GROUNDWATER CHEMICAL QUALITY BULLETIN

MAHARASHTRA

ABSTRACT

Periodic ground water quality assessment (2018-24) highlighting the findings, significant trends and groundwater contamination status

CGWB, CR, Maharashtra

1.0 INTRODUCTION

Ground water is an important resource widely used for drinking, irrigation and industrial purposes. Ground water plays an important rolein sustainable socio-economic development. In regions with scarcityof fresh surface water sources, dependence on ground water increases exponentially. The groundwater resources of Maharashtra fulfill substantial proportions of irrigation and drinking water needs. However, heightened reliance on groundwater across various sectors has resulted in declining water quality and dwindling water levels. The ground water quality is dependent upon chemical characteristics of rocksand minerals composition of aquifer material. Due to redox reaction, ions can be dissolved from minerals by dissolution and crystallization within aquifer and concentrate beyond permissible limits. Poor groundwater quality can also be due to excessive use of fertilizers, urbanization and industrial effluent discharge. According to UNESCO more than 80%of health issues are caused due to consumption of poor-quality water. Inorganic contaminants including Salinity, Fluoride, Nitrate, Arsenic, Iron and Uranium are important in determining the suitability of groundwater for drinking purposes.

Therefore, periodic ground water quality assessment is important to alert people who utilize it for domestic and irrigation purposes. Numerous studies have been carried out on the poor quality of groundwater. A Ground water bulletin has been prepared by CGWB depicting changes in terms of water quality in the groundwater regime of the country through different seasons. It is an effort to obtain information on groundwater levels through representative monitoring wells. However, an extensive temporal and spatial study of Maharashtra State is lacking. Our efforts in the present study are to fulfill the following objectives:

- To present the scenario of ground water quality of Maharashtra State.
- To identify the present hot spots area based on poor-quality ground water through spatial distribution based on 2024 chemical quality data.
- To assess temporal variation of ground water quality showing improvement / deterioration from 2018 to 2024.

2.0 STUDY AREA

Maharashtra state having 3,07,762 sq.kms geographical area is the 3rd largest state of India and is one of the fastest developing states. The state having a ~750 kms coastline to its west abutting against the Arabian Sea lies between North Latitude 15°40'–22°00 and East Longitudes 73°00'–80°59'E and is in west-central part of India (**Figure 1**). It is bounded on north by Gujarat, north-east and east by Madhya Pradesh, south-east south by Telangana, south-west by Karnataka and Goa and in the west by the Arabian Sea. Administratively, the state is governed by 36 districts which are grouped into six divisions namely Konkan, Pune, Nashik, Chatrapati Sambhaji Nagar, Amravati and Nagpur. The State is further divided into five regions namely Konkan, Western Maharashtra, Khandesh, Marathwada and Vidarbha. The state is mainly an agriculture State with around 82% of the rural population relying on agriculture. Maharashtra's economy is primarily agrarian, focusing on food and cash crops like rice, jowar, wheat, pulses, turmeric, onions, cotton, sugarcane, and oil seeds. The state also has vast areas for fruit cultivation, primarily mangoes, bananas, grapes, and oranges.

Geomorphologically, Maharashtra State is divided into three units: the Sahyadri Range, Western Coastal Tract, and Eastern Plateau. It is divided into six major basins: Godavari, Krishna, Tapi, Narmada, Mahanadi, and Coastal. 75% of the state is drained by eastward flowing rivers to the Bay of Bengal, while 25% is drained by westward flowing rivers to the Arabian Sea. The state's tropical monsoon climate is influenced by its Western Coast location and topography. Maharashtra receives 85% of its annual rainfall from the SW monsoon, with the Konkan coast experiencing high rainfall up to 3000 mm. The Sahyadris ranges act as a barrier to the advancing southwest monsoon, receiving copious rainfall. However, they form a rain shadow zone on the eastern side, with rainfall generally between 400-700 mm. The east of Marathwada and Vidarbha receives up to 1250 mm rainfall.

The geology of Maharashtra is famous for the Deccan Traps, which occur in all the districts of the state except Bhandara, Gondia, and Gadchiroli given in **Figure 2**. The area formation wise is underlain by basalt (hard rock) aquifers (82% of the geographical area); other aquifers are, namely, gneisses, schists, and granite (11%), rocks belonging to the Precambrian age (2%) and alluvium (5%). The other geological formations, older and younger than Deccan Traps, occur in the northeast and as isolated patches in the Sindhudurg and Ratnagiri districts.

The State of Maharashtra is covered mostly by highly heterogeneous and structurally complicated rock formations, wherein it is very difficult to generalise any methodology or guidelines on hydrogeological aspects. In Deccan Trap Basalt, there is no well-defined, uniformly distributed, homogeneous aquifer system. As per the 2023 ground water resource assessment, as compared to the 2022 assessment, the annual ground water recharge in 2023 has increased from 32.28 to 32.76 BCM, the annual extractable ground water recharge from 30.45 to 30.95 BCM, and the annual ground water extraction from 16.65 to 16.66 BCM. There is a marginal decrease in the Stage of ground water extraction by 0.85% i.e., from 54.68 % to 53.83 %.

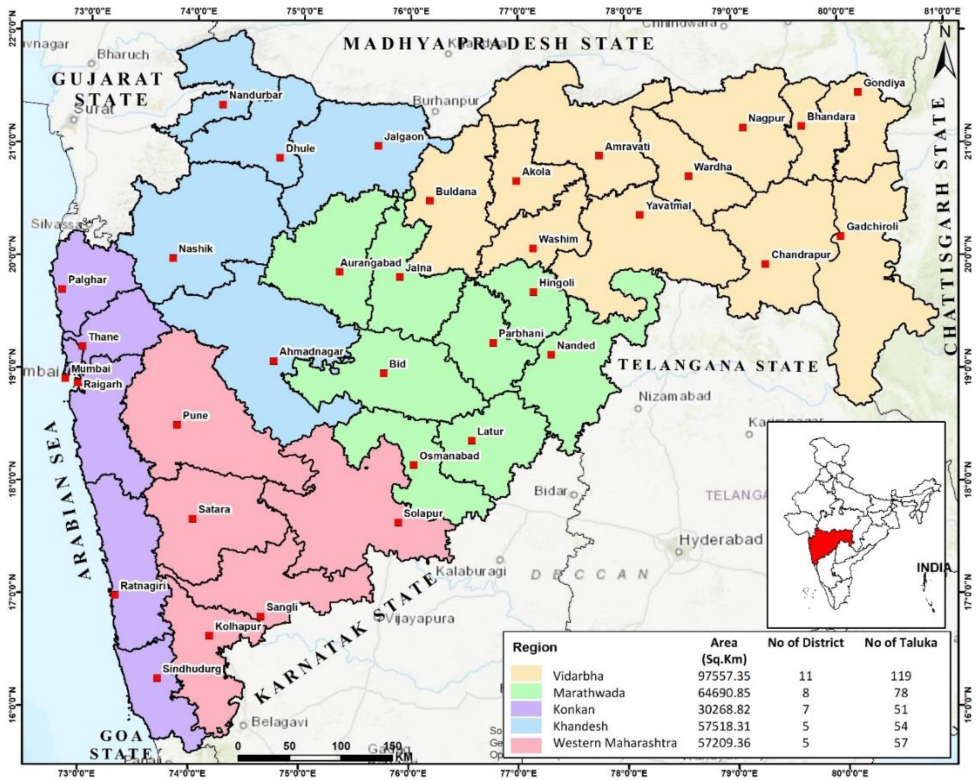


Figure-1. Geographical map of Maharashtra State.

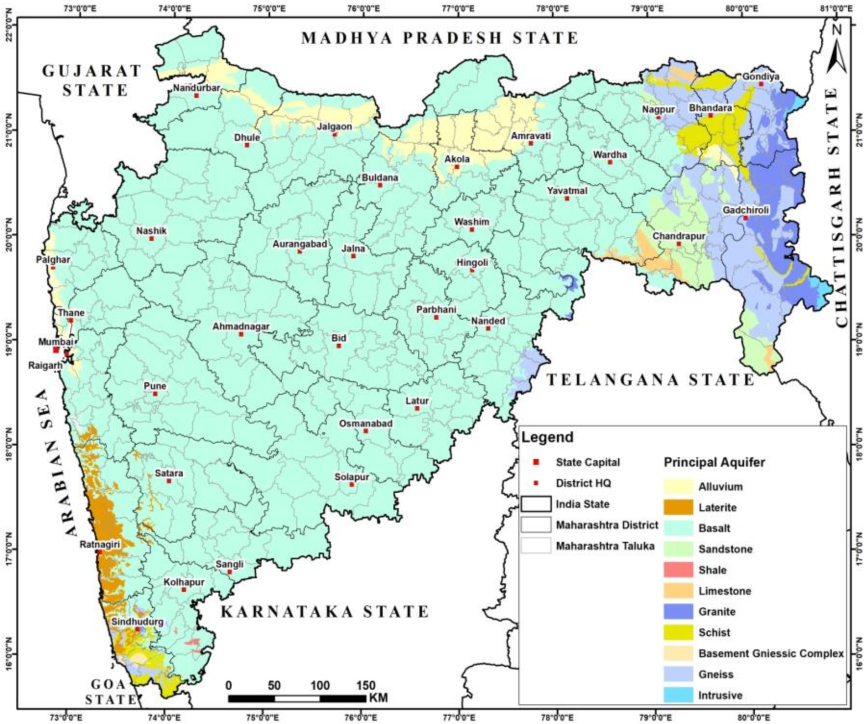


Figure-2. Map showing major aquifers of Maharashtra

3.0 GROUND WATER QUALITY MONITORING

Monitoring ground water quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Ground water is commonly tappedfrom phreatic aquifers. The probable causes of deterioration in ground water quality are depicted in **Figure 3.** The main objective of the ground water quality monitoring programme is to get information on the distribution of water quality on a regional scale as well as creating a background data bank of different chemical constituents in groundwater. The chemical quality of shallow groundwater was monitored by the CGWB, CR, Nagpur, during pre-monsoon in 2024 through 592 water quality monitoring stations located all over the state (**Figure 4**). The district-wise distribution of water quality monitoring stations of CGWB is given in **Table 1**.

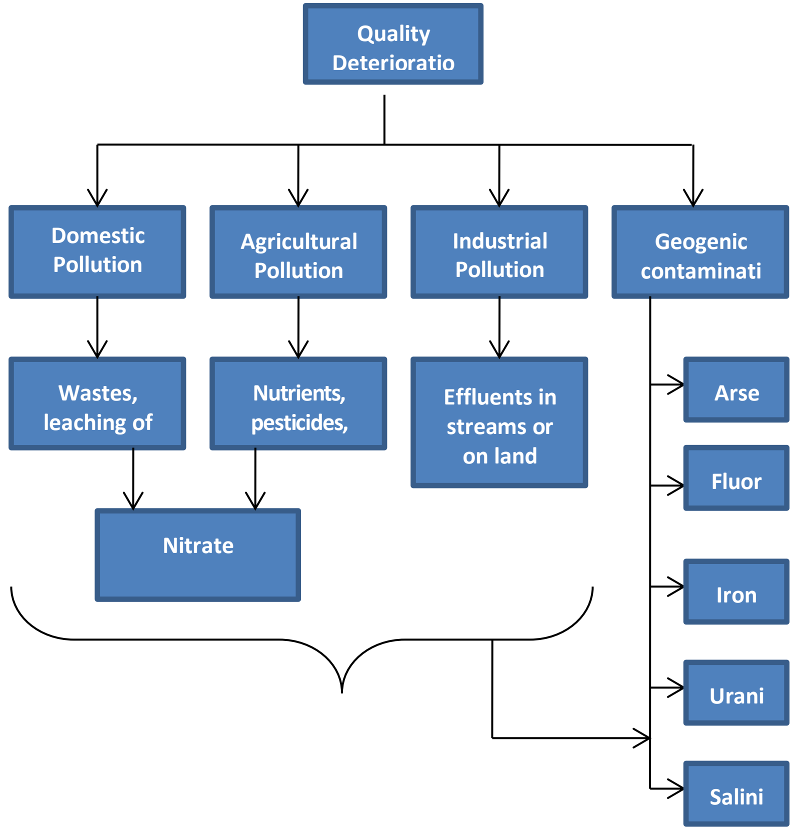


Figure 3. Schematic diagram illustrates the potential factors contributing to the degradation of groundwater quality.

