Technical Report: Series' D ' For Official Use Only

GROUND WATER QUALITY IN SHALLOW AQUIFER OF TRIPURA

GOVERNMENT OFINDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, GANGA REJUVENATION & RIVER DEVELOPMENT

CENTRAL GROUND WATER BOARD, NORTH EASTERN REGION, GUWAHATI

2023

FOREWORD

Groundwater is a vital resource for Tripura state, serving as the principal source of public, industrial, rural water supplies, and irrigation. However, concerns are rising about the deterioration of groundwater quality due to both geogenic and anthropogenic activities. It is crucial to have prior information on the quality of groundwater resources available in Tripura for judicious management of this resource.

The Central Ground Water Board, North Eastern Region, constantly monitors the quality, quantity, availability, and non-availability of groundwater in the state through a network of various Groundwater Monitoring Stations (GWMS), mainly representing dug wells. Samples are collected during the month of March/April every year, following standard practice of collection and analysis.

This report summarizes various aspects of groundwater quality in the shallow aquifers of Tripura, with special reference to pH, EC, TDS, turbidity, carbonate and bicarbonate alkalinity, calcium, magnesium, and total hardness, chloride, sodium, potassium, sulphate, nitrate, fluoride, arsenic, iron and uranium.

The dedicated efforts of the officers of the Board for compiling the trend data and preparing the report deserve appreciation. This report will help in better understanding the quality aspects of groundwater resources in Tripura and will be a valuable guide for planners, policymakers, administrators, and all other stakeholders to optimize the development and management of this precious resource in the state.

(Biplab Ray)
Regional Director (I/c)
Central Ground Water Board
North Eastern Region

GROUND WATER QUALITY IN SHALLOW AQUIFER OF TRIPURA

PRINCIPALCONTRIBUTERS

Shri. Rinkumoni Barman, STA (Chemical)
Shri. Gopal Sahoo, Scientist-B (Chemical)

Dr. Snigdha Dutta, STA (Chemical)

Dr. Keisham Radhapyari, Scientist 'D' (Chemical)

DATA CONTRIBUTION

Officer-in-Charges and Officers of SUO, Agartala

Contents

1

GENERAL INTRODUCTION

1.1 INTRODUCTION

Ground water, a copious and readily obtainable freshwater resource, is stored in subterranean reservoirs known as aquifers and is replenished through precipitation and surface water. In India, groundwater is a crucial source of water for drinking, agriculture, and industry. India's usage of groundwater surpasses that of any other country globally, with over 60% of its irrigated area being irrigated by it. Nevertheless, owing to excessive use and inadequate administration, the groundwater predicament in India is precarious.

The exigency to promptly address the predicament of groundwater caliber in India is imperative. The hydrogeological milieu of the nation is exceedingly heterogeneous, and the caliber of subterranean water varies considerably across diverse regions due to a plethora of natural and anthropogenic elements. The co-occurrence of multifarious organic and inorganic constituents, comprising of heavy metals, pesticides, nitrates, and sulfates, has culminated in the deterioration of the caliber of subterranean water in numerous regions of the country. The levels of these contaminants often exceed the permissible limits set by the World Health Organization (WHO), thereby posing a significant threat to human health. Moreover, the hydrochemical characteristics of groundwater in India are highly complex and often exhibit significant spatial and temporal variations. The composition of groundwater is influenced by a wide range of geological, hydrological, and anthropogenic factors, which makes the assessment of groundwater quality a highly challenging task. The growing demand for groundwater in various sectors such as agriculture, industry, and domestic use has led to an increased exploitation of the resource, leading to further deterioration of groundwater quality. In the state of Tripura, groundwater is a primary source of water, particularly in rural areas where the availability of surface water is limited.

However, the quality of groundwater in Tripura is a matter of concern due to the potential presence of various pollutants, including natural and anthropogenic sources. The sources of wastes and associated types of contaminants most likely to affect ground-water quality in Tripura are listed in Table 1.

Table 1 Natural and human factors affecting quality of ground water

Natural factors		Human factors	
Source	**Types of contaminant**	**Sources**	**Types of contaminant**
Precipitation	Dissolved gases, dust and emission products	Agricultural	Fertilizers, pesticides and herbicides
Infiltration	Organic material, mineral, biochemical products etc.	Urban activities	Solids, organic matter, nitrates, metallic trace elements, detergents, chloride etc.
Aquifer rocks	Mineral contents	Mining	Metallic trace elements and phosphates
		Industrial facilities	Biochemical Oxygen Demand, sodium, chloride, suspended solids

This groundwater quality report for Tripura aims to provide a comprehensive overview of the current status of groundwater quality in the state. The report will focus on analyzing key physico-chemical parameters such as pH, electrical conductivity, total dissolved solids, and major ions such as chloride, fluoride, nitrate, and sulfate. These parameters are essential indicators of groundwater quality and are used to evaluate the suitability of groundwater for various uses. The report will also highlight the distribution of different pollutants and their sources, including both natural sources such as geogenic processes and anthropogenic sources such as agricultural practices, industrial activities, and domestic waste disposal. The identification of these sources is crucial for the implementation of effective management strategies to prevent further contamination and improve groundwater quality. Furthermore, the report will also discuss the potential health impacts of consuming contaminated groundwater. Contaminants such as fluoride, nitrate, and arsenic can have severe health consequences, especially for vulnerable populations such as children and pregnant women.

The findings of this report will be essential for policymakers, researchers, and local communities in designing effective groundwater management strategies and promoting sustainable groundwater use. The report will also serve as a baseline for future studies and monitoring programs to assess the effectiveness of the implemented measures in improving groundwater quality in Tripura. Overall, this report will contribute to the sustainable management of groundwater resources in Tripura, ensuring its availability and accessibility for future generations.

1.2 STUDY AREA

Tripura, a lush green picturesque state, is situated in the northeastern part of India, which covers a geographical area of 10,491.69 sq. km. It is situated between North Latitudes 22° 56′32″and 24° 31′ 51″ and East Longitudes 91° 09′15″ and 92°19′51″and falls in survey of India Degree Sheet No.79 M and parts of 78 P, 84 A and 83 D. The Tropic of Cancer passes through the southern part of the state. It is a land-locked state and bounded by Bangladesh on three sides i.e. the west, south-southeast and north. Its north-eastern and eastern boundary is demarcated by the border with Assam and Mizoram respectively. The state shares 856 Km (84 %) of international border with Bangladesh, while it shares 109 km state border with Mizoram and 53 km state border with Assam.

The state is connected to other parts of the country by road, rail and air. The road distance from Agartala to Kolkata was less than 350 km before the partition of the country and now it is 1700 km via Shillong in Meghalaya, Guwahati in Assam and Sliliguri in West Bengal. National Highway 8 (earlier 44), known as Agartala - Assam road, is the only road link with the rest of India through the state of Assam and Meghalaya. Agartala, the State Capital is connected with district towns, sub-divisional headquarters and block headquarters by State Highways and other prominent metalled roads. Sabroom - Agartala – Silchar – Lumding -Guwahati railway line passes through the state, which connects Agartala with Guwahati and the rest of the country. However, Agartala is very well connected with other cities of the country by air through a number of daily flights.

1.3 RAINFALL

Rainfall occurs under the spell of southwest monsoon and the maximum rainfall is commonly recorded in the month of June and July. The average annual rainfall for the last 42 years (1977–2018) of the state is 2262 mm. The average nos. of rainy days for last 5 years is 95. Both the maximum rainfall of 4009.5mm (1978) and the minimum rainfall of 1205.6 mm

(1994) had been recorded at Agartala. The co-efficient of variation of rainfall ranges from 7–30%, which suggests a low variability of annual rainfall. Broad patterns and distribution of rainfall is shown in Figure 2.1, which reveals that rainfall increases from SW to NE in the state. The highest rainfall value of 2500mm has a N-S disposition through North Tripura district. The lowest rainfall lies around Udaipur-Amarpur area of Gomati district.

Table 2 Station wise Average Rainfall in the State of Tripura

Stations	Monthly rainfall (in mm)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Kailasahar	3.2	22.5	25.5	197.8	636.3	418.3	173.2	143.1	197.7	97.3	3.4	35.7	1954.0
Dharmanagar	0.0	18.6	60.2	208	624.3	490.8	268.8	241.6	248.7	106.3	36.0	20.3	2323.6
Kanchanpur	0.0	4.2	75.1	142.6	548.9	719.6	266.5	274.7	150.2	160.1	9.6	24.8	2376.3
Kamalpur	22.0	14.2	43.6	300.4	894.0	544.6	174.2	578.0	265.0	130.6	8.2	46.4	3021.2
Chawmanu	0.0	2.5	37.5	163.5	472.0	693.2	162.4	262.4	159.5	137.2	29.0	15.5	2134.7
Gandacherra	0.0	1.5	18.8	235.5	756.8	676.8	385.2	157.1	67.1	122.1	5.2	9.6	2435.7
Khowai	12.4	11.4	79.2	158.4	834.0	511.6	312.0	257.6	98.2	55.8	2.2	33.6	2366.4
Teliamura	19.4	9.0	71.0	122.0	676.8	645.6	202.4	186.8	50.0	65.6	25.2	11.6	2085.4
Sonamura	0.0	0.0	9.0	205.0	381.2	386.6	184.6	129.4	173.4	38.2	29.4	2.2	1539.0
Bishalgarh	0.0	19.2	27.4	240.7	521.2	393.6	169.6	45.2	41.3	17.2	0.0	6.2	1481.6
Sadar	0.0	9.1	28.4	172.0	558.0	444.9	215.0	160.7	83.2	46.9	21.0	23.5	1762.7
Jirania	0.0	8.2	28.2	149.2	661.6	521.5	202.0	228.7	108.5	53.7	19.0	25.0	2005.6
Matabari	0.0	0.5	18.6	271.7	561.5	326.6	249.0	231.8	233.3	47.9	19.2	2.0	1962.1
Amarpur	0.0	0.0	36.7	208.9	647.8	433.7	298.9	232.1	51.7	28.5	32.4	6.2	1976.9
Belonia	0.0	2.4	5.6	248.8	388.4	484.8	381.0	346.4	114.2	76.2	0.2	6.4	2054.4
Sabroom	0.0	0.0	11.0	0.0	480.4	916.2	679.2	340.5	109.6	165.8	10.8	0.0	2713.5
Bogafa	0.0	4.2	12.2	215.0	504.4	595.0	344.5	239.6	75.2	68.8	1.6	5.0	2065.5
Average	**3.4**	**7.5**	**34.6**	**190.6**	**596.9**	**541.4**	**274.6**	**238.6**	**131.0**	**83.4**	**14.8**	**16.1**	**2132.9**

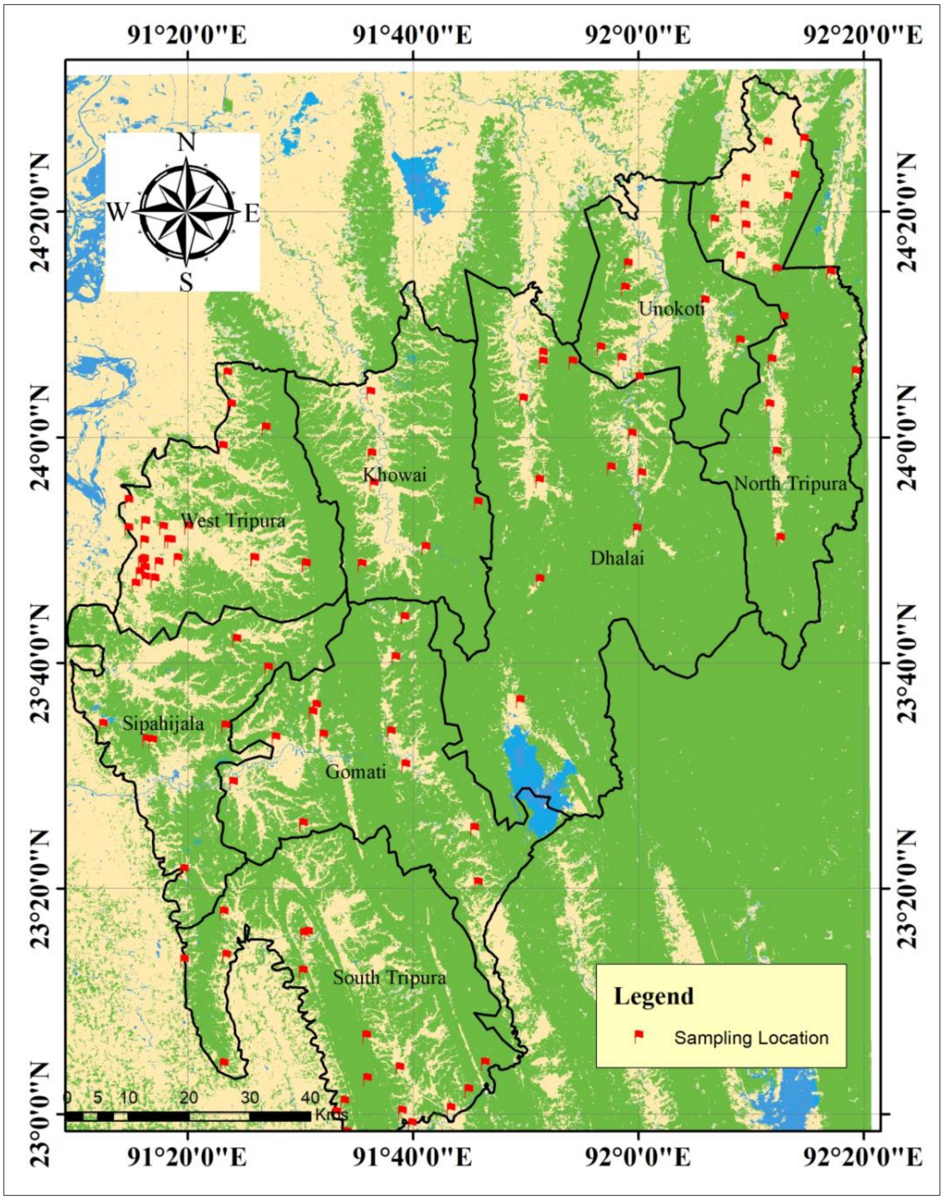

Figure 1 Map of Tripura with sampling locations

1.4 DRAINAGE

The state of Tripura is criss-crossed by many major rivers that originate in the hill ranges and flow either northwards or westwards through narrow valleys. The valleys are terraced, with the uppermost terrace characterized by steep erosional scarps along the river banks. The rivers are fed by numerous tributaries arising from the catchment areas. The flow of surface water ranges from 1.05 lakh m^3/km^2 in the Gomati basin to 0.2 lakh m^3/km^2 in the

Buri Gang basin, and the total annual river flow generated within the state are approximately estimated as 793 million cubic meters (MCM). The Gomati River carries the maximum volume of water, followed by Manu and Khowai rivers. The state is losing a large volume of water generated by the river systems to neighboring Bangladesh. At present, the Gomati is being harnessed for generation of hydel power, and three medium irrigation projects, namely Gomati in South Tripura, Khowai in West Tripura, and Manu in North Tripura, are under operation for irrigation of cultivated land on a small scale. The major rivers in the state are Khowai, Manu, Deo, Juri, Dhalai, Longai, Gomati, Haora, Muhuri, and Buri Gang. The catchment of Longai is shared by Tripura, Mizoram, and Assam states, whereas that of Fenny is shared by Tripura and Bangladesh. The combined flow length of the ten major rivers within the state is about 896 km, and the whole drainage system ultimately forms a part of the Meghna basin.

1.5 GEOLOGY

The geological formations in Tripura can be divided into four groups: Surma Group, Tipam Group, Dupitila Group, and Recent Group. The Surma Group is made up of lower, more arenaceous, Upper Bhuban unit and upper, mainly argillaceous Bokabil Unit, and consists of calcareous sandstones, calcareous shales, and limestone with fossils. The Tipam Group is transitional to the underlying Bokabil Formation and composed of light yellow to light buff and brownish yellow sandstones with occasional thin bands of siltstone, boulders of calcareous concretion, and coal streaks. The Dupitila Group consists of earthy brown to buff sandy clay, mottled clay, clayey sandstone, and coarse to gritty ferruginous sandstone, and unconformably overlies the Tipam Formation. The Recent Group is comprised of Recent Alluvium formation belonging to Quaternary age and includes Pleistocene and Holocene sediments, which form a four-tier system of terraces.

1.6 HYDROGEOLOGY

The semi-consolidated Tertiary formations form the main hydrogeological unit of the State. These formations consist of friable sand stones, clayey sand stone, sandy shales and shales. The semi-consolidated formations can be further subdivided into three principal zones. The first one is confined to central part of Agartala-Udaipur, Khowai-Amarpur, Ambasa, Kailasker, Kumarghat and Dharam Nagar syncline valley; where the yield prospects are good. Fine to medium grained sand stones form the principal aquifer. West of Tripura, artesian belt has been delineated and the yield of such wells are found to be in the order of 1 to 3 m^3/hr. High autoflow discharge of 54 m^3/hr is observed in Khowai valley. The second one is confined to unconfined aquifers of moderate regional extent with yield prospect of 50-100 m^3/hr. This zone extends bordering the hill ranges i.e. the marginal part of Agartala-Udaipur, Khowai-Amarpur, Kamapur-Ambasa, Kailaskar-Kumarbagh and Dharam Nagar valleys. Artesian conditions are rare in these zones. The third zone, comprising moderately thick discontinuous aquifers with yield prospects less than 50m^3/hr, is located in the intermontane and smaller valleys. These areas are mostly occupied by argillaceous formations belonging to Surma series.

1.7 HYDROCHEMISTRY

Hydrochemistry is an interdisciplinary science that deals with the chemistry of water in the natural environment. It is essential to study the entire system like atmospheric water (rainwater), surface water and ground water simultaneously in evaluating their hydrochemistry and pollution effect.

The atmosphere is composed of water vapour, dust particles and various gaseous components such as N_2, O_2, CO_2, CH_4, CO, SO_x, NO_x etc. Pollutants in the atmosphere can be transported long distances by the wind. These pollutants are mostly washed down by precipitation and partly as dry fall out. Composition of rainwater is determined by the source of water vapour and by the ion, which are taken up during transport through the atmosphere. In general, chemical composition of rainwater shows that rainwater is only slightly mineralized with specific electrical conductance (EC) generally below 50 µS/cm, chloride below 5 mg/l and HCO_3 below 10 mg/l. Among the cations, concentration of Ca, Mg, Na & K vary considerably but the total cations content is generally below 15 mg/l except in samples contaminated with dust (Ground Water Quality-CGWB (2010). The concentration of sulphates and nitrates in rainwater may be high in areas near industrial hubs.

Surface water is found extremely variable in its chemical composition due to variations in relative contributions of ground water and surface water sources. The mineral content in river water usually bears an inverse relationship to discharge. The mineral content of river water tends to increase from source to mouth, although the increase may not be continuous or uniform. Other factors like discharge of city wastewater, industrial waste and mixing of waters can also affect the nature and concentration of minerals in surface water. Among anions, bicarbonates are the most important and constitute over 50% of the total anions in terms of milli equivalent per liter (meq/l). In case of cations, alkaline earths or normally calcium predominates.

