# Assessment of major ion concentration in groundwater around landfill area, Salcete, Goa.

A Dissertation for

GEO-651: Discipline specific dissertation

Credits: 16

Submitted in partial fulfilment of

M.Sc. in Applied Geology

by

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**GOA UNIVERSITY**

May 2024



Examined by: Seal of the School

# DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "**Assessment of major ion concentration in groundwater around landfill area, Salcete, Goa.**" is based on the results of investigations carried out by me in the in the Master of Science Degree in Applied Geology at the School of Earth Ocean and Atmospheric Sciences, Goa University, under the Supervision of Mr Mahesh M. Mayekar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations or other findings given the dissertation.

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Date: 2/05/2024

Place: Goa University

# COMPLETION CERTIFICATE

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# CONTENTS

# PREFACE

The quality of groundwater is a vital concern in regions proximate to landfill sites due to the potential for contamination from various pollutants leaching into the aquifer. In the case of Salcete, Goa, where rapid urbanization and industrialization have led to increased waste generation, the assessment of groundwater quality around landfill areas becomes imperative. This preface introduces a comprehensive study aimed at evaluating the major elemental composition of groundwater in the vicinity of the landfill area in Salcete, Goa. The degradation of groundwater quality poses significant environmental and public health risks, as contaminated water may infiltrate into drinking water sources and agricultural lands, thereby impacting ecosystems and human well-being. Hence, there is a pressing need to monitor and assess groundwater quality, particularly in areas where anthropogenic activities such as landfilling can potentially degrade water resources. This study aims to provide insights into the major elemental composition of groundwater in the Salcete region, focusing on key parameters such as extent of contaminants associated with landfill leachate and assess the potential risks posed to human health and the environment.

The findings of this study are intended to inform policymakers, environmental agencies, and local communities about the current status of groundwater quality in the vicinity of the landfill area. By identifying sources of contamination and evaluating the spatial distribution of major elements, appropriate remedial measures can be implemented to mitigate the adverse impacts of landfill leachate on groundwater resources.

It is hoped that this research will contribute to the development of effective strategies for the sustainable management of groundwater in Salcete, Goa, and serve as a basis for future studies aimed at addressing the complex challenges associated with waste management and environmental protection in rapidly developing regions.

# ACKNOWLEDGMENT

I would like to express my deepest gratitude to all those who have contributed to the completion of my dissertation.

Firstly, I would like to thank my dissertation guide, Mr. Mahesh Mayekar, Assistant Professor, School of Earth, and Ocean & Atmospheric Sciences for his invaluable guidance, unwavering support, and insightful feedback throughout every stage of this research. His expertise, encouragement, and patience have been instrumental in shaping this dissertation.

I extend my sincere appreciation to the Goa University for their financial support, which made this research possible.

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Special thanks goes to my family for their unwavering love, encouragement, and belief in me. Their constant support and understanding have been my source of strength throughout this endeavour.

Thank you all once again for your valuable contributions to this work.

# LIST OF FIGURES

# Tables

# ABBREVIATION

| Entity | Abbreviation used |
|---|---|
| Banded Iron Formation | BIF |
| Bureau of Indian Standards | BIS |
| Dissolved oxygen | DO |
| Electrical Conductivity | EC |
| Total dissolved solids | TDS |

# ABSTRACT

Groundwater is the most reliable resource for consumptive uses worldwide, but it is vulnerable to anthropogenic pollution in this post-industrialization era. Pollution of the resource may result from anthropogenic activities; hence, analysing the effects of leachate on groundwater is imperative. Physical, chemical and microbial characteristics of water helps in determining groundwater quality. Solid garbage is typically disposed of in an open manner on land without the use of hygienic land filling techniques or treatments. The likelihood of groundwater contamination is higher in the vicinity of landfill sites because leachate from the neighbouring dumping site may act as a pollution source. Users of nearby resources and the surrounding ecosystem are at serious risk from this kind of groundwater resource contamination. This study assesses the spatial distribution of physical chemical parameters of groundwater using 16 well water samples, around Sansodo prime landfill site of Margao city, Goa.

# Chapter 1

# Introduction

## 1.1 General Introduction

Hydrosphere of earth is sum of all the water that covers up the earth and the water cycle that distributes it around the planet. The abundance of water on the earth is its unique feature that clearly distinguishes our "blue planet" from the others in the solar system. The earth's hydrosphere is comprised of salt water and fresh water resources. Of the total volume of water on the earth, 94% is saline water while 6% is fresh water. Of this fresh water, 27% is glacial and 1% is usable portable surface water in the form of rivers, lakes. The remaining 72% is groundwater, which is utilized for domestic needs and most vulnerable to contamination by human activities. Groundwater is one of the earth's most widely distributed and most important natural resources. Groundwater exists wherever water penetrates beneath the surface. The rocks beneath the surface are permeable enough to transmit water, and at places, the rate of infiltration is so sufficient that the rocks are saturated to an appreciable thickness. This water may be fresh or brackish in quality. As the fresh water constitutes very little quantity of the total water available, we must think as to how best we can exploit it, with the growth of population, today in many of the place's water has become a critical source. In many places it is dwindling both in quality and quantity, creating problems for the communities involve (Sreenivasa, 2013).This study focusses on hydrological analysis of groundwater quality for major cation and anions around Sansodo area, it is an area garbage dump landfill of Margao city, Salcete, Goa, India. The study of concentration of ion in groundwater quality becomes an important aspect nowadays as firstly it determines ion composition of water and also chemical quality of water can be determined by it (Quality of ground water, 2016).In this research study a hydro geochemical water quality analysis is done by collection of 16 well water samples near the Margao landfill area, to understand the impact of the landfill leachates on groundwater quality, which is used for drinking purpose. Water samples were collected in month of May (pre-monsoon) and during February (post monsoon) to study seasonal changes in groundwater.

**1.2 Physiography of Goa**

The State of Goa located between 14° 53'54" and 15° 48'00" north latitudes and 73° 40'33"and 74° 20'13" east longitudes is situated on the western coast of peninsular India. It is bounded in the north by Maharashtra State, in the east and south by Karnataka State and in the west by the Arabian Sea. The State has a total geographical area of 3702 Sq. km., which is administratively divided into two districts with 12 talukas. In the Salcete taluka lies the Margao city which lies to latitude of $15.2832^0$N and longitude of $73.9862^0$E where the study took place (R & D.Dhayamalar, 2021)

**1.3 Geology of Goa**

The Dharwad Super group includes the Archean aged rocks known as the Goa group. According to the classification system developed by Gokul et al. (1985), the Goa Group of rocks is made up of four Formations: The Barcem Formation, the Sanvordem Formation, the Bicholim Formation, and the Vageri Formation. A.G. Dessai (2012) extended this concept further, dividing the Goa Group of rocks into two Groups: The Barcem Group and the Ponda Group. An unconformity separates these Groups from one another. The Barcem Group, which includes the Barcem Formation, the oldest formation, is comparable to the Bababudan Group of the Dharwar Craton. It is located on the Tonalite-Trondjemite-Granodiorite (TTG) Gneissic basement. Over 2000m of Barcem Formation are present. Metavolcanics and metasedimentary make up this material. Sanvordem, Bicholim, and Vageri Formations make form the Ponda Group, which is comparable to the Chitra Durga Group of the Dharwar craton. The Chandranath Granite is covered by the met conglomerates, metagreywackes, and argillites of the Sanvordem Formation. Banded iron formations (BIF) and metasediments make up the Bicholim Formation, which sits beneath the Sanvordem Formation. The newest formation, Vageri Formation, is composed of metagreywackes and metabasalt. It is located over Bicholim Formation. Due to its extensive geographic coverage, the laterite deposit in Goa is an important geological formation (Dessai, 2011). The widespread development on a variety of rock types is one of the most distinctive features of laterites in Goa. The diverse Dharwar schists and metasediments, the more mafic gneisses, the mafic-ultramafic intrusive, and the Deccan basalts have all served as their foundation. On the other hand, most Peninsular gneisses have poor laterite development, and laterite is frequently missing where granite is visible. According to Ibrampurkar (2014), laterites can either be of detrital origin, which typically occupies hill slopes and valley parts, or they can form in situ on crystalline rocks and on alluvial valley fills**.**

Major part of the Goa State is underlain by rocks of Precambrian age comprising of banded biotite gneisses, Meta volcanism, phyllites, biotite and chlorite schists, greywacke, conglomerate (tilloid), pink phyllites with associated banded ferruginous quartzite and chert breccia. These rocks are intruded by ultra-basic, basic sills and dykes, followed by granites and pegmatites. Dolerite dykes and quartz veins form the youngest intrusive in the area. The Deccan Trap basalts of Late Cretaceous to Early Eocene age occupy a small portion in the north-eastern part in the high altitudes**.**

Almost all formations in the state have undergone lateritisation to various degrees depending upon the climate and rock type. The lateritisation is more pronounced in the coastal areas than in the hilly regions Phyllites, Schists and Meta volcanism are more susceptible to lateritisation and the gneissic / granitic rocks are least susceptible. In general, the thickness of laterites varies from about 3 to 30 mts. (Ibrampurkar, 2014).

Laterites are highly porous due to the process of leaching and weathering. Hence, they have very good capacity to hold and transmit groundwater. Groundwater in laterites occurs under phreatic conditions. Major portion of the state is occupied mainly by crystalline rocks and consolidated and metamorphosed sedimentaries, which do not possess primary porosity. Secondary porosity introduced through weathering, fracturing and jointing, produces the void spaces to hold and transmit ground water. Groundwater in these rocks occurs under water table conditions in the weathered zone and under semi confined and confined conditions in the deeper fractured zone. Beach sands along the coast and alluvium along major rivers have limited occurrence and the ground water occurs in the primary porosity under water table conditions (R & D.Dhayamalar, 2021)

| | | |
|---|---|---|
| Residual rocks | | Laterites |
| Basic Intrusives (Late) | 65-66 Ma | Dolerites |
| Deccan Traps | 64-67 Ma | Basalts |
| Basic Intrusives | | Meta dolerite |
| Bondla Mafic Ultramafic Complex | | Dunite-Peridotite-Gabbro and equivalents |
| Ponda Group (Chitra Durga Group) | Vageri Formation | Meta basalts, Argillites and Metagraywackes |
| | Bicholim Formation | Banded Ferruginous quartzites, Manganiferous Chert Breccia with pink ferruginous phyllites, Limestones, Pink ferruginous phyllites, quartz-Chlorite-Amphibole Schist, Metagreywacke, Argillite |
| | Sanvordem Formation | Metagraywackes, Argillites, Quartzite, Tilloid |
| ----------------------------------Unconformity---------------------------------- | | |
| Barcem Group (Bababudan Group) Barcem Formation | Barcem Formation | Metagabbro, Peridotite, Talc Chlorite Schist Quartzite, Quartz-Sericite Schist Red Phyllite Quartz Porphyry Massive, Schistose and Vesicular Metabasalt |
| ----------------------------------Unconformity---------------------------------- | | |
| Canacona Granite | 2979+4 Ma | Potassic Porphyritic Granite |
| Chandranath Granite Gneiss | 2900-2700 Ma | Granodiorite Gneisses |
| Basement: Anmode Ghat Trondjemite Gneiss | 3400-3300 Ma | Tonalite-Trondjemite-Granodiorite (TTG) Gneiss |

Table 1.1: Lithostratigraphic classification of supracrustal rocks from Goa (AG. Dessai, 2011)

## 1.4 Geology of study area

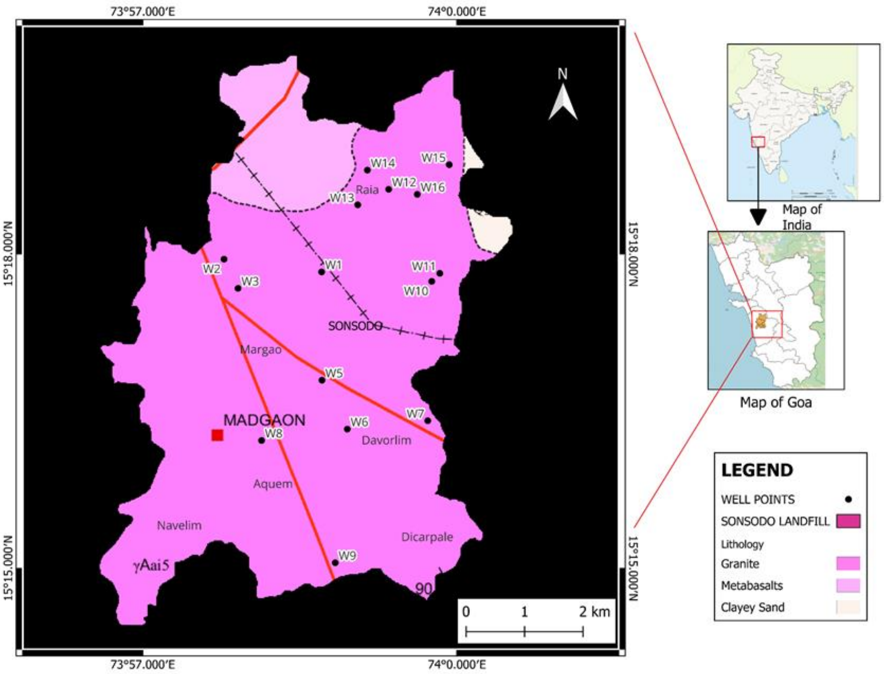


Figure1.1: Geological map of study area (GSI map, second edition, 2023)

The rocks present in the study area are of Precambrian age. At the basement of the study area rock present is granite which is a common type of intrusive igneous rock that is granular and phaneritic in texture. It is typically composed of feldspar, quartz, and mica minerals. In the geological context of Goa, India, granite formations are significant. Granites indicate episodes of magmatic activity and the processes involved in the formation of the Earth's crust during the Archean Eon. Granite often hosts economically important minerals and ores. In the case of Goa, granite formations may contain deposits of minerals such as iron, manganese, and bauxite, which have been historically mined in the region. Including groundwater perspective granite generally has low porosity, meaning it contains few interconnected pore spaces where water can be stored. However, the fractures and joints within granite provide pathways for water flow. These fractures increase the permeability of granite, allowing water to move through the rock. Granite can serve as an aquifer, especially in regions where it is extensively fractured. Fractured granite aquifers are characterized by rapid groundwater movement along fracture networks. These aquifers can yield significant quantities of water to wells and springs. Since all wells lies within the granitic formation there good water recharge for the well water. Overlying the granite formation in study area in some parts of Raia village are the Meta basalts. Meta-basalts are metamorphosed basalts, which are igneous rocks that have undergone metamorphism due to intense heat and pressure. Meta basalts belong to Barcem group of goa group of formations and belongs to the younger Chitra-Durga group of Dharwar super group of peninsular India. Meta-basalts often contain fractures and joints formed during the metamorphic process or inherited from the original volcanic activity. These fractures can serve as pathways for groundwater flow, allowing water to percolate through the rock and contributing to groundwater recharge and movement. Overlying met basalts is Clayey sand which is seen in some parts of Raia village belongs to Mandovi group of goa group of formations it is an active fluvial deposit of late Holocene age. Clayey sand formations within the Goa Group represent sedimentary deposits that have undergone lithification, resulting in the formation of cohesive rock units with a mixture of sand and clay minerals.

### 1.5 Climate and Rainfall

The State has a tropical-maritime monsoonal type climate with distinct aerographic influence. The climate is equable and humid throughout the year. Due to the maritime climate the diurnal variation in temperature is not much. The months of January and February are dry with clear skies and generally pleasant. May is the hottest month with temperature around 30°C and January the coolest month with temp 25°C. Rain occurs during the monsoon period from June to September. Over 90 percent of annual rainfall occurs during monsoon period. The balance of 10 percent occurs during the pre-monsoon period from March to May and post monsoon period from October to December. However, the rainy period extends from May to November.

In South Goa it ranged 2611.7 mm at Mormugao in west coast and maximum at Sanguem in the east again ghat section indicating that the rainfall increases from west to east. The overall annual normal rainfall in south Goa is 3733.13mm (R & D.Dhayamalar, 2021).

## 1.6 Study Area

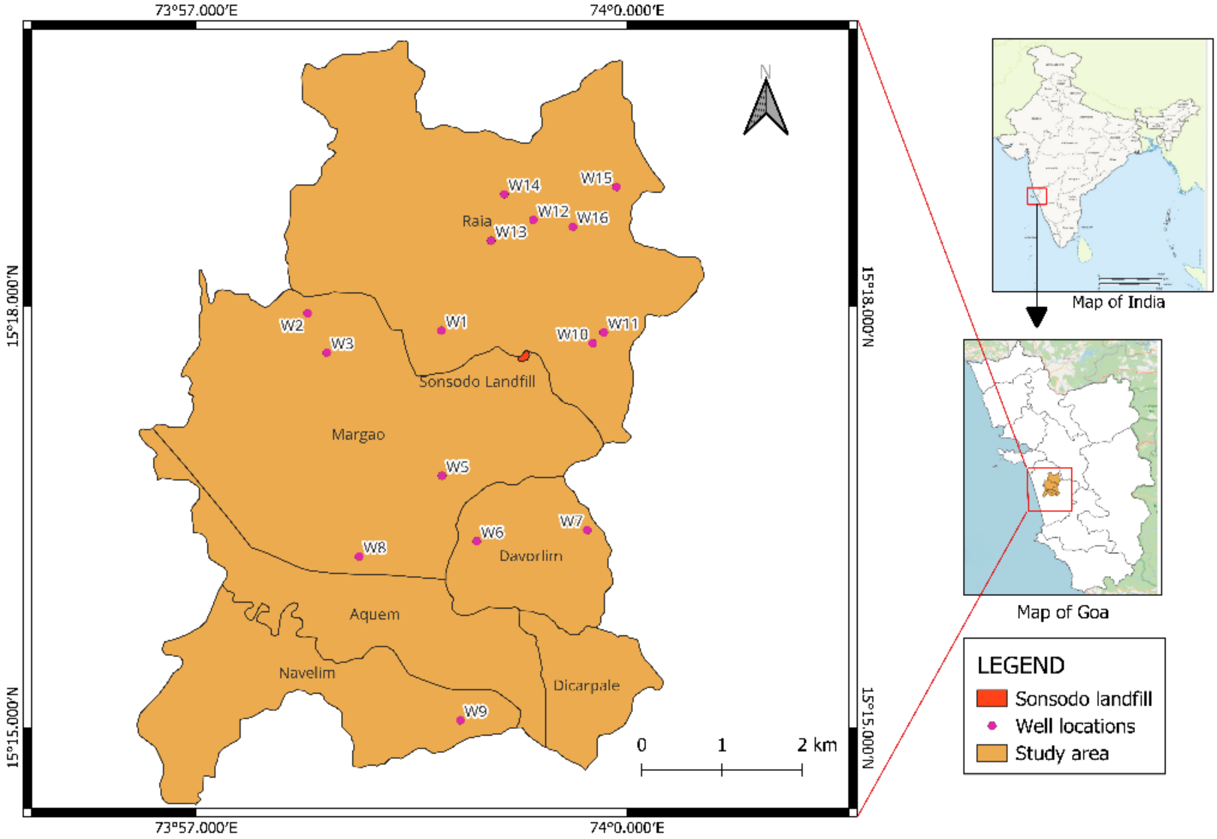


Figure 1.2: Map of study area (Bhuvan Portal)

The study area is a part of Salcete taluka of Goa and is located in the South Goa district. The study area is created by using Topo -sheet number 48E15-SE-B3 of scale 1:25000. The villages of the study area around the prime landfill site includes Navelim village, Daverlim Village, Aquem, Raia village and also part of  Margao city .