Table 1: District wise distribution of Water Quality Monitoring Stations

S. No.	District	Number of Water Quality Monitoring Stations					
		2018-19	2019-20	2022-23	2023-24		2024-25
		Pre-Monsoon				Post-Monsoon	Pre-Monsoon
1	Ahmednagar	56	52	63	79	79	41
2	Akola	16	14	20	25	13	14
3	Amravati	77	54	49	77	35	30
4	Chatrapati Sambhaji Nagar	31	15	37	40	27	08
5	Beed	47	39	53	63	36	19
6	Bhandara	23	22	28	29	11	18
7	Buldhana	31	22	43	72	28	22
8	Chandrapur	48	41	48	55	23	32
9	Dhule	26	23	31	36	20	18
10	Gadchiroli	30	24	35	37	17	18
11	Gondia	20	14	16	18	8	09
12	Hingoli	20	21	29	25	9	10
13	Jalgaon	37	34	50	52	33	20
14	Jalna	35	15	33	41	24	16
15	Kolhapur	32	40	36	40	2	10
16	Latur	36	24	23	25	14	13
17	Mumbai City	6	6	3	6	6	06
18	Mumbai Urban	15	13	9	16	15	-
19	Nagpur	71	63	71	71	31	28
20	Nanded	31	41	47	46	18	24
21	Nandurbar	16	12	17	23	5	07
22	Nashik	58	55	66	71	40	37
23	Dharashiv	30	18	21	24	13	07
24	Palghar	34	21	25	37	1	-
25	Parbhani	22	18	37	37	16	20
26	Pune	45	37	35	53	49	14
27	Raigad	35	35	34	50	48	16
28	Ratnagiri	58	59	57	54	0	10
29	Sangli	33	33	39	38	24	19
30	Satara	48	35	48	53	14	16
31	Sindudurg	48	50	49	54	0	07
32	Solapur	46	24	30	32	27	21
33	Thane	22	15	19	19	19	15
34	Wardha	43	39	59	53	36	21
35	Washim	11	15	32	48	13	07
36	Yavatmal	38	37	66	68	31	19
	Total	**1275**	**1080**	**1358**	**1567**	**785**	**592**

The present bulletin is based on the changing scenario in water quality in network observation wells of CGWB in the years from 2018 to 2024 (Year 2020 and 2021 data not incorporated due to COVID pandemic).

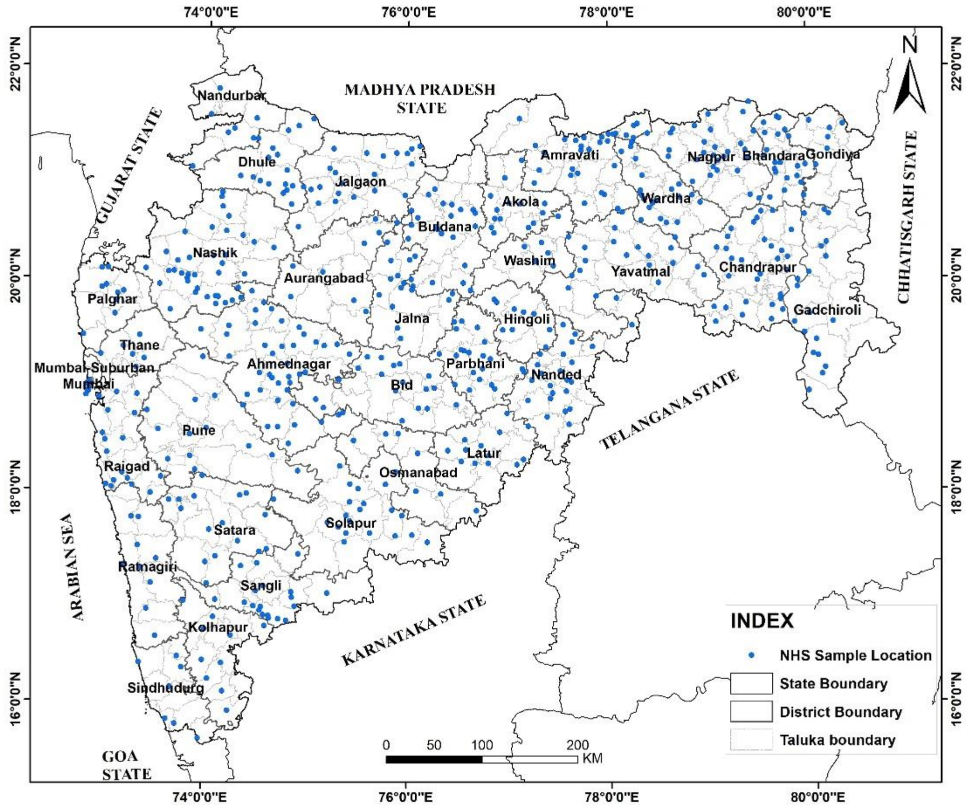


Figure 4: Map showing Groundwater Quality Monitoring Stations in Maharashtra (2024)

4.0 GROUND WATER QUALITY SCENARIO

The main objectives of ground water quality monitoring are to assess the suitability of ground water for drinking purposes, as the quality of drinking water is a powerful environmental determinant of the health of a community. Bureau of Indian Standards (BIS), vide its document IS: 10500:2012, Edition 3.2 (2012-22), has recommended the quality standards for drinking water. The quality of groundwater in Maharashtra has been evaluated by sampling and analysis of water samples collected from National Hydrograph Station (NHS) or Groundwater Monitoring wells. The ground water samples collected fromphreatic aquifers are analysed for all the major basic parameters and heavy metals. A total 1199 samples were collected for trend analysis which includes n=592 ground water samples for basic analysis and n=607 for heavy metal analysis pre-monsoon water quality of the unconfined aquifer. Based on the results, it is found that ground water of Maharashtra state is mostly of calcium bicarbonate (Ca-HCO_3) type when the electrical conductivity of water is below 750 µS/cm at 25°C. They are of mixed cations and mixed anions type when the electrical conductance is between 750 and 3000 µS/cm and waters with an electrical conductance above 3000 µS/cm are of sodium chloride (Na-Cl) type. However, other types of water are also found among thesegeneral classifications, which may be due to the local variations in hydro-chemical environments and anthropogenic activities. Nevertheless, the occurrence of high concentrations of some water chemical qualityparameters such as salinity (EC), TDS, total hardness, sulphate, chloride, fluoride, nitrate and uranium, and the changes in ground water quality based on these parameters have been observed in some parts of Maharashtra.

4.1 QUALITY ASSESSMENT OF GROUNDWATER IN UNCONFINED AQUIFERS

Unconfined aquifers are extensively tapped for water supply and irrigation across the state; therefore, their quality is of paramount importance. The chemical water quality parameters like Electrical Conductivity, total dissolved solids, Fluoride, Nitrate and Uranium etc., are main constituents defining the quality of ground water in unconfined aquifers. Therefore, the presence of ions and the changes in chemical quality with respect to the following constituents are discussed below:

- Electrical Conductivity (> 3000 µS/cm)
- Fluoride (>1.5 mg/L)
- Nitrate (>45 mg/L)
- Uranium (>30 ppb)

4.1.1 THE ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) or Total dissolved solids or Salinity is the dissolved salt content in a water body. Different substances that dissolve inwater give taste and odor. Electrical conductivity represents the total number of cations and anions present in groundwater, indicating ionic mobility of different ions, total dissolved solids and saline nature of water. In general water having EC < 1500 µS/cm at 25 °C, is considered as fresh water, EC 1500–15000 µS/cm, is considered as brackish water and >15000 µS/cm is considered as saline water. Salinity always exists in ground water but in variable amounts. It is mostly influenced by aquifer material, solubility of minerals, duration of contact and factors such asthe permeability of soil, drainage facilities, quantity of rainfall and above all, the climate of the area. BIS has recommended a drinking water standard for total dissolved solids a limit of 500 mg/L corresponding to EC of about 750 µS/cm that can be extended to a TDS of 2000 mg/L corresponding to EC of about 3000 µS/cm in case of no alternate source. Water having TDS morethan 2000 mg/L is not suitable for drinking purposes.

PRESENT SCENARIO OF ELECTRICAL CONDUCTIVTY (EC) VALUE IN GROUND WATER OF MAHARASHTRA STATE IN INDIA

Distribution of Electrical Conductivity (EC)

The EC value of ground water in the State varies from 42 µS/cm at Achirne, Vaibhavwadi block of Sindhudurg, to 11040 µS/cm at 25°C at Ashthi, Bhatkuli block of Amravati district. Grouping water samples based on EC values, it is found that 26.8 % of them have EC less than 750 µS/cm, 68.4 % have between 750 and 3000 µS/cm and the remaining 4.7 % of the samples have EC above 3000 µS/cm given in **Figure 5**. The higher EC 11040 µS/cm values found in the samples from the Amravati district may be due to inland salinity. The higher values of EC (>3000 µS/cm) were mainly found in the samples collected from the wells in the parts of Amravati, Akola, Aurangabad, and Buldhana districts. The inland salinity problems existing in the Purna alluvium basin of Amravati, Akola, and Buldhana districts, wherein the sluggish movement of groundwater and lack of regular recharging are causing an increase in the in the EC of ground water encountered at deeper depths. In the western part of Maharashtra, especially in the western coastal tract of the state, EC observed in the ground water less than 750 µS/cm, due to the physiographical, climate, and hydrogeological conditions existing in the area in **Figure 5**. The number of samples analyzed per district, along with their minimum, maximum, and mean EC values based on NHS 2024 Data is given in **Table 2**. High EC value > 3000 µ S/cm have been recorded in 28.6% samples at Akola district, it is attributed to the part of inland salinity of Purna basin.

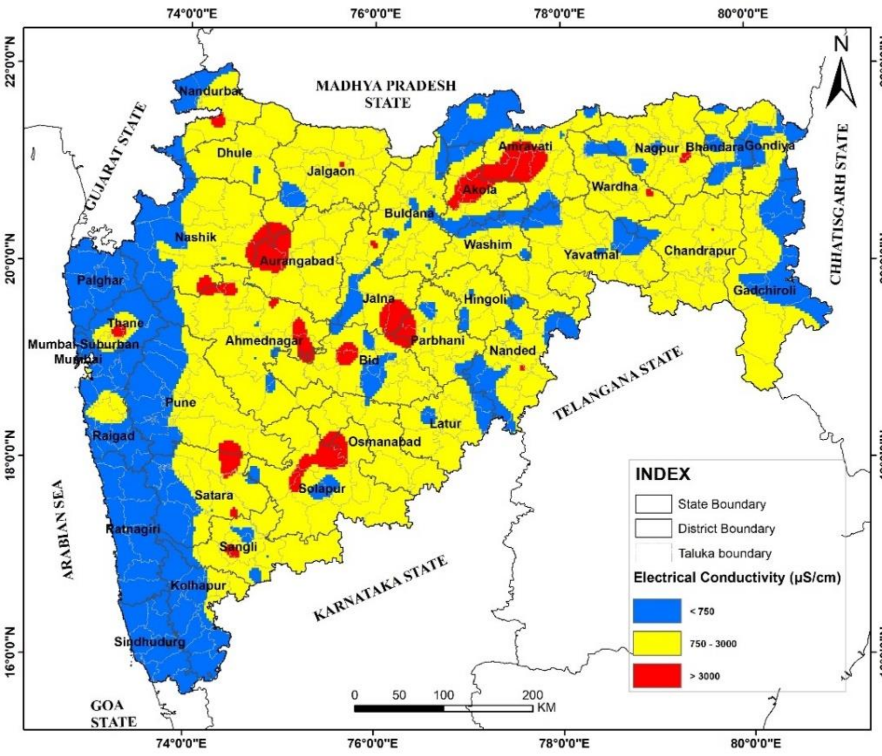


Figure 5: Distribution of Electrical Conductivity in Maharashtra State (2024).

TEMPORAL VARIATION OF EC IN GROUND WATER FROM YEAR 2018 TO 2024

In comparison to 2018 (**Table 3**), it has been observed that there is marginal decrease in the no. of Districts having EC more than 3000 µS/cm in 2024. Periodic variation in suitability Classes of groundwater Electrical Conductivity (EC) presented in **Table 4** and it is observed that increase by 1.5% locations having EC> 3000 µS/cm.

