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नगालैंड के सतही जलभृत में भूजल की गुणवत्ता

GROUND WATER QUALITY IN SHALLOW AQUIFER OF NAGALAND

केंद्रीय भूजल बोर्ड

Central Ground Water Board

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NORTH EASTERN REGION

गुर्वाहाटी

GUWAHATI

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FOREWORD

Groundwater serves as an important source for drinking water and irrigation in Nagaland. Of late, owing to increased anthropogenic activities as well as geogenic actions groundwater quality issues have posed a threat in the state. Hence it is crucial to have prior information on the groundwater quality available in Nagaland for judicious management of this resource.

The Central Ground Water Board, North Eastern Region, regularly 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.

Sixteen physico-chemical parameters including pH, EC, TDS, turbidity, carbonate and bicarbonate alkalinity, total alkalinity, calcium, magnesium, total hardness, chloride, sodium, potassium, sulphate, nitrate, and fluoride were analyzed for the samples collected within the state. Heavy metals, viz., Iron and Arsenic and radioactive Uranium content of the samples were also being considered for a holistic approach in characterizing the groundwater quality of Nagaland.

The dedicated efforts of the officers of the Board for compiling the data and preparing the report deserve appreciation. This report will help in better understanding the quality aspects of groundwater resources in Nagaland 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.

Regional Director
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GROUND WATER QUALITY IN SHALLOW AQUIFER OF NAGALAND

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Table of Contents

Chapter 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

With increasing demand of groundwater (GW) for municipal, agricultural and industrial purposes the stress on this vital water resource is growing day by day. The overall use and management of GW plays an essential role. More than 2.5 billion people across the globe directly depends on GW consumption and approximately 50% of the arable land is irrigated by GW. GW serves as a significant natural resource not only because of its sustainability but also due to its higher efficiency (Abou Zakhem B. & Hafez R., 2015).

The quality of recharged water, inland surface water, atmospheric precipitation, climate change and sub-surface geochemical processes are some of the factors that determine the quality of GW (Şen, Z., 2015, Srivastava P. K. et al., 2012). When contaminants are present in GW this not only affects water quality but also causes hazard to human health and other living species, economic development as well. Changes in GW quality occurs because of infiltrated particles in the soil (Fitts, 2013), co-occurrence of multifarious organic and inorganic constituents, comprising of heavy metals, nitrates, sulfates and pesticides culminates in the deterioration of the caliber of the GW in numerous regions. The levels of these contaminants may exceed the permissible limits set by the World Health Organization (WHO) or Bureau of Indian Standards (BIS) in the Indian scenario. Periodic monitoring of concentration of physico-chemical parameters for drinking and agricultural purpose is essential and also the criteria for contamination must be improved from time to time (Bhardwaj R. M., 2005).

Groundwater quality is shaped by both natural and anthropogenic processes. Among the natural factors influencing initial water composition are:

1. The chemistry of precipitation.

2. The leaching of organic and inorganic materials from soils, rocks, and vegetation as water infiltrates the surface and moves through subsurface geological formations.

3. The duration of contact between water and geological materials.

As groundwater flows through geological formations, it acquires a range of dissolved inorganic chemical constituents in varying concentrations due to chemical and biochemical interactions. These interactions dictate the levels of dissolved minerals present in groundwater. Groundwater quality is further influenced by contributions from the atmosphere, surface water bodies, and human activities. Anthropogenic impacts on water quality occur when groundwater is extracted or when chemicals and pollutants are introduced directly into aquifers. Waste discharges from agricultural, industrial, and urban activities often lead to the introduction of contaminants into the groundwater system. A detailed list of waste sources and their associated pollutants, with relevance to groundwater contamination in the North Eastern Region, is provided 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

Consequently, assessing groundwater quality is critical for hydrogeological research. The variability in groundwater quality within a region is determined by physicochemical parameters that are strongly influenced by geological formations and anthropogenic activities. This document provides a comprehensive analysis of groundwater quality of Nagaland.

The aim of this study is to determine the nature of GW in Nagaland state alongwith the suitability for drinking as well as irrigation purposes. Here we have elaborately studied the various physicochemical parameters in GW samples collected mostly from the densely inhabited district of Dimapur of Nagaland state in north-eastern part of India where GW is considered a primary source of water. This GW quality report for Nagaland aims to provide a thorough insight into the current status of GW quality in the state. This findings from this report would help to determine the suitability of GW for domestic and irrigation purposes while drawing the attention towards contaminants posing as health hazards for human life. For the implementation of effective management strategies in order to prevent further improve the GW quality, identification of these sources is an imperative task.

1.2.STUDY AREA

Nagaland (Figure 1) has an area of 16,579 square kilometers. The state capital is Kohima. It has a total population of 19,90,036. Nagaland is bounded by Assam to the west and north-west, Arunachal Pradesh to the north-east, Manipur to the south and Myanmar to the east. Nagaland spreads within Latitude 93° 41’00” E to 93°50’10” E and Longitude 25°46’30” N to 25°58’30” N.

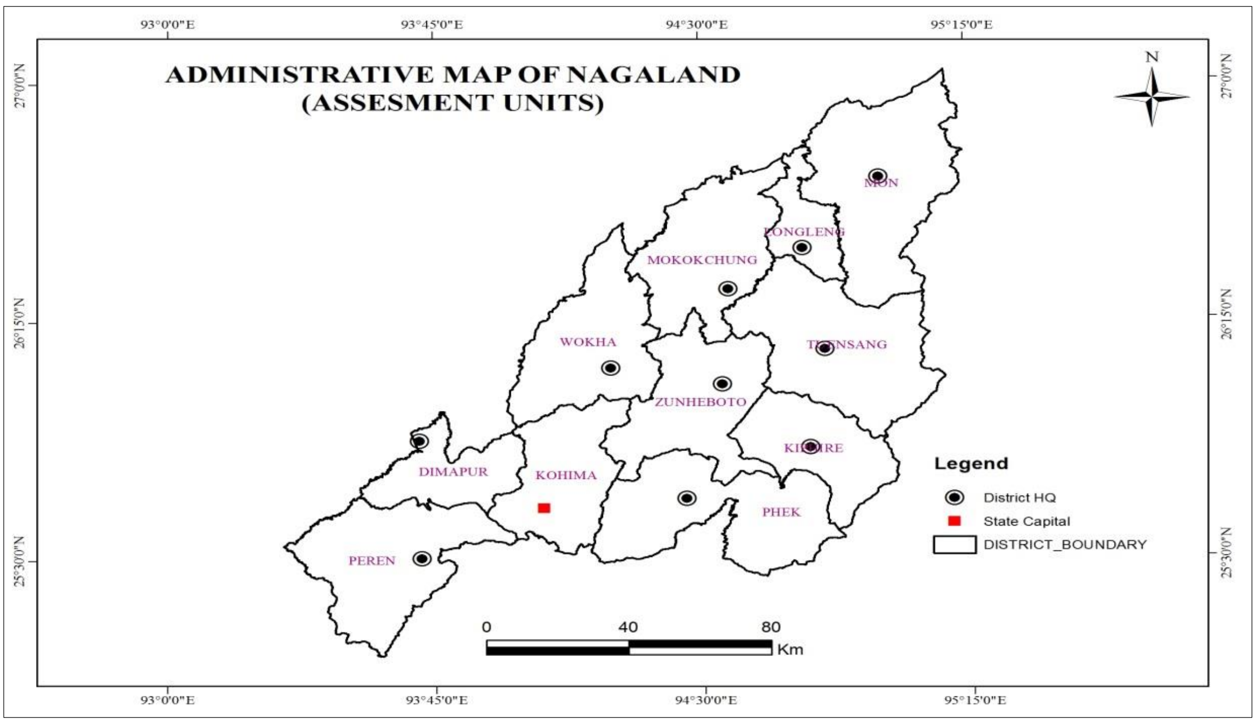


Figure 1: Administrative map of Nagaland.

1.3.CLIMATE

Nagaland has a wet-dry climate. It records an average annual rainfall of 1715 mm. Rain is mostly common in the months of southwest monsoon (May to September). Temperature decreases in places with greater elevation. Summer temperature ranges from 21-23°C to 38-40°C. Whereas during winter temperature drops as low as 4°C. Frost is common at higher elevation. Humidity levels are higher throughout the state.

1.4.GEOLOGY

Nagaland consists of narrow strip of hills running from east to south west and surrounded by the Assam plains to its north and north east. The Naga Hills form part of the major Indo-Myanmar orogenic belt. These are the westernmost morphotectonic unit of Myanmar orogen known as the Central Lowland of Myanmar. The hills rising from the Brahmaputra valley is 2000 feet in elevation while towards southeast it is more than 6000 feet. The Naga hills merge with the Patkai range along the Myanmar border elevating to a height of 12552 feet at Mt. Saramati.

The Cenozoic sequence exposed in Nagaland (Figure 2) mostly consist of geosynclinal sediments that include molasses and flysch ones. Nagaland is divided into four geomorphotectonic units which resulted due to the collision and consequent subduction of the Indian plate under the Myanmar plate. These four units are (a) Foreland or shelf part (b) Belt of Schuppen, (c) Kohima-Patkai Synclinorium or Inner Fold belt and (d) Eastern zone including the Naga Hill Ophiolite. (Geological Report, Kiphere district, Nagaland). The Naga Hills Ophiolite (NHO) forms the Naga-Arkan Yoma flysch trough of Upper Cretaceous-Middle Eocene age. The NHO have tectonic contacts on either side which is evident from their transport into the Disang flysch in the west and, in turn, have been over-ridden in places by the Nimi Formation (Cretaceous-Lower Eocene) and Naga Metamorphics (Pre-Mesozoic) from the east. The generalized litho-stratigraphic succession of eastern part of Nagaland (modified after Agarwal) are Naga Metamorphics, Nimi Formation, Ophiolite Complex, Disang Group, Jopi Formation, Laterites and High Level Terraces. The metamorphic rocks from these groups tectonically interlayered with a sequence of mantle perioditite tectonites, mostly serpentinized, mafic and ultramafic cumulates, high-level plutons of quartz dolerite to plagiogranite composition and a mildly metamorphosed pillowed basalt–limestone/marble–ferruginous and radiolarian chert association. (Bhowmik, S. K., 2021).

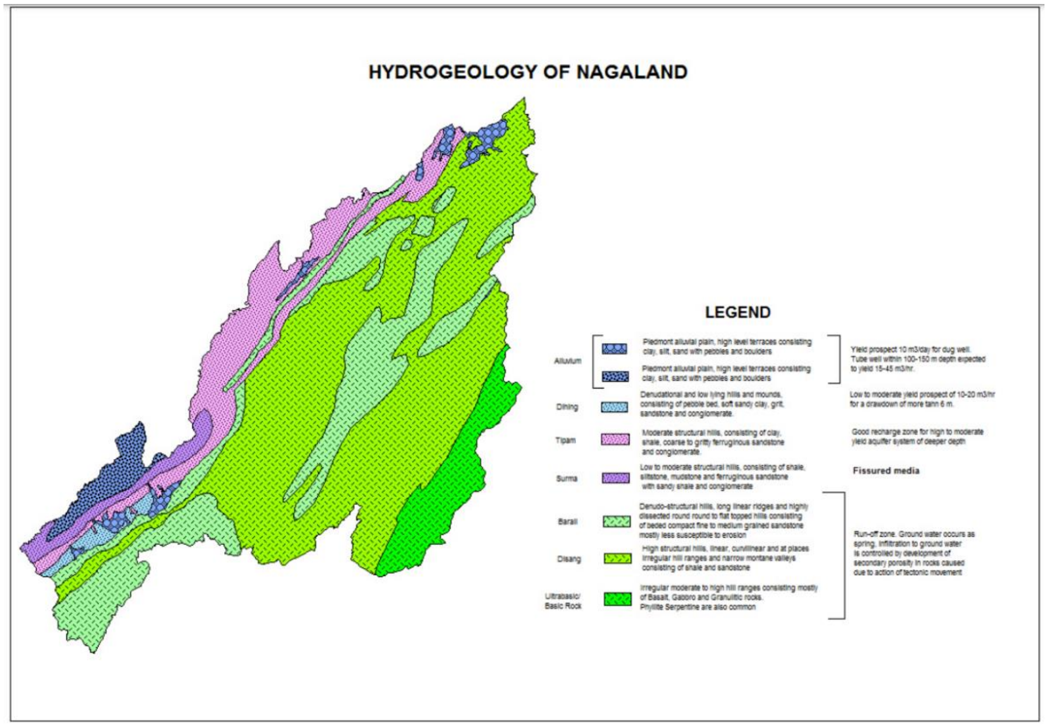


Figure 2: Hydrogeological map of Nagaland.

1.5.RIVERS

Doyang, the largest river in the state along with Dhansiri and Dikhu flow westward and flows into Brahmaputra. Tizu is another important river that flows into Chindwin river in Myanmar. There are also various tributaries of the Chindwin river from Myanmar in the southeast. Jhanzi, Dhansiri, Milak, Zungki, etc. are other important rivers. Doyang hydroelectric power plant of capacity 75MW is built on the Doyang river.

1.6. HYDROCHEMISTRY

Hydrochemistry is an interdisciplinary field that focuses on the chemical properties of water in the natural environment. To fully understand hydrochemistry and its effects on pollution, it is necessary to study atmospheric water (i.e. rainwater), surface water, and groundwater simultaneously. The atmosphere contains various gaseous components, such as N_2, O_2, CO_2, CH_4, CO, SO_x, NO_x as well as water vapours and dust particles. The wind can transport these pollutants over long distances, and are typically deposited onto the earth's surface as precipitation or dry fallout. The chemical composition of rainwater is influenced by the source of water vapours and the ions that are picked up during transport through the atmosphere. Generally, the chemical composition of rainwater shows that it is slightly mineralized, with a specific electrical conductance (EC) typically below 50 µS/cm, chloride below 5 mg/L, and HCO_3 below 10 mg/L. The concentrations of Ca, Mg, Na, and K can vary significantly among the cations, but the total cation content is below 15 mg/l, except in samples contaminated with dust. In areas near industrial hubs, the concentrations of sulphates and nitrates in rainwater may be high. However, this has not been observed in the North Eastern Region.

The chemical composition of surface water is highly variable due to the relative contributions of groundwater and surface water sources. Typically, the mineral content in river water has an inverse relationship with its discharge. The mineral content of river water generally increases from the source to the mouth, although this increase may not be consistent or uniform. Additionally, the discharge of city wastewater, industrial waste, and mixing of waters can also impact the concentration and nature of minerals present in surface water. Bicarbonates are the most significant anions present, constituting over 50% of the total anions in terms of milliequivalent per liter (meq/L). In terms of cations, calcium is typically the most prevalent alkaline earth present.

