EVALUATION OF UNDERGROUND WATER QUALITY IN NORTH SAURASHTRA AGRO CLIMATIC ZONE

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JUNAGADH – 362 001

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A

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"EVALUATION OF UNDERGROUND WATER QUALITY IN NORTH SAURASHTRA AGRO CLIMATIC ZONE"

ABSTRACT

Key words: Underground water, pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO_3^{-2}, HCO_3^{-}, Cl^{-}, SO_4^{-2}, SAR, SSP, RSC and RSBC

A survey experiment entitled "Evaluation of underground water quality in north Saurashtra Agro climatic Zone" was carried out during summer season of 2021. Collecting 480 underground water samples from cultivated fields of north Saurashtra Agro climatic Zone.

On the basis of analyzed data of water samples, collected from different district of north Saurashtra Agro climatic zone of Gujarat. The results in quality of underground water revealed that almost 62.5 per cent of irrigation water were found in saline EC ranged from 0.75 to 2.25 dS/m. The overall EC values ranged between 0.59 to 5.20 dS/m with mean value of 1.98 dS/m. The overall pH values ranged between 6.62 to 8.96 and mean value of 7.75. Almost 292 samples of underground water are found in between 7.5 to 8.5.

The results indicated that among the cations Na^{+} was dominant followed by Ca^{+2}, $Mg^{+2}$and K^{+}. The mean values of among cations Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} are 2.80, 1.77, 13.13 and 0.04 me/L, respectively. The anions dominance Cl^{-} was dominant followed by HCO_3^{-}, SO_4^{-2} and CO_3^{-2}. The mean values of different anions Cl^{-}, HCO_3^{-}, CO_3^{-2} and SO_4^{-2} are 12.29, 4.65, 0.07 and 0.73me/L, respectively.

The overall mean value of SAR was found 3.09, which varied from 0.62 to 10.56 and overall 99.58, 0.42, 0.00 and 0.00 per cent samples fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall mean value of RSC was found 0.15me/L, and varied from 0.00 to 1.89me/L. Overall 98.54, 1.46 and 0.00 per cent samples were found under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was found 69.57, which varied from 32.39 to 90.79. overall, 40.42 and 59.58 per cent samples fall under good and fair classes of SSP, respectively.

The results further indicated that the highly significant positively relationship was observed between EC with SSP and SAR. The EC was significant positive correlated with RSBC, Cl^- and Na^+. The RSC was significant positive correlated with CO_3^{-2} and HCO_3^-. The RSBC was significant positive correlated with HCO_3^-. The SAR was significant positive correlated with $Na^+$and Cl^-. The SSP was significant positive correlated with Na^+ and Cl^-.

Overall 60.83 percent of the 480 samples were found to have a pH between 7.5 and 8.5, whereas 34.58 percent of the samples had a pH below 7.5. In case of water quality, almost all underground water samples of north Saurashtra Agro climatic Zone having higher amount of soluble salts mainly due to dominance of Na^+ and Cl^- ions.

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C E R T I F I C A T E – I

This is to certify that the thesis entitled **"EVALUATION OF UNDERGROUND WATER QUALITY IN NORTH SAURASHTRA AGRO CLIMATIC ZONE"** submitted by **Miss JADAV BHUMIKA BHAGVANBHAI (Reg. No. 2010120036)** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the Junagadh Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title. The candidate has fulfilled all prescribe requirements. The assistance and help received during the course of investigation have been fully acknowledged. She has successfully completed the comprehensive/ preliminary examination held on **April 5, 2022** as required under the regulation for post-graduate studies. She has submitted *kachcha* bound thesis on **July 18, 2022.**

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LIST OF ABBREVIATIONS

%	: Percentage
Fig.	: Figure
dS/m	: decisiemen per metre
Me/L	: milliequivalent per litre
K^+	: Potassium ion
Ca^{+2}	: Calcium ion
Na^+	: Sodium ion
Mg^{+2}	: Magnesium ion
HCO_3^-	: Bicarbonate ion
CO_3^{-2}	: Carbonate ion
SO_4^{-2}	: Sulphate ion
Cl^-	: Chloride ion
pH	: Negative logarithm of H^+ ion concentration
EC	: Electrical Conductivity of water
mmol/l	: milli moles per litre
ppm	: parts per million
SP	: Sodium percentage
CEC	: Cation exchange capacity
EDTA	: Ethylene diamine tetraacetic acid
ESP	: Exchangeable sodium percentage
GIS	: Geographic information system
GPS	: Global positioning system
RSC	: Residual sodium carbonate
SAR	: Sodium adsorption ratio
SSP	: Soluble Sodium Percentage
RSBC	: Residual sodium bicarbonate
CSSRI	: Central Soil Salinity Research Institute
MR	: Magnesium ratio
PI	: Perameability index
USDA	: United States Department of Agriculture
MH	: Magnesium Hazard