## 1.7 Topography

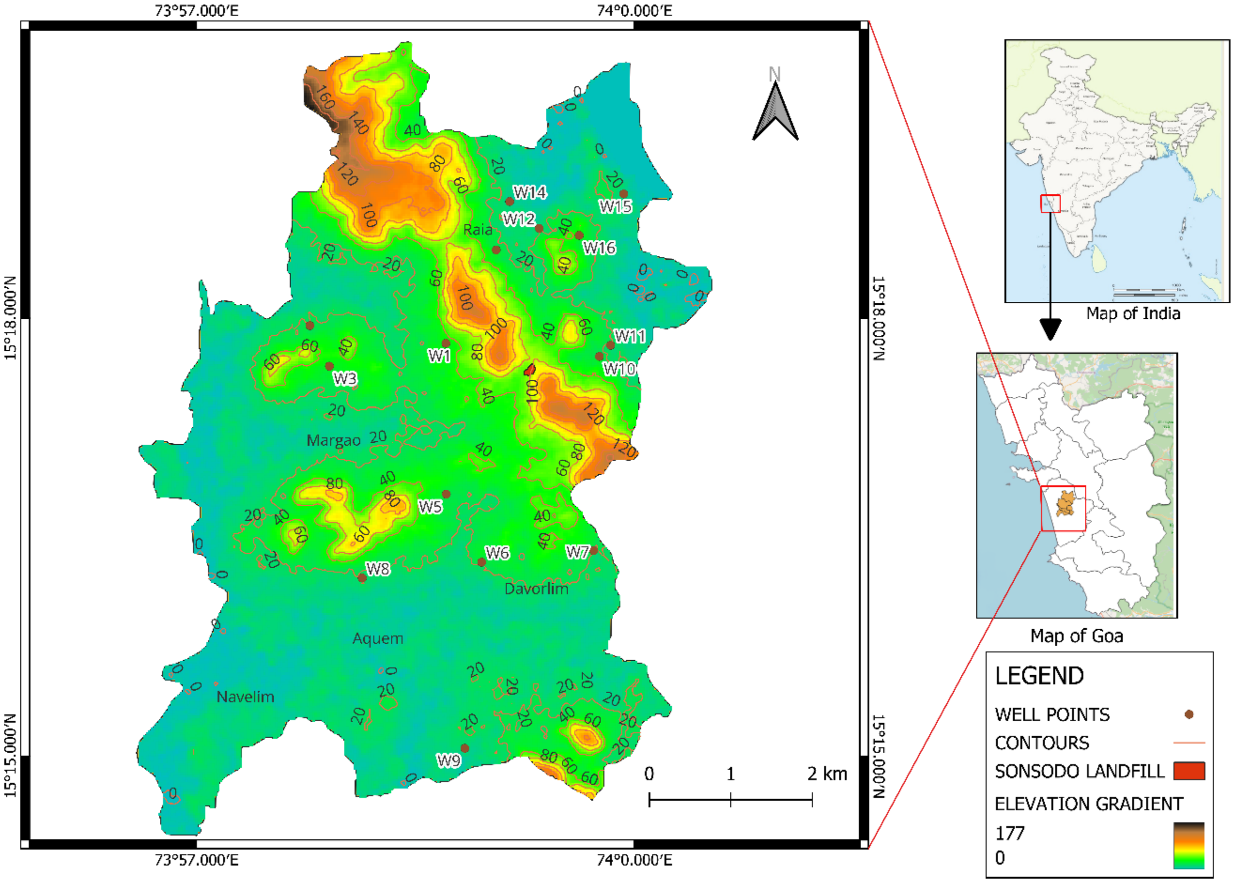


Figure 1.3: Topographic map of study area.

The study area consists of plains and elevated topography. There are isolated tablelands in the North West direction with elevation 160-60 m above mean sea level. The Low-lying area with elevation less than 25 m msl is seen in Raia village of the study area. The North boundary of study area shows Maximum elevation 160 meters above mean sea level.

## 1.8 Drainage

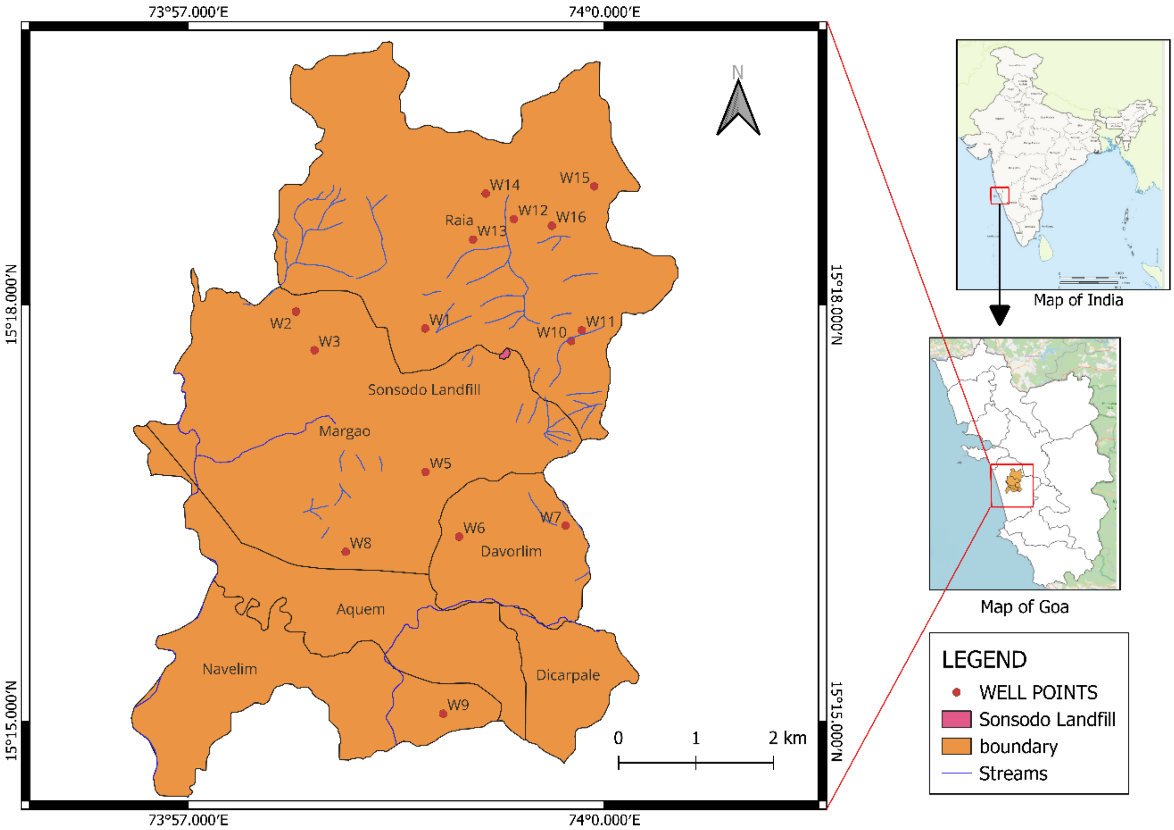


Figure 1.4: Drainage map study area

Along India's western coastline is the state of Goa. The study area which is around land fill site consist of major Sal River that is most significant river in the vicinity of Margao, which flows through the city. The Sal River is fed by several tributaries and smaller streams as it flows through the region.

## 1.9 Soil

The soil in the study area is predominantly influenced by its coastal location, tropical climate, and geological characteristics. Typical soil types found in the region include Laterite soil is widespread in study area it is a type of tropical soil that develops in hot and humid climates with heavy rainfall.

Laterite soils are typically rich in iron and aluminium oxides, giving them a reddish-brown colour. They are well-drained but can be relatively infertile and acidic. Lateritic Gravelly Soil in some parts of the study area region, especially in hilly or elevated areas, lateritic gravelly soil may be present. This type of soil is similar to laterite soil but contains a higher proportion of gravel-sized particles. Lateritic gravelly soil is often found on slopes and hillsides and may pose challenges for agriculture due to its poor water-holding capacity

Alluvial Soil: are along the banks of the Sal River and other water bodies in the study area, there are deposits of alluvial soil. Alluvial soil is formed by the deposition of silt, clay, and sand carried by rivers and streams.

## 1.10 Land use Land Cover

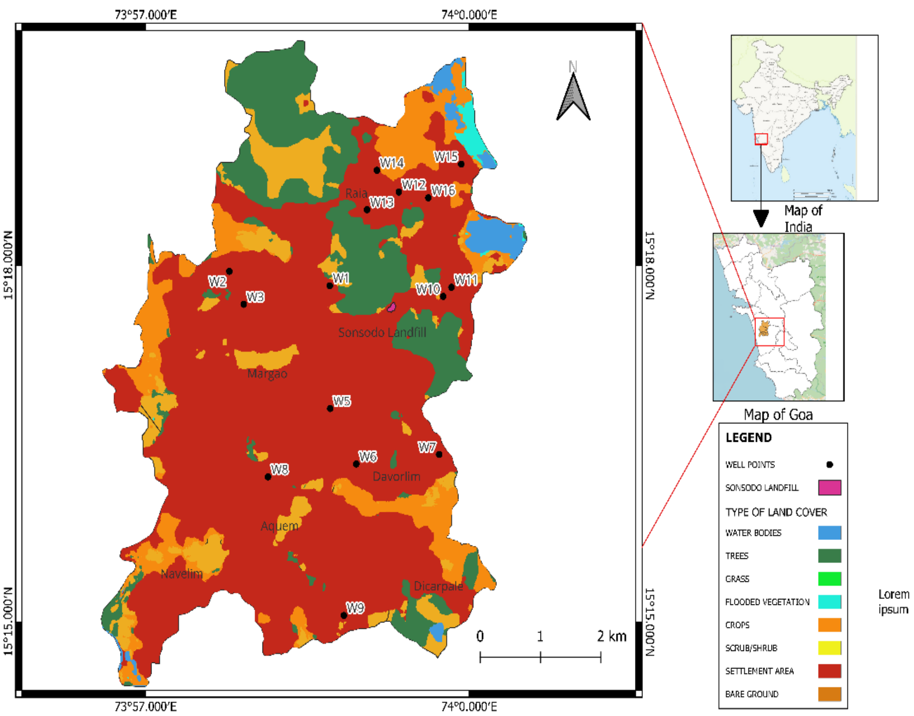


Figure 1.5: Land use land cover

The human use of land resources gives rise to “land usage, “which varies depending on its function, such as food production, housing provision, recreation, material extraction and processing, and the biophysical qualities of the land itself. Land cover refers to the physical and biological cover on the land’s surface, including water, flora, bare ground, and artificial constructions (Ellis, 2007). The land use and the land cover studies indicate the following order of land use categories: barren land < built-up land < agriculture land < water bodies. Salcete is a taluka in South Goa known for its mix of urban and rural landscapes. Study area includes urban centres such as Margao, which serve as commercial and administrative hubs. These urban areas consist of residential neighbourhoods, commercial districts, industrial zones, transportation networks such as roadway, railways, institutional facilities such as schools and hospitals, and also recreational spaces parks playgrounds, and civic amenities. Navelim is primarily a residential area with some vegetation. Land use in Navelim includes residential neighbourhoods, small-scale commercial establishments, educational institutions, religious sites (temples, churches), agricultural fields, and patches of natural vegetation. Rural areas like Raia is a predominantly rural area with agricultural land and dispersed residential settlements. The land use in Raia consists mainly of agricultural fields, residential clusters, and religious structures, water bodies like ponds and streams, and patches of natural vegetation. Daverlim is area with residential areas interspersed with agricultural land and natural features. Land use in Daverlim includes residential neighbourhoods, agricultural fields mainly for horticulture and subsistence farming, small-scale commercial activities, religious sites, and pockets of green spaces.

### 1.11 Hydrology

Hydrology is the scientific study of water, its distribution, movement, and properties on the Earth's surface, in the soil and underlying rocks, and in the atmosphere. It encompasses various aspects of the water cycle, including precipitation, evaporation, and infiltration, runoff, and groundwater flow**.** Salcete is a taluka in the southern part of Goa, India. Its hydrology is influenced by various factors similar to those affecting the rest of Goa. Salcete's topography consists of a mix of coastal plains and hilly terrain, with the Western Ghats forming the eastern boundary of the taluka. This diverse topography influences the flow of surface water and groundwater recharge patterns. Several rivers and streams traverse through Salcete, including the Sal, Zuari, and Kushavati rivers. These water bodies play a vital role in the hydrological cycle of the region, providing water for irrigation, domestic use, and supporting local ecosystems. Groundwater is an essential source of water for both domestic and agricultural purposes in Salcete. The hydrogeological characteristics of the region, including soil types and geological formations, influence groundwater availability and quality. Goa, experiences a tropical monsoon climate characterized by heavy rainfall during the monsoon season (June to September). The seasonal rainfall pattern replenishes surface water bodies and recharges groundwater aquifers. Effective water management practices, including rainwater harvesting, watershed management, and groundwater conservation, are crucial for sustainable water use in Salcete. Additionally, efforts to mitigate water pollution and ensure water quality are essential for safeguarding public health and environmental sustainability. Rapid urbanization and developmental activities in Salcete, particularly along the coastline, can impact the hydrology of the region through changes in land use, increased surface runoff, and alterations to natural drainage patterns. Sustainable development practices that consider water resource management are necessary to mitigate potential adverse effects on the hydrological system.

### 1.12 Objectives of Study area

**2.** To check seasonal variation in ground water and to prepare groundwater flow net.

**3.** To assess the concentration of major cation and anion in the water samples.

**4.** Evaluating potential risk of groundwater contamination due to landfill leachate on human health and to know suitability of groundwater for drinking purpose using BIS (2012) standard.

# CHAPTER 2

## Literature Review

Assessment of pollution potential of the leachate from municipal solid waste disposal site and its impact on groundwater quality study was conducted by (Singh et al., 2016). Physicochemical parameters of leachate as well as groundwater samples were determined to evaluate for leachate pollution index as well as water quality index. According to the study done leachate pollution index was found to be moderate with a pH of 7.5 which indicates Varanasi solid waste dumping site is at the mature stage of the landfill. Water quality index of major groundwater samples are found to be good for drinking purpose only 3 of the samples show unsuitable for drinking purpose. The principal component analysis aimed to examine the compositional patterns within the water system and its associated influencing factors. Among the four components analysed natural and anthropogenic influences, hardness, weathering and agriculture, and agriculture and anthropogenic factors, the first component representing natural and anthropogenic influences, accounted for the highest percentage of variance at 36%. Hierarchical cluster analysis depicts three types of clusters such as Ca-HCO3, Na-Mg-HCO3, and Na-HCO3 type of water in the study area.

Assessment on groundwater quality from wells located near Municipal Solid waste dumping site of Solapur City, Maharashtra study conducted by B.L Chavan et al.(2014). Study was conducted on quality of water body which includes physiochemical and microbial characteristics. Groundwater contamination is due to solid waste dumping or due to the source rock characteristics were studied. The results reveal that the groundwater contamination is more frequent in wells located near landfill sites than the wells located away from such sites.

A study on contamination of ground and surface water bodies by leachate leakage from a landfill in Bangalore, India was conducted by Naveen et al., 2018 .The study discusses the physical and chemical Characterisation of landfill leachate and nearby water bodies which reveals high contamination of organic and inorganic constituents and also did batch wise leach test were conducted to know heavy metal contamination. Based on physicochemical analysis the quality of water was found to be unsuitable for drinking purpose. Piper diagram identifies the hydro geochemical facies. The diagram shows that well water sample is high in concentration of Ca 320 mg/L, Based on physicochemical analysis the quality of water was found to be unsuitable for drinking purpose.

# CHAPTER 3

# Methodology

## 3.1 Pre Field Preparation

In line with the goals established. Google Earth Pro was used to locate communities along the Sonsodo Landfill area. Utilizing Survey of India top sheets 48/E15 –SE- B3 at a scale of 1:50000, wells were located. The depth to the groundwater level, the thickness of the water column, and the overall depth of the wells were all included in a format that was created for the gathering of field data.

## 3.2 FIELD WORK

Monitoring of dug wells, tube wells, or drilled wells is one of the most widely used methods for investigating groundwater. As a result, a reconnaissance field trip was conducted to identify locally available open wells. For monitoring ground water levels and water quality, a network of 16 wells was created in the villages of from Raia village, Navelim village, Daverlim village and Santemol village. Figure 1.1 depicts the monitoring wells' well network map. Table lists 2.1 the latitude and longitude of monitoring wells in the study region. All of the data required for the study was collected at each well site and was documented in excel sheet for further assessment. Fieldwork was conducted for two months once in month of June 2023 and other in month of February 2024. The pH and EC of groundwater for all 16 wells were tested in the field alongside wells using portable instruments. Groundwater samples were then analysed in laboratory.

## 3.3 PHYSICAL PARAMETER

### 3.3.1pH

Groundwater samples were analysed using Five Go-mettler Toledo portable pH meter. The pH of the electrode was calibrated prior going to the field using standard methods by using standard solutions of pH 4, pH 7, pH 10 for making sure that the value is of electrode probe is neutral to carry out further tests in the field .The readings of each sample in field were recorded using following procedure.

**Procedure:**

i Collection of water sample from the public well with the help of a bucket.

ii Take out the pH meter probe out of 3M of KCl solution tube.

iii Insert the pH meter probe into the bucket with well water sample such that the ph. meter probe is inserted halfway in the water.

iv Once probe is inserted switch on the ON/OFF to ON and wait until pH meter beeps showing the value of pH of water sample.

v Note down the reading displayed on the pH meter screen on the field diary.

vi Rinse the probe with distilled water.

vii And lastly immerse it in 3M KCL solution.

### 3.3.2Electrical Conductivity

The electrical conductivity of water samples from all 23 wells was measured in the field with a Solinst TLC EC metre. The following approach was used to acquire the EC values for each sample, and the values were reported in miliSeimens (µ).

**Procedure:**

i Firstly rinse the electrode probe with distilled water.

ii Turn on the switch of EC. Meter ON/OFF by pushing the switch to ON.

iii The display on EC meter screen should show the number 000.

iv Lower the probe into the well until it makes a beep sound is displayed on screen of EC meter when reaching the surface of water. Note down the value.

v The value noted down is value of the Electrical Conductivity of Surface well water, expressed in µs.

vi Further lower the Ec. meter probe until it reaches bottom of the well.

vii Examine the numbers on the screen. The figure on the screen is the value obtained of the well water bottom. Expressed in µs.

### 3.3.3 Dissolved Oxygen

An on-the-go Five Go-mettler Toledo portable pH metre was used to assess the dissolved oxygen content of water samples from all 16 wells.

**Procedure:**

i. Take the Do meter machine, and take out the electrode probe out of 3M KCl solution tube.

ii. Depress the ON/OFF switch. Monitor the screen of the Do meter it should display the value of 0.00 mg/l.

iii. Once the probe is taken out insert the tip of the probe in the bucket filled with well water samples to about half inch.

iv. Wait until the instrument beeps.

v. Note down the value of reading displayed on screen. The value displayed is the DO of the water in mg/l.

vi. Rinse the probe with distilled water and immerse it in a 3M KCl solution

### 3.4 Chemical Parameter

**Laboratory Test**

Water Samples were collected from around the landfill area of Sansodo Margao, Salcete, and Goa. The samples collected were evenly dispersed throughout the study area region. Sample collection was done in 500 ml of polyethylene bottles. To avoid contamination all samples were collected with keeping in mind all the safety precautions and all the protocols of standard method was followed.

#### 3.4.1 Estimation of Total Hardness

Total hardness provides valuable information about the overall mineral content of water. This can be relevant for assessing its suitability for specific purposes, such as drinking, industrial use, or aquaculture. So the total hardness was calculated in laboratory using trimetric method. The procedure for the following method is as follows.