Table 2: District wise Range and distribution of EC in shallow GW of Maharashtra

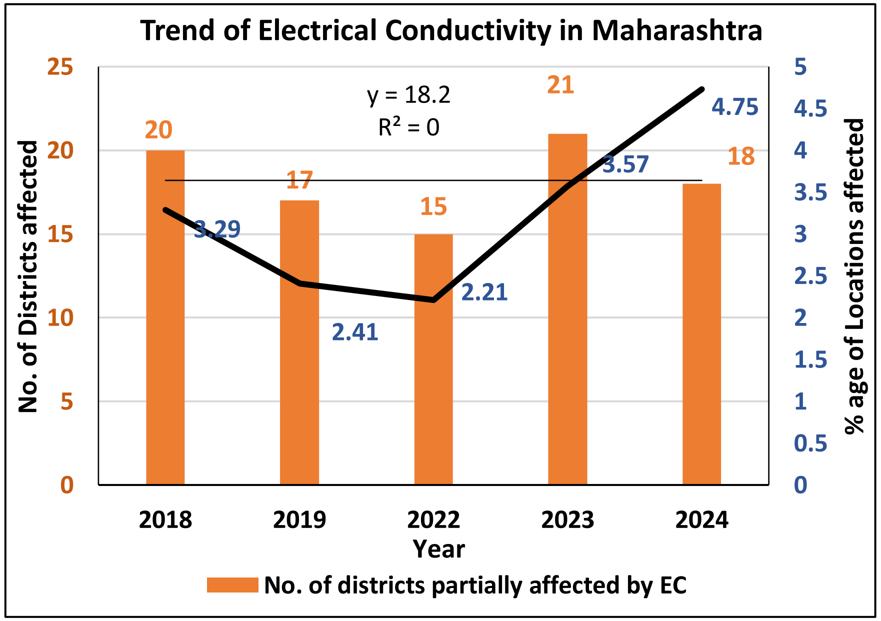
District	Electrical Conductivity (EC) µS/cm						
	No. of samples	Min	Max	Mean	% of samples		
					< 750	< 750-3000	>3000
Ahmednagar	41	493	4133	1564	12.2	80.5	7.3
Akola	14	600	7708	2141	14.3	57.1	28.6
Amravati	30	395.6	11040	1811	16.7	73.3	10.0
Beed	19	109	4935	1453	26.3	63.2	10.5
Bhandara	18	145	1710	851	61.1	38.9	0.0
Buldana	22	145	2654	1257	27.3	72.7	0.0
Chandrapur	32	728	3015	1575	3.1	93.8	3.1
Chatrapati Sambhaji Nagar	8	1232	9090	2448	0.0	87.5	12.5
Dharashiv	7	692	2225	1286	14.3	85.7	0.0
Dhule	18	681	2279	1386	11.1	88.9	0.0
Gadchiroli	18	645	2040	1178	11.1	88.9	0.0
Gondia	9	409	1538	885	33.3	66.7	0.0
Hingoli	10	528	2435	1113	10.0	90.0	0.0
Jalgaon	20	898	3131	1452	0.0	95.0	5.0
Jalna	16	696	3555	1372	18.8	75.0	6.3
Kolhapur	10	90	2144	512	80.0	20.0	0.0
Latur	13	432	1806	1052	30.8	69.2	0.0
MUMBAI CITY	6	565	980	715	66.7	33.3	0.0
Nagpur	28	311	3114	1233	14.3	82.1	3.6
Nanded	24	508	3214	1138	25.0	70.8	4.2
Nandurbar	7	335	3875	1536	42.9	42.9	14.3
Nashik	37	191	6327	1224	24.3	73.0	2.7
Parbhani	20	552	8455	1403	20.0	75.0	5.0
Pune	14	192	2181	956	42.9	57.1	0.0
Raigad	16	51	1610	485	81.3	18.8	0.0
Ratnagiri	10	64	760	269	90.0	10.0	0.0
Sangli	19	312.6	4416	1338	15.8	78.9	5.3
Satara	16	143.7	7032	1321	43.8	43.8	12.5
Sindudurg	7	42	290	193	100.0	0.0	0.0
Solapur	21	393	8572	1799	19.0	71.4	9.5
Thane	15	266	5018	804	86.7	6.7	6.7
Wardha	21	498	3057	1257	9.5	85.7	4.8
Washim	7	711	1342	1045	14.3	85.7	0.0
Yavatmal	19	488	1724	974	26.3	73.7	0.0
Grand Total	**592**				**26.8**	**68.4**	**4.7**

Table 3: Comparative change in number of locations having EC > 3000 µS/cm in various districts

S. No.	District	Number of Locations having EC > 3000 µS/cm					
		2018	2019	2022	2023		2024
		Pre-Monsoon				Post-Monsoon	Pre-Monsoon
1	Ahmednagar	7	1	6	15	8	3
2	Akola	2	2	4	3	4	4
3	Amravati	2	3	2	6	2	3
4	Chatrapati Sambhaji Nagar	2	0	2	2	2	1
5	Beed	2	1	3	3	1	2
6	Bhandara	0	0	0	0	0	0
7	Buldhana	1	2	1	1	0	0
8	Chandrapur	0	1	1	3	0	1
9	Dhule	3	1	1	0	1	0
10	Gadchiroli	0	0	0	0	0	0
11	Gondia	0	0	0	0	0	0
12	Hingoli	1	1	0	0	0	0
13	Jalgaon	0	1	0	1	1	1
14	Jalna	2	0	1	1	1	1
15	Kolhapur	0	1	0	0	0	0
16	Latur	2	0	0	0	0	0
17	Mumbai City	0	0	0	0	0	0
18	Mumbai Urban	0	0	0	0	0	-
19	Nagpur	0	0	2	2	1	1
20	Nanded	1	1	0	2	0	1
21	Nandurbar	1	1	0	1	0	1
22	Nashik	5	3	2	2	1	1
23	Dharashiv	1	1	0	0	0	-
24	Palghar	0	0	0	0	0	-
25	Parbhani	0	0	1	1	1	1
26	Pune	0	0	0	0	1	0
27	Raigad	0	1	0	2	0	0
28	Ratnagiri	1	1	0	1	0	0
29	Sangli	1	2	1	2	1	1
30	Satara	2	0	0	1	1	2
31	Sindudurg	0	0	0	0	0	0
32	Solapur	4	3	2	5	6	2
33	Thane	0	0	0	1	0	1
34	Wardha	0	0	1	1	1	1
35	Washim	0	0	0	0	1	0
36	Yavatmal	1	0	0	0	0	0
	Total	**41**	**27**	**30**	**56**	**34**	**28**

Table 4: Periodic variation in suitability Classes of groundwater Electrical Conductivity (EC)

Parameter	Class	Percentage of samples					Periodic Variation 2018–2024
		2018 (n=1275)	2019 (n=1080)	2022 (n=1358)	2023 (n=1567)	2024 (n=592)	
Salinity as EC (µS/cm)	< 750	37.41	45.28	34.61	32.55	26.85	-8.49
	750 – 3000	59.37	52.22	63.18	63.88	68.41	6.99
	> 3000	3.22	2.50	2.21	3.57	4.75	1.47



During pre-monsoon 2024, an EC > 3000 µS/cm value was observed in 34 locations of 18 districts in the state, and 4.7% locations are affected. Increasing trend in EC values have been observed in compared to previous years.

PRESENT SCENARIO OF NITRATE CONCENTRATION IN GROUND WATER OF THE STATE

4.1.2 NITRATE(NO_3)

Nitrate is a naturally occurring compound that is formed in the soil when nitrogen and oxygen combine. The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants through a process called nitrogen fixation. Dissolved nitrogen in the form of NO_3 is the most common contaminant in groundwater. Nitrate in groundwater generally originates from non-point sources such as the leaching of chemical fertilizers and animal manure, groundwater pollution from septic and sewage discharges, etc. Some chemical and microbiological processes, such as nitrification and denitrification, also influence the nitrate concentration in groundwater. As per the BIS (2012) standard for drinking water, the maximum desirable limit of nitrate concentration in water is 45 mg/L with no relaxation. Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methemoglobinemia, particularly in infants. Adults can tolerate slightly higher concentrations. The specified limits are not to be exceeded in the public water supply.

Distribution of Nitrate (NO_3)

The probable sources of nitrate contamination of ground water are excessive application of fertilizers, bacterial nitrification of organic nitrogen, and seepage from animal and human manure. In the State, nitrate in ground water samples variesfrom BDL to 446 mg/L. Approximate 59.5 % of the samples, spread over the entire State, have nitrate below 45 mg/L and 44.5 % samples have more than 45 mg/L.

Spatial distribution of nitrate (**Figure 6**) indicates high nitrate >45 mg/L found throughout the Maharashtra the state. The data is computed for district wise, minimum, maximum, and mean Nitrate values based on NHS 2024 Data is given in **Table 5**. During pre-monsoon 2023, NO_3 >45 mg/L value was observed in 35.7% locations of the state, while during the pre-monsoon 2024 it was reduced to 40.5% locations and enhanced contractions of Nitrate due to anthropogenic activities given in **Table 6**.

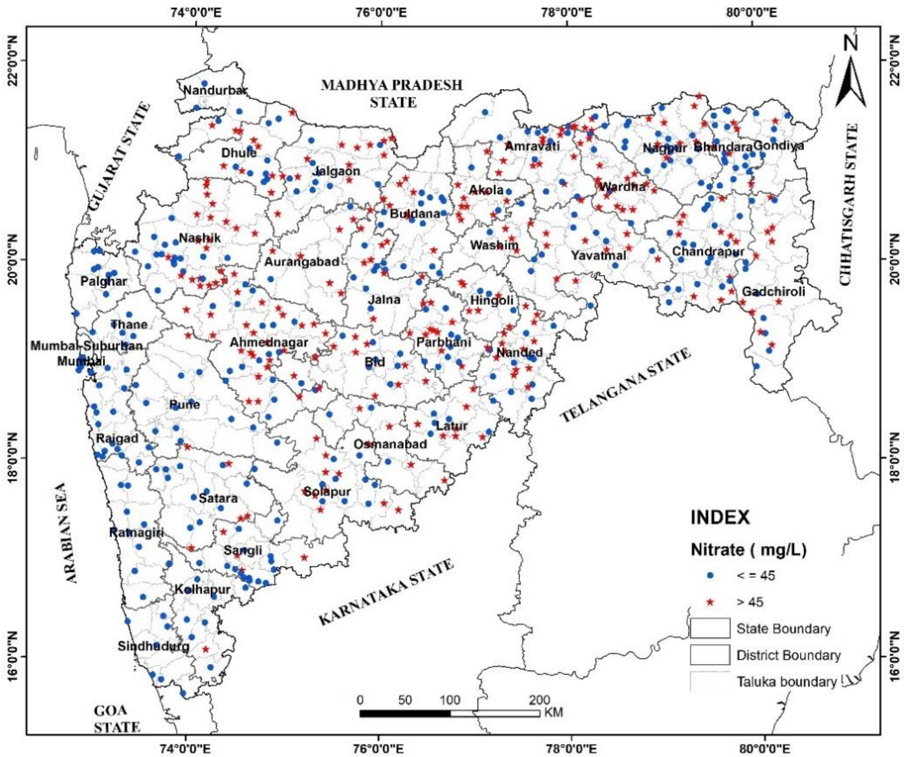


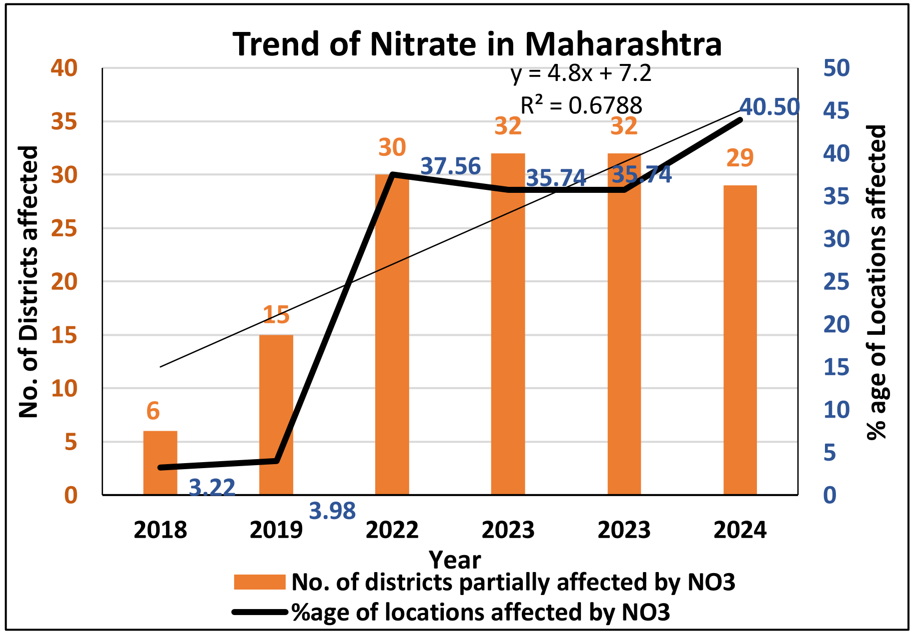
Figure 6: Distribution of Nitrate (>45 mg/L) in Maharashtra State (2024)