KR	: Kelly’s Ratio
TDS	: Total dissolved solids
USSL	: United Stated Sanility Laboratory
WQI	: Water Quality Index
PS	: Potential Salinity
CAI1	: Chloroalkaline Indices
R^2	: Percentage of variance
r	: Correlation coefficient
<	: Lower than
>	: Greater than
EC	: Electrical conductivity
et al.	: et alibi (and others)

CHAPTER-I

INTRODUCTION

Water is the essential source for living organisms on the earth surface. The quality of both surface and underground water can be judged by analysis and impact of such water on soil properties can also be studied. One of the most valuable, renewable and widely available resources on the planet is groundwater. Water is an ubiquitous solvent that can be utilized as a catalyst in both chemical and biochemical reactions. Earth's surface is covered by 97.2 per cent salty water, 2.8 per cent fresh water and around 20 per cent groundwater (Kumar, 2011). In agriculture, groundwater is crucial for irrigation of crops grown in the dry seasons as well as for watering crops. On an average, groundwater sources provide around 45 per cent of the irrigation water needed.

The primary goal of water analysis is to appraise the quality of irrigation water and its effect on soil properties and ultimately on the plant growth. As such, much of the explanation of the water analysis is based on as prediction of the consequence for the soil. The dangers which must be considered when judging quality of saline water for irrigation purposes are salinity hazard, sodicity hazard, specific ion toxicity and permeability hazard *etc*. In arid and semi-arid regions, underground water is generally saline or contains high residual sodium carbonate. Nearly 84 per cent of the area in arid Rajasthan has groundwater over 2.2 dS/m EC and constitutes 60 per cent sources of the underground water. Quality of irrigation water is one of the main factors to be considered in agriculture (Jha *et al.* 2012).

Water, a prime nutrient which sustains life, is often the listing factor for successful crop production in semiarid and arid regions. This necessitates explanation of various sources of irrigation water. Water tends to be of varying qualities. As the statement goes “Hard water makes soft land and soft water makes hard land” (Scofield and Headly, 1936). Irrigation with poor quality water modify the soil behaviors mainly by changing the ions associated with the exchange complex.

The water used for irrigation purpose always contain soluble salts in respective of their source, but the total concentrations and the kind of salt present in any irrigation water are important in deciding whether, it will suitable for irrigation or not.

Most of India's groundwater is of marginal to extremely harmful quality, making it impossible to use for irrigation and drinking (CGWB, 2010). Water quality

refers to the characteristics of a water source and can be evaluated using its visual, physical, chemical and biological characteristics. How much water may be utilized for agriculture depends on many factors, including water quality, soil type, plant tolerance to salt, climate and drainage conditions (Michael, 1990). High-quality water could boost agricultural output when used in conjunction with effective soil and water management techniques (Liang *et al*., 2005). The physical and chemical characteristics of soil, microbial processes and eventually plant growth are all negatively impacted by excessive salts (Garcia and Hernandez, 1996; Zahran, 1997; Rietz and Haynes, 2003; Tejada and Gonzalez, 2005).

According to Tyagi *et al.* (2012), it currently accounts for more than 60% of all irrigated land in India and is crucial for both the country's economic development and food security. Due to increased demands from municipalities, industry and energy production, the agricultural sector will use about 23% (24.3 mha-m/year) of all water resources (105 m ha-m/year) by 2025 AD, while being the resource's primary consumer (89%) of water. This further reduces the availability of high-quality water for irrigation (Minhas and Tyagi, 1998). Irrigation water contains dissolved salts regardless of where it is produced; the kind and concentration depend on the source and the pre-treatment methods used. It normally contains salts in the range of 200-2000 parts per million or 200-2000 g of total dissolved salts (TDS) per cubic metre. Irrigation water is often taken from surface or groundwater sources. As a result, irrigation water has 10-100 times more salt than regular rainwater. One hectare of soil receives about 5 tonnes of salt in a single season when 1000 mm of medium-quality water is applied to it (Hillel, 1987).