The downward movement of water through soil is not a passive process; as it moves, it becomes enriched in CO_2. This can make it a powerful agent of weathering and its general solution effects. Therefore, groundwater's chemical makeup is influenced by various factors, including the frequency of rainfall, which leaches out salts; the time that rainwater spends in the root zone and intermediate zone; and organic matter. Additionally, the groundwater front does not move uniformly, as the soil strata are usually heterogeneous. The flow of percolating water through larger pores is much faster than through finer pores. The net result of all these factors is that the composition of groundwater can vary from place to place and over time. Before reaching the saturated zone, percolating water is charged with oxygen and CO_2, and is particularly aggressive in the initial stages. However, as free CO_2 associated with the percolating water is gradually consumed through interaction with minerals, the water becomes less aggressive.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

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

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.

$$CH_2O + O_2 = CO_2 + H_2O$$

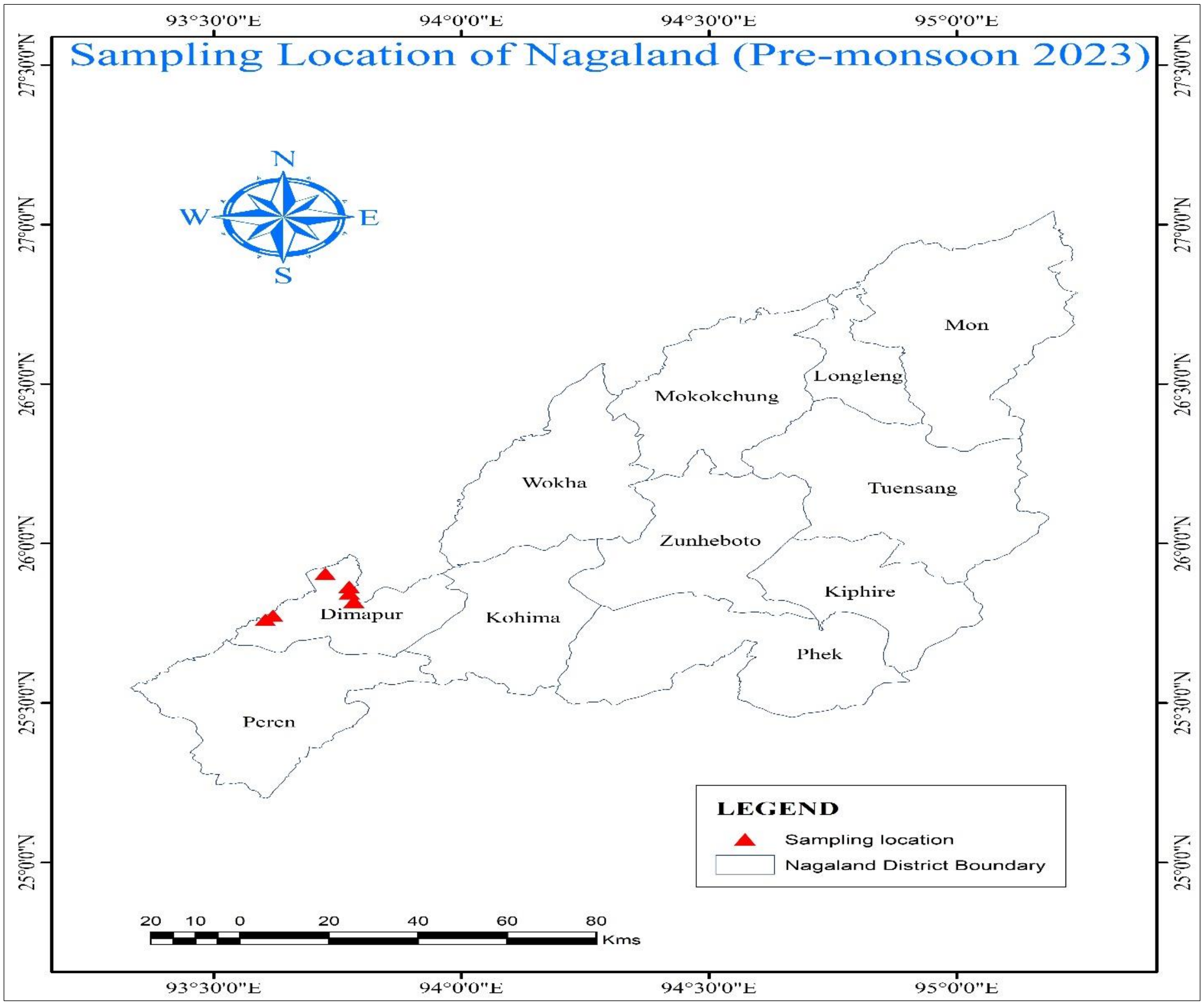
(Organic matter)

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

1.7.GROUNDWATER MONITORING & METHODOLOGY

Monitoring of GW quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. GW 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 quality of GW is controlled by geochemical processes dependent upon the nature of lithology, topographical features, recharge and rock weathering associated with mineral dissolution, ion exchange, and evaporation. (Saravanan et al. 2015; Subba Rao et al. 2017). The main objective of GW 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 in order to know GW condition and its variation, in both time and space. Figure 1 consists of a map showing the sample points. 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. Eight (08) samples from Dimapur district were collected during the pre-monsoon of 2022, i.e. in the month of March 2022. Pre-monsoon being a dry spell just before the arrival of monsoon results in higher elemental concentration as compared to the post-monsoon period. The sample points from which GW samples were collected were marked using their geographical coordinates from GPS. Their latitudes and longitudes were further imported to ArcGIS for spatial distribution analysis.


Sampling Location of Nagaland (Pre-monsoon 2023)
93°30'0"E
94°0'0"E
94°30'0"E
95°0'0"E
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
25°30'0"N
25°0'0"N
N
W
E
S
Mon
Longleng
Mokokchung
Wokha
Tuensang
Zunheboto
Kiphire
Dimapur
Kohima
Phek
Peren
LEGEND
Sampling location
Nagaland District Boundary
20 10 0 20 40 60 80
Kms

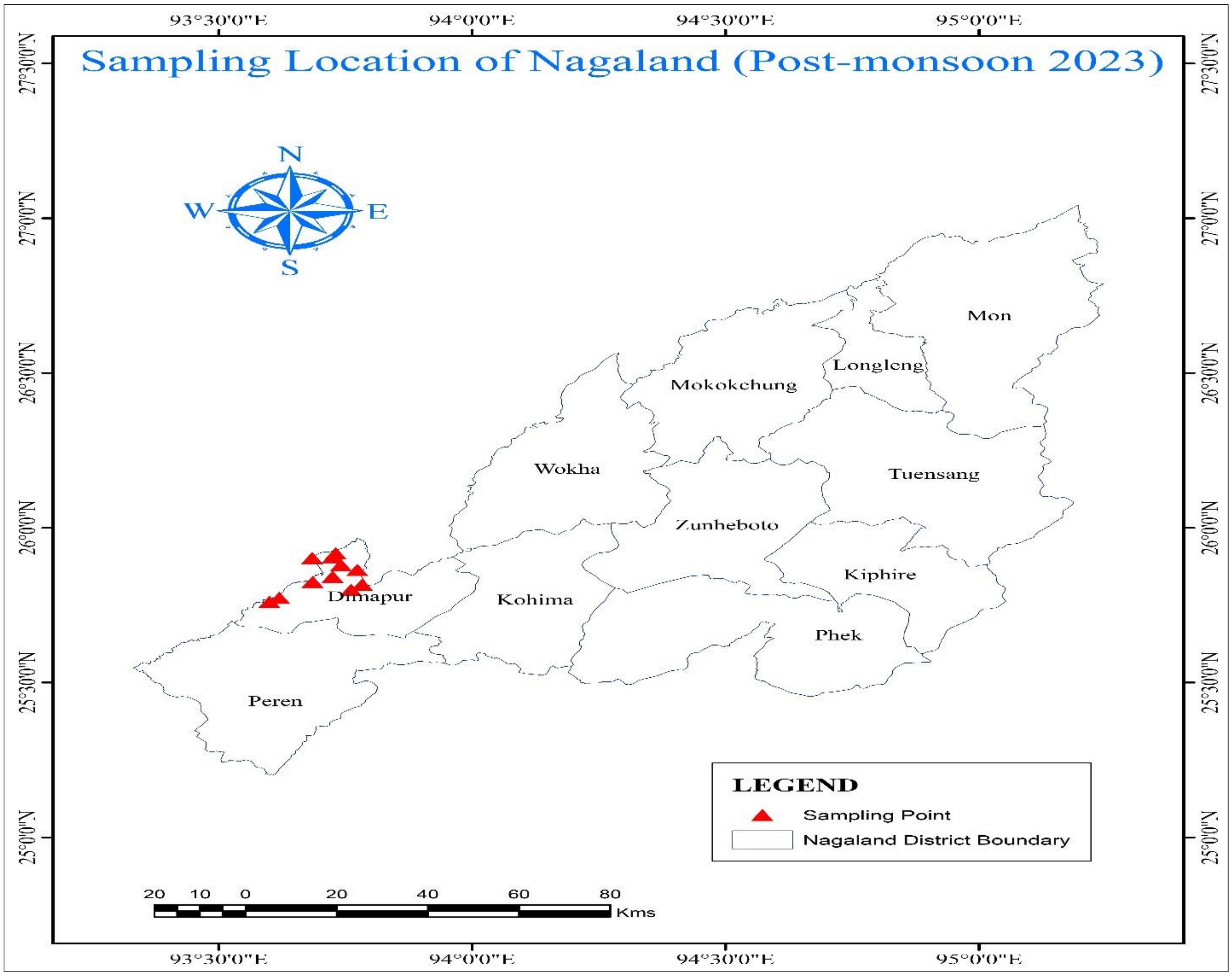


Figure 3: Sampling location of Nagaland 2023 during Pre-monsoon (up) and Post-monsoon (down).

1.5.1. SAMPLE COLLECTION

The samples were collected in clean, sterile and air-tight high density polyethylene bottles (HDPE) as per APHA protocol (APHA, 23rd Ed). For basic ions analysis the samples were collected in 1L HDPE bottles while for trace metals samples were collected in 60mL HDPE bottles. The samples in 60mL bottles were filtered with a 0.45-micron membrane using a syringe filtration unit technique. Immediately after filtration 0.5 mL trace elemental grade HNO_3 acid is added as preservatives. If the samples were obtained from wells then it is made sure the wells were pumped before sampling to have a stable water temperature, turbidity and other physical parameters. Also, caution was being taken while filling the bottles to avoid interference from air headspace. Spot analysis of pH, electrical conductivity (EC), dissolved oxygen (DO) and oxidation-reduction potential (ORP) were done using a water test kit. All the sets of samples were labeled and transferred to the laboratory in ice box with ice pads maintaining a temperature of ≤4ºC.

1.5.2. ANALYTICAL TECHNIQUES & QUALITY CONTROL

Standard analysis procedures described in APHA, 23rd edition (Table 2) were employed for analyzing the GW samples. While analysis, QA/QC protocols were being followed that included blank run, external calibration and standardization by National Institute of Standards and Technology (NIST) certified standard reference materials, retesting, etc. Physical water quality parameters such as pH, EC, TDS, turbidity were measured by pH-meter, conductivity meter and nephalo-turbidity meter respectively. Na and K were analyzed in flame-photometer. NO_3^- and SO_4^{2-} analysis were done in UV-Visible spectrophotometer (Labindia, UV-3200) setting the λ_{max} at 220 nm and 420 nm respectively. Fluoride analysis was done in ion-meter (Oakton Ion 700). Total hardness (TH) as $CaCO_3$, CO_3^{2-}, HCO_3^- and Cl^- were analyzed by volumetric titration method.

Table 2: Analytical methods/equipment for Groundwater quality analysis.

Parameters	Method adopted	Instrument/technique used
PHYSICO-CHEMICAL		
pH	Electrometric method	pH meter
Conductivity	Electrometric method	Conductivity meter
Turbidity	Turbidimetric method	Nephalo-turbidity meter
TDS	Electrometric	Conductivity/TDS Meter
Alkalinity	Titrimetric method	(Titration by H_2SO_4)
Chloride (Cl)	Argentometric /Chromatographic method	(Titration by $AgNO_3$)/Ion Chromatograph
Sodium (Na)	Flame Emission Spectroscopy/ Chromatographic method	Flame photometer/ Ion Chromatograph
Potassium (K)	Flame Emission Spectroscopy/ Chromatographic method	Flame photometer / Ion Chromatograph
Total Harness	Titrimetric method	(Titration by EDTA)
Calcium (Ca)	Titrimetric method/ Chromatographic method	(Titration by EDTA)/ Ion Chromatograph
Fluoride (F^-)	Electrometric method/ Chromatographic method	Ion Meter/ Ion Chromatograph
Sulphate (SO_4^{-2})	Turbidimetric method/ Chromatographic method	UV-visible Spectrophotometer/ Ion Chromatograph
Nitrate (NO_3^-)	Ultraviolet screening/ Chromatographic method	UV-visible Spectrophotometer/ Ion Chromatograph
Phosphate	Molybdophosphoric acid/ Chromatographic method	UV-VIS Spectrophotometer / Ion Chromatograph
Dissolved Oxygen (DO)	Electrometric	DO meter
HEAVY METALS AND RADIOACTIVE URANIUM		
Uranium (U)	Plasma Spectroscopy/Fluorescence Spectrometry	ICP-MS/Uranium analyzer
Iron (Fe)	Colorimetric method/Atomic absorption spectroscopy/Palsma Spectroscopy	UV-visible Spectrophotometer/AAS

Arsenic	Hydride generation/ Plasma Spectroscopy	AAS/ICPMS
Cr, Mn, Fe, Ni, Cu, Zn, Se, Ag, Cd and Pb	Atomic Spectroscopy/ Plasma Spectroscopy	AAS/ICPMS
Mercury	Cold Vapour Generation followed by tomic Spectroscopy/ Plasma Spectroscopy	Mercury Analyser/AAS
Arsenic (+3 & +5)	Ion chromatography	Ion chromatograph

All the chemicals used were of analytical grade (Merck). Ultrapure water was used exclusively. For establishing the reliability and quality of the analytical results errors in the ionic balance ought to be < 5% for each analysis. The formula for ionic balance was calculated by $[\{(T^{Z+} - T^{Z-})/(T^{Z+} + T^{Z-})\} \times 100]$ where T^{Z-}/ T^{Z+} are the ions. The ionic balance errors (%IBE) for all GW samples were found to be within the recommended limit of 5% (Burton, R.F., 1983).

The spatial distribution of the GW quality parameters were obtained by using ArcGIS 10.7.1, a geostatistical software package. Inverse Distance Weighted interpolation technique is adopted to prepare the spatial variations map to assess the GW quality of the study area for drinking purpose.

Chapter 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 (Table 3).

Table 3: Water quality criteria parameters for various uses.

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 Substancesadversely 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 downby 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	DesirableLimits(mg/L)	Permissiblelimits(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 TurbidityUnit.

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

S. No.	Nature of soil	Crop Growth	Upper permissible safe limit of electrical conductivity in water µs/cm at 25°C
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 renderitun suitable 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 (Hazenunit)	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, affect staste, corrosivity and the water supply system
6	Hardnessas CaCO3 (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. Intracesitis 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.

S. No.	Parameters	Prescribed limits IS:10500,2012		Probable Effects
		Desirable Limit	Permissible Limit	
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.
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 anemiainin fants. 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 acathartic 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 aemia (bluebabies) 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.

S. No.	Parameters	Prescribed limits IS:10500,2012		Probable Effects
		Desirable Limit	Permissible Limit	
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 chronicexposures. Burning in the mouth, severe inflammation of the gastro-intestinaltract with vomiting and diarrhoea, chronic toxicity producesnausea, severe abdominal pain, paralysis, mental confusion, visual disturbances, anaemia etc.
19	Zinc (Zn) (mg/L)	5	15	An essential and beneficia lelement in human metabolism.Taste threshold for Zn occurs at about 5mg/L imparts astringent Taste to water.
20	Chromium (Cr) (mg/L)	0.05	No relaxation	Hexa valent state of Chromium produces lung tumors can produce cutaneous and nasal mucous membrane ulcers and Dermatitis.
21	Boron (B) (mg/L)	0.5	2.4	Affects central nervous system its salt may cause nausea, cramps, convulsions, comaetc.
22	Alkalinity (mg/L) as CaCO3	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 and diarrhea, stimulate secondary hyperthyroid is mand boneloss
25	Sodium (Na) (mg/L)	No guidelines		Harmful to persons suffering From cardiac, renal and circulatory diseases.

S. No.	Parameters	Prescribed limits IS:10500,2012 Desirable Limit	Prescribed limits IS:10500,2012 Permissible Limit	Probable Effects
26	Potassium (K) (mg/L)	No guidelines		An essential nutritional element but its excessive amounts is cathartic
27	Silica (SiO_2) (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 (per100mL) (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 (As) (mg/L)	0.01	No relaxation	Various skin diseases, Carcinogenic
31	Uranium (U) (mg/L)	0.03	No relaxation	Kidney disease, Carcinogenic

Chapter 3

ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING & DOMESTIC PURPOSE

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, sulphate, trace metals and uranium. The values were compared with the values of drinking water standard of BIS (IS 10500:2012) and WHO (2017) for urnaium. The overall chemical quality of Nagaland is provided in Annexure I to IV.

