Field Strength Elements (HFSEs) such as Zirconium (Zr) (75–712 ppm), Niobium (Nb) (33–167 ppm), Hafnium (Hf) (0.8–3.6 ppm), and Yttrium (Y) (8–76 ppm) confirm the presence of zircon, titanite, rutile, and other resistant accessory minerals, which persist even through deep tropical weathering. These HFSE distributions clearly reflect a mixed geological framework—dominantly volcanic, but with sedimentary and intertrappean contributions in regions like Mandla, Dindori, and Balaghat. Additionally, occasional detection of Lead (Pb) up to 54 ppm, Lithium (Li) up to 65 ppm, Arsenic (As) up to 11 ppm, and minor amounts of Antimony, Bismuth, Cadmium, and Silver show weak but detectable signatures of accessory mineralisation, though still within typical crustal limits.

iii) Rare Earth Elements (REEs)

The REE profile of upper Narmada rocks reinforces their strongly basaltic origin. Light REEs (LREEs) such as Lanthanum (La) (10–44 ppm), Cerium (Ce) (23–110 ppm), Praseodymium (Pr) (2–10 ppm), and Neodymium (Nd) (17–95 ppm) appear consistently enriched relative to Heavy REEs (HREEs) like Yb, Lu, Tb, and Dy. This LREE enrichment pattern is characteristic of Deccan Trap basalts and remains preserved even in strongly weathered terrains due to the stability of REE-bearing accessory minerals. HREE concentrations remain low but stable (e.g., Yb 0.5–3.9 ppm, Lu 0.2–1.7 ppm), consistent with minimal heavy-REE host minerals.

Notably, the Mandla–Balaghat and Dindori regions show the highest REE variability, with Ce values occasionally exceeding 110 ppm and Nd reaching 94 ppm, suggesting localized enrichment due to retention in resistant phases like allanite, monazite, and zircon. Europium (Eu), Samarium (Sm), and Gadolinium (Gd) values show characteristic Deccan basalt anomalies, confirming the presence of plagioclase-rich mineral assemblages. Overall, the REE systematics clearly differentiate the upper basin as a dominantly basaltic geochemical province with modest sedimentary overprints and minimal anthropogenic disturbance.

6.2Chemical composition of the rocks in the Middle Narmada basin

The chemical composition of the Middle Narmada Basin derived from NGCM datasets across Toposheet Nos. 54L/08, 46J/16, 46N/04, 46J/09, 55E/07–08, 46N/15, and 46N/16 reveals a complex but dominantly basaltic to basalt–sedimentary mixed geological environment. This zone covers the central districts of Sagar, Dhar, Barwani, Jhabua, Bhopal, Raisen, Sehore, Indore, and

Khargone, all of which lie within the Deccan Volcanic Province but additionally include intertrappean limestone–sandstone formations, Vindhyan sediments, and alluvial patches. The chemical profiles from these districts illustrate strong signatures of mafic lithology marked by high Fe, Mg, Ca, Ti, Cr, Ni, and Co while elevated SiO_2 and alkali metals in some toposheets reflect the contribution of sandstone, siltstone, and calcareous intertrappean strata. This combination produces a geochemically hybrid middle basin where basaltic characteristics dominate but are periodically overprinted by sedimentary and alluvial geochemical inputs.

i) Major Oxides

The major oxide chemistry of the Middle Narmada Basin rocks reveals a broad spectrum arising from mixed volcanic and sedimentary parent materials. Silicon dioxide (SiO_2) ranges from 31–75%, with the lower values in Dhar–Barwani indicating fresher Deccan Trap basalts, while higher silica concentrations in Sagar, Vidisha, and Bhopal reflect quartz-rich Vindhyan sandstones and weathered claystones. Aluminium oxide (Al_2O_3) commonly falls between 7–20%, representing extensive feldspar weathering into clay minerals such as kaolinite, illite, and smectite, particularly in eastern middle basin districts. Iron oxide (Fe_2O_3) is characteristically high (9–24%), most pronounced in Jhabua and Dhar–Barwani where lateritic enrichment and basaltic minerals like magnetite–ilmenite dominate. Magnesium oxide (MgO) varies between 1.4–4.9% and Calcium oxide (CaO) between 1.3–16%, reflecting the presence of mafic minerals (augite, olivine) and calcic plagioclase in basaltic flows, as well as carbonate-rich intertrappean layers. Manganese oxide (MnO) stays low (0.07–0.3%), consistent with typical basalt-derived soils. Sodium oxide (Na_2O) ranges from 0.18–1.87% and Potassium oxide (K_2O) from 0.42–3.17%, marking zones of varying feldspar decomposition, with higher K_2O in shale–sandstone terrains and lower values in unaltered basaltic areas. Titanium oxide (TiO_2) shows consistent enrichment (1–5%), a diagnostic feature of Deccan basalts due to abundant titanomagnetite and ilmenite. Phosphorus pentoxide (P_2O_5) remains uniformly low (0.04–0.32%), indicating naturally low apatite content typical of both basaltic and sedimentary terrains of the basin.

ii) Trace & Heavy Metals

Trace metal distributions in the Middle Narmada Basin strongly reflect the mafic–intermediate volcanic foundation of the region. Chromium (Cr) levels range from 80 to over 1100 ppm, with Dhar, Barwani, and Jhabua recording the highest concentrations characteristic of ultramafic–mafic source rocks. Nickel (Ni) displays a similar trend, spanning 22–172 ppm, while cobalt (Co) ranges from 9–80 ppm, all confirming the dominance of basaltic material, particularly in the southwestern districts. Moderate concentrations of copper (Cu) (22–61 ppm) and zinc (Zn) (70–390 ppm) reflect natural mafic sources with localized sedimentary enrichment. Barium (Ba) values vary widely (75–1232 ppm), especially high in Sagar–Vidisha–Bhopal where felsic sandstone and shale components contribute. Strontium (Sr) spans 60–420 ppm, highlighting plagioclase weathering, while rubidium (Rb) (6–66 ppm) is elevated in sedimentary terrains, signifying higher K-bearing mineral content. High Field Strength Elements including zirconium (Zr) (160–700+ ppm), niobium (Nb) (30–160 ppm), hafnium (Hf) (0.8–3.6 ppm), and yttrium (Y) (6–70 ppm) appear significantly enriched due to the presence of resistant accessory minerals such as zircon, titanite, rutile, and monazite. Additionally, trace occurrences of lead (Pb) (up to ~97 ppm), lithium (Li) (~65 ppm), arsenic (As) (~10 ppm), tungsten (W) (up to 377 ppm), molybdenum, silver, cadmium, and bismuth appear in geogenic background levels, with no indication of anthropogenic contamination in these bedrock-derived samples. The overall trace metal pattern firmly indicates a composite landscape shaped primarily by Deccan Trap volcanism modified by sedimentary intrusions.

iii) Rare Earth Elements

The rare earth element (REE) geochemistry of the Middle Narmada Basin reveals clear enrichment in light rare earth elements (LREEs) and moderate but consistent levels of heavy rare earth elements (HREEs) a pattern characteristic of Deccan Trap basalts and associated weathering crusts. Lanthanum (La) values typically range from 10–44 ppm, cerium (Ce) from 35–110 ppm, praseodymium (Pr) between 2–10 ppm, and neodymium (Nd) between 18–95 ppm, showing strong LREE dominance driven by the presence of monazite, allanite, and LREE-enriched basaltic minerals. Europium (Eu) concentrations remain low (0.5–1.7 ppm), reflecting mild to moderate negative Eu anomalies caused by plagioclase fractionation in parent lava flows. Among HREEs, elements such as samarium (Sm) (1.8–10 ppm), gadolinium (Gd) (3.9–10.6 ppm), dysprosium

(Dy) (4–10 ppm), erbium (Er) (1.7–5 ppm), ytterbium (Yb) (1–4 ppm), and lutetium (Lu) (0.3–1.4 ppm) show moderately enriched but tightly clustered values that point to the persistence of zircon, titanite, and xenotime in both volcanic and sedimentary settings. Collectively, the REE distribution highlights the mixed provenance of Middle Basin rocks, where basaltic LREE enrichment intersects with sedimentary contributions from Vindhyan and Gondwana formations, producing a balanced but distinctly mafic-biased REE signature.

6.3 Chemical Composition of the Rocks in the Lower Narmada Basin

The Geochemical data used for lower basin is taken from the GEOROC geochemical dataset of the Lower Narmada region. This area for which data is available mainly includes Chhota Udaipur and nearby parts of Gujarat and western Madhya Pradesh. The rocks here are mainly formed due to alkaline and post-Deccan volcanic activity related to the Narmada-Son Lineament.

Most of the rocks are alkaline basalts, lamprophyres, and ultramafic rocks. These rocks are formed from deep mantle sources. Because of this, they contain high amounts of iron, magnesium, calcium, and many rare elements.

The Lower Narmada Basin is a geologically complex and petrogenetically important part of the Deccan Volcanic Province. It contains a wide variety of volcanic, plutonic, and metamorphic rocks.

The geochemical character of this region is different from the typical lava sequences of the Western Ghats. The Lower Narmada Basin shows a higher abundance of alkaline rocks, high-magnesium picrites, and a rare bimodal volcanic sequence at Mount Pavagadh.

i) Metal Oxides

In the lower Narmada Basin, the metal oxides in the rocks have different amounts in Picrite Basalt, rhyolite, dacite, and pitchstone rock of Pavagadh, Rajpipla and Amba Dongar. Picrite and basalt have low silica, with silicon dioxide (SiO_2) between 46.20 and 50.79 wt.%, while rhyolite, dacite, and pitchstone have very high silica from 70.31 to 79.68 wt.%. Titanium dioxide (TiO_2) is higher in picrite and basalt at 1.18–2.67 wt.% and much lower in the silicic rocks at 0.35–0.67 wt.%. Aluminum oxide (Al_2O_3) varies from 10.19 to 16.66 wt.% in all rock types. Iron oxide (Fe_2O_3) and magnesium oxide (MgO) are high in picrite and basalt, with Fe_2O_3 at 11.53–14.80 wt.% and MgO at 4.47–18.60 wt.%, but they are very low in rhyolite, dacite, and pitchstone, where Fe_2O_3 is only

2.50–5.50 wt.% and MgO is 0.06–1.73 wt.%. Calcium oxide (CaO) is around 9.16–10.32 wt.% in picrite and basalt but drops to 0.15–3.93 wt.% in silicic rocks. Sodium oxide (Na_2O) ranges from 1.02 to 3.12 wt.% in picrite and basalt and from 0.90 to 4.37 wt.% in silicic rocks. Potassium oxide (K_2O) is low in picrite and basalt at 0.24–1.69 wt.% but high in rhyolite at 5.87–6.04 wt.%. Phosphorus pentoxide (P_2O_5) is higher in picrite and basalt at 0.22–0.54 wt.% and very low in silicic rocks at 0.01–0.08 wt.%. This pattern shows that the magma became richer in silica and poorer in iron and magnesium with time.

The Amba Dongar alkaline carbonatite complex formed during the final stage of Deccan volcanism and is one of the most distinctive alkaline provinces worldwide. The rocks contain more than 50 wt.% carbonate minerals, mainly calcite, dolomite, ankerite, and siderite. Sovite rocks are rich in CaO, whereas ankeritic types show higher MgO and FeO contents. The carbonatites have elevated P2O5 values of 0.50–0.76 wt.% due to magmatic apatite and MnO concentrations reaching up to 0.52 wt.% from manganese-bearing carbonates. Fluorine is also abundant, with values up to 0.32 wt.%, reflecting extensive fluorite mineralization. This magmatism originated from a compositionally varied subcontinental mantle during lithospheric rifting.

In Godhra Chhota Udepur Region Phengite is rich in silica and aluminium, with silicon dioxide (SiO_2) between 46.6 and 48.8 wt.% and aluminium oxide (Al_2O_3) between 28.7 and 34.7 wt.%, and it also contains high potassium oxide (K_2O) from 8.98 to 10.2 wt.% but very low calcium oxide (CaO). Garnet core has lower silica at about 37.0 wt.% and aluminium oxide at 20.8 wt.%, but it is very rich in iron oxide (FeO) at 29.6 wt.% and has noticeable calcium oxide at 5.55 wt.%. Biotite shows moderate silica at 39.1 wt.%, aluminium oxide at 16.7 wt.%, high iron oxide at 19.4 wt.% and magnesium oxide (MgO) at 9.76 wt.%, along with high potassium oxide at 7.13 wt.%. Chlorite is poor in silica at 24.9 wt.% but rich in iron oxide at 28.8 wt.% and magnesium oxide at 11.3 wt.%, while sodium oxide (Na_2O) and potassium oxide are almost absent. Plagioclase is very rich in silica at 68.5 wt.% and sodium oxide at 12.5 wt.%, but it contains very little iron oxide at 0.12 wt.% and magnesium oxide is below detection. Overall, the data show that mica minerals are potassium rich, garnet and chlorite are iron rich, and plagioclase is silica and sodium rich in the Amba Dongar complex.

ii) Trace & Heavy Metals

The trace & Heavy Metal element content is very different in basalt, rhyolite, picrite, carbonatite, and Rajula basalt. Barium (Ba) is high in Pavagadh basalt at 1640 ppm but extremely high in carbonatite at about 10,100 ppm, while rhyolite and Rajula basalt have much lower values of 165 ppm and 121 ppm. Strontium (Sr) is also high in Pavagadh basalt at 986 ppm and reaches about 2000 ppm in carbonatite, whereas rhyolite has only 165 ppm and picrite has 306 ppm. Rubidium (Rb) is moderate in rhyolite at 44 ppm and Rajula basalt at 48 ppm but is very low or only present in traces in carbonatite. Niobium (Nb) shows strong enrichment in carbonatite at about 250 ppm, compared to 54.4 ppm in Pavagadh basalt and only 12.0 ppm in Rajula basalt. Zirconium (Zr) ranges from 147 to 243 ppm in basalt, rhyolite, and picrite but is not detected in carbonatite. Thorium (Th) is low in all rocks, around 3.4–6.8 ppm, and is present only in trace amounts in carbonatite. Yttrium (Y) is highest in carbonatite at 130 ppm, while basalt, rhyolite, picrite, and Rajula basalt show lower values between 23.0 and 40.5 ppm. Overall, carbonatite is strongly enriched in barium, strontium, niobium, and yttrium compared to the other rock types.

iii) Rare Earth Metals

The rare earth element data show clear differences between picrite, basalt flows, and basalt dykes from the Pavagadh. In Pavagadh picrite, light rare earth elements such as lanthanum (La) range from 14.40 to 21.50 ppm, cerium (Ce) from 29.72 to 47.07 ppm, and neodymium (Nd) from 17.10 to 25.91 ppm, while heavy rare earth elements like ytterbium (Yb) are low at 1.13–1.82 ppm and lutetium (Lu) at 0.16–0.27 ppm. The basalt flow is the most enriched, where La reaches 26.05 ppm, Ce 55.19 ppm, Nd 31.38 ppm, samarium (Sm) 8.50 ppm, and heavy rare earths like dysprosium (Dy) 7.47 ppm, Yb 3.20 ppm, and Lu 0.45 ppm. Basalt dykes have lower light rare earths, with La 11.97 ppm and Ce 28.56 ppm, but show relatively higher heavy rare earth contents, with Yb at 2.81 ppm and Lu at 0.39 ppm. Which is presented in below. Overall, basalt flows are richest in rare earth elements, picrites show moderate values, and basalt dykes are poorer in light rare earth elements but comparatively richer in heavy rare earth elements.