India's entire arable land area is irrigated to a degree of about 33%. The primary source of water in this region is natural rainfall. Due to the favorable climate, India's population growth, urbanization, agricultural activities and industrialization along with increased mechanization in every aspect of life have resulted in a steady rise in the demands placed on water. Water resources in India are enough. According to estimates, India's water supply contains 70 per cent contaminated water. Due to the high level of water contamination, wells are therefore crucial for irrigation. Wells on the property make it possible for crops to be irrigation as needed. When it doesn't rain much, crops can still be saved by applying protective irrigation from wells. In addition, well irrigation frees the farmer from the whims of the canal irrigation system.

Quality of irrigation water is one of the main factors to be understood in irrigated agriculture. "Injudicious irrigations" even with good quality waters, turn many

agriculturally good soils into saline or alkali conditions, specific ion toxicity in plants and restricted water infiltration into soils with consequent adverse effects on the crop production. Irrigation with saline waters further complicates the problem where the interactions of several factors are to be understood.

Any assessment of the salt and alkali condition in an irrigated area must be take the quality of the irrigation water into account. In order to use irrigation water wisely and produce a crop yield that is sustainable, it is required to evaluate the quality of the irrigation water. Due to an excess of boron, fluoride, iron, nitrates, arsenic. The groundwater in many areas, especially those that are prone to drought, is unsuitable for direct consumption.

The quality of irrigation water is crucial for long-term soil production. Using subpar water over a lengthy period of time can lower the soil productivity or even lead it to become barren, depending on the amount and type of elements present in it as well as the soil's texture. Low or mildly saline waters occasionally seem to promote crop development because there are more nutritious ions present. However, excessive amounts of the soluble salts in the water can cause them to accumulate in the top layer, particularly in fine-textured or poorly drained soils. It drastically reduces crop yield and results in the emergence of troublesome soils. A steady and high-quality water supply is one of the most important factors in increasing crop productivity. The concentration and composition of the dissolved salts in water determine its quality for irrigation purpose.

Assessment of the quality parameters of well and tube well irrigation water is necessary for judicious use of irrigation water and to obtain a sustainable crop yield. The main soluble constituents in water Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} as cations and Cl^{-}, SO_4^{-2}, HCO_3^{-} and CO_3^{-2} as anions concentration to certain extent.

In India, 8.087 million hectares of land are estimated to be harmed by the salinity and sodicity of the water (Abrol and Bhumbla, 1971; Yadav *et al*. 1983). A total of 1.649 million hectares of land in Gujarat are lost to agriculture as a result of salt and sodicity, which are common both in the coastal and inland regions. The agriculture land of Saurashtra's Bhal tract, which is close to the Gulf of Cambay, is impacted by salt. Areas under the command of Ukai-Kankarapar are also affected by salt. The villages of Surat, Valsad, Bharuch, Bhavnagar, Morbi, Amreli, Jamnagar, Gir-Somnath, Junagadh and Devboomi Dwarka all have coastal saline soils.

The quality of underground water is the limiting factor in the irrigated area of nouth Saurashtra Agro climatic zone. The north Saurashtra Agro climatic zone include Jamnagar, Devbhoomi Dwarka, Morbi, Suredranagar and part of Amreli, Bhavnagar and Rajkot districts. The total geographical area of this region is about 49,345.43 km^2.The quality of available groundwater is not fit for consumption in this region owing to excessive salinity, fluoride and/or nitrate. In this region, excessive withdrawal of groundwater from coastal aquifers has lead to ingress of sea water in the coastal aquifers rendering many thousands irrigation wells useless in coastal areas of north Saurashtra region.

Underground waters, in contrast to surface waters, are not necessarily suited for irrigation. Their salt concentration and composition are location and spatially, affecting the water quality for agricultural use (Singh and Bishnoi, 2005).

It is necessary to characterize groundwater before it can be used in agriculture and used to grow crops that can be sustained over time. But performing routine chemical studies of groundwater across a wide area takes a while. As a result, connections between widely used and simple to measure factors of groundwater would need to be established in forecasting future the impact of soil and water quality parameters on yield without analyzing too many water parameters (independent variable). The nature, properties and quality of irrigation water must be assessed in order to determine the likelihood of the occurrence of secondary salinization or sodification in this area.