**Requirements**

Beaker, Conical flask of 250ml. Eriochrome Black T indicator 0.02 N EDTA Solution. Ammonium chloride buffer solution. Distilled water. Glass rod.Burrete. Spatula, butter paper and weighing Machine.

**Preparation of Reagents**

**1)** Preparation of EDTA solution **w**eigh 3.273 g of EDTA powder on a weighing Machine and then dissolve in it 1000ml of distilled water.

2) Preparation of Ammonium buffer solution for preparing of ammonium buffer solution. Weigh 16.9g ammonium chloride ($NH_4Cl$) in 143ml concentrated ammonium hydroxide ($NH_4OH$) in. Weigh 1.25g magnesium salt of EDTA and dilute to 250ml with distilled water. If Magnesium Salt is unavailable weigh 1.179g disodium salt of EDTA grade and 780mg

$MgSO_4.7H_2O$ or 644 mg $MgCl_2.6h_2O$ in 50 ml distilled water. Add this above solution of $NH_4Cl$ in $NH_4OH$ and dilute to250ml.

3) Preparation of Eriochrome Black T indicator weigh 0.5g Eriochrome Black T indicator in 80ml of 90% ethanol make up to 100ml with 95% ethanol.

**Procedure**

Take a burette and rinse it with distilled water. Set the burette on burette stand and fill burette with 0.02N EDTA solution. Rinse the pipette with distilled water and pipette out 25 ml of water sample in clean conical flask of 250 ml and add Ammonium buffer. Then add 1 drop of Eriochrome black T indicator in the flask and titrate it against 0.02 N EDTA solution. The end point of titration should be determined by colour change from wine red to blue.

$Hardness=ml\ of\ the\ EDTA\ titrant\times 1\times 1000 ml\ of\ sample\ taken\ for\ titration$

Estimation of Calcium Hardness [EDTA Titrimetric 1.29 (S.A.P.)]

### 3.4.2 Calcium hardness

Trimetric analysis is used to determine calcium hardness.

**Requirements**

Beaker, Conical flask 250ml, Murexide indicator powder, 1N sodium hydroxide solution, 0.02N EDTA solution, distilled water, glass rod, Burette etc.

**Preparation of Reagents**

1) Preparation of 0.02N EDTA Solution for preparation of 0.02 N EDTA solution weigh 3.273g of EDTA powder and dissolve it in 1000ml of distilled water.
2) Preparation of 1N Sodium Hydroxide Solution weigh 4.5g of sodium hydroxide in 100ml distilled water and allow it to cool.

**Procedure**

i Rinse the burette with distilled water fill burette it with 0.02 N EDTA solution.

ii Rinse pipette with distilled water and pipette out 25 ml of water sample in clean 250ml conical flask and add 2ml NaOH solution.

iii Now add a pinch of Murexide indicator powder to the sample solution and titrate it against 0.02N EDTA solution.

iv The endpoint is determined by the change in colour from pink to purple.

**Calculation**

$Calcium\ (as\ Ca)\ mgl = ml\ of\ EDTA\ titrant$×0.01×40.008 divided by 5 into *1000

### 3.4.3 Magnesium Hardness

$Mg\ in\ mgl$ = ($TH\ asMgCaCO3L - Calcium\ Hardness\ asCaCO3L$) ×0.243

Where; TH = Total Hardness, MgCaCO3/L

### 3.4.4 Estimation of Sodium and Potassium

**Requirements and Preparations**

i Standard solution weigh 635 mg of “Anal R” grade NaCl and dissolve 250 ml of double distilled water dillute1:10 with 100 ppm .Now take 40 ml of the solution of Na.

ii Potassium value standard solution of (K) 477 mg of Anal R grade KCl and dissolved 250 ml of double distilled water 1000 ppm, 1:10 with double solution 100 ppm .Take 40 ml of this solution dissolve in 60 ml double distilled water to mark 100ml of 40 ppm of solution.

iii Stock solution 11.68 Anal R Sodium chloride, transfer in in 1 ml volumetric flask and ad 0.059 of Anal R Potassium chloride in Volumetric flask of same funnel dilute 1:100 with help of Double distilled water.

**Procedure**

a. Switch on the main switch of flame photometer turn on the gas cylinder for providing fuel to the burner of flame of flame photometer.

b. Turn on the tab of the flame photometer and type calculate for Na and K

c. Place the distilled water filled in beaker as stock solution and insert the suction pipe of flame photometer in the beaker.

d. Let the water aspirate and indication of it is when flame change its colour to blue indicate atomisation of stock solution drain,

e. Follow sample procedure as step d for sample solution and note down the values on the worksheet.

### 3.4.5 Chloride

Mohr's method was used to evaluate chloride levels in water samples. It determines taste and odour of water.

**Requirements**

Burette, Pipette, measuring cylinder, conical flasks, Acid or alkali for adjusting pH.

**Preparation of Reagents**

**i** Standard silver Nitrate solution (0.014N) weigh 2.395g of $AgNO_3$ and transfer it in distilled in water and dilute 1L.

ii Potassium Chromate Indicator weigh 5g of potassium chromate and add it in a distilled water. Add silver nitrate solution till a definite red precipitate is formed. Let it sit for 12 hours. Filter the solution and dilute the filtrate to 1 L with distilled water.

**Procedure**

1. Take 25mL water sample and dilute it with 50mL distilled water.

2. pH of the sample needs to be checked using pH meter. (pH should be within the range of 7 ,8 if not pH is adjusted using acid or alkali).

3. Now add 0.5mL potassium Chromate indicator and titrate it against 0.0141N standard silver nitrate solution.

4. End point is determined by formation of reddish-brown precipitate.

Calculation: $Chloride\ (as\ Cl)=ml\ of\ AgNO3\ titrant{-}0.2\times500ml\ of\ sample\ taken\ for\ titration.$

### 3.4.6 Alkalinity

Measure the total and phenolphthalein alkalinity using dye indicators. Make a bicarbonate, carbonate, and hydroxide alkalinity calculation.

Requirements: burette with burette stand, 50mL pipette, 250mL conical flask, phenolphthalein indicator, bromocresol indicator.

**Procedure:**

1. Collect 50 ml water sample in a 250 ml conical flask, then add 3 drops of phenolphthalein indicator to the sample, and titrate the 50ml sample against 0.02N sulfuric acid in burette to pH 8.3 and estimate phenolphthalein alkalinity. Phenolphthalein indicator will change colour, from pink to clear, at pH 8.3.
2. Use the same sample and to it add 3 drops of bromocresol green indicator. Titrate 50ml of sample against the 0.02 N of Sulfuric acid to pH of 4.5 and estimate total alkalinity. Bromocresol green indicator will change colour from blue to yellow, at pH 4.5.Amount of acid used up during titration since the start of step 1that is used to react with hydroxide, Carbonate and bicarbonate and it will constitute the total alkalinity.

3. Note that even after adding of the Phenolphthalein indicator if colour during titration doesn't develop it means there is no phenolphthalein alkalinity and it ultimately indicates that phenolphthalein alkalinity is "absent".

**Calculation**: $phenolphthalein\ Alk.(in\ mgLas\ CaCO3)=A1\times N\times 50{,}000V$

Where: A1 = volume of sulfuric acid used in mL;

N = normality of acid used to titrate;

V= volume of sample used in Ml.

$Total\ Alk$alinity $(inmgLas\ CaCO3)=A2\times N\times 50{,}000V$

Where: A2 = volume of acid used in mL starting from step 1 (i.e., A2>A1)

$hydroxide\ Al.(mhLas\ CaCO3)=50{,}000\times 10pH-pKw$

Where: pKw = 15 at 24°C

$Carbonate\ Alk.(mgLas\ CaCO3)=2\times(Phenolphthalein\ Alk.-Hydroxide\ Alk.)$

$Bicarbonate\ Alk.(mgLas\ CaCO3)=Total\ Alk.-[Carbonate\ Alk.+Hydroxide\ Alk.]$

### 3.4.7 Estimation of Nitrite

Is used to find both dissolved nitrogen –nitrite in the given well water sample.

**Preparation of Reagents**

1. Sulphuric Sample solution measure 1 g of the Sulphuric sample with weighing machine add the weighed sample in 10ml of Conc. HCl and add it to 60 ml of the distilled water. Moderately heating of the solution accelerates the dissolution. After cooling, the solution is made upto 100ml with distilled.

2. N-(1-nepthyl)-ethylene diamine dihydrogen chloride solution dissolve 0.1 g N (1-nepthyl) ethylene diamine dihydrogen chloride in distilled water and the volume is made upto 100ml. This solution is to be stored best in tinted brown solution glass.
3. Stock solution weigh 0.365g of $NaNo_2$ and then add it to 500 ml of distilled water. 1ml= 10µ mole $No_2^-$ - N.
4. Working Solution dilute 5 ml stock solution to 500 ml with distilled water 1ml = 0.1µmol $No_2^-$ - N.

**Procedure**

Take 1, 2, 3, 4 and 5 ml of the working solution in 50 ml graduated tubes and dilute them upto the mark with distilled water. Add 1 ml sulphuric sample and add 1ml of the $d_1$ansene and shake well. Record the absorption after 20 mins in 1 cm of curette at 540nm. The dye show to be exposed to light.

# CHAPTER 4

# HYDROGEOLOGICAL INVESTIGATION

Hydrogeological investigation is the process of studying the properties and behaviour of water in the subsurface. It involves the use of various tools and techniques to gather data about the hydrogeological system, such as the geology and hydrology of an area, the quantity and quality of groundwater, and the potential for water resource development and management.

Hydrogeological investigation is important in many applications, such as in the planning and design of groundwater supply systems, the identification of potential water sources for mining or industrial operations, the assessment of environmental impacts related to groundwater, and the evaluation of potential impacts of climate change on groundwater resources.

Hydrogeological investigation may involve a range of activities, such as geological mapping, hydrological data collection, aquifer testing, water quality analysis, and computer modelling of groundwater flow and transport. The results of hydrogeological investigations can be used to make informed decisions about the sustainable use and management of groundwater resources.

## 4.1 Hydrogeology of study area

Occurrence and movement of ground water depends upon the type of rock formation, structure, topography, rainfall, recharge etc. Ground water in the south district occurs in rocks having primary porosity & permeability or in those having secondary porosity acquired due to weathering, leaking, tectonics, solutions etc.

The hydrogeology of study area is characterized by the occurrence of groundwater in various rock formations with varying degrees of permeability and porosity. These formations include:

- Laterite: Laterite is a residual soil formed by the intense weathering of rocks in a hot and humid climate. It can be a good source of groundwater, especially in fractured and weathered zones.
- Alluvium: Alluvium is unconsolidated sediment deposited by rivers and streams. It can be a good aquifer if it is coarse-grained and well-sorted. However, alluvium is not widespread in South Goa.
- Granite and granite gneiss: These are hard, igneous rocks that are generally poor in groundwater. However, they can store and transmit groundwater in fractures and weathered zones.
- Metavolcanics and metasedimentary: These are metamorphic rocks that were originally volcanic or sedimentary rocks. Their groundwater potential varies depending on the degree of metamorphism. In their unaltered state, Metavolcanics are very poor in groundwater. However, groundwater can be found in zones of secondary porosity and permeability caused by weathering, joints, and fractures.

# Chapter 5

## Groundwater Quality Assessment

### 5.1.1 Physical Parameters

**Table 5.1: Well locations**

| WELL NO. | LATITUDE | LONGITUDE |
|---|---|---|
| W1 | 15°17'49.7"N | 73°58'42.5"E |
| W2 | 15°17'57.0"N | 73°57'46.6"E |
| W3 | 15°17'40.3"N | 73°57'54.6"E |
| W4 | 15°176.30"N | 73°59′1.75"E |
| W5 | 15°16'47.7"N | 73°58'42.7"E |
| W6 | 15°16'19.7"N | 73°58'57.2"E |
| W7 | 15°16'24.5"N | 73°59'43.3"E |
| W8 | 15°16'13.2"N | 73°58'08.1"E |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E |
| W10 | 15°17'44.3"N | 73°59'45.6"E |
| W11 | 15°17'48.9"N | 73°59'50.2"E |
| W12 | 15°18'37.0"N | 73°59'20.9"E |
| W13 | 15°18'28.1"N | 73°59'03.2"E |
| W14 | 15°18'48.0"N | 73°59'08.7"E |
| W15 | 15°18'51.1"N | 73°59'55.6"E |
| W16 | 15°18'34.1"N | 73°59'37.3"E |

### 5.1.2 pH

pH is the measure of hydrogen or hydroxyl ion concentration in water .The water solution can be classified as basic or acidic based on the amount of free hydrogen and hydroxyl ions present. The logarithmic unit of pH is used to determine the acidity or basicity of water. A crucial element in the chemistry and toxicity of water is pH. The amounts and forms of toxic chemicals in water can change due to pH changes. For instance, metals including copper, arsenic, lead, mercury, and aluminium are generally more soluble at lower pH levels.

The rate at which ammonia transforms from its benign to toxic form increases in more basic waters. Geochemical processes that involve oxidation-reduction and dissolution-precipitation rely on pH. For instance, a high pH causes minerals like calcite to precipitate, whereas an acidic pH increases the solubility of minerals. As a result, acidic water would be more corrosive, and alkaline water would lead to deposition of minerals (encrustation).

The concentration of carbon dioxide in the atmosphere rises, for example, and this effectively lowers the pH of water due to a number of other variables. Since compounds in the water can alter pH, pH is a crucial sign that the water's chemical composition is changing. Acceptable limit range of pH is 6.5 to 8.5, according to BIS (2012).

**Observation:**

The pH of groundwater samples for 15 wells were determined using a Five Go-mettler Toledo portable pH meter during pre-monsoon.

During premonsoon, pH levels of water samples ranged from 5.47 to 7.68. The lowest pH value recorded was 5.47 for well W4, while the highest value recorded was 7.68 for well W15. The average value of pH is 6.4. Only two out of 15 well samples exhibited pH level below the permissible limit of drinking water (6.5-8.5) as defined by the Bureau of Indian (BIS) Standard in 2012.

**Inference**

Low pH concentration in groundwater during pre-monsoon for well W4 and W13 may be due to warmer temperature during premonsoon season, where organic matter decomposition in soil and waterbodies accelerates. This process releases organic acids into the water, lowering its pH.

**Table 5.2: pH measurements of observed wells**

| Well NO | LATITUDE | LONGITUDE | pH Pre-monsoon |
|---|---|---|---|
| W1 | 15°17'49.7"N | 73°58'42.5"E | 6.65 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 6.41 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 6.49 |
| W4 | 15°176.30"N | 73°59′1.75"E | 5.47 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 6.39 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 6.01 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 6.33 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 7.08 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 6.51 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 6.43 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 6.69 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 6.61 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 5.84 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 6.04 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 7.68 |

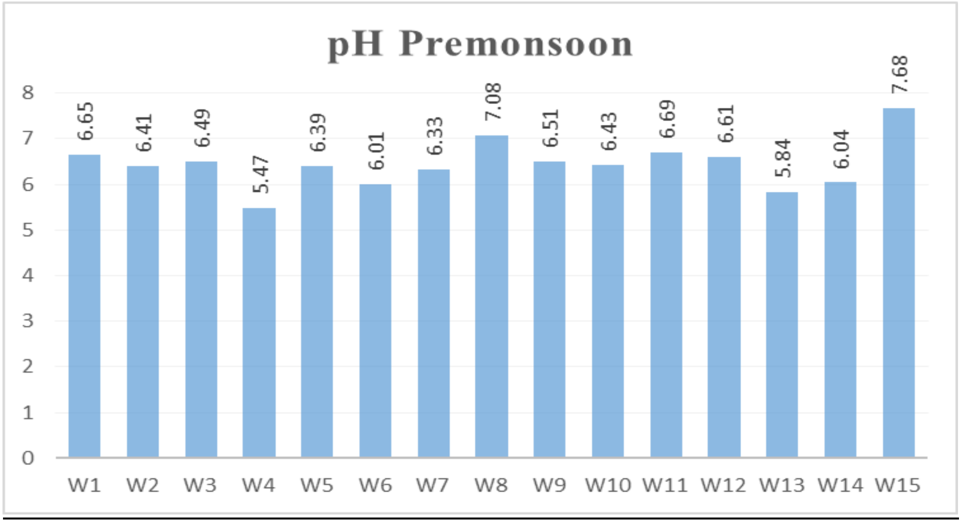


**Figure 5.1: Pre-monsoon pH graph**

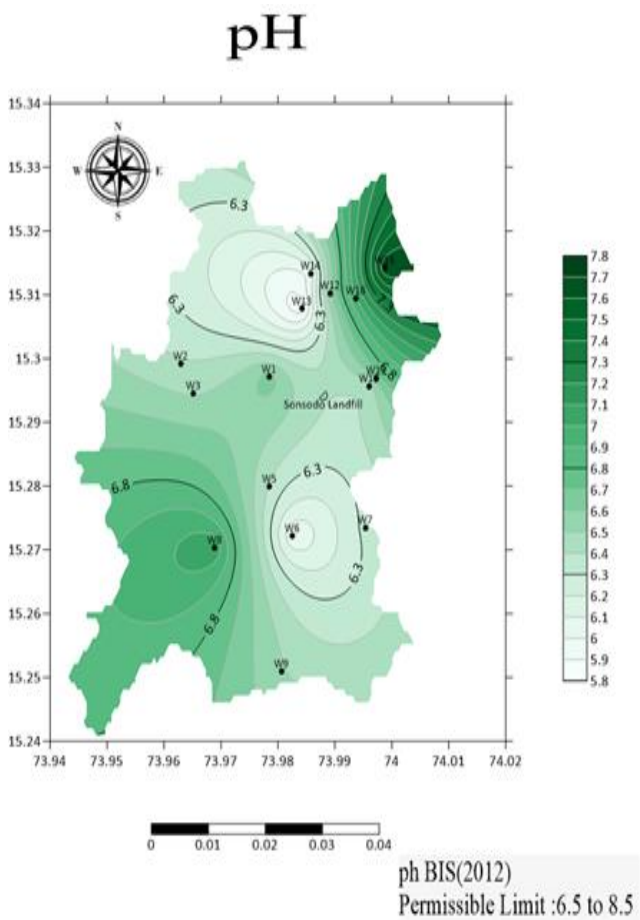


**Figure 5.2: Pre-monsoon pH contour map**

### 5.1.3 Electrical Conductivity (EC)

Electrical conductivity expresses the ability of a substance or medium to conduct electricity. Electrical conductivity (EC) is an important parameter in groundwater quality assessments for drinking and irrigation, since it is related to the concentration of charged particles in the water. EC is measured by an electronic probe, which applies an electric voltage between two electrodes. The resistance of the water is measured by the drop in the voltage. EC, which is inversely proportional to the resistance, is then the conductance per unit distance. Pure liquid water has a very low electrical conductivity. The presence of charged particles in the water increases its conductivity. In general, as the concentration of total dissolved solids (TDS) in the water increases, its conductance also increases.

Electrical conductivity is categorized by the CGWB (2021) as fresh (EC < 750 µS/cm), moderate (EC between 751 and 2250), slightly mineralized (2251-2000), and highly mineralized (> 3000).

**Observations**

Electrical conductivity (EC) measurements were conducted for 15 wells in premonsoon and for 16 wells during post monsoon periods. The highest EC recorded during premonsoon was 872 µS/cm for well W15, while lowest value was recorded for well W1 with value of 45 µS/cm. On other hand during post monsoon the highest EC value obtained was 1536 µS/cm recorded for well W15, with lowest value at 54 µS/cm recorded for well W1. The average EC value during premonsoon was 262 µS/cm, slightly lower than the value recorded 262.3 µS/cm post monsoon.The data recorded exhibit higher EC levels during post monsoon compared to premonsoon.