At Amba dongar the ankeritic dyke has small amounts of these elements, with cerium (Ce) at 0.27%, lanthanum (La) at 0.08%, yttrium (Y) at 0.013%, niobium (Nb) at 0.025%, and zirconium (Zr) not detected. The ring sovite contains even lower values, where Ce is 0.09%, La is 0.025%, Y is 0.004%, Nb is 0.027%, and Zr is also not detected. The sovite sample is more enriched, with

Ce 0.30%, La 0.145%, Y 0.015%, Nb 0.057%, and Zr 0.02%. The radioactive dyke is the richest in these elements, showing more than 0.30% Ce and more than 0.10% La, while Nb and Zr are present in high amounts and Y is not reported. Overall, sovite and radioactive dykes are richer in rare earth and related elements than ankeritic dyke and ring sovite.

7. Recommendations

- Increase surface-water monitoring stations and change sampling from quarterly to at least monthly, with real-time monitoring at critical locations such as urban drains, industrial outlets, drinking-water intakes.
- Monitor a complete parameter set in every surface-water sample location including Physical, Chemical, Biological, Pesticide and Heavy metals.
- Increase groundwater monitoring frequency for drinking-water wells and borewells to monthly, and to daily at high-risk locations where contamination is suspected.
- Include all community and domestic supply wells in the formal monitoring network and analyze groundwater for the same parameters as surface water.
- When poor surface or groundwater quality is detected, conduct rapid source identification (sewage leakage, agricultural runoff, or industrial contamination) and immediately provide mitigation measures such as alternate water supply or point-of-use treatment.
- Expand systematic soil, and rock geochemical sampling across the basin in coordination with relevant agencies, covering surface and sub-surface soil, and representative rock types.
- Analyze soil and rock samples for major and trace elements, heavy metals, organic carbon, and particle size, and include mineralogy and selected isotopes where resources permit to identify contamination sources and pathways.
- Publish all sampling locations, methods, analytical procedures, and metadata to allow long-term comparison and future studies.
- Upload all monitoring data to a single open-access basin-level water-quality portal with machine-readable formats, regular updates, real-time sensor feeds, quality-control flags, station metadata, and simple public summaries such as potable/not-potable status with color-coded risk levels.

- Install continuous multi-parameter sensors at priority locations with telemetry and automated alerts when limits are exceeded, supported by regular laboratory verification.
- Provide low-cost water-quality display or testing units at community water points to inform the public about basic water safety conditions.
- Define clear institutional roles and a rapid response protocol specifying responsibility for investigation, public advisories, and corrective actions when water quality deteriorates.
- Strengthen coordination among water-quality agencies, public health departments, municipal bodies, and scientific institutions, and invest in laboratory capacity, trained staff, and mobile monitoring teams.
- Map existing monitoring stations, identify gaps, add priority stations, launch a pilot of continuous sensors, include all community wells in regular monitoring, and establish a dedicated fund for rapid pollution response and remediation.
- Enforce preventive measures such as strict effluent standard compliance, improved sewage treatment, protection of river buffer zones, adoption of agricultural best practices to reduce nutrient and pesticide runoff, and strong industrial source control.

- Soil and lithological profile are also very important parameters to explore, as they affect the overall river ecosystem.
- There is a need for further ground-truthing and continued monitoring of water and soil quality in the Narmada River Basin. Mapping of all point and non-point sources affecting river health is required to be done.
- Continuous monitoring and assessment would lead to decision-making for effective management plans and strategies to control overall river health.

8. References

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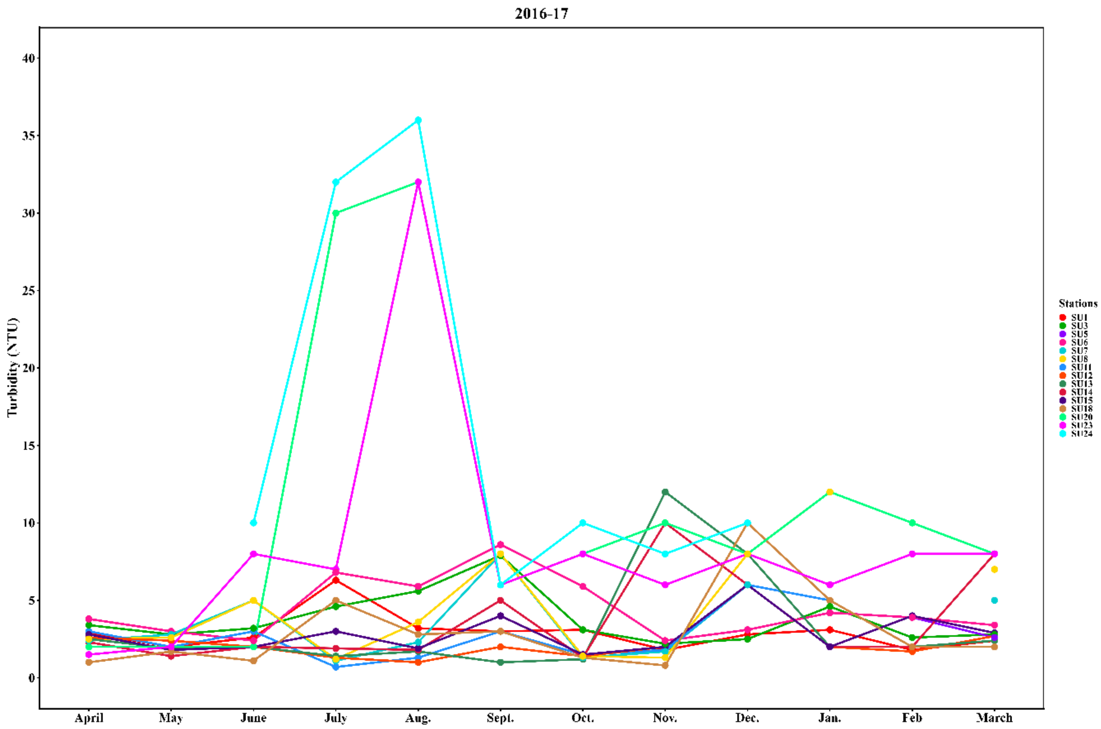
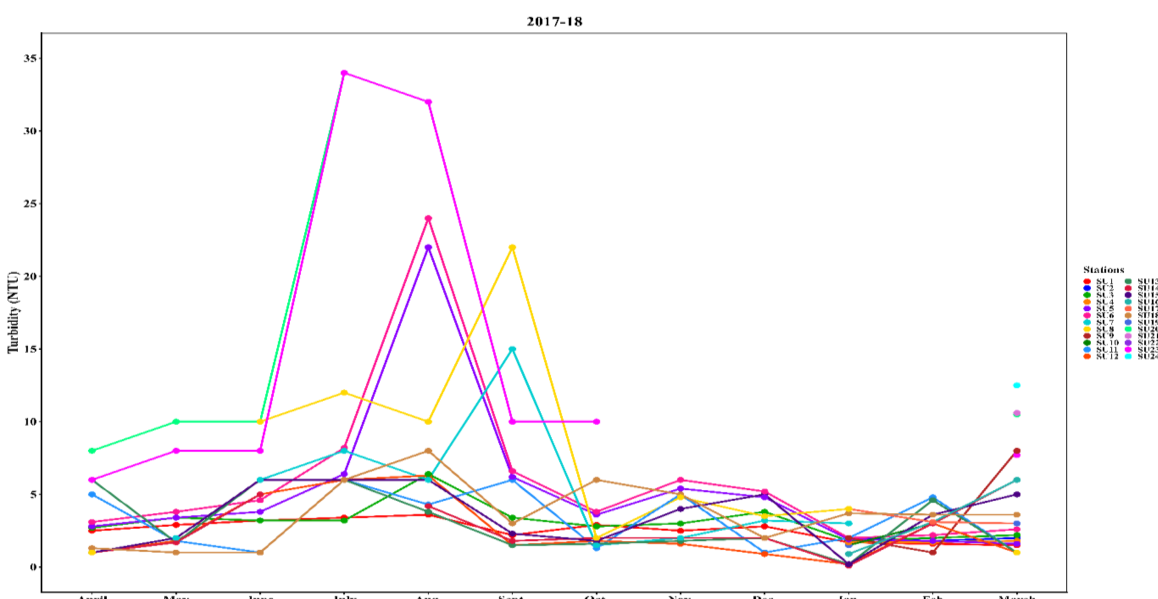
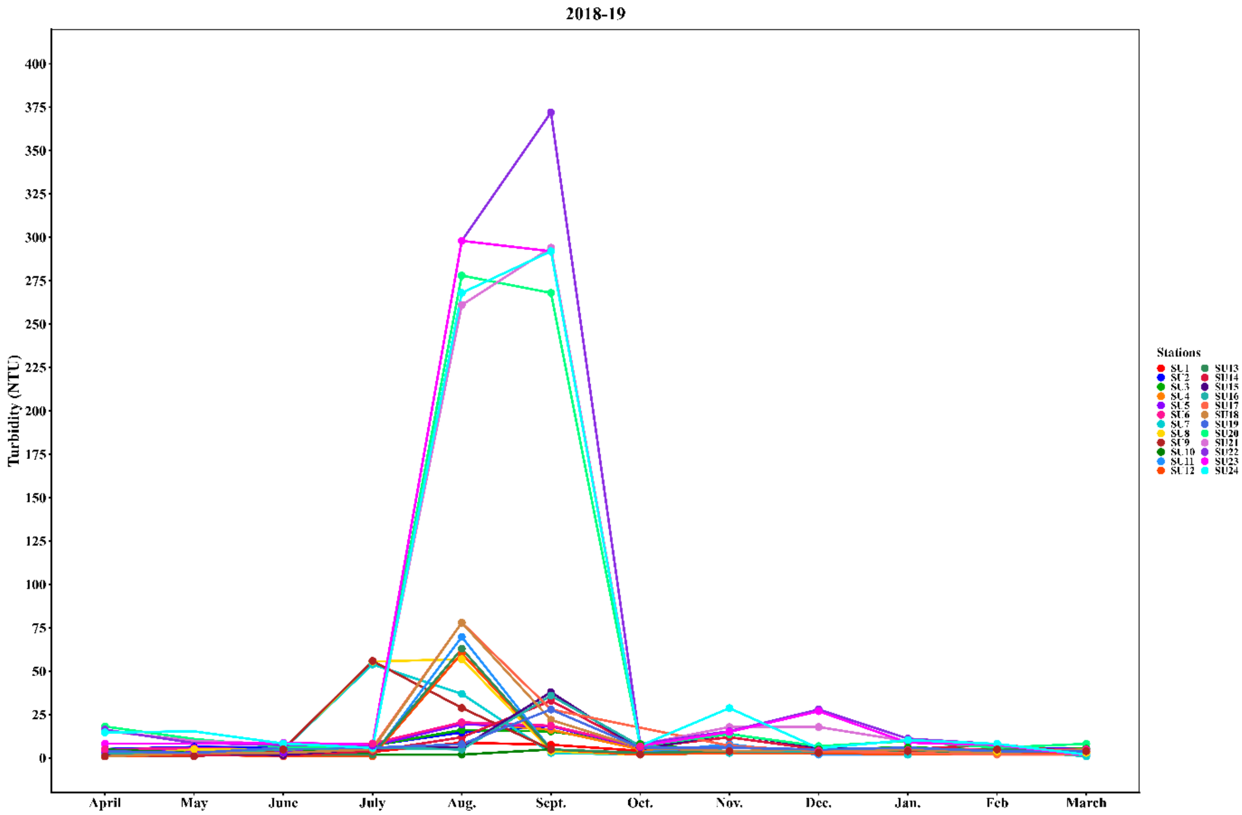
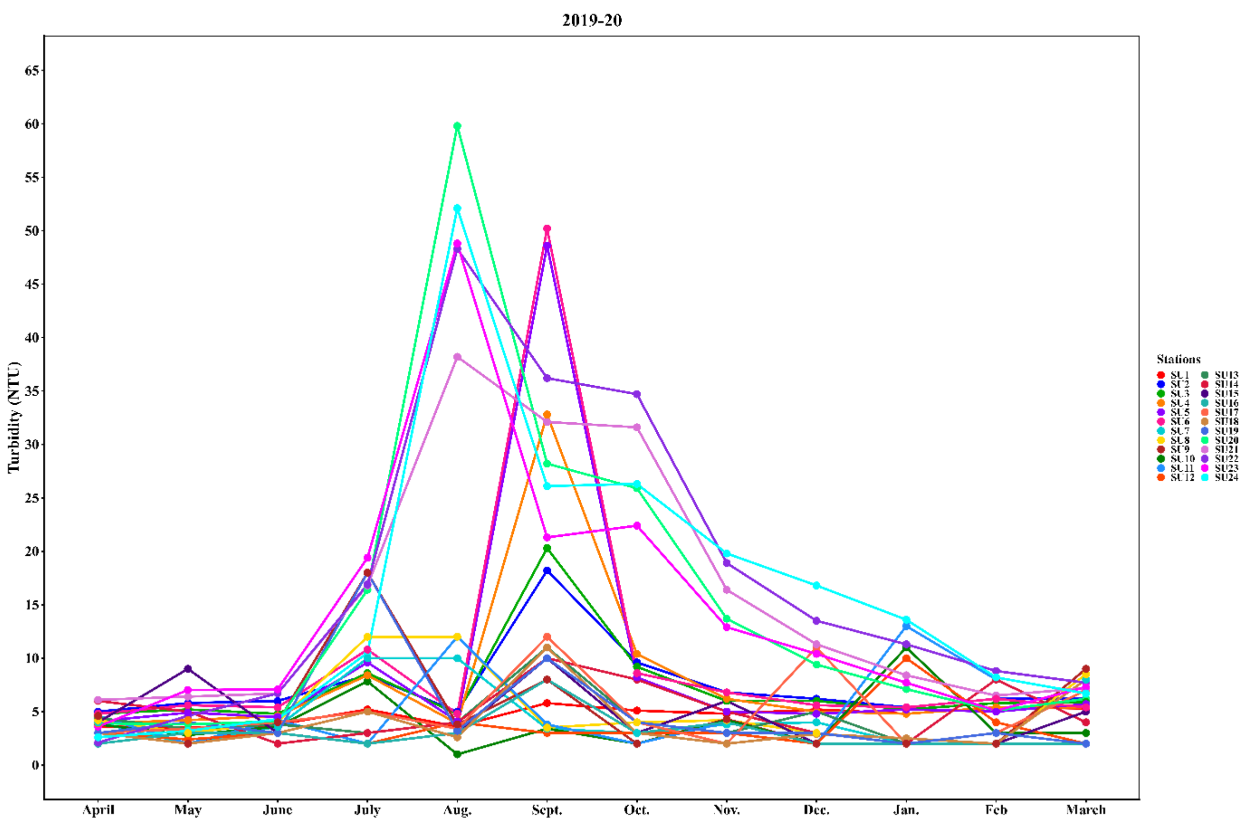
9. ANNEXURES