However, only few studies have been carried out in determining the quality of well waters and soils. It is therefore, felt necessary to carry out research on "EVALUATION OF UNDERGROUND WATER QUALITY IN NORTH SAURASHTRA AGRO CLIMATIC ZONE" with following objectives.

OBJECTIVES:

1) To determine the salinity and sodicity indices of underground water in north Saurashtra Agro climatic zone
2) To evaluate quality parameters of underground water in north Saurashtra Agro climatic Zone

CHAPTER - II

REVIEW OF LITERATURE

The literature concerning the present investigation has been reviewed under following major headings:

2.1 Salinity and sodicity indices of underground water

2.2 Quality of underground water

2.3 Inter-relationship between different properties of underground water

2.1 SALINITY AND SODICITY INDICES OF UNDERGROUND WATER

The quality of the well fluids in the Junagadh district were found to have a wide range of salinity dangers, with EC values ranging from 0.4 to 11.0 dS/m and a mean value of 2.11 dS/m, according to an investigation of subterranean well waters in the district. However, there was very little alkali risk in the area. Most of the waters had pH values in the range of 7.5 to 8.5, with an average of 8.0. Further evidence suggested that some of the wells have RSC issues. The RSC, SAR, and SSP values were 0.55 to 5.2me/L, 0.60 to 11.2, and 12.2 to 77.4 per cent correspondingly, with mean values of 2.28 me/L, 3.40, and 35.81 per cent. (Anon., 1994).

According to Nilsood *et al.* (1998). water samples from the Talwandi Sabtensi (Bhatinda district) were collected 88 villages and the EC of the samples ranged from 0.55 to 13.74 dS/m, while the levels of soluble carbonate, bicarbonate and RSC varied from nil to 3.2, 2.0 to 17.7 and traces to 14.6 me/L, respectively, which indicated that they would be suitable for irrigation in marginal-saline, marginal-sodic and poor conditions. There, sodicity is more prevalent than salinity.

Sharma and Minhas (1998) classified the ground waters of the Bhakra irrigation system's irrigation circle in the Kaithal district and observed that4.7, 6.8 and 4.4% of the waters in the command area had EC values less than 2.0 between 2 to 4 and more than 4.0 dS/m with SAR issues.

Yadav (1999) studied the chemical composition and quality of irrigation water samples were collected from 64 villages of Mahendragarh district. The pH, EC, SAR and RSC in irrigation waters were varied from 7.6-9.7, 0.2-23.4 dS/m, 0.19-80.49 and nil- 33.50 me/Lwith mean values of 8.68, 3.24 dS/m, 1.56 and 3.57 me/L, respectively.

Srivastava and Lallanram (2000) collected water samples from Kalmeshwar tehsil and found that 76 per cent of total samples were moderately suitable and only 3

per cent were sutiable for irrigation. In case of water samples collected from Katoltensil, 94 per cent of the total samples were unsuitable, only 6.0 per cent of total samples were found moderately suitable for irrigation.

Das and Maji (2001) reported that EC and SAR of groundwater of well/tube well decreased from June onwards, attaining minimum, increased from November onwards and reaching maximum during March to May.

Verma *et al*. (2003) collected 556 water samples from seven tensils of Charu district (Rajasthan) during October to February 1995-2000. They found that EC of water samples were ranged from 0.4 to 19.7 dS/m. About 32 per cent of water samples had EC< 2.0 dS/m, while 36 per cent water samples showed EC between 2-4 dS/m. The pH of water samples ranged from 7.2-9.3, the Cl^- was dominant anion and it ranged from 1.2-200.4 me/L, while Na was the dominant cation and it ranged from 1.7-118.0 me/L. The SAR of water samples ranged from 2.2 to 33.5 and RSC of water varied from nil to 13.1 me/L. About 75 per cent water samples were recorded RSC< 2.5 me/L. Whereas, 8.8 per cent samples had RSC between 2.5 to 5.0 me/L and 16.2 per cent samples had RSC > 5.0 me/L.

Kabaria (2004) collected 20 irrigation water samples each from 11 talukas of Amreli district during before monsoon (May, 2003) and after monsoon (Nov,2003). He found that all the water quality indicies (EC, SAR, RSC, SSP) of well/tube well water samples collected after monsoon improved in comparision to the samples collected before monsoon.