3.1 Drinking water specification as per 10500:2012

Values of drinking water standard of BIS (IS 10500:2012) are given in Table 7 to Table 10:

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 [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)	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 Cl_2), 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 NO_3^-), mg/L, Max	45	No relaxation	IS 3025 (Part 34)
xvii)	Phenolic compounds (as C_6H_5OH), 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 SO_4^{2-}) mg/L, Max	200	400	IS 3025 (Part 24)
xxi)	Sulphide (as H_2S), 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 $CaCO_3$), 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 [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.	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	0.0005	No relaxation	ASTM 5175* or APHA 6630
viii.	Polynuclear aromatic hydro-carbons (as PAH), mg/L, Max	0.0001	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			
	b) Dibromochloromethane, mg/L, Max	0.1	No relaxation	ASTM D 3973-85*or APHA 6232
		0.1	No relaxation	
	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 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 [BIS, IS 10500].

(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. PHYSIOCHEMICAL PARAMETERS FOR DRINKING WATER & DOMESTIC PURPOSE

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.

3.2.1. PRE-MONSOON GROUND WATER QUALITY FOR DRINKING PURPOSES IN NAGALAND

For the pre-monsoon samples pH values are within the BIS limit of 6.5 to 8.5. All of the EC are less than 3000 µS/cm. From the mean concentration (mg/L) of cations the order of the cations is Ca^{2+}> Na^{+}> K^{+} > Mg^{2+} while that of the anions varies as HCO_3^{-}> Cl^{-}> SO_4^{2-}> NO_3^{-} >F^{-}. Concentration of most of the ionic species are within the permissible limits. Heavy metals analysed during pre-monsoon are Iron ($Fe^{+2/+3}$) and Arsenic ($As^{+2/+3}$) along with radioactive Uranium. None of the samples are showing iron level beyond BIS permissible limit of 1.0 mg/L and arsenic level above permissible limit of 0.01 mg/L. Statistical data set and summary of physicochemical parameters of groundwater samples OF Nagaland during pre-monsoon season is tabulated in Table 11.

Some of the parameters of significance for the region are depicted pictorially from Figure 4 to Figure 8.

Table 11: Statistical data set and summary of physicochemical parameters of groundwater samples collected from Nagaland during pre-monsoon 2023.

Parameters	Unit	Statistical details				Prescribed limits	
		Mean	Minimum	Maximum	Std. deviation	BIS	WHO
pH		7.05	6.49	7.84	0.48	6.5-8.5	6.5-8.5
EC	(µs/cm) 25 °C	349.85	110.80	596.90	172.49	–	–
TDS	mg/L	227.40	72.02	387.99	112.12	2000	1000
CO3-2	mg/L	0.00	0.00	0.00	0.00	–	
HCO3-1	mg/L	97.68	18.31	305.24	98.38	–	125-130
TA (as CaCO3)	mg/L	97.68	18.31	305.24	98.38	600	–
Cl-	mg/L	57.45	19.89	112.70	29.25	1000	250
SO4-2	mg/L	15.11	2.94	37.58	14.06	400	250
NO3-1	mg/L	14.12	0.00	42.64	15.26	–	50
F-	mg/L	0.04	0.00	0.15	0.05	1.5	1.5
TH (as CaCO3)	mg/L	124.17	65.00	265.00	66.48	600	–
Ca+2	mg/L	37.03	18.01	90.07	24.64	200	75
Mg+2	mg/L	7.67	3.62	10.91	2.94	100	125
Na	mg/L	33.89	4.79	71.52	21.53	–	200
K	mg/L	8.31	1.34	22.37	8.60	–	12
Fe	mg/L	0.32	0.01	0.69	0.28	1	0.3
As	µg/L	0.21	0.03	0.79	0.26	10	10
U	µg/L	0.14	0.00	0.41	0.15	–	30

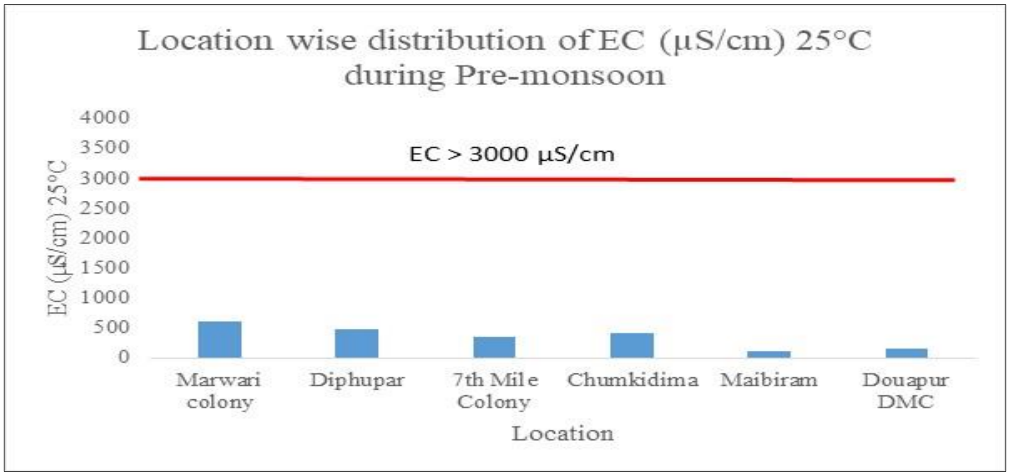


Figure 4: EC distributions in groundwater of Nagaland during pre-monsoon, 2023.

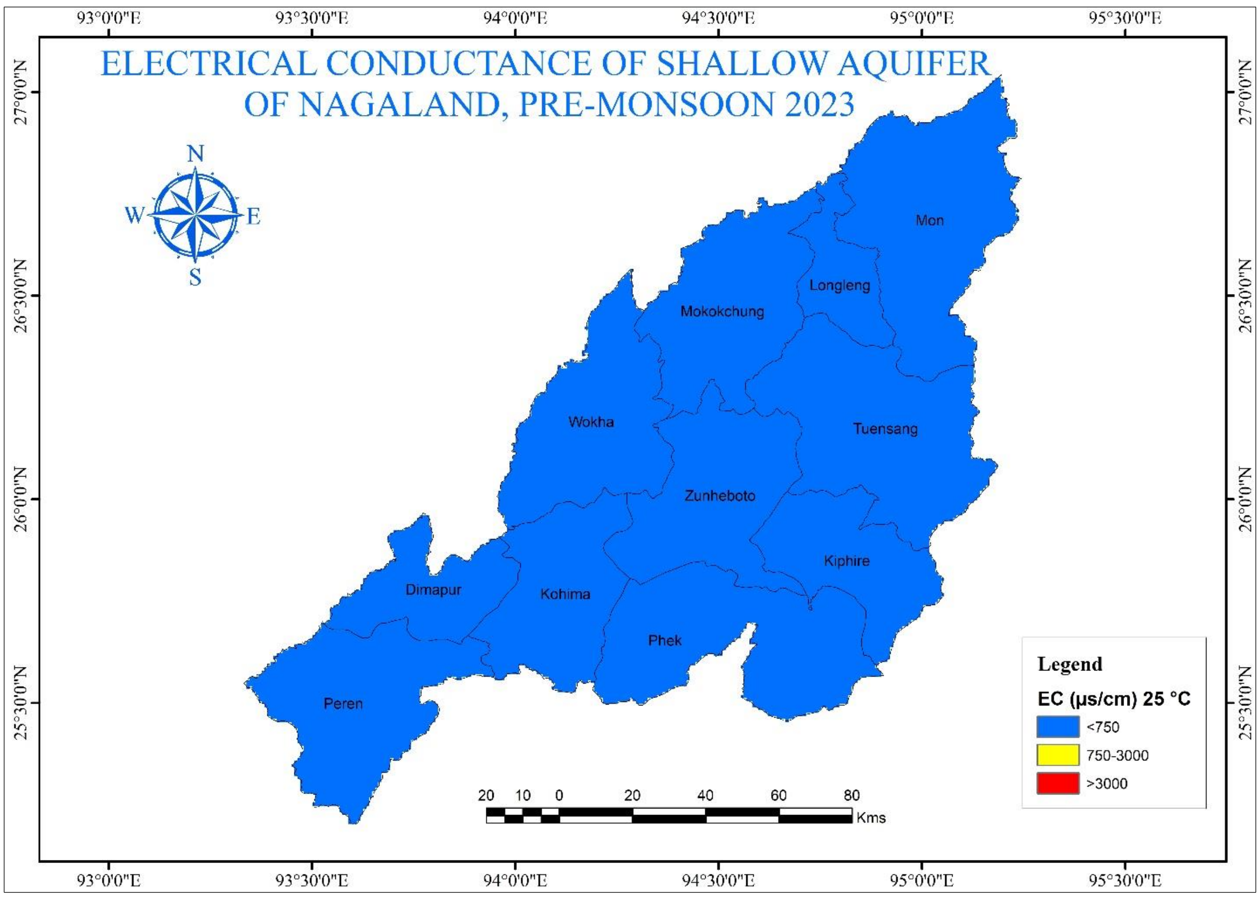


Figure 5: Map showing the spatial distribution of EC in groundwater of Nagaland during pre-monsoon, 2023.

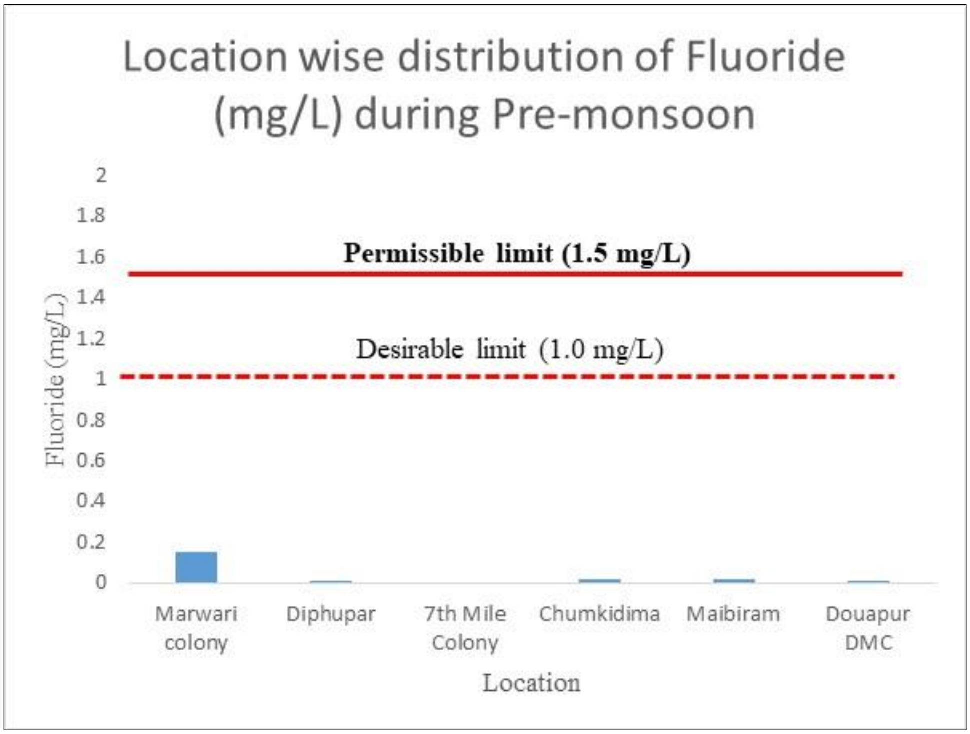


Figure 6: Fluoride distributions in groundwater of Nagaland during pre-monsoon, 2023.

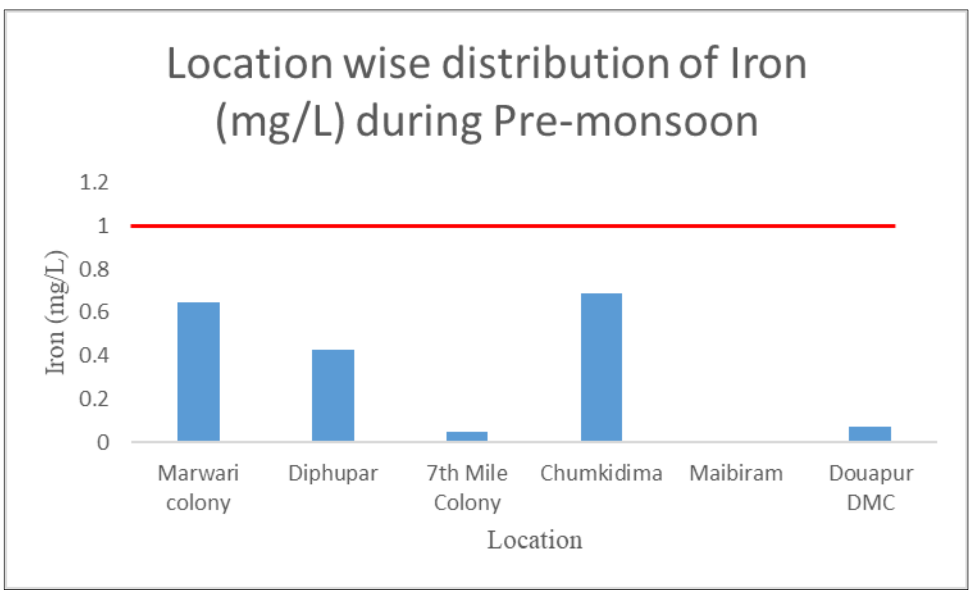


Figure 7: Iron distributions in groundwater of Nagaland during pre-monsoon, 2023.

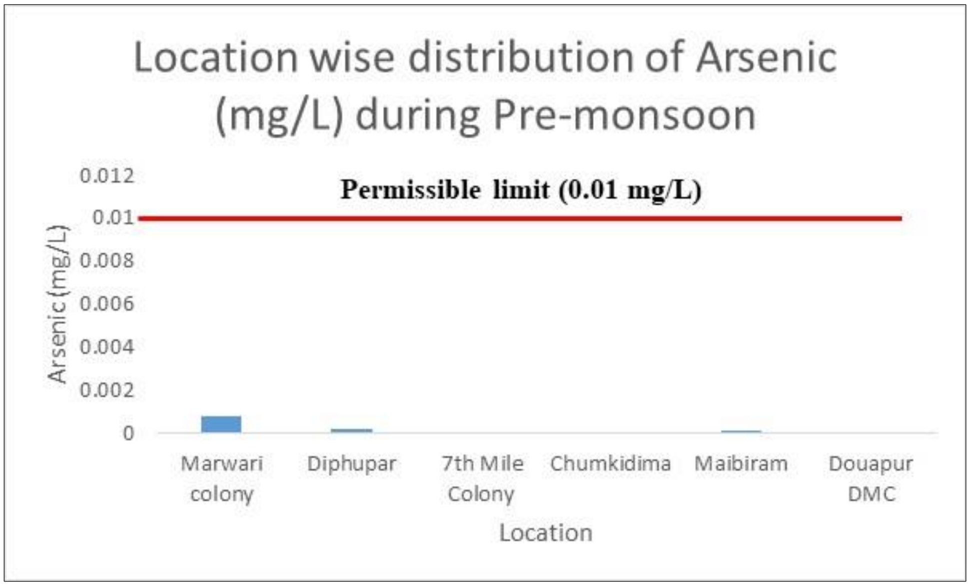


Figure 8: Arsenic distributions in groundwater of Nagaland during pre-monsoon, 2023.