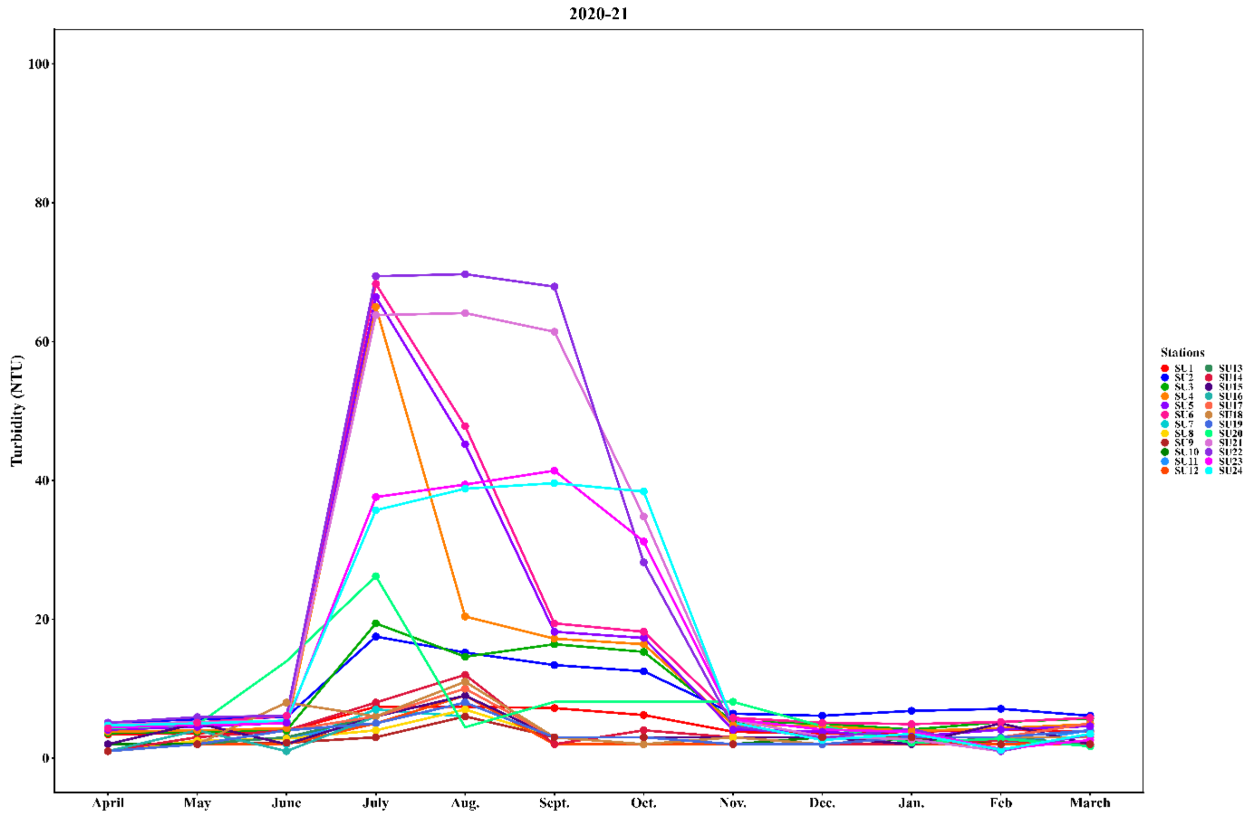
Annexure 3A: Monthly variation of turbidity for 9 years (2016-2025) at different sampling stations of the Upper Narmada Basin

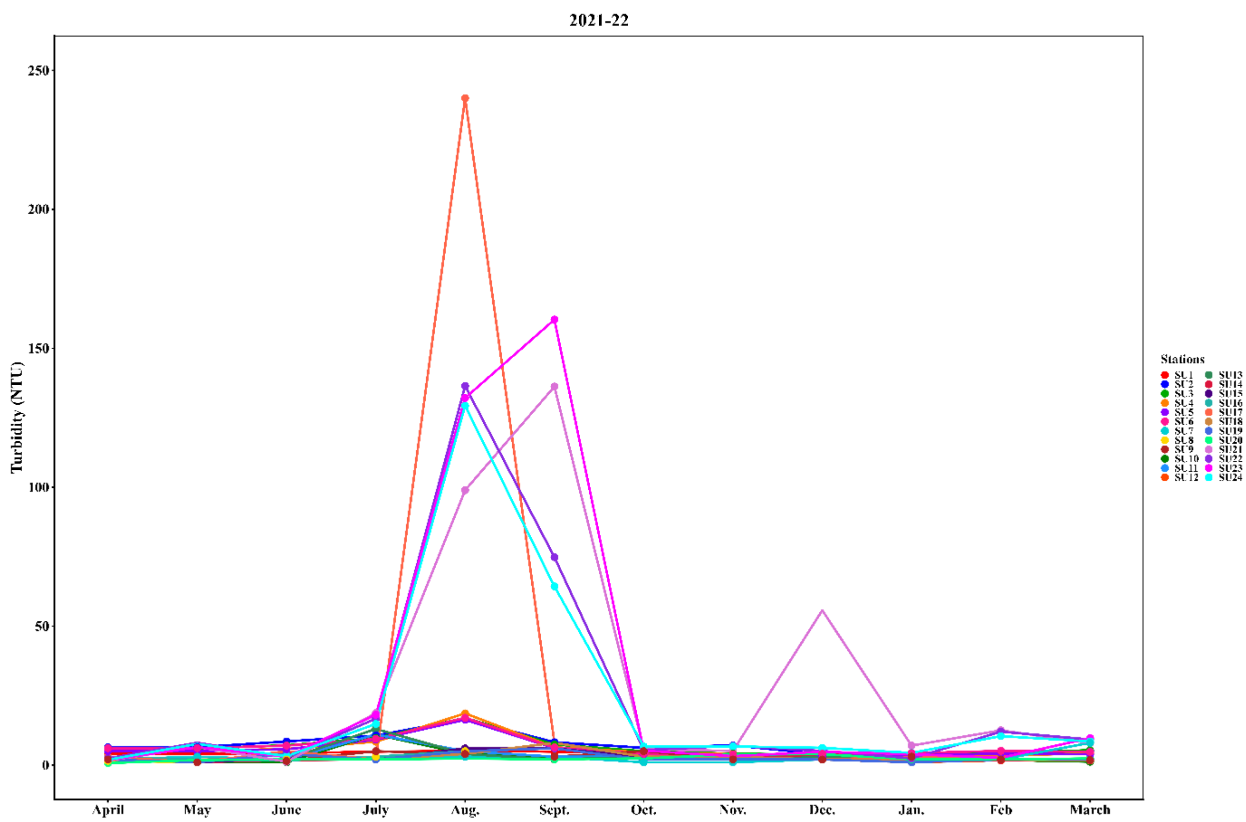


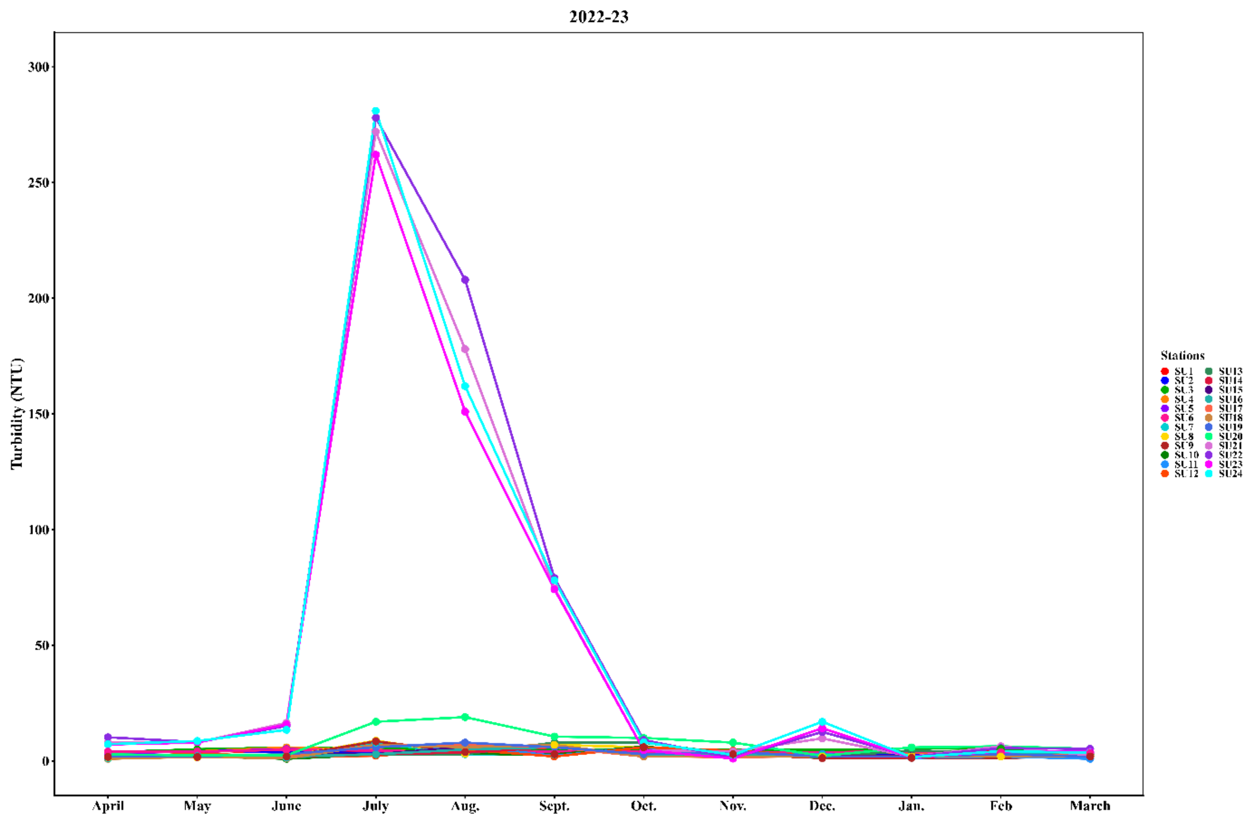



2018-19
Turbidity (NTU)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1
SU2
SU3
SU4
SU5
SU6
SU7
SU8
SU9
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
SU18
SU19
SU20
SU21
SU22
SU23
SU24


2019-20
Turbidity (NTU)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1
SU2
SU3
SU4
SU5
SU6
SU7
SU8
SU9
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
SU18
SU19
SU20
SU21
SU22
SU23
SU24


2020-21
Turbidity (NTU)
0
20
40
60
80
100
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1 SU2 SU3 SU4 SU5 SU6 SU7 SU8 SU9 SU10 SU11 SU12
SU13 SU14 SU15 SU16 SU17 SU18 SU19 SU20 SU21 SU22 SU23 SU24


2021-22
Turbidity (NTU)
0
50
100
150
200
250
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1 SU2 SU3 SU4 SU5 SU6 SU7 SU8 SU9 SU10 SU11 SU12
SU13 SU14 SU15 SU16 SU17 SU18 SU19 SU20 SU21 SU22 SU23 SU24



2022-23
Turbidity (NTU)
300
250
200
150
100
50
0
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1
SU2
SU3
SU4
SU5
SU6
SU7
SU8
SU9
SU10
SU11
SU12
SU13
SU14
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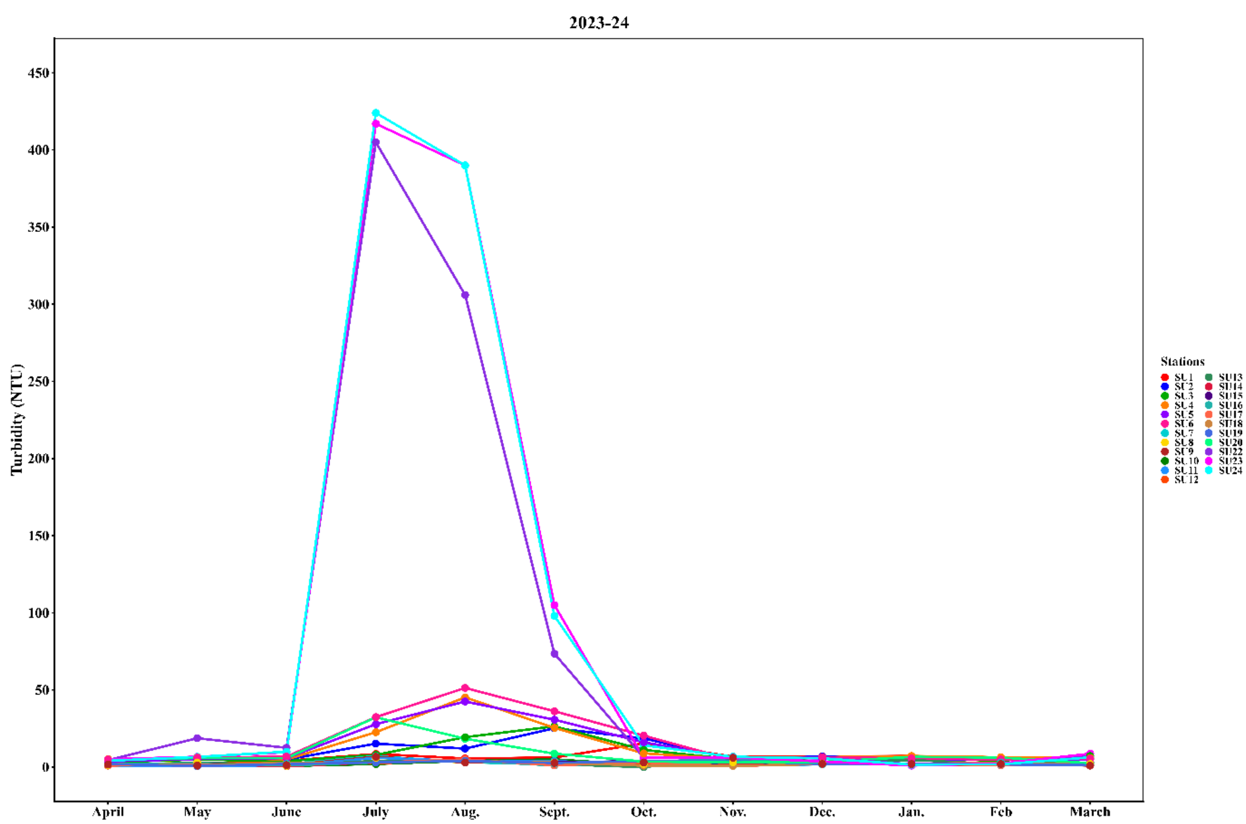
SU21
SU22
SU23
SU24