Patel (2004) collected 164 underground irrigation water samples from Suredranagar district and indicated that almost half of water samples from cultivate fields were saline(EC>2.5 dS/m). The EC value was ranged between 0.4 to 12.0 dS/m with a mean value of 3.5 dS/m. The waters were alkaline in reaction (mean pH value 7.82). The SAR values were ranged from 1.47 to 14.7 with a mean value of 14.5.

Singh and Bishnoi (2004) reported that on the basis of Residual Sodium Carbonate (RSC): 74.3; 12.8; 5.7 and 7.2 per cent samples in Muktsar district of Punjab were in the category of < 2.5, 2.5 to 5, 5 to7.5 and >7.5 me/L, respectively.

Hadiyal (2005) analyzed 53 underground irrigation water samples from Porbandar district and found that 50 per cent samples of water from cultivated fields of the Porbandar district were saline (EC > 2.25 dS/m). The EC values were ranged between 1.20 to 18.60 dS/m with mean value of 6.14 dS/m. The waters were alkaline in reaction (mean pH value 7.97). The SAR values were ranged from 3.06 to 33.84 with

a mean value of 10.14.

Subramani *et al. (*2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India. They concluded that the pH values of groundwater ranges from 6.9 to 9.2, with an average value of 8.2 and alkaline in nature, also the EC values ranges from 80 µS/cm to 3,740 µS/cm and groundwater in the area is generally high to very high saline in nature.

Sarkar and Hassan (2006) asserted that groundwater quality in Basin of Bangladesh and obtained pH range of basin water is 7.75 to 8.09 with an average 7.97 and obtained EC range of basin water is 0.64 to 1.06 dS/m and these EC and pH range found within the acceptable range of crop production.

Savalia *et al*. (2006) investigated that the underground water of open wells/tube wells situated at higher elevations have low pH, EC, SSP and SAR as compared that of lower elevations in different land slopes of Southern Saurashtra region.

Singh *et al*. (2006) studied the quality of soil and underground water samples collected from 60 tube wells distributed at 60 sites of non-command area of Degana tehsil, Nagaur district, Rajasthan, India. EC, SAR and RSC of underground water samples varied from 1.25 to 9.66 dS/m, 6.3 to 35.2 and 0 to 10.0 me/L, respectively.

Basavaraj *et al*. (2007) found that pH values of water from open wells and bore wells pH ranged from 7.0 to 8.7 and EC values varied from 0.1 to 1.0 dS/m. Among the different sources of irrigation, the mean values of electrical conductivity of open wells were more than those of bore wells. Residual sodium carbonate (RSC) values ranged from 0.2 to 2.8 me/Lin North-Eastern region of Karnataka.

Khan and Sharma (2007) assessed the quality of groundwater of Churu district of Rajasthan. Total 258 samples were assessed for SAR and RSC values in deciding water quality for irrigation purpose. The groundwater is largely sodic due to medium to high SAR range. It is from 0.05 to 68.11 with an average value of 16.28. About 67 percent waters have SAR less than 18. Higher values of SAR generally found in alluvium and schist/phyllite aquifers. Salinity in groundwater is generally high *i.e.,* 77 percent samples have EC more than 3.0 dS/m. Due to high salinity, the RSC is low in most of the samples and range from 0.0 to 26.0 me/L.

Rajput *et al*. (2008) studiedto determine the quality of the ground waters of Mohindergarh block of Mohindergarh district, Haryana. Their effect on soil properties and to categorize them for their suitability for irrigation. According to Manchanda's classification, half of the waters (51.2 per cent) were sodic having EC < 4 dS/m, SAR

> 10 (mmol /l) and RSC < 2.50 me/Lfollowed by saline-sodic (30.1 per cent) and good quality (18.7 per cent) waters. Whereas according to CSSRI classification, 16.87, 2.54, 1.00, 25.19, 7.44, 7.44 and 28.41 per cent samples were good, marginal saline, saline, high SAR with saline, marginally alkali, alkali and highly alkali, respectively. The waters were mostly Na-Mg-Ca type with dominance of chlorides followed by sulphate.

Hannan *et al*. (2010) conducted a survey in which 100 water samples collected from farmer's tube wells in Pakistan were evaluated for their quality characteristics and found that tube well water quality is the major contributing factor towards the low yield of crops, as it is not fit for irrigation in most of the areas. The data depicted the average values of EC, SAR and RSC corresponding to 1.93 + or 0.67 dS/m, 12.2 + or - 65.00 (mmol/l) and 3.6 + or - 1.96 (mmol/l), respectively.