3.2.2. POST-MONSOON GROUND WATER QUALITY FOR DRINKING PURPOSES IN NAGALAND

For the pre-monsoon samples pH values are within the BIS limit of 6.5 to 8.5. The EC of the samples are less than 3000 µS/cm. From the mean concentration (mg/L) of cations the order of the cations is $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ while that of the anions varies as $Cl^- > HCO_3^- > NO_3^- > SO_4^{2-} > F^-$. Concentration of most of the ionic species are within the permissible limits except for K^+. Maximum K^+ level was found from Zakesatho Colony in Dimapur district (44.3 mg/L). Cl^-, total hardness and total alkalinity (as $CaCO_3$) are other parameters which are below permissible limits. Heavy metals analysed during pre-monsoon are Fe, As, Mn, Cu, Pb, Zn, Ni, Cd, Cr, Se, Hg along with radioactive Uranium. 3 of the samples are showing iron level beyond BIS permissible limit of 1.0 mg/L while none of the samples have Arsenic above permissible limit of 0.01 mg/L. A total of 4 samples have Manganese concentration beyond permissible limit of 0.3 mg/L. Other trace metals exceeding prescribed limits is Nickel (3 samples from Chumkidima, Diphupar and Douapur DMC).

Some of the parameters of significance for the region are depicted pictorially from Figure 9 to Figure 13.

Table 12: Statistical data set and summary of physicochemical parameters of groundwater samples collected from Nagaland during post-monsoon 2023.

Parameters		Statistical details				Prescribed limits	
		Mean	Minimum	Maximum	Std. deviation	BIS	WHO
pH		6.68	6.40	8.33	0.52	6.5-8.5	6.5-8.5
EC	(µs/cm) 25 °C	396.48	102.70	923.60	245.17	–	–
TDS	mg/L	257.71	66.76	600.34	159.36	2000	1000
CO3-2	mg/L	0.27	0.00	3.00	0.86	–	
HCO3-1	mg/L	23.86	12.21	42.73	9.19	–	125-130
TA (as CaCO3)	mg/L	24.14	12.21	45.73	9.77	600	–
Cl-	mg/L	116.99	56.72	209.16	42.11	1000	250
SO4-2	mg/L	15.41	3.15	47.10	14.85	400	250
NO3-1	mg/L	20.38	4.22	40.94	11.85	–	50
F-	mg/L	0.50	0.25	0.80	0.19	1.5	1.5
TH (as CaCO3)	mg/L	110.45	35.00	210.00	57.86	600	–
Ca+2	mg/L	23.11	6.00	44.04	13.59	200	75
Mg+2	mg/L	12.79	2.42	27.89	7.17	100	125
Na	mg/L	54.45	23.30	114.50	25.75	–	200
K	mg/L	23.24	7.19	44.30	11.26	–	12
Fe	mg/L	0.72	0.05	2.83	0.97	1	0.3
As	µg/L	0.96	0.05	5.40	1.51	10	10
U	µg/L	0.16	0.01	0.58	0.19	–	30

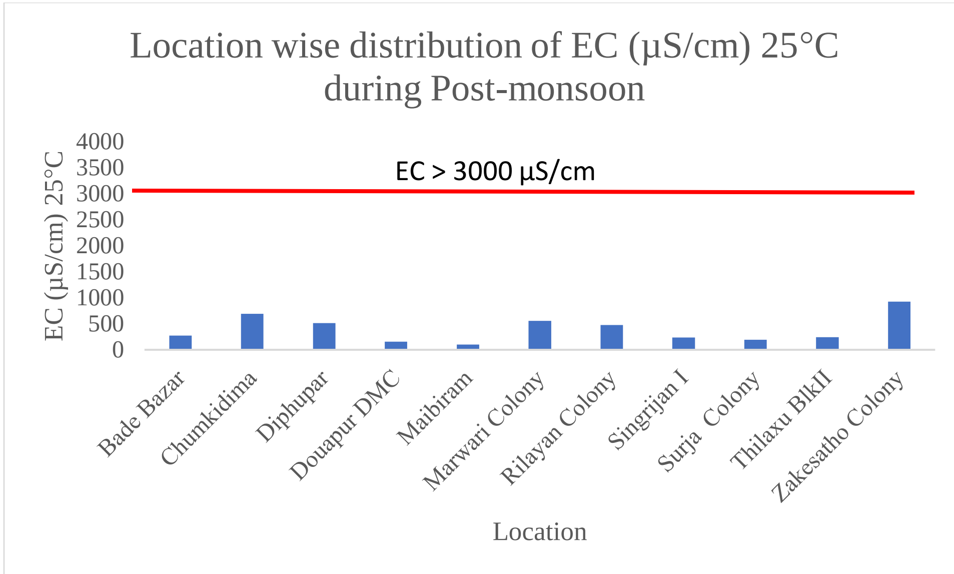


Figure 9: EC distributions in groundwater of Nagaland during post-monsoon, 2023.

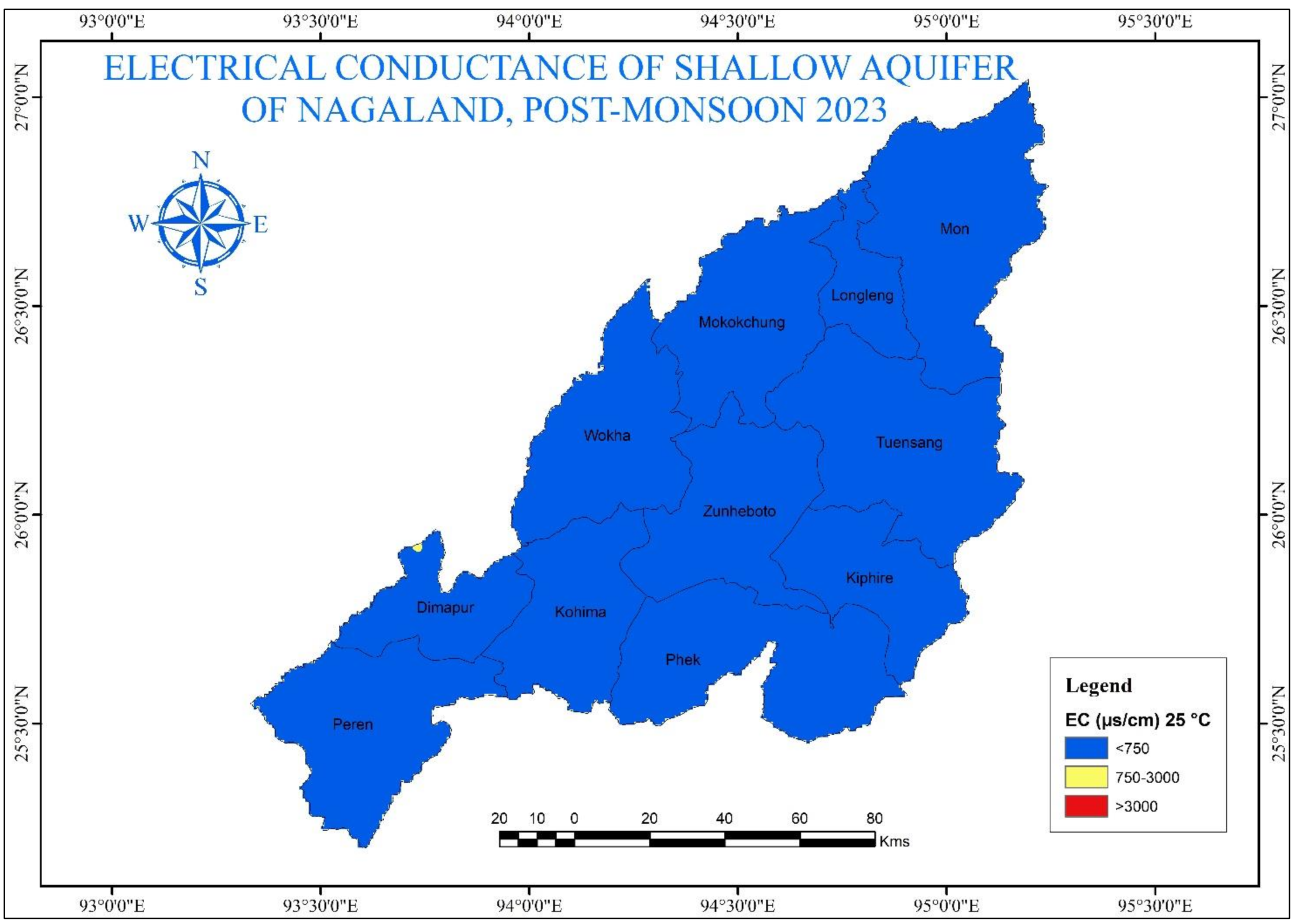


Figure 10: Map showing the spatial distribution of EC in groundwater of Nagaland during post-monsoon, 2023.

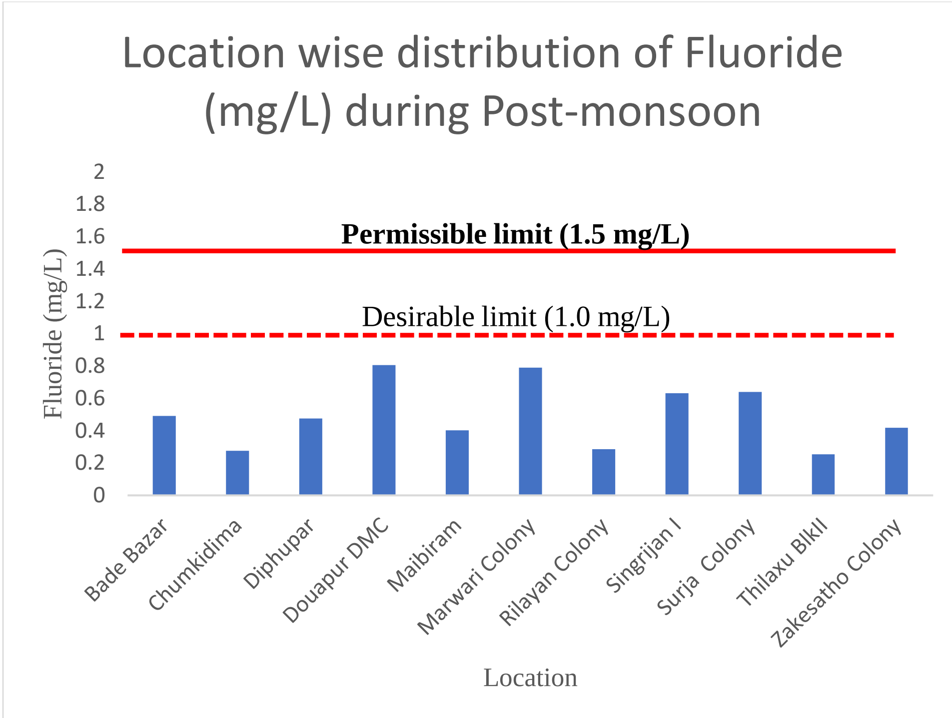


Figure 11: Fluoride distributions in groundwater of Nagaland during post-monsoon, 2023.

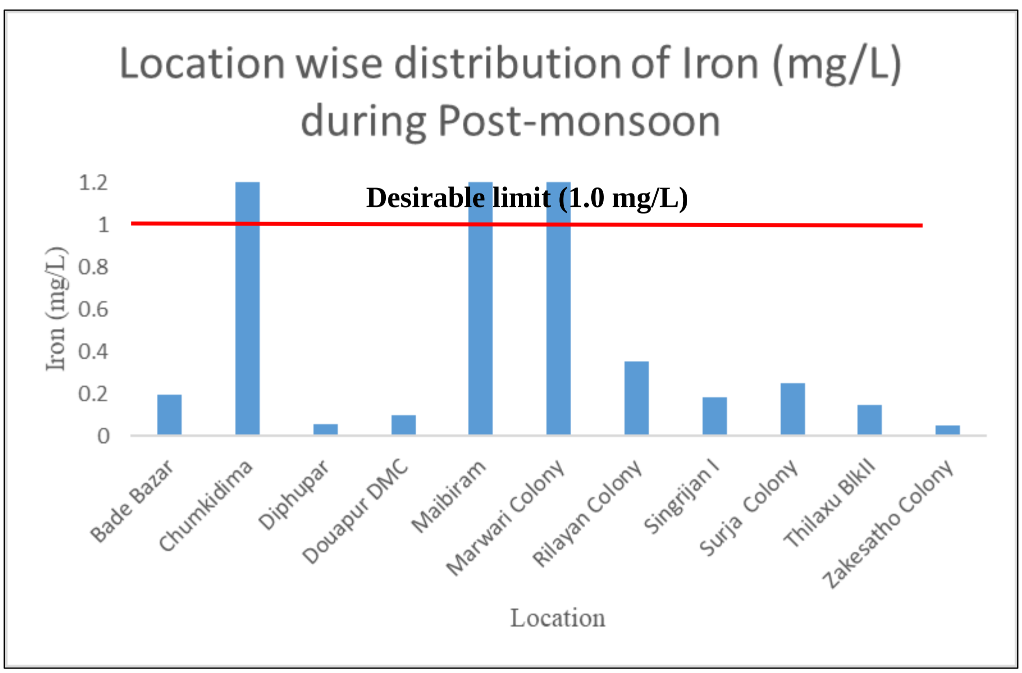


Figure 12: Iron distributions in groundwater of Nagaland during post-monsoon, 2023.

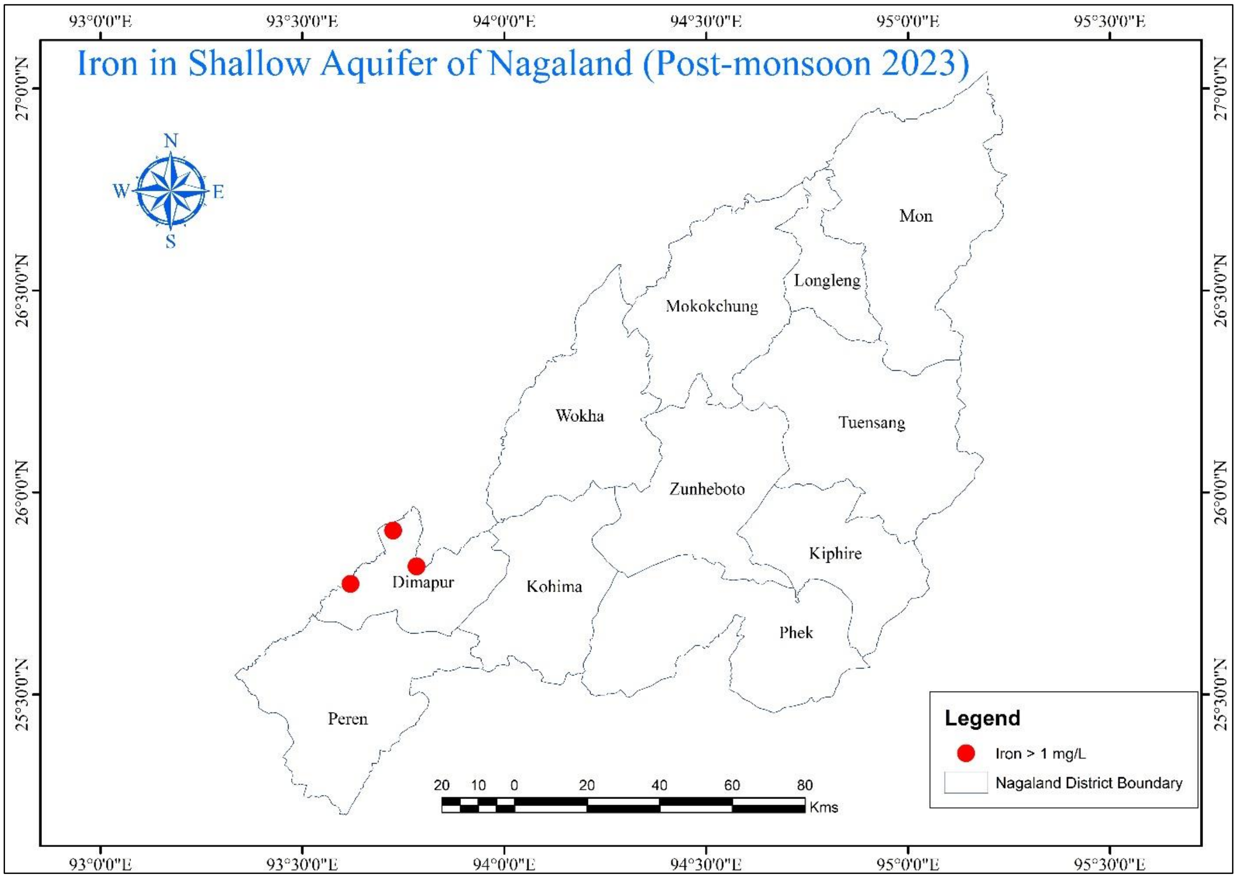


Figure 13: Map showing the point location of iron in groundwater of Nagaland during post-monsoon, 2023.