2023-24
Turbidity (NTU)
450
400
350
300
250
200
150
100
50
0
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1
SU2
SU3
SU4
SU5
SU6
SU7
SU8
SU9
SU10
SU11
SU12
SU13
SU14
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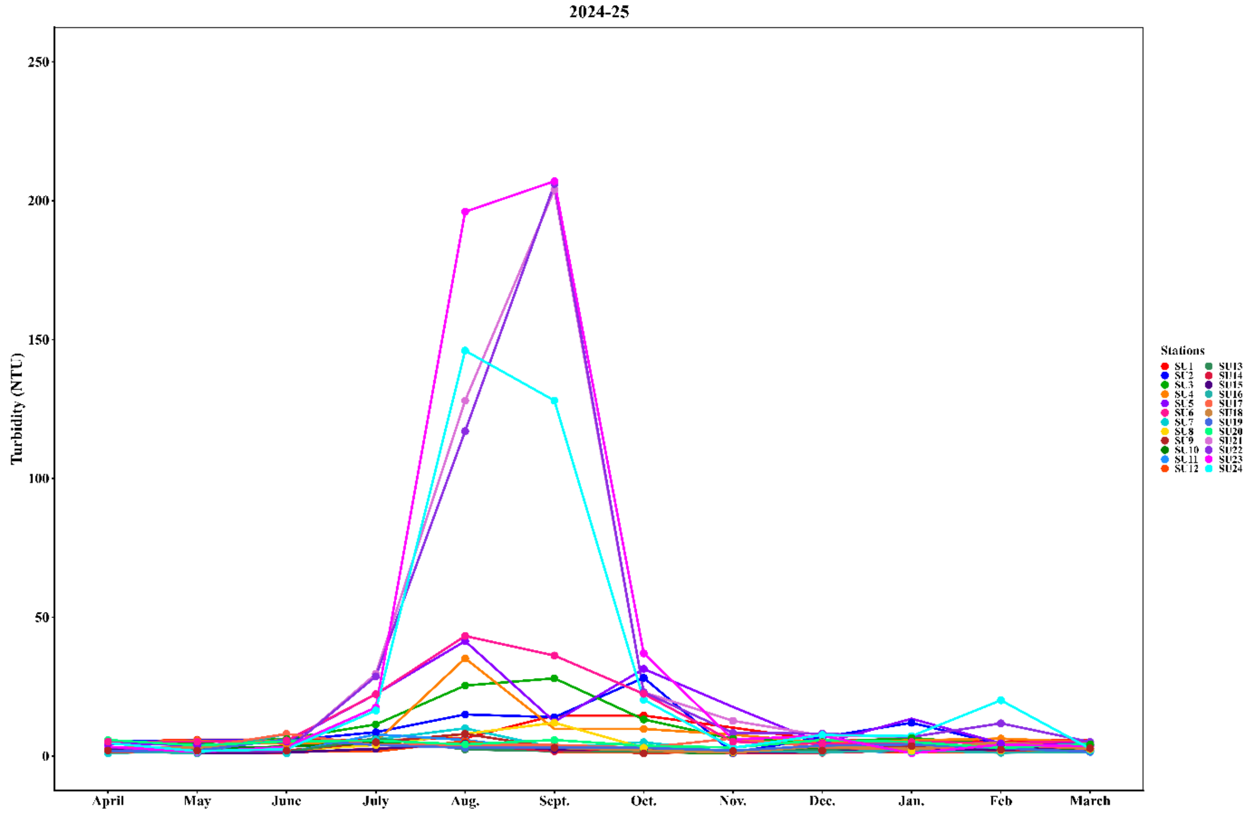
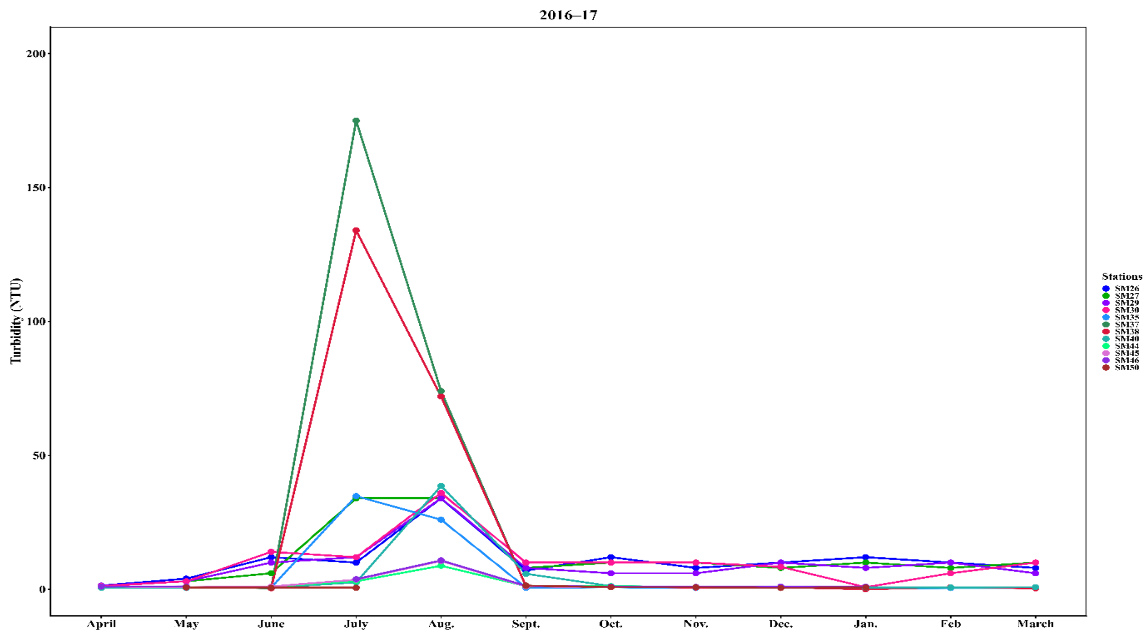
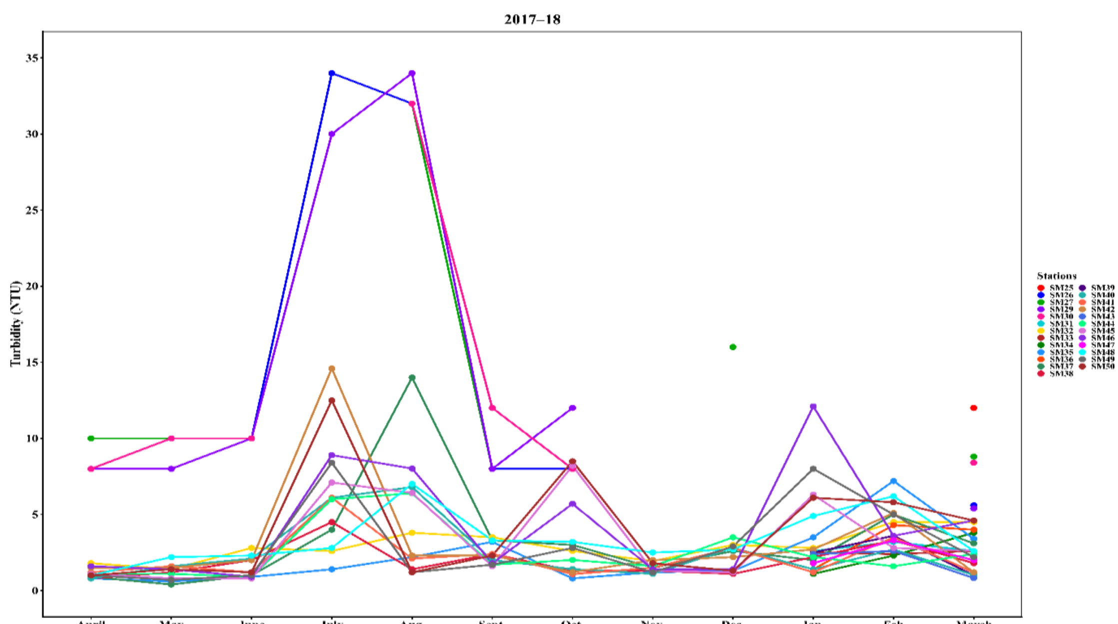
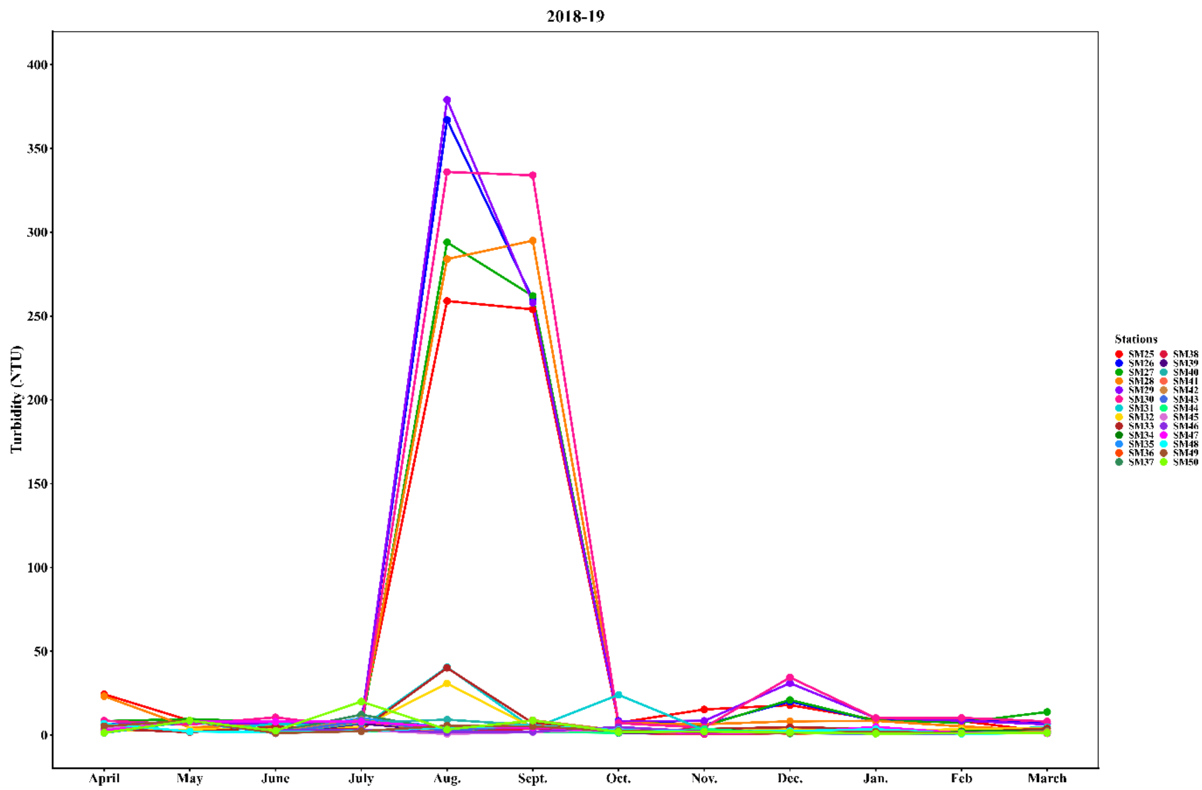
SU20
SU22
SU23
SU24


2024-25
Turbidity (NTU)
250
200
150
100
50
0
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SU1
SU2
SU3
SU4
SU5
SU6
SU7
SU8
SU9
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
SU18
SU19
SU20
SU21
SU22
SU23
SU24

Annexure 3 B: Monthly data variation of turbidity for 9 years (2016-2025) at different sampling stations of the Middle Narmada Basin






2018-19
Turbidity (NTU)
0
50
100
150
200
250
300
350
400
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM38
SM26 SM39
SM27 SM40
SM28 SM41
SM29 SM42
SM30 SM43
SM31 SM44
SM32 SM45
SM33 SM46
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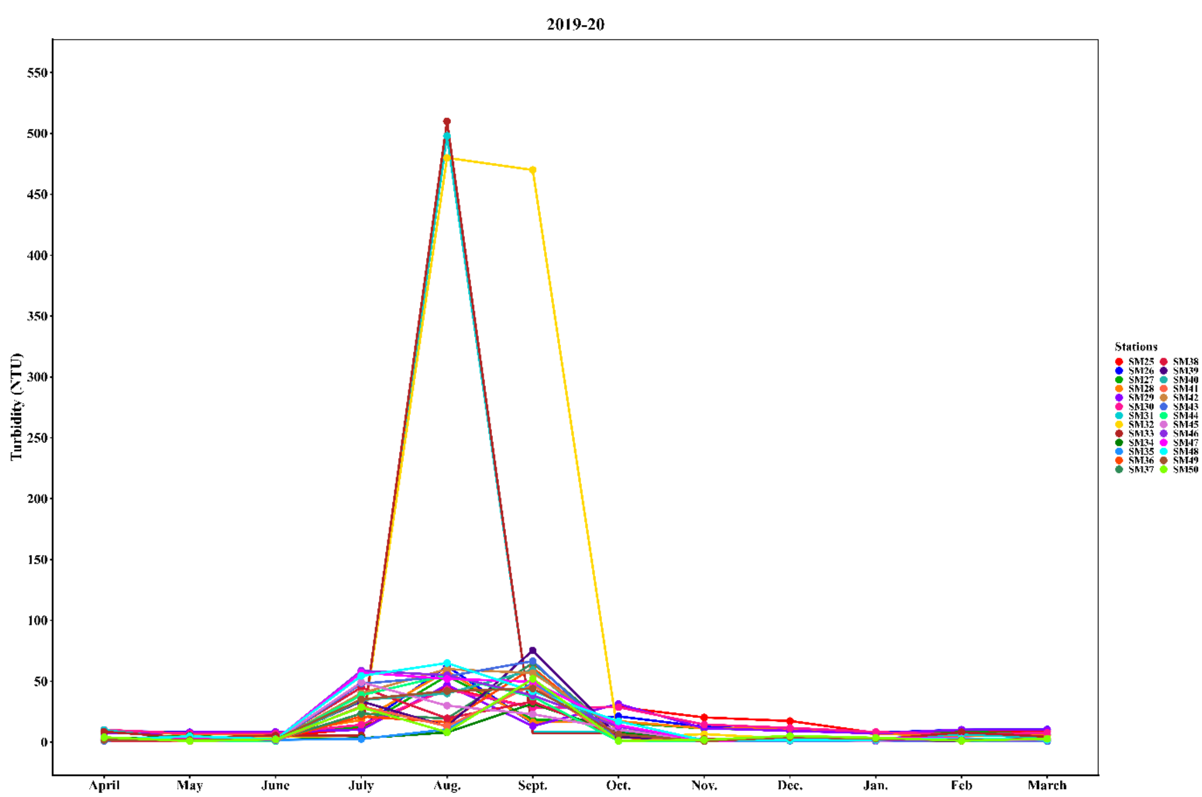
SM36 SM49
SM37 SM50