Nishanthiny*et al.* (2010) examined that the water quality of selected wells in Jaffna, Sri Lanka and based on RSC analysis, reported that 61, 15 and 24 per cent of the wells had good, doubtful and unsuitable irrigation water quality, respectively.

Rajput (2010) collected 220 underground well/tube well water samples from Bhavnagar district and found that almost half of the samples of irrigation water were found saline (EC 0.75 dS/m and above). The overall EC values ranged between 0.38 and 18.2 dS/m with a mean value of 2.77 dS/m. The overall mean value of SAR was found 9.80, which varied from 1.32 to 26.3 and overall 49.6, 34.1, 14.1 and 2.2 per cent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values ranged from 0.00 to 4.17 me/L with mean value of 0.39 me/L and overall 87.7, 5.5 and 6.8 me/L percent samples under fell under safe, marginal and unsafe classes of RSC, respectively. The overall meanvalue of SSP was found 68.7, which varied range from 30.3 to 90.5 and 25.5 and 74.5 per cent samples fell under safe and unsafe classes of SSP, respectively.

Sojitra (2010) collected 280 underground irrigation water samples from Junagadh district and reported that almost three fourth (3/4) of the samples of water from cultivated fields were found saline (EC 0.75 dS/m and above). The EC values were ranged between 0.38 and 16.2 dS/m with a mean value of 3.10 dS/m. The waters were alkaline in reaction (mean pH value 7.71). The SAR values were ranged from 1.23 to 28.9 with a mean value of 8.88 and overall 46.0, 30, 18.6 and 5.4 percent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC value ranged from 0.0 to 8.80 me/L with mean value of 0.54 me/L and overall 85, 6.8 and 8.2 per cent samples fell under safe, marginal and unsafe classes of RSC, respectively. The

overall mean value of SSP was found 64.3, which varied from 33.3 to 87.1 and 24.6 and 75.4 per cent samples fell under safe and unsafe classes of SSP, respectively.

Garg (2011) observed that presence of dissolved salts in higher proportion is a common feature of groundwater in Western Rajasthan. The groundwater is medium to highly saline with high concentration of chlorides and sulphates of sodium. A survey has shown that more than 84 per cent of the area has groundwater over EC 2.2 dS/m. However, chemical quality of water in the major parts of Western Rajasthan is brackish to saline.

An investigation was carried by Vasanthavigar*et al. (*2012) in sub basin of Thirumanimuttar in Tamil Nadu on groundwater quality for determining its suitability for agricultural purposes. They investigated that water is neutral to alkaline in nature with pH ranging from 6.78 to 9.22 with an average of 7.37 and electrical conductivity (EC) ranges from 473.31 to 2,210.56 (mS/cm) in the study area.

Ahamed *et al*. (2013) collected groundwater samples from Alathur Blocklocated in Perambalur District of the state of Tamil Nadu. These samples were further analysed in two seasons for major cations, anions and other parameters such aelectrical conductivity, total dissolved solids, Kelly's ratio, sodium absorption ratio(SAR), magnesium ratio, sodium chloro-alkaline indices, residual sodiumcarbonate and permeability Index to know the suitability of groundwater for irrigation purpose. Results revealed that the subsurface water is alkaline (Na+ K) than the alkaline earth (Ca+ Mg) type.

Gandhi (2013) studied evaluation ofwater resources of the soils of Girnartoposequence of South Saurashtra region. The SAR ranged from 0.92 to 4.86 with the mean value of 2.66. However, SAR increased gradually with decreasing elevation.

Mehdi *et al.*(2013) assessed sixty five groundwater samples for various parameters such as electrical conductivity (EC), magnesium ratio (MR), permeability index (PI), sodium adsorption ratio (SAR), soluablesodium percentage(SSP) and residual sodium carbonate (RSC). The analysis report revealed that 5.62, 68.60 and 25.78 per cent of the ground waters of Ardabil plain of Iran were in good, permissible and unsuitable for irrigation with aerial coverage of about 61,745 and 280 km^2, respectively.

Rajput and Polara (2013) evaluated the underground well waters of district Bhavnagar, Gujarat and reported that the pH values of irrigation water ranged from

6.79-8.78 with mean value of 7.72 indicating that the water of the region was alkaline in nature. The EC, SAR and RSC values ranged from 0.38-18.2 dS/m, 0.32-26.3 (mmol/l) and 0.0-4.17 me/L with mean value of 2.77 dS/m, 9.80 (mmol/l) and 0.39 me/L, respectively.