The downward percolating water is not inactive, and it is enriched in CO_2. It can also act as a strong weathering agent apart from general solution effect. Consequently, the chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. It may also be pointed out that the water front does not move in a uniform manner as the soil strata are generally quite heterogeneous. The movement of percolating water through larger pores is much more rapid than through the finer pores. The overall effect of all these factors is that the composition of ground water varies from time to time and from place to place. Before reaching the saturated zone, percolating water is charged with oxygen and carbon dioxide and is most aggressive in the initial stages. This water gradually loses its aggressiveness, as free CO_2 associated with the percolating water gets gradually exhausted through interaction of water with minerals.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO^-_3$$

$$H^+ + \text{Feldspar} + H_2O \rightarrow \text{Clay} + H_4SiO_4 + \text{Cation}$$

The oxygen present in this water is used for the oxidation of organic matter that subsequently generates CO_2 to form H_2CO_3. This process goes on until oxygen is fully consumed.

$$CH_2O + O_2 = CO_2 + H_2O$$

(Organic matter)

Apart from these reactions, there are several other reactions including microbiological mediated reactions, which tend to alter the chemical composition of the percolating water.

1.8 GROUND WATER MONITORING STATIONS/WELLS

Monitoring of ground water quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Ground Water is commonly tapped from phreatic aquifers through dug wells in a major part of the region and through springs and hand pumps in hilly areas. The main objective of ground water quality monitoring programme is to get information on the distribution of water quality on a regional scale as well as create a background data bank of different chemical constituents in ground water.

Central Ground Water Board, North Eastern Region, has set up a number of Ground Water Monitoring Wells (GWMW) in different hydrogeological conditions (Fig 1) in order to know ground water condition and its variation, in both time and space. Monitoring of water levels and collections of water samples are being carried out periodically to observe any change in water level and its quality consequent to changes in inputs and outputs.

1.9 METHODOLOGY

To establish the ground water chemistry of the state, samples from different corners of the states of North Eastern region have been collected during the month of March/April (pre-monsoon) which is generally a dry period, leading to maximum concentration of elements in the water samples. Composite sampling has been adopted to collect water samples to make it a representative sample. The water samples so collected were chemically analyzed. While sampling for groundwater, samples were collected in Polyethylene bottles. Preservative (1:1 HCl solution, pH <2, approx. 2 ml /L sample) were added to each water samples collected for iron analysis and (1:1 HNO_3 solution, pH <2, approx. 2 ml /L sample) were added to each water samples collected for Arsenic analysis at the time of sampling and the containers were sealed. All probable safety measures were taken at every stage, starting from sample collection, storage, transportation and final analysis of the samples to avoid or minimize contamination.

Analysis of samples for other physico-chemical and elemental constituents was carried out as per the standard practice stipulated by APHA, 2012 guidelines (APHA, 2012). The parameters which are concerned other than arsenic is pH, conductivity, turbidity, alkalinity, total dissolved solids, chloride, total hardness, calcium, magnesium, sulphate, nitrate, sodium, potassium, fluoride and iron. The samples were analyzed in Regional Chemical Laboratory, CGWB, NER.

2

WATER QUALITY CRITERIA

The available quality of groundwater is the resultant of all the processes and reactions, which taken place since the condensation of water in the atmosphere to the time it is retrieved in the form of groundwater from its source. The water has excellent capability to accumulate substances in soluble form as it moves over and into the land resource, from the biological processes and from human activities. Urbanization, agricultural development and discharges of municipal and industrial residues significantly alter characteristics of groundwater resource. The prevailing climatic conditions, topography, geological formations and use and abuse of this vital resource have significant effect on the characteristics of the water, because of which its quality varies with locations.

The definition of criteria and standards for water quality vary with the type of use. The characteristic of water required for human consumption, livestock, irrigation, industries etc., have different water quality requirements. The term water quality criteria may be defined as the "Scientific data evaluated to derive recommendations for characteristics of water for specific use'. The term standard applies to any definite rule, principle or measure established by any statutory Authority. The distinction between criteria and standards is important, as the two are neither interchangeable nor they become synonyms for the objective or goal. Realistic standards are dependent on criteria, designated uses and implementation as well as identification and monitoring procedure. The changes in all these factors may provide a basis for alteration in standards. In formulation of water quality criteria, the selection of water quality parameters depends on its use. Sayers, et.al.

(1976 as quoted in CGWB & CPCB 2000) identified the key water quality parameters according to its various uses (Table 2.0).

Table 3: Water quality criteria parameters for various uses (Sayers et.al., 1976).

Public Water supply	Industrial Water supply	Agricultural water supply	Aquaticlife& wild life water supply	Recreation and Aesthetics
Coliform bacteria, Turbidity, colour, Taste, Odour, TDS, CI, F, SO4, NO3, CN, Trace Metals, Trace Organics Radioactive substances	Processing pH, Turbidity, Colour, Alkalinity, Acidity, TDS, Suspended solids, Trace metals, Trace Organics Cooling PH, Temp, Silica, AI, Fe, Mg, Total hardness, Alkalinity /Acidity Suspended solids, Salinity	Farmstead Same as for public supply Live-stock Same as for public supply Irrigation TDS, EC, Na, Ca, Mg, K, B, Cl and Trace metals	Temp, DO, pH,Alkalinity, Acidity, TDS Salinity, pH, DCOs, Turbidity, Colour, Settleable materials, Toxic substances, Nutrients, Floating materials	Recreations Tem, Turbidity, Colour, Odour, Floating Materials, Settable Materials Nutrients, Coliforms Aesthetics Same as for Recreation and Substances adversely affecting wild life

2.1 Water Quality Criteria for Drinking Purpose

With the objective of safe guarding water from degradation and to establish a basis for improvement in water quality, standards / guide lines / regulations have been laid down by various national and international organizations such as; Bureau of Indian Standards (BIS), World Health Organization (WHO), European Economic Community (EEC), Environmental Protection Agency (EPA), United States, and Inland Waters Directorate, Canada. The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institutions (ISI) has laid down the standard specification for drinking water during 1983, which have been revised and updated from time to time. In order to enable the users, to exercise their discretion towards water quality criteria, the maximum permissible limit has been prescribed especially where no alternative sources are available. The national water quality standards describe essential and desirable characteristics required to be evaluated to assess suitability of water for drinking purposes. The important water quality characteristics as laid down in BIS standard (IS 10500: 2012) are summarized in **Table- 4**

Table 4: Drinking Water Characteristics (IS 10500: 2012).

S. No.	Parameters	Desirable Limits (mg/L)	Permissible limits (mg/L)
Essential Characteristics			
1	Colour Hazen Unit	5	15
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity (NTU*)	1	5
5	pH	6.5-8.5	No relaxation
6	Total Hardness, $CaCO_3$	200	600
7	Iron (Fe)	1.0	No relaxation
8	Chloride (Cl)	250	1000
9	Residual Free Chlorine	0.2	1
10	Fluoride(F)	1.0	1.5
Desirable Characteristics			
11	Dissolved Solids	500	2000
12	Calcium (Ca)	75	200
13	Magnesium (Mg)	30	100
14	Copper (Cu)	0.05	1.5
15	Manganese (Mn)	0.1	0.3
16	Sulphate (SO_4)	200	400
17	Nitrate (NO_3)	45	No relaxation
18	Phenolic Compounds	0.001	0.002
19	Mercury (Hg)	0.001	No relaxation
20	Cadmium (Cd)	0.003	No relaxation
21	Selenium (Se)	0.01	No relaxation
22	Arsenic (As)	0.01	No relaxation

23	Cyanide (CN)	0.05	No relaxation
24	Lead(Pb)	0.01	No relaxation
25	Zinc (Zn)	5.0	15
26	Hexavalent Chromium	0.05	No relaxation
27	Alkalinity	200	600
28	Aluminum (Al)	0.03	0.2
29	Boron(B)	0.5	2.4
30	Pesticides	Absent	0.001
31	Uranium	0.03	No relaxation

***NTU-** Nephelometric Turbidity Unit.

N.B. The fluoride limits vary with average annual temperature of the areas. Similarly, the limits for magnesium are based on sulphate contents of water. When sulphate content is 250 mg/L or above, the magnesium should be between 30 and 50 mg/L but if sulphate is lower, higher content of magnesium is permissible.

2.2 Water Quality Criteria for Irrigation Purpose

Water quality plays a significant role in irrigated agriculture. Many problems originate due to inefficient management of water for agriculture use, especially when it carries high salt loads. The effect of total dissolved salts in irrigation water (measured in terms of electrical conductance) on crop growth is extremely important. Soil water passes in to the plant through the root zone due to osmotic pressure and the plants root able to assimilate water and nutrients. Thus, the dissolved solid contents of the residual water in the root zone also have to be maintained within limits by proper leaching. These effects are visible in plants by their stunted growth, low yield, discoloration and even leaf burns at margin or top. The safe limits of electrical conductivity for crops of different degrees of salt tolerances under varying soil textures and drainage conditions are presented in **Table - 5.**

Table 5: Safe Limits for electrical conductivity for irrigation water (IS:11624-1986).

S. No.	Nature of soil	Crop Growth	Upper permissible safe limit of electrical conductivity in water μs/cm at 25°C
1	Deep black soil and alluvial soils having clay content more than 30%; soils that are fairly to moderately well Drained	Semi-tolerant	1500
		Tolerant	2000
2	Textured soils having clay contents of 20-30%; soils that are well drained internally and have good surface drainage system	Semi-tolerant	2000
		Tolerant	4000
3	Medium textured soils having clay10-20%; internally very well drained and having good surface drainage system	Semi-tolerant	4000
		Tolerant	6000
4	Light textured soils having clay less than10%; soils that have excellent Internal and surface drainage system.	Semi-tolerant	6000
		Tolerant	8000

In addition to problems caused by total amount of salts, some of the specific ions like sodium, boron and trace elements, if present in water in excess, also render it unsuitable for agricultural use.

2.3 Effects of Water Quality Parameters on Human Health and Distribution for Various Users

It is essential to ensure that various constituents are within prescribed limits in drinking water supplies to avoid impact on human health (Table – 6). Man, life forms and domestic animals are affected by alteration in water quality due to natural or anthropogenic reasons. The effect of these substances depends on the quantity of water consumed per day and their concentration in water.

Table 6: Effects of water quality parameters on human health when used for drinking Purpose.

S. No.	Parameters	Prescribed limits IS:10500,2012		Probable Effects
		Desirable Limit	Permissible Limit	
1	Colour (Hazen unit)	5	15	Makes water aesthetically undesirable
2	Odour	Essentially free from objectionable odour		Makes water aesthetically undesirable
3	Taste	Agreeable		Makes water aesthetically undesirable
4	Turbidity (NTU)	1	5	High turbidity indicates contamination/Pollution.
5	pH	6.5	8.5	Indicative of acidic or alkaline waters, affects taste, corrosivity and the water supply system
6	Hardnessas $CaCO_3$ (mg/L)	200	600	Affects water supply system (Scaling), Excessive soap consumption, and calcification of arteries. There is no conclusive proof but it may cause urinary concretions, diseases of kidney or bladder and stomach disorder.
7	Iron(mg/L)	1.0	No relaxation	Gives bitter sweet astringent taste, causes staining of laundry and porcelain. Intra cesitis essential for nutrition.
8	Chloride(mg/L)	250	1000	May be injurious to some people suffering from diseases of heart or kidneys. Taste, indigestion, corrosion and palatability are affected.
9	Residual Chlorine (mg/L) Only when water is Chlorinated	0.20	-	Excessive chlorination of drinking water may cause asthma, colitis and eczema.
10	Total Dissolved Solids-TDS (mg/L)	500	2000	Palatability decreases and may cause gastro intestinal irritation inhuman, may have laxative effect particularly upon transits and corrosion may damage water system.
11	Calcium (Ca) (mg/L)	75	200	Causes encrustation in water supply system. While insufficiency causes a severe type of rickets, excess causes concretions in the body such as kidney or bladder stones and Irritation in urinary passages.

S. No.	Parameters	Prescribed limits IS:10500,2012		Probable Effects
		Desirable Limit	Permissible Limit	
12	Magnesium (Mg) (mg/L)	30	100	Its salts are cathartics and diuretic. High concentration may have laxative effect particularly on new users. Magnesium deficiency is associated with structural and functional changes. It is essential as an activator of many enzyme systems.
13	Copper (Cu) (mg/L)	0.5	1.50	Astringent taste but essential and beneficial element in human metabolism. Deficiency results in nutritional anemia in infants. Large amount may result in liver damage, cause central nervous system irritation and depression. In water supply it enhance corrosion of aluminum in particular
14	Sulphate (SO_4) (mg/L)	200	400	Causes gastro intestinal irritation along with Mg or Na, can have a cathartic effect on users, concentration more than 750mg/L may have laxative effect along with Magnesium.
15	Nitrate (NO_3) (mg/L)	45	No relaxation	Cause infant methaemoglobin anemia (blue babies) at very high concentration, causes gastric cancer and affects adversely Central nervous system and cardiovascular system.
16	Fluoride (F) (mg/L)	1.0	1.50	Reduce dental carries, very high concentration may cause crippling skeletal fluorosis.
17	Cadmium (Cd) (mg/L)	0.003	No relaxation	Acute toxicity may be associated with renal, arterial hypertension,itai-itai disease, (a bone disease).Cadmium salt causes cramps, nausea, vomiting and diarrhea.
18	Lead (Pb) (mg/L)	0.01	No relaxation	Toxic in both acute and chronic exposures. Burning in the mouth, severe inflammation of the gastro-intestinal tract with vomiting and diarrhea, chronic toxicity produces nausea, severe abdominal pain, paralysis, mental confusion, visual disturbances, anaemia etc.
19	Zinc (Zn) (mg/L)	5	15	An essential and beneficial element in human metabolism. Taste threshold for Zn occurs at about 5mg/L imparts astringent taste to water.
20	Chromium (Cr^{6+}) (mg/L)	0.05	No relaxation	Hexavalent state of Chromium produces lung tumors can produce cutaneous and nasal mucous membrane ulcers and Dermatitis.

S. No.	Parameters	Prescribed limits IS:10500,2012		Probable Effects
		Desirable Limit	Permissible Limit	
21	Boron(B) (mg/L)	0.5	2.4	Affects central nervous system its salt may cause nausea, cramps, convulsions, coma, etc.
22	Alkalinity (mg/L) as$CaCO_3$	200	600	Impart distinctly unpleasant taste may be deleterious to human being in presence of high pH, hardness and total dissolved solids.
23	Pesticides: (mg/l)	Absent	0.001	Imparts toxicity and accumulated in different organs of human body affecting immune and nervous systems may be carcinogenic.
24	Phosphate (PO_4) (mg/L)	No guideline		High concentration may cause vomiting an diarrhea, stimulate secondary hyper thyroidism and bone loss
25	Sodium (Na) (mg/L)	No guidelines		Harmful to persons suffering From cardiac, renal and circulatory diseases.
26	Potassium (K) (mg/L)	No guidelines		An essential nutritional element but its excessive amounts is cathartic
27	Silica (SiO2) (mg/L)	No guidelines		-
28	Nickel (Ni) (mg/L)	0.02		Non-toxic element but may be carcinogenic in animals, can react with DNA resulting in DNA damage in animals.
29	Pathogens (a)Total coliform (per 100ml) (b) Faecal Coliform (per100ml)	nil		Cause water borne diseases like coliform Jaundice, Typhoid, Cholera etc. produce infections involving skin mucous membrane of eyes, ears and throat.
30	Arsenic (mg/L)	0.01	No relaxation	Various skin diseases, Carcinogenic
31	Uranium (mg/L)	0.03	No relaxation	Kidney disease, Carcinogenic

3

ASSESSMENT OF GROUND WATER QUALITY FOR DRINKING PURPOSES

Different physical parameters studied are appearance, colour, odour, taste, turbidity, electrical conductivity and total dissolved solids. Different chemical parameters studied are pH, alkalinity, total hardness, calcium, magnesium, iron, sodium, potassium, nitrate, chloride, fluoride and sulphate. The values were compared with the values of drinking water standard of BIS (IS 10500:2012). The overall chemical quality of Tripura for the year 2022-2023 is provided in Annexure 6.

3.1 Drinking water specification

Values of drinking water standard of BIS (IS 10500:2012) are given below:

Table 7: Organoleptic and Physical Parameters [BIS, IS 10500]

(*Foreword and Clause 4*)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the absence of Alternate Source	Method of Test
i)	Odour	Agreeable	Agreeable	Part 5
ii)	pH value	6.5-8.5	No relaxation	Part 11
iii)	Taste	Agreeable	Agreeable	Parts 7 and 8
iv)	Turbidity, NTU, Max	1	5	Part 10
v)	Total dissolved solids, mg/l, Max	500	2 000	Part 16

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 8: General Parameters Concerning Substances Undesirable in Excessive amounts.

(*Foreword and Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the absence of Alternate Source	Method of Test
i)	Aluminium (as Al), mg/l, Max	0.03	0.2	IS 3025 (Part 55)
ii)	Ammonia (as total ammonia-N), mg/l, Max	0.5	No relaxation	IS 3025 (Part 34)
iii)	Anionic detergents (as MBAS), mg/l, Max	0.2	1.0	Annex K of IS 13428
iv)	Barium (as Ba), mg/l, Max	0.7	No relaxation	Annex F of IS 13428* or IS 15302
v)	Boron (as B), mg/l, Max	0.5	1.0	IS 3025 (Part 57)
vi)	Calcium (as Ca), mg/l, Max	75	200	IS 3025 (Part 40)
vii)	Chloramines (as Cl2), mg/l, Max	4.0	No relaxation	IS 3025 (Part 26)* or APHA 4500-Cl G
viii)	Chloride (as Cl), mg/l, Max	250	1 000	IS 3025 (Part 32)
ix)	Copper (as Cu), mg/l, Max	0.05	1.5	IS 3025 (Part 42)
x)	Fluoride (as F) mg/l, Max	1.0	1.5	IS 3025 (Part 60)
xi)	Free residual chlorine, mg/l, Min	0.2	1	IS 3025 (Part 26)
xii)	Iron (as Fe), mg/l, Max	1.0	No relaxation	IS 3025 (Part 53)
xiii)	Magnesium (as Mg), mg/l, Max	30	100	IS 3025 (Part 46)
xiv)	Manganese (as Mn), mg/l, Max	0.1	0.3	IS 3025 (Part 59)
xv)	Mineral oil, mg/l, Max	0.5	No relaxation	Clause 6 of IS 3025 (Part 39) Infrared partition method
xvi)	Nitrate (as NO3), mg/l, Max	45	No relaxation	IS 3025 (Part 34)
xvii)	Phenolic compounds (as C6H5OH), mg/l, Max	0.001	0.002	IS 3025 (Part 43)
xviii)	Selenium (as Se), mg/l, Max	0.01	No relaxation	IS 3025 (Part 56) or IS 15303*
xix)	Silver (as Ag), mg/l, Max	0.1	No relaxation	Annex J of IS 13428
xx)	Sulphate (as SO4) mg/l, Max	200	400	IS 3025 (Part 24)
xxi)	Sulphide (as H2S), mg/l, Max	0.05	No relaxation	IS 3025 (Part 29)
xxii)	Total alkalinity as calcium carbonate, mg/l, Max	200	600	IS 3025 (Part 23)
xxiii)	Total hardness (as CaCO3), mg/l, Max	200	600	IS 3025 (Part 21)
xxiv)	Zinc (as Zn), mg/l, Max	5	15	IS 3025 (Part 49)

NOTES

1 In case of dispute, the method indicated by '*' shall be the referee method.

2 It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 9: Parameters Concerning Toxic Substances.

(ForewordandClause4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the absence of Alternate Source	Method of Test
i.	Cadmium (as Cd), mg/l, Max	0.003	No relaxation	IS 3025 (Part 41)
ii.	Cyanide (as CN), mg/l, Max	0.05	No relaxation	IS 3025 (Part 27)
iii.	Lead (as Pb), mg/l, Max	0.01	No relaxation	IS 3025 (Part 47)
iv.	Mercury (as Hg), mg/l, Max	0.001	No relaxation	IS 3025 (Part 48)/ Mercury analyser
v.	Molybdenum (as Mo), mg/l, Max	0.07	No relaxation	IS 3025 (Part 2)
vi.	Nickel (as Ni), mg/l, Max	0.02	No relaxation	IS 3025 (Part 54)
vii.	Polychlorinated biphenyls, mg/l, Max	0.000 5	No relaxation	ASTM 5175* or APHA 6630
viii.	Polynuclear aromatic hydro-carbons (as PAH), mg/l, Max	0.000 1	No relaxation	APHA 6440
ix.	Total arsenic (as As), mg/l, Max	0.01	No	IS 3025 (Part 37)
x.	Total chromium (as Cr), mg/l, Max	0.05	No relaxation	IS 3025 (Part 52)
xi.	Trihalomethanes:			
	a) Bromoform, mg/l, Max	0.1	No relaxation	ASTM D 3973-85*or APHA 6232
	b) Dibromochloromethane, mg/l, Max	0.1	No relaxation	ASTM D 3973-85*or APHA 6232
	c) Bromodichloromethane, mg/l, Max	0.06	No relaxation	ASTM D 3973-85*or APHA 6232
	d) Chloroform, mg/l, Max	0.2	No relaxation	ASTM D 3973-85* or APHA 6232

NOTES

1. In case of dispute, the method indicated by '*' shall be the referee method.
2. It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under ‘acceptable’ render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source’ in col 4, above which the sources will have to be rejected.