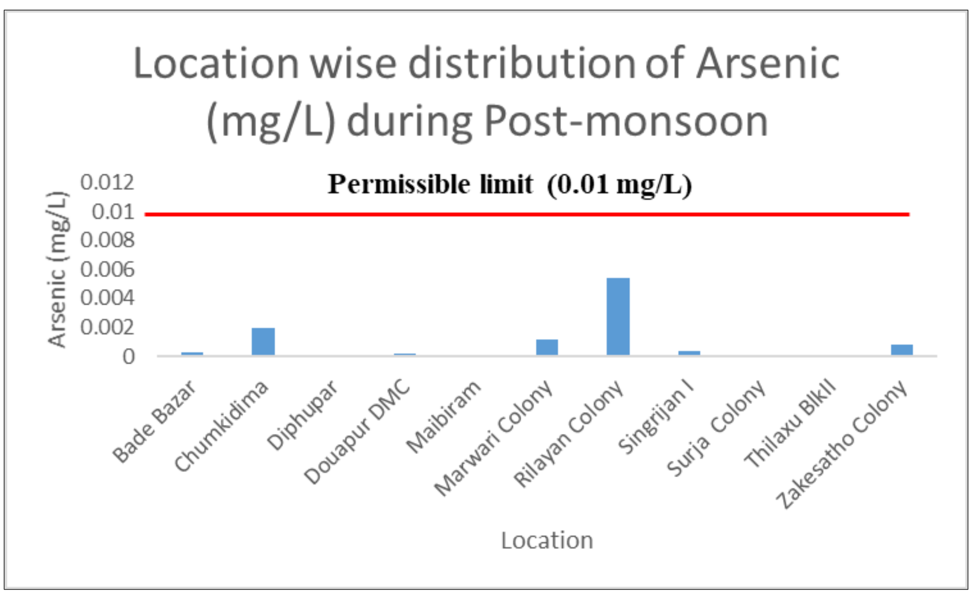


Figure 14: Arsenic distributions in groundwater of Nagaland during post-monsoon, 2023.

3.3. TRENDS 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 7 years trend of some significant parameters in GW of Nagaland. We have plotted graphs with 3 variables with the years 2017 to 2023 on X-axis, followed by number of districts affected and subsequently the percentage of locations affected. The number of locations exceeding the BIS drinking water permissible limits and the graphs depicting the trend analysis of each significant chemical parameters are summed in Table 13-17 & Figures 14-21.

DISTRIBUTION OF ELECTRICAL CONDUCTIVITY (EC)

- The EC value of ground waters in the State varies from 102.7 at Maibiram to 923.6 µS/cm at Zakesatho Colony at 25°C.
- Grouping water samples based on EC values, it is found that none of them have EC above 3000µS/cm.
- The map showing aerial distribution of EC in pre and post monsoon.
- Trend analysis of seven years showing no significant change in EC and no sample has EC more than 3000 µS/cm in 2023.

Table 13: Periodic Variation in suitability classes of salinity in groundwater of Nagaland.

Periodic Variation in suitability classes of salinity in groundwater of Nagaland							
Parameter	Class	Percentage of samples					Periodic Variation 2017-2023
		2017 (n= 13)	2019 (n=8)	2020 (n=2)	2022 (n=8)	2023 (n= 17)	
Salinity as EC	<750 µS/cm	100	100	100	100	94.12	-5.88
	750-3000 µS/cm	0	0	0	0	5.88	5.88
	>3000 µS/cm	0	0	0	0	0.00	0

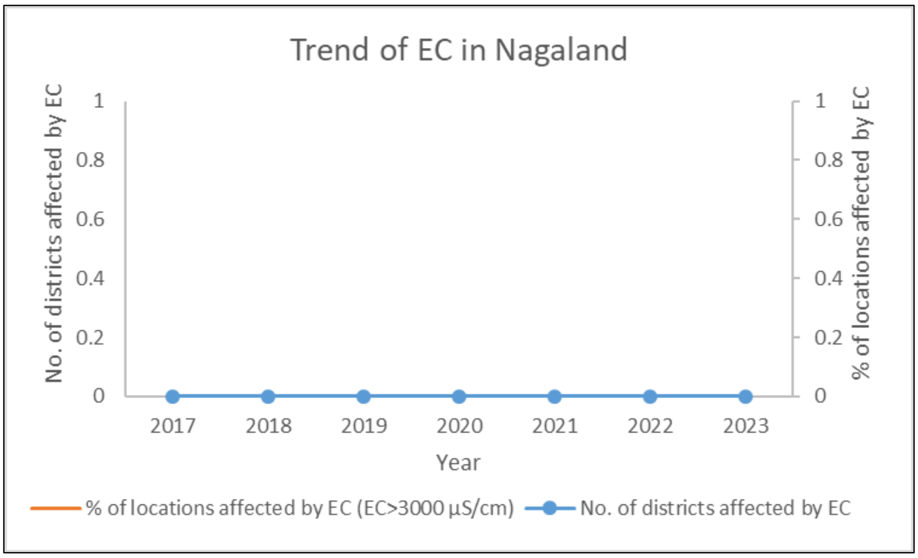


Figure 15: 7 years trend analysis graph of EC.

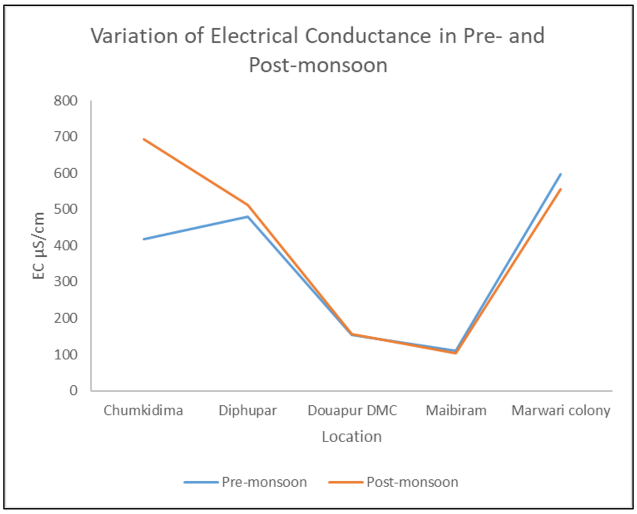


Figure 16: Variation in EC during pre and post-monsoon 2023.

DISTRIBUTION OF NITRATE

- The nitrate value of ground waters in the State varies from 0 mg/L at Maibiramto 42.64 mg/L at 7th Mile Colony.
- Grouping water samples based on Nitrate values, it is found that none of them have nitrate above the permissible limit of 45 mg/L.

- Trend analysis (Table 14), of seven years showing no significant change in concentration of nitrate.

Table 14: Periodic Variation in suitability classes of Nitrate in groundwater of Nagaland.

Periodic Variation in suitability classes of Nitrate in groundwater of Nagaland							
Parameter	Class	Percentage of samples					Periodic Variation 2017-2023
		2017 (n= 13)	2019 (n= 8)	2020 (n= 2)	2022 (n= 8)	2023 (n= 17)	
Nitrate as NO3	<45 mg/L	100	100	100	100	100.00	0.00
	>45 mg/L	0	0	0	0	0.00	0.00

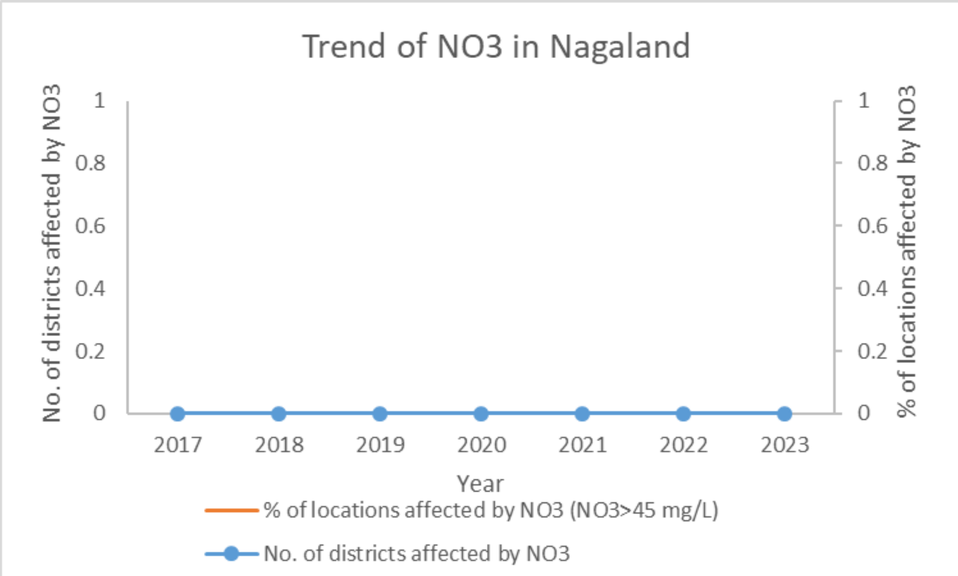


Figure 17: 7 years trend analysis graph of nitrate.

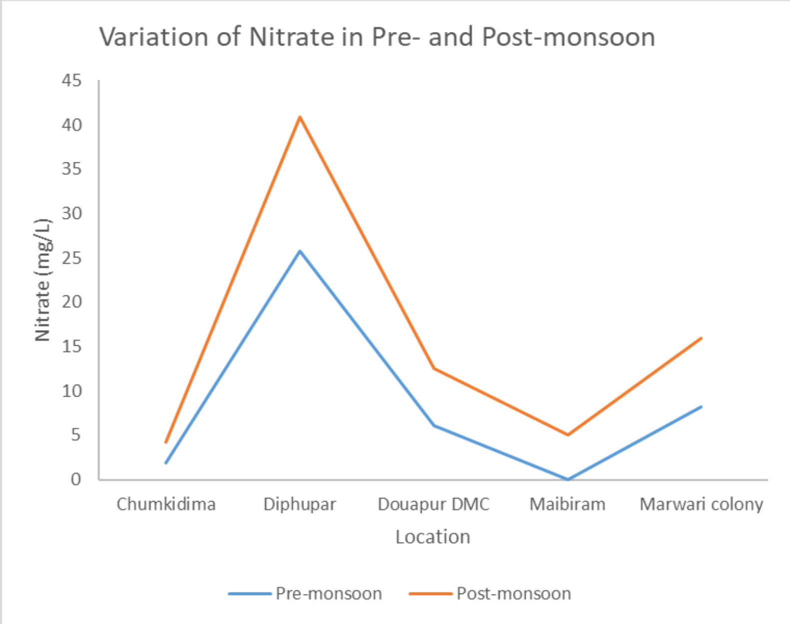


Figure 18: Variation in NO_3 during pre and post-monsoon 2023.

DISTRIBUTION OF FLUORIDE (F)

- The fluoride value of ground waters in the State varies from 0 mg/L at 7th Mile Colonyto 0.80 mg/L at Douapur DMC.
- Grouping water samples based on Fluoride values, it is found that none of them have fluoride above the permissible limit of 1.5 mg/L.
- Trend analysis (Table 15), of seven years showing no change in trend in Fluoride content.

Table 15: Periodic Variation in suitability classes of Fluoride in groundwater of Nagaland.

Periodic Variation in suitibility classes of Fluoride in groundwater of Nagaland							
Parameter	Class	Percentage of samples					Periodic Variation 2017-2023
		2017 (n= 13)	2019 (n= 8)	2020 (n= 2)	2022 (n= 8)	2023 (n= 17)	
Fluoride as F	<1.5 mg/L	100	100	100	100	100.00	0.00
	>1.5 mg/L	0	0	0	0	0.00	0.00

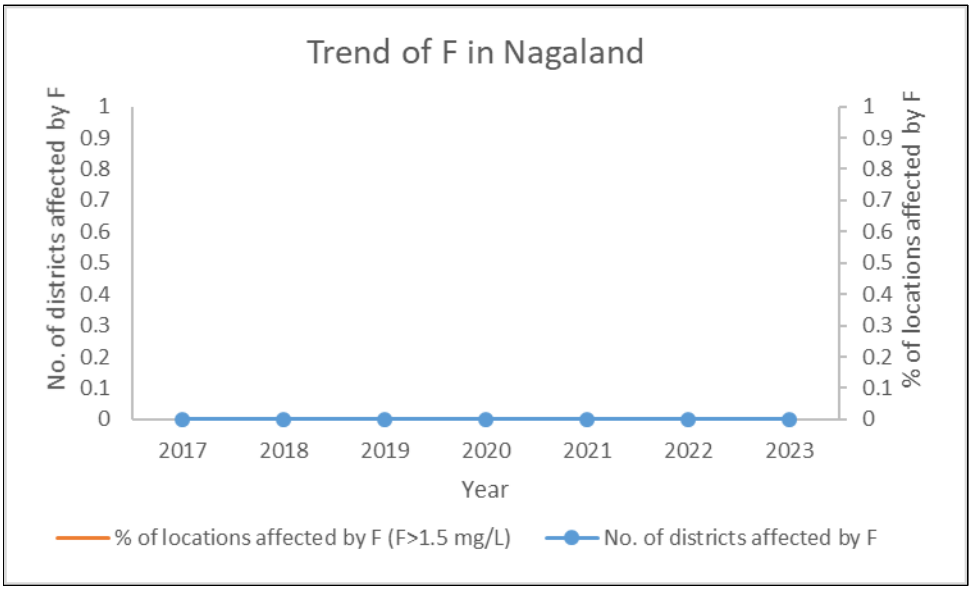


Figure 19: 7 years trend analysis graph of fluoride.

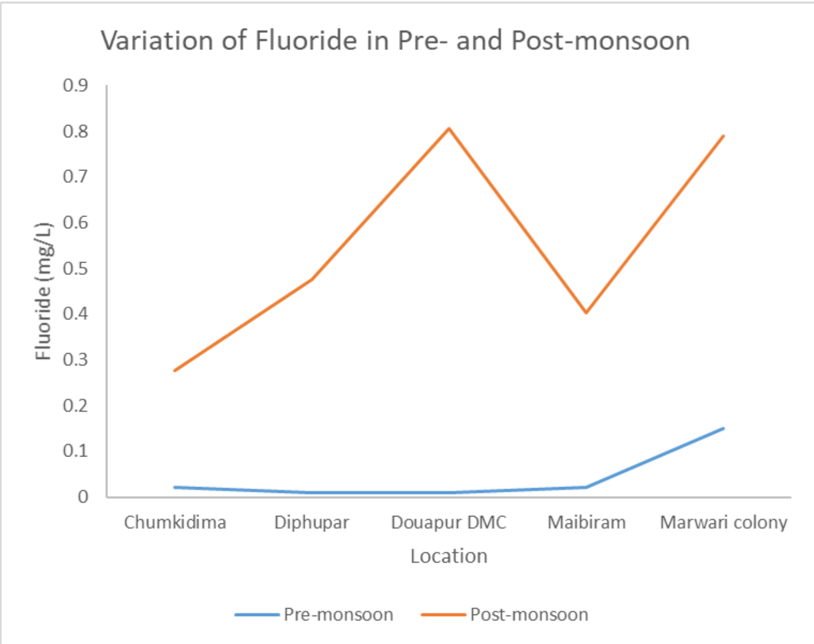


Figure 20: Variation in Fluoride during pre and post-monsoon 2023.

DISTRIBUTION OF IRON (Fe)

- The iron value of ground waters in the State varies from 0.01 mg/L at Maibiram to 2.83 mg/L at Maibiram.
- Grouping water samples based on Iron values, it is found that an average of 17.64% of them have iron above the permissible limit of 1.0 mg/L.
- Trend analysis (Table 16), of seven years showing increasing trend in Iron content.