Table 5: District wise Range and distribution of Nitrate in shallow GW of Maharashtra

S No.	District	No. of samples	Min	Max	Mean	% of samples <45	% of samples >45
			mg/L				
1	Ahmednagar	41	10	165	54.5	39.0	61.0
2	Akola	14	1	53	44.0	21.4	78.6
3	Amravati	30	2	402	80.8	46.7	53.3
4	Beed	19	8	466	62.1	42.1	57.9
5	Bhandara	18	0	54	28.7	83.3	16.7
6	Buldana	22	0	284	56.7	63.6	36.4
7	Chandrapur	32	2	79	33.6	62.5	37.5
8	Chatrapati Sambhaji Nagar	8	29	102	56.6	25.0	75.0
9	Dharashiv	7	10	162	57.6	42.9	57.1
10	Dhule	18	7	54	39.7	50.0	50.0
11	Gadchiroli	18	7	56	42.7	44.4	55.6
12	Gondia	9	2	52	27.7	66.7	33.3
13	Hingoli	10	7	75	43.1	40.0	60.0
14	Jalgaon	20	8	165	54.7	45.0	55.0
15	Jalna	16	6	58	42.9	43.8	56.3
16	Kolhapur	10	0	48	10.4	90.0	10.0
17	Latur	13	3	99	47.5	46.2	53.8
18	MUMBAI CITY	6	1	10	6.0	100.0	0.0
19	Nagpur	28	2	74	32.3	67.9	32.1
20	Nanded	24	5	67	44.0	41.7	58.3
21	Nandurbar	7	7	53	29.6	71.4	28.6
22	Nashik	37	1	259	69.3	45.9	54.1
23	Parbhani	20	5	66	41.2	45.0	55.0
24	Pune	14	2	47	21.4	92.9	7.1
25	Raigad	16	0	24	8.2	100.0	0.0
26	Ratnagiri	10	0	19	2.8	100.0	0.0
27	Sangli	19	6	123	32.7	78.9	21.1
28	Satara	16	4	205	41.9	68.8	31.3
29	Sindudurg	7	0	0	0.0	100.0	0.0
30	Solapur	21	10	53	38.0	47.6	52.4
31	Thane	15	4	36	12.9	100.0	0.0
32	Wardha	21	6	58	48.0	19.0	81.0
33	Washim	7	7	51	38.6	42.9	57.1
34	Yavatmal	19	5	58	39.2	47.4	52.6
Grand Total		**592**			**42.5**	59.5	40.5

Table 6: Periodic variation in suitability Classes of groundwater Nitrate (NO_3) of Maharashtra given in table and presented in bar diagram.

Parameter	Class	Percentage of samples					Periodic Variation 2018–2024
		2018 (n=1275)	2019 (n=1080)	2022 (n=1358)	2023 (n=1567)	2024 (n=592)	
Nitrate as NO_3 (mg/L)	< 45	96.78	96.02	62.44	64.26	59.5	-6.34
	> 45	3.22	3.98	37.56	35.74	40.5	23.01



TEMPORAL VARIATION OF NO_3 IN GROUND WATER DURING THE PERIOD FROM 2018 TO 2024

It has been observed (**Table 7**) that 260 locations in various Districts have high Nitrate (> 45 mg/L) content in ground water and it has increased from 3.22% to 40.5% in the years 2018 to 2024.

Table 7: Comparative change in number of locations having Nitrate >45 mg/L in various districts

Sr No	District	Number of Locations having NO_3 > 45 mg/L					
		2018	2019	2022	2023		2024
		Pre-Monsoon				Post-Monsoon	Pre-Monsoon
1	Ahmednagar	0	1	28	32	45	25
2	Akola	0	5	12	14	10	11
3	Amravati	0	0	27	40	26	16
4	Aurangabad	0	0	27	29	25	6
5	Beed	0	1	26	30	19	11
6	Bhandara	2	0	4	9	6	3
7	Buldhana	0	1	24	39	27	8
8	Chandrapur	0	0	13	19	12	12
9	Dhule	19	3	20	23	13	9
10	Gadchiroli	0	0	18	17	13	10
11	Gondia	3	2	6	10	5	3
12	Hingoli	0	0	8	7	9	6
13	Jalgaon	0	0	34	23	26	11
14	Jalna	0	0	23	26	20	9
15	Kolhapur	0	1	2	3	2	1
16	Latur	2	1	11	2	13	7
17	Mumbai City	0	0	0	0	0	0
18	Nagpur	9	3	22	25	20	9
19	Nanded	0	0	17	22	11	14
20	Nandurbar	0	0	4	5	2	2
21	Nashik	6	15	33	29	23	20
22	Osmanabad	0	0	3	2	4	4
23	Parbhani	0	3	17	15	12	11
24	Pune	0	0	3	13	14	1
25	Raigad	0	0	0	1	0	0
26	Ratnagiri	0	0	0	0	0	0
27	Sangli	0	2	16	9	11	4
28	Satara	0	0	8	11	3	5
29	Sindudurg	0	0	0	1	0	0
30	Solapur	0	1	19	17	20	11
31	Thane	0	0	1	1	1	0
32	Wardha	0	0	38	34	30	17
33	Washim	0	0	14	21	11	4
34	Yavatmal	0	3	32	31	27	10
	Total	**41**	**43**	**510**	**560**	**460**	260

4.1.3 FLUORIDE

Fluorine does not occur in the elemental state in nature because of its high reactivity. It exists in the form of fluorides in a few minerals of which Fluorspar, Cryolite, Fluorite & Fluorapatite are the most common. Most of the fluoride found in groundwater naturally occurs from the breakdown of rocks and soil or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in groundwater in small amounts. The type of rocks, climatic conditions, nature of hydro geological strata and time of contact between rock and the circulating groundwater affect the occurrence offluoride in natural water.

BIS has recommended a desirable limit of 1.0 mg/L of fluoride concentration in drinking water and maximum permissible limit of 1.5 mg/L in case no alternative source of drinking water is available. It is well known that small amounts of fluoride (up to 1.0 mg/L) have proven to be beneficial in reducing tooth decay. However, high concentrations(>1.5mg/L) have resulted in staining of tooth enamel while at still higher levels of fluoride (> 5.0 mg/L) further critical problems such as stiffness of bones occur. Water having fluoride concentration of more than 1.5mg/L is not suitable for drinking purposes. High Fluoride >1.5mg/L is mainly attributed due to geogenic conditions. The fluoride content in ground water from observation wells in a major part of the State is found to beless than 1.0 mg/L.

Distribution of Fluoride (F)

Fluoride in small amounts in drinking water is beneficial for dental health while in large amounts it is injurious. The fluoride content in ground water ranges from 0.03 to 4.9 mg/L. BIS recommends that fluoride concentration up to 1.0 mg/L in drinking water is desirable, upto 1.50 mg/L is permitted and above 1.50 mg/L is injurious.

Classification of samples based on this recommendation, it is found that 91.5 % samples have fluoride in desirable range, 6.5 % in the permissible and the remaining 1.9 % have fluoride above 1.50 mg/L. Map showing spatial distribution (**Figure 7**) of fluoride contents in ground water indicates that ground waters with fluoride above 1.50 mg/L are found mainly in isolated patches in the parts of Beed Chandrapur, Gadchiroli, Nanded, Nandurbar, and Solapur districts of the State.

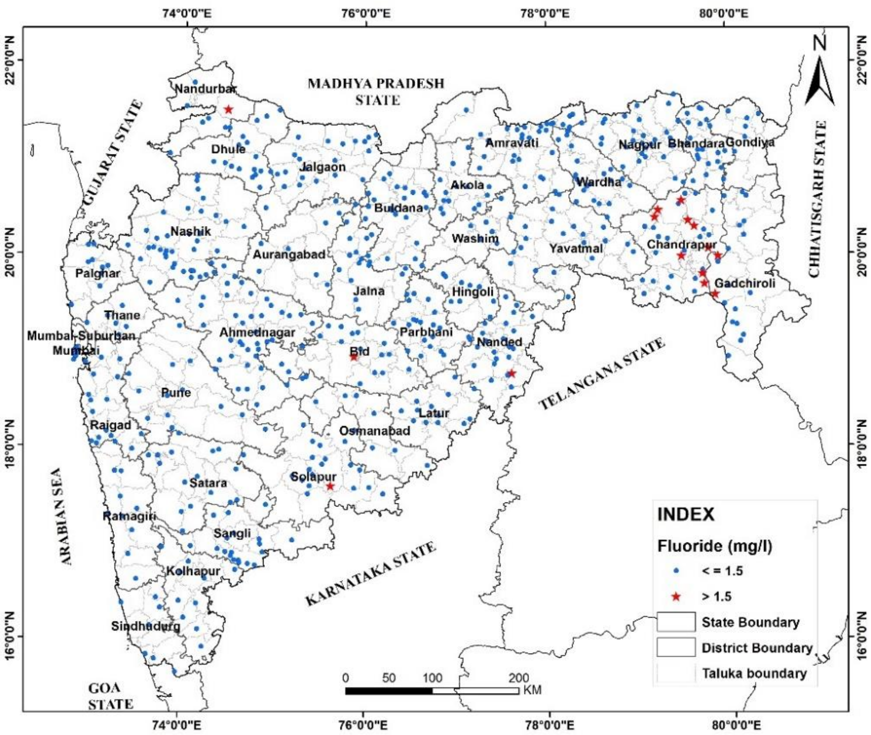


Figure 7: Distribution of Fluoride (> 1.5 mg/L) in Maharashtra state (2024)

Table 8 given below provides for the number of samples analyzed per district, along with their minimum, maximum, and mean Fluoride values based on NHS 2024 Data.