Reddy (2013) analysed twenty groundwater samples were collected at identical locations from Semi-arid region of Bhaskar Rao Kunta watershed. The interpreted results were indicated that the groundwater quality stands on EC values; 20 and 80 per cent of the samples fall under medium to high salinity category in pre and post-monsoon seasons and stands on sodium percent (SP) values, 25 and 75 per cent of the samples fall under excellent to good category in both seasons. The remaining indexes SAR, RSC and Kelly's ratio values stands on 100 per cent of the samples and fall under the excellent and excellent to good category in both seasons.

Sanjay *et al.* (2013) reported that the pH, EC, SAR and RSC values of water samples collected from Kalanaur Block varied from 7.08-8.81, 2-3 (dS/m), 9-15 and 0-1 (me/L), respectively. In cations, the average values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 19.49, 5.05, 1.82 and 0.74 me/L, respectively whereas in anions, the average values for CO_3^{-2}, SO_4^{-2}, HCO_3^- and Cl^- were found to be 0.40, 2.26, 5.39, and 16.65 me/L, respectively.

Dhiman (2014) collected and analyzed 27 underground water samples from Rajkot district and reported that majority of sites have SAR < 10 indicating water class to be of excellent quality and 81.48 per cent samples have RSC less than the permissible limit of 1.5.

Kumar *et al.* (2014) studied the groundwater quality for irrigation of Bahadurgarh block of Jhajjar district (Haryana) found that 25.9, 56.90 and 17.2 per cent water samples were of good quality, saline and alkaline in nature, respectively. Out of the saline water, 19.8, 2.5 and 34.6 per cent were marginally saline, saline and withhigh SAR saline, respectively.

An investigation was carried out by Patil *et al.* (2014) for assessment of ground water quality in Ahmedpur tehsil of Latur district, Maharashtra and concluded that the water samples are alkaline in nature which has pH range from 7.18 to 8.81 with an average of 7.9.

Gummadi*et al*.(2015) collected the water samples from canals, bore wells and open wells in Bapatlamandal and Coastal Andhra Pradesh, month wise during 2009-2010 (October to May) and chemically analysed it to check its suitability for irrigation

.The analysis revealed that most of the samples were within the lower limit of pH (7.54 to 8.52). The electrical conductivity of the samples ranged from 453.24 to 658.4 µS/cm. The other parameters like sodium adsorption ratio(SAR), residual sodium carbonate(RSC) varied from 0.72–0.99 and -2.46 to -1.3 me/L, respectively.

Polara and Chuhan(2015) collected 180 well/tube well water samples from the Gir Somnath district of Saurashtra region and analayaed that almost three fourth of the samples of irrigation waters were found saline (EC 0.75 dS/m and above). The EC values ranged from 1.15 to 12.39 with a mean value of 3.31 dS/m. The waters are alkaline in reaction (pH 7.71). The overall RSC values ranged from 0 to 2.60 with mean value of 2.22 me/L and overall 92.2, 7.2 and 7.6 per cent samples fell under safe, marginal and unsafe classes RSC, respectively. The overall mean value of SSP was found 64.06, which varied between 44.24 to 85.35 and overall 31.7 and 68.3 per cent samples fell under safe and unsafe classes, respectively. The SAR values ranged from 4.02 to 19.43 with a mean value of 8.59 and overall 7.2, 42.8, 37.8 and 12.2 per cent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively.

Yadagiri *et al.* (2015) assessed fifty groundwater samples for suitability of irrigation purposes in parts of Kothur area, Mahabubnagar district, Andhra Pradesh and observed that the SAR values ranged from 0.63 to 3.6 belonged to the excellent category. The analytical data plotted on the US salinity diagram (USDA, 1954) illustrated that 80 per cent of the groundwater samples fall in the field of C_2S_1, indicating medium salinity and low sodium water, which can be used for irrigation on all types of soil without danger of exchangeable sodium.

Bhat (2016) collected ground water samples from Gohana block of Sonipat, Haryana and found SAR ranges in between 4.03 and 24.16 (mmol/L). He classified samples as excellent (50.6 per cent), good (44.4 per cent) and rest in doubtful categories and RSC of groundwater varied from 0 to 9.2 me/L. The majority of the samples are moderately suitable for irrigation purpose.