Table 10: Parameters Concerning Radioactive Substances.

(Foreword and Clause 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the absence of Alternate Source	Method of Test
	Radioactive materials:			
	a) Alpha emitters Bq/l, Max	0.1	No relaxation	Part 2
	b) Beta emitters Bq/l, Max	1.0	No relaxation	Part 1

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

3.2 Ground water quality for domestic purposes

The pH range for each district varies, with the minimum pH being as low as 4.15 in Unakoti district and as high as 9.017 in the same district (Annexure II). The pH range for other districts is relatively narrow, with the minimum pH being above 6 in all districts except for North Tripura, which has a minimum pH of 6.372. The maximum pH for all districts is below 9, except for South Tripura, which has a maximum pH of 8.915.

There are several factors that can influence the pH of a solution, including geological and environmental factors. In this case, it is likely that differences in soil composition, climate, and water sources are contributing to the variation in pH across districts. The Unakoti district, which has the lowest minimum pH, is known for its rocky terrain, which may be contributing to the high acidity in the soil. On the other hand, districts with a higher maximum pH, such as South Tripura, may have more alkaline soil due to factors such as higher rainfall and vegetation cover. It is important to note that pH can have a significant impact on agriculture and other industries that rely on soil quality, as different crops and plants thrive in different pH ranges. Therefore, understanding the pH range for each district can be useful for farmers and other stakeholders in determining which crops or industries may be best suited for each region.

The electrical conductivity (EC) and total dissolved solids (TDS) values provided for the eight districts in Tripura are measures of water quality. EC is a measure of the ability of water to conduct an electric current, and it increases with the concentration of dissolved ions in the water, including salts and minerals. TDS is a measure of the total concentration of dissolved solids in the water, including minerals, salts, and other organic matter.

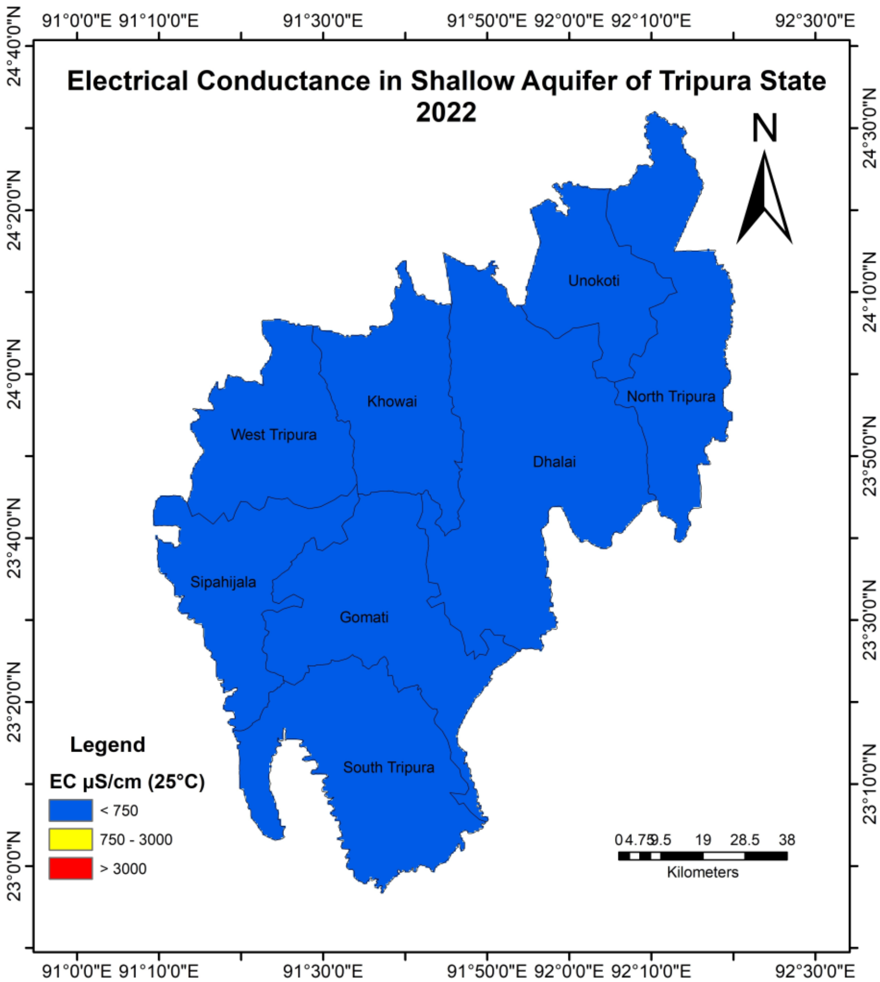

Figure 2 Electrical Conductance in shallow aquifer of Tripura during 2022

Figure 2 shows the distribution of EC in the state during 2022. The statistical analyzed data infer that the water quality in the different districts of Tripura varies significantly. The districts of Dhalai, Khowai, and Sepahijala have the highest EC and TDS values, which suggests that the water in these regions may be more mineral-rich and potentially harder. In contrast, the districts of North Tripura and West Tripura have the lowest EC and TDS values, indicating that the water in these regions may be softer and have lower mineral content.

Cations: The districts of Dhalai, Khowai, Sepahijala, and Unakoti have higher ranges of Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) and Total Hardness (TH). These districts are known for having hard water due to the presence of sedimentary rocks and limestone deposits in the region. The groundwater in these districts comes in contact with these rocks and dissolves minerals like calcium and magnesium, resulting in hard water. Sodium and potassium are monovalent cations that are not harmful to human health at normal concentrations. Sodium is important for maintaining body fluid balance, while potassium is essential for muscle and nerve function. However, high levels of sodium can cause water to taste salty and can be harmful to individuals with high blood pressure. The districts of Gomti, North Tripura, South Tripura, and West Tripura have higher ranges of Na^{+} and K^{+}. These districts are known for having alluvial soils with a high concentration of sodium and potassium. The groundwater in these districts comes in contact with these soils and dissolves sodium and potassium, resulting in elevated levels of these cations in the water.

Figure 3 shows the distribution of iron in the state during 2022 while the spatial distribution among the districts is shown in Figure 4-6. Fe concentration ranges from a minimum of 0.021 mg/L to a maximum of 6.54 mg/L in different districts of Tripura. Highest concentration of Fe has been detected in South Tripura and is mainly concentrated in the southern and the western part of the district (Fig 5d). The probable reason for this variation in Fe concentration could be the difference in the geological composition of the soil, natural weathering and erosion, and the human-induced activities such as agriculture, deforestation, and industrialization. In general, the soil in Tripura is formed by the weathering of underlying rocks, and the Fe concentration in the soil is influenced by the type and composition of the parent rock. The Fe concentration in the soil is also affected by factors such as soil pH, organic matter content, and the availability of other nutrients. For instance, the soils in the South Tripura district have a higher Fe concentration, which could be attributed to the presence of ferruginous rocks and high organic matter content in the soil. Human activities such as agriculture, deforestation, and industrialization can also affect the

Fe concentration in the soil. For example, the West Tripura district, which has a higher Fe concentration, has a large number of industries that could contribute to the higher Fe levels in the soil. The use of fertilizers and pesticides in agriculture can also affect the Fe concentration in the soil.

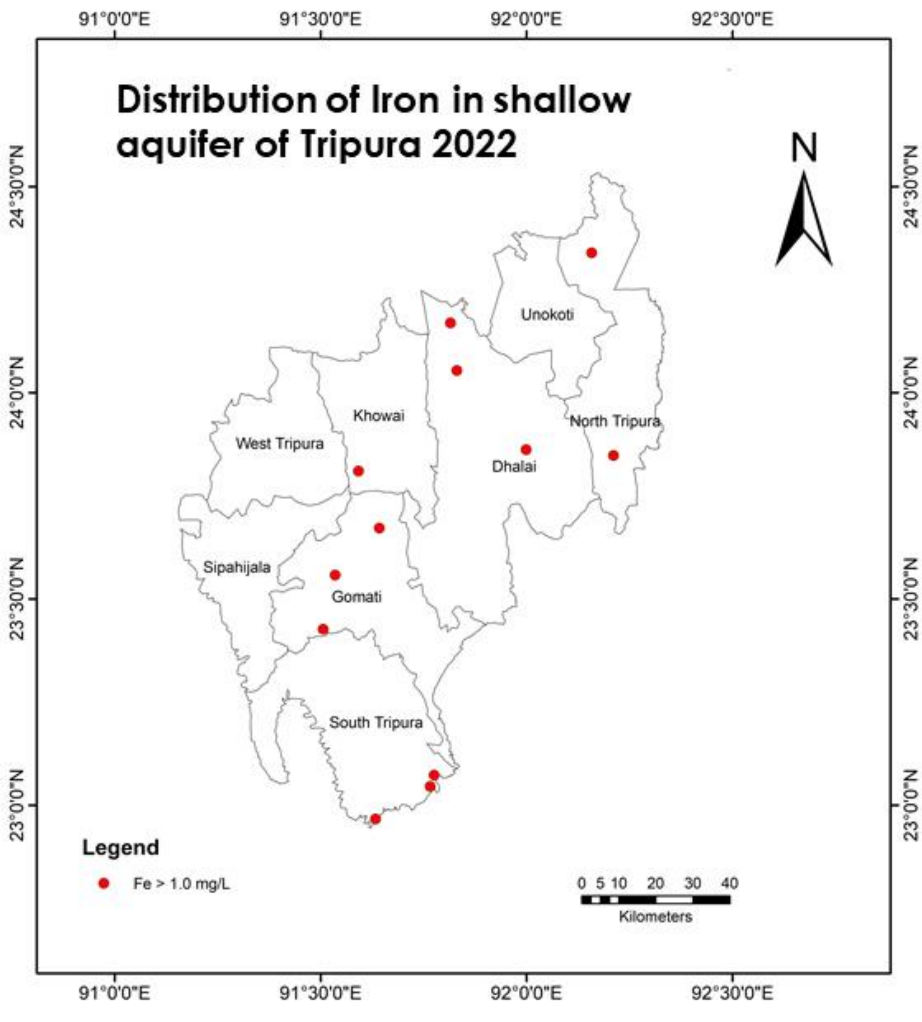

Figure 3 Distribution of iron in shallow aquifer of Tripura during 2022

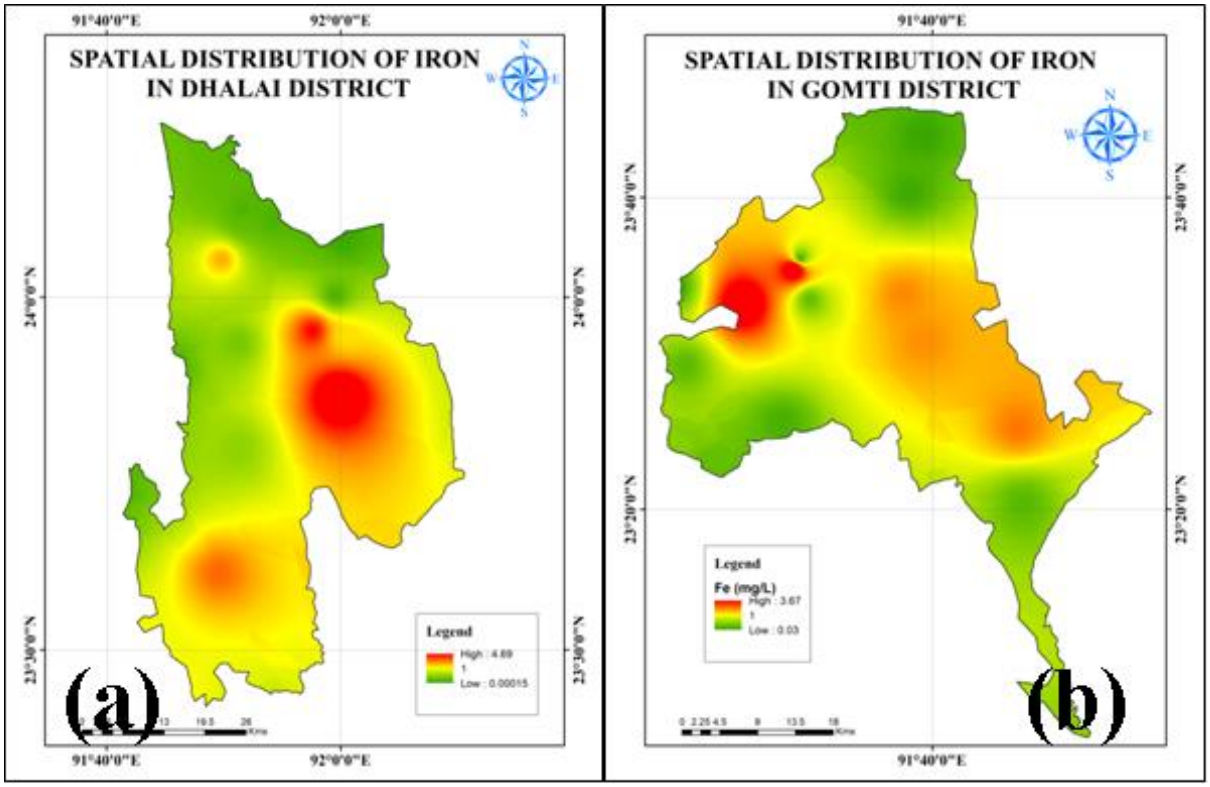

Figure 4 Spatial distribution of Iron in (a). Dhalai district and (b). Gomti district of Tripura.

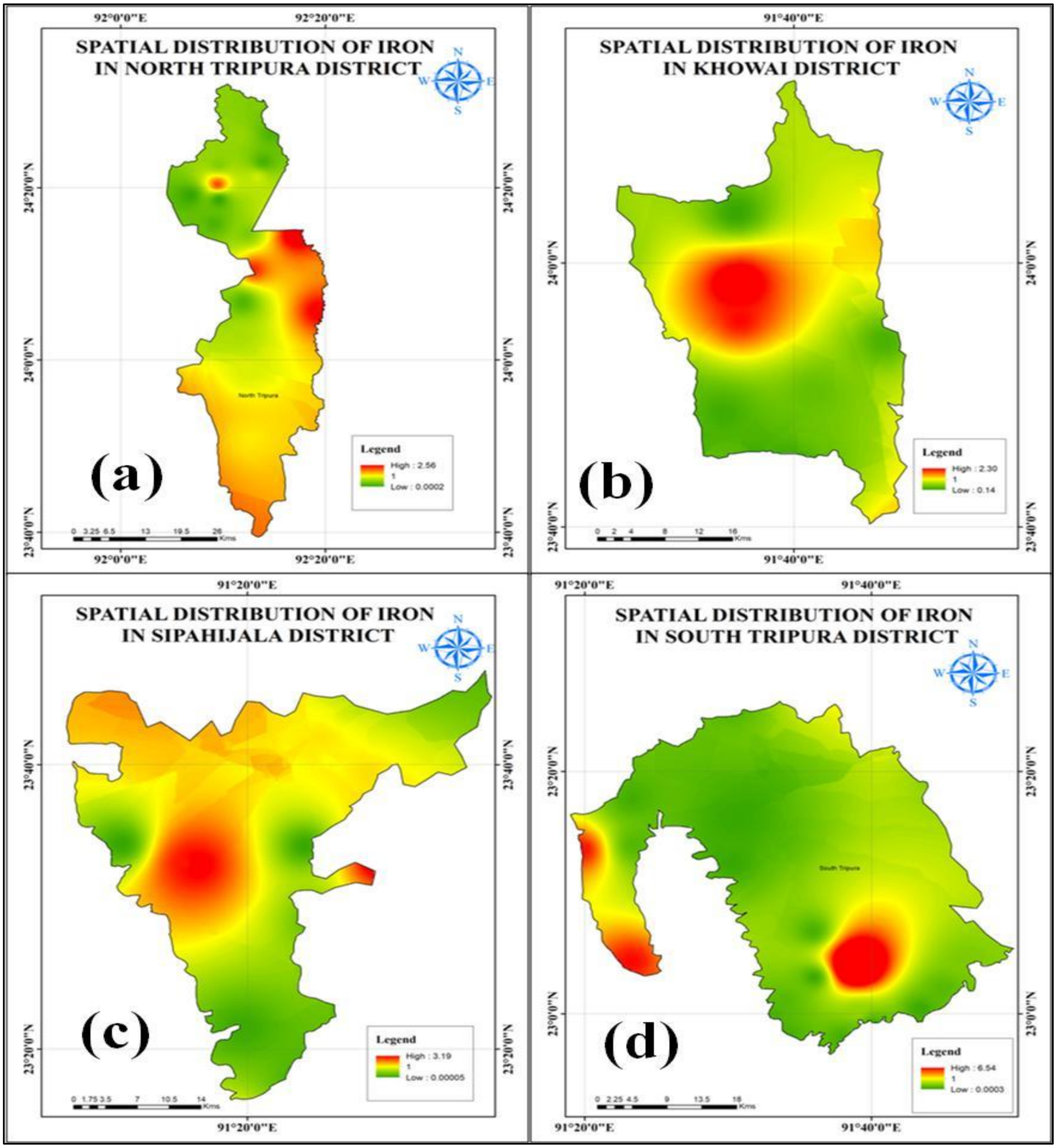

Figure 5 Spatial distribution of Iron in (a) Khowai (b) North Tripura (c) Sipahijala and (d) South Tripura district.