Table 16: Periodic Variation in suitability classes of Iron in groundwater of Nagaland.

Periodic Variation in suitability classes of Iron in groundwater of Nagaland							
Parameter	Class	Percentage of samples					Periodic Variation 2017-2023
		2017 (n= 13)	2019 (n= 8)	2020 (n= 2)	2022 (n= 8)	2023 (n= 17)	
Iron as Fe	<1 mg/L	100	100	0	75	82.35	0
	>1 mg/L	0	0	100	25	17.65	0

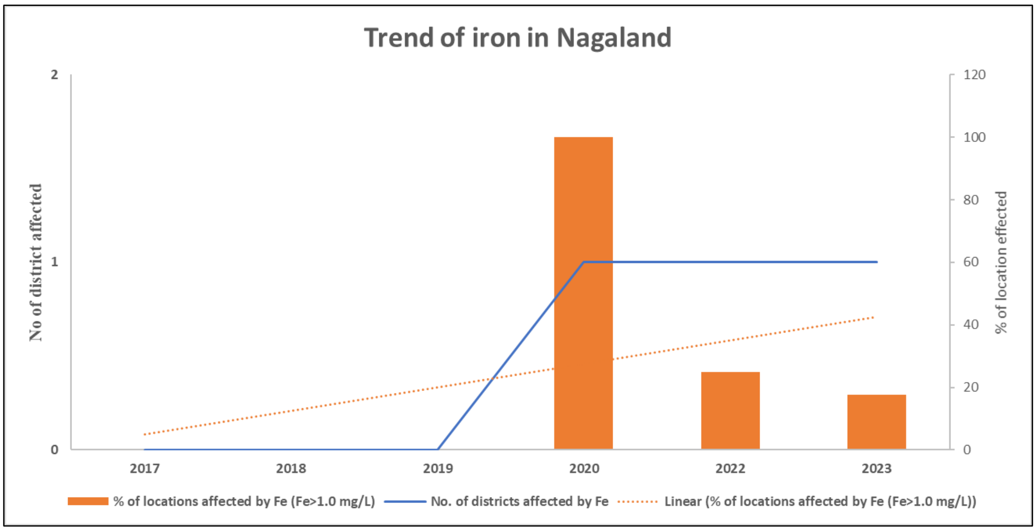


Figure 21: 7 years trend analysis graph of iron.

DISTRIBUTION OF ARSENIC

- The arsenic value of ground waters in the State varies from 0.00002 mg/L at Chumkidima to 0.0054 mg/L at Rilayan Colony.
- Grouping water samples based on arsenic values, it is found that none of them have arsenic above the permissible limit of 0.01 mg/L.
- Trend analysis (Table 17), of seven years showing similar trend in arsenic content since 2017.

Table 17: Periodic Variation in suitability classes of Arsenic in groundwater of Nagaland.

Periodic Variation in suitability classes of Arsenic in groundwater of Nagaland							
Parameter	Class	Percentage of samples					Periodic Variation 2017-2023
		2017 (n= 13)	2019 (n= 8)	2020 (n= 2)	2022 (n= 8)	2023 (n= 17)	
Arsenic as As	<0.01 mg/L	100	100	100	100	100	0
	>0.01 mg/L	0	0	0	0	0	0

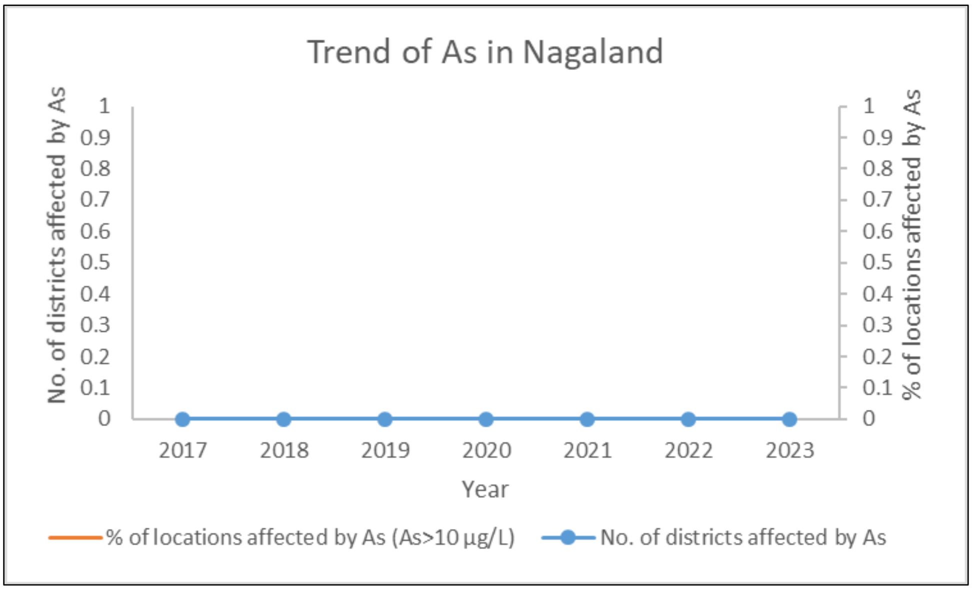


Figure 22:7 years trend analysis graph of arsenic.

Chapter 4

ASSESSMENT OF GROUND WATER QUALITY OF NAGALAND FOR IRRIGATION FEASIBILTY

When there is excessive accumulation of soluble salts in soil the crop production is reduced. Plants growing under osmotically produced water stresses are one of the major causes for reduction in crop production. 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. The parameters with values greater than these limits renders water unfit for irrigation. Higher residency time in the aquifers and low mobility of ground water resulted in more mineralization and leads to higher EC and 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 determines 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. Mathematically SAR is calculated as

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

As per Richards classification water with SAR<10 makes it suitable for irrigation.
Soluble Sodium Pecentage (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 is 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). Continuos 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 Ratio

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:

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

The MR>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, 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. GROUND WATER QUALITY SCENARIO FOR IRRIGATION IN NAGALAND

Quality of ground water, soil types and cropping practices play an important role for a suitable irrigation practice. Salinity and alkalinity of ground water are two main problems for irrigation. Hence, it is important to check the chemical constituents that affect the suitability of water for irrigation in terms of total concentration of dissolved salts, relative proportion of bicarbonate to calcium, magnesium and relative proportion of sodium to calcium.

The following table indicates the categories of the water samples analysed during pre-monsoon according to the various irrigation indices.

Table 18: Classification of ground water samples of Nagaland for irrigation purposes.

Parameters	Range	Classification	Number of samples
Salinity hazard (EC) (µS/cm)	<250	Excellent	7
	250-750	Good	9
	750-2000	Permissible	1
	2000-3000	Doubtful	0
	>3000	Unsuitable	0
Alkalinity hazard (SAR)	<10	Excellent	17
	10--18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0
Percent Sodium (%Na)	<20	Excellent	1
	20-40	Good	5

Parameters	Range	Classification	Number of samples
	40-60	Permissible	3
	60-80	Doubtful	8
	>80	Unsuitable	0
Kelly's Index (KI)	<1	Suitable	9
	>1	Unsuitable	8
Residual sodium carbonate (RSC)	<1.25	Suitable	17
	1.25-2.5	Marginally suitable	0
	>2.5	Unsuitable	0
Soluble Sodium Percentage (SSP)	<50	Suitable	9
	>50	Unsuitable	8

Different inidces indicate the water quality for irrigation purposes. The salinity hazard is absent for most of the samples. The alkalinity hazard (SAR) for all the samples is categorized as excellent. The Na % indicates that the groundwater is excellent to permissible for irrigation except a few samples which falls under doubtful category. High concentration of sodium tends to be absorbed by clay particles, displacing Ca^{2+} and Mg^{2+} ions thereby reducing the permeability resulting in poor internal drainage in soil making the soil dry. Similarly, based on calculated value of Kelly's ratio (KR), more than 52% samples are suitable for irrigation purpose with value of KR < 1. As per the RSC value-based classification of irrigation water given by Lloyd and Heathcote, 100% samples are suitable for irrigation with RSC value less than 1.25.

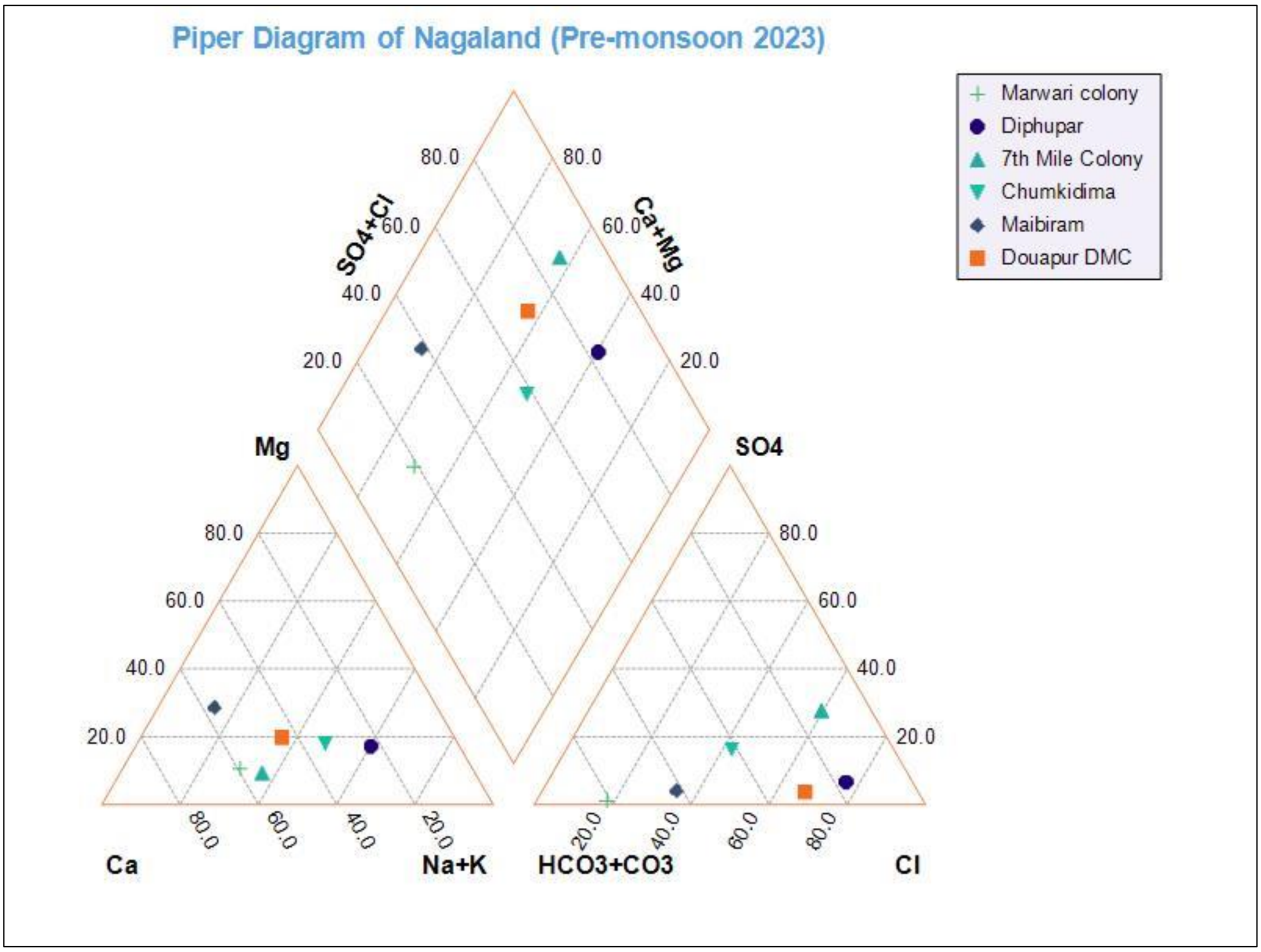


Figure 23: Piper plot for classification of ground water of Nagaland during pre-monsoon 2023.

Water can be classified into different hydrochemical facies using Piper diagram. The above Figure is the Piper plot of Nagaland during the pre-monsoon. Considering the cation triangle one sample from Malibiram is calcium dominant, one from Diphupar is sodium dominant and rest are in mostly no dominant zone. The anion triangle shows 2 samples from Marwari colony and Maibiram are HCO_3 type, 1 sample from Chumkidima has no dominancy and rest are Cl type. Thus, on combining the results in the diamond plot 2 samples from Marwari colony and Maibiram fall under Ca-Mg-HCO_3 type, indicating fresh water. One location from Diphupar is in slightly alkaline i.e. Na-Cl type and remaining are mixed type.

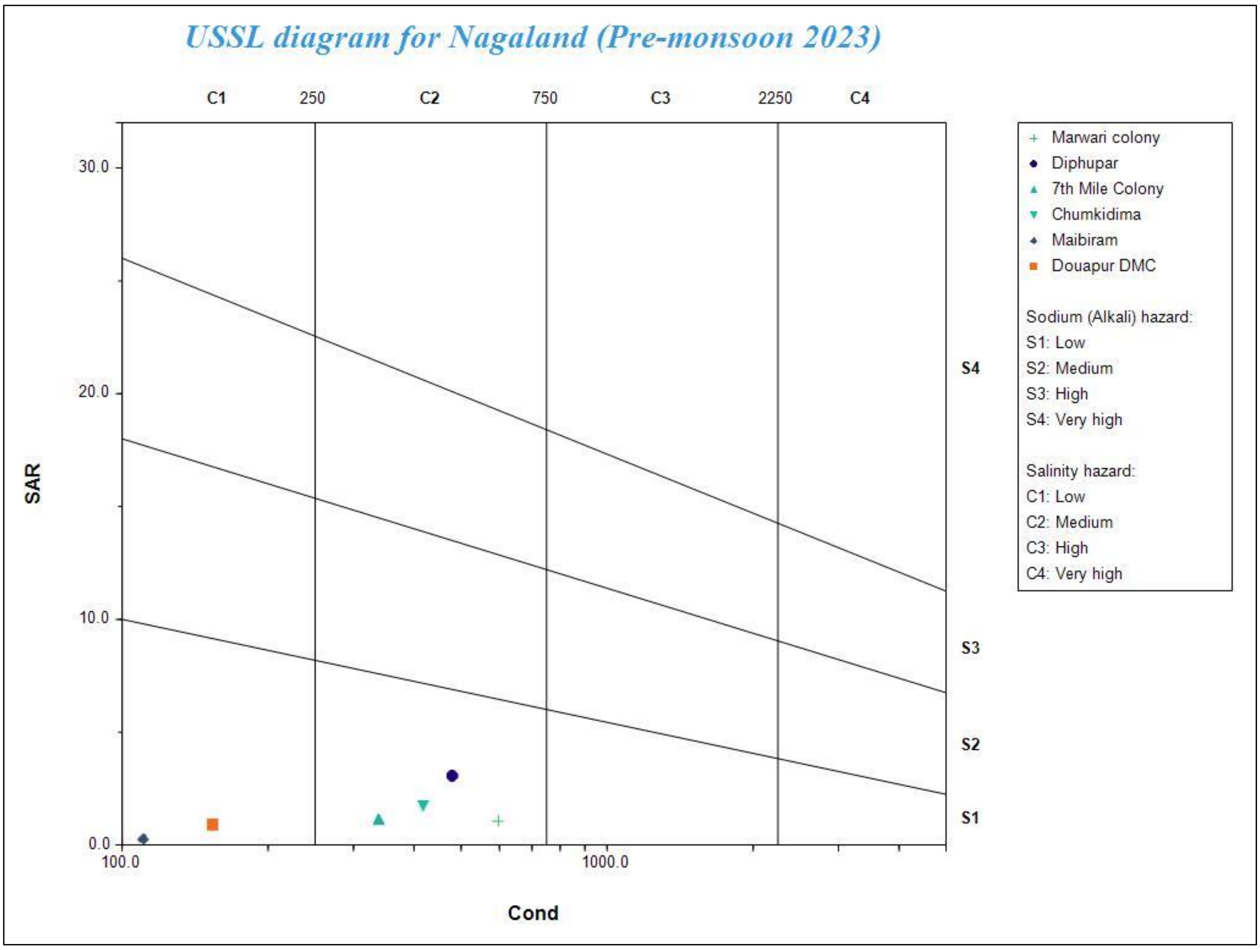


Figure 24: USSL salinity diagram for classification of ground water in Nagaland during pre-monsoon 2023.