2019-20
Turbidity (NTU)
0
50
100
150
200
250
300
350
400
450
500
550
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM38
SM26 SM39
SM27 SM40
SM28 SM41
SM29 SM42
SM30 SM43
SM31 SM44
SM32 SM45
SM33 SM46
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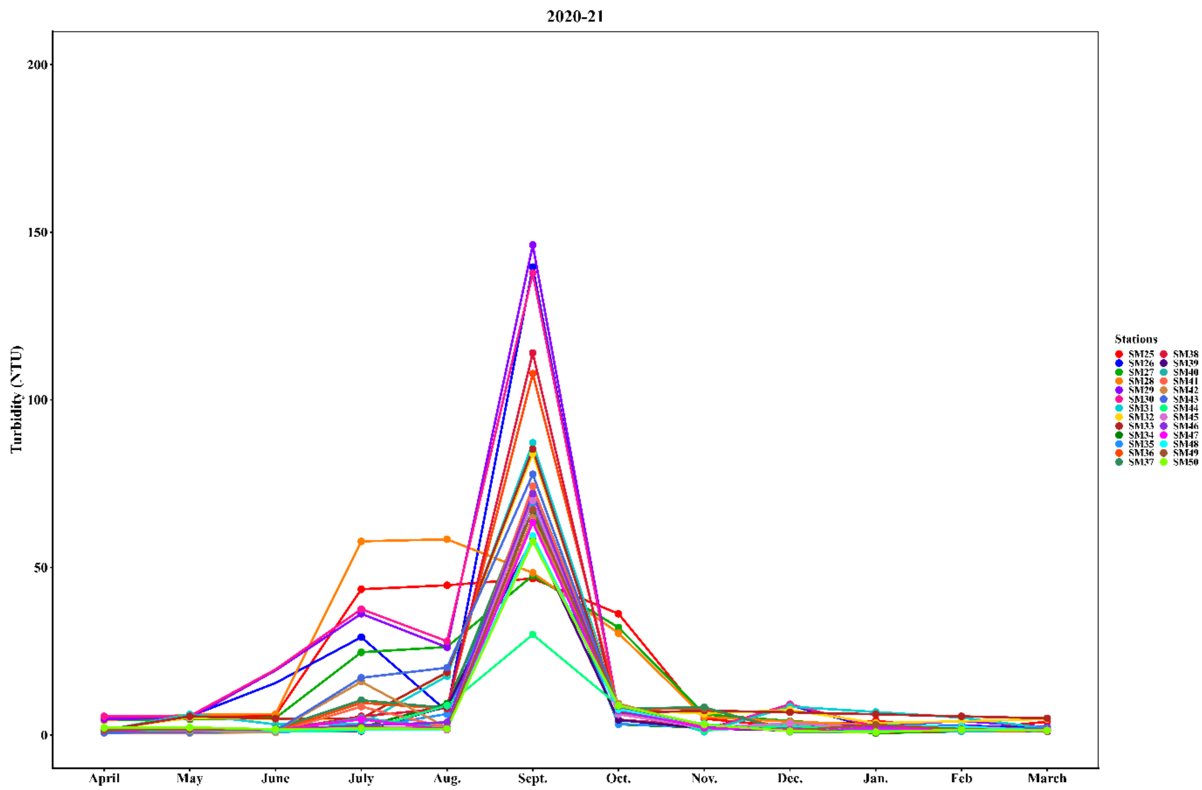
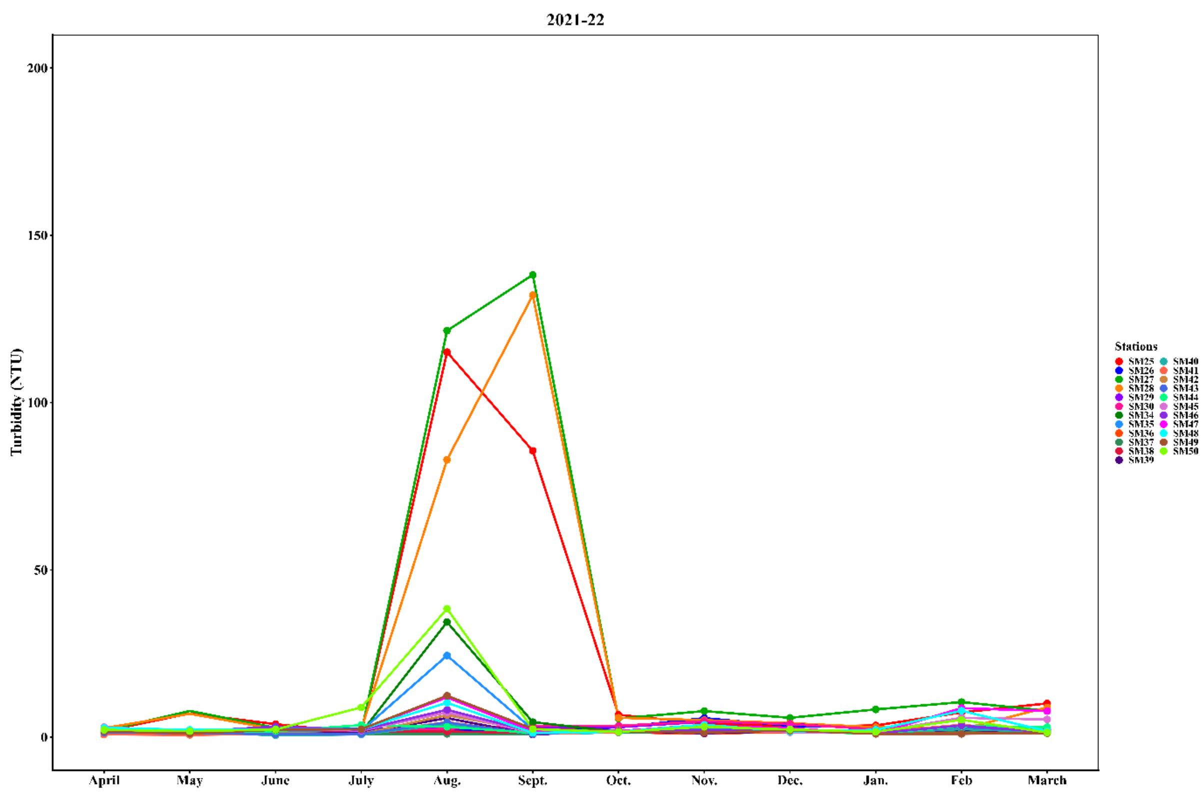
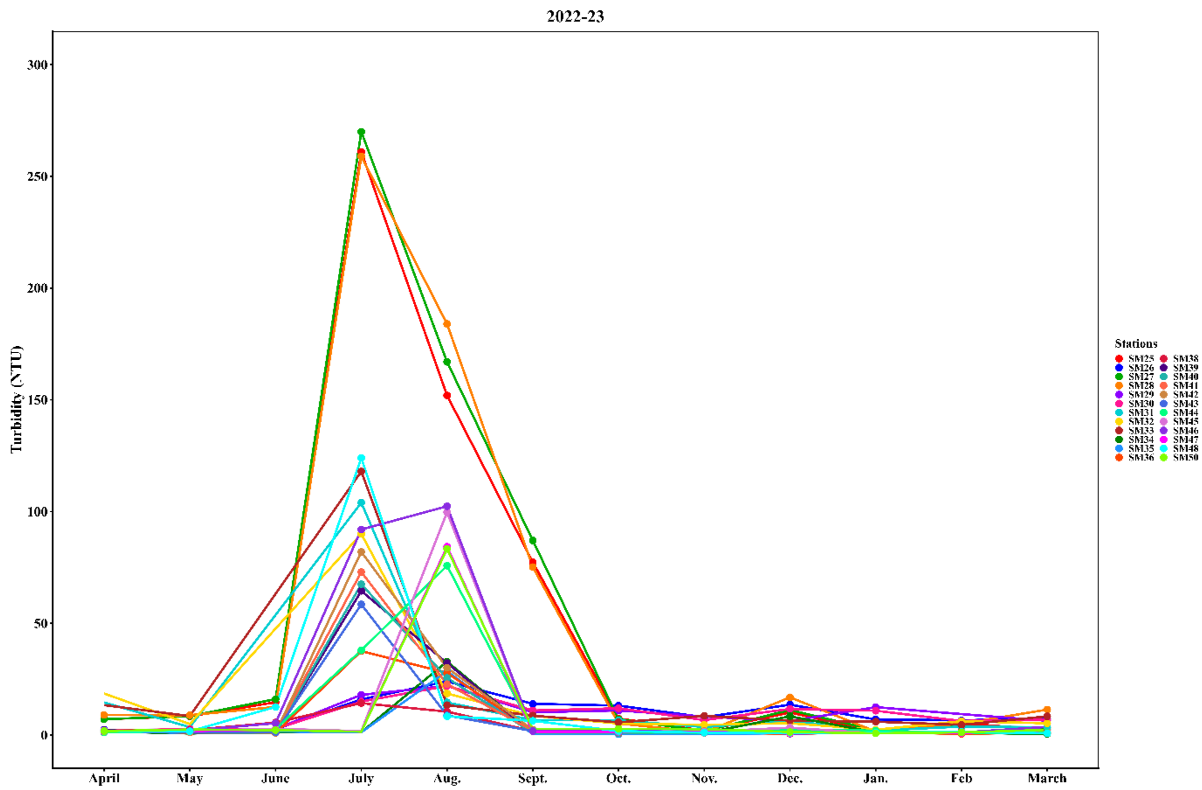
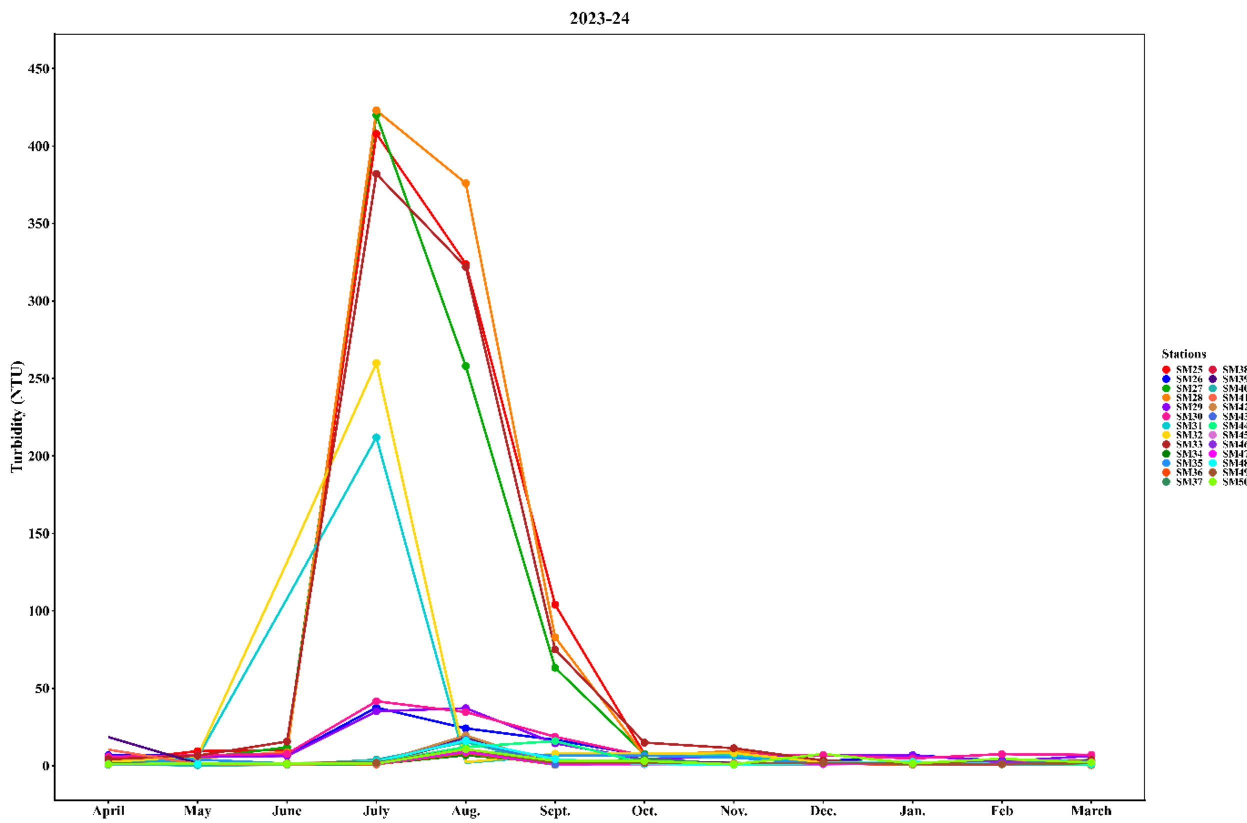
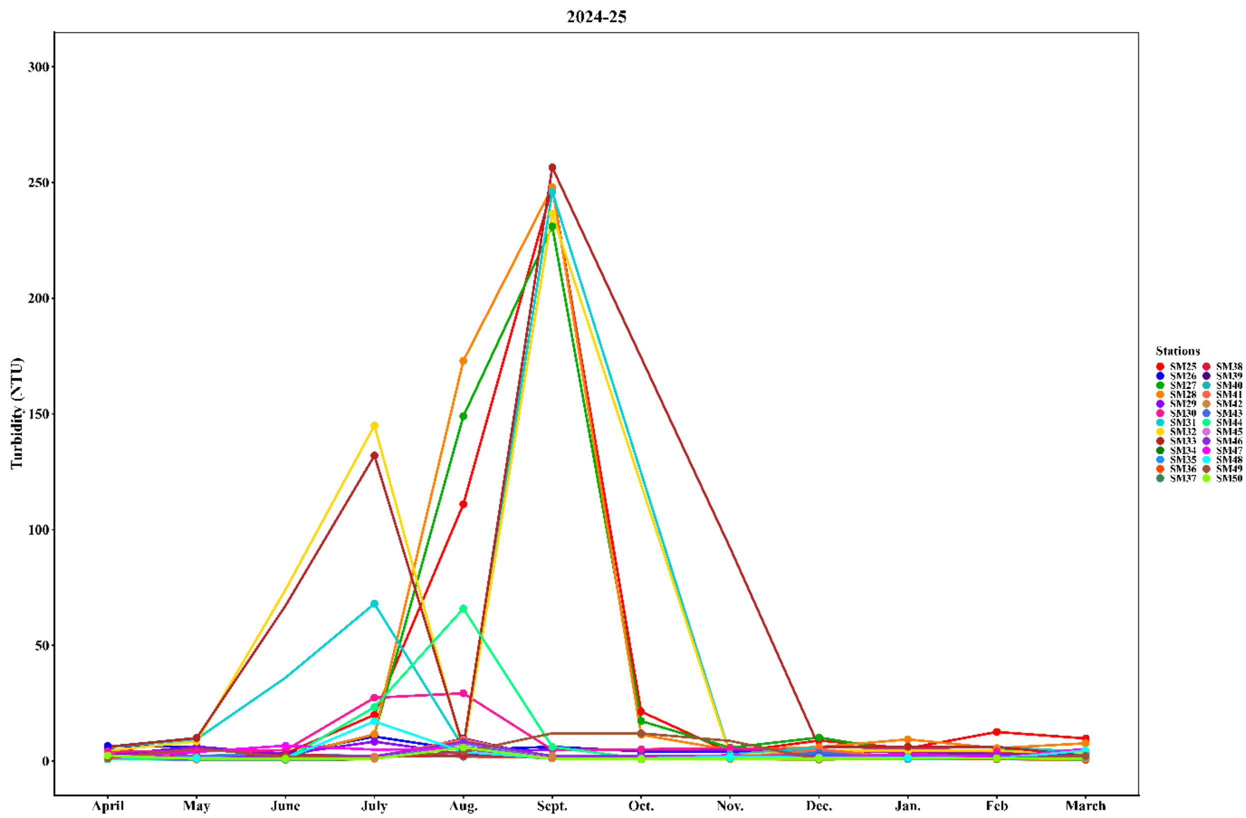
SM36 SM49
SM37 SM50