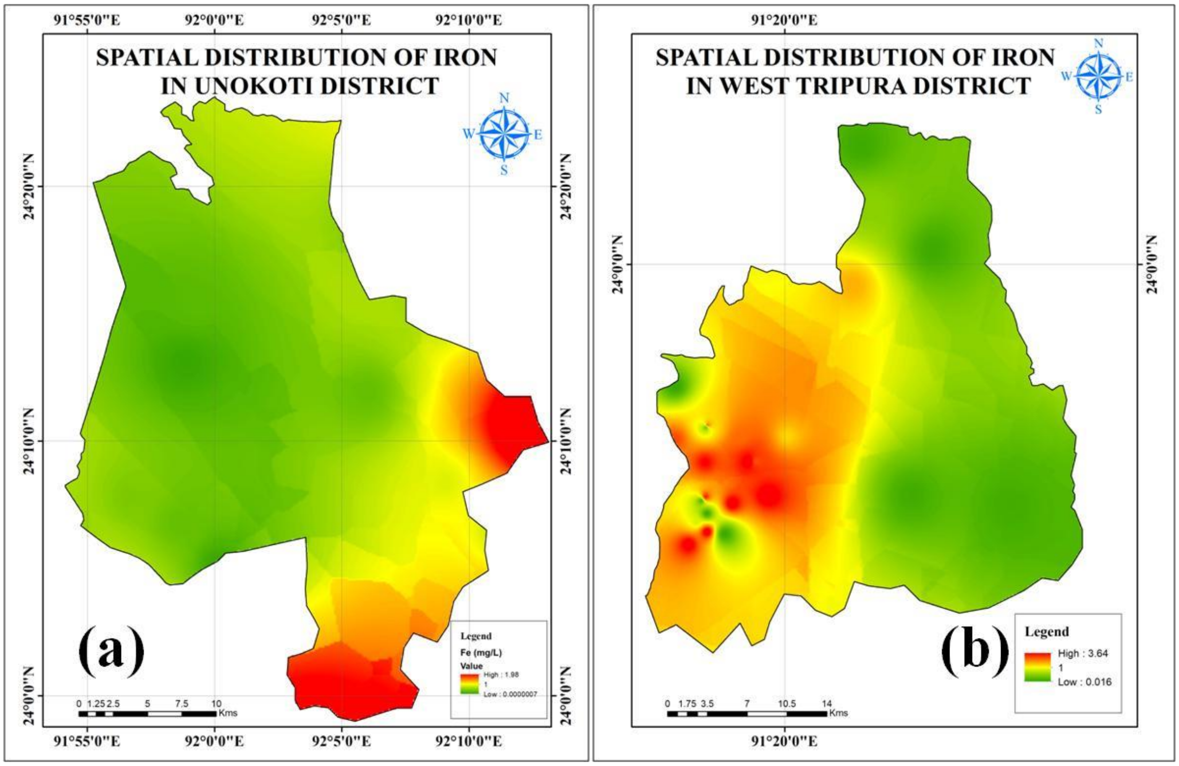

Figure 6 Spatial distribution of Iron in (a) Unokoti and (b) West Tripura district.

Anions: Bicarbonate (HCO_3^-) is a common anion found in natural waters, which originates from the dissolution of minerals such as calcite, dolomite, and gypsum. In the given data, the HCO_3^- values range from a minimum of 12.2 mg/L in North Tripura to a maximum of 311.3 mg/L in Khowai district. The high HCO_3^- levels in Khowai could be due to the presence of carbonate rocks in the area, which are highly soluble in water and can release significant amounts of HCO_3^-.

Chloride (Cl^-) is an important anion that is often used as an indicator of the extent of seawater intrusion, urbanization, and industrial pollution in groundwater. In the given data, the Cl^- values range from a minimum of 7.1 mg/L in Unakoti district to a maximum of 141.8 mg/L in the same district. The high Cl^- values in Unakoti district may be due to anthropogenic activities such as the discharge of industrial effluents and the use of fertilizers, which can increase the Cl^- concentration in groundwater. The distribution of chloride is shown in Figure 7.

Sulfate (SO_4^{2-}) is another common anion found in natural waters, which originates from the oxidation of sulfide minerals and the weathering of sulfate minerals. In the given data, the SO_4^{2-} values range from a minimum of 0.1 mg/L in North Tripura to a maximum of 134 mg/L in Gomti district. The high SO_4^{2-} values in Gomti district could be due to the presence of gypsum and other sulfate minerals in the area, which can release significant amounts of SO_4^{2-} into the groundwater.

Nitrate (NO_3^-) is an important nutrient for plants but can be harmful to human health at high concentrations. In the given data, the NO_3^- values range from a minimum of 0.1 mg/L in Sepahijala and South Tripura districts to a maximum of 13.7 mg/L in North Tripura district. The high NO_3^- values in North Tripura district may be due to the use of fertilizers and animal manure in agriculture, which can increase the NO_3^- concentration in groundwater.

Fluoride (F^-) is a naturally occurring element that is essential for dental health but can be harmful to human health at high concentrations. Spatial distribution of fluoride is shown in Figure 8. In the given data, the F^- values range from a minimum of 0.1 mg/L in North Tripura district to a maximum of 1.4 mg/L in the Khowai district (Fig 5). The high F^- values in Khowai district could be due to the presence of fluoride-rich minerals such as fluorite and apatite in the area.

The chemical composition of groundwater in various districts of Tripura is influenced by several factors, including the local geology, anthropogenic activities, and agricultural practices. Understanding the chemical composition of groundwater is important for ensuring the availability of safe drinking water and sustainable groundwater management practices.

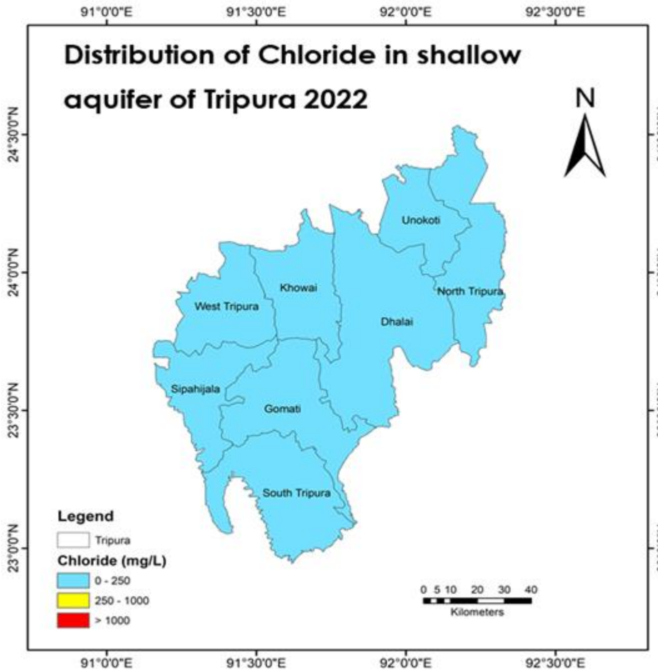

Figure 7 Distribution of chloride in shallow aquifer of Tripura during 2022

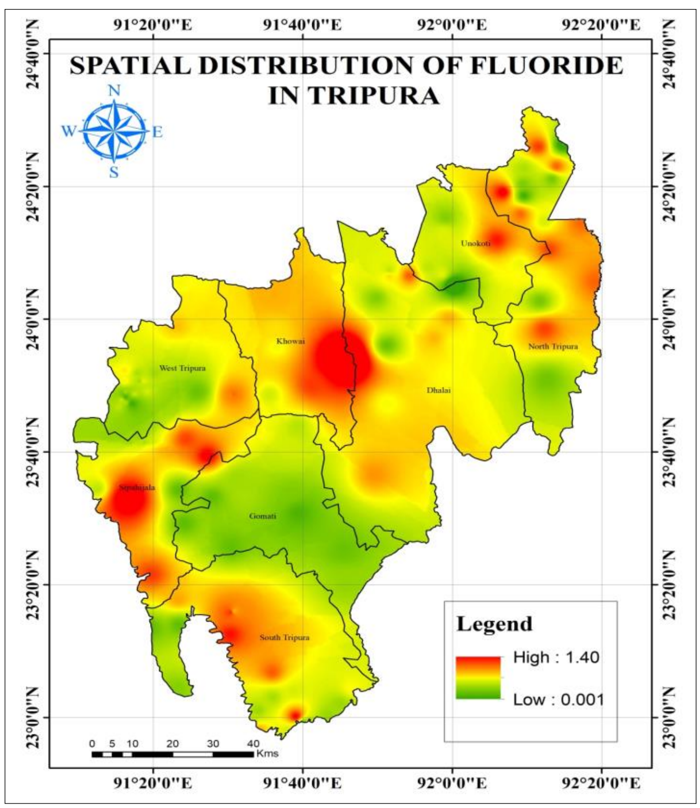

Figure 8 Spatial distribution map of Fluoride in Tripura

3.3 Trend analysis of significant parameters

Trend analysis is necessary in order to determine whether the measured values of the water quality variables increase or decrease during a time period. In this case we have studied 6 years trend of some significant parameters in GW of Tripura. We have plotted graphs with 3 variables with the years 2017 to 2022 on X-axis, followed by number of districts affected and subsequently the percentage of locations affected. Figure 9(a-h) depicts the trend analysis graphs of each significant chemical parameters.

Year	Total No. of samples analysed	No. of districts affected by EC	Total No. of locations affected by EC	% of locations affected by EC (EC > 3000 µs/cm)
2017	87	0	0	0
2018	84	0	0	0
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

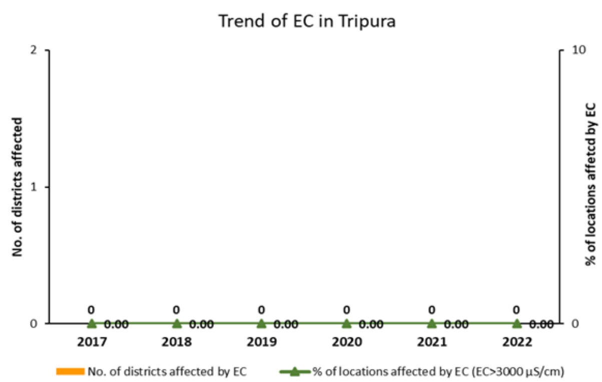

Figure 9 (a): 6 years EC data comparison (up) and trend analysis graph of EC (down).

Year	Total Number of samples analysed	No. of districts affected by Cl	Total No of locations affected by Cl	% of locations affected by Cl (Cl >1000 mg/L)
2017	87	0	0	0
2018	84	0	0	0
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

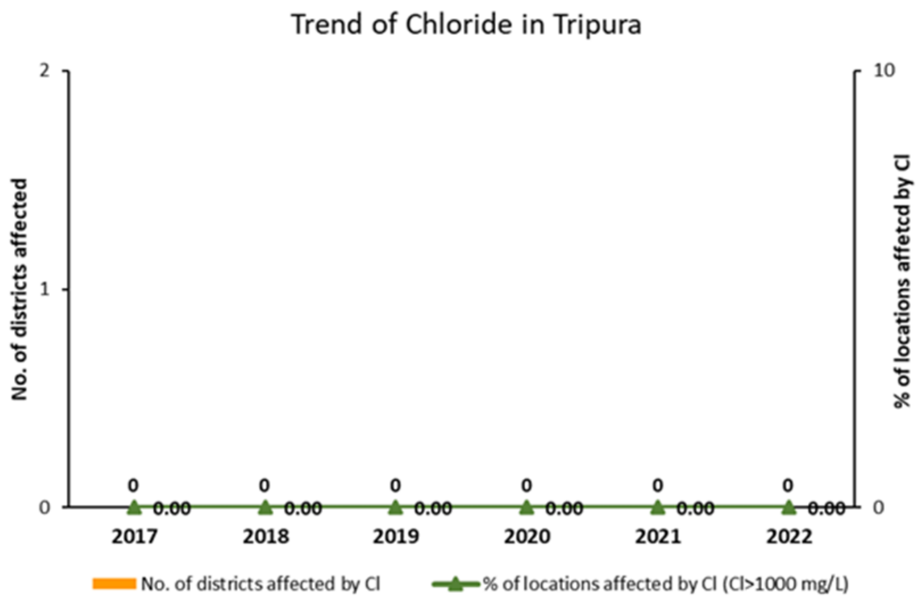

Figure 9 (b): 6 years chloride data comparison (up) and trend analysis graph of chloride (down).

Year	Total No. of samples analysed	No. of districts affected by F	Total No. of locations affected by F	% of locations affected by F
2017	87	0	0	0
2018	84	0	0	0
2019	89	2	2	2.24
2020	99	1	2	2.02
2021	90	0	0	0
2022	67	0	0	0

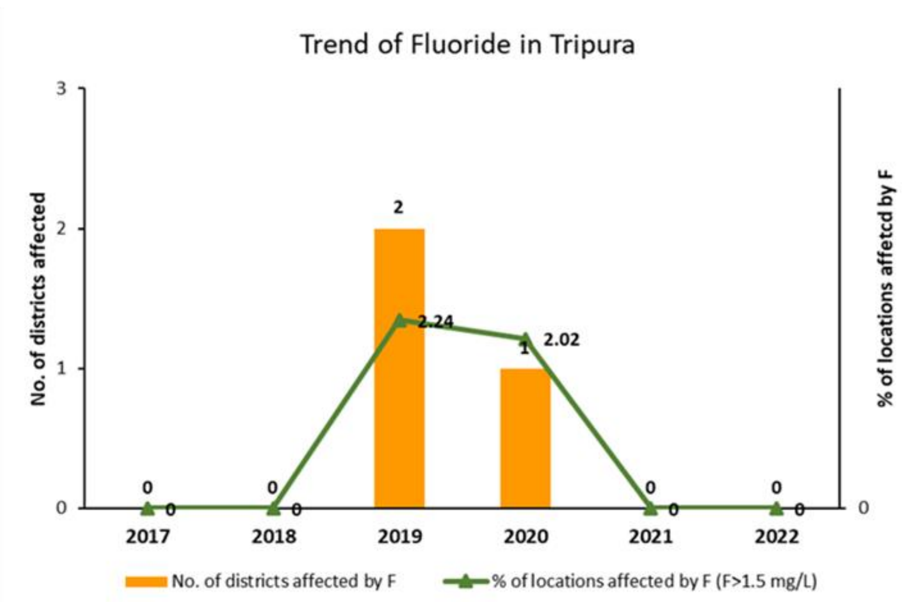

Figure 9(c): 6 years fluoride data comparison (up) and trend analysis graph of fluoride (down).

Year	Total No. of samples analysed	No. of districts affected by NO_3^-	Total No. of locations affected by NO_3^-	% of locations affected by NO_3^-
2017	87	0	0	0
2018	84	0	0	0
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

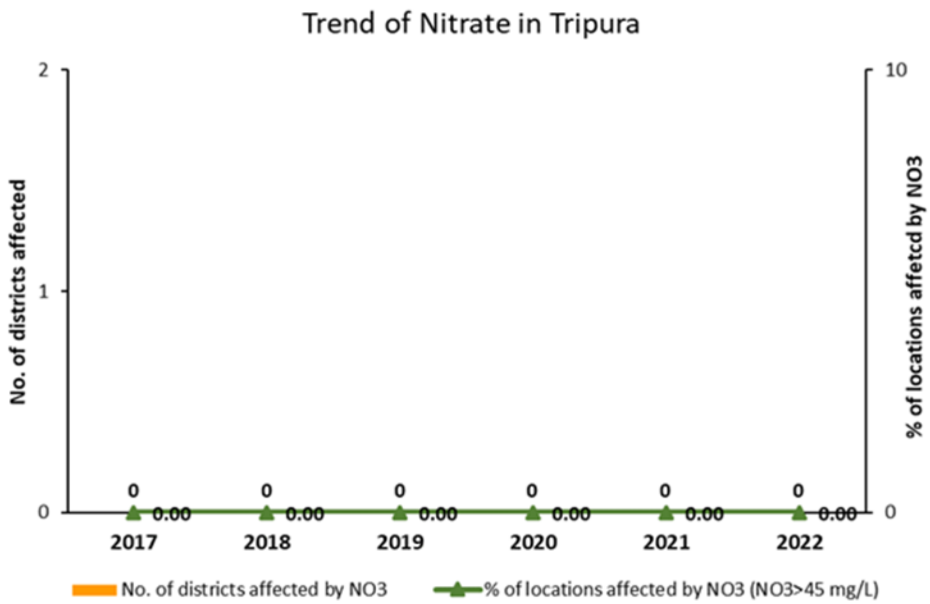

Figure 9(d): 6 years nitrate data comparison (up) and trend analysis graph of nitrate (down).

Year	Total Number of samples analysed	No. of districts affected by TH	Total No of locations affected by TH	% of locations affected by TH (TH >600 mg/L)
2017	87	0	0	0
2018	84	0	0	0
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

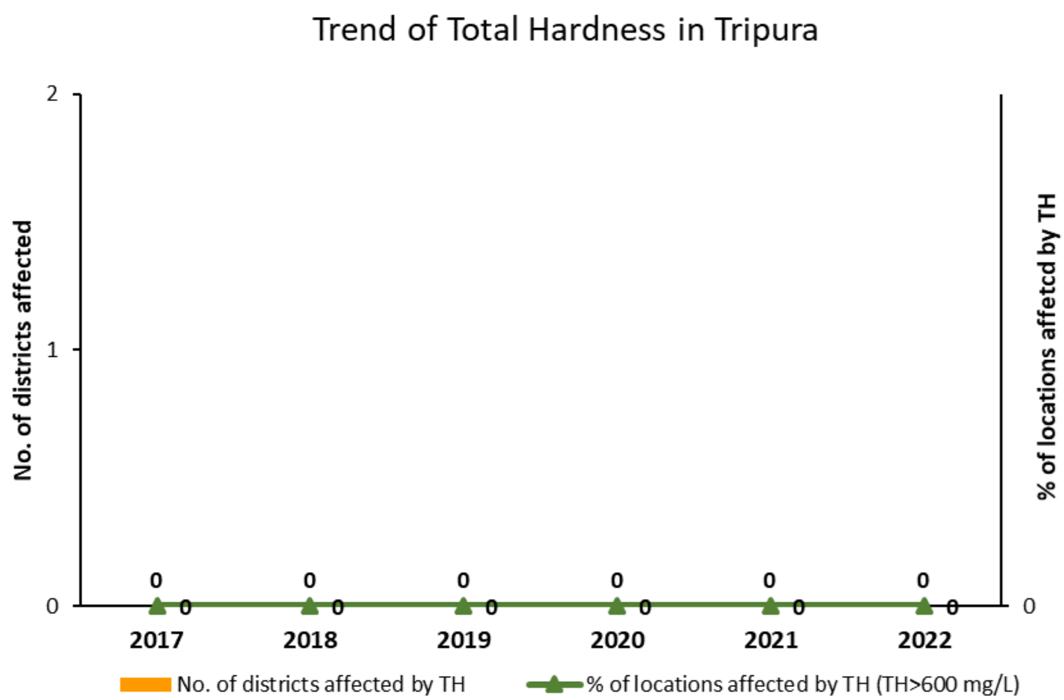

Figure 9(e): 6 years TH data comparison (up) and trend analysis graph of TH (down).