Table 8: District wise Range and distribution of Fluoride in shallow GW of Maharashtra

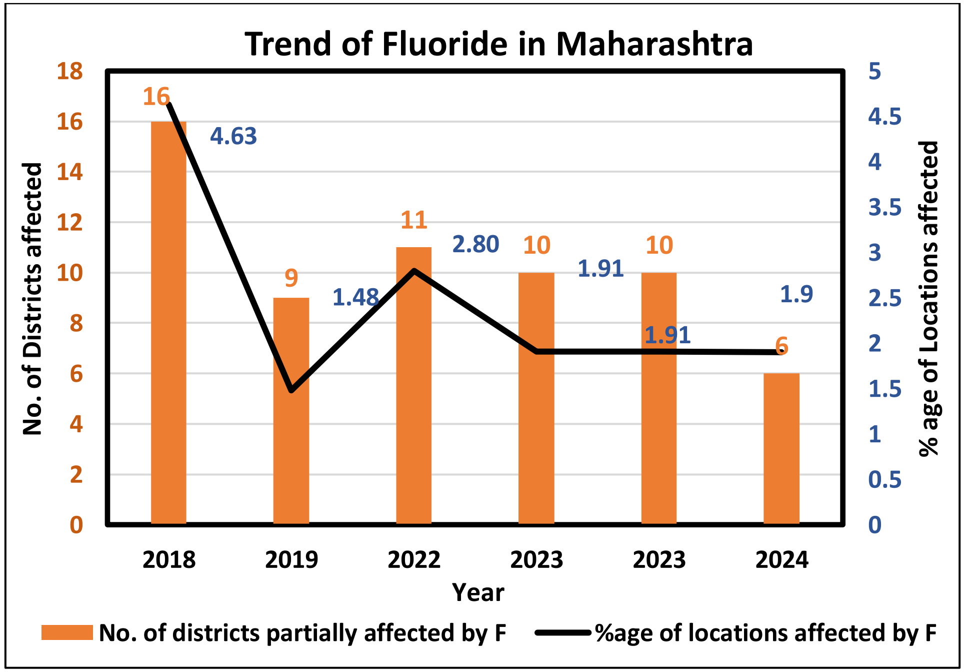
Sr no.	District	No. of samples	Min	Max	Mean	Samples (%)		
			Fluoride					
			mg/L			< 1.0	1.0 – 1.5	> 1.5
1	Ahmednagar	41	0.09	1.05	0.47	95.1	4.9	0.0
2	Akola	14	0.18	0.68	0.35	100.0	0.0	0.0
3	Amravati	30	0.14	1.36	0.44	96.7	3.3	0.0
4	Beed	19	0.25	4.9	0.71	94.7	0.0	5.3
5	Bhandara	18	0.1	1.46	0.58	72.2	27.8	0.0
6	Buldana	22	0.14	1.46	0.49	81.8	18.2	0.0
7	Chandrapur	32	0.15	4.65	1.08	56.3	12.5	31.3
8	Chatrapati Sambhaji Nagar	8	0.23	0.45	0.33	100.0	0.0	0.0
9	Dharashiv	7	0.23	1.2	0.60	85.7	14.3	0.0
10	Dhule	18	0.31	0.82	0.51	100.0	0.0	0.0
11	Gadchiroli	18	0.15	1.59	0.56	83.3	11.1	5.6
12	Gondia	9	0.19	0.96	0.51	100.0	0.0	0.0
13	Hingoli	10	0.69	1.46	1.06	40.0	60.0	0.0
14	Jalgaon	20	0.09	0.42	0.24	100.0	0.0	0.0
15	Jalna	16	0.2	0.65	0.35	100.0	0.0	0.0
16	Kolhapur	10	0.1	0.36	0.22	100.0	0.0	0.0
17	Latur	13	0.15	0.72	0.34	100.0	0.0	0.0
18	Mumbai City	6	0.08	0.58	0.19	100.0	0.0	0.0
19	Nagpur	28	0.06	1.46	0.55	89.3	10.7	0.0
20	Nanded	24	0.24	1.56	0.74	91.7	4.2	4.2
21	Nandurbar	7	0.2	1.51	0.45	85.7	0.0	14.3
22	Nashik	37	0.09	1.16	0.39	94.6	5.4	0.0
23	Parbhani	20	0.39	1.5	0.96	55.0	45.0	0.0
24	Pune	14	0.11	0.68	0.29	100.0	0.0	0.0
25	Raigad	16	0.059	0.12	0.09	100.0	0.0	0.0
26	Ratnagiri	10	0.03	0.22	0.07	100.0	0.0	0.0
27	Sangli	19	0.17	0.86	0.36	100.0	0.0	0.0
28	Satara	16	0.09	0.49	0.34	100.0	0.0	0.0
29	Sindudurg	7	0.075	0.107	0.09	100.0	0.0	0.0
30	Solapur	21	0.07	3.89	0.37	95.2	0.0	4.8
31	Thane	15	0.1	0.19	0.14	100.0	0.0	0.0
32	Wardha	21	0.22	0.8	0.39	100.0	0.0	0.0
33	Washim	7	0.2	0.47	0.31	100.0	0.0	0.0
34	Yavatmal	19	0.17	1.34	0.45	94.7	5.3	0.0
Grand Total		592		4.9	0.48	91.5	6.5	1.9

TEMPORAL VARIATION OF FLUORIDE IN GROUND WATER FROM 2018 TO 2024

It has been observed (Table 9 and 10) that the total number of locations affected byhigh fluoride has decreased from 59 in 2018 to 15 in 2024. District wise distribution of Fluoride in different categories <1.0, 1-1.5 and >1.5 mg/L given in **Figure 8**.

Table 9: Periodic variation in suitability Classes of Fluoride in groundwater of Maharashtra

Parameter	Class	Percentage of samples					Periodic Variation 2018-2024
		2018 (n=1275)	2019 (n=1080)	2022 (n=1358)	2023 (n=1567)	2024 (n=592)	
Fluoride as F (mg/L)	< 1.0	83.76	90.56	88.66	90.75	91.5	2.45
	1 – 1.5	11.61	7.96	8.54	7.34	6.5	-1.89
	> 1.5	4.63	1.48	2.80	1.91	1.9	-0.64



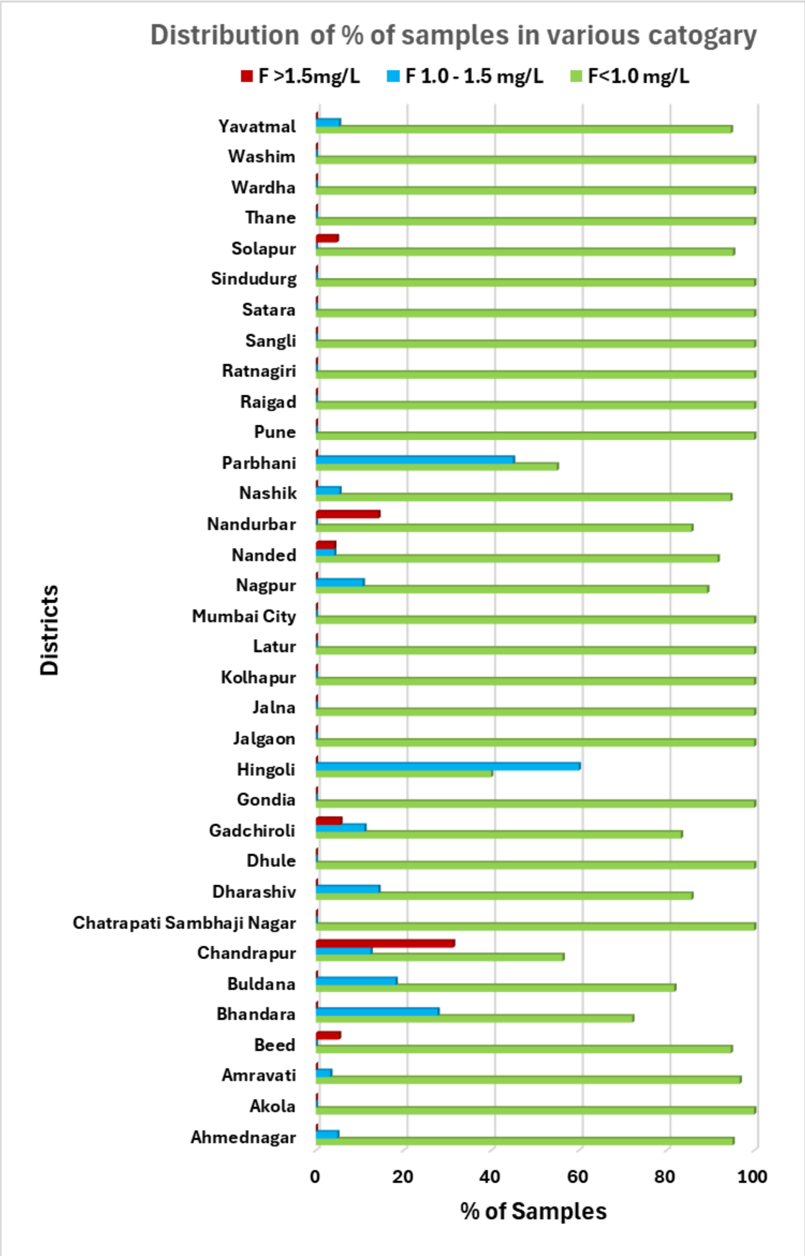


Figure 8: District wise distribution of Fluoride in different categories.

Table 10: Comparative Change in number of Locations having F > 1.5 mg/L

No.	District	Number of Locations having F > 1.5 mg/L					
		2018	2019	2022	2023		2024
		Pre-Monsoon				Post-Monsoon	Pre-Monsoon
1	Ahmednagar	2	2	1	0	0	0
2	Akola	0	0	0	1	0	0
3	Amravati	4	1	0	0	0	0
4	Aurangabad	0	0	0	0	0	0
5	Beed	5	0	4	0	0	1
6	Bhandara	3	0	5	4	0	0
7	Buldhana	1	0	0	1	0	0
8	Chandrapur	20	6	14	9	2	10
9	Dhule	1	0	0	0	0	0
10	Gadchiroli	3	0	1	3	0	1
11	Gondia	0	0	3	0	0	0
12	Hingoli	1	0	3	2	0	0
13	Jalgaon	0	0	0	0	0	0
14	Jalna	3	1	0	0	0	0
15	Kolhapur	0	0	0	0	0	0
16	Latur	0	0	0	0	0	0
17	Mumbai City	0	0	0	0	0	0
18	Nagpur	3	0	0	0	0	0
19	Nanded	3	1	2	0	1	1
20	Nandurbar	0	0	1	1	0	1
21	Nashik	0	0	0	0	0	0
22	Osmanabad	1	0	0	2	0	0
23	Palghar	0	0	0	0	0	0
24	Parbhani	2	1	2	6	0	0
25	Pune	0	0	0	0	0	0
26	Raigad	0	0	0	0	0	0
27	Ratnagiri	0	0	0	0	0	0
28	Sangli	0	0	0	0	0	0
29	Satara	0	0	0	0	0	0
30	Sindudurg	0	0	0	0	0	0
31	Solapur	6	2	0	0	0	1
32	Thane	0	0	0	0	0	0
33	Wardha	0	0	0	0	0	0
34	Washim	0	1	0	0	0	0
35	Yavatmal	1	1	2	1	0	0
	Total	59	16	38	30	03	15

4. HEAVY METAL

4.1. ARSENIC

Arsenic, a naturally occurring element, is widely distributed throughout the Earth's crust and can be found in various environmental mediums such as water, air, food, and soil. It exists intwo primary forms: organic and inorganic. While natural processes like biological activities, weathering reactions, and volcanic emissions contribute to arsenic release, human activities also play a significant role. Anthropogenic sources include mining activities, fossil fuel combustion, the use of arsenical pesticides, herbicides, and crop desiccants, as well as arsenic additives in livestock feed, especially poultry feed. Although the use of arsenical products like pesticides and herbicides has declined over recent decades, their use in wood preservation remains common. The maximum permissible limit for arsenic according to the Bureau of Indian Standards (BIS) is10 parts per billion (ppb).

PRESENT SCENARIO IN MAHARASHTRA W. R.T ARSENIC

Distribution of Arsenic (As)

The chemical analysis of the n= 607 water samples collected from NHS monitoring stations for pre-monsoon 2024 for arsenic content in ground water shows that arsenic concentration in ground water samples is below the permissible limit set by BIS (10 ppb) for drinking. As per the heavy metal analysis done in the year 2024, the number of districts having Arsenic concentration in ground water samples has been presented in **Table-11.** The data shows that the overall concentration of arsenic in groundwater of Maharashtra lies in the range of BDL to 7.46 ppb. The highest concentration of 7.46 ppb was found in Sillori, Kamleshwar of Nagpur district. This indicates that the geochemical condition may not be favorable for the dissolution of arsenic in groundwater as the major portion of the state is occupied by the volcanic igneous rocks (basalts), unlike volcano-sedimentary rocks, which contain higher than igneous rocks. The point value map for the arsenic presented in **Figure 9**.