**Inference**

Electrical conductivity of groundwater was observed to increase in post-monsoon as compared to premonsoon. The substantial reason could be rainfall experienced during monsoon period which often leads to heightened surface runoff, which transports dissolved solids like salt and minerals and also organic matter into nearby groundwater reservoirs. Moreover presence of laterite soil present in the study area could be a contributing factor, as laterite soils often contain a significant amount of soluble minerals, including iron, aluminum, and various oxides. During the monsoon season, heavy rainfall can leach these minerals from the laterite soil, leading to an increase in dissolved solids in the groundwater. The dissolved minerals contribute to higher electrical conductivity in the groundwater, which consequently elevates the electrical conductivity readings during post monsoon.

**Table 5.3: EC measurements of observed wells**

| Well NO | LATITUDE | LONGITUDE | Electrical conductivity | |
|---|---|---|---|---|
| | | | Pre-monsoon µS/cm | Post-monsoon µS/cm |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 45 | 54 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 290 | 371 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 323 | 405 |
| W4 | 15°176.30"N | 73°59′1.75"E | 83 | 99 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 140 | 255 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 12 | 122 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 107 | 197 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 544 | 1536 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 168 | 121 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 67 | 34 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 54 | 140 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 77 | 168 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 165 | 140 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 95 | 210 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 872 | 144 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | - | 201 |

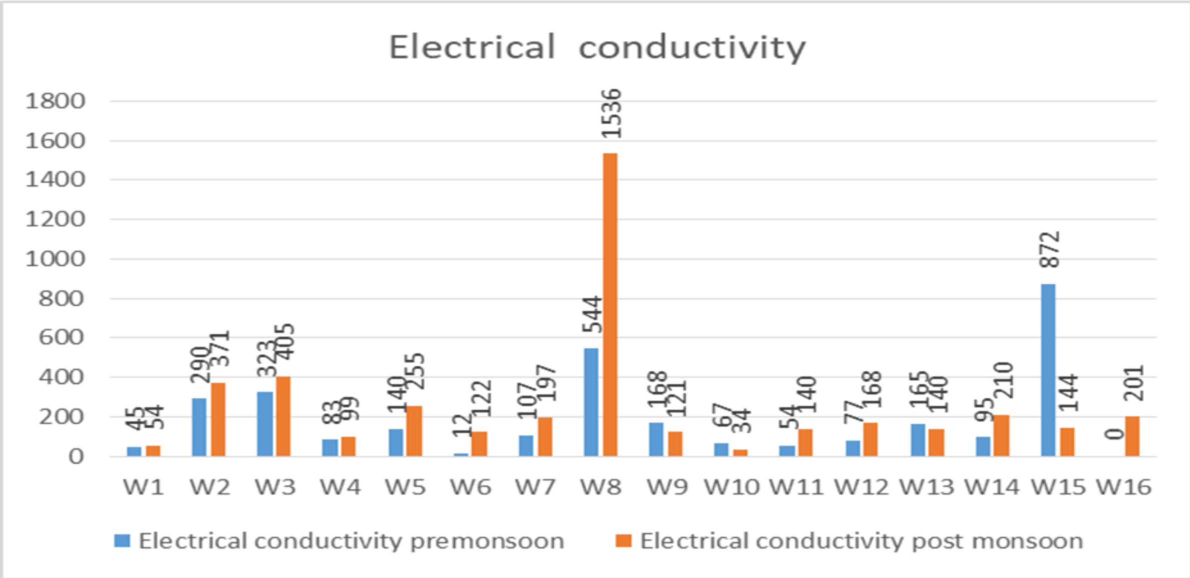


**Figure 5.3: EC graph for pre-monsoon and post-monsoon**

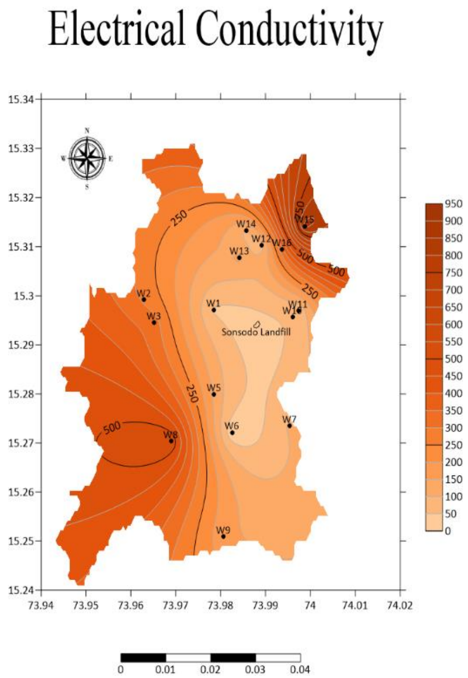


**Figure 5.4: Pre-monsoon EC contour map**

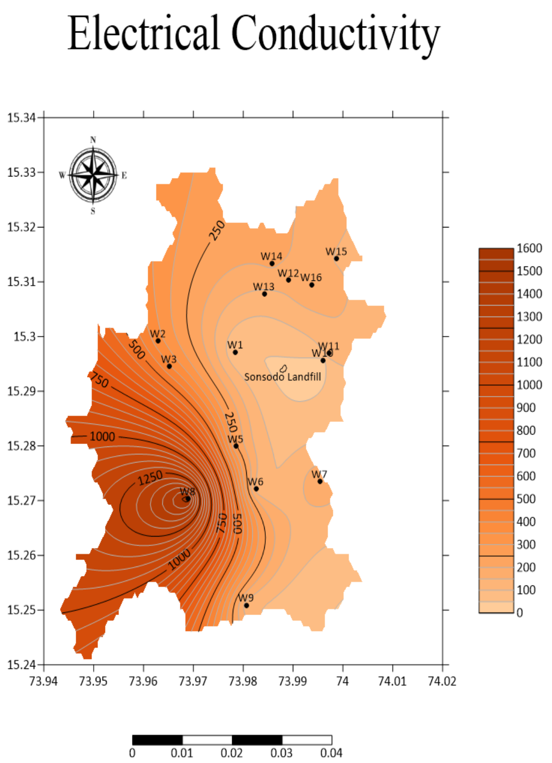


**Figure 5.5: Post-monsoon EC contour map**

### 5.1.4 Total Dissolved solids

Total Dissolved Solids (TDS) is a crucial parameter in studying groundwater quality as it provides valuable information about the composition of dissolved substances in well samples. TDS serves as an indicator of overall water quality. High TDS concentrations may indicate contamination from natural sources such as geological formations or anthropogenic activities like industrial discharges or agricultural runoff. Monitoring TDS levels helps identify potential sources of contamination and assess the suitability of groundwater for various uses. Elevated TDS levels can affect the taste and odor of water. Dissolved salts and minerals contribute to a salty or brackish taste, which may render the water unpalatable for drinking or agricultural use. Monitoring TDS levels helps ensure water meets aesthetic standards and is acceptable for consumption or other purposes. According to Bureau of Indian Standards (BIS) the drinking water acceptable limit ≤ 500 mg/L, and drinking Water desirable limit TDS: ≤ 300 mg/L.

**Observation**

The TDS in groundwater were derived from Ec measurements across 15 wells in the study area during pre-monsoon and 16 wells during post monsoon period. TDS level in premonsoon ranged from 28.8 mg/L-558 mg/L with an average of 129.7 mg/L. During post monsoon TDS ranged from 21.76 mg/L to 983.4 mg/L with an average of 167.88 mg/L. The highest TDS reading observed during premonsoon was 558 ppm in well W15, while the lowest observed 28 ppm for well W1. Whereas the highest reading during post monsoon was 983ppm in W8, and lowest recorded 21 ppm for well W10. On average, TDS levels found 129.7 ppm during premonsoon and 167.8 ppm during post-monsoon.

The variation in level of TDS of pre and post monsoon is seen (fig 4.4). TDS level in two out of 15 wells, W8 and W15 were above allowable limit and rest 13 wells were within the allowable limit of 500 mg/L according to BIS of 2012 during pre-monsoon period.

During post monsoon TDS level for 1 out of 16 wells i.e. W8 was above allowable limit of 500 mg/L as defined by BIS (2012).

**Inference**

The presence of high TDS levels in groundwater during the post-monsoon might be because of significant contamination from landfill leachate. Landfills receive various types of waste, including organic and inorganic materials, which can leach into the surrounding soil and groundwater, especially during periods of heavy rainfall. Landfill leachate contains a complex mixture of dissolved substances, including organic matter, heavy metals, and other pollutants.

During the post-monsoon period, rainwater percolates through the landfill, leaching soluble substances from the waste materials and transporting them into the underlying groundwater aquifers hence elevating TDS level in groundwater.

**Table 5.4: TDS measurements for observed wells**

| Well NO | LATITUDE | LONGITUDE | Total Dissolved Solids | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 28.8 | 34.56 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 185.6 | 237.44 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 206.72 | 259.2 |
| W4 | 15°176.30"N | 73°59′1.75"E | 53.12 | 63.36 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 89.6 | 163.2 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 7.68 | 78.08 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 68.48 | 126.08 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 348.16 | 983.04 |
| W9 | 15° 15' 03.2"N | 73° 58' 50.3" E | 107.52 | 77.44 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 42.88 | 21.76 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 34.56 | 89.6 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 49.28 | 107.52 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 105.6 | 89.6 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 60.81 | 134.4 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 558.08 | 92.16 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0 | 128.64 |

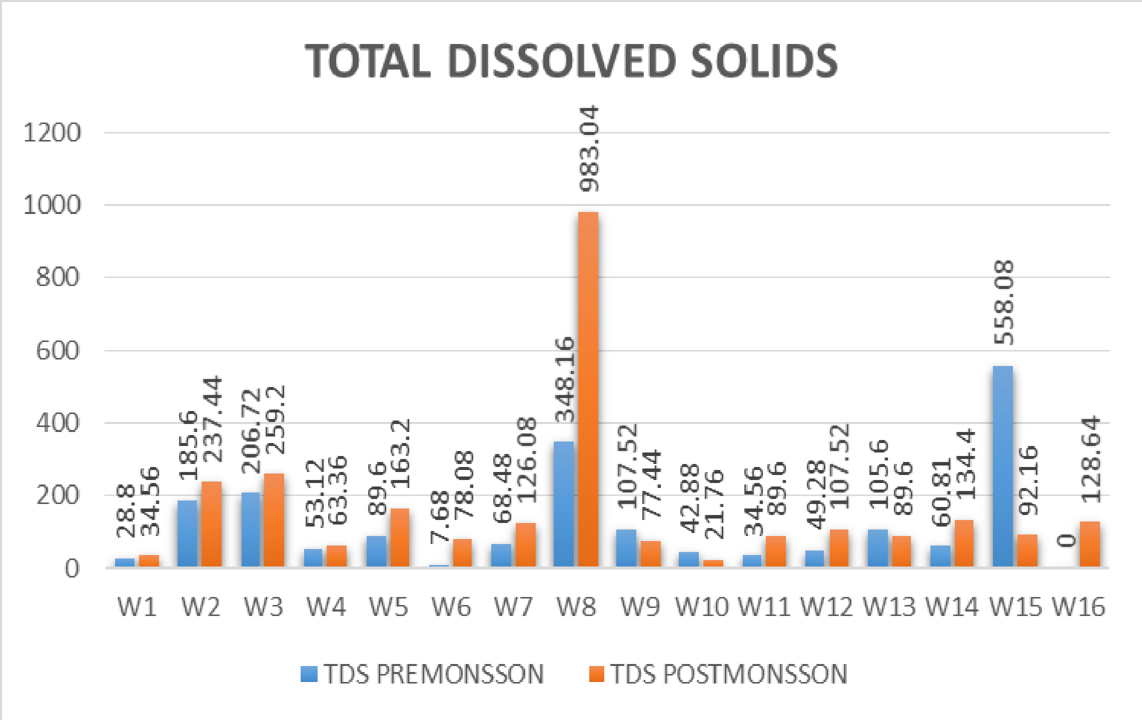


**Figure 5.6: TDS measurement graph**

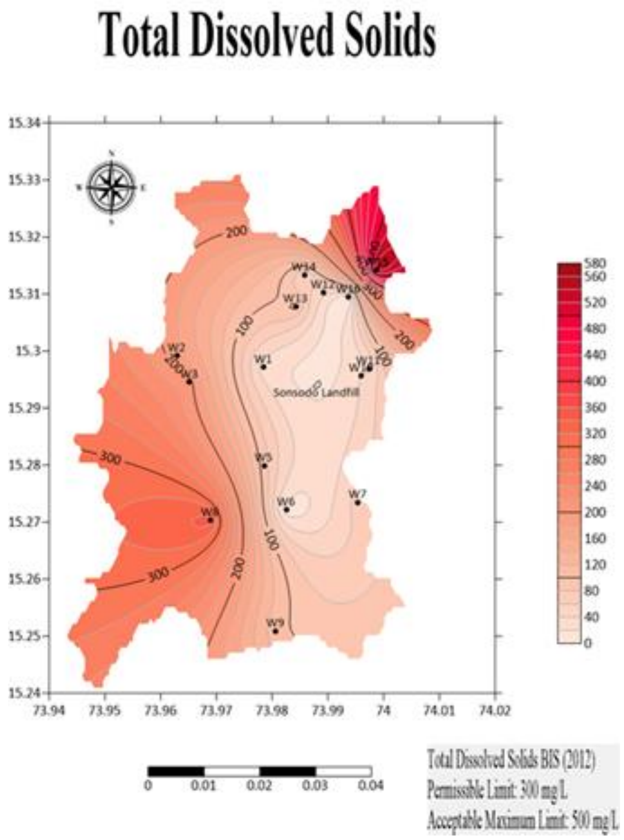


**Figure 5.7: Pre-monsoon TDS contour map**

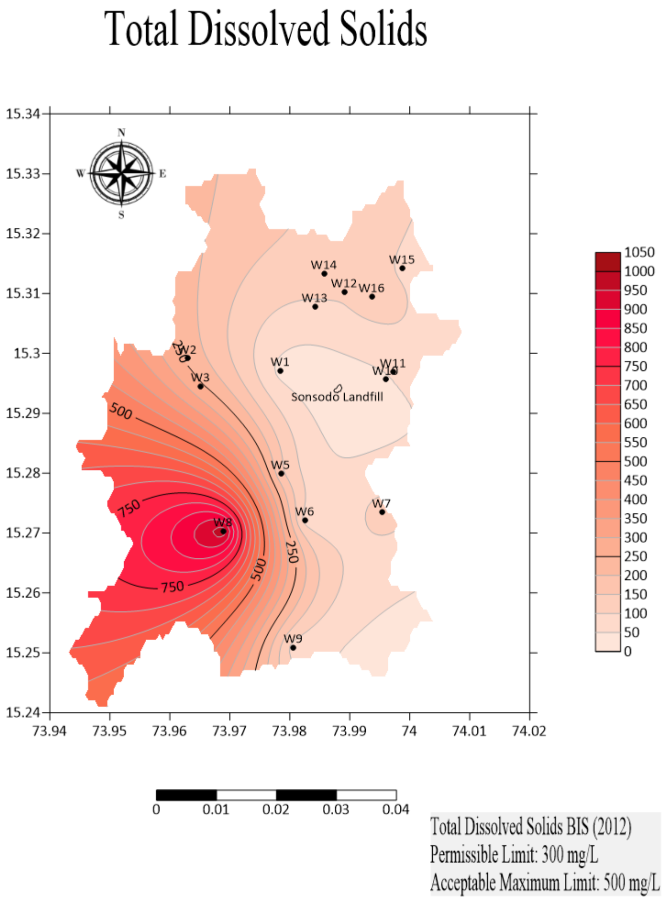


**Figure 5.8: Post-monsoon TDS contour map**

### 5.1.5 Dissolved Oxygen (DO)

Dissolved oxygen (DO) plays a crucial role in groundwater quality analysis, particularly in assessing the health and sustainability of groundwater resources. Changes in dissolved oxygen concentrations can indicate pollution or contamination of groundwater. The presence or absence of dissolved oxygen can provide insights into the redox (reduction-oxidation) conditions of groundwater. Oxygen is often depleted in anaerobic (low-oxygen) environments where reducing conditions prevail, leading to the potential for the presence of certain pollutants such as nitrate, iron, manganese, and organic compounds. Conversely, the presence of dissolved oxygen indicates aerobic (high-oxygen) conditions, which may be more favourable for microbial degradation of contaminants.

In general, groundwater that is more exposed to the atmosphere and is located close to the surface will have greater DO concentrations than groundwater that is located deeper and more far from the surface. Furthermore, due to increased exposure to oxygen and air, groundwater that seeps through permeable rock formations may have higher DO levels. However, the DO levels may be lower because bacteria and other microorganisms may absorb oxygen in groundwater that is contaminated with organic waste or other chemicals that they can ingest.

**Observation**

The DO levels measured during June 2023 is tabulated in table 6. Dissolved oxygen level ranged from 2.74 to 8.84 mg/L with an average of 5.5 mg/L.Three out of 15 wells W5, W6, W7 are within the permissible limit as defined by BIS 2012. DO level in 5 out of 15 wells W1, W9, W13, W14, W15 were above Permissible range of BIS 2012.

**Inference**

During the pre-monsoon period, atmospheric conditions often lead to increased oxygen levels in the air. Higher temperatures, increased wind activity, and decreased humidity promote oxygen exchange between the atmosphere and water bodies through processes such as diffusion and aeration. In many regions, water temperatures tend to decrease during the pre-monsoon period as compared to the hotter months preceding it. Cooler water can hold more dissolved oxygen than warmer water due to its higher solubility. Therefore, the drop in water temperature during the pre-monsoon period can result in higher dissolved oxygen concentrations.