Year	Total No. of samples analysed	No. of districts affected by Fe	Total No. of locations affected by Fe	% of locations affected by Fe
2017	87	5	16	18.39
2018	84	3	11	13.09
2019	89	6	10	11.23
2020	99	6	17	17.10
2021	90	8	28	31.11
2022	67	5	12	17.91

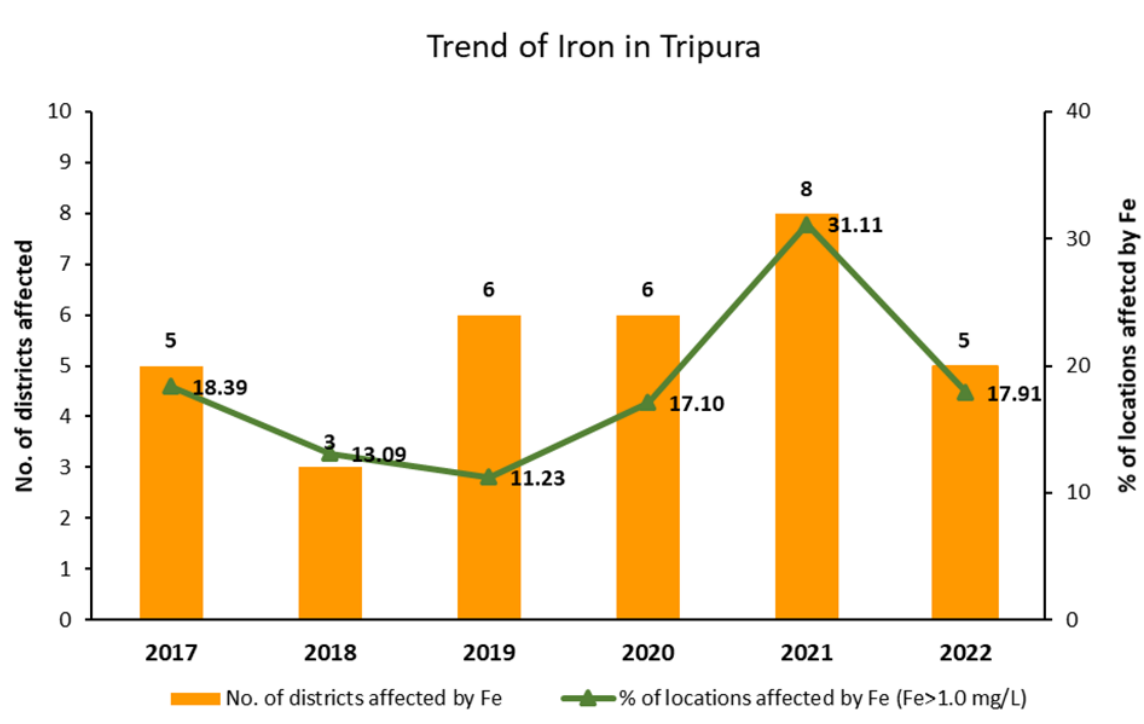

Figure 9(f): 6 years iron data comparison (up) and trend analysis graph of iron (down).

Year	Total Number of samples analysed	No. of districts affected by As	Total No of locations affected by As	% of locations affected by As (As >0.01 mg/L)
2017	87	2	5	5.74
2018	84	0	0	0
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

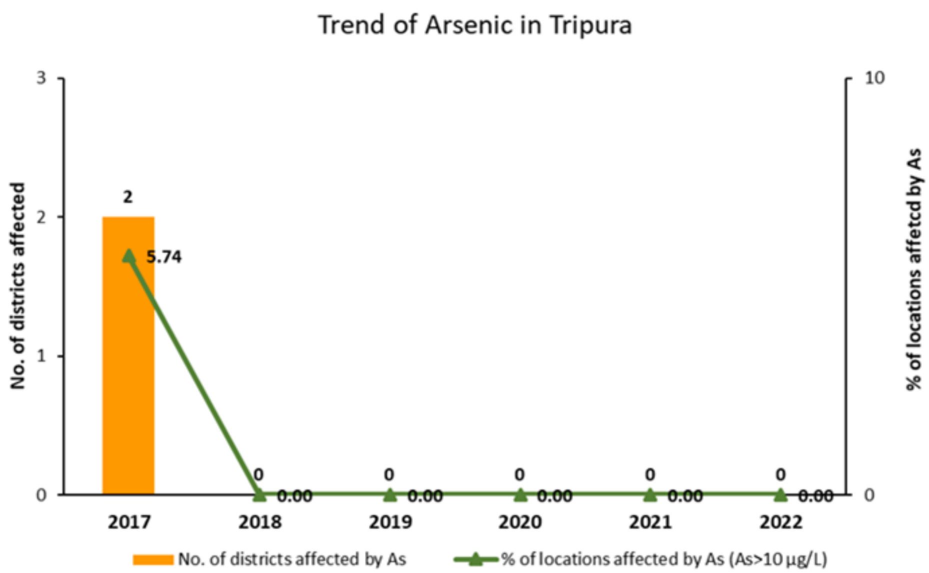

Figure 9(g): 6 years arsenic data comparison (up) and trend analysis graph of arsenic (down).

Year	Total Number of samples analysed	No. of districts affected by U	Total No of locations affected by U	% of locations affected by U (U >0.03 mg/L)
2019	89	0	0	0
2020	99	0	0	0
2021	90	0	0	0
2022	67	0	0	0

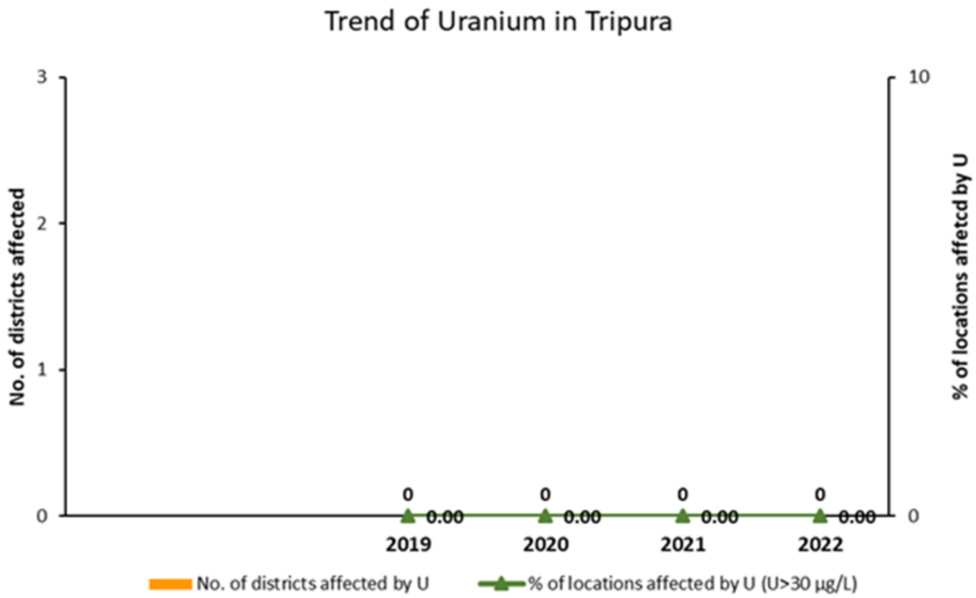

Figure 9(h): 6 years uranium data comparison (up) and trend analysis graph of uranium (down).

4

ASSESSMENT OF GROUND WATER QUALITY FOR FEASIBILTY IN IRRIGATION

The accumulation of soluble salts in soil beyond a certain threshold can lead to a decrease in crop yield. One of the primary reasons behind this reduction in production is the presence of osmotic water stress on plants. The primary sources of soluble salts in agriculture soils are:

- Irrigation water
- Salt deposits in soil
- Drainage water, draining from upper lying to lower lying lands
- Capillary flow of water-especially in shallow water table areas
- Soil reclamation practices and use of fertilizers
- Weathering of soil minerals and
- Precipitation

Suitability of ground water for irrigation purpose is evaluated based on chemical characteristics indicative of their potential to create soil condition hazardous to crop growth and yield. Various indices are used for assessment and classification of ground water into different categories. Some of the widely used criteria are discussed below.

4.1. IRRIGATION WATER QUALITY CRITERIA

4.1.1. Salinity based on Electrical conductivity and chlorinity

Electrical conductivity (EC), total dissolved solids (TDS) and chlorinity are used as a measure of salinity of ground water. Water with EC<3000 µS/cm at 25ºC and TDS<1000 mg/L is safe to be used for irrigation purpose. Water parameters that exceed these limits can render it unsuitable for irrigation. Groundwater that spends a longer time in the aquifers and has low mobility tends to become more mineralized, which results in higher levels of electrical conductivity (EC) and total dissolved solids (TDS). Chlorinity in ground water should be below 500 mg/L for being suitable to be used in irrigation.

4.1.2. Sodium hazards

The absolute and relative concentration of sodium and also calcium and magnesium determine the sodium hazard in water used for irrigation purpose. Accumulation of exchangeable sodium results in alkali soil and it is associated with poor tilt and low permeability. Sodium Absorption Ratio (SAR) is recommended by the U. S. Salinity Laboratory since it more accurately depicts the sodium absorbed by the soil. SAR is mathematically calculated as

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

As per Richards classification water with SAR<10 makes it suitable for irrigation.

Soluble Sodium Percentage (SSP) is another criterion that represents the sodium in water exchanged by calcium by Base Exchange process that decreases the soil permeability.

$$SSP = \frac{Na * 100}{Ca + Mg + Na}$$

Water with SSP<50 are of good quality for irrigation. Besides these two indices, percent sodium (%Na) is another factor in assessing the suitability of irrigation water.

$$\% Na = \frac{(Na + K)}{(Ca + Mg + Na + K)} * 100$$

Kelly’s Index (KI) developed in 1951 is another index included in sodium hazard.

$$KI = \frac{Na}{Ca + Mg}$$

Water with KI>1 is considered of poor quality for irrigation.

4.1.3. Effects of bicarbonate ion concentration

The residual alkalinity is denoted by Residual Sodium Carbonate (RSC) as developed by Eaton in 1950. Water containing high concentration of bicarbonate ions, the calcium and magnesium may precipitate as carbonates in the soil. When the Ca and Mg precipitates out, the relative proportion of sodium in that water increases. RSC is calculated as shown below:

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

RSC<1.25 is suitable for irrigation, 1.25<RSC>2.50 is marginally suitable and that >2.50 is unsuitable for irrigation.

4.1.4. Permeability

Doneen in 1964 developed Permeability Index (PI). Continuous application of water may affect soil permeability by precipitation of certain elements in the top soil that reduces void space hindering water dynamics. In such case PI of that water gives an idea of the permeability of the top soil.

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} * 100$$

Water with PI>75% is suitable for irrigation.

4.1.5. Magnesium Hazard

The relative proportion of magnesium in water is calculated as Magnesium Ratio (MR) and it was developed by Llyod and Heathcote in 1985. It is formulated as below:

$$MH = \frac{(Mg * 100)}{(Ca + Mg)}$$

The MH>50 is considered unsuitable for irrigation purpose.

4.1.6. US SALINITY Laboratory Diagram/Wilcox plot and Piper Diagram

US SALINITY Laboratory Diagram: One of the most important procedures which have been in use for considerable period of time till date is the one recommended by the U.S. Salinity Laboratory (U. S. S. L. 1954) and is briefly out lined below. The diagram is proposed with the assumption that water is used under average conditions with respect to soil texture, filtration rate, and drainage, quantity of water used, climate and tolerance of corps. The diagram takes into consideration the salinity and sodium hazard of irrigation waters.

Piper Diagram: Hydro-chemical facies are very useful in investigating diagnostic chemical character of water in hydrologic systems. Different types of facies within the same group formations are due to characteristic ground water flow through the aquifer system and effect of local recharge. The types of facies are inter-linked with the geology of the area and distribution of facies with the hydrogeological controls. Hydrochemical facies are delineated by plotting percentage reacting value of major ions on tri-linear diagrams know as Piper Diagram.

4.2. FEASIBILTY FOR AGRICULTURE PURPOSE

The salinity in all the districts of Tripura is low and the water may be categorized as low saline water. All of the samples have Sodium Absorption Ratio (SAR) values below 10, indicating that the groundwater is suitable for irrigation in terms of SAR. However, 15% of the groundwater samples have Soluble Sodium Percentage (SSP) above 50%, which makes them unsuitable for irrigation (Fig 10a). Additionally, the percentage of sodium in 5.45% of the groundwater samples falls into the Doubtful category, while 34.45% fall into the Poor category, 42.72% fall into the Good category, and the remaining samples fall into the Excellent category (Fig 10b). Overall, while most of the groundwater samples are suitable for irrigation, caution needs to be taken with the samples in the Doubtful and

Poor categories, and proper management practices can improve the quality of the groundwater for irrigation purposes (**Annexure I**).

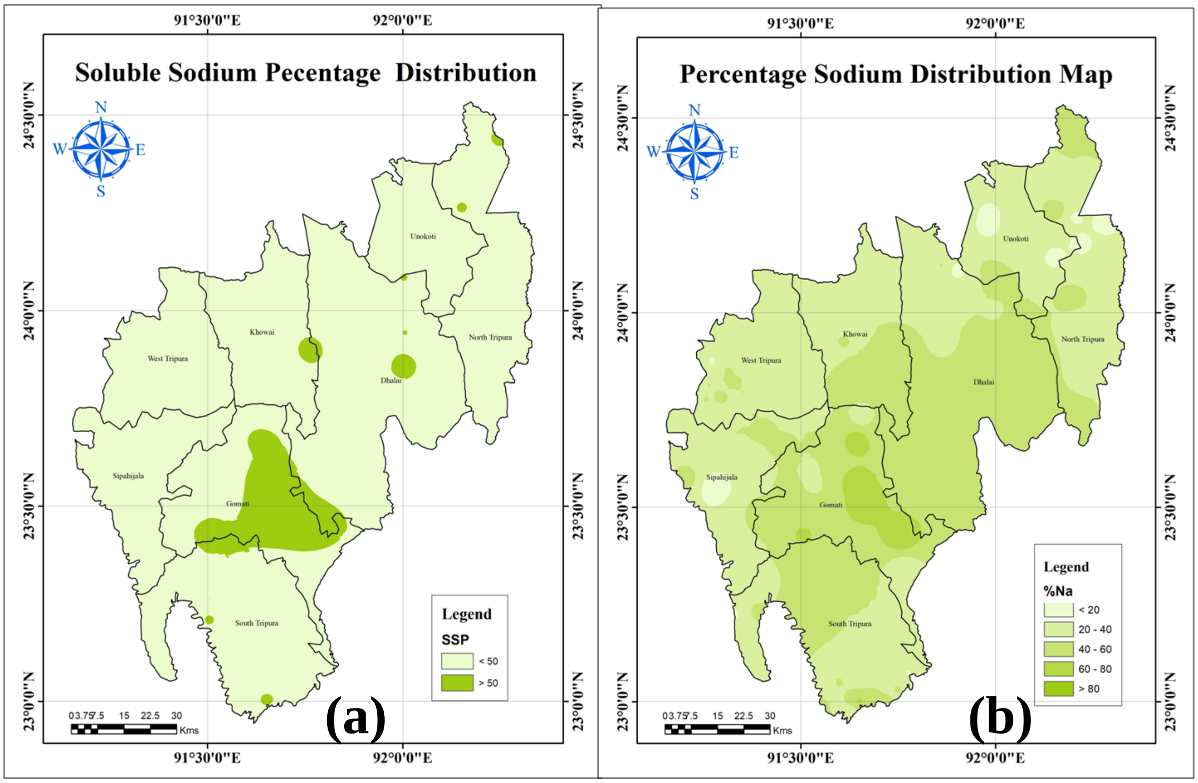

Figure 10 (a) Soluble Sodium Percentage distribution (b) Percentage Sodium distribution map of Tripura.

A small percentage of the analyzed groundwater samples have high Kelly's Ratio values, indicating a potential for soil salinization and unsuitability for irrigation. Additionally, one groundwater sample shows a high Residual Sodium Carbonate value, indicating a potential for soil alkalization and unsuitability for irrigation (Fig 11a). These results emphasize the importance of regular monitoring of groundwater quality for irrigation purposes, as well as the need for proper management practices to maintain soil health and productivity. The Permeability Index (PI) is an indicator of the ability of water to permeate through soil. The higher the PI value, the better the water can permeate through the soil. The given information states that 63.63% of the groundwater samples have a PI value above 75, indicating that they have good permeability and can easily penetrate the soil. The remaining groundwater samples, which lie in the range of 25-75 PI, indicate that they have moderate to poor permeability. These samples may have some limitations in their ability to penetrate the soil, and may require management practices such as soil amendment, irrigation scheduling, or crop selection to maximize their effectiveness for irrigation purposes. The Magnesium Hazard (MH) is an indicator of the potential for water to cause magnesium-related issues in soil, such as soil structural problems, plant nutrient imbalances, and reduced soil permeability. The analyzed data states that 42.72% of the groundwater samples have an MH value above 50, indicating that they have a high potential to cause magnesium-related issues in soil (Fig 11b). This result suggests that the groundwater in the affected samples may not be suitable for irrigation purposes without proper management practices. It may be necessary to modify irrigation methods, such as using low-volume irrigation or drip irrigation, or to amend the soil with appropriate materials to manage the high magnesium levels in the water. Alternatively, other sources of water with lower MH values may need to be explored for irrigation purposes.

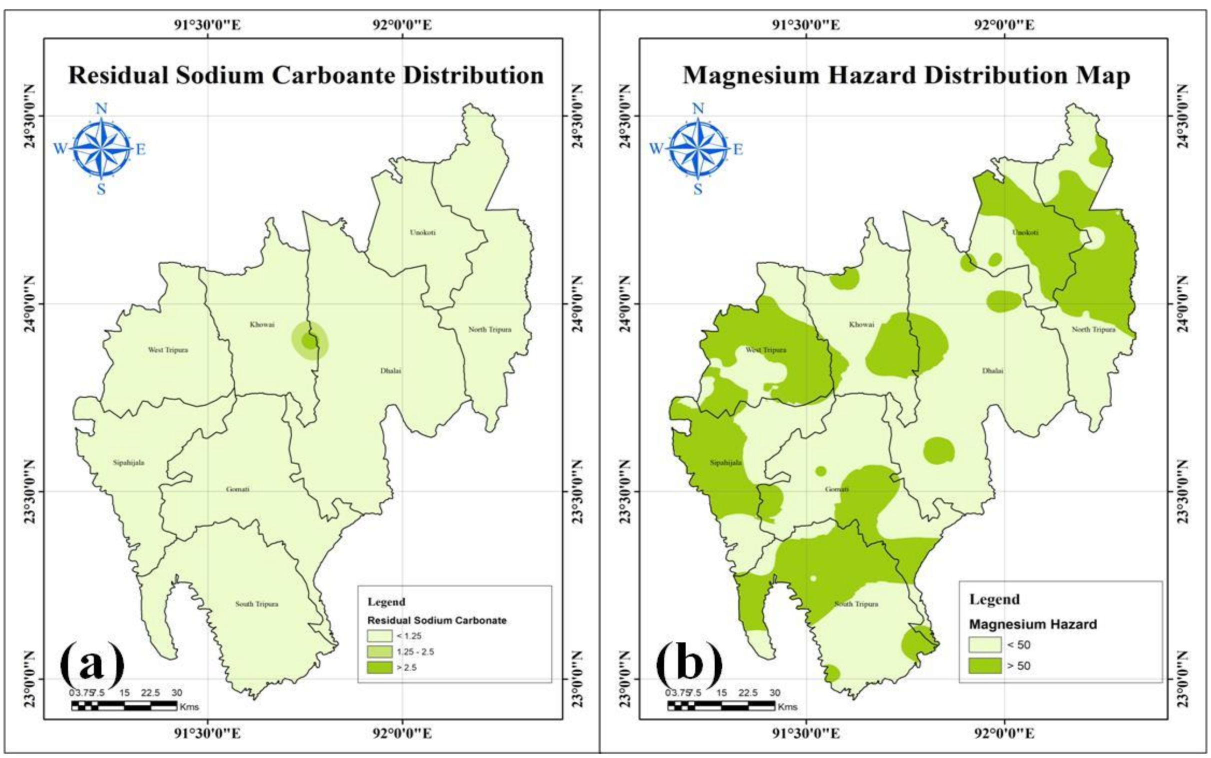

Figure 11 (a). Residual Sodium Carbonate distribution (b). Magnesium Hazard distribution map of Tripura.

