GROUNDWATER CHEMICAL QUALITY BULLETIN GOA, PRE- MONSOON 2024

ABSTRACT

A comprehensive analysis of groundwater across Goa was undertaken to evaluate contamination levels of specific basic parameters and trace metal water quality parameters like Electrical conductivity, Nitrate, Fluoride, Uranium, Iron, Arsenic and Manganese. Analysis shows the temporal variation of these parameters during the period of 2019 to 2024 in pre-monsoon seasons. During 2023, the trend stations were identified and sampling was carried out from these stations only in 2023 and 2024: 2 samples for basic parameters and 6 for trace metal analysis.

Shallow groundwater across Goa is predominantly fresh, with all samples exhibiting electrical conductivity values below the 750 µS/cm threshold. Analysis of key parameters and trace metals revealed that water quality generally adheres to drinking water standards. However, one sample exceeded the BIS limits w.r.t Nitrate and Manganese during Pre Monsoon-2024. A comparative analysis of 2019, 2022 and 2023 data indicated the presence of localized contamination. Specifically, nitrate and manganese levels exceeded permissible limits in four and six locations respectively during 2019, rendering the water unsuitable for consumption without treatment. Moreover the analysis shows the ground water in the phreatic aquifer is suitable for drinking purpose.

CGWB, SWR, Bengaluru

1.0 INTRODUCTION

Groundwater constitutes a critical resource indispensable for socioeconomic development, serving as a primary input for potable water supply, irrigation, and industrial operations. Regions characterized by limited surface water availability exhibit a heightened reliance on groundwater to fulfil a significant proportion of water demands. Excessive groundwater extraction across diverse sectors has resulted in declining water levels and compromised water quality. Groundwater quality is modulated by the geochemical attributes of the aquifer, including the petrochemical composition of the aquifer matrix. Redox processes facilitate mineral dissolution and precipitation within the aquifer, potentially leading to ion concentrations exceeding permissible standards. Anthropogenic activities such as intensive fertilization, urbanization, and industrial effluent discharge exacerbate groundwater contamination. The consumption of contaminated water is a primary vector for waterborne diseases affecting a substantial global population. Key inorganic contaminants impacting groundwater suitability for potable consumption encompass salinity, fluoride, nitrate, arsenic, iron, and uranium. From the previous water quality data in 2022 and 2019, occurrence of Nitrate and Manganese in excess had been recorded. Although, during May-2023 monitoring, fortunately the shallow ground water samples tested from the state of Goa were devoid of any such contaminants, but periodic monitoring of the water quality is of much importance to address any quality issues arising in future.

Every year CGWB, SWR, Bengaluru collects water samples for analysis of crucial general parameters and trace metals in the month of May. During May-2024 samples were collected from trend stations only, which were finalised based on the contaminated samples of May-2023 monitoring. Here, an attempt has been made, aiming to

1. Present current ground water scenario of the state.
2. To mark the hotspots of poor- ground water quality.
3. To assess the trend or variation of water quality on a temporal basis using the water quality data of pre- monsoon season of the years 2024, 2023, 2022 and 2019.

2.0 STUDY AREA

Goa is a western Indian state occupying a geographical area of 3,702 square kilometres. Bounded by the Arabian Sea to the west, Maharashtra to the north, and Karnataka to the east and south, the state spans latitudes 14°53' N to 15°40' N and longitudes 73°40' E to 74°20' E. For administrative governance, the state is divided into two districts, North Goa and South Goa. The North Goa district comprising six taluks has a total area of 1463.13 sq.km and South Goa comprising six taluks covers an area of 2238.87 sq.km. The major water bearing formations in the state of Goa are granite and granite gneiss, meta-volcanic and meta-sedimentary, laterite and alluvium. The hydrogeological set up of the state has been given in figure 1. The region's monsoon climate provides significant groundwater recharge, filling unconfined and confined aquifers. While groundwater quality is generally good, declining groundwater levels due to excessive pumping for tourism, agriculture, and domestic use pose a significant threat, necessitating sustainable groundwater management practices.