**Table 5.5: Dissolved Oxygen measurements of observed wells**

| Well NO | LATITUDE | LONGITUDE | Dissolved Oxygen Pre-monsoon (mg/L) |
|---|---|---|---|
| W1 | 15°17'49.7"N | 73°58'42.5"E | 8.84 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 5.41 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 4.17 |
| W4 | 15°176.30"N | 73°59′1.75"E | 4.97 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 3.26 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 2.74 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 3.75 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 5.19 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 6.57 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 5.67 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 6.32 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 6.3 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 6.5 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 7.1 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 6.6 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0 |

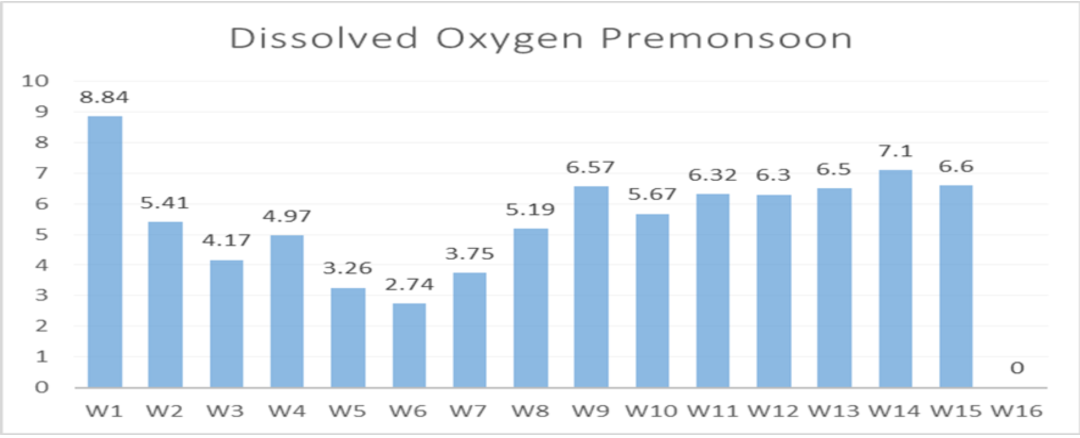


**Figure 5.9: Graphical representation of Dissolved Oxygen in groundwater during pre-monsoon**

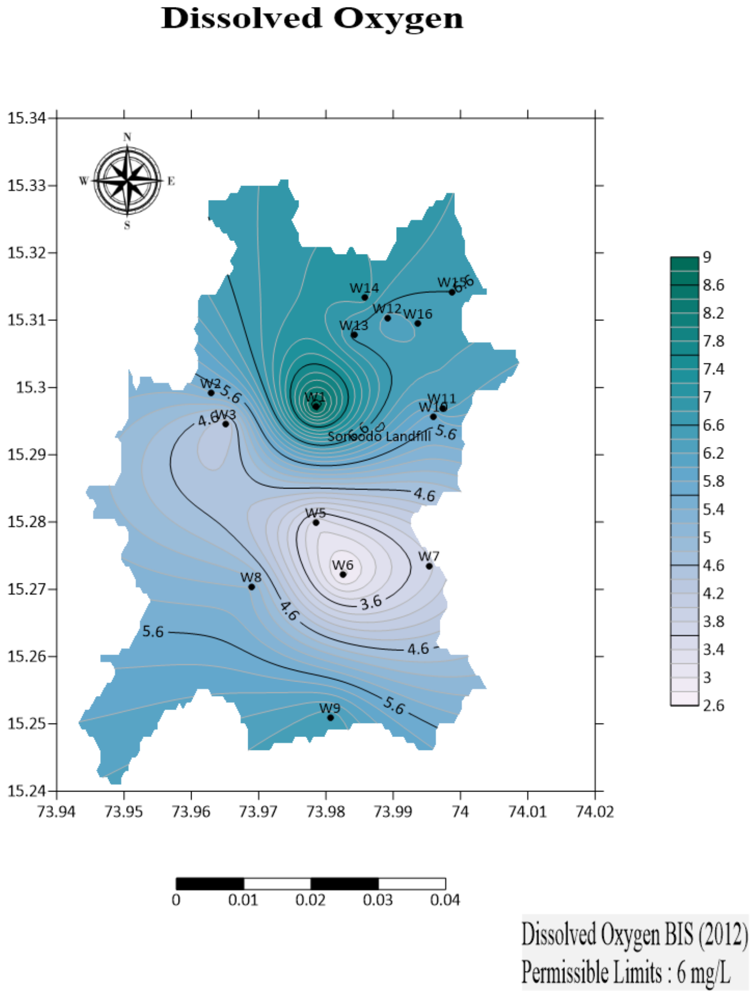


**Figure 5.10: Pre-monsoon Dissolved Oxygen contour map**

### 5.1.6 Chemical parameter

### 5.1.7 Calcium

One of the principal inorganic cations that occurs naturally as Ca2+ is calcium. Both freshwater and saltwater can contain it. It develops as a result of the dislocation of salts in water, such as CaCl or CaS04. It increases the overall hardness of the water. Rocks including limestone, marble, calcite, dolomite, gypsum, fluorite, and apatite leach calcium into the water. Freshwater contains 4 to 100 mg/L. Cell walls of aquatic plants contain a significant amount of calcium. It plays a significant role in the structure of aquatic creatures' bones and shells. Eutrophic waters frequently have high calcium concentrations. Calcium hardness may be up to 200 mg/L, while BIS (2012) states that 75 mg/L or mg/L is the acceptable maximum.

Standard methods were used to determine the calcium hardness [EDTA Titrimetric: 1.29 (S.A.P., May 1999)] and the results are provided in table 6.

**Observations**

The Calcium values in the water samples ranged from 3.20 – 41.61 mg/L during premonsoon with average of 33.81 mg/L .During post monsoon the dissolved oxygen in groundwater ranged from 3.20 – 248 mg/ with an average of 56.27. The highest value of Calcium during premonsoon is 41.61 mg/L shown in well W8 and lowest value is 3.20 mg/L shown by well W10. During post monsoon, the highest value of Calcium is 248 mg/L shown by well W8 and the lowest value is 3.20 mg/L shown in well W12.

According to BIS standards all wells samples were within permissible limit during premonsoon period. In post monsoon 1 out of 16 wells W8 was above acceptable maximum limit of 200 mg/L as defined by BIS standards.

**Inference**

W18 showed high value of calcium during post monsoon period possible reason might be due to land fill leachate contamination as during the post-monsoon period, when rainfall decreases, the percolation of landfill leachate into the groundwater may intensify. This increased percolation can enhance the transport of dissolved ions from the landfill site into the aquifer, thereby elevating the calcium hardness of the groundwater.

**Table 5.6: Pre and post-monsoon Calcium observation table**

| WELL NO | LATITUDE | LONGITUDE | Calcium | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 11.20 | 17.60 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 22.40 | 20.80 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 28.81 | 33.61 |
| W4 | 15°176.30"N | 73°59′1.75"E | 17.60 | 33.61 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 25.61 | 19.20 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 17.60 | 14.40 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 19.20 | 32.01 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 41.61 | 248.05 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 24.00 | 68.81 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 3.20 | 43.21 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 17.60 | 30.41 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 19.20 | 3.20 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 4.80 | 43.21 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 8.00 | 265.65 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 27.21 | 8.00 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0.00 | 19.20 |

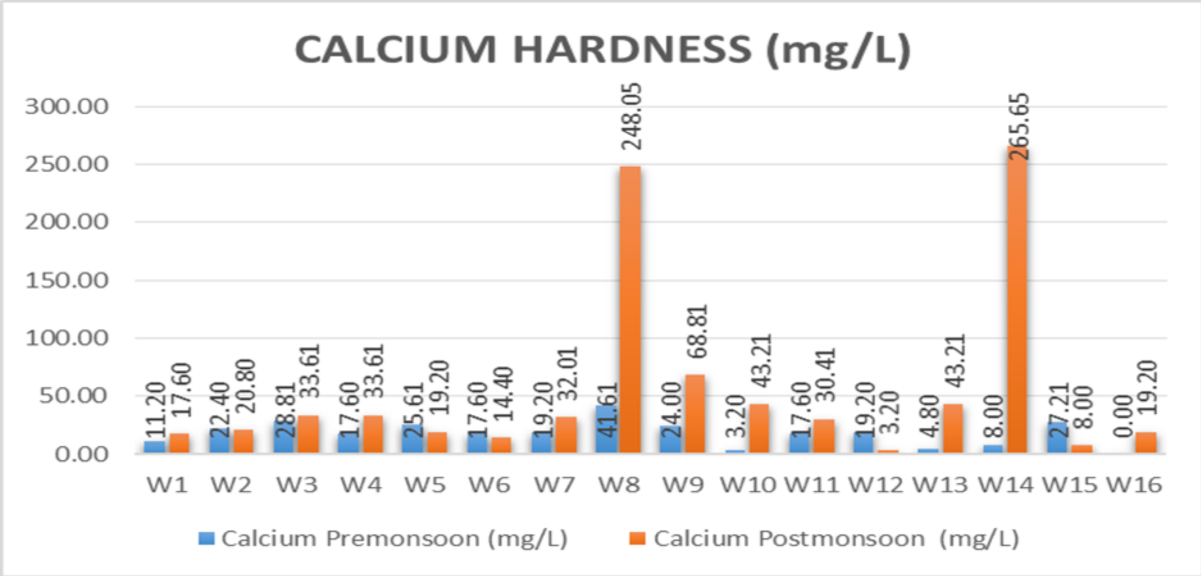


Figure 5.11: Pre and post monsoon graphical representation of Calcium in groundwater

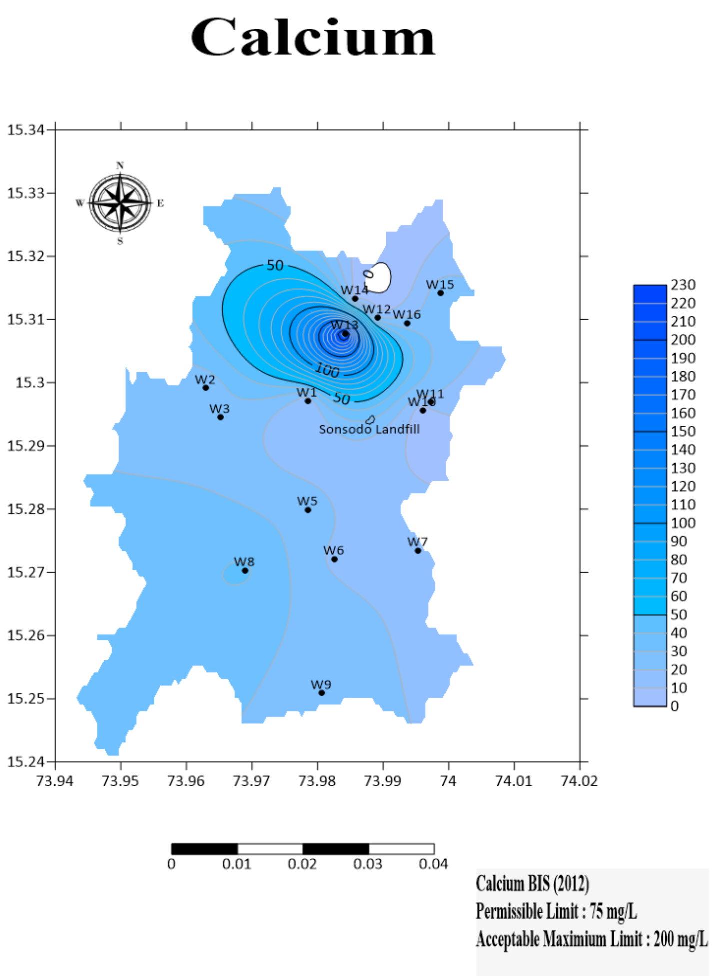


Figure 5.12: Pre-monsoon Calcium contour map

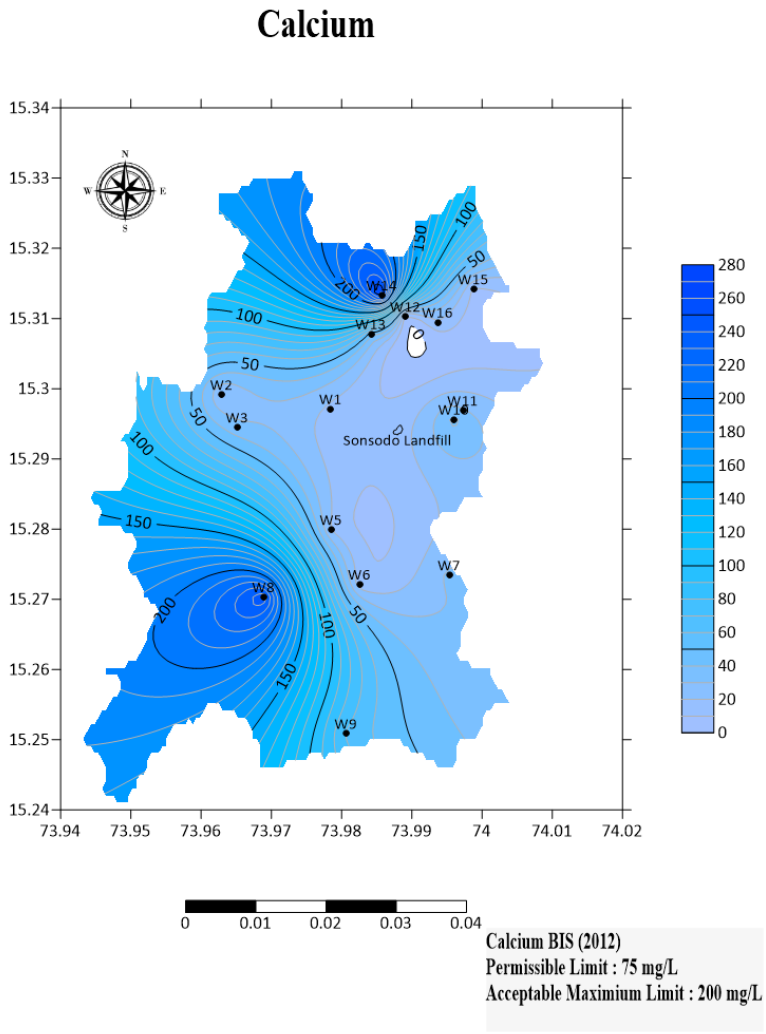


**Figure 5.13: Post-monsoon Calcium contour map**

### 5.1.8 Magnesium

Magnesium is an essential mineral for human health, playing a critical role in various physiological processes such as muscle and nerve function, blood glucose control, and blood pressure regulation. Therefore, understanding the magnesium content in groundwater is crucial for assessing its suitability for human consumption. Minerals contain significant amounts of magnesium (Mg2+). Dolomite, ferromagnesian minerals like olivine, pyroxene, amphiboles, and dark-coloured micas are the main sources of magnesium in groundwater.

Chlorite, montmorillonite, and serpentine are examples of metamorphic rocks that contain magnesium in their structural makeup (Nag, 2009). The amount of dissolved CO2 in the groundwater affects the reaction involving the magnesium solution (Saha et al., 2019). Magnesium is a filler or fire retardant that chemical firms add to plastics and other products. In addition, it enters the ecosystem as a result of feeding cattle and applying fertiliser. Since magnesium and calcium both contribute to total hardness, determining magnesium hardness is simple if total hardness and calcium hardness are known. BIS 2012 states that up to 100 mg/L of magnesium hardness is allowed but that the recommended limit is 30 mg/L.

**Observation Table**

The magnesium level in the water samples exhibit a ranged of 2.1 – 120 mg/L during premonsoon with an average of 18.8 mg/L .During the post magnesium in water samples exhibit a ranged of 4.5 mg/L to 120mg/.L, with an average of 37.11 mg/. Notably, well W13 records the highest magnesium concentration during pre-monsoon (120.5 mg/L) and highest magnesium concentration during post monsoon for well W8 (134 mg/L).

One out of 15 well samples i.e. W13 exhibit magnesium levels above the acceptable limit of 100 mg/L as defined by BIS (2012) and in post monsoon well W8 show magnesium level in groundwater above maximum acceptable limits.

**Inference**

High magnesium level in groundwater during post monsoon in well W8 during post monsoon might be due to anthropogenic sources and also due to less dilution effect of rainfall after post monsoon leading concentration of magnesium ions in groundwater.

**Table 5.7: Pre-monsoon and post-monsoon Magnesium values**

| Well NO | LATITUDE | LONGITUDE | Magnesium | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-Monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 9.9 | 9.3 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 23.7 | 40.6 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 28.0 | 26.8 |
| W4 | 15°176.30"N | 73°59′1.75"E | 4.5 | 2.5 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 13.2 | 26.4 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 9.3 | 12.1 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 2.1 | 53.5 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 23.9 | 134.1 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 8.7 | 76.6 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 11.9 | 8.9 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 2.5 | 17.9 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 8.9 | 24.5 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 120.5 | 5.1 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 9.7 | 100.8 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 5.1 | 27.2 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | - | 27.4 |

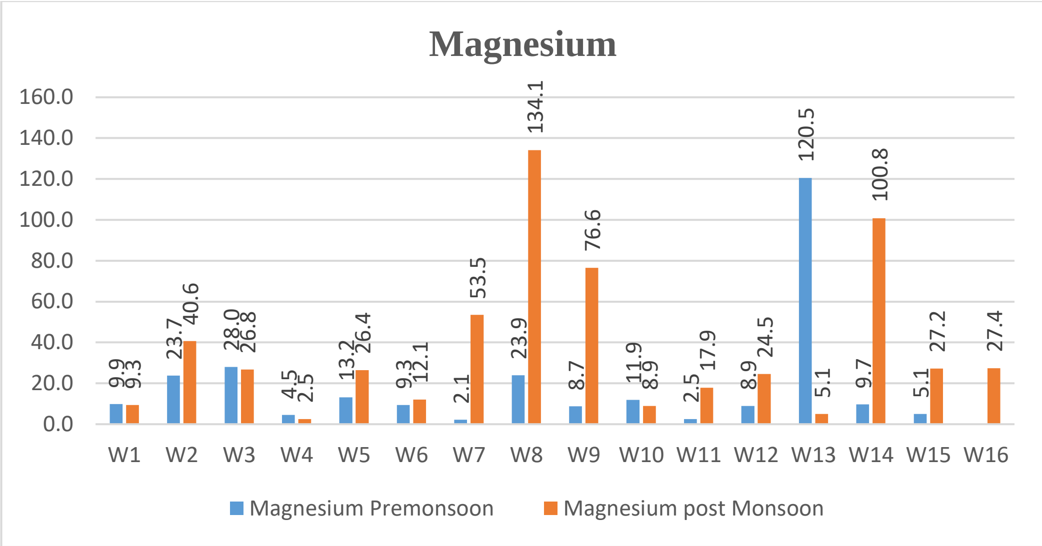


**Figure 5.14: Pre-monsoon and post-monsoon graphical representation of Magnesium level**

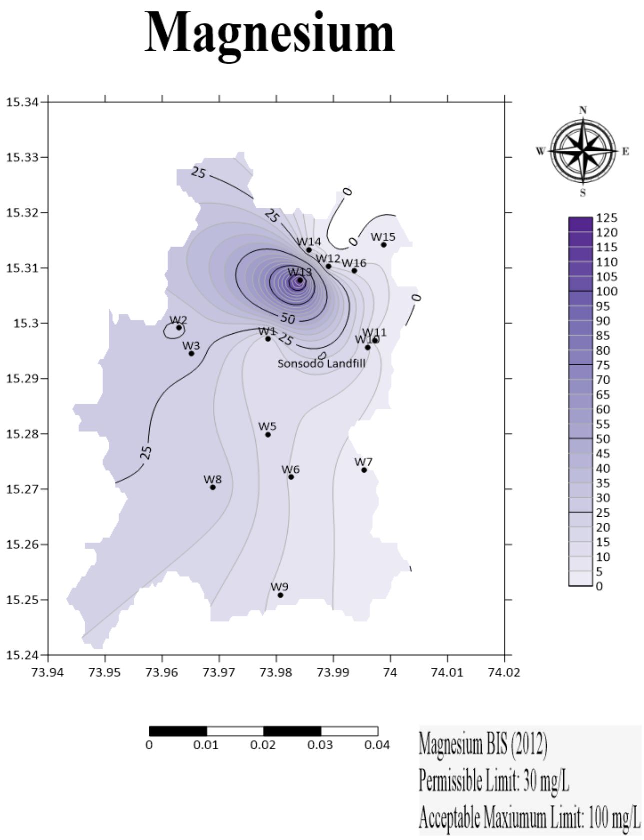


**Figure 5.15 : Pre-monsoon Magnesium contour map**

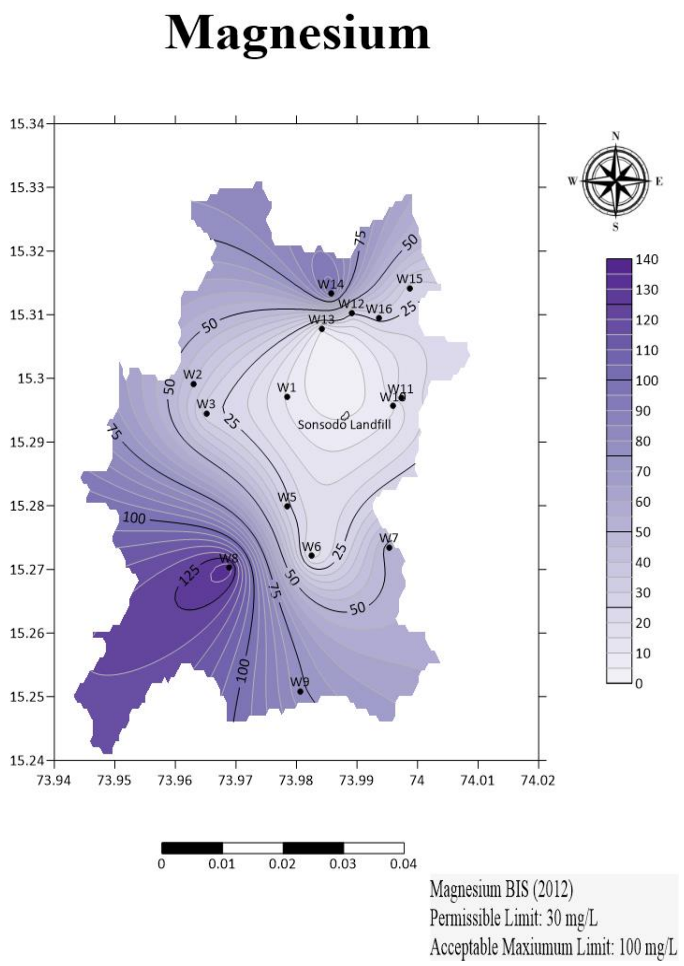


**Figure 5.16: Post-monsoon Magnesium contour map**

### 5.1.9 Total Hardness

The total hardness of well water itself doesn't necessarily indicate groundwater quality in terms of safety or potability. Hardness is primarily a characteristic related to mineral content, not contamination. Hard water contains a higher concentration of dissolved minerals, primarily calcium and magnesium. This can come from the natural minerals in the rocks and soil that the groundwater flows through. While hard water might not be ideal for certain household applications, it generally does not pose a direct health risk at typical concentrations found in groundwater. The Bureau of Indian Standards (BIS) does not set a specific maximum permissible limit for total hardness in drinking water. This is because hardness itself is not considered a health concern. However, the BIS standard 2012 desirable limits for various water quality parameters, including hardness. As per this standard, the desirable limit for total hardness (as CaCO3) in drinking water is 200 mg/L. The permissible limit of 600 mg/L acknowledges situations where exceeding the desirable limit might be unavoidable. According to USGS classification of total hardness, as CaCO3, 0-60 mg/L is considered soft, 61-120 mg/L is considered moderately hard, 121-180 mg/L is considered hard and more than 180 mg/L is considered as very hard.