2020-21
Turbidity (NTU)
200
150
100
50
0
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM38
SM26 SM39
SM27 SM40
SM28 SM41
SM29 SM42
SM30 SM43
SM31 SM44
SM32 SM45
SM33 SM46
SM34 SM47
SM35 SM48
SM36 SM49
SM37 SM50


2021-22
Turbidity (NTU)
200
150
100
50
0
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM40
SM26 SM41
SM27 SM42
SM28 SM43
SM29 SM44
SM30 SM45
SM34 SM46
SM35 SM47
SM36 SM48
SM37 SM49
SM38 SM50
SM39


2022-23
Turbidity (NTU)
0
50
100
150
200
250
300
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM26 SM27 SM28 SM29 SM30 SM31 SM32 SM33 SM34 SM35 SM36
SM38 SM39 SM40 SM41 SM42 SM43 SM44 SM45 SM46 SM47 SM48 SM50


2023-24
Turbidity (NTU)
0
50
100
150
200
250
300
350
400
450
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb
March
Stations
SM25 SM26 SM27 SM28 SM29 SM30 SM31 SM32 SM33 SM34 SM35 SM36 SM37
SM38 SM39 SM40 SM41 SM42 SM43 SM44 SM45 SM46 SM47 SM48 SM49 SM50



Annexure 5A: Detailed soil Survey report, Survey areas in Narmada River Basin (Source - https://slusi.da.gov.in/dss/searchdss.html)

S No	**Dataset Number**	**Surveyed Area**	**Total area reported & mapped** (hectares)
1	**Dataset 1**	Subwatersheds Ndlf, Nd1g, Nd1h, Nd1j, Nd1k, Nd1m, Nd1n, Nd1p, Nd1t and Nd1u of Narmada Catchment; Tahsil & District: Barwani, Madhya Pradesh.	25,245 ha
2	**Dataset 2**	Surveyed area - Nm2b, Nm2c, Nm3b, Nm3f, Nm3j, Nm5f and Nm5g. Narmada catchment Madhya Pradesh.	12325 ha
3	**Dataset 3**	Survey area: Nm4a, Nm4f, Nm4g, Nm4q and Nm4t Subwatersheds of Narmada Catchment, Madhya Pradesh	10,786 ha
4	**Dataset 4**	"5D2D1f1-5, D2a1-8, D2b1-5, D2c1-2, D3a1-6, D3b1-2, D3c1-2, D3d1-2, D3f1-6 and D3h1-2" micro watersheds of Narmada Catchment (RVP), Taluka. - Khategaon, Dist.- Dewas and Taluka-Nasarulaganj, Dist.- Sehore, Madhya Pradesh State	33918 ha

5	**Dataset 5**	"5D2D3g1 to g5, D4a1 to a4, D4b1 to b4, D4c1 to c3, D4h1 to h9, D4j1 to j8, D4k1 to k3, D4m1, D5j1 to j2 and D6h1 to h2" micro watersheds of Narmada Catchment (5D2),RVP, Taluka-Khategaon, Dist.-Dewas, and Taluka-Nasarulaganj, Dist.- Sehore, Madhya Pradesh State	35,005 ha
6	**Dataset 6**	Surveyed area : Subwatersheds - Nc7w, Nd8h, Nd8j, Nf4v and Ng3h, Narmada catchment, Tahsil Manawar and Dhar of Dhar District and, Maheshwar, Thikari of Khargone District, Madhya Pradesh.	7940 ha
7	**Dataset 7**	Subwatersheds - Nn8n, Nn8p Nn8q, Nn8r and Nn8t Narmada Catchment Tahsil - Harsud , Dist - Khandwa (Madhya Pradesh)	14738 ha
8	**Dataset 8**	Survey area - Nk3v, Nk3x, Nk3y, Nk4d, Nk4m and Nk4n Subwatersheds of Narmada R.V.P. Catchment, Madhya Pradesh.	15,663 ha
9	**Dataset 9**	Surveyed area: Subwatersheds - Nn8a, Nn8b, Nn8c, Nn8d, Narmada catchment, Tahsil - Khirkıya of Hoshangabad district and Harsud tahsil of Khandwa district, Madhya Pradesh	8555 ha
10	**Dataset 10**	Subwatersheds: Nk1h, Nk1j, Nn5k, Nn5m & Nn5p-Narmada Catchment, Madhya Pradesh	12697 hectares
11	**Dataset 11**	Surveyed Area: Nh5a, Nh5b, Nh5c, Nh5g, Nh6c, Nh6k and Nh6m Subwatersheds, Narmada Catchment (Madhya Pradesh)	9231 ha
12	**Dataset 12**	Subwatersheds – Nk6a, Nk6∂, Nk6c, Nk6d, Nk9a, Nk9d, Nk9i, Nk9m, Nk9r Narmada catchment. Tahsil–Pandhana and Khandwa of Khandwa District and Jhirnya Tahsil of Khargone District, Madhya Pradesh	17,449 ha
13	**Dataset 13**	Survey area: - Nh7b, Nh7d, Nh7h, Nh8a, Nh8b, Nh8c, Nh8h, and Nh8k Sub watersheds of Narmada Catchment, Madhya Pradesh.	10,695 ha
14	**Dataset 14**	Surveyed area: Subwatersheds - Nn9g, Nn9f, Nn9g, Nn9h, Nn9i, Nn9m and Nn9n Narmada catchment, Madhya Pradesh	15056 ha
15	**Dataset 15**	Subwatersheds Nk1a, Nk1n, Nk1p, Nk2a and Nk2b, Narmada Catchment, Madhya Pradesh	12,879 ha

16	**Dataset 16**	Surveyed area: Nk3b, Nk3c, Nk3f, Nk3k, Nk3m and Nk3q Subwatersheds, Narmada Catchment (Madhya Pradesh)	18263 ha
17	**Dataset 17**	Subwatersheds - Nk5p, Nk5s, Nk5t, Nk5u and Nk5w. Narmada catchment Tahsil Harsud and Khandwa of Khandwa district, Madhya Pradesh	983 ha
18	**Dataset 18**	Subwatersheds - Nn5n, Nn8f, Nn8g, Nn8j, Nn8m and Nn9q; Narmada catchment, Tahsil - Khirkhiya of Hoshangabad district and Harsud tahsil of Khandwa district, Madhya Pradesh	13469 ha
19	**Dataset 19**	Subwatersheds- Nn2b, Nn2c, Nn2f, Nn2g, Nn2h, Nn2j, Nn2k and Nn2r, Narmada Catchment, Madhya Pradesh.	17270 ha
20	**Dataset 20**	Subwatersheds–Nn5d .Nn5f, Nr5h & Nn5j Narmada Catchment, Madhya Pradesh	8,871 ha
21	**Dataset 21**	Survey area - Nn4a, Nn4h and Nn4j Subwatersheds of Narmada R.V.P. catchment M.P.	7591 ha
22	**Dataset 22**	Subwatersheds -Nn4k, Nn4m, Nn4q,Nn4r, Nn4s and Nn4t, Narmada catchment, Madhya Pradesh	17,717 ha
23	**Dataset 23**	Subwatershed - Nn6m, Nn7c, Nn7f, Nn7g, Nn7j and Nn7k Narmada catchment, Madhya Pradesh	9905 ha
24	**Dataset 24**	Surveyed area : Nn1c, Nn1d, Nn1f, Nn1g and Nn1j subwatersheds, Narmada Catchment, Madhya Pradesh	12232 ha
25	**Dataset 25**	Survey Area: “5D3D1a1, b1 to b9, c4 to c8, d1 to d9, f1 to f4, g1 to g4 and h1 to h3”, micro-watersheds, Narmada Catchments, Taluka- Handia, Harda and Timarni, District-Harda, Madhya Pradesh State	34,283 ha
26	**Dataset 26**	Surveyed area: Priority subwatersheds Nq6j, Nq6k, Nq6p and Nq6s; Narmada catchment	10,553 ha
27	**Dataset 27**	Surveyed Area: Nr1d, Nr1g, Nr1h, Nr1j, Nr1k, Nr1m & Nr1n Subwatersheds of Narmada RVP Catchment (MP)	12,155 ha
28	**Dataset 28**	Survey area: Detailed Soil Survey and Land Use Plan of “5D5C6m6, m7, n4, p2 to p7, r1 to r3, t1 to t5; 5D6A1a1 to a5, b2, b4, b7, c1, c2, d1 to d6, f1, f2, g1 to g3 & k1” micro-watersheds of Narmada Catchments, Taluka- Jabalpur and Shahpura dist.- Jabalpur & Taluka- Lakhnadou Dist.- Seoni, Madhya Pradesh using Remote Sensing	33631 ha

29	**Dataset 29**	Survey Area: 5D4B6f1-5, 5D4B7g1-3, j1-2, n1-2, r1-2, 5D4B8a1-3, c4-6, j1, m2 and z1-4 micro-watersheds, Narmada Catchment District-Jabalpur, Madhya Pradesh State	17,725 ha
30	**Dataset 30**	Survey Area: Detailed Soil Survey and Land Use Plan of "5D5C6m3,m5, n1-2, n3, n5; 5D5C7c2, c4, f1-f3, g1-2, h1-h4, j1-7, k1-3, m1-2, n1-n4, p1-p4, q1-q3, 5D6A1b1, b3, b5-6" micro-watersheds of Narmada Catchments, Taluka-Jabalpur and Shahpura dist.-Jabalpur, Madhya Pradesh using Remote Sensing	32, 814 ha
31	**Dataset 31**	Report on Detailed Soil and Land Use Survey of "5D4A8g1, j-1-2, 5D4B1a1-3, b1-3, d1-5, g1-4, k3-4, 5D4B2f1-2, 5D4B7a1-2, b1-2, c1-2, d1-2" Micro-watersheds of Narmada catchment, Taluka- Shahpur& Patan, Distt- Jabalpur & Taluka- Kardi, Dist-Narsinghpur, Madhya Pradesh State	23,947 ha
32	**Dataset 32**	SURVEY AREA: Subwatersheds Nv1d, Nv1g, Nv1m, Nv1n, Nv1p, Nv1q, Nv1r, Nv1s, Nv1t, & Nv1v, Narmada catchment, Tah. -Niwas, Dist. - Mandla (MP)	16,500 ha
33	**Dataset 33**	Subwatersheds Ny1b, Ny1c, Ny1f and Ny1h of Narmada Catchment. Tehsil and District: - Mandla, Madhya Pradesh	7,704 ha
34	**Dataset 34**	Subwatersheds Nv1x, Nv5b, Nv5d, Nv5f, Nv5g, Nv5h, Nv5j, Nv5k, & Nv5m; Narmada Catchment, Tahsil-Niwas, District-Mandla, Madhya Pradesh	18,062 ha
35	**Dataset 35**	Subwatersheds NV6k, NV6p, NV6r, & NV6u of Narmada Catchment, Tehsil and District: Mandla, Madhya Pradesh State.	8,341 ha
36	**Dataset 36**	Subwatersheds Nv4g, h, j, k, m, n and p of Narmada Catchment, Tah. and Distt- Mandla, Madhya Pradesh	12,270 ha
37	**Dataset 37**	Report on Detailed Soil Survey and Land Use ofNv5n, Nv5q, Nv5r, Nv5s, Nv5t, Nv5u, and Nv5y Sub watersheds of Narmada RVP Catchments, Tahsil: Niwas, District: Mandla, Madhya Pradesh	13,238 ha
38	**Dataset 38**	Sub watersheds Nv6a, Nv6b, Nv6c, Nv6d, Nv6f, Nv6g & Nv6j of Narmada Catchment, Tehsil and District: Mandla, Madhya Pradesh	12,687 ha.