3.0 GROUND WATER QUALITY MONITORING

The Central Ground Water Board (CGWB) in Bengaluru has undertaken a comprehensive effort to assess groundwater quality within Goa. To achieve this, a regular sampling program had been implemented, collecting water samples from various aquifer locations across the state. This initiative involves analysing the chemical composition of the water to understand its suitability for different uses and to identify potential contamination issues. While sampling frequency was increased to twice yearly in 2023, historical data from previous year's pre-monsoon samples, are also being analysed to establish long-term trends in groundwater quality. During the Pre- monsoon season 2024, a total of 2 basic and 6 trace metal samples were collected from the trend stations out of the existing National Hydrograph Stations. Spatial distribution of sampling locations has been given in Figure 2 for basic and trace metal samples. The district wise numbers are furnished in Table 1 and 2 for basic and trace metal samples respectively.

Table 1: District wise distribution of water Quality Monitoring Stations

Sl. No.	District	No. of basic samples collected			
		2019	2023	2023	2024
1	North Goa	42	2	2	2
2	South Goa	27	8	8	0
	Total	**69**	**10**	**10**	**2**

Table 2: District wise distribution of Water Quality Monitoring Stations

Sl. No.	District	No. of trace metal samples collected		
		2019	2023	2024
1	North Goa	41	5	5
2	South Goa	23	1	1
	Total	**64**	**6**	**6**