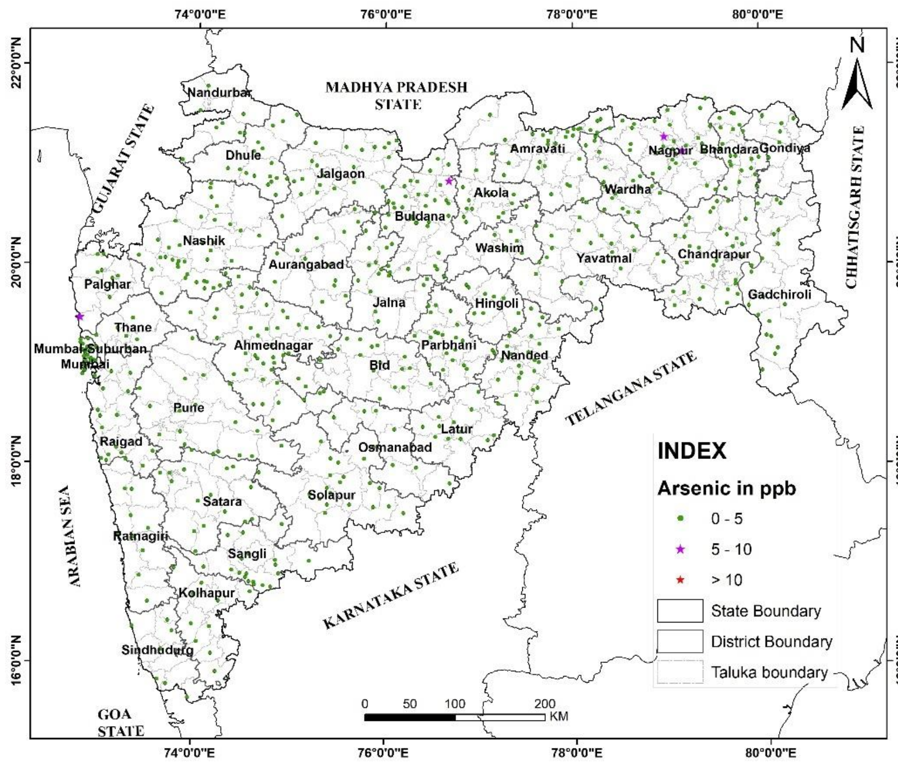


Figure 9: Distribution of Arsenic in the ground water in Maharashtra state (2019)

Table 11: District wise Range and distribution of Arsenic in shallow GW of Maharashtra

Arsenic					
Sr. no.	District	Samples (n=609)	As (ppb)		
			Min	Max	Mean
1	Ahmednagar	41	0.21	2.09	0.66
2	Akola	14	0.14	2.94	0.79
3	Amravati	30	0.24	2.98	0.81
4	Beed	18	0.11	1.94	0.70
5	Bhandara	18	0.02	0.34	0.09
6	Buldana	34	0.19	5.06	0.96
7	Chandrapur	30	0.05	2.56	0.50
8	Chatrapati Sambhaji Nagar	13	0.24	1.84	0.62
9	Dharashiv	7	0.14	0.69	0.40
10	Dhule	18	0.25	2.79	1.26
11	Gadchiroli	18	0.06	0.55	0.21
12	Gondia	9	0.02	0.41	0.17
13	Hingoli	10	0.12	1.13	0.38
14	Jalgaon	21	0.15	1.99	0.78
15	Jalna	16	0.28	0.71	0.45
16	Kolhapur	10	0.02	0.35	0.09
17	Latur	12	0.09	1.45	0.37
18	MUMBAI CITY	6	0.21	4.56	2.25
19	MUMBAI SUBURBAN	19	0.07	1.42	0.50
20	Nagpur	29	0.07	7.46	1.55
21	Nanded	24	0.09	2.11	0.55
22	Nandurbar	7	0.09	2.86	1.07
23	Nashik	37	0.06	2.48	0.70
24	Parbhani	20	0.13	1.23	0.58
25	Pune	18	0.04	1.74	0.73
26	Raigad	16	0.00	1.01	0.24
27	Sangli	19	0.12	3.36	0.44
28	Satara	16	0.07	1.78	0.41
29	Solapur	18	0.17	1.60	0.63
30	Thane	15	0.06	5.40	0.57
31	Wardha	20	0.11	1.97	0.68
32	Washim	7	0.22	1.61	0.70
33	Yavatmal	19	0.23	4.04	0.84

4.2 IRON

Iron is a common constituent in soil and ground water. It is present in water either as soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air, the water turns cloudydue to oxidation of ferrous iron into reddish brown ferric oxide.

The concentration of iron in natural water is controlled by both physico-chemical and microbiological factors. It is contributed to ground water mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks. The permissible Iron concentration in ground water is less than 1.0 mg/L as per the BISStandard for drinking water.

PRESENT DAY SCENARIO IN MAHARASHTRA W. R.T IRON

Distribution of Iron (Fe)

The iron content in ground water ranges from BDL to 0.9 mg/L. BIS recommends that iron concentration up to 1.0 mg/L in drinking water is acceptable. Classification of samples based on this recommendation; it is found that all samples have iron within the maximum permissible 1.0 mg/L. Map showing spatial distribution (**Figure 10**) of iron content in ground water (2024) indicates that all ground waters within the permissible limit (1.0 mg/L) prescribed by BIS for drinking water. The number of samples analyzed per district, along with their minimum, maximum,and mean Iron values based on NHS 2024 is given in **Table 12**.

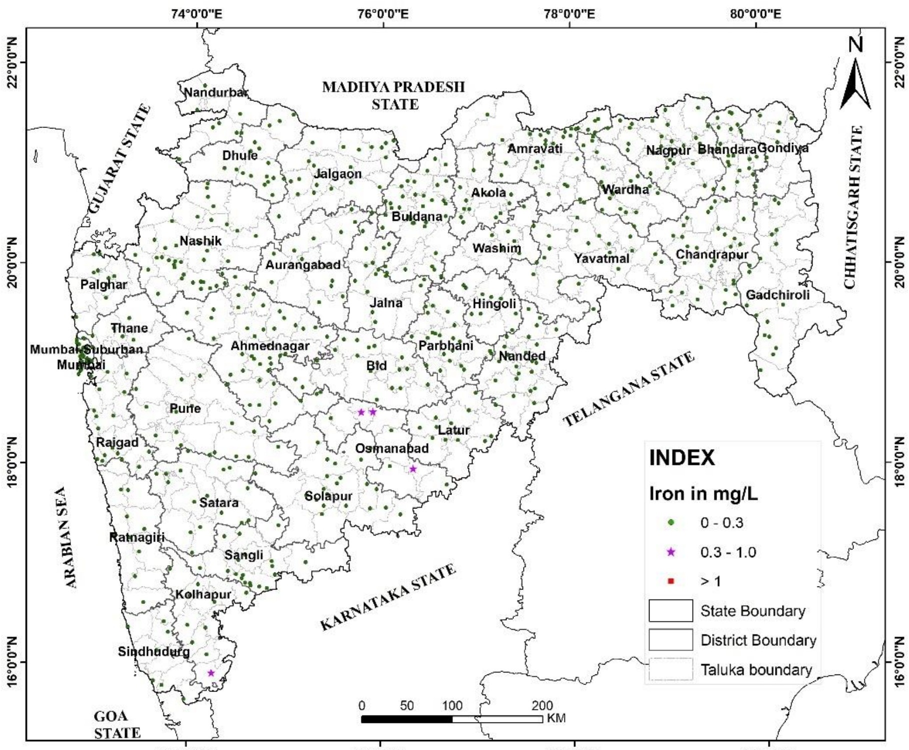


Figure 10: Distribution of Iron (1.0 mg/L) in the ground water in Maharashtra (2019)

IRON IN GROUND WATER IN 2024

The chemical analysis results of 2024 compared with 2019 for each district, The number of locations and concentration of Iron is significantly reduced in the ground water of state has been presented in **Table-13**. The district wise comparison of average Iron concentration between 2019 and 2024 is presented in **Figure 11**.

Table 12: District wise Range and distribution of Iron in shallow GW of Maharashtra

Sr no	District	Samples (n=609)	Fe mg/L		
			Min	Max	Mean
1	Ahmednagar	41	BDL	0.152	0.004
2	Akola	14	BDL	0.017	0.001
3	Amravati	30	BDL	0.004	0.000
4	Beed	18	BDL	0.004	0.000
5	Bhandara	18	BDL	0.033	0.002
6	Buldana	34	BDL	0.015	0.000
7	Chandrapur	30	BDL	0.000	0.000
8	Chatrapati Sambhaji Nagar	13	BDL	0.000	0.000
9	Dharashiv	7	BDL	0.930	0.285
10	Dhule	18	BDL	0.000	0.000
11	Gadchiroli	18	BDL	0.000	0.000
12	Gondia	9	BDL	0.014	0.002
13	Hingoli	10	BDL	0.000	0.000
14	Jalgaon	21	BDL	0.000	0.000
15	Jalna	16	BDL	0.000	0.000
16	Kolhapur	10	BDL	0.615	0.068
17	Latur	12	BDL	0.047	0.004
18	MUMBAI CITY	6	BDL	0.000	0.000
19	MUMBAI SUBURBAN	19	BDL	0.000	0.000
20	Nagpur	29	BDL	0.020	0.002
21	Nanded	24	BDL	0.027	0.001
22	Nandurbar	7	BDL	0.010	0.001
23	Nashik	37	BDL	0.000	0.000
24	Parbhani	20	BDL	0.032	0.002
25	Pune	18	BDL	0.011	0.001
26	Raigad	16	BDL	0.048	0.008
27	Sangli	19	BDL	0.000	0.000
28	Satara	16	BDL	0.017	0.001
29	Solapur	18	BDL	0.037	0.002
30	Thane	15	BDL	0.000	0.000
31	Wardha	20	BDL	0.000	0.000
32	Washim	7	BDL	0.000	0.000
33	Yavatmal	19	BDL	0.000	0.000

Table 13 The district wise comparation average Iron concentration between 2019 and 2024

Sr. no	District	Iron					
		Samples 2019			Samples 2024		
		Samples (n=1073)	Location having >1 mg/L	Mean Fe mg/L	Samples (n=609)	Location having >1 mg/L	Mean Fe mg/L
1	Ahmednagar	52	1	0.099	41	0	0.004
2	Akola	13	0	0.050	14	0	0.001
3	Amravati	54	0	0.050	30	0	0.000
4	Beed	39	1	0.080	18	0	0.000
5	Bhandara	23	0	0.240	18	0	0.002
6	Buldana	22	4	0.730	34	0	0.000
7	Chandrapur	41	3	0.610	30	0	0.000
8	Chatrapati Sambhaji Nagar	15	0	0.050	13	0	0.000
9	Dharashiv	14	0	0.150	7	0	0.285
10	Dhule	23	2	0.290	18	0	0.000
11	Gadchiroli	24	1	0.210	18	0	0.000
12	Gondia	15	0	0.330	9	0	0.002
13	Hingoli	21	0	0.030	10	0	0.000
14	Jalgaon	22	0	0.030	21	0	0.000
15	Jalna	15	0	0.150	16	0	0.000
16	Kolhapur	39	0	0.050	10	0	0.068
17	Latur	22	1	0.170	12	0	0.004
18	MUMBAI CITY	25	0	0.010	6	0	0.000
19	Nagpur	65	0	0.190	29	0	0.002
20	Nanded	41	1	0.110	24	0	0.001
21	Nandurbar	12	1	0.180	7	0	0.001
22	Nashik	56	1	0.080	37	0	0.000
23	Parbhani	18	0	0.030	20	0	0.002
24	Pune	47	1	0.080	18	0	0.001
25	Raigad	38	0	0.030	16	0	0.008
26	Sangli	32	0	0.100	19	0	0.000
27	Satara	36	0	0.050	16	0	0.001
28	Solapur	51	5	0.670	18	0	0.002
29	Thane	35	0	0.020	15	0	0.000
30	Wardha	38	2	0.190	20	0	0.000
31	Washim	16	7	1.110	7	0	0.000
32	Yavatmal	37	0	0.170	19	0	0.000