**Observations**

The total hardness values in the water samples ranges from 28--144 mg/L during pre-monsoon and 44-800mg/L during post-monsoon. The highest value of total hardness during pre-monsoon is 144 mg/L shown by W3 and the lowest value is 28 mg/L shown by W11. During post-monsoon, the highest value of total hardness is 800 mg/L shown by W8 and the lowest value is 44mg/L shown by W4. The Average value of total hardness is 111.2 mg/L during pre-monsoon and 209 mg/L during post-monsoon.

Based on the USGS classification of total hardness during premonsoon period 9 wells, namely W1, W4, W6,W7, W9, W10,W12,W14,W16 were found to be “soft” (0–60 mg/l),4 out 15 wells W2, W5, W13 were "moderately hard” and 2 wells were “hard”. During post monsoon two wells namely W1, W4 were found to be soft (0–60 mg/l) also 5 out of 16 wells namely W6, W10, W11, W12, W13 were “moderately hard”(60-120 mg/l) . And 5 out of 16 well exhibited “hard “120-180 mg/L and 3 wells showed “very hard” value range which was above 180 mg/L.

According to BIS (2012), all wells showed total hardness values within the acceptable limits (below 300mg/L) for premonsoon period. During post- monsoon only two wells namely W8 and W9 showed total hardness values above maximum acceptable limit (300 mg/L) according BIS (2012).

**Inference**

Increase in total hardness during post monsoon might be due to decrease in rainfall, which indicates less dilution effect. Consequently, the concentration of dissolved minerals, including calcium and magnesium ions, becomes more concentrated, leading to higher hardness levels in groundwater.

**Table 5.8: Observation table for Total Hardness**

| WELL NO | LATITUDE | LONGITUDE | Total Hardness | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 52 | 56 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 120 | 188 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 144 | 144 |
| W4 | 15°176.30"N | 73°59′1.75"E | 36 | 44 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 80 | 128 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 56 | 64 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 28 | 252 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 140 | 800 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 60 | 384 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 52 | 80 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 28 | 104 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 56 | 104 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 64 | 64 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 48 | 200 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 48 | 120 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0 | 132 |

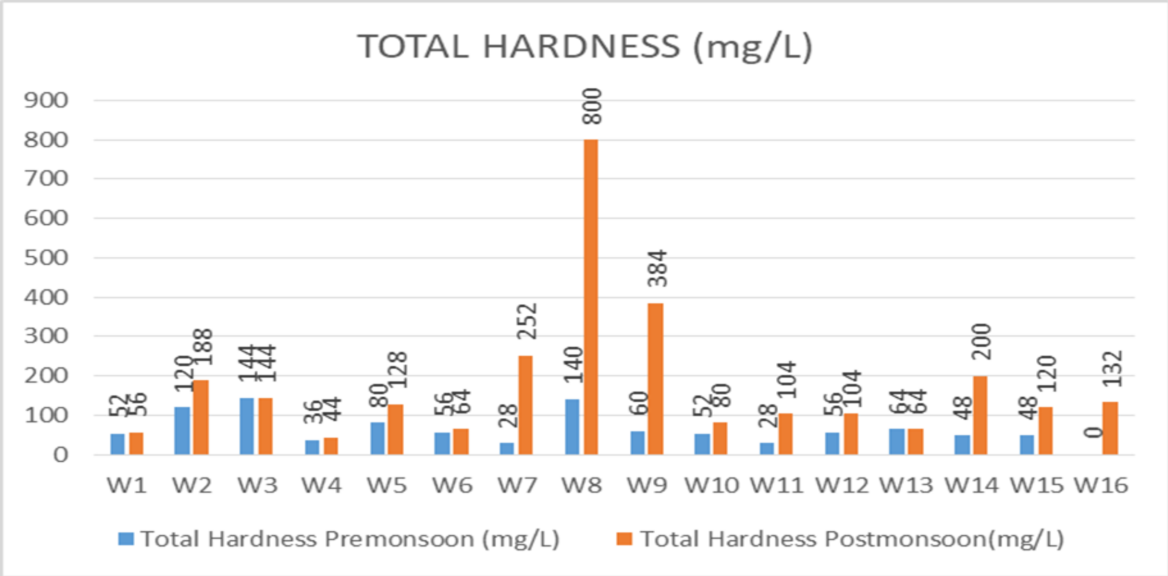


**Figure 5.17: Pre and post monsoon graphical representation of Total Hardness**

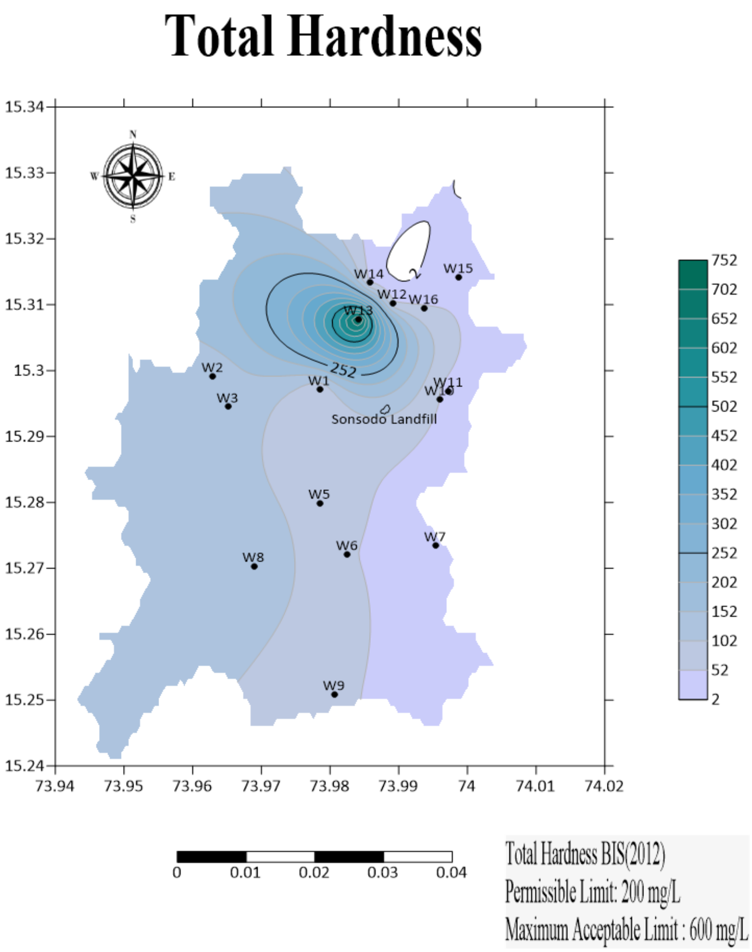


**Figure 5.18: Pre-monsoon contour map of Total hardness**

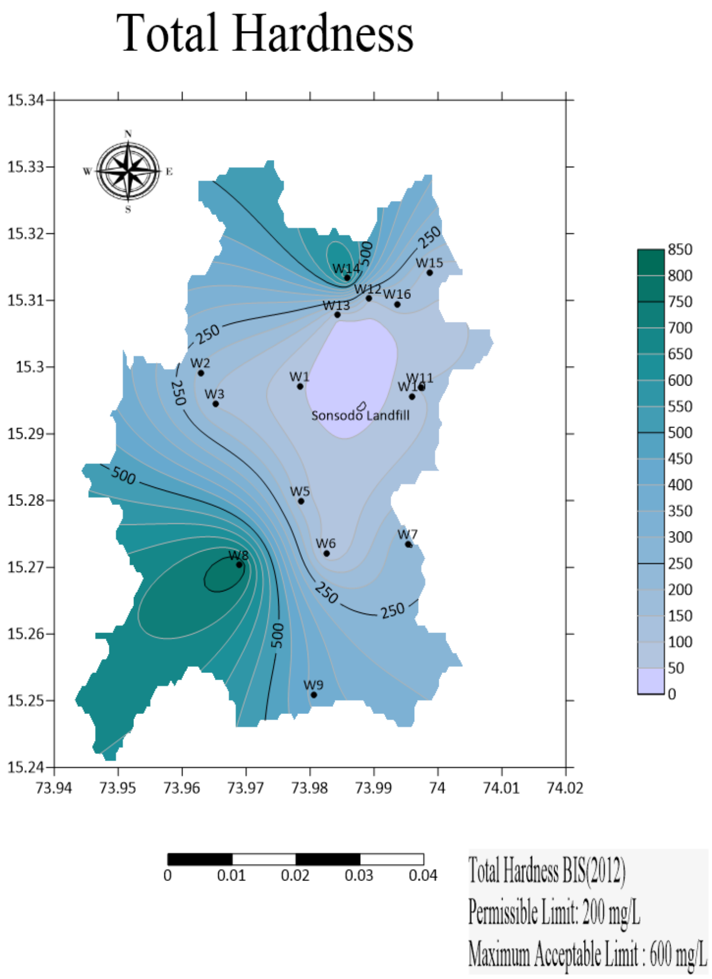


**Figure 5.19: Post-monsoon contour map of Total hardness**

### 5.1.10 Sodium

Sodium is an essential nutrient, consuming water with very high sodium levels for extended periods can potentially contribute to health problems in some individuals, particularly those with pre-existing conditions like high blood pressure or kidney issues. According Bureau of Indian Standards (BIS) desirable Limit of sodium content in water is 200 mg/L - This level ensures a pleasant taste for most people. Sodium can significantly affect the taste of water.

Levels exceeding the Bureau of Indian Standards (BIS) desirable limit of 200 mg/L can impart a salty taste, making the water unpleasant to drink.

**Observations**

The Sodium concentrations in the water samples range from 4.4 to 40.5 mg/L during the pre-monsoon period and 4.1 to 29.2 mg/L during the post-monsoon period. Well W8 exhibits the highest Sodium level during pre-monsoon (40.5 mg/L), while W15 demonstrates the lowest (4.4 mg/L). In contrast, during post-monsoon, well W2 and W3 records the highest Sodium concentration (29.2 mg/L), with W4 showing the lowest values (4.1 mg/L). On average, Sodium content measures 13.57 mg/L during the pre-monsoon and increased to 15.95 mg/L during the post-monsoon period.

All samples fall within the acceptable limits for drinking water according to BIS standards (2012) during the pre-monsoon and post-monsoon period.

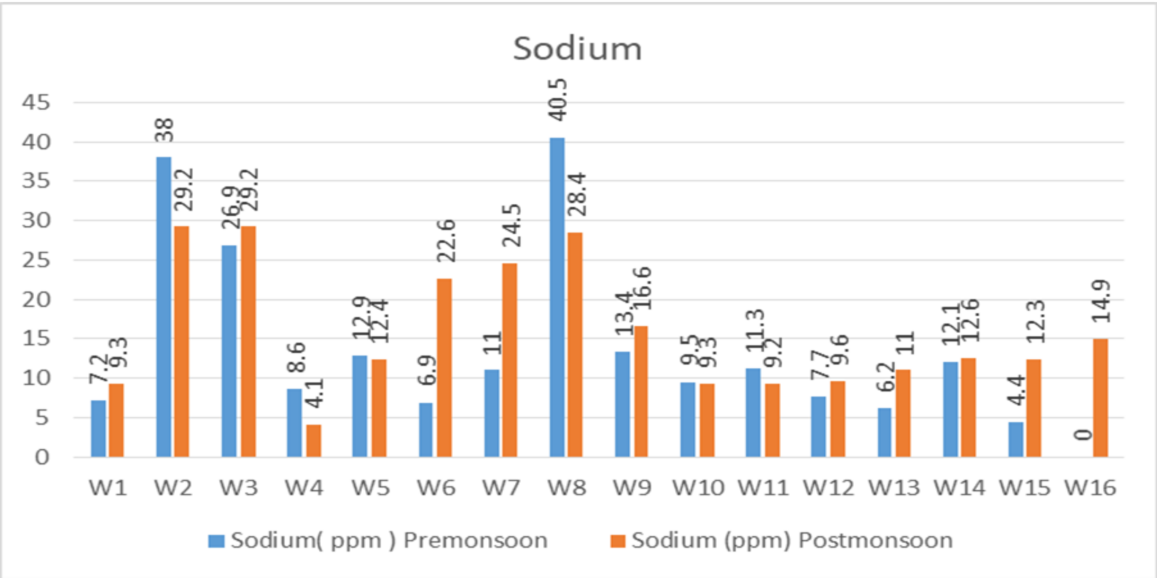


**Figure 5.20: Pre & post-monsoon graphical representation of Sodium**

**Table 5.9: Pre-monsoon and post-monsoon Sodium observation table**

| Well NO | LATITUDE | LONGITUDE | Sodium | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 7.2 | 9.3 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 38 | 29.2 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 26.9 | 29.2 |
| W4 | 15°176.30"N | 73°59′1.75"E | 8.6 | 4.1 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 12.9 | 12.4 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 6.9 | 22.6 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 11 | 24.5 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 40.5 | 28.4 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 13.4 | 16.6 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 9.5 | 9.3 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 11.3 | 9.2 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 7.7 | 9.6 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 6.2 | 11 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 12.1 | 12.6 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 4.4 | 12.3 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0 | 14.9 |

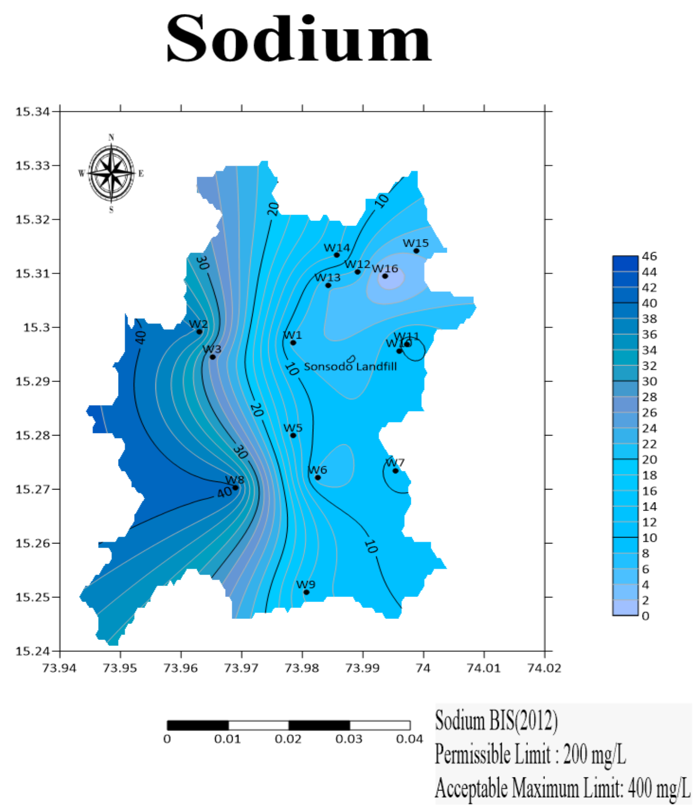


**Figure 5.21: Pre-monsoon Sodium contour map**

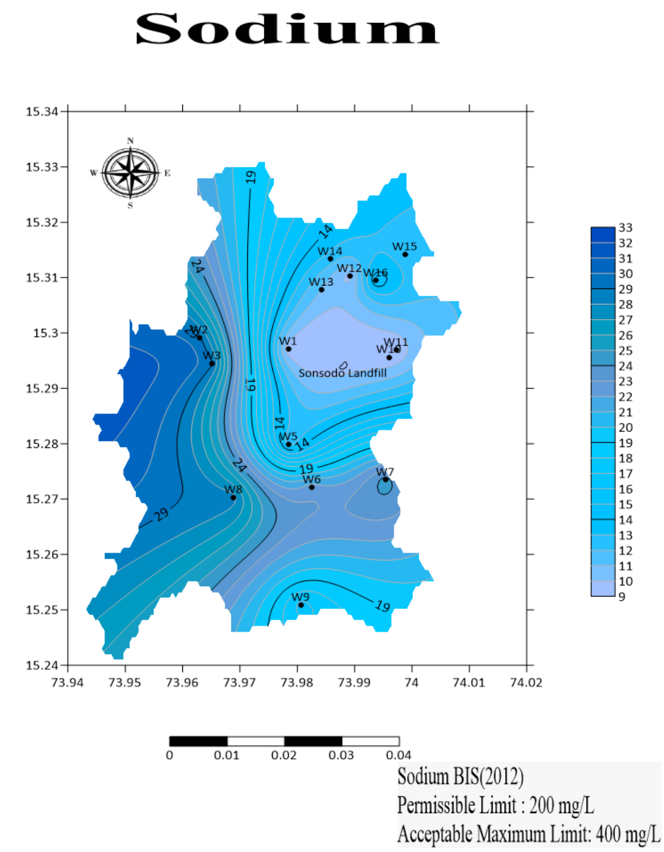


**Figure 5.22: Post-monson Sodium contour map**

### 5.1.11 Potassium

Potassium is an essential dietary mineral for humans and plays a crucial role in various bodily functions. Unlike some other minerals, very low levels in drinking water are unlikely to cause health concerns in healthy individuals.According to BIS the maximum permissible limit is 10 mg/l in drinking water and maximum concentration is 12mg/l

**Observations**

The potassium concentrations in the water samples range from 2 to 58.1 mg/L during the pre-monsoon period and 0.5 to 48 mg/L during the post-monsoon period. Well W8 exhibits the highest potassium level during pre-monsoon (58.1 mg/L), while W6 shows the lowest (2 mg/L). In contrast, during post-monsoon, well W7 records the highest potassium concentration (48 mg/L), with W5 showing the lowest values (0.5 mg/L). On average, potassium content measures 20.64 mg/L during the pre-monsoon and decreases to 8.96 mg/L during the post-monsoon period.