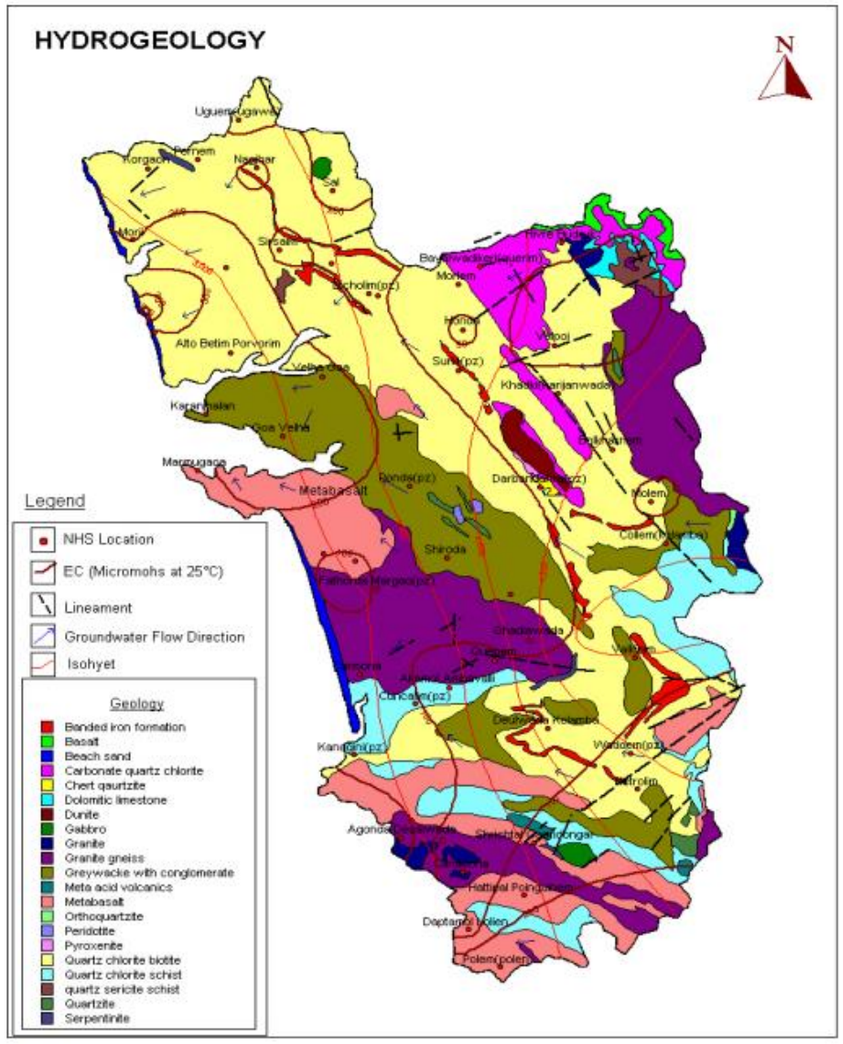

Figure 1: Hydrogeological map of Goa

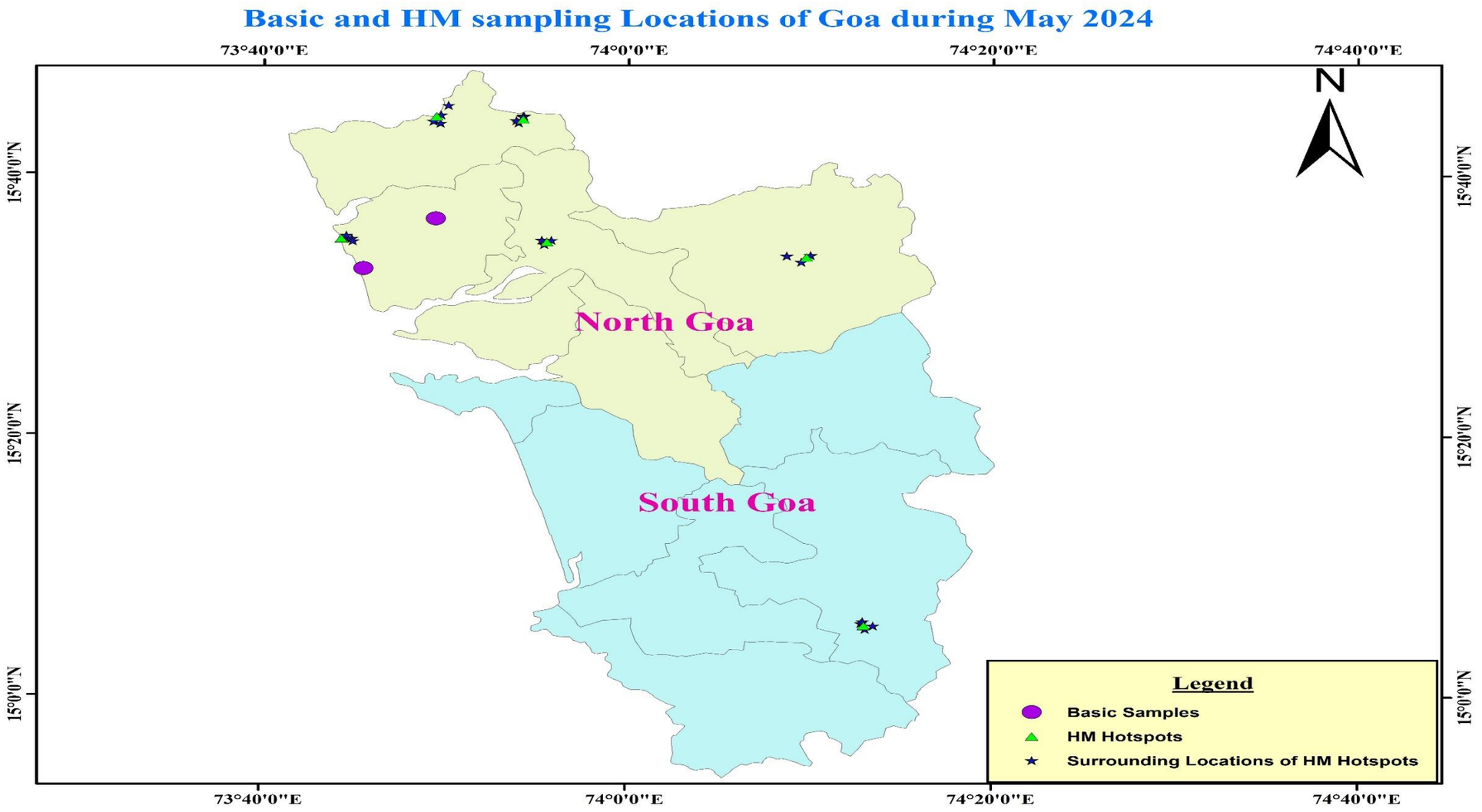

Figure 2: Spatial Distribution of Basic and Heavy Metal Sampling Locations in Goa during Pre Monsoon-2024