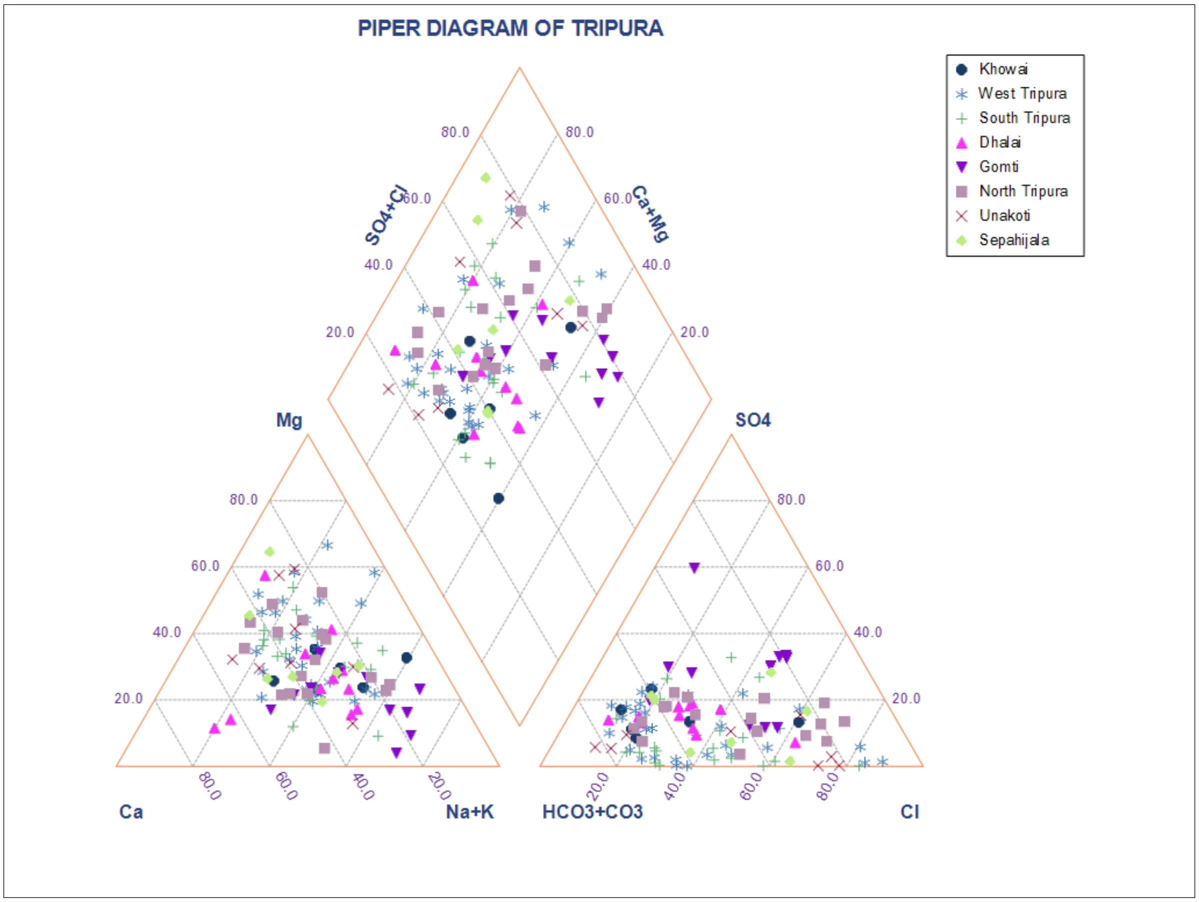

Figure 12 Piper diagram of Tripura.

The piper diagram (Fig 12) shows that most of the groundwater samples fall within the "no dominant type" category, which means that the concentration of these three major cations are roughly equal. This may indicate that the water is relatively fresh and has not undergone significant mineralization processes. In the anion triangle, a mix of HCO_3^-+ CO_3^{2-} type and chloride type indicates that the water has a relatively high concentration of these two anions, which may be due to dissolution of minerals or contamination from anthropogenic sources. Overall, when both the cation and anion triangles are taken into consideration, the water is classified as falling into the Magnesium bicarbonate type and the mixed type in the piper diagram.

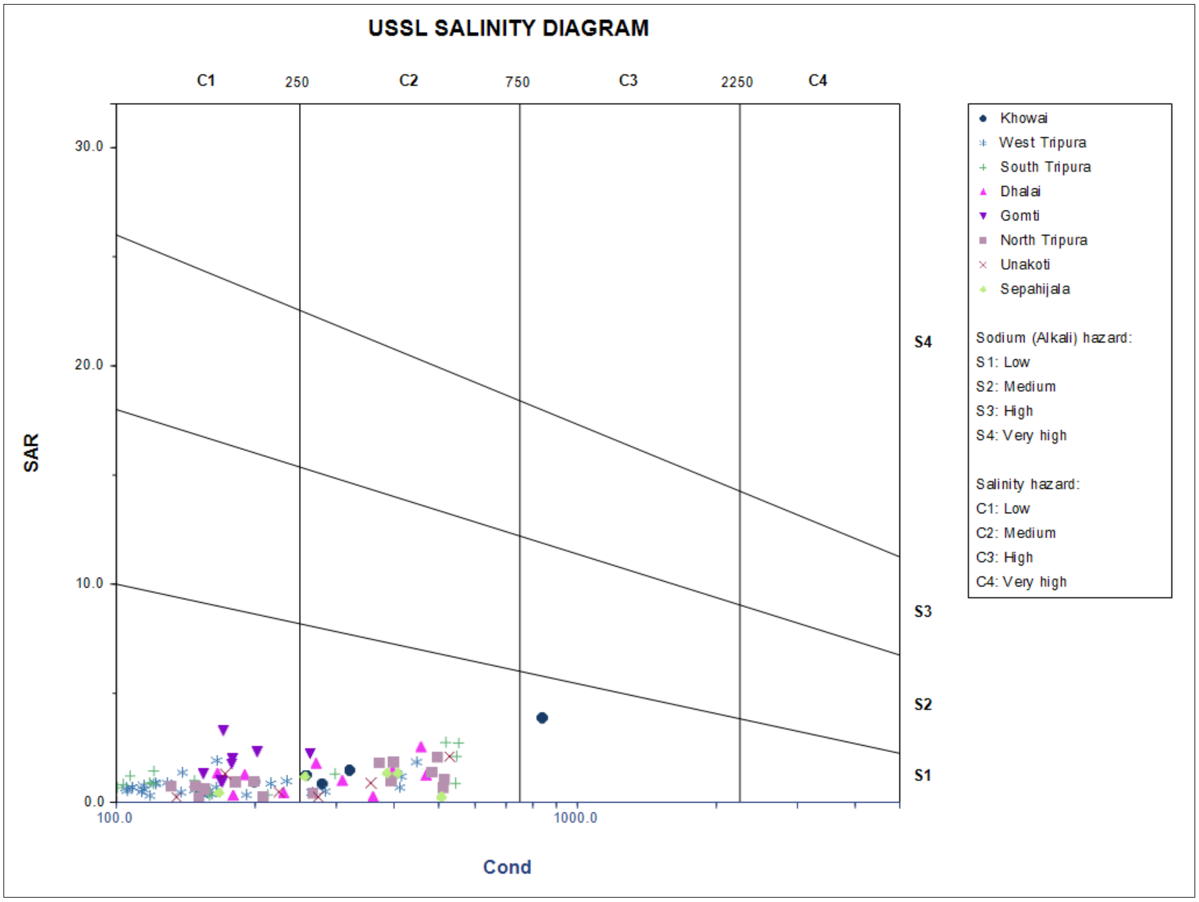

Figure 13 US SALINITY Laboratory Diagram of Tripura.

The US SALINITY Laboratory Diagram shows that most of the analyzed groundwater samples fall in the C1S1 category, which is the lowest level of salinity on the diagram. This means that the water has a low concentration of both sodium and chloride ions, and a low overall TDS. Figure 13 shows the USSSL diagram of Tripura state.

The next most common category for the groundwater samples is C2S1, which is slightly higher in salinity than C1S1, but still relatively low overall. Finally, there is one sample from Khowai district that falls into the C3S1 category, which is slightly higher in salinity than C2S1.

5. REMEDIAL MEASURES

Iron/Manganses

a) Oxidation and filtration: Before iron and manganese can be filtered, they need to be oxidized to a state in which they can form insoluble complexes. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $Fe(OH)_3$. Manganese (Mn^{2+}) is oxidized to (Mn^{4+}), which forms insoluble (MnO_2). The common chemical oxidants in water treatment are chlorine, chlorine dioxide, potassium permanganate and ozone. The dose of potassium permanganate, however, must be carefully controlled. Too little permanganate will not oxidize all the iron and manganese, and too much will allow permanganate to enter the distribution system and cause a pink color.

Ozone may be used for iron and manganese oxidation. Ozone may not be effective for oxidation in the presence of humic or fulvic materials. If not dosed carefully, ozone can oxidize reduced manganese to permanganate and result in pink water formation as well. Manganese dioxide particles, also formed by oxidation of reduced manganese, must be carefully coagulated to ensure their removal.

A low-cost method of providing oxidation is to use the oxygen in air as the oxidizing agent. Water is simply passed down a series of porous trays to provide contact between air and water. No chemical dosing is required. This method is not effective for water in which the iron is complexed with humic materials or other large organic molecules.

Oxidation and Filtration Method for Fe and Mn Removal from Ground Water In general, manganese oxidation is more difficult than iron because the reaction rate is slower. A longer detention time (10 to 30 minutes) following chemical addition is needed prior to filtration to allow the reaction to take place. Manganese greensand is by far the most common medium in use for removal of iron and manganese through pressure filtration. Greensand is a processed material consisting of nodular grains of the zeolite mineral glauconite. The material is coated with manganese oxide. The ion exchange properties of the glauconite facilitates the bonding of the coating. This treatment gives the media a catalytic effect in the chemical oxidation reduction reactions necessary for iron and manganese removal. This coating is maintained through either continuous or intermittent feed of potassium permanganate.

Anthra/sand (also iron-man sand) are other types of media available for removal of iron and manganese. They consist of select anthracite and sand with a chemically bonded manganese oxide coating.

Electromedia is a proprietary multi-media formulation which uses a naturally occurring zeolite and does not require potassium permanganate regeneration. Finally, macrolite, is a manufactured ceramic material with a spherical shape and a rough, textured surface. The principal removal mechanism is physical straining rather than contact oxidation or adsorption. Each medium has its advantages and disadvantages. Selection of a medium and oxidant should be based on pilot testing in which all necessary design criteria can be determined.

b) Ion Exchange Ion exchange should be considered only for the removal of small quantities of iron and manganese because there is a risk of rapid clogging. Ion exchange involves the use of synthetic resins where a pre-saturate ion on the solid phase (the "adsorbent," usually sodium) is exchanged for the unwanted ions in water. One of the major difficulties in using this method for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the media. Cleaning would then be required using acid or sodium bisulfate.

c) Combined Photo-Electrochemical (CPE) Method Different processes, such as electrochemical (EC), photo (UV), and combined photo-electrochemical (CPE) methods are used. A cell containing aluminium electrode as anode, graphite electrode as cathode and UV lamp are used and filled with waste water enriched with iron and manganese as an electrolytic solution. A limited quantity of sodium chloride salt is added to enhance the electric conductivity through the solution. A comparison between different methods was undertaken to evaluate the applied conditions and the efficiency of Fe and Mn removal at different times and initial concentrations. The results revealed that CPE method was the best choice for the simultaneous removal of both iron and manganese in a short time < 10 min.

d) Sequestration is the addition of chemicals to groundwater aimed at controlling problems caused by iron and manganese without removing them. These chemicals are added to groundwater at the well head or at the pump intake before the water has a chance to come in contact with air or chlorine. If the water contains less than 1.0 mg/L iron and less than 0.3 mg/L manganese, using polyphosphates followed by chlorination can be an effective and inexpensive method for mitigating iron and manganese problems. No sludge is generated in this method. Below these concentrations, the polyphosphates combine with the iron and manganese preventing them from being oxidized. Any of the three polyphosphates (pyrophosphate, tripolyphosphate, or metaphosphate) can be used. Applying sodium silicate and chlorine simultaneously has also been used to sequester iron and manganese. However, while this technique is reliable in the case of iron treatment, it has not been found to be effective in manganese control.

5

CONCLUSION

The groundwater quality of the Tripura has been evaluated to find its suitability for drinking and irrigation purposes based on physicochemical parameters. The analysis of groundwater samples from various districts in Tripura shows that most of the samples have low salinity levels and are suitable for irrigation purposes in terms of SAR. However, caution needs to be taken with samples that have high SSP values, and proper management practices can improve groundwater quality for irrigation purposes. Some samples have high Kelly's Ratio values, indicating a potential for soil salinization, and one sample has a high Residual Sodium Carbonate value, indicating a potential for soil alkalization, making them unsuitable for irrigation without proper management practices. Additionally, some samples have moderate to poor permeability, and some have a high potential to cause magnesium-related issues in soil, requiring appropriate management practices for effective irrigation. The piper diagram shows that the groundwater is relatively fresh and falls into the Magnesium bicarbonate type and the mixed type. The US SALINITY Laboratory Diagram indicates that most samples fall into the C1S1 category, with some falling into C2S1 and one sample falling into C3S1. In conclusion, regular monitoring of groundwater quality is necessary, and proper management practices are required to maintain soil health and productivity for effective irrigation in Tripura.

The data generated suggests that the pH, electrical conductivity (EC), total dissolved solids (TDS), and ion concentrations vary significantly across the eight districts in Tripura. The pH range is relatively narrow for most districts except for Unakoti, which has the lowest minimum pH of 4.15 and the highest maximum pH of

9.017. Factors such as soil composition, climate, and water sources are likely contributing to this variation in pH. EC and TDS values suggest that the water in the districts of Dhalai, Khowai, and Sepahijala may be more mineral-rich and potentially harder, while the water in North Tripura and West Tripura may be softer and have lower mineral content.

The districts of Dhalai, Khowai, Sepahijala, and Unakoti have higher ranges of calcium, magnesium, and total hardness, indicating that they have hard water due to the presence of sedimentary rocks and limestone deposits. The districts of Gomti, North Tripura, South Tripura, and West Tripura have higher ranges of sodium and potassium due to the high concentration of these cations in alluvial soils. The Fe concentration ranges from a minimum of 0.021 mg/L to a maximum of 6.54 mg/L in different districts of Tripura, with the highest concentration detected in South Tripura. The variation in Fe concentration could be due to the difference in the geological composition of the soil, natural weathering and erosion, and human-induced activities such as agriculture, deforestation, and industrialization. Bicarbonate levels range from a minimum of 12.2 mg/L in North Tripura to a maximum of 311.3 mg/L in Khowai district. The high HCO_3^- levels in Khowai could be due to the presence of carbonate rocks in the area, which are highly soluble in water and can release significant amounts of bicarbonate. Chloride levels range from a minimum of 7.1 mg/L in Unakoti district to a maximum of 141.8 mg/L in Khowai district, indicating the extent of urbanization, and industrial pollution in groundwater.

A number of groundwater samples showed high iron concentration which exceeds the BIS permissible limits of drinking water. Thus, water samples are not suitable for drinking purpose. Trend analysis showing decreasing trend in respect of fluoride. However, increasing trend is observed in respect of iron and no trend in respect of total hardness. In view of long-term adverse effects of iron on the health and material, there is immediate necessity for developing sustainable low-cost effective treatment technologies for such contaminants remediation for sustainable access to safe drinking water. It is important to state that in some of water samples the concentration of fluoride is either higher or lower than the desirable limit for drinking purposes. Since both the aspects are injurious to human health, a proper blending will be required to bring the fluoride concentration within the desirable limit. These findings may help in developing sustainable low-cost effective treatment technologies/strategies for contaminants remediation for sustainable access to safe drinking water.

REFERENCES

1. Mondal P, Bhowmick S, Chatterjee D, Figoli A, Bruggen B. V. Remediation of inorganic arsenic in groundwater for safe water supply: A critical assessment of technological solutions. Chemosphere 2013; 92: 157–170.
2. National Research Council (NRC), 1999. Arsenic in Drinking Water. The National Academies Press, Washington, DC, p. 330.
3. Pontius F. W, Brown K. G, Chen C. J. Health implications of arsenic in drinking water. J Am Water Works Assoc 1994; 86(9): 52–63.
4. Kapaj S, Peterson H, Liber K, Bhattacharya P. Human health effects from chronic arsenic poisoning –a review. J Environ Sci Health A 2006; 41(10): 2399–2428.
5. World Health Organization (WHO), Guidelines for drinking water quality. Recommendations, Vol. 1, 3rd ed., World Health Organization, Geneva; 2004, p. 306–308.
6. Mondal P, Majunder C. B, Mohanty B. Laboratory based approaches for arsenic remediation from contaminated water: recent developments. J Hazard Mater 2006; B137: 464–479.
7. Mohan D, Pittman C. U. Arsenic removal from water/ wastewater using adsorbents – A critical review. J Hazard Mater 2007; 142: 1–53.
8. Brinkel J, Khan M. H, Kraemer A. A systematic review of arsenic exposure and its social and mental health effects with special reference to Bangladesh. J Environ Res Public Health 2009; 6: 1609–1619.
9. Guo X, Fujino Y, Ye X, Liu J, Takesumi Y. Japan Inner Mongolia Arsenic Pollution Study Group, Association between multi-level inorganic arsenic exposure from drinking water and skin lesion in China. Int J Environ Res Public Health 2006; 3(3): 262–267.
10. Wade T. J, Xia Y, Wu K, Li Y, Ning Z, Le C, Lu X, Feng Y, He X, Mumford J. L, Increased mortality associated with well-water arsenic exposure in Inner Mongolia, China. Int J Environ Res Public Health 2009; 6: 1107–1123.

11. Habuda-Stanić M, Kuleš M, Kalajdžić B, Romić Ž, Quality of groundwater in eastern Croatia. The problem of arsenic pollution. Desalination 2007; 210: 157–162.
12. Brammer H, Ravenscroft P. Arsenic in groundwater: A threat to sustainable agriculture in South and South-east Asia. Environ Internat 2009; 35: 647–654.
13. Burkel R.S, Stoll R.C. Naturally occurring arsenic in sandstone aquifer water supply wells of North Eastern Wisconsin. Ground Water Monit. Rem 1999; 19: 114–121.
14. Chandrasekharam D, Karmakar J, Berner Z, Stueben D. Arsenic contamination in groundwater, Murshidabad district, West Bengal. Water-Rock Interaction, proceedings of the 10th International symposium. Balkema; 2001, p. 271–350.
15. Singh A. K, Arsenic contamination in the groundwater of North Eastern India. In: Proceedings of National Seminar on Hydrology, Roorkee, India; 2004.
16. Thambidurai P, Chandrashekhar A. K, Chandrasekharam D. Geochemical signature of arsenic-contaminated groundwater in Barak Valley (Assam) and surrounding areas, northeastern India. Procedia Earth and Planetary Science 2013: 7: 834–837.
17. Linthoingambi N. D, Chandra Y. I, Shihua Q. I. Recent status of arsenic contamination in groundwater of northeastern India – A review, report and opinion 2009; 1(3): 22–32.
18. Chakraborti D, Sengupta M. K, Rahman M.M, Ahmed S, Chowdhury U.K, Hossain M.A. Groundwater arsenic contamination and its health effects in the Ganga–Meghna–Brahmaputra plain. J Environ Monit 2004; 6(6): 74N–83N.
19. Nordborg G. E. D, Mahanta C. Arsenic in the groundwater of the Brahmaputra floodplains, Assam, India – Source, distribution and release mechanisms (Ph. D. Thesis)
20. APHA. 2012, Standard Methods for the Examination of Water and Wastewater, 22nd edn. American Public Health Association, Washington, D.C
21. Bureau of Indian Standards (BIS), IS 10500:2012, Indian Standard Drinking Water-Specification (Second Revision), New Delhi.
22. Disaster Risk Reduction, Indo Global Social Service Society, www.igsss.org.