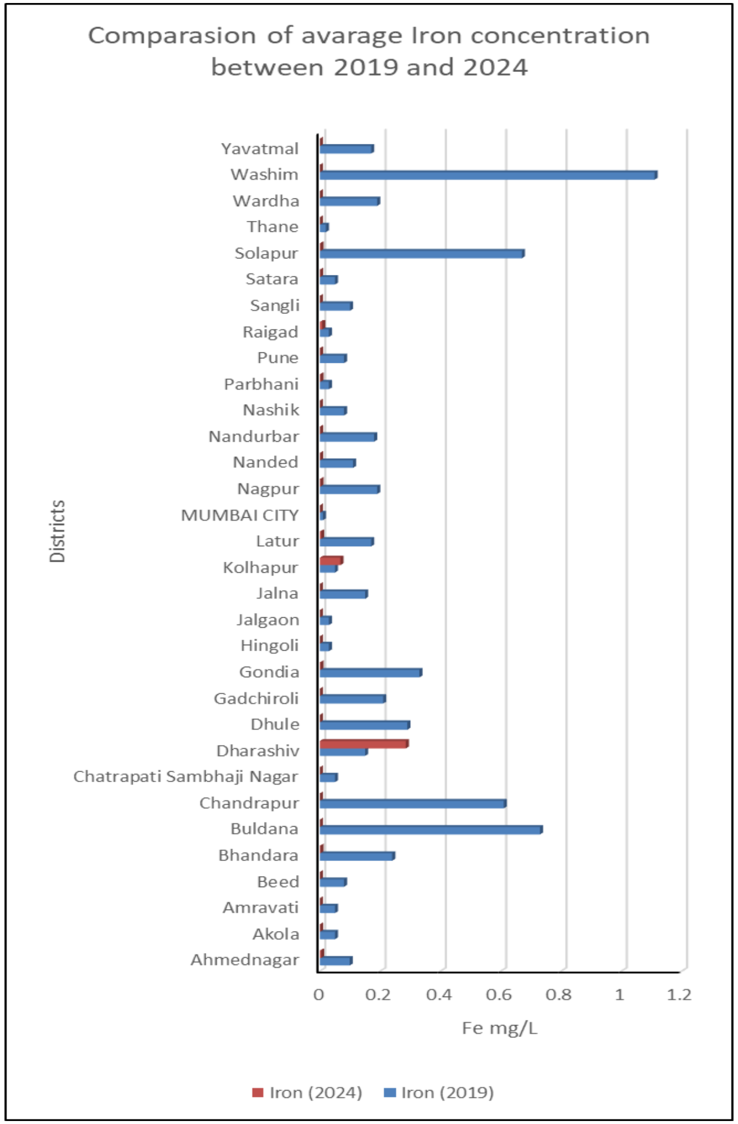


Figure 11 The district wise comparison of average Iron concentration between 2019 and 2024

4.2 URANIUM

Uranium occurs naturally in groundwater and surface water. Uranium being naturally occurring in groundwater and surface water poses health risks due to its radioactive properties. Sources include natural deposits, nuclear industry emissions, coal combustion, and phosphate fertilizers. Human exposure occurs mainly through drinking water, food, air, and occupational hazards. Concentrationsexceeding 30 ppb, according to BIS standards, can cause damage tointernal organs with prolonged intake, necessitating caution in consumption.

PRESENT DAY SCENARIO IN MAHARASHTRA W. R.T URANIUM

Distribution of Uranium (U)

The uranium (U) content in ground water ranges from BDL to 74.73 ppb. BIS recommends that uranium concentration up to 30 ppb indrinking water is acceptable. Classification of samples based on this recommendation; it is found that 0.32 % samples have uraniumabove 30 ppb in pre-monsoon 2024. During pre-monsoon 2024, the higher uranium concentration (>30 ppb) in groundwater samples was found in two locations: 74.73 ppb at Khair Langi (Bhandara district) and 46.22 ppb at Dhabetekdi (Gondia district). The concentrations and distributions of uranium in groundwater from aquifers in Maharashtra indicate that the concentration of U in groundwater is negligible and found well within the permissible limit of <30 ppb (BIS) except for two dug wells during the pre-monsoon presented in **Figure 12**. The source of uranium in the ground water samples may be geogenic contamination from host aquifer.

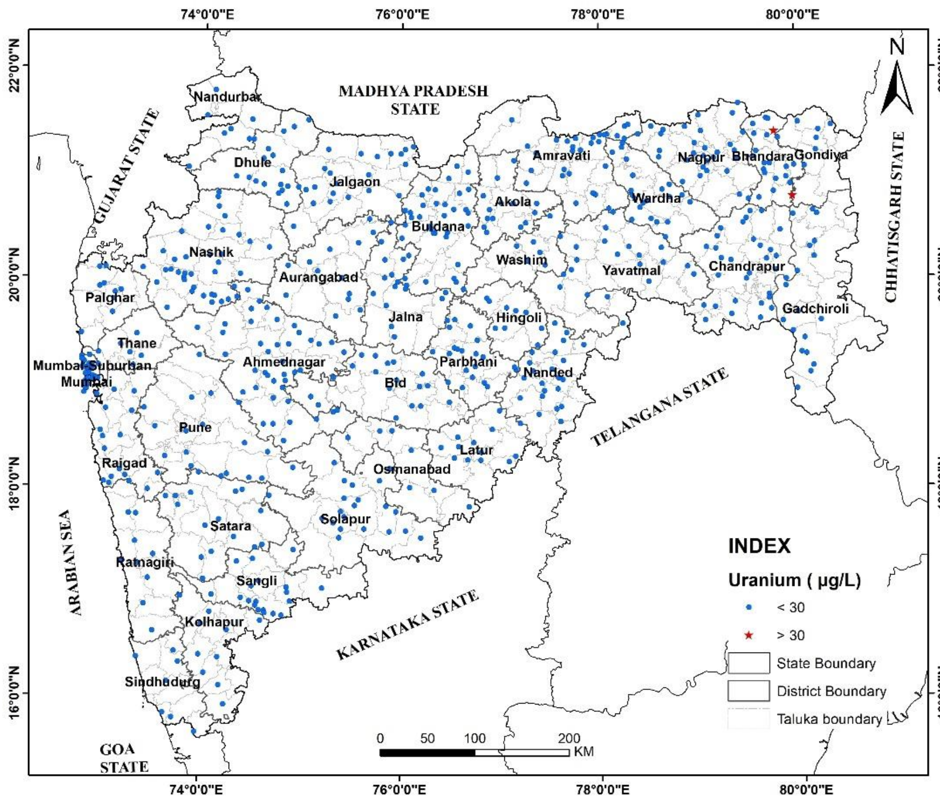


Figure 12: Map showing Locations and affected area having Uranium (>30 ppb) in ground water in Maharashtra state

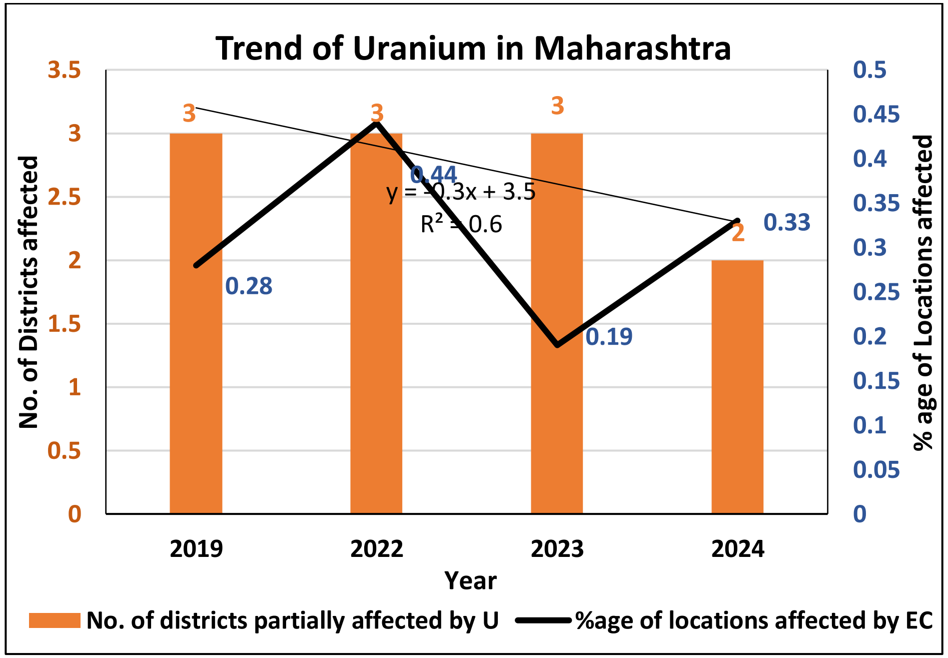
The number of samples analyzed per district, along with their minimum, maximum, and mean Uranium values based on NHS 2024. Data is given in **Table 14.** The Bhandara district has a higher average concentration of U (9.57 ppb). The periodically variation from 2019 to 2024 in suitability Classes of Uranium content in groundwater of State given in **Table 15**.

Table 14: District wise Range and distribution of Uranium in shallow GW of Maharashtra

Uranium					
Sr No	District	Samples (n=609)	U (ppb)		
			Min	Max	Mean
1	Ahmednagar	41	0.06	12.09	1.98
2	Akola	14	0.12	6.23	1.81
3	Amravati	30	0.10	13.84	2.17
4	Beed	18	0.00	3.45	1.48
5	Bhandara	18	0.04	74.73	9.57
6	Buldana	34	0.00	4.31	0.93
7	Chandrapur	30	0.26	18.19	4.40
8	Chatrapati Sambhaji Nagar	13	0.20	6.36	2.03
9	Dharashiv	7	0.23	1.63	0.82
10	Dhule	18	0.29	5.42	1.99
11	Gadchiroli	18	0.04	8.90	2.54
12	Gondia	9	0.04	46.22	6.55
13	Hingoli	10	0.04	2.39	0.60
14	Jalgaon	21	0.03	4.22	1.24
15	Jalna	16	0.06	3.55	0.83
16	Kolhapur	10	0.00	1.42	0.20
17	Latur	12	0.08	3.16	0.78
18	MUMBAI CITY	24	0.00	0.72	0.27
19	Nagpur	29	0.13	25.82	5.16
20	Nanded	24	0.00	11.32	2.19
21	Nandurbar	7	0.00	1.50	0.43
22	Nashik	37	0.00	12.69	1.74
23	Parbhani	20	0.11	2.62	1.02
24	Pune	18	0.00	3.25	0.95
25	Raigad	16	0.00	1.66	0.12
26	Sangli	19	0.01	4.84	1.19
27	Satara	16	0.00	3.79	0.86
28	Solapur	18	0.00	1.11	0.36
29	Thane	15	0.00	0.69	0.19
30	Wardha	20	0.12	8.17	2.01
31	Washim	7	0.04	1.91	0.78
33	Yavatmal	19	0.06	4.26	1.28

Table 15: Periodic variation in suitability Classes of Uranium content in groundwater of State

Parameter	Class	Percentage of samples					Periodic Variation 2019-2024
		2019	2022	2023		2024	
		(n=1073)	(n=1358)	(n=1567)	(n=748)	(n=609)	
		Pre-monsoon			Post-monsoon	Pre-monsoon	
Uranium ppb	<30	99.72	99.56	99.81	99.87	99.68	-0.048
	>30	0.28	0.44	0.19	0.13	0.32	0.048



TEMPORAL VARIATION OF URANIUM IN GROUND WATER 2019 TO 2024

It has been observed (**Table 16**) that the total number of districts and locations affected by high Uranium has not changed from 2019 to 2024.

Table 16: Comparative Change in number of Locations having U>30ppb

Sr No	District	Number of locations having U>30 ppb				
		2019 (n=1073)	2022 (n=1358)	2023 (n=1567)	2023 (n=748)	2024 (n=609)
		Pre-monsoon			Post-monsoon	Pre-monsoon
1	Ahmednagar	0	0	0	0	0
2	Akola	0	0	0	0	0
3	Amravati	0	0	0	0	0
4	Beed	0	0	0	0	0
5	Bhandara	1	3	1	1	1
6	Buldana	0	0	0	0	0
7	Chandrapur	0	0	0	0	0
8	Chatrapati Sambhaji Nagar	0	0	0	0	0
9	Dharashiv	0	0	0	0	0
10	Dhule	0	0	0	0	0
11	Gadchiroli	0	0	0	0	0
12	Gondia	1	2	1	0	1
13	Hingoli	0	0	0	0	0
14	Jalgaon	0	0	0	0	0
15	Jalna	0	0	0	0	0
16	Kolhapur	0	0	0	0	0
17	Latur	0	0	0	0	0
18	MUMBAI CITY	0	0	0	0	0
19	Nagpur	1	1	1	0	0
20	Nanded	0	0	0	0	0
21	Nandurbar	0	0	0	0	0
22	Nashik	0	0	0	0	0
23	Parbhani	0	0	0	0	0
24	Pune	0	0	0	0	0
25	Raigad	0	0	0	0	0
26	Sangli	0	0	0	0	0
27	Satara	0	0	0	0	0
28	Solapur	0	0	0	0	0
29	Thane	0	0	0	0	0
30	Wardha	0	0	0	0	0
31	Washim	0	0	0	0	0
32	Yavatmal	0	0	0	0	0
	Total	**3**	**6**	**3**	**1**	**2**

5. SUMMARY

The analytical results show that compared to 2018, more locations in Maharashtra had groundwater samples exceeding permissible limits for Nitrate by 2024, Salinity has increased marginally while Fluoride has decreased in 2024 as compared to 2018. This decline in water quality may stem from geogenic or anthropogenic sources. While most samples from Central Ground Water Board observation wells meet drinking water standards for basic parameters and heavy metals, some exceed permissible limits, posing health risks with prolonged use.