4.0 GROUND WATER QUALITY SCENARIO

The primary objective of groundwater quality monitoring is to assess its suitability for human consumption, given the established correlation between water quality and public health. In order to evaluate groundwater against prescribed standards, inorganic parameters including the trace metals are analysed in samples collected from phreatic aquifers, adhering to the guidelines outlined in IS: 10500:2012, Edition 3.2 (2012-15) by the Bureau of Indian Standards. Analysis reveals, key water quality parameters like salinity (EC), fluoride, nitrate, iron, manganese, arsenic and uranium including all the parameters tested, lie well within the permissible limits of drinking water standards.

4.1 QUALITY ASSESSMENT OF GROUNDWATER IN UNCONFINED AQUIFERS

Given the extensive reliance on unconfined aquifers for water supply and irrigation, their chemical quality is of critical importance. Key parameters influencing groundwater quality within these aquifers include TDS, fluoride, nitrate, iron, manganese, and uranium. The subsequent sections will analyse the presence and temporal variations of these constituents in groundwater samples collected during the years 2019, 2022, 2023 and 2024 National Hydrological Survey (NHS). A compressive overview of range of occurrence the water quality parameters have been given in table 3 and 4 for basic parameters and trace metals respectively.

Table 3: District wise range and distribution of key basic parameters in shallow GW of Goa

Sl. No.	Parameters	Desirable limit	Permissible limit		North Goa (n= 2)	South Goa (n=0)
1	EC in µS/cm	750	3000	Min.	290	NS
				Max.	700	NS
				Mean	495	NS
2	NO_3 in mg/L	45	No Relaxation	Min.	34	NS
				Max,	96	NS
				Mean	65	NS
3	F in mg/L	1	1.5	Min.	0.05	NS
				Max.	0.07	NS
				Mean	0.06	NS

*NS-No samples

Table 4: District wise range and distribution of key trace metals in shallow GW of Goa

Sl. No.	Parameter	Desirable limit	Permissible limit		North Goa (n= 5)	South Goa (n=1)
1	Uranium in ppb	30	No Relaxation	Min.	0.000	0.000
				Max.	0.000	0.000
				Mean	0.000	0.000
2	Iron in mg/L	1	No Relaxation	Min.	0.000	0.005
				Max,	0.407	0.005
				Mean	0.155	0.005
3	Manganese in mg/L	0.3	No Relaxation	Min.	0.001	0.018
				Max.	0.565	0.018
				Mean	0.144	0.018
4	Arsenic in ppb	10	50	Min.	0.017	0.043
				Max.	0.170	0.043
				Mean	0.150	0.043

4.1.1 ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC), a surrogate for Total Dissolved Solids (TDS) and salinity, quantifies the dissolved ion content of water. It reflects the combined ionic mobility of cations and anions, providing an indirect measure of water salinity. A general classification of water based on EC is as follows:

- Freshwater: EC < 1500 µS/cm
- Brackish water: EC 1500 - 15000 µS/cm
- Saline water: EC > 15000 µS/cm

All the water samples tested were having electrical conductivity less than 750 µS/cm which is equivalence to the desirable limit of TDS i.e. 500 mg/L. The permissible limit TDS in drinking water is 2000 mg/L which corresponds to an EC value of 3000 µS/cm. Hence the phreatic aquifer of the state is mostly fresh in nature. The periodic variation of EC during 2019, 2022, 2023 and 2024 pre-monsoon season has been given in table 5.

Table 5: The periodic variation of EC in shallow aquifer of Goa

Parameter	Class	Percentage of samples			
EC in µS/cm		**2019**	**2022**	**2023**	**2024**
		n= 69	n=72	n= 10	n= 2
	< 750	98.55	100	100	100
	750 - 3000	1.45	0.00	0.00	0.00
	> 3000	0.00	0.00	0.00	0.00

4.1.2 NITRATE

Nitrate, a naturally occurring ion, is primarily introduced into groundwater through human activities such as agriculture and wastewater disposal. Differentiating between natural and human-induced nitrate sources can be challenging due to ongoing biogeochemical processes within the aquifer. The Bureau of Indian Standards (BIS) has set a maximum safe level of nitrate in drinking water at 45 mg/L. While nitrate itself is relatively harmless, high concentrations can pose serious health risks like methemoglobinemia, especially for infants. Adults are generally more tolerant.