39	**Dataset 39**	“5D4A4p2, p3 , q1,q2 & q3, 5D4A6a3,b2, b4, c1, c2, c4, f3,f4, h3, m3, t1, t3, u2, v1,v2, v3 & w4, 5D4A7a1, b1, b2, c1, c2, f1 & f3” micro watersheds of Narmada Catchment (RVP), Taluka- Bareli & Udaipura, Dist. – Raisen and Taluka- Tendukhera, Dist. – Narsimhapur, Madhya Pradesh	36,993 ha
40	**Dataset 40**	5D4A2v2 to v4, 5D4A4a1 to a7, b1 to b4, c1 to c4, d1 to d3, f1 to f8 and h1 to h9” micro watersheds of Narmada Catchment (RVP), Taluka- Bareli, Silwani and Udaipura, Dist. -Raisen, Madhya Pradesh	38,787 ha
41	**Dataset 41**	“5D4A1j1 to j5, p1 to p3, r1 to r5, s1 to s3, t1 to t4, u1 to u3, x1 to x3, 5D4A2a1 to a4, b1 to b3, c1 to c3, d1 to d6, q1 to q3 & v1” micro watersheds of Narmada Catchment (RVP), Taluka- Budhani, , Dist. – Sehore and Talukas- Bareli & Bari, , Dist. - Raisen, Madhya Pradesh State	38,046 ha
42	**Dataset 42**	“5D2D5a1 to a6, b1 to b5, c1 to c4, d1 to d5, f1 to f3, g1 to g2, m1 to m3, 5D2D7a1 to a2, b1 to b5 and c1 to c4 ”micro-watersheds, Narmada Catchments taluka- Nasrullaganj, and Rehti, District-Sehore, Madhya Pradesh	36,597 ha
43	**Dataset 43**	“5D6A1g4,h1 to h3, j1 to j3, k2 to k4, m1 ,m2, n1 to n4, p1 to p3, q1 to q3, r1 to r3, s1 to s3, t1 to t7, y1,\ y3, y6 & y7 ” micro watersheds of Narmada Catchment (RVP), Taluka- Lakhandaun &Ghansaur, Dist. – Seoni, Taluka+ Dist.- Jabalpur, Madhya Pradesh	32,665 ha
44	**Dataset 44**	Nf2j, Nf2k subwatersheds, Narmada catchment	6414 ha
45	**Dataset 45**	Subwatershds Nf3a, Nf3b, Nf3g and Nf3r, Narmada catchment, Tahsil: Bhikangaon, Kasarawad, District: Khargone, Madhya Pradesh	10830 ha
46	**Dataset 46**	Subwatershds Nf4q and Nf6f. Narmada catchment, Tahsil - Bhagwanpura and Khargone of Khargone District, Madhya Pradesh	6231 ha
47	**Dataset 47**	Subwatershds Ng3a, Ng3j, Ng3k, Ng3n and Ng5a Narmada Catchment, Tahsil – Maheshwar of Khargone – District, Madhya-Pradesh. 5867 ha	5867 ha

Table 4.3.A - Wells which exceed the acceptable BIS limit of pH in terms of 2022–2024 average as well as post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	G_1_BRH_009	Bharuch	9.37	9.25
2	G_1_BRH_004	Bharuch	9.27	8.74
3	SBRHPz-22	Bharuch	9.11	8.82
4	G_1_BRH_010	Bharuch	9.10	8.99
5	NHP_CHU_008	Chhota Udepur	9.10	8.87
6	SBRHPz-06	Narmada	9.03	8.69
7	SBRHPz-05	Narmada	9.01	8.54
8	BR-40	Narmada	8.98	8.70
9	G_2_VAD_009	Chhota Udepur	8.96	8.59
10	G_1_BRH_005	Bharuch	8.92	9.05
11	G_2_VAD_007	Chhota Udepur	8.88	8.67
12	NHP_NMR_003	Narmada	8.88	8.89
13	G_2_BHR_006	Bharuch	8.86	8.92
14	NHP_BRH_006	Bharuch	8.85	8.95
15	BR-41	Narmada	8.82	8.51
16	G_1_BRH_006	Bharuch	8.80	8.55
17	BR-20	Bharuch	8.78	8.61
18	NHP_CHU_010	Chhota Udepur	8.75	8.70
19	BR-29	Bharuch	8.73	8.69
20	G_1_BRH_011	Bharuch	8.72	8.65
21	NCCA-030A	Chhota Udepur	8.72	8.65
22	NCCA-025A	Chhota Udepur	8.69	8.52
23	BR-24	Bharuch	8.67	8.83
24	G_2_BHR_007	Bharuch	8.65	8.57
25	G_2_NMR_018	Narmada	8.64	8.68
26	G_2_VAD_018	Vadodara	8.63	8.55
27	BR-16	Bharuch	8.60	8.65
28	G_1_BRH_007	Bharuch	8.58	8.81
29	SVADPz-05	Chhota Udepur	8.53	8.65

Table 4.3.B - Wells which exceed the acceptable BIS limit of pH in post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	PM-047	Panchmahals	9.31	8.47
2	G_2_PMS_004	Panchmahals	9.20	8.40
3	BD-58	Narmada	9.05	8.34
4	BR-36	Narmada	9.03	8.47
5	BR-30	Narmada	8.97	8.48
6	BR-48	Narmada	8.95	8.45
7	BR-60	Bharuch	8.89	8.46
8	G_2_BHR_001	Bharuch	8.85	8.39
9	G_2_PMS_006	Panchmahals	8.85	8.45
10	NCCA-019A	Vadodara	8.81	8.48
11	SVADPz-16	Vadodara	8.81	8.48
12	SVADPz-17	Vadodara	8.77	8.47
13	SBRHPz-04	Bharuch	8.75	8.01
14	PM-046	Panchmahals	8.71	8.23
15	G_2_BHR_005	Bharuch	8.69	8.45
16	SVADPz-30	Chhota Udepur	8.69	8.49
17	BR-45	Narmada	8.66	8.46
18	NCCA-041A	Vadodara	8.65	8.43
19	SVADPz-27	Vadodara	8.65	8.43
20	BR-37	Narmada	8.64	8.41
21	G_2_PMS_005	Panchmahals	8.64	8.22
22	NHP_CHU_001	Chhota Udepur	8.61	8.41
23	HPII_BRH_005	Bharuch	8.56	8.48
24	BR-38	Narmada	8.55	8.44
25	SVADPz-07	Chhota Udepur	8.55	8.18
26	BD-40	Chhota Udepur	8.53	8.11
27	BD-38	Chhota Udepur	8.52	8.31
28	BR-08	Narmada	8.52	8.23

Table 4.3.C. Wells which exceed the E.U. limit of E.C. in terms of 2022–2024 average as well as post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	G_2_BHR_005	Bharuch	12140.00	11810.00	11972.50
2	HPII_BRH_004	Bharuch	11240.00	11390.00	11611.43
3	HPII_BRH_006	Bharuch	9041.00	9606.00	7520.88
4	G_1_BRH_011	Bharuch	7840.00	7668.00	8087.25
5	SBRHPz-04	Bharuch	7893.00	7128.00	10153.88
6	HPII_BRH_005	Bharuch	6850.00	6784.00	7024.25
7	NCCA-028A	Chhota Udepur	5794.00	6163.00	4034.63
8	SVADPz-34	Chhota Udepur	5794.00	6163.00	4290.88
9	G_1_BRH_005	Bharuch	4770.00	5280.00	4852.50
10	G_2_BHR_007	Bharuch	3556.00	3695.00	4031.38
11	NHP_BRH_005	Bharuch	2992.00	2903.00	2928.33
12	G_1_BRH_006	Bharuch	5824.00	2872.00	6542.00
13	G_2_BHR_006	Bharuch	3743.00	2778.00	3942.63

Table 4.3.D - Wells which exceed the permissible BIS limit of TDS in terms of 2022–2024 average as well as post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	G_2_BHR_005	Bharuch	7527.00	6766.00	7195.67
2	HPII_BRH_004	Bharuch	6932.00	6570.00	7059.29
3	HPII_BRH_006	Bharuch	5574.00	5546.00	4601.82
4	G_1_BRH_011	Bharuch	4834.00	4810.00	4916.63
5	SBRHPz-04	Bharuch	4942.00	4054.00	6255.03
6	HPII_BRH_005	Bharuch	4190.00	3918.00	4252.29
7	NCCA-028A	Chhota Udepur	3350.00	3590.00	2402.92
8	SVADPz-34	Chhota Udepur	3350.00	3590.00	2566.67
9	G_1_BRH_005	Bharuch	2926.00	3058.00	2976.55
10	G_2_BHR_007	Bharuch	2240.00	2124.00	2441.19
11	G_1_BRH_006	Bharuch	3669.00	1662.00	3955.91
12	G_2_BHR_006	Bharuch	2395.52	1596.00	2410.36

Table 4.3.E. - Wells which exceed the acceptable BIS limit of TDS in post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	NHP_BRH_005	Bharuch	1674.00	1805.67
2	BD-58	Narmada	1360.00	1750.83
3	NCCA-041A	Vadodara	1204.00	1151.96
4	SVADPz-27	Vadodara	1204.00	1151.96
5	PM-045	Panchmahals	1160.00	746.80
6	G_2_NMR_018	Narmada	1144.00	1439.20
7	BR-20	Bharuch	1124.00	1395.38
8	G_1_BRH_009	Bharuch	1102.00	1185.89
9	BR-60	Bharuch	1098.00	1434.77
10	G_1_BRH_010	Bharuch	1010.00	1939.19
11	G_2_VAD_007	Chhota Udepur	988.00	1025.26
12	NHP_CHU_001	Chhota Udepur	952.00	1147.33
13	BR-24	Bharuch	950.00	799.77
14	SBRHPz-06	Narmada	950.00	941.71
15	PM-046	Panchmahals	934.00	772.10
16	G_2_PMS_004	Panchmahals	908.00	897.78
17	NHP_CHU_009	Chhota Udepur	890.00	870.07
18	SVADPz-30	Chhota Udepur	852.00	1137.98
19	BR-16	Bharuch	834.00	914.17
20	BD-40	Chhota Udepur	762.00	1077.28
21	G_2_VAD_011	Chhota Udepur	750.00	1102.39
22	G_1_BRH_004	Bharuch	732.00	934.73
23	SBRHPz-22	Bharuch	714.00	1082.21
24	NCCA-030A	Chhota Udepur	706.00	704.49

Sr. No.	Well id	District	Post 24	22-24 Avg.
25	NHP_CHU_008	Chhota Udepur	702.00	704.00
26	G_1_BRH_007	Bharuch	696.00	869.36
27	NHP_CHU_010	Chhota Udepur	696.00	732.40
28	NCCA-026	Chhota Udepur	682.00	729.41
29	BR-48	Narmada	664.00	471.88
30	NHP_BRH_006	Bharuch	646.00	677.10
31	BR-36	Narmada	628.00	476.40
32	SVADPZ-28	Vadodara	628.00	707.17
33	BD-55	Vadodara	618.00	616.52
34	BR-29	Bharuch	600.00	963.95
35	SBRHPz-10	Bharuch	594.00	703.28
36	BD-31	Chhota Udepur	588.00	612.30
37	NHP_VAD_007	Vadodara	586.00	617.78
38	G_2_VAD_002	Chhota Udepur	576.00	397.13
39	SVADPz-33	Chhota Udepur	574.00	595.12
40	BD-19	Chhota Udepur	568.00	415.78
41	SVADPz-17	Vadodara	550.00	696.29
42	BD-09	Chhota Udepur	542.00	610.58
43	G_2_VAD_014	Chhota Udepur	540.00	614.82
44	G_2_VAD_016	Chhota Udepur	532.00	576.09
45	BD-11	Chhota Udepur	524.00	620.18
46	BR-41	Narmada	516.00	584.68
47	SVADPz-05	Chhota Udepur	514.00	477.04

Table 4.3.F - Wells which exceed the permissible BIS limit of Alkalinity in TDS in terms of 2022–2024 average as well as post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	G_1_BRH_005	Bharuch	620.40	655.60	568.00
2	NHP_BRH_005	Bharuch	713.60	633.20	539.60
3	G_1_BRH_009	Bharuch	746.80	319.60	450.60
4	G_2_VAD_007	Chhota Udepur	603.60	313.20	397.20
5	BR-48	Narmada	620.00	289.60	360.40

Table 4.3.G. - Wells which exceed the acceptable BIS limit of Alkalinity in post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	NHP_CHU_009	Chhota Udepur	454.00	403.07
2	NCCA-041A	Vadodara	442.80	364.20
3	SVADPz-27	Vadodara	442.80	364.20
4	BD-58	Narmada	440.40	274.90
5	G_2_NMR_018	Narmada	435.60	276.90
6	SBRHPz-06	Narmada	430.80	423.40
7	BR-20	Bharuch	389.20	363.20
8	G_2_BHR_006	Bharuch	365.60	370.10
9	NHP_CHU_001	Chhota Udepur	364.40	268.40
10	NCCA-030A	Chhota Udepur	363.20	433.50
11	G_1_BRH_010	Bharuch	362.00	434.50
12	NHP_CHU_008	Chhota Udepur	359.20	362.27
13	G_2_BHR_007	Bharuch	352.00	313.90
14	G_1_BRH_011	Bharuch	351.20	378.40
15	PM-045	Panchmahals	338.40	398.80
16	G_1_BRH_009	Bharuch	319.60	450.60
17	SVADPz-33	Chhota Udepur	314.80	311.70
18	BR-24	Bharuch	314.40	269.20
19	G_2_VAD_007	Chhota Udepur	313.20	397.20
20	SVADPz-30	Chhota Udepur	312.40	373.80
21	BR-16	Bharuch	309.20	292.50
22	NHP_VAD_007	Vadodara	292.80	346.40
23	NCCA-026	Chhota Udepur	292.40	400.80
24	BD-55	Vadodara	290.80	266.30
25	G_1_BRH_006	Bharuch	290.80	367.00
26	SBRHPz-22	Bharuch	290.80	290.40
27	BR-48	Narmada	289.60	360.40
28	NCCA-028A	Chhota Udepur	289.60	299.90
29	SVADPz-34	Chhota Udepur	289.60	299.90
30	BR-29	Bharuch	287.20	308.20
31	BR-60	Bharuch	278.40	286.60
32	G_1_BRH_004	Bharuch	266.80	309.10
33	G_2_PMS_004	Panchmahals	260.40	281.30
34	NHP_BRH_006	Bharuch	258.80	313.07
35	BD-40	Chhota Udepur	255.20	319.20
36	G_2_VAD_016	Chhota Udepur	250.40	271.90
37	BR-28	Bharuch	250.00	247.20
38	BR-36	Narmada	247.60	325.60
39	BD-19	Chhota Udepur	246.80	217.20
40	SVADPz-05	Chhota Udepur	242.40	222.70
41	G_2_VAD_014	Chhota Udepur	241.60	232.10
42	SVADPz-31	Chhota Udepur	230.80	242.60
43	BR-40	Narmada	226.00	217.30
44	BD-09	Chhota Udepur	223.60	230.20
45	SBRHPz-25	Narmada	223.20	227.90
46	SVADPz-17	Vadodara	220.00	245.30
47	BD-31	Chhota Udepur	218.80	301.80
48	PM-046	Panchmahals	216.40	308.90
49	BR-41	Narmada	210.80	255.50
50	NHP_CHU_010	Chhota Udepur	208.80	218.40
51	G_2_BHR_005	Bharuch	206.80	292.00
52	HPII_BRH_005	Bharuch	201.60	219.80
53	G_2_VAD_015	Chhota Udepur	200.40	206.30

Table 4.3.H. - Wells which exceed the permissible BIS limit of Chloride in in terms of 2022–2024 average or post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	G_2_BHR_005	Bharuch	4797.60	4423.78	2770.12
2	HPII_BRH_004	Bharuch	4097.95	4047.98	2803.31
3	HPII_BRH_006	Bharuch	3598.19	3748.13	2179.71
4	G_1_BRH_011	Bharuch	2748.62	3358.32	2336.79
5	NHP_CHU_009	Chhota Udepur	209.89	3134.43	1234.72
6	SBRHPz-04	Bharuch	2448.77	2158.92	2391.85
7	NCCA-028A	Chhota Udepur	1699.15	1959.02	1044.75
8	SVADPz-34	Chhota Udepur	1699.15	1959.02	1044.82
9	HPII_BRH_005	Bharuch	2548.72	1939.03	1797.82
10	G_2_BHR_007	Bharuch	1599.20	1179.41	937.40
11	G_1_BRH_005	Bharuch	1139.43	1049.47	917.90
12	G_1_BRH_006	Bharuch	739.63	779.61	1393.79