DISTRICT WISE CONTAMINANT WISE STATUS SUMMARY BASED ON NHS 2024 PRE- MONSOON DATA

The **Table 17** provides a detailed summary of groundwater quality across various districts in Maharashtra, focusing on basic parameters (electrical conductivity, nitrate, fluoride) and heavy metals (iron, arsenic, uranium).

Basic Parameters:

- Electrical Conductivity (EC): 5.7% of samples exceed permissible limits, with higher occurrences in districts like Akola (28.6%), Nandurbar (14.3%), and Satara and Chatrapati Sambhaji Nagar (12.5%).
- Nitrate (NO_3): 40.5 % of samples exceed limits, with more than 50% samples affected in Akola, Ahmednagar, Amravati, Beed, Chatrapati Sambhaji Nagar, Dharashiv, Dhule, Gadchiroli, Hingoli, Jalgoan, Jalna, Latur, Nanded, Nashik, Parbhani, Solapur, Wardha, Washim and Yavatmal.
- Fluoride (F): 1.9 % of samples cross permissible level with 06 districts affected partially Beed, Chandrapur, Chatrapati Sambhaji Nagar, Gadchiroli, Hingoli, Nanded, Nandurbar, and Solapur.

Heavy Metals:

- Iron (Fe): No sample was found to be more than the permissible level of Iron (> 1 mg/L).
- Arsenic (As): No sample was observed by arsenic > 10 ppb permissible level.
- Uranium (U): Detected in 0.32% samples, indicating that the concentration of U in groundwater is negligible and found well within the permissible limit except for two dug wells with U concentration of 74.73 ppb and 46.22 ppb found in Khair Langi (Bhandara district) and Dhabetekdi (Gondia district), respectively.

STATE SUMMARY

A summary of groundwater quality in the state of Maharashtra, broken down by the number of samples collected and the percentage of those samples that are contaminated with various parameters is given in **Table 18.**

Table 17: Summary of Groundwater Quality of State: Samples and Contamination Percentage

Samples	EC (µS/cm)	NO3 (mg/L)	F (mg/L)	U (µg/L)	Fe (mg/L)	As (µg/L)
Number	592	592	592	607	607	607
> Permissible limit	28	260	15	2	0	0
% Permissible limit	4.74	40.5	1.91	0.32	0	0

A Graphical representation of the same is depicted in **Figure 13.**

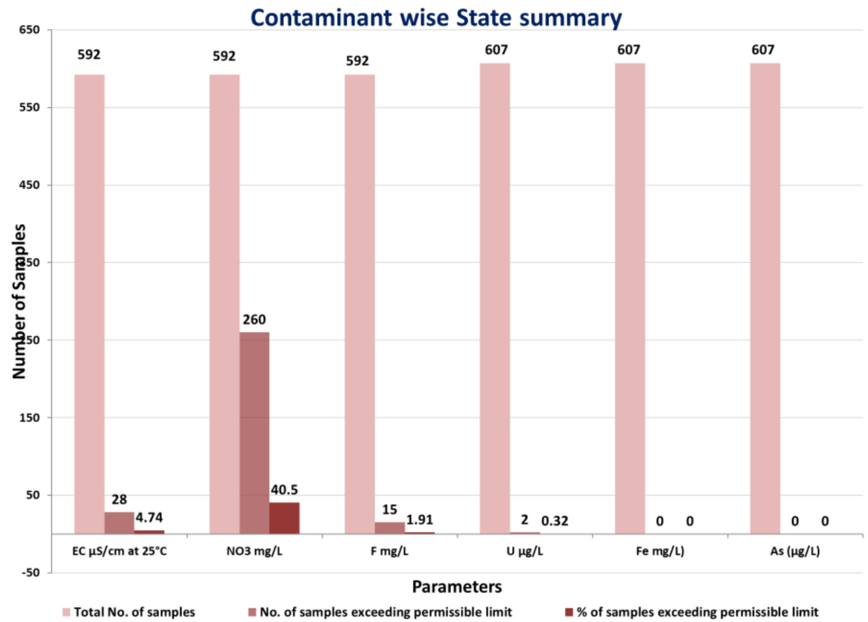


Figure 13: Graphical representation of samples and contamination percentage

The groundwater quality assessment in Maharashtra revealed notable levels of contamination across various parameters. Fluoride emerged as the predominant contaminant, with 1.91 % of samples surpassing permissible limits, followed by Electrical Conductivityat 3.57%, and Uranium at 0.32 %. Nitrate contamination was observed in 35.74 % of samples, while Iron (Fe) and Arsenic (As) exhibited lower levels of contamination, with 3.36% and 0% of samples exceeding permissible limits, respectively. It was observed that there were temporal variations in groundwater contents, with concentrations decreasing, which may be groundwater dilution due recharge fresh water.

REMOVAL TECHNIQUES/METHODS

The remediation of groundwater contamination is majorly classified into two techniques: in situ and ex situ. The in-situ techniques are based on the alteration of the releasing mechanism of the contaminants. Most of the ex-situ methods applied to the groundwater extracted from the aquifers are based on the following processes:

- **Precipitation processes:** Coagulation/filtration, direct filtration, coagulation, assisted microfiltration, enhanced coagulation, lime/softening, and enhanced lime softening.
- **Adsorptive processes:** Adsorption onto activated alumina, activated carbon, and iron/manganese oxide-based or coated filter media.
- **Ion exchange processes:** Specifically, anion exchange.
- **Membrane processes:** Nano-filtration, reverse osmosis, and electro-dialysis.

Proposed remedial measures

The water supplied for drinking purposes goes through pre-treatment processes like reverse osmosis, ion exchange, electro-dialysis, adsorption, coagulation, and precipitation. Most of the contaminants are sporadic in nature. Blending of contaminated groundwater with good quality surface water or groundwater. Conjunctive use of water is to be adopted for the sustainable and continuous supply of the water. Alternative sources (F shallow, as deep wells, or less contaminated aquifers) of groundwater and surface water sources may be identified. The column methods need periodical assessment and corrective action, like cleaning of the column and other parts of the filter plant, and chemical methods generate huge amounts of sludge; the disposal of it is a big environmental problem. A proper sludge disposal plan may be a workout to ensure further damage to the environment.

RECOMMENDATIONS

The artificial recharge of ground water by rainwater harvesting, blending good quality water with contaminated water for water supply and adopting treatment technologies are few remedial measures for improving and protecting the ground water quality as discussed removal techniques and method section. The proper treatment and disposal of the waste and wastewater from domestic and industrial sources can also prevent the ground water from getting polluted. The above measures along with creating awareness among the people can help to solve the problems related to ground water quality.

The study emphasizes the need for a multi-sector approach to conserving ground water resources, including conjunctive use, ground water legislation, agency involvement, community participation, awareness campaigns, pump selection, high-tech irrigation systems, low water requirement crops, and tissue culture technology.

Mass awareness programs/campaigning may be initiated to prevent further harm to human health. A few identified contaminated bore wells in the area should be sealed. Efficient removal plants may be installed to provide safe drinking water. Periodically drinking water quality checked to prevent further health impact. Rainwater harvesting structures may be installed to improve the quality and quantity of the water.

Table 18: Summary of Groundwater Quality in Various Districts of Maharashtra, Highlighting Basic Parameters (Electrical Conductivity, Nitrate, Fluoride) and Heavy Metals (Iron, Arsenic, Uranium)

Sr No	District	No. of samples for BA	EC (µS/cm)		Nitrate (mg/L)		Fluoride (mg/L)		No. of samples for HM	Uranium (µg/L)		Iron (mg/L)		Arsenic (µg/L)	
		596	>3000	%	>45	%	>1.5	%	609	>30	%	>1.0	%	>10	%
1	Ahmednagar	41	3	7.3	25	61.0	0	0.0	41	0	0.0	0	0.0	0	0.0
2	Akola	14	4	28.6	11	78.6	0	0.0	14	0	0.0	0	0.0	0	0.0
3	Amravati	30	3	10.0	16	53.3	0	0.0	30	0	0.0	0	0.0	0	0.0
4	Beed	19	2	10.5	11	57.9	1	5.3	18	0	0.0	0	0.0	0	0.0
5	Bhandara	18	0	0.0	3	16.7	0	0.0	18	1	5.6	0	0.0	0	0.0
6	Buldana	22	0	0.0	8	36.4	0	0.0	34	0	0.0	0	0.0	0	0.0
7	Chandrapur	32	1	3.1	12	37.5	10	31.3	30	0	0.0	0	0.0	0	0.0
8	Chatrapati Sambhaji Nagar	8	1	12.5	6	75.0	0	0.0	13	0	0.0	0	0.0	0	0.0
9	Dharashiv	7	0	0.0	4	57.1	0	0.0	7	0	0.0	0	0.0	0	0.0
10	Dhule	18	0	0.0	9	50.0	0	0.0	18	0	0.0	0	0.0	0	0.0
11	Gadchiroli	18	0	0.0	10	55.6	1	5.6	18	0	0.0	0	0.0	0	0.0
12	Gondia	9	0	0.0	3	33.3	0	0.0	9	1	11.1	0	0.0	0	0.0
13	Hingoli	10	0	0.0	6	60.0	0	0.0	10	0	0.0	0	0.0	0	0.0
14	Jalgaon	20	1	5.0	11	55.0	0	0.0	21	0	0.0	0	0.0	0	0.0
15	Jalna	16	1	6.3	9	56.3	0	0.0	16	0	0.0	0	0.0	0	0.0
16	Kolhapur	10	0	0.0	1	10.0	0	0.0	10	0	0.0	0	0.0	0	0.0
17	Latur	13	0	0.0	7	53.8	0	0.0	12	0	0.0	0	0.0	0	0.0
18	MUMBAI CITY	6	0	0.0	0	0.0	0	0.0	24	0	0.0	0	0.0	0	0.0
19	Nagpur	28	1	3.6	9	32.1	0	0.0	29	0	0.0	0	0.0	0	0.0
20	Nanded	24	1	4.2	14	58.3	1	4.2	24	0	0.0	0	0.0	0	0.0
21	Nandurbar	7	1	14.3	2	28.6	1	14.3	7	0	0.0	0	0.0	0	0.0
22	Nashik	37	1	2.7	20	54.1	0	0.0	37	0	0.0	0	0.0	0	0.0
23	Parbhani	20	1	5.0	11	55.0	0	0.0	20	0	0.0	0	0.0	0	0.0
24	Pune	14	0	0.0	1	7.1	0	0.0	18	0	0.0	0	0.0	0	0.0
25	Raigad	16	0	0.0	0	0.0	0	0.0	16	0	0.0	0	0.0	0	0.0
26	Ratnagiri	10	0	0.0	0	0.0	0	0.0		0	0.0	0	0.0	0	0.0
27	Sangli	19	1	5.3	4	21.1	0	0.0	19	0	0.0	0	0.0	0	0.0
28	Satara	16	2	12.5	5	31.3	0	0.0	16	0	0.0	0	0.0	0	0.0
29	Sindudurg	7	0	0.0	0	0.0	0	0.0		0	0.0	0	0.0	0	0.0
30	Solapur	21	2	9.5	11	52.4	1	4.8	18	0	0.0	0	0.0	0	0.0
31	Thane	15	1	6.7	0	0.0	0	0.0	15	0	0.0	0	0.0	0	0.0
32	Wardha	21	1	4.8	17	81.0	0	0.0	20	0	0.0	0	0.0	0	0.0
33	Washim	7	0	0.0	4	57.1	0	0.0	7	0	0.0	0	0.0	0	0.0
34	Yavatmal	19	0	0.0	10	52.6	0	0.0	19	0	0.0	0	0	0	0.0

It is quality
rather than quantity
that matters...