Out of the 2 samples tested from North Goa, one was above the limit (Calangute -96 mg/l) and another was having nitrate concentration less than 45 mg/L during the pre- monsoon season of 2024. Hence the phreatic aquifer is mostly fresh in nature. The periodic variation of nitrate during 2019, 2022, 2023 and 2024 pre- monsoon has been given in table 6. It is worth mentioning that during the 2019 monitoring, 4 locations (3- North Goa and 1- South Goa) exceeded the permissible limit of nitrate.

Table 6: The periodic variation of Nitrate in shallow aquifer of Goa

Parameter	Class	Percentage of samples			
Nitrate in mg/L		**2019**	**2022**	**2023**	**2024**
		n= 69	n=72	n= 10	n= 2
	< 45	94.20	100	100	50
	> 45	5.80	0.00	0.00	50

4.1.3 FLUORIDE

Fluorine, a highly reactive element, primarily exists as fluoride ions within minerals. These ions are released into groundwater through the natural processes of weathering and dissolution. The concentration of fluoride in groundwater is influenced by geological factors such as rock type, climatic conditions, and the duration of water-rock interaction.

Excessive fluoride consumption can lead to dental and skeletal fluorosis. To protect public health, the Bureau of Indian Standards (BIS) has established permissible and desirable limits for fluoride in drinking water at 1.5 mg/L and 1 mg/L, respectively. While low fluoride levels can benefit dental health, exceeding these limits poses significant health risks. Implementing effective defluoridation technologies is essential in areas with high fluoride concentrations.

Analysis results show that during the pre-monsoon 2024 monitoring, all the samples were with the desirable limit of 1 mg/L. Table 7 shows the periodic variation of fluoride during 2019, 2022, 2023 and 2024 pre- monsoon season.

Table 7: The periodic variation of Fluoride in shallow aquifer of Goa

Parameter	Class	Percentage of samples			
Fluoride in mg/L		**2019**	**2022**	**2023**	**2024**
		n= 69	n=72	n= 10	n= 2
	< 1.5	100	100	100	100
	> 1.5	0.00	0.00	0.00	0.00

4.1.4 IRON

Iron is a prevalent element found in both soil and groundwater. Its solubility varies based on its oxidation state, with ferrous iron (Fe^{2+}) being more soluble than ferric iron (Fe^{3+}). Ferrous iron imparts a clear appearance to water, while ferric iron, formed through oxidation, causes turbidity and a reddish-brown discoloration. Iron enters groundwater primarily through the weathering of iron-bearing minerals present in igneous, sedimentary, and metamorphic rocks. Minerals like hematite, magnetite, and sulphide ores contribute significantly to iron concentrations. The Bureau of Indian Standards (BIS) has set a maximum permissible limit of 1.0 mg/L for iron in drinking water. Exceeding this limit can negatively impact water quality, affecting taste, odour, and overall appearance.

All the samples were found to have iron content within the permissible limit of 1 mg/L. The periodic variation of iron during 2019, 2022, 2023 and 2024 pre- monsoon has been given in table 8.

Table 8: The periodic variation of iron in shallow aquifer of Goa

Parameter	Class	Percentage of samples		
Iron in mg/L		**2019**	**2023**	**2024**
		n= 64	**n=6**	**n=6**
	< 1.0	100	100	100
	> 1.0	0.00	0.00	0.00

4.1.5 URANIUM

Uranium, a naturally occurring radioactive element, is present in both groundwater and surface water. Human activities, such as those in the nuclear industry, coal combustion, and phosphate fertilizer production, have contributed to increased uranium levels in water bodies. People are primarily exposed to uranium through consuming contaminated water or food, inhaling contaminated air, or occupational exposure. The Bureau of Indian Standards (BIS) has set a maximum permissible limit of 30 parts per billion (ppb) for uranium in drinking water. Exceeding this limit poses significant health risks, including the potential for chronic kidney damage. None of the location was found to exceed the permissible limit of Uranium during pre- monsoon 2024 in shallow aquifer of Goa. Table 9 shows the periodic variation of uranium during 2019, 2023 and 2024 pre- monsoon season.