The data plotted on the US salinity diagram reveals that most of the groundwater samples from Nagaland fall in the field C1S1 and C2S1 indicating low salinity-low sodium water and medium salinity hazard with low sodium hazard. Hence this can be used for irrigation for almost all types of soil with little danger of exchangeable sodium. No samples fall under the C3S1 category. The irrigation parameters viz. Salinity hazard (EC), Alkalinity hazard (SAR), Percent Sodium (%Na), Kelly's index (KI) and Residual Sodium Carbonate (RSC) are shown in Annexure V and VI.

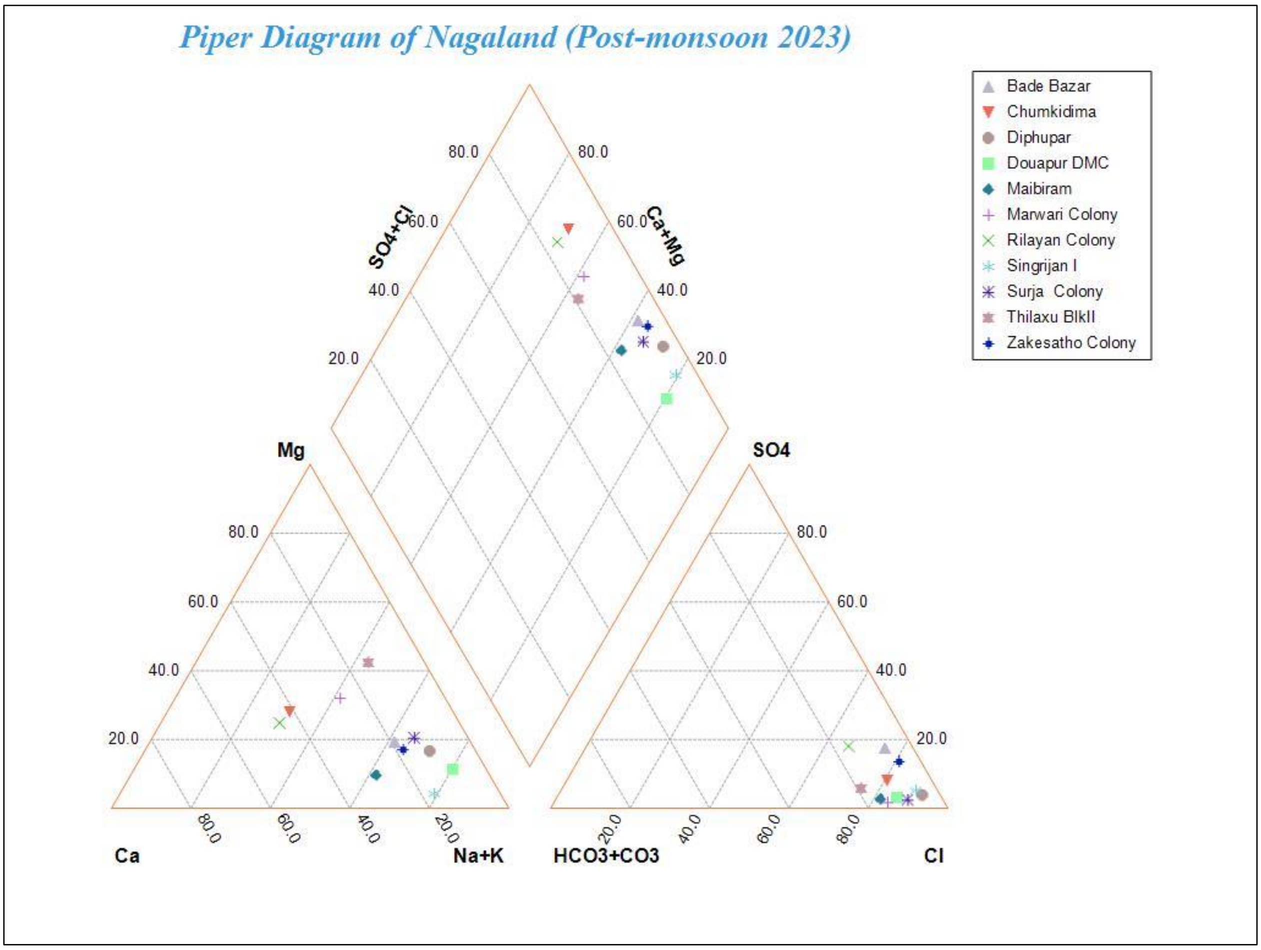


Figure 25: Piper plot for classification of ground water of Nagaland during post-monsoon 2023.

The cation triangle shows that the samples are mostly Na-K type while some samples (Rilayan colony, Chumkidima) have no dominancy. The anion tringle is plotted to be mostly Cl type. Therefore, in the combined plot most of the samples are shown to be dominantly Ca-Cl and Na-Cl type. It is also earlier discussed that from the mean concentration Cl^- from anion and Na^+ and Ca^{2+} are dominant types of ionic species.

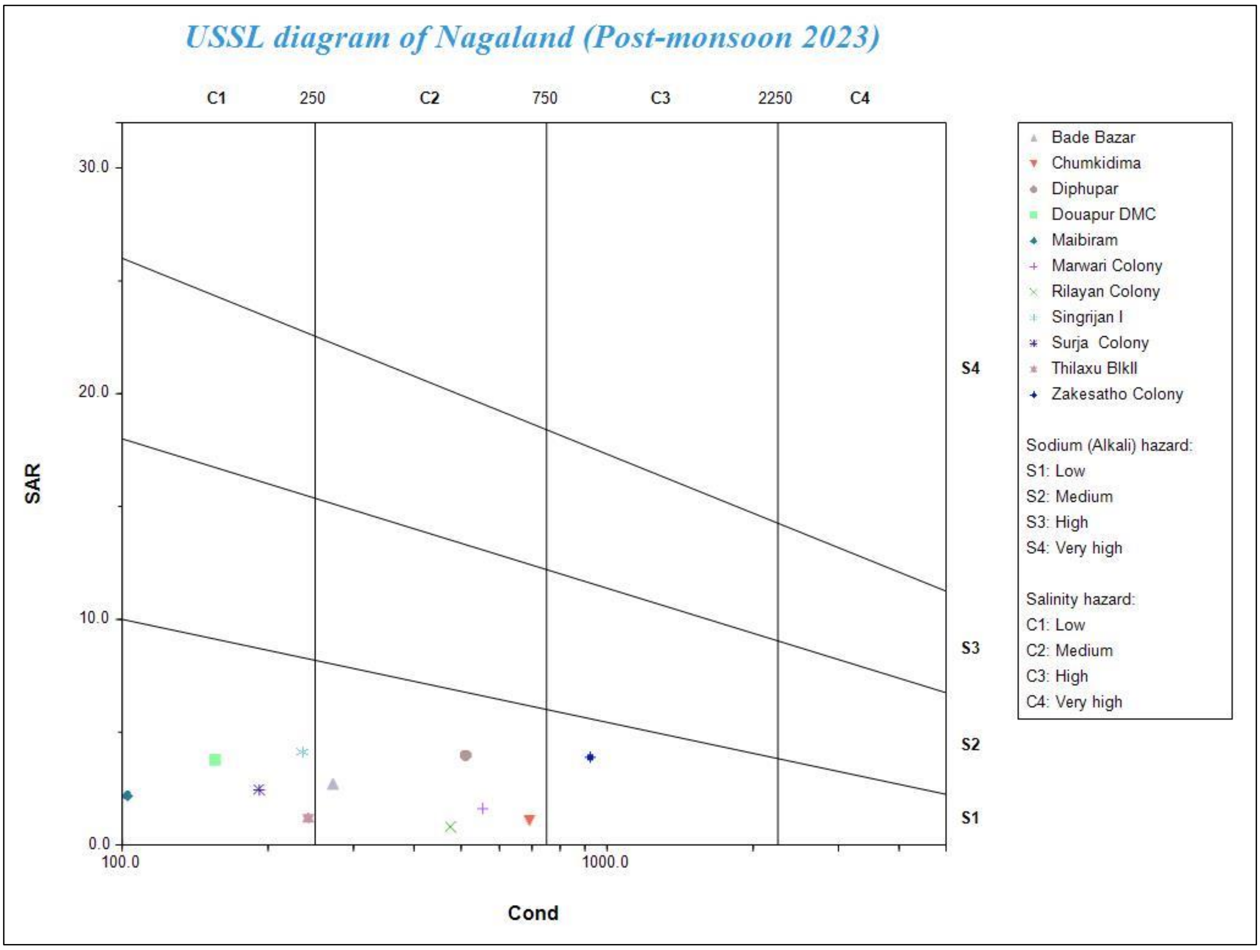


Figure 26: USSL salinity diagram for classification of ground water in Nagaland during post-monsoon 2023.

Most of the post-monsoon samples are classified as C1S1 and C2S1 type indicating low sodium hazard with low and medium salinity hazard. One of the samples fall under C3S1 type from Zakesatho Colony, the location has a comparatively high EC (923.60 µs/cm) and have slightly higher alkalinity due to high sodium and chloride concentration.

Chapter 5

ASSESSMENT OF GROUND WATER USING WATER QUALITY INDEXING TECHNIQUES

In order to assess the level of pollution in the water resources several indices have been developed and subsequently classifying the quality based on the degree of pollution (Sahu and Sikdar, 2008; Bouderbala A, 2017). For the suitability of drinking purpose Water Quality Index (WQI) is being calculated for the major cations and anions, viz. HCO_3^{-1}, Cl^-, SO_4^{-2}, NO_3^{-1}, F^-, Ca^{+2}, Mg^{+2}, TH (as $CaCO_3$), Na and K together with pH, EC and TDS. The equations for the calculation of WQI are as shown below:

Equations	Details
$q_i = \left(\frac{M_i}{S_i}\right) \times 100$	M_i = Measured reading of ith parameter
	Wi=Relative weight of ithparameter
$W_i = w_i / \sum_{i=1}^{n} w_i$	*Wi*=weight of each parameter
$SI_i = W_i \times q_i$	*Si*=recommended standard for each parameter
$WQI = \sum_{i=1}^{n} SI_i$	*qi*=quality rating scale
	SIi=sub-index of each parameter.

The first step is weight assigning for each of the 13 parameters based on their relative significance to the overall quality of drinking water. The second step is a calculation of relative weight (W_i) followed by calculation of quality rating scale (q_i) and finally the sub-index (SI_i) for each parameter where "*i*" is the individual parameter. The relative weights of the basic parameters used for WQI calculation are as shown in table below.

Table 5 a: Relative weights of basic parameters for WQI

Chemical	Weight (wi) parameters	W_i	S_i
pH	4	0.08889	8.5
EC	3	0.06667	1500
TDS	2	0.04444	500
HCO_3^-	4	0.08889	300
Cl^-	3	0.06667	200
SO_4^{2-}	5	0.11111	200
NO_3^-	5	0.11111	45
F^-	5	0.11111	1.5
Ca^{2+}	3	0.06667	75
Mg^{2+}	3	0.06667	30
Total Hardness	2	0.04444	300
Na	3	0.06667	200
K	3	0.06667	10
	45	**1.00000**	

WQI is being calculated for all the samples collected during pre-monsoon as well as post-monsoon. The samples were classified accordingly as shown in the Table 19. The table shows the data about both pre and post-monsoon samples collected from all over the state based on the classification.

Table 19: Classification of sample based on WQI.

Clasiification range of WQI	Water quality status	Pre-monsoon		Post-monsoon		Classification based on
		No. of samples	% of samples	No. of samples	% of samples	
<50	Excellent	5	83.33	6	54.55	Yenugu et al. 2020
50-100	Good	1	16.67	5	45.45	
101-200	Poor	0	0.00	0	0	
201-300	Very poor	0	0.00	0	0	
>300	Unsuitable for drinking	0	0.00	0	0	

The WQI of the pre-monsoon samples are mostly classified as excellent and good. Considering the post-monsoon samples almost 55% are excellent and 45% are good. Figure 26 and 27 shows the location-wise graph for pre and post-monsoon samples.

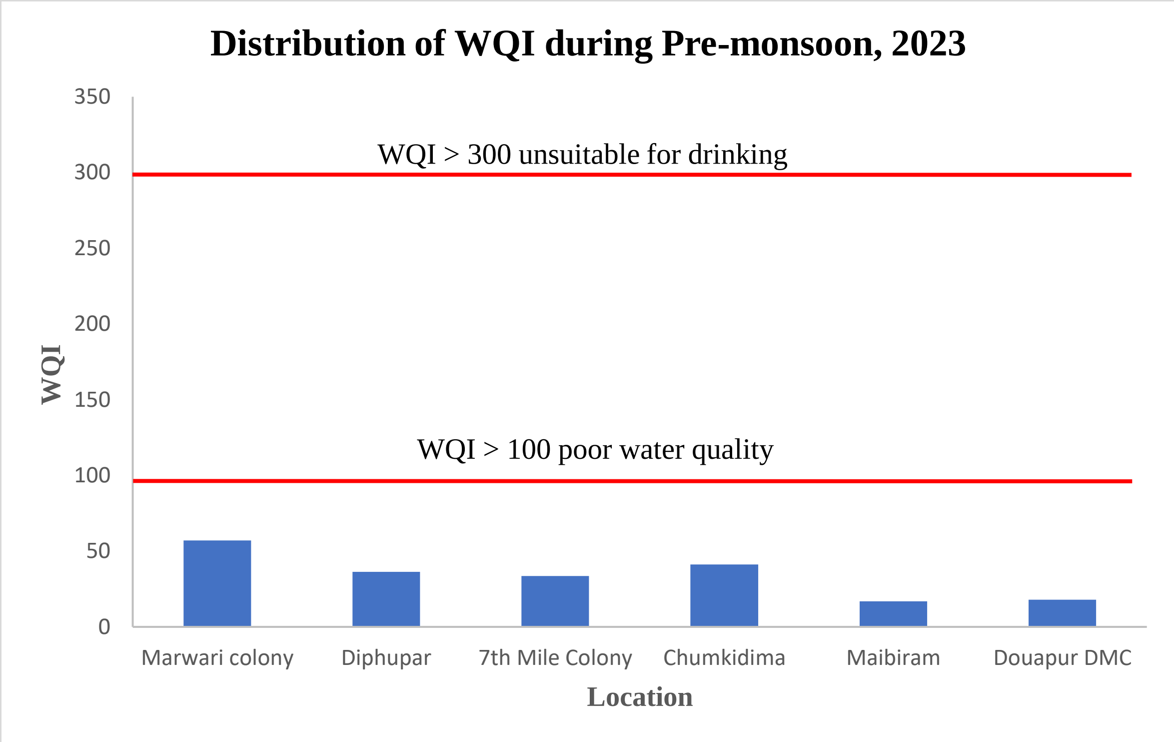


Figure 27: Distribution of WQI of Nagaland during pre-monsoon 2023.