23. Rural Volunteers Centre, Silapathar, Assam, Rural Technology Action Group North-East, Initiated and sponsored by the principal scientific advisor to the Government of India, https://www.iitg.ernet.in/mech/Rutag-pal/activities_10-11.htm,
24. Das S, Bora S. S, Lahan J. P, Barooah M, Yadav R. N. S, Chetia M. Groundwater arsenic contamination in north eastern states of India, J Environ Res Develop 2015; 09(03): 621–632
25. Deb KanungoTushar, Arsenic Mitigation Processes on Trial and Tested in Barak Valley, Assam, India, Int.J.Pharm Drug Anal Vol: 3 Issue:1 Page:12-18.

ANNEXURES I: IRRIGATION INDICES

District	Block	Locations	SAR	SSP	%Na	KI	RSC	PI	MH
Dhalai	Salema	Abhanga New	0.31	15.66	20.02	0.19	-0.60	62.35	14.20
Dhalai	Chawmanu	Chawmanu	2.52	53.53	54.44	1.15	0.60	84.78	37.42
Dhalai	Durga Ch'muhani	Darlang Basti	0.25	8.45	10.24	0.09	-0.90	47.06	63.83
Dhalai	Dumburnagar	Durga Cherra	1.44	39.17	44.65	0.64	-0.10	74.47	51.93
Dhalai	Durga Ch'muhani	Durga Chowmuhani	0.98	36.25	41.72	0.57	-0.70	74.30	39.92
Dhalai	Manu	J.M Complex, Chailengta	1.77	50.50	53.69	1.02	0.30	90.95	33.25
Dhalai	Durga Chowmuhani	Kali Kumar Para	0.42	16.75	22.95	0.20	-0.40	63.12	18.10
Dhalai	Ambassa	Lalchari	0.47	26.97	32.56	0.37	-0.20	97.75	49.93
Dhalai	Manu	Manu New	1.23	31.43	35.73	0.46	-0.70	60.97	63.83
Dhalai	Ganganagar	Nuna Cherra	1.33	47.21	49.21	0.89	-0.10	95.24	45.38
Dhalai	Manu	Sindhu Kumar	1.25	41.84	43.49	0.72	0.20	89.37	46.60
Gomti	Amarpur	Amarpur	1.98	62.58	67.77	1.67	-0.10	104.04	71.38
Gomti	Amarpur	Bampur	1.75	61.57	67.97	1.60	-0.20	102.12	49.93
Gomti	Killa	Dewanbari	0.91	34.49	36.23	0.53	-0.40	80.34	53.27
Gomti	Tepania	Dhawajnagar	0.78	41.49	44.13	0.71	-0.20	103.23	49.93
Gomti	Ompi	Twidu	0.43	19.41	31.91	0.24	-0.30	76.88	24.92
Gomti	Ompi	Ompi colony	3.27	65.36	71.25	1.89	-0.10	90.67	13.25
Gomti	Matabari	Gorjee Bazar	2.22	59.99	63.03	1.50	-0.50	88.19	45.38
Gomti	Amarpur	Jatanbari	2.30	67.71	72.32	2.10	-0.10	105.79	33.25
Gomti	Killa	Joingkami	0.97	37.50	39.24	0.60	-0.40	83.15	38.38
Gomti	Kankra-ban	Kankraban	1.29	49.11	52.24	0.96	-0.30	92.95	55.49
Gomti	Killa	Noabari-2	0.53	32.53	35.76	0.48	-0.20	103.71	33.25
Khowai	Kalyanpur	Kalyanpur	0.92	32.71	41.24	0.49	0.20	81.49	38.81
Khowai	Khowai	Khowai	0.82	25.77	34.27	0.35	-0.10	65.13	53.51
Khowai	Telia-mura	Pachim Howaibari	1.44	46.33	52.74	0.86	-0.60	80.65	49.93
Khowai	Kalyanpur	Kathalbari	0.46	21.41	28.41	0.27	-0.40	77.59	35.64
Khowai	Mungia-kami	Tuimadhu	1.22	37.36	43.84	0.60	-0.10	76.29	52.31
Khowai	Mungia-kami	45 Miles	3.84	58.90	59.60	1.43	3.21	84.72	80.52
North Tripura	Dasda	Ananda Bazar	0.91	35.21	39.14	0.54	-0.30	83.79	35.64
North Tripura	Yubaraj-nagar	Baghbassa	0.73	32.03	34.76	0.47	-0.30	85.81	41.59
North Tripura	Kadam-tala	Churaibari	1.32	56.98	59.26	1.32	-0.30	95.50	59.94
North Tripura	Panisagar	Deocherra	0.59	29.29	34.06	0.41	-0.60	74.06	59.94
North Tripura	Yubaraj-nagar	Dharmanagar	0.74	32.31	34.51	0.48	-0.20	88.76	33.25

District	Block	Locations	SAR	SSP	%Na	KI	RSC	PI	MH
North Tripura	Laljuri	Kanchanpur	2.06	50.13	53.24	1.01	-1.10	73.90	57.08
North Tripura	Damcherra	Khedacherra	0.97	26.50	27.58	0.36	-0.29	60.09	72.18
North Tripura	Yubaraj-nagar	Krishnapur	0.40	18.95	26.81	0.23	-0.50	73.04	59.94
North Tripura	Pani-sagar	Kunjanagar	0.27	14.93	16.52	0.18	-0.30	82.26	58.27
North Tripura	Kadam-tala	Lalchhara	1.80	48.75	51.74	0.95	-0.40	82.46	11.03
North Tripura	Laljuri	Laljuri	0.66	20.87	22.08	0.26	-2.20	45.11	51.55
North Tripura	Laljuri	Naba Joypara (Natun Basti)	0.26	11.95	15.88	0.14	-0.70	62.76	42.03
North Tripura	Damcherra	Narendra Nagar	0.20	10.59	13.46	0.12	-0.40	74.52	49.93
North Tripura	Panisagar	Panisagar	1.82	57.62	59.15	1.36	-0.60	83.44	55.49
North Tripura	Yubraj-naga	Rajnagar	0.95	31.25	32.46	0.45	-1.10	64.05	31.74
North Tripura	Kalacherra	Sanicherra	1.03	28.99	35.68	0.41	-1.60	55.28	59.31
North Tripura	Dasda	Satnala	1.38	33.30	35.92	0.50	-0.90	61.08	49.93
Sepahijala	Boxnagar	Dakshin Kalamcherra	1.16	42.89	48.34	0.75	-0.70	76.58	58.27
Sepahijala	Jampui-jala	Gongrai	1.32	36.63	44.12	0.58	0.00	72.81	34.54
Sepahijala	Kanthalia	Kanthalia Bazar	0.42	20.20	26.50	0.25	-0.30	80.03	35.64
Sepahijala	Nalchar	Rajib Nagar	0.33	24.60	32.72	0.33	-0.20	107.27	39.92
Sepahijala	Nalchar	Lalmaibari	0.24	8.92	12.20	0.10	-2.00	39.77	51.55
Sepahijala	Nalchar	Shivnagar	0.20	6.62	7.93	0.07	-2.90	31.14	69.95
Sepahijala	Jampui-jala	Tufaniamura	1.31	35.70	43.53	0.56	-0.10	70.56	49.93
South Tripura	Poangbari	Aamli Ghat	0.84	37.24	40.37	0.59	-0.20	93.42	39.92
South Tripura	Karbook	Ananda Bandhu Para	0.47	22.49	23.50	0.29	-0.50	75.88	61.48
South Tripura	Rupaichhari	Baishnabpur	1.00	38.17	40.66	0.62	-0.10	90.32	38.38
South Tripura	Rajnagar	Barkashari	0.49	21.94	27.34	0.28	-0.40	76.57	46.60
South Tripura	Rajnagar	Gaurangar bazar	0.41	23.23	25.54	0.30	-0.40	83.60	44.37
South Tripura	Satchand	Bijaynagar	1.29	45.47	47.80	0.83	-0.80	74.24	58.27
South Tripura	Hrishya-mukh	Jagatpur	2.71	51.35	51.91	1.06	1.01	79.74	60.55
South Tripura	Satchand	Kalirbazar	0.86	33.21	35.60	0.50	-0.40	79.95	33.25
South Tripura	Rupaichhari	Magroom	0.30	14.93	19.29	0.18	-0.70	65.72	66.61
South	Satchand	Manubazar	0.34	18.66	20.17	0.23	0.00	96.29	45.38

District	Block	Locations	SAR	SSP	%Na	KI	RSC	PI	MH
Tripura									
South Tripura	Bharat Chandra Nagar	Manur Mukh	1.43	35.77	40.85	0.56	0.90	73.24	39.32
South Tripura	Bagafa	Michara	2.73	51.56	52.12	1.06	0.91	79.83	72.68
South Tripura	Satchand	Motu Mogpara	2.09	62.36	63.84	1.66	-0.20	98.83	24.92
South Tripura	Satchand	Paschim Jalefa OW	0.40	20.45	23.57	0.26	-0.10	90.05	49.93
South Tripura	Poangbari	Poangbari	0.66	29.93	32.74	0.43	-0.50	78.84	58.27
South Tripura	Poangbari	Purba Takka	0.81	37.51	40.72	0.60	-0.40	86.65	33.25
South Tripura	Rajnagar	Radhanagar	0.27	15.88	18.19	0.19	-0.50	75.42	49.93
South Tripura	Rajnagar	Rajnagar	0.84	43.44	44.36	0.77	0.00	116.54	66.61
South Tripura	Satchand	Sabroom	0.89	38.56	40.21	0.63	0.20	105.91	19.92
South Tripura	Satchand	Shashi-Chandrapur	0.34	14.74	19.49	0.17	-1.20	52.32	47.30
South Tripura	Poangbari	Srinagar	1.20	42.76	44.68	0.75	0.40	100.23	53.78
Unakoti	Kumarghat	Chandra- moni Kami	0.45	17.88	22.82	0.22	-1.50	48.19	38.02
Unakoti	Kumarghat	Dumdum	0.46	25.36	30.18	0.34	-0.10	99.61	44.37
Unakoti	Chandipur	Jarultali	0.35	14.48	17.05	0.17	-1.60	43.31	71.38
Unakoti	Kumarghat	Kanchanbari	2.07	45.04	47.11	0.82	-1.70	66.10	56.19
Unakoti	Kumarghat	Kanchan-cherra	1.28	51.92	55.48	1.08	-0.40	89.57	28.49
Unakoti	Pecharthal	Karaicherra	0.22	8.18	13.93	0.09	-1.60	44.44	66.61
Unakoti	Chandipur	Pancham-nagar	0.21	10.42	14.44	0.12	-0.20	76.72	37.42
Unakoti	Pecharthal	Pecharthal	0.85	24.67	26.15	0.33	0.50	65.57	55.82
West Tripura	Jirania	Sadhupara	0.43	14.99	18.44	0.18	-0.10	61.60	56.60
West Tripura	Mohanpur	Ishanpur	0.85	32.28	38.50	0.48	-0.30	80.58	37.42
West Tripura	Jirania	Khumulwng	0.16	9.13	11.23	0.10	-0.40	76.93	58.27
West Tripura	Mohanpur	Simna	0.55	24.68	27.60	0.33	-0.30	81.15	28.49
West Tripura	Hezamara	Pukua bari	0.45	20.20	24.14	0.25	-0.20	79.26	37.42
West Tripura	Mohanpur	Tarapur	0.97	33.81	38.27	0.51	0.00	83.22	94.43
West Tripura	Old Agartala	R.K Nagar	0.52	25.97	29.15	0.35	0.00	96.62	45.38
West Tripura	Agartala M. C.	A.D Nagar	0.67	23.93	27.46	0.31	-1.90	44.87	60.81
West Tripura	Dukli	Madhuban	1.18	36.60	39.41	0.58	-1.70	55.72	80.92

District	Block	Locations	SAR	SSP	%Na	KI	RSC	PI	MH
West Tripura	AMC	Panchamukh	0.32	16.04	19.28	0.19	-1.00	54.01	42.78
West Tripura	AMC	Hapania	0.89	39.91	43.10	0.66	0.10	106.74	44.37
West Tripura	AMC	Madhuban	1.84	49.91	52.46	1.00	-1.40	66.06	41.10
West Tripura	AMC	Subhashnagar	0.76	35.08	38.53	0.54	0.10	103.23	39.92
West Tripura	AMC	Bordowali	0.37	16.31	18.62	0.19	-0.30	73.32	61.05
West Tripura	AMC	GSI Campus	0.68	31.43	34.72	0.46	-0.10	93.83	54.48
West Tripura	AMC	Narsinghgarh	0.60	27.07	28.14	0.37	-0.10	88.60	69.18
West Tripura	AMC	Lankamura	0.68	27.63	29.36	0.38	-0.10	83.08	49.93
West Tripura	AMC	Nutan Nagar	0.34	13.81	14.87	0.16	-0.50	64.94	54.48
West Tripura	AMC	Barjala	0.30	13.96	17.33	0.16	-0.80	62.03	70.54
West Tripura	AMC	Ramnagar	0.90	37.86	40.21	0.61	0.10	99.79	36.29
West Tripura	AMC	AD Nagar	1.36	51.81	53.67	1.08	-0.20	98.52	49.93
West Tripura	AMC	Badharghat	0.47	22.47	27.35	0.29	-0.70	68.71	53.78
West Tripura	AMC	ONGC Colony	0.69	31.62	34.70	0.46	0.10	99.79	54.48
West Tripura	AMC	Khumulwng	0.86	40.54	42.60	0.68	-0.20	98.16	37.42
West Tripura	AMC	Sadhupara	0.49	17.57	21.91	0.21	-0.40	63.93	85.16
West Tripura	AMC	Reshambagan	1.91	53.26	56.61	1.14	0.30	96.83	49.93
West Tripura	AMC	Gurudaspara	0.83	38.20	41.57	0.62	0.30	113.48	33.25
West Tripura	AMC	R K Nagar	0.64	30.14	33.37	0.43	-0.20	90.45	45.38
West Tripura	AMC	Nanda Nagar	0.57	28.59	32.15	0.40	0.00	100.08	59.94

ANNEXURES II: DISTRICT WISE STATISTICAL DATA OF TRIPURA

S. No.	Districts		pH	EC (µs/cm) 25°C	Turbidity (NTU)	TDS	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
1	Dhalai	Min	7.6	87.5	0.0	44.9	0.0	36.6	10.6	9.0	0.3	0.3	8.0	2.4	40.0	6.0	2.9
		Max	8.6	470.7	0.2	244.3	15.0	158.7	67.4	40.1	4.7	0.7	36.0	27.9	180.0	63.6	15.9
2	Gomti	Min	7.4	74.2	0.0	38.8	0.0	24.4	14.2	6.0	0.8	0.2	4.0	2.4	30.0	6.7	1.8
		Max	8.3	263.6	0.3	136.8	6.0	79.4	53.2	134.0	7.0	0.4	26.0	9.7	80.0	65.1	34.7
3	Khowai	Min	7.7	152.3	0.0	79.6	0.0	48.8	17.7	11.4	0.2	0.4	14.0	6.1	70.0	8.8	5.9
		Max	8.6	841.1	0.2	440.2	51.0	311.3	67.4	51.0	6.9	1.4	26.0	35.2	180.0	118.6	19.1
4	North Tripura	Min	6.4	34.5	0.0	19.7	0.0	12.2	7.1	0.1	0.0	0.1	2.0	1.2	15.0	1.2	0.1
		Max	8.6	515.0	1.0	269.7	18.0	189.3	117.0	57.1	13.7	1.7	38.0	31.5	190.0	48.5	18.3
5	Sepahijala	Min	7.3	50.6	0.0	24.8	0.0	18.3	10.6	2.1	0.1	0.3	6.0	2.4	25.0	3.8	2.4
		Max	8.7	508.0	0.3	253.5	12.0	140.4	74.4	58.4	7.1	0.9	34.0	34.0	200.0	35.7	23.6
6	South Tripura	Min	7.6	71.1	0.0	37.3	0.0	24.4	10.6	0.0	0.0	0.2	4.0	2.4	30.0	4.3	0.7
		Max	8.9	553.0	0.4	293.6	18.0	225.9	70.9	32.7	4.4	0.8	40.0	29.1	165.0	80.7	17.2
7	Unakoti	Min	4.2	93.6	0.0	50.0	0.0	18.3	7.1	0.0	0.0	0.0	10.0	2.4	35.0	4.3	3.0
		Max	9.0	529.7	0.3	286.1	15.0	207.6	141.8	18.2	6.7	0.7	30.0	24.3	170.0	60.3	8.9
8	West Tripura	Min	6.3	66.0	0.0	32.8	0.0	18.3	7.1	0.0	0.0	0.2	2.0	3.6	40.0	2.8	1.0
		Max	8.9	448.6	0.3	221.9	6.0	164.8	95.7	32.1	12.1	0.7	26.0	27.9	150.0	38.9	9.3

ANNEXURE – III

Chemical Quality of Water Samples Collected from GWMS of Tripura during Pre-monsoon Season, 2022 (Basic constituents)

District	Block	Location	Long	Lat	pH	EC (µs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
Tripura																	
Khowai	Mungia-kami	45 Miles	91.96056	23.95250	8.35	110.80	21.00	610.49	21.27	7.59	0.99	0.44	125.00	36.03	8.48	145.96	68.60
Dhalai	Salema	Abhanga New	91.83083	24.05389	7.04	232.90	0.00	109.89	10.64	5.55	2.00	0.14	80.00	22.02	6.06	13.29	5.74
Dhalai	Ambassa	Ambassa	91.86667	23.91528	7.44	210.80	0.00	97.68	7.09	15.86	0.99	0.25	75.00	18.01	7.27	14.45	6.05
North Tripura	Dasda	Ananda Bazar	92.210833	23.848056	7.37	229.30	0.00	103.78	10.64	1.71	11.79	0.27	40.00	12.01	2.42	20.43	11.96
North Tripura	Yubarajnagar	Baghbassa	92.21861	24.34056	7.15	175.30	0.00	85.47	10.64	5.39	3.20	0.23	60.00	14.01	6.06	13.14	6.65
South Tripura	Rupaichhari	Baishnabpur	91.76608	23.04547	7.02	114.40	0.00	42.73	7.09	22.97	4.84	0.21	50.00	10.01	6.06	11.75	3.61
Unakoti	Kumarghat	Chandra-moni Kami	92.198333	24.111944	7.38	274.20	0.00	115.99	14.18	10.75	5.18	0.16	100.00	24.02	9.70	13.54	8.22
Dhalai	Chawmanu	Chawmanu	91.99900	23.86219	7.88	426.80	0.00	201.46	31.91	10.69	3.63	0.36	105.00	28.02	8.48	45.00	6.54