Table 9: Periodic variation of Uranium in shallow aquifer of Goa

Parameter	Class	Percentage of samples		
Uranium in ppb		2019	2023	2024
		n= 64	n=6	n=6
	< 30	100	100	100
	> 30	0.00	0.00	0.00

4.1.6 MANGANESE

Manganese is an essential trace element naturally found in both groundwater and surface water. However, human activities such as mining, industrial processes, and agriculture can increase manganese levels in these water sources. People are primarily exposed to manganese by consuming contaminated water or food. Excessive manganese intake can lead to Manganism, a neurological condition with symptoms similar to Parkinson's disease. To protect public health, the Bureau of Indian Standards (BIS) has set a maximum permissible limit of 0.3 mg/L for manganese in drinking water.

All the samples were having manganese concentration of less than 0.3 mg/L during 2024 except the sample from Nagargaon (0.565 mg/l). However, during 2019, 5 water samples were exceeding the permissible limit of Mn in the state. The periodic variation of Manganese during 2019, 2023 and 2024 pre- monsoon has been given in Table 10.

Table 10: Periodic variation of Manganese in shallow aquifer of Goa

Parameter	Class	Percentage of samples		
Manganese in mg/L		2019	2023	2024
		n= 64	n=6	n=6
	< 0.3	90.62	100	83.3
	< 0.3	9.38	0.00	16.7

4.1.7 ARSENIC

Arsenic, a naturally occurring toxic element, is widely distributed in the Earth's crust. It exists in both organic and inorganic forms, with the latter posing a more significant health risk. While natural processes contribute to arsenic release, human activities such as mining, burning fossil fuels, and the use of arsenic-based chemicals have exacerbated the problem. Arsenic contamination of drinking water is a critical health concern. Long-term exposure can lead to a variety of health issues, including cancer, skin lesions, cardiovascular problems, neurological damage, respiratory ailments, and reproductive issues. The severity of these effects depends on the level of exposure and individual susceptibility. To safeguard public health, the Bureau of Indian Standards (BIS) has established a desirable limit of 10 parts per billion (ppb) and a permissible limit of 50 ppb for arsenic in drinking water. The shallow aquifer is free from the arsenic contamination during pre- monsoon season of 2024. The periodic variation of Arsenic during 2019, 2023 and 2024 pre- monsoon has been given in Table 11.

Table 11: Periodic variation of Arsenic in shallow aquifer of Goa

Parameter	Class	Percentage of samples		
Arsenic in ppb		2019	2023	2024
		n= 64	n=6	n=6
	< 10	100	100	100
	< 10	0.00	0.00	0.00

5. SUMMARY

Over all the shallow ground water of the state is fresh in nature with all the samples having EC less than 750 µS/cm. All the basic parameters and trace metals tested remained within the permissible limit of drinking water standard. The comparison with 2019, 2022 and 2023 water quality shows occurrence of nitrate contamination in 4 locations and high concentrations of manganese in 6 locations during 2019 and 1 sample during 2024 rendering the water unsuitable for drinking without treatment. However, during 2024 pre- monsoon monitoring all parameters were within the limits except Nitrate in one sample from Calangute, North Goa. Table 12 shows the contaminant wise summary of the shallow ground water quality of the state.

Table 12: Summary of Groundwater Quality in Goa: Samples Collected and Contamination Percentage

	Number of samples contaminated (% of samples contaminated)								
Goa State	Total no. of Basic samples	EC	NO3	F	Total no. of HM samples	Fe	Mn	U	As
Pre Monsoon-2024	2	0 (0%)	1 (50%)	0 (0%)	6	0 (0 %)	1 (16.7 %)	0 (0 %)	0 (0 %)