Table 4.3.I. - Wells which exceed the acceptable BIS limit of Chloride in post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	G_2_BHR_006	Bharuch	629.68	573.71	738.25
2	NHP_BRH_005	Bharuch	549.72	489.76	533.07
3	BD-58	Narmada	749.62	399.80	447.83
4	PM-046	Panchmahals	199.89	311.84	265.22
5	NCCA-041A	Vadodara	311.83	307.85	278.64
6	SVADPz-27	Vadodara	311.83	307.85	278.64
7	PM-045	Panchmahals	345.82	292.00	207.59
8	G_2_NMR_018	Narmada	359.82	289.86	355.39
9	G_2_VAD_011	Chhota Udepur	159.91	263.87	299.41
10	BR-28	Bharuch	59.97	259.87	160.27

Table 4.3.J. - Wells which exceed the acceptable BIS limit of Fluoride in post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	BD-16	Chhota Udepur	0.20	1.45	0.75
2	BD-18	Chhota Udepur	1.10	1.45	0.95
3	BR-60	Bharuch	1.16	1.45	0.87
4	G_1_BRH_006	Bharuch	1.11	1.45	1.18
5	G_1_BRH_009	Bharuch	1.27	1.45	1.02
6	G_2_VAD_007	Chhota Udepur	1.89	1.45	1.28
7	G_2_VAD_015	Chhota Udepur	1.79	1.45	1.09
8	NHP_BRH_008	Bharuch	0.87	1.45	0.99
9	NHP_CHU_001	Chhota Udepur	1.85	1.45	1.63
10	NHP_CHU_002	Chhota Udepur	1.67	1.45	1.58
11	NHP_CHU_008	Chhota Udepur	1.79	1.45	1.41
12	NHP_CHU_009	Chhota Udepur	1.66	1.45	1.43
13	SVADPz-07	Chhota Udepur	1.97	1.45	1.30
14	SRT-36	Surat	0.17	1.41	0.51
15	BR-29	Bharuch	1.89	1.39	1.36
16	G_1_BRH_004	Bharuch	0.65	1.39	0.79
17	G_2_NMR_011	Narmada	0.49	1.37	0.41
18	NHP_CHU_010	Chhota Udepur	1.04	1.36	1.07
19	SVADPz-30	Chhota Udepur	1.78	1.36	1.23
20	BD-27	Chhota Udepur	0.80	1.30	0.87
21	BD-40	Chhota Udepur	1.37	1.26	1.09
22	BR-08	Narmada	0.54	1.25	0.72
23	G_2_VAD_008	Chhota Udepur	0.28	1.22	0.89
24	NHP_CHU_004	Chhota Udepur	1.26	1.21	0.98
25	SVADPZ-28	Vadodara	0.24	1.21	0.54
26	NCCA-026	Chhota Udepur	0.13	1.18	0.67
27	SBRHPz-09	Bharuch	0.98	1.14	0.55
28	SBRHPz-12	Bharuch	0.15	1.09	0.69
29	SBRHPz-25	Narmada	1.11	1.08	0.61
30	SBRHPz-22	Bharuch	0.14	1.07	0.59
31	SVADPz-29	Narmada	1.66	1.06	0.90
32	BD-26	Chhota Udepur	1.49	1.02	0.72
33	G_2_VAD_009	Chhota Udepur	1.50	1.01	1.18
34	G_2_VAD_017	Chhota Udepur	1.05	1.01	0.76

Table 4.3.K. - Wells which exceed the permissible BIS limit of Total Hardness in terms of 2022–2024 average or post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	NCCA-028A	Chhota Udepur	1586.00	1502.40	943.05
2	SVADPz-34	Chhota Udepur	1586.00	1502.40	943.05
3	NHP_CHU_009	Chhota Udepur	202.00	1482.00	648.00
4	G_2_BHR_005	Bharuch	1312.00	986.00	1533.38
5	PM-045	Panchmahals	763.20	745.60	428.13
6	HPII_BRH_006	Bharuch	1026.00	722.00	986.75
7	NHP_BRH_005	Bharuch	560.00	702.40	520.80
8	BD-58	Narmada	1092.00	648.40	658.07
9	SBRHPz-04	Bharuch	1024.00	541.60	1351.45
10	HPII_BRH_004	Bharuch	590.00	508.00	1076.14
11	G_1_BRH_011	Bharuch	896.00	497.20	1094.28
12	HPII_BRH_005	Bharuch	576.00	472.00	795.13
13	G_1_BRH_005	Bharuch	294.00	460.00	638.75
14	G_1_BRH_006	Bharuch	268.00	306.00	915.88

Table 4.3.L. - Wells which exceed the acceptable BIS limit of Total Hardness in post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	G_2_PMS_004	Panchmahals	457.60	425.90
2	BD-11	Chhota Udepur	422.00	340.10
3	NCCA-041A	Vadodara	390.40	433.55
4	SVADPz-27	Vadodara	390.40	433.55
5	G_2_VAD_002	Chhota Udepur	383.20	210.40
6	PM-046	Panchmahals	368.80	334.47
7	G_2_NMR_018	Narmada	358.80	411.97
8	NHP_VAD_007	Vadodara	352.80	299.90
9	G_2_VAD_014	Chhota Udepur	352.40	318.92
10	SVADPz-30	Chhota Udepur	345.60	468.65
11	BD-40	Chhota Udepur	343.60	498.03
12	NHP_CHU_003	Chhota Udepur	331.60	458.53
13	G_2_VAD_011	Chhota Udepur	315.60	394.20
14	G_2_VAD_016	Chhota Udepur	302.00	276.88
15	BD-12	Chhota Udepur	298.00	275.40
16	BD-14	Chhota Udepur	279.20	259.30
17	BD-19	Chhota Udepur	275.60	274.37
18	BR-32	Narmada	275.60	260.12

Sr. No.	Well id	District	Post 24	22-24 Avg.
25	NHP_CHU_001	Chhota Udepur	258.00	417.33
26	NHP_BRH_008	Bharuch	256.80	231.73
27	BR-37	Narmada	256.40	268.53
28	SVADPz-32	Chhota Udepur	255.60	302.83
29	BD-26	Chhota Udepur	252.00	221.37
30	BR-28	Bharuch	249.60	230.43
31	SVADPz-33	Chhota Udepur	248.80	295.73
32	BR-20	Bharuch	239.60	390.43
33	BR-16	Bharuch	236.40	325.40
34	BD-09	Chhota Udepur	235.60	243.40
35	BD-36	Chhota Udepur	232.00	231.10
36	BD-18	Chhota Udepur	229.60	199.70
37	BR-48	Narmada	216.00	261.93
38	BR-24	Bharuch	212.80	274.80
39	G_2_VAD_008	Chhota Udepur	211.20	275.65
40	SVADPz-36	Chhota Udepur	211.20	241.02
41	SVADPz-06	Chhota Udepur	210.80	234.65
42	BD-31	Chhota Udepur	210.40	278.47

19	NCCA-026	Chhota Udepur	275.60	349.77
20	SVADPz-08	Chhota Udepur	274.00	210.58
21	NCCA-030A	Chhota Udepur	264.00	293.45
22	G_2_VAD_007	Chhota Udepur	263.20	365.65
23	BD-55	Vadodara	262.40	285.97
24	G_2_NMR_009	Narmada	260.80	244.10

43	BR-36	Narmada	210.40	220.37
44	G_1_BRH_010	Bharuch	210.40	527.80
45	SBRHPz-25	Narmada	209.20	208.31
46	NHP_CHU_008	Chhota Udepur	208.40	238.13
47	SBRHPz-06	Narmada	204.00	338.63

Table 4.3.M. - Wells which exceed the acceptable BIS limit of Calcium in post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	NHP_CHU_009	Chhota Udepur	19.20	378.08	149.49
2	NHP_BRH_005	Bharuch	200.00	160.00	138.67
3	NCCA-028A	Chhota Udepur	138.40	142.56	139.32
4	SVADPz-34	Chhota Udepur	138.40	142.56	139.32
5	BD-58	Narmada	64.00	136.80	100.20
6	BD-11	Chhota Udepur	73.60	113.60	66.27
7	HPII_BRH_004	Bharuch	19.20	111.20	191.91
8	G_2_VAD_011	Chhota Udepur	14.40	91.04	71.00
9	G_2_VAD_014	Chhota Udepur	112.00	87.84	67.90
10	SVADPz-08	Chhota Udepur	37.44	86.88	47.56
11	PM-045	Panchmahals	150.40	85.60	78.40
12	NHP_CHU_003	Chhota Udepur	136.00	85.44	105.81
13	HPII_BRH_006	Bharuch	23.20	76.00	164.47
14	G_2_VAD_016	Chhota Udepur	16.00	75.52	55.16
15	BD-40	Chhota Udepur	66.24	75.04	90.71

Table 4.3.N. - Wells which exceed the permissible BIS limit of Magnesium in terms of 2022–2024 average or post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	NCCA-028A	Chhota Udepur	301.94	279.05	144.33
2	SVADPz-34	Chhota Udepur	301.94	279.05	144.33
3	G_2_BHR_005	Bharuch	311.68	228.79	230.01
4	NHP_CHU_009	Chhota Udepur	37.50	130.71	66.76
5	HPII_BRH_006	Bharuch	235.71	129.54	139.15
6	PM-045	Panchmahals	94.28	129.44	56.45
7	G_2_PMS_004	Panchmahals	189.93	104.22	67.74
8	HPII_BRH_005	Bharuch	23.86	101.69	98.13
9	SBRHPz-04	Bharuch	234.73	92.92	187.46
10	G_1_BRH_011	Bharuch	207.95	86.00	154.66

Table 4.3.O. - Wells which exceed the acceptable BIS limit of Magnesium in post-monsoon 2024 values.

Sr. No.	Well id	District	Post 24	22-24 Avg.
1	G_1_BRH_005	Bharuch	94.67	88.81
2	NCCA-041A	Vadodara	77.73	62.94
3	SVADPz-27	Vadodara	77.73	62.94
4	BD-58	Narmada	74.61	98.94
5	NHP_VAD_007	Vadodara	73.93	51.17
6	NHP_BRH_005	Bharuch	73.63	42.37
7	SVADPz-30	Chhota Udepur	73.05	64.54
8	PM-046	Panchmahals	61.56	43.36
9	G_2_VAD_002	Chhota Udepur	51.62	24.54
10	BR-28	Bharuch	51.43	32.42
11	G_2_NMR_018	Narmada	48.60	55.09
12	BD-55	Vadodara	48.31	35.53
13	NCCA-030A	Chhota Udepur	47.73	40.51
14	BR-20	Bharuch	45.88	50.79
15	NCCA-026	Chhota Udepur	43.25	49.26
16	BR-37	Narmada	42.95	35.14
17	BR-16	Bharuch	40.71	44.93
18	BR-24	Bharuch	39.35	40.31
19	SBRHPz-06	Narmada	39.35	40.27

Sr. No.	Well id	District	Post 24	22-24 Avg.
20	NHP_CHU_001	Chhota Udepur	38.86	58.69
21	SVADPz-33	Chhota Udepur	38.57	42.30
22	BD-40	Chhota Udepur	37.99	65.82
23	BR-48	Narmada	37.21	36.98
24	NHP_CHU_008	Chhota Udepur	36.23	26.34
25	NHP_BRH_011	Bharuch	35.84	25.04
26	BD-14	Chhota Udepur	34.67	29.22
27	SBRHPz-22	Bharuch	34.19	46.40
28	BR-36	Narmada	33.70	30.59
29	BD-11	Chhota Udepur	33.60	42.32
30	SBRHPz-25	Narmada	33.41	26.45
31	G_2_VAD_014	Chhota Udepur	32.34	36.15
32	BR-40	Narmada	31.56	27.89
33	BD-12	Chhota Udepur	31.36	34.40
34	NHP_BRH_008	Bharuch	30.97	30.31
35	G_1_BRH_010	Bharuch	30.78	64.34
36	BD-18	Chhota Udepur	30.10	26.69
37	G_2_PMS_005	Panchmahals	30.10	26.38

Table 4.3.P. - Wells which exceed the permissible E.U. limit of Sodium in terms of 2022–2024 average or post-monsoon 2024 values.

Sr. No.	Well id	District	Pre 24	Post 24	22-24 Avg.
1	HPII_BRH_004	Bharuch	2934.50	2110.25	1919.61
2	NHP_BRH_008	Bharuch	3288.00	17.20	1109.49
3	G_2_BHR_005	Bharuch	2524.00	1799.00	1664.90
4	HPII_BRH_006	Bharuch	1297.00	1540.00	1258.83
5	HPII_BRH_005	Bharuch	1143.00	1531.50	1204.37
6	SBRHPz-04	Bharuch	1726.00	1378.75	1703.95
7	G_1_BRH_005	Bharuch	1331.75	1067.00	760.56
8	G_1_BRH_011	Bharuch	1273.75	1043.25	1389.16
9	NCCA-028A	Chhota Udepur	511.25	738.00	561.54
10	SVADPz-34	Chhota Udepur	511.25	738.00	561.61
11	NHP_CHU_009	Chhota Udepur	260.75	596.25	385.62

12	BR-60	Bharuch	578.95	501.90	289.93
13	BR-20	Bharuch	379.45	425.20	339.91
14	G_2_BHR_007	Bharuch	535.20	394.25	532.63
15	G_2_BHR_006	Bharuch	474.80	385.70	518.71
16	G_1_BRH_009	Bharuch	425.15	382.55	342.62
17	G_2_VAD_007	Chhota Udepur	246.55	369.50	239.64
18	G_1_BRH_006	Bharuch	392.80	352.60	923.84
19	BR-24	Bharuch	270.05	298.95	196.64
20	G_1_BRH_010	Bharuch	367.40	285.45	453.91
21	SVADPz-30	Chhota Udepur	307.25	284.75	264.42
22	BR-16	Bharuch	225.05	265.10	217.76
23	BR-28	Bharuch	67.64	230.85	122.20
24	G_1_BRH_004	Bharuch	245.45	227.25	234.44
25	SBRHPz-06	Narmada	308.25	226.65	246.40
26	NHP_CHU_008	Chhota Udepur	226.35	222.60	188.43
27	NHP_CHU_001	Chhota Udepur	144.50	209.60	212.03
28	BR-29	Bharuch	326.50	199.35	254.03
29	SBRHPz-22	Bharuch	234.65	189.20	212.96
30	G_1_BRH_007	Bharuch	280.25	151.45	237.38
31	G_2_NMR_018	Narmada	180.55	144.60	226.66
32	BD-58	Narmada	289.05	124.80	250.36
33	G_2_VAD_011	Chhota Udepur	245.10	110.07	219.23
34	NHP_BRH_005	Bharuch	434.10	79.75	327.58