District	Block	Location	Long	Lat	pH	EC (μs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
North Tripura	Kadamtala	Churaibari	92.24667	24.43778	7.36	244.40	0.00	97.68	17.73	21.72	8.16	0.37	80.00	22.02	6.06	23.45	9.06
North Tripura	Dasda	Dataram	92.22833	23.76528	7.75	322.10	0.00	164.83	10.64	4.42	1.88	0.55	120.00	26.02	13.34	18.00	6.32
North Tripura	Panisagar	Deocherra	92.15972	24.31028	6.58	236.60	0.00	30.52	21.27	1.74	33.57	0.29	30.00	6.00	3.64	21.03	9.87
Gomati	Killa	Dewanbari	91.53528	23.55778	6.91	204.80	0.00	79.36	10.64	15.22	7.16	0.30	85.00	20.02	8.49	7.75	2.76
North Tripura	Yubarajnagar	Dharmanagar	92.15972	24.37889	7.36	209.00	0.00	73.26	14.18	21.91	4.48	0.34	70.00	16.01	7.27	12.61	8.38
Gomati	Matabari	Dhawajnagar	91.46500	23.55361	6.30	86.03	0.00	30.52	10.64	14.45	9.51	0.12	25.00	8.01	1.21	17.16	3.94
Unakoti	Kumarghat	Dumdum	91.945197	24.129543	7.14	109.30	0.00	54.94	7.09	24.05	10.38	0.16	40.00	8.01	4.85	14.28	6.52
Dhalai	Dumburnagar	Durga Cherra	91.82583	23.60889	7.18	232.50	0.00	128.20	14.18	8.55	1.26	0.42	110.00	26.02	10.91	11.20	2.44
Dhalai	Durga Chowmuhani	Durga Chowmuhani	91.86028	24.12167	6.73	309.50	0.00	61.05	35.45	22.52	22.06	0.09	65.00	14.01	7.27	31.90	10.60
Unakoti	Gaurnagar	Gaurnagar	92.01667	24.32500	6.82	321.80	0.00	48.84	31.91	26.92	25.70	0.09	65.00	14.01	7.27	24.24	18.57
Sepahijala	Jampuijala	Gongrai	91.45389	23.65667	6.63	58.43	0.00	30.52	7.09	22.66	1.04	0.18	45.00	4.00	8.49	3.49	3.60
Gomati	Matabari	Gorjee Bazar	91.50583	23.42667	6.92	197.50	0.00	42.73	28.36	9.50	25.16	0.15	60.00	12.01	7.28	13.57	9.78

District	Block	Location	Long	Lat	pH	EC (µs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
West Tripura	Mohanpur	Ishanpur	91.39917	24.04528	6.75	413.10	0.00	85.47	60.27	12.89	35.83	0.25	115.00	28.02	10.91	31.43	14.13
Unakoti	Chandipur	Jarultali	91.985833	24.254167	6.90	114.60	0.00	42.73	10.64	32.34	3.06	0.11	30.00	6.00	3.64	18.57	5.99
Gomati	Amarpur	Jatanbari	91.75833	23.42000	6.32	189.30	0.00	30.52	17.73	16.09	17.86	0.11	25.00	8.01	1.21	15.26	16.73
Gomati	Killa	Joingkami	91.51750	23.60111	6.99	438.60	0.00	115.99	31.91	23.47	16.80	0.29	90.00	18.01	10.91	34.71	3.10
Dhalai	Durga Chowmuhani	Kali Kumar Para	91.86000	23.10139	6.59	109.70	0.00	18.31	10.64	41.59	18.25	0.10	75.00	24.02	3.63	6.86	5.15
South Tripura	Satchand	Kalirbazar	91.59983	23.11480	7.62	115.90	0.00	85.47	10.64	8.27	0.84	0.32	65.00	12.01	8.49	12.15	4.03
Dhalai	Durga Chowmuhani	Kamalpur	91.81528	24.16944	6.96	194.10	0.00	54.94	14.18	21.17	4.16	0.13	65.00	12.01	8.49	8.28	4.41
Unakoti	Kumarghat	Kanchanbari	91.976667	24.113611	7.26	497.20	0.00	97.68	53.18	1.23	3.39	0.14	85.00	20.02	8.49	33.20	7.52
Unakoti	Kumarghat	Kanchan-cherra	92.0025	24.085528	7.01	249.80	0.00	42.73	17.73	33.57	35.08	0.15	30.00	8.01	2.42	37.30	13.89
North Tripura	Dasda	Kanchanpur	92.19500	24.04556	7.25	612.70	0.00	85.47	63.81	11.81	8.22	0.18	100.00	18.01	13.34	35.96	11.02
Gomati	Kankraban	Kankraban	91.40194	23.48750	6.92	192.50	0.00	91.57	14.18	11.81	5.24	0.43	105.00	26.02	9.70	5.78	2.81
Unakoti	Pecharthal	Karaicherra	92.15139	24.14000	7.49	255.60	0.00	79.36	28.36	8.27	4.49	0.23	75.00	18.01	7.27	21.23	5.36

District	Block	Location	Long	Lat	pH	EC (μs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
Khowai	Kalyanpur	Kathalbari	91.60694	23.97278	7.00	223.10	0.00	103.78	21.27	11.74	3.67	0.68	90.00	16.01	12.13	8.81	8.27
North Tripura	Damcherra	Khedacherra	92.32250	24.09444	7.58	418.60	0.00	268.61	10.64	5.78	0.64	0.24	180.00	50.04	13.33	32.17	6.56
Khowai	Khowai	Khowai	91.60500	24.06389	7.38	228.80	0.00	134.31	7.09	5.40	0.73	0.54	105.00	22.02	12.13	13.89	2.90
West Tripura	Belbari	Khumulwng	91.433	23.818	7.01	89.99	0.00	24.42	7.09	15.25	1.19	0.21	40.00	12.01	2.42	2.73	0.90
North Tripura	Yubrajnagar	Krishnapur	92.15778	24.33944	7.43	469.70	0.00	122.10	35.45	8.56	16.46	0.20	125.00	36.03	8.48	15.34	9.65
Unakoti	Kumarghat	Kumarghat	92.04194	24.16500	7.41	243.40	0.00	128.20	7.09	9.22	5.47	0.15	100.00	30.02	6.05	12.35	11.03
North Tripura	Panisagar	Kunjanagar	92.205556	24.245556	7.25	102.90	0.00	54.94	10.64	1.21	0.51	0.21	35.00	8.01	3.64	8.95	2.77
Dhalai	Ambassa	Lalchari	91.85444	23.93417	6.59	74.90	0.00	30.52	7.09	3.21	6.79	0.12	30.00	8.01	2.42	3.63	3.91
North Tripura	Kadamtala	Lalchhara	92.19222	24.43250	7.53	416.10	0.00	128.20	28.36	18.54	7.70	0.30	110.00	32.03	7.27	26.48	8.85
North Tripura	Laljuri	Laljuri	92.19833	24.11194	7.04	205.00	0.00	73.26	60.27	6.09	34.95	0.16	35.00	8.01	3.64	62.04	9.08
West Tripura	Dukli	Madhuban	91.28583	23.78861	6.14	471.50	0.00	18.31	53.18	4.42	40.85	0.13	45.00	12.01	3.63	39.11	6.00
South Tripura	Rupaichhari	Magroom	91.77552	23.07297	6.99	124.30	0.00	61.05	17.73	3.99	0.00	0.13	45.00	12.01	3.63	16.32	0.96
Dhalai	Manu	Manu New	91.99194	24.00250	7.68	369.80	0.00	225.88	28.36	11.00	13.29	0.30	170.00	34.03	20.61	32.51	4.32

District	Block	Location	Long	Lat	pH	EC (µs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
South Tripura	Bagafa	Michara	91.51278	23.26639	7.76	393.80	0.00	262.51	35.45	23.41	0.80	0.65	135.00	24.02	18.19	83.22	4.50
North Tripura	Laljuri	Naba Joypara (Natun Basti)	92.21639	24.17500	7.04	167.90	0.00	61.05	10.64	27.92	7.86	0.20	40.00	12.01	2.42	18.99	11.80
North Tripura	Damcherra	Narendra Nagar	92.28519	24.24155	7.43	180.80	0.00	103.78	7.09	3.62	0.92	0.25	70.00	12.01	9.70	11.01	5.20
Gomati	Matabari	Noabari	91.56583	23.51194	6.86	470.60	0.00	183.15	28.36	27.74	10.17	0.22	175.00	42.03	16.97	28.90	8.12
Dhalai	Ganganagar	Nuna Cherra	91.85528	23.78750	6.87	133.30	0.00	61.05	10.64	9.01	5.32	0.26	55.00	18.01	2.42	6.87	2.48
Gomati	Ompi	Ompi colony	91.64222	23.67181	7.05	270.40	0.00	109.89	28.36	15.54	15.87	0.26	135.00	24.02	18.19	10.27	8.28
Khowai	Telia-mura	Pachim Howaibari	91.59194	23.81000	7.00	401.20	0.00	67.15	39.00	17.40	20.43	0.24	80.00	12.01	12.13	28.75	10.37
Unakoti	Chandipur	Panchamnagar	91.98111	24.21806	7.04	146.70	0.00	73.26	7.09	3.33	12.12	0.09	65.00	16.01	6.06	8.29	3.55
North Tripura	Panisagar	Panisagar	92.18333	24.24167	6.68	476.10	0.00	24.42	39.00	36.20	42.89	0.45	65.00	10.01	9.70	28.82	20.06
Unakoti	Pecharthal	Pecharthal	92.09972	24.19861	7.56	410.30	0.00	177.04	14.18	13.95	9.23	0.12	170.00	42.03	15.76	10.70	6.82
South Tripura	Poangbari	Poangbari	91.57010	23.02757	7.62	184.30	0.00	103.78	10.64	15.01	13.06	0.26	90.00	18.01	10.91	18.24	7.29

District	Block	Location	Long	Lat	pH	EC (µs/cm) 25°C	CO_3^-	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-	Ca^{+2} (as Ca)	Mg^{+2} (as Mg)	TH (as $CaCO_3$)	Na	K
							mg/L										
North Tripura	Yubrajnagar	Rajnagar 1	92.10111	24.31833	7.18	164.40	0.00	91.57	7.09	3.33	1.77	0.14	65.00	6.00	12.13	4.97	7.94
South Tripura	Rajnagar	Rajnagar	91.39167	23.23222	7.33	76.12	0.00	48.84	10.64	32.55	11.40	0.12	75.00	16.01	8.49	10.14	1.52
South Tripura	Satchand	Sabroom	91.72381	23.00622	7.02	88.78	0.00	48.84	14.18	4.30	15.40	0.16	55.00	10.01	7.28	8.26	1.98
Dhalai	Manu	Sadhupara	91.96056	23.95250	7.04	278.30	0.00	158.73	17.73	12.21	1.86	0.26	120.00	46.04	1.19	19.95	5.38
North Tripura	Dasda	Satnala	92.205833	23.975556	7.56	509.50	0.00	170.94	28.36	8.04	3.41	0.24	165.00	36.03	18.19	15.75	8.15
South Tripura	Satchand	Shashi-Chandrapur	91.633334	22.966667	7.52	166.60	0.00	103.78	10.64	11.78	5.15	0.27	75.00	14.01	9.70	18.22	6.46
West Tripura	Mohanpur	Simna	91.393333	24.092222	8.27	239.10	0.00	30.52	14.18	7.61	42.29	0.00	50.00	16.01	2.42	11.53	2.93
Dhalai	Manu	Sindhu Kumar	91.960556	23.9525	7.00	250.30	0.00	146.52	10.64	13.01	4.56	0.33	85.00	20.02	8.49	21.30	6.97
South Tripura	Poangbari	Srinagar	91.55363	22.99885	7.44	258.00	0.00	73.26	42.54	5.69	0.00	0.20	75.00	16.01	8.49	20.94	8.26
Sepahijala	Jampui-jala	Tufaniamura	91.40694	23.69861	7.71	237.10	0.00	140.41	17.73	16.96	6.41	0.35	95.00	4.00	20.63	27.35	18.16
South Tripura	Satchand	Tuichama	91.66168	23.15667	6.97	317.50	0.00	122.10	14.18	22.49	9.18	0.87	130.00	32.03	12.12	14.21	4.14

ANNEXURE IV

Chemical Quality of Water Samples Collected from GWMS of Tripura during Pre-monsoon Season, 2022 (Fe, As, U)

District	Block	Location	Long	Lat	Fe (mg/L)	As (ug/L)	U (ug/L)
Tripura							
Khowai	Mungia-kami	45 Miles	91.96056	23.95250	0.59	0.05	0.08
Dhalai	Salema	Abhanga New	91.83083	24.05389	1.65	0.10	0.00
Dhalai	Ambassa	Ambassa	91.86667	23.91528	0.25	0.09	0.17
North Tripura	Dasda	Ananda Bazar	92.21083333	23.848056	1.24	0.05	0.08
North Tripura	Yubarajnagar	Baghbassa	92.21861	24.34056	0.42	0.08	0.04
South Tripura	Rupaichhari	Baishnabpur	91.76608	23.04547	1.09	0.04	0.00
Unakoti	Kumarghat	Chandra- moni Kami	92.19833333	24.111944	0.74	0.00	0.17
Dhalai	Chawmanu	Chawmanu	91.99900	23.86219	2.85	0.14	0.00
North Tripura	Kadamtala	Churaibari	92.24667	24.43778	0.27	0.04	0.35
North Tripura	Dasda	Dataram	92.22833	23.76528	0.11	0.05	0.21
North Tripura	Panisagar	Deocherra	92.15972	24.31028	0.16	0.10	0.02
Gomati	Killa	Dewanbari	91.53528	23.55778	2.83	0.20	0.01
North Tripura	Yubarajnagar	Dharmanagar	92.15972	24.37889	0.23	0.48	0.17
Gomati	Matabari	Dhawajnagar	91.46500	23.55361	0.10	0.00	0.00
Unakoti	Kumarghat	Dumdum	91.945197	24.129543	0.87	0.26	0.00

District	Block	Location	Long	Lat	Fe (mg/L)	As (ug/L)	U (ug/L)
Dhalai	Dumburnagar	Durga Cherra	91.82583	23.60889	0.23	0.70	0.00
Dhalai	Durga Chowmuhani	Durga Chowmuhani	91.86028	24.12167	0.16	0.50	0.00
Unakoti	Gaurnagar	Gaurnagar	92.01667	24.32500	0.14	0.19	0.02
Sepahijala	Jampuijala	Gongrai	91.45389	23.65667	0.01	0.09	0.00
Gomati	Matabari	Gorjee Bazar	91.50583	23.42667	2.97	0.00	0.00
West Tripura	Mohanpur	Ishanpur	91.39917	24.04528	0.11	0.00	0.00
Unakoti	Chandipur	Jarultali	91.98583333	24.254167	0.18	0.00	0.00
Gomati	Amarpur	Jatanbari	91.75833	23.42000	0.00	0.00	0.00
Gomati	Killa	Joingkami	91.51750	23.60111	0.16	0.00	0.04
Dhalai	Durga Chowmuhani	Kali Kumar Para	91.86000	23.10139	0.27	0.13	0.03
South Tripura	Satchand	Kalirbazar	91.59983	23.11480	0.01	0.00	0.00
Dhalai	Durga Chowmuhani	Kamalpur	91.81528	24.16944	1.55	0.28	0.08
Unakoti	Kumarghat	Kanchanbari	91.97666667	24.113611	0.18	0.15	0.00
Unakoti	Kumarghat	Kanchan-cherra	92.0025	24.085528	0.16	1.58	0.01
North Tripura	Dasda	Kanchanpur	92.19500	24.04556	0.66	0.32	0.02
Gomati	Kankraban	Kankraban	91.40194	23.48750	0.01	0.10	0.00
Unakoti	Pecharthal	Karaicherra	92.15139	24.14000	0.61	0.06	0.00
Khowai	Kalyanpur	Kathalbari	91.60694	23.97278	0.05	0.36	0.00

District	Block	Location	Long	Lat	Fe (mg/L)	As (ug/L)	U (ug/L)
North Tripura	Damcherra	Khedacherra	92.32250	24.09444	0.89	0.51	0.11
Khowai	Khowai	Khowai	91.60500	24.06389	0.01	0.00	0.00
West Tripura	Belbari	Khumulwng	91.433	23.818	0.03	1.84	0.00
North Tripura	Yubrajnagar	Krishnapur	92.15778	24.33944	3.17	0.39	0.33
Unakoti	Kumarghat	Kumarghat	92.04194	24.16500	0.38	0.06	0.00
North Tripura	Panisagar	Kunjanagar	92.20555556	24.245556	0.36	0.07	0.00
Dhalai	Ambassa	Lalchari	91.85444	23.93417	0.23	0.51	0.00
North Tripura	Kadamtala	Lalchhara	92.19222	24.43250	0.68	0.12	0.40
North Tripura	Laljuri	Laljuri	92.19833	24.11194	0.12	0.14	0.04
West Tripura	Dukli	Madhuban	91.28583	23.78861	0.22	0.00	0.00
South Tripura	Rupaichhari	Magroom	91.77552	23.07297	3.17	0.00	0.00
Dhalai	Manu	Manu New	91.99194	24.00250	0.04	0.12	0.00
South Tripura	Bagafa	Michara	91.51278	23.26639	0.19	0.03	0.03
North Tripura	Laljuri	Naba Joypara (Natun Basti)	92.21639	24.17500	0.35	0.09	0.01
North Tripura	Damcherra	Narendra Nagar	92.28519	24.24155	0.68	0.07	0.02
Gomati	Matabari	Noabari	91.56583	23.51194	0.53	0.00	0.00
Dhalai	Ganganagar	Nuna Cherra	91.85528	23.78750	0.61	0.07	0.26
Gomati	Ompi	Ompi colony	91.64222	23.67181	3.20	0.00	0.01
Khowai	Telia-mura	Pachim Howaibari	91.59194	23.81000	2.55	0.15	0.05

District	Block	Location	Long	Lat	Fe (mg/L)	As (ug/L)	U (ug/L)
Unakoti	Chandipur	Panchamnagar	91.98111	24.21806	0.27	0.10	0.04
North Tripura	Panisagar	Panisagar	92.18333	24.24167	0.23	0.15	0.12
Unakoti	Pecharthal	Pecharthal	92.09972	24.19861	0.22	0.41	0.65
South Tripura	Poangbari	Poangbari	91.57010	23.02757	0.31	0.00	0.00
North Tripura	Yubrajnagar	Rajnagar 1	92.10111	24.31833	0.33	0.05	0.06
South Tripura	Rajnagar	Rajnagar	91.39167	23.23222	0.02	0.05	0.00
South Tripura	Satchand	Sabroom	91.72381	23.00622	0.02	1.28	0.00
Dhalai	Manu	Sadhupara	91.96056	23.95250	0.03	0.20	0.00
North Tripura	Dasda	Satnala	92.20583333	23.975556	0.63	0.09	0.01
South Tripura	Satchand	Shashi-Chandrapur	91.633334	22.966667	2.92	0.00	0.00
West Tripura	Mohanpur	Simna	91.39333333	24.092222	0.37	0.15	0.01
Dhalai	Manu	Sindhu Kumar	91.96055556	23.9525	0.02	0.04	0.12
South Tripura	Poangbari	Srinagar	91.55363	22.99885	0.16	0.00	0.00
Sepahijala	Jampui-jala	Tufaniamura	91.40694	23.69861	0.02	0.00	0.01
South Tripura	Satchand	Tuichama	91.66168	23.15667	0.03	0.12	0.00