During the pre-monsoon period, 5 out of 15 samples (W4, W5, W10, W11, and W12) met the acceptable drinking water limit of 12 mg/L set by the BIS (2012). In the post-monsoon period, 13 out of 16 samples were within the acceptable limits for drinking. However, samples W3, W7, W8 exceeded the maximum allowable limit according to the BIS (2012).

**Inference**

Landfill sites often contain waste materials rich in potassium, such as food waste and organic matter. During the monsoon season, rainfall can leach potassium from these waste materials, generating leachate that infiltrates into the surrounding soil and groundwater. The post-monsoon period may witness continued leachate percolation from landfills, leading to elevated potassium levels in groundwater, as all these wells W3 ,W7, W8 are 4-5 km away from the landfill.

**Table 5.10: Pre-monsoon and post-monsoon Potassium observation table**

| Well NO | LATITUDE | LONGITUDE | Potassium | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 30.5 | 2.7 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 23.6 | 7 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 18.1 | 15 |
| W4 | 15°176.30"N | 73°59′1.75"E | 8 | 1.5 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 11.8 | 10.7 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 2 | 2.6 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 5.8 | 48 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 58.1 | 17.6 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 31.5 | 4.4 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 8.2 | 1.3 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 11.3 | 0.5 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 8 | 4.6 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 35.6 | 2.8 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 53.2 | 9.2 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 24.6 | 3.8 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0 | 11.7 |

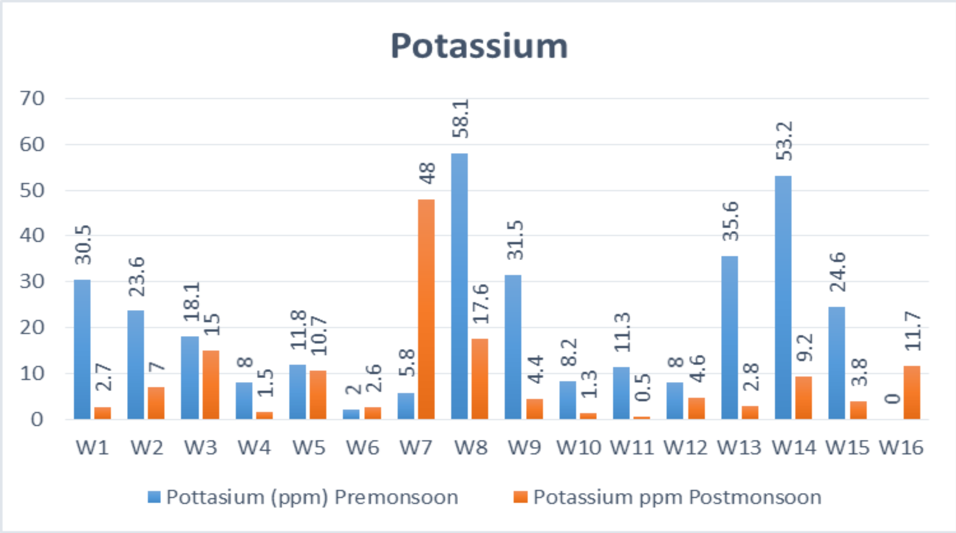


**Figure 5.23: Pre-monsoon and post-monsoon graphical representation of Potassium**

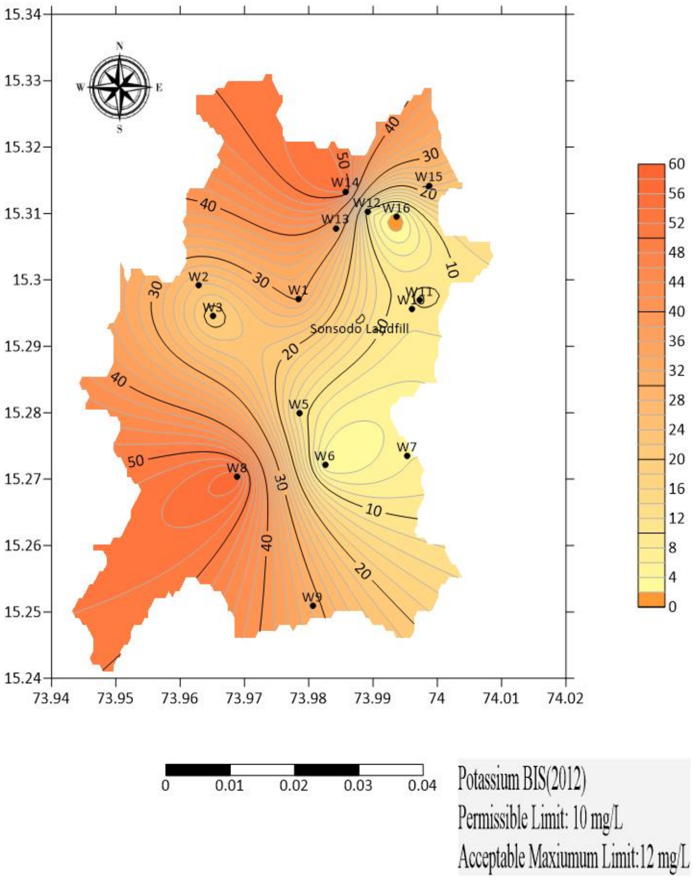


**Figure 5.24: Pre-monsoon Potassium contour map**

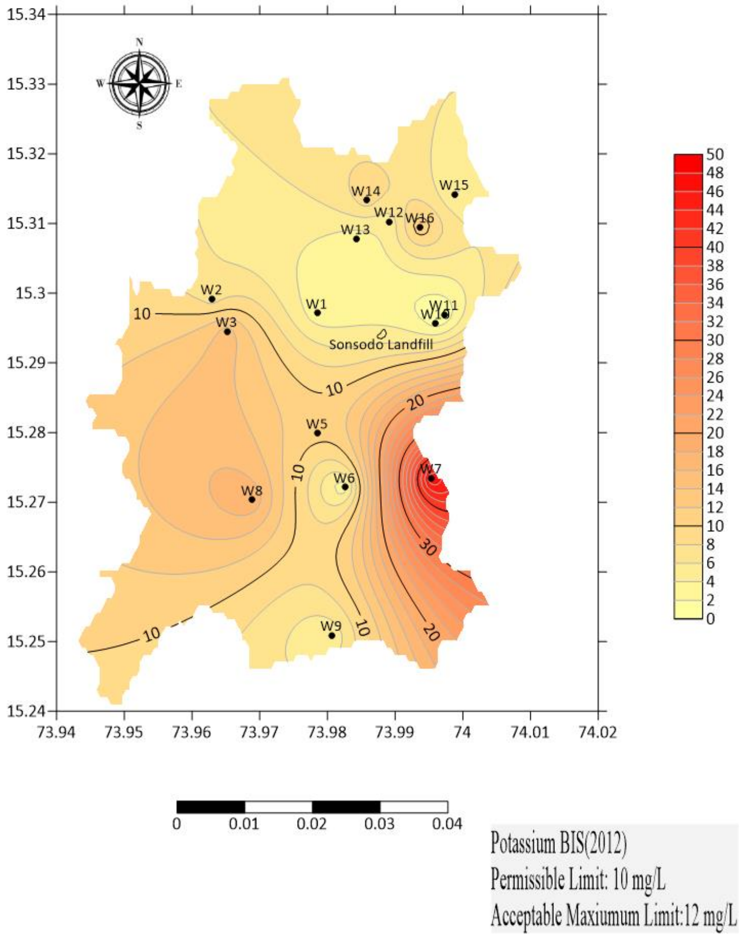


**Figure 5.25: Post-monsoon Potassium contour map**

### 5.1.12 Chloride

Chloride (Cl-) is an important indicator of groundwater quality for several reasons. Chloride occurs naturally in groundwater due to the weathering of rocks and minerals. However, elevated levels of chloride can indicate contamination from various sources. High chloride levels can point towards sources like seawater intrusion in coastal areas, saltwater infiltration can increase chloride concentrations significantly. This can render groundwater unsuitable for drinking or irrigation. Wastewater discharge improper disposal of sewage or industrial wastewater can introduce chloride into groundwater. According to the Bureau of Indian Standards (BIS). Desirable Limit or permissible limit for chloride in drinking water is 250 mg/L. This means that chloride levels below 250 mg/L are considered ideal for taste and aesthetic reasons. Above permissible limit Chloride can give salty taste and odour to water and such water used is corrosive in nature. (DRINKING WATER — SPECIFICATION, 2012).

**Observations**

The chloride concentrations in the water samples range from 990 to 2102.5 mg/L during the pre-monsoon period and 171.25 to 927.5 mg/L during the post-monsoon period. Well W11 exhibits the highest chloride level during pre-monsoon (2102.5 mg/L), while W3 shows the lowest (990 mg/L). In contrast, during post-monsoon, well W11 records the highest chloride concentration (927.5 mg/L), with W10 showing the lowest values (171.25 mg/L). On average, chloride content measures 1364.8 mg/L during the pre-monsoon and decreases to 295 mg/L during the post-monsoon period.

During pre-monsoon, for all well samples exhibited chloride levels exceeds the acceptable limit of 250 mg/L according to BIS (2012). Whereas for post-monsoon period 8 out of 16 wells exceeds the acceptable limit of 250 mg/L according to BIS (2012).

**Inference**

Increase in level of chloride is seen to significant during post -monsoon .The post-monsoon period is characterized by decreased rainfall intensity and soil saturation, allowing for increased percolation of landfill leachate into groundwater. As rainfall diminishes, the leachate generated during the monsoon continues to seep deeper into the ground, carrying chlorides with it. This prolonged infiltration contributes to a sustained increase in chloride levels in groundwater during the post-monsoon period.

**Table 5.11: Pre-monsoon & post-monsoon Chloride observation table**

| WELL NO | LATITUDE | LONGITUDE | Chloride | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 1052.5 | 190 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 1727.5 | 440 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 990 | 215 |
| W4 | 15°176.30"N | 73°59′1.75"E | 1302.5 | 240 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 1552.5 | 190 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 1627.5 | 377.5 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 1465 | 315 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 1877.5 | 240 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 1227.5 | 177.5 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 1140 | 171.25 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 2102.5 | 227.5 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 1690 | 377.5 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 1302.5 | 927.5 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 1477.5 | 177.5 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 1302.5 | 190 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | - | 265 |

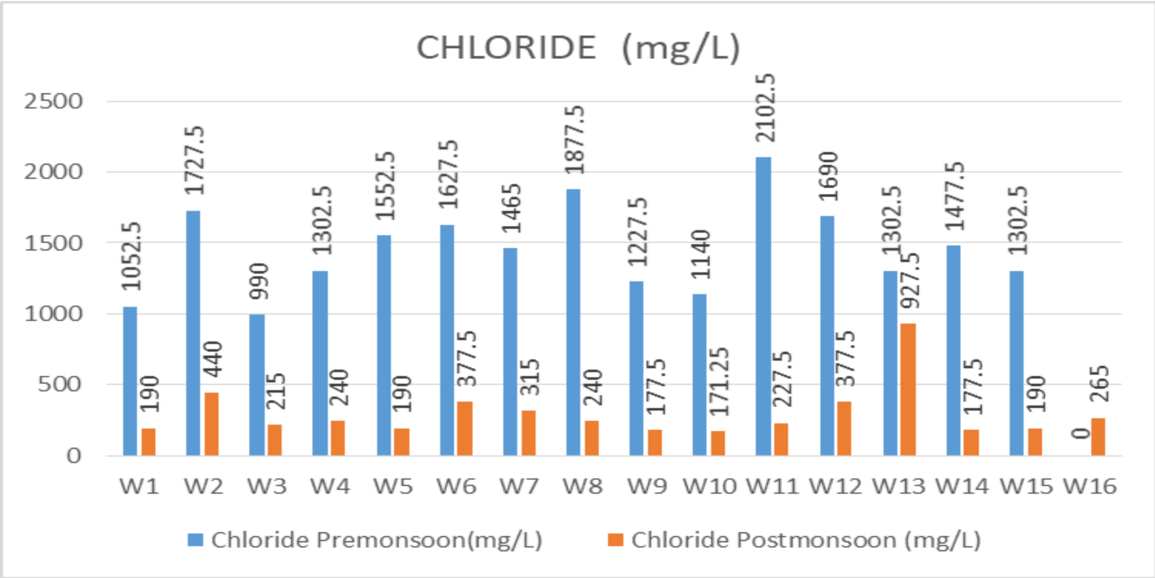


**Figure 5.26: Pre-monsoon and post-monsoon graphical representation of Chloride**

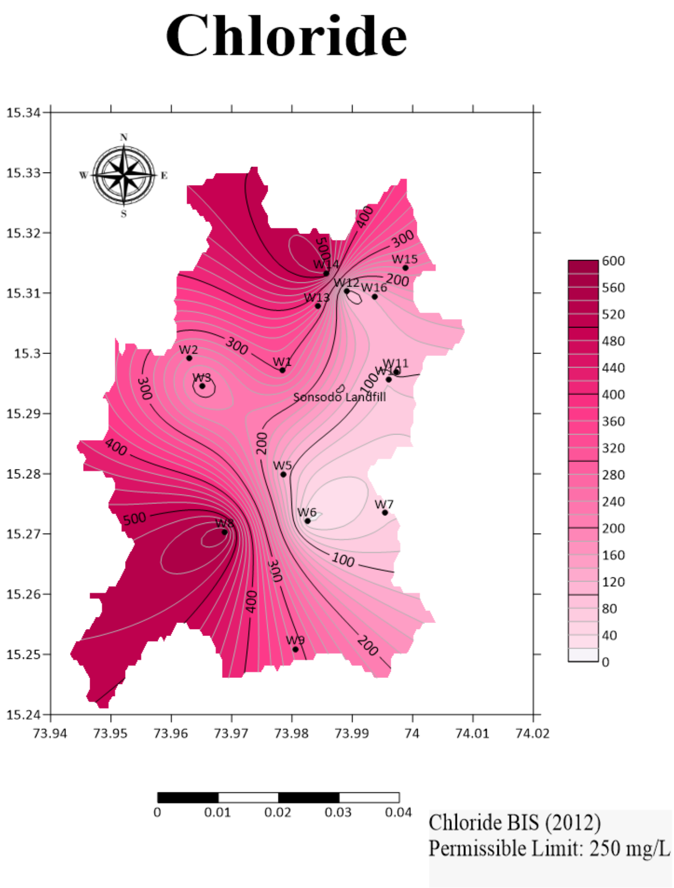


**Figure 5.27: Chloride pre-monsoon contour map**

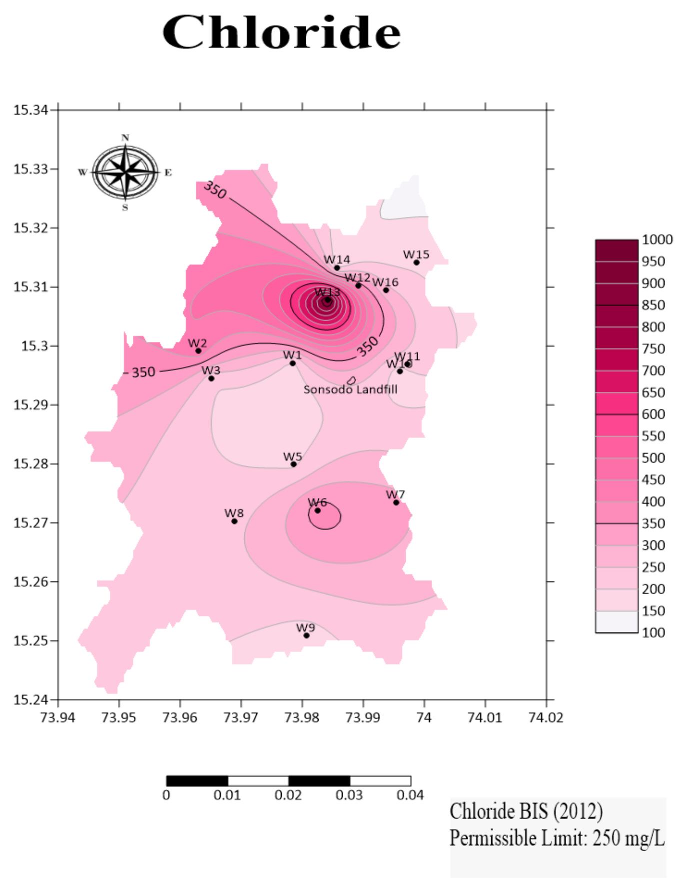


**Figure 5.28: Chloride post-monsoon contour map**

### 5.1.13 Total Alkalinity

Total alkalinity testing is a crucial aspect of analysing groundwater quality for well water. Alkalinity measures the water's ability to neutralize acids. This buffering capacity helps maintain a stable pH, which is important for several reasons sufficient alkalinity helps prevent corrosion of pipes and plumbing infrastructure as highly acidic water can leach metals from pipes, posing potential health risks. Very High Alkalinity can impart a bitter taste to water and potentially contribute to scale build up in pipes and appliances. Whereas low Alkalinity may lead to corrosion and potential metal leaching, introducing health risks depending on the metal. Alkalinity is measured Parts per million (ppm) or milligrams per litre (mg/L) are commonly used units to express total alkalinity. The permitted range for drinking water's total alkalinity is 200mg/L according to BIS (2012). Table lists the findings of the titrimetric determination of total alkalinity content.

**Observation**

Alkalinity level in groundwater samples for all wells during premonsoon period are within drinking water permissible limit 200 mg/L according BIS (2012). The total alkalinity concentrations in the water samples range from 10 to 66 mg/L. Well W5 exhibits the highest alkalinity level during pre-monsoon (66 mg/L), while W10 shows the lowest (10 mg/L).

**Inference**

The pre-monsoon period might witness the decomposition of organic matter in soil and vegetation. This decomposition process can release organic acids and other compounds into the soil and groundwater, contributing to increased alkalinity. This might lead to elevation in alkalinity in groundwater during premonsoon.