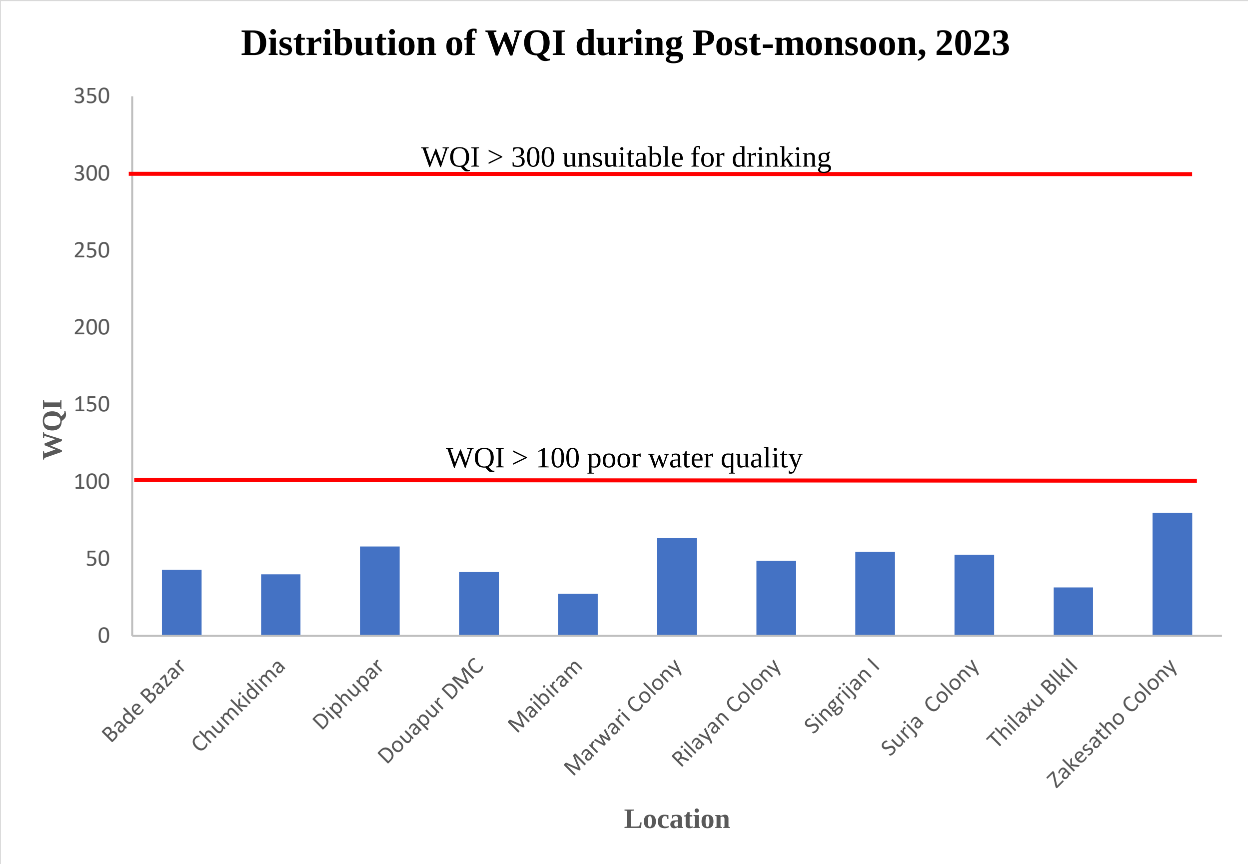


Figure 28: Distribution of WQI of Nagaland during post-monsoon 2023.

Chapter 6

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.

Chapter 7

CONCLUSIONS

Based on the physico-chemical parameters the GW of Nagaland is being assessed from drinking and irrigation perspectives. The electrical conductivity of GW samples within the state has a maximum value of 923.6 µS/cm thus indicating the GW to be of low salinity. The groundwater quality assessment indicates that the Sodium Adsorption Ratio (SAR) for all samples falls in the excellent category. The Na% analysis shows that most samples are suitable for irrigation, though a few fall into the doubtful category. High sodium levels can reduce soil permeability by displacing calcium and magnesium, leading to poor drainage. Kelly's ratio (KR) reveals that over 52% of the samples are suitable for irrigation with KR values below 1. Proper management practices can improve GW quality for irrigation purposes in those areas. The US Salinity laboratory diagram indicates that majority of the samples fall into the C1S1 and C2S1 category. The piper diagram shows that the GW is relatively fresh to mix type with some locations having Ca-Cl and Na-Cl dominancy. The GW within the state has not undergone momentous mineralization processes while the diamond symbolizing mixed type of samples. The anion triangle has shown majority of the samples to be of chloride type. In conclusion, regular monitoring of GW quality is necessary, and proper management practices are required to maintain soil health and productivity for effective irrigation in Nagaland.

The data generated suggests that the pH, electrical conductivity (EC), total dissolved solids (TDS), and ion concentrations vary significantly across the 17 locations in Dimapur, Nagaland. The lowest pH value is reported from Diphupar with 6.40 while Marwari Colony reports highest pH of 8.33. Maximum EC is 923.60 µS/cm from Zakesatho Colony which indicates low salinity of GW of Nagaland. Factors such as soil composition, climate, and water sources are likely contributing to the variation in pH, EC and TDS of the GW. The major cations and anions are within the safe limits as prescribed by BIS. The ionic balance evaluation is done and for all the opposite ions are well balanced within ±5%. The Fe concentration ranges from a minimum of 0.01 mg/L to a maximum of 2.83 mg/L. Chumkidima, Maibiram and Marwari Colony have recorded iron above BIS permissible limits of 1.0 mg/L. The contamination by Fe concentration in these three locations can be attributed to geogenic reasons, viz. erosion, natural weathering, difference in the geological composition of the soil etc. In the post-monsoon 4 samples from Chumkidima, Diphuipar, Douapur DMC, and Thilaxu show Mn concentration higher than permissible limit. Before consuming or using it for domestic purposes the GW from these locations need suitable treatment beforehand or else there will be adverse effects of iron/manganese on the health and resources. There is immediate necessity for developing sustainable low-cost effective treatment technologies/strategies for such contaminants by remediation for sustainable access to safe drinking water.

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ANNEXURES

ANNEXURE – I: CHEMICAL QUALITY OF WATER SAMPLES COLLECTED FROM GWMS OF NAGALAND DURING PRE-MONSOON SEASON, 2023 (BASIC CONSTITUENTS)

District	Location	Longitude	Latitude	pH	EC	Turbidity	TDS	CO_3^{2-}	HCO_3^-	Total Alkalinity	Cl^-	SO_4^{2-}	NO_3^-	F^-	Total Hardness	Ca^{2+}	Mg^{2+}	Na^+	K^+
					(µS/cm @25°C)	(NTU)	mg/L												
Dimapur	Marwari colony	93.72536	25.9056	6.72	596.90	0.33	387.99	0.00	305.24	305.24	39.77	2.94	8.24	0.15	265.00	90.07	9.67	39.32	22.37
Dimapur	Diphupar	93.77333	25.8644	7.84	480.60	0.70	312.39	0.00	42.73	42.73	112.70	12.75	25.81	0.01	105.00	24.02	10.91	71.52	3.82
Dimapur	7th Mile Colony	93.77417	25.8439	7.52	338.70	0.25	220.16	0.00	18.31	18.31	49.72	30.85	42.64	0.00	105.00	36.03	3.62	26.52	2.14
Dimapur	Chumkidima	93.78306	25.8169	6.75	418.30	0.22	271.90	0.00	122.10	122.10	72.92	37.58	1.89	0.02	130.00	34.03	10.91	44.97	18.26
Dimapur	Maibiram	93.61953	25.7736	6.97	110.80	0.64	72.02	0.00	61.05	61.05	19.89	2.99	0.00	0.02	75.00	20.02	6.06	4.79	1.94
Dimapur	Douapur DMC	93.60444	25.7611	6.49	153.80	0.20	99.97	0.00	36.63	36.63	49.72	3.55	6.14	0.01	65.00	18.01	4.85	16.22	1.34

ANNEXURE II: CHEMICAL QUALITY OF WATER SAMPLES COLLECTED FROM GWMS OF NAGALAND DURING PRE-MONSOON SEASON, 2023 (Fe, As & U)

District	Location	Longitude	Latitude	Fe	As	U
				mg/L	(µg/L)	
Dimapur	Marwari colony	93.72536	25.9056	0.65	0.79	0.05
Dimapur	Diphupar	93.77333	25.8644	0.43	0.22	0.27
Dimapur	7th Mile Colony	93.77417	25.8439	0.05	0.06	0.41
Dimapur	Chumkidima	93.78306	25.8169	0.69	0.03	0.00
Dimapur	Maibiram	93.61953	25.7736	0.01	0.14	0.01
Dimapur	Douapur DMC	93.60444	25.7611	0.07	0.05	0.09

ANNEXURE – III: CHEMICAL QUALITY OF WATER SAMPLES COLLECTED FROM GWMS OF NAGALAND DURING POST-MONSOON SEASON, 2023 (BASIC CONSTITUENTS)

District	Location	Longitude	Latitude	pH	EC	Turbidity	TDS	CO_3^{2-}	HCO_3^-	Total Alkalinity	Cl^-	SO_4^{2-}	NO_3^-	F^-	Total Hardness	Ca^{2+}	Mg^{2+}	Na^+	K^+
					(µS/cm @25°C)	(NTU)	mg/L												
Dimapur	Bade Bazar	93.6853	25.826	6.51	272.60	0.80	177.19	0.00	18.31	18.31	113.44	35.29	4.84	0.49	100.00	20.02	12.13	61.70	21.20
Dimapur	Chumkidima	93.7831	25.817	6.57	692.70	0.04	450.26	0.00	30.52	30.52	127.62	17.01	4.22	0.28	185.00	44.04	18.18	33.57	7.60
Dimapur	Diphupar	93.7733	25.864	6.40	512.30	0.02	333.00	0.00	12.21	12.21	145.35	7.88	40.94	0.47	85.00	14.01	12.13	83.70	28.10
Dimapur	Douapur DMC	93.6003	25.761	6.49	155.80	0.80	101.27	0.00	18.31	18.31	81.54	3.89	12.57	0.80	35.00	6.00	4.85	51.00	25.00
Dimapur	Maibiram	93.6194	25.774	6.47	102.70	0.23	66.76	0.00	24.42	24.42	74.45	3.15	5.06	0.40	60.00	18.01	3.63	38.50	10.80
Dimapur	Marwari Colony	93.7253	25.906	8.33	554.40	1.30	360.36	3.00	42.73	45.73	166.62	4.25	15.91	0.79	210.00	38.03	27.89	53.30	26.50
Dimapur	Rilayan Colony	93.6844	25.903	6.52	476.60	0.02	309.79	0.00	36.63	36.63	88.63	32.38	27.11	0.28	170.00	44.04	14.54	23.30	17.70
Dimapur	Singrijan I	93.7247	25.842	6.53	236.00	0.06	153.40	0.00	12.21	12.21	116.99	9.02	29.37	0.63	50.00	16.01	2.42	66.80	35.30
Dimapur	Surja Colony	93.7614	25.8	6.54	191.90	0.04	124.74	0.00	18.31	18.31	106.35	3.74	29.17	0.64	75.00	12.01	10.92	48.40	32.00
Dimapur	Thilaxu BlkII	93.7411	25.88	6.53	242.70	1.20	157.76	0.00	24.42	24.42	56.72	5.78	27.00	0.25	80.00	8.01	14.56	24.20	7.19
Dimapur	Zakesatho Colony	93.7308	25.918	6.56	923.60	0.07	600.34	0.00	24.42	24.42	209.16	47.10	27.96	0.42	165.00	34.03	19.40	114.50	44.30

ANNEXURE IV: CHEMICAL QUALITY OF WATER SAMPLES COLLECTED FROM GWMS OF NAGALAND DURING POST-MONSOON SEASON, 2023 (Fe, As & U)

District	Location	Longitude	Latitude	Fe	Mn	Cu	Zn	Ni	Cr	As	U	Pb	Cd	Se	Hg
				mg/L						(µg/L)					
Dimapur	Bade Bazar	93.68528	25.82556	0.1927	0.0206	0.0004	0.0085	0.0015	0.0033	0.2894	0.5783	0.5118	0.0182	0.1776	0.0054
Dimapur	Chumkidima	93.78306	25.81694	1.3190	0.8701	0.0021	0.0194	0.0288	0.0024	1.9457	0.0574	0.6265	0.0357	0.6668	0.0186
Dimapur	Diphupar	93.77333	25.86444	0.0582	0.4905	0.0408	0.0829	0.0718	0.0020	0.1189	0.4298	6.8121	0.1703	0.6658	0.0109
Dimapur	Douapur DMC	93.60028	25.76111	0.0985	0.5952	0.0017	0.0298	0.0333	0.0023	0.1537	0.0533	0.6101	0.1534	0.3203	0.0118
Dimapur	Maibiram	93.61944	25.77361	2.8265	0.2035	0.0007	0.0345	0.0125	0.0018	0.0526	0.0080	0.3217	0.0457	0.0230	0.0069
Dimapur	Marwari Colony	93.72528	25.90556	2.4898	0.2687	0.0009	0.0416	0.0083	0.0027	1.1794	0.0353	0.6260	0.0215	0.1065	0.0070
Dimapur	Rilayan Colony	93.68444	25.9025	0.3521	0.0881	0.0030	0.1087	0.0017	0.0037	5.3994	0.2270	0.6649	0.0073	0.0179	0.0097
Dimapur	Singrijan I	93.72472	25.84222	0.1805	0.0027	0.0008	0.0110	0.0013	0.0024	0.3319	0.3050	0.2365	0.0097	0.4747	0.0306
Dimapur	Surja Colony	93.76139	25.8	0.2490	0.1267	0.0018	0.0284	0.0345	0.0043	0.1215	0.0192	0.5031	0.0582	0.0823	0.0093
Dimapur	Thilaxu BlkII	93.74111	25.87972	0.1460	0.3552	0.0028	0.0124	0.0227	0.0024	0.1137	0.0733	0.2129	0.0563	0.1927	0.0085
Dimapur	Zakesatho Colony	93.73078	25.9177	0.0508	0.0040	0.0001	0.0007	0.0007	0.0014	0.8348	0.0090	0.0285	BDL	0.0797	0.0035

ANNEXURES V: IRRIGATION INDICES OF SAMPLE LOCATIONS DURING PRE-MONSOON 2023

District	Location	SSP	SAR	RSC	% Na	KI	MR	PI
Dimapur	Marwari colony	24.39	0.37	-0.30	30.10	0.32	15.01	56.31
Dimapur	Diphupar	59.70	1.07	-1.40	60.44	1.48	42.78	75.77
Dimapur	7th Mile Colony	35.45	0.40	-1.80	36.52	0.55	14.20	52.29
Dimapur	Chumkidima	42.93	0.61	-0.60	48.24	0.75	34.54	74.00
Dimapur	Maibiram	12.20	0.09	-0.50	14.67	0.14	33.25	70.78
Dimapur	Douapur DMC	35.18	0.31	-0.70	36.27	0.54	30.69	73.83

ANNEXURES VI: IRRIGATION INDICES OF SAMPLE LOCATIONS DURING POST-MONSOON 2023

District	Location	SSP	SAR	RSC	% Na	KI	MR	PI
Dimapur	Bade Bazar	57.30	0.95	-1.70	61.73	1.34	49.93	69.01
Dimapur	Chumkidima	28.30	0.38	-3.20	30.90	0.39	40.47	42.01
Dimapur	Diphupar	68.17	1.40	-1.50	71.95	2.14	58.76	76.56
Dimapur	Douapur DMC	76.02	1.33	-0.40	80.33	3.17	57.08	94.80
Dimapur	Maibiram	58.25	0.76	-0.80	61.91	1.40	24.92	80.27
Dimapur	Marwari Colony	35.57	0.57	-3.40	41.64	0.55	54.70	48.42
Dimapur	Rilayan Colony	22.96	0.27	-2.80	30.13	0.30	35.22	40.53
Dimapur	Singrijan I	74.39	1.45	-0.80	79.20	2.91	19.92	85.85
Dimapur	Surja Colony	58.40	0.86	-1.20	66.10	1.40	59.94	73.61

District	Location	SSP	SAR	RSC	% Na	KI	MR	PI
Dimapur	Thilaxu BlkII	39.69	0.42	-1.20	43.61	0.66	74.96	63.56
Dimapur	Zakesatho Colony	60.15	1.37	-2.90	64.95	1.51	48.41	67.79

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