**Table 5.12: Total Alkalinity observation table**

| WELL No. | LATITUDE | LONGITUDE | Total Alkalinity Pre-monsoon (mg/L) |
|---|---|---|---|
| W1 | 15°17'49.7"N | 73°58'42.5"E | 14 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 54 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 28 |
| W4 | 15°176.30"N | 73°59′1.75"E | 22 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 66 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 24 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 42 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 42 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 22 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 10 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 26 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 24 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 24 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 30 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 14 |

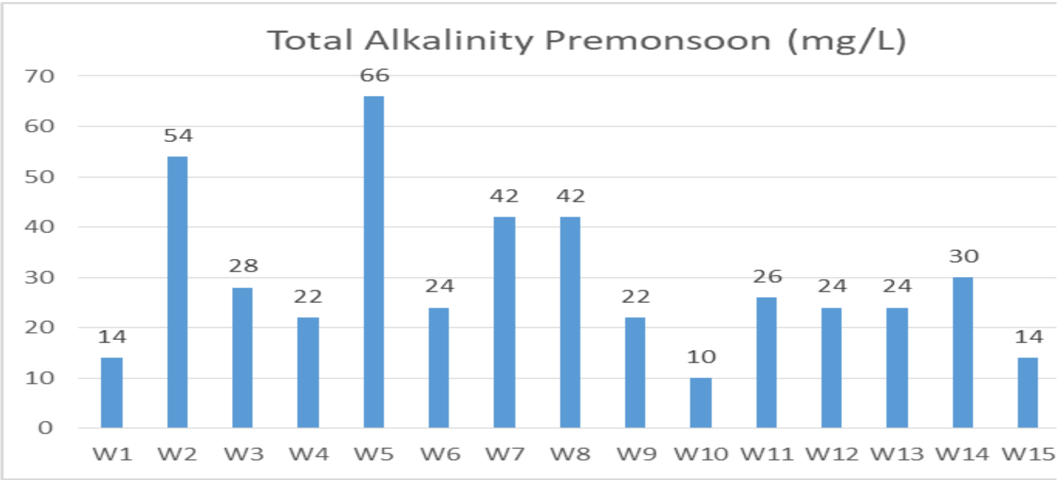


**Figure 5.29 Graphical representation of Total Alkalinity value**

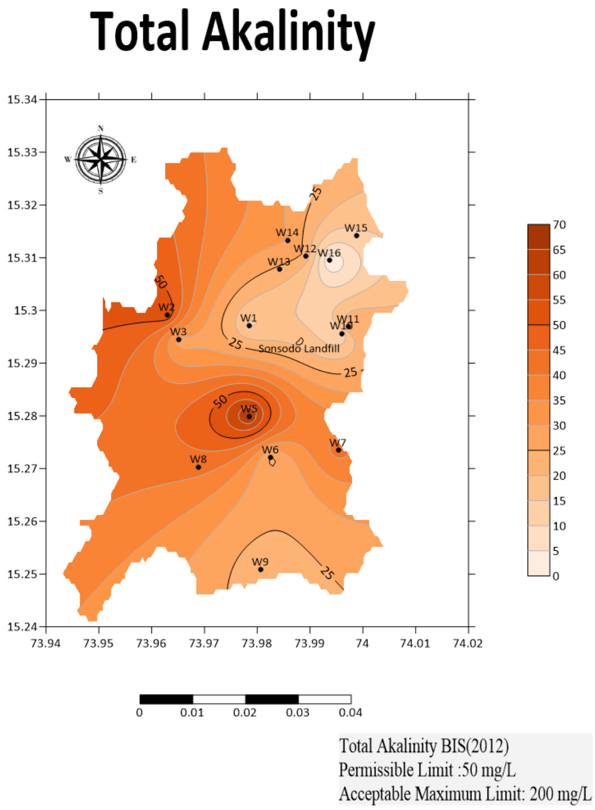


**Figure 5.30: Pre-monsoon Total Alkalinity contour map**

### 5.1.14 Nitrite

The permissible limit for nitrite in drinking water in India, as per the Bureau of Indian Standards (BIS) IS 10500:2012, is 3 milligrams per litre (mg/L) or 3 parts per million (ppm).

This standard sets the maximum permissible limit for various parameters in drinking water, including nitrite, to ensure its safety for human consumption.

**Observations**

Nitrite levels in groundwater during pre-monsoon and post-monsoon are within permissible limit of BIS (2012) 3mg/L. The average concentration of nitrite was found to be 1.08 mg/L and 0.05 mg/L in groundwater during pre-monsoon and post-monsoon respectively.

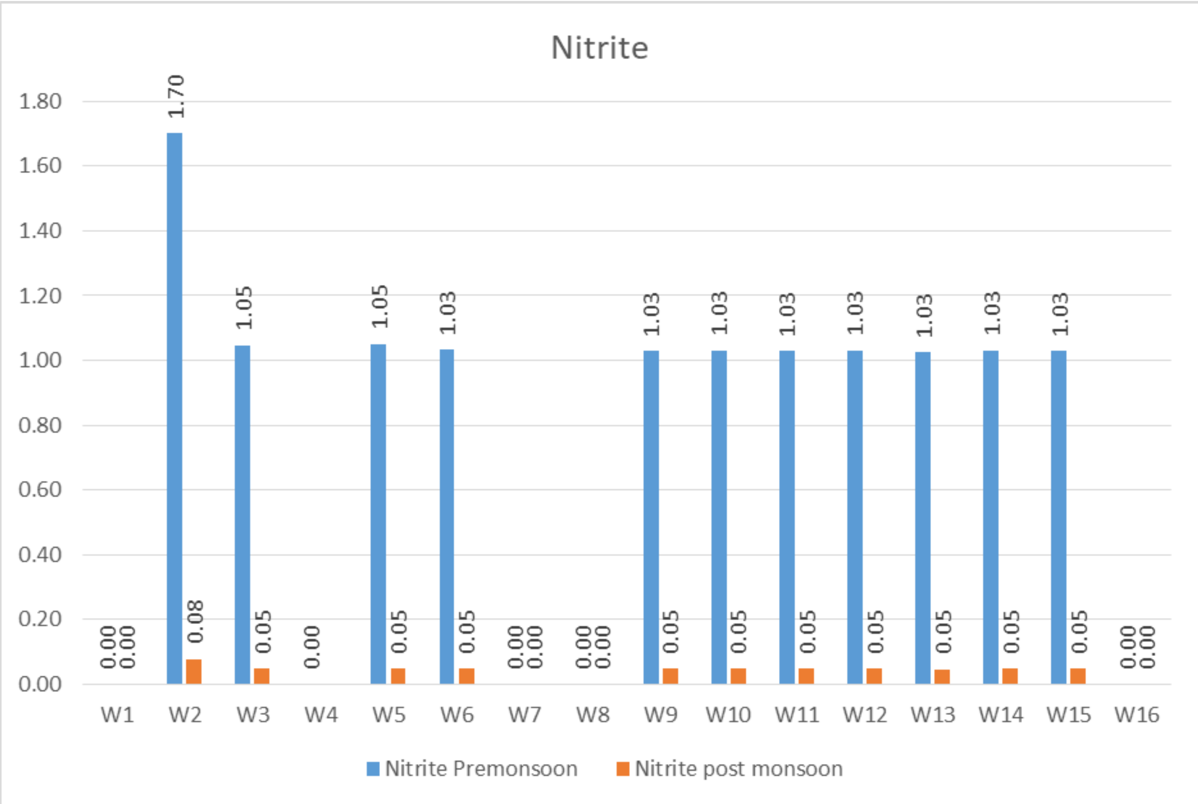


**Figure 5.31: Graphical representation of Nitrite**

**Table 5.13: Observation table of Nitrite**

| Well no | LATITUDE | LONGITUDE | Nitrite | |
|---|---|---|---|---|
| | | | Pre-monsoon (mg/L) | Post-monsoon (mg/L) |
| W1 | 15°17'49.7"N | 73°58'42.5"E | 0.00 | 0.00 |
| W2 | 15°17'57.0"N | 73°57'46.6"E | 1.70 | 0.08 |
| W3 | 15°17'40.3"N | 73°57'54.6"E | 1.05 | 0.05 |
| W4 | 15°176.30"N | 73°59′1.75"E | 0.00 | 0 |
| W5 | 15°16'47.7"N | 73°58'42.7"E | 1.05 | 0.05 |
| W6 | 15°16'19.7"N | 73°58'57.2"E | 1.03 | 0.05 |
| W7 | 15°16'24.5"N | 73°59'43.3"E | 0.00 | 0.00 |
| W8 | 15°16'13.2"N | 73°58'08.1"E | 0.00 | 0.00 |
| W9 | 15° 15' 03.2" N | 73° 58' 50.3" E | 1.03 | 0.05 |
| W10 | 15°17'44.3"N | 73°59'45.6"E | 1.03 | 0.05 |
| W11 | 15°17'48.9"N | 73°59'50.2"E | 1.03 | 0.05 |
| W12 | 15°18'37.0"N | 73°59'20.9"E | 1.03 | 0.05 |
| W13 | 15°18'28.1"N | 73°59'03.2"E | 1.03 | 0.05 |
| W14 | 15°18'48.0"N | 73°59'08.7"E | 1.03 | 0.05 |
| W15 | 15°18'51.1"N | 73°59'55.6"E | 1.03 | 0.05 |
| W16 | 15°18'34.1"N | 73°59'37.3"E | 0.00 | 0.00 |

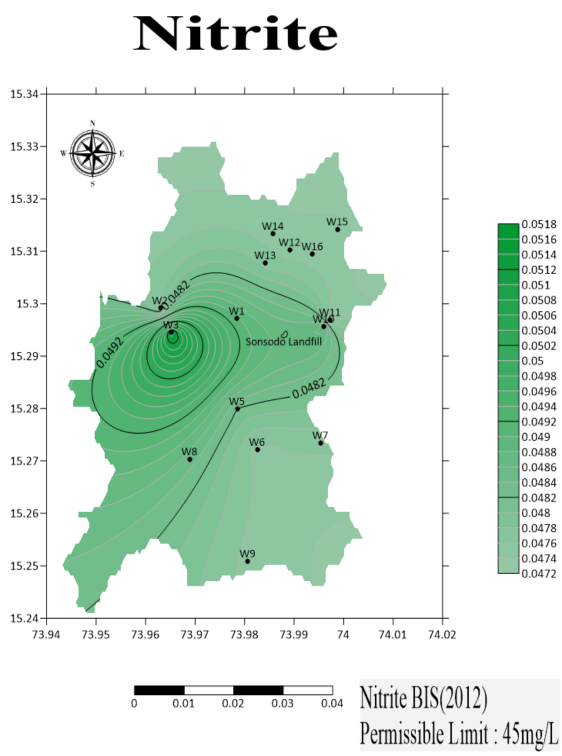


**Figure 5.32: Pre monsoon Nitrite contour map**

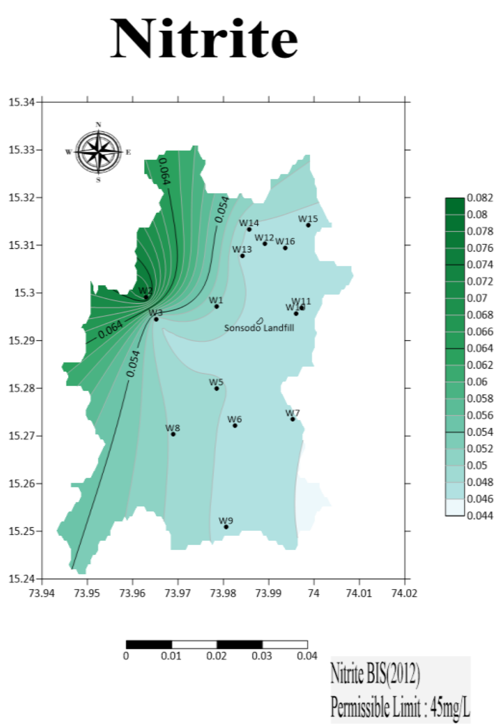


**Figure 5.33: Post monsoon Nitrite contour map**

### 5.1.15 Flow net analysis

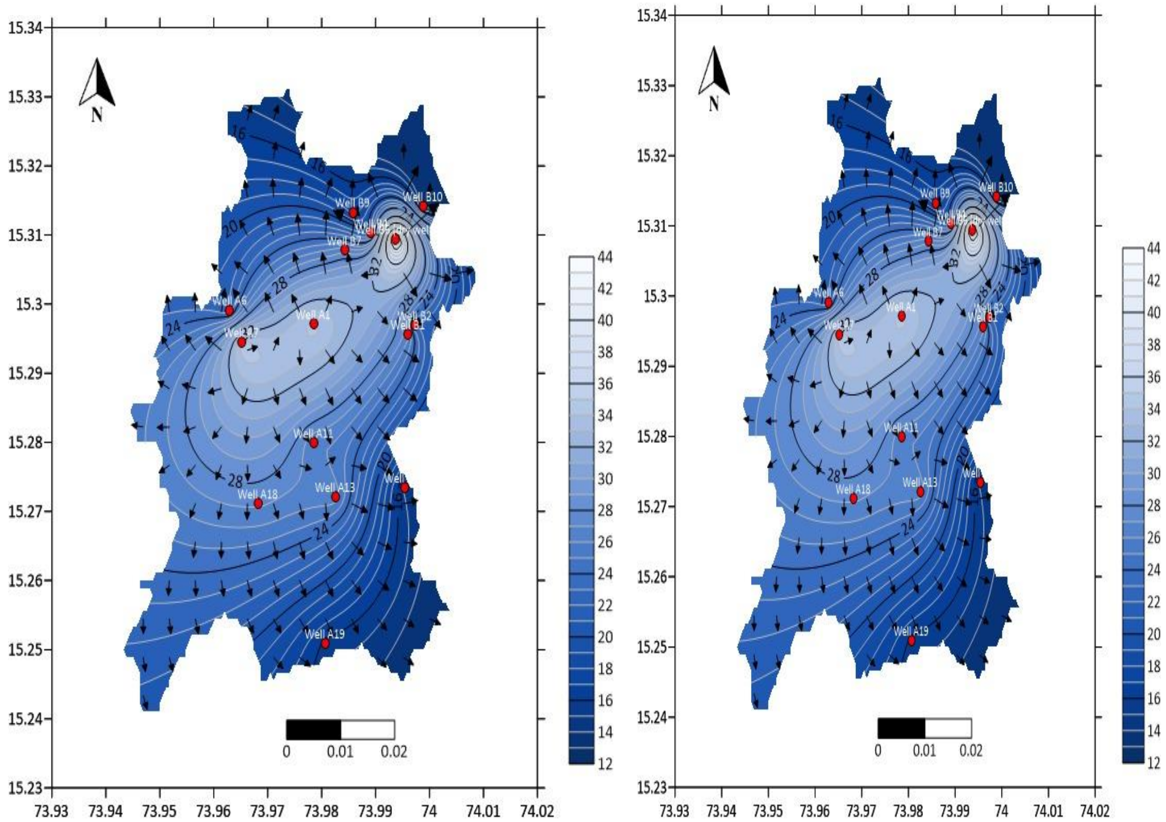

**Figure 5.34: Flow net analysis during a) post-monsoon and b) pre-monsoon**

**Observations**

The depicted figures, as shown in Figure 4.6, illustrate the pre-monsoon and post-monsoon flow nets of groundwater. Based on the flow net generated it was observed that there is not much variation seen in groundwater flow direction during premonsoon and post monsoon period. The flow net shows groundwater mount at the isolated hill in Sonsodo village. The groundwater is seen flowing in all direction from the Sonsodo hill. The groundwater flow is towards The Zuari River in north east direction and towards Sal River in the southeast direction.

# CHAPTER 6

## Conclusion

- Based on the flow net generated it was observed that there is not much variation seen in groundwater flow direction during premonsoon and post monsoon period. The flow net shows groundwater mount at the isolated hill in Sonsodo village. The groundwater is seen flowing in all direction from the Sonsodo hill. The groundwater flow is towards the Zuari River in north east direction and towards Sal River in the southeast direction.

- .The pH value ranged from 5.47 to 7.68 with an average of 6.4. 2 out of 15 well samples exhibited pH level below the permissible limit of drinking water (6.5-8.5) as defined BIS (2012).
- .The EC in groundwater ranged from 45 µS/cm to 872 µS/cm with an average of 202.8 µS/cm during pre-monsoon period. EC during post monsoon ranged from 54 µS/cm to1536 µS/cm with average of 262.3 µS/cm. Overall EC during post monsoon was higher as compared to premonsoon. Higher level of EC during post monsoon indicates higher salt content which might be due to contamination of groundwater with leachate from landfill.
- TDS level ranged from 28 ppm to 558 ppm with average of 129.7 ppm during premonsoon period,  With an average of 129.7 mg/L. Whereas during post monsoon TDS level ranged from 21 ppm to 983 ppm with average 167 mg/L. Well W8, which is 4 km from the landfill site showed high TDS level in groundwater which is above drinking water permissible limit of 300mg/L as defined by BIS (2012). Overall higher level of TDS was observed in groundwater during post monsoon as compared to premonsoon

- Dissolved oxygen level ranged from 2.74 to 8.84 mg/L with an average of 5.5 mg/L. Only 3 out of 15 wells i.e. W5, W6, W7 were within the permissible limit as defined by BIS 2012.
- The Calcium values in the water samples ranged from 3.20 – 41.61 mg/L during premonsoon period with an average 33.87 mg/L. During post monsoon, calcium level in groundwater ranged from 3.20 – 248 mg/L with an average of 56.27. According to BIS standards all wells samples were within permissible limit during premonsoon period. In post monsoon 1 out of 16 wells i.e. W8 was above acceptable maximum limit of 200 mg/L.
- During pre-monsoon, the magnesium level in the water samples ranged from 2.1 – 120 mg/L with an average of 18.8 mg/L .During the post-monsoon magnesium in groundwater water samples ranged from 4.5 mg/L to 120mg/.L, with an average of 37.11 mg/L. One out of 15 well samples i.e. W13 during pre-monsoon and W8 in post monsoon exhibited magnesium level above acceptable limits of 100mg/L. It may be noted that W 13 is located 2.4km from the Sansodo landfill area and W8 is located 4.4 km from landfill area.
- The total hardness values in the water samples ranges from 28--144 mg/L with an average of 111.2 mg/L during pre-monsoon .During post monsoon total hardness ranged from 44-800mg/L with an average of 209 mg/L. Based on the USGS classification, during premonsoon 9 out of 15 wells were found to be soft (0–60 mg/l), 4 wells were "moderately hard” and 2 wells were found to be “hard”. According to BIS (2012), all wells showed total hardness values within the acceptable limits (below 300mg/L) for premonsoon period. During post- monsoon only two wells namely W8 and W9 showed total hardness values above maximum acceptable limit (300 mg/L) according BIS

(2012). W9 is located 4.4 km from landfill area and exhibits high level of total hardness during post monsoon.

- The Sodium concentrations in the water samples ranged from 4.4 to 40.5 mg/L with an average of 13.57 mg/L during the pre-monsoon .During post monsoon concentrations in the water samples range from 4.1 to 29.2 mg/L with average of 15.95 mg/L.
- The potassium concentrations in the water samples ranged from 2 to 58.1 mg/L with an average of 20.64 mg/L during pre-monsoon .During post monsoon potassium ranged from 0.5 to 48 mg/L with an average of 8.96 mg/L. During the pre-monsoon period, 5 out of 15 sample were within the acceptable drinking water standard of 12 mg/L as per the BIS (2012). In the post-monsoon period, 13 out of 16 samples were within the acceptable limits for drinking. However, samples W3, W7, W8 exceeded the acceptable limit according to the BIS (2012). Higher range of potassium concentration is seen during premonsoon season which might be due to the infiltration of agricultural runoff.

- The chloride concentrations in the water samples range from 990 to 2102.5 mg/L with an average of 1364.8 mg/L during the pre-monsoon period. During post- monsoon chloride ranged from 171.25 to 927.5 mg/with an average of 295 mg/.Increase in chloride content in groundwater is seen during premonsoon season , the cause of it might be because of anthropogenic sources like agricultural discharges and industrial discharges
- Alkalinity level in groundwater samples for all wells during premonsoon period were within drinking water permissible limit 200 mg/L according BIS (2012). The total alkalinity concentrations in the water samples ranged from 10 to 66 mg/L. Well W5 exhibits the highest alkalinity level during pre-monsoon (66 mg/L), while W10 shows the lowest (10 mg/L).

- The average concentration of nitrite was found to be 1.08 mg/L and 0.05 mg/L in groundwater during pre-monsoon and post-monsoon respectively. All the samples in premonsoon and post monsoon were within permissible limit of BIS (2012) 3mg/L

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