Grewal *et al.* (2016) have 81 groundwater analyzed for various irrigation indices such as Sodium adsorption ratio (SAR), Sodium percentage (Na percent), Residual sodium carbonate (RSC), Permeability Index (PI), Kelly's Ratio (KR), Magnesium Hazard (MH) and Hardness were calculated. The SAR, Na per cent, RSC, PI, KR, MH and hardness varied from 4.03 to 24.16 (mmol/L),53.55 to 93.00 percent, 0 to 9.2 me/L, 57.27 to 148.99, 1.11 to 13.14, 64.29 to 81.11 and 29.92 to 2403.30 mg/L, respectively. The analysis of the various parameters indicated the moderate suitability of

groundwater for irrigation purpose.

Kausar *et al*. (2016) indicated that on EC basis, 45.99 per cent water samples under fit category, 26.67 percent marginally fit and 27.33 per cent were found unfit for irrigation. On the other hand, 42.10 percent water samples were recorded fit on the basis of SAR, 39.62 per cent marginally fit and 18.28 per cent declared unfit for irrigation. While on basis of RSC, 64.42 per cent water samples were fit, 30.41 per cent marginally fit and 5.17 per cent were unfit for soil irrigation.

Evaluation of ground water samples were collected from open and tube-wells located in different villages of Matar Tehsil of Kheda district, Gujarat. The results indicated that pH, EC, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) ranged from 6.67 to 8.79, 0.26 to 12.63 dS/m, 1.79 to 37.06 and 0 to 13.8 me/L (Singh *et al*. 2016).

Hadiya and Polara (2017) studied water samples from cultivated farmer's fields of the Dev Bhumi Dwarka district and found that the EC values were ranged between 0.34 to 7.45 dS/m with mean value of 1.79 dS/m. The waters were alkaline in reaction (pH 7.88) with range values of 7.07 to 8.73. The SAR values were ranged from 0.15 to 10.39 with a mean value of 4.23 and overall 62.5, 13.3, 24.2 and 0.0 per cent samples under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values ranged from 0.00 to 4.90 me/L with a mean value of 0.26 me/Land overall 92.5, 5.0 and 2.5 per cent samples fall under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was 43.16, which varied between 5.19 to 75.22 and overall 67.5 and 32.5 per cent samples fall under safe and unsafe class, respectively.

Meena (2017) analyzed forty water samples from Bilara tehsil of Jodhpur of Rajasthan and observed that 15, 70 and 15 per cent water samples were under saline, high saline and marginally alkali categories, respectively.

More *et al*. (2017) studied 505 region wise irrigation water samples colllected either from well, bore well or canal of Western Maharashtra and analyzed for pH, EC, cations and anions. The result concluded that the irrigation water used for grape gardens showed higher values of EC, SAR and RSC in Sangli region in 2013-14 as compared to Solapur, Pune and Nashik regions that might be indication of maximum accumulation of salts in soil, might be resulted into salt affected soil.

Singh (2017) collected 40 water samples from Pipar city tehsil of Jodhpur, Rajasthan and observed that 10, 17.50, 60 and 12.50 per cent water samples were under good, marginally saline, high SAR saline and highly alkali categories, respectively.

Rawat *et al*. (2018) focused on the evaluation of the suitability of water samples of forty-four fixed bore wells of Kanchipuram district, Tamil Nadu, India. Water quality indices, namely SAR, ESP, RSC and Kelly's ratio, permeability index, chloroalkaline indices (CAI_1 and CAI_2), potential salinity (PS), magnesium hazard, total dissolved solids and total hardness, have been calculated for separate bore wells. Majority of the wells are fall under moderate to unsuitable category of water for irrigation purposes.

Riaz *et al*. (2018) collected and analysed the groundwater samples for various physico-chemical properties. The values of EC, SAR, and RSC were ranged from 0.03 to 15.39 dS/m, 0.02 to 52.66, and 0 to 43.3 me/L, respectively.

Evaluation of groundwater quality for irrigation is crucial in arid and semi arid regions was observed by Singh *et al*. (2018). They reported that EC, SAR and RSC in groundwater ranged from 0.47 - 6.06 (dS/m), 3.69 - 28.59 and 0 - 5.70 (me/L), respectively.

Krishan *et al.* (2020) studied on region Mewat (renamed as Nuh) district of Haryana, India. The district showed an average salinity of 6.7 g/l in pre-monsoon, 7.3 g/L in monsoon and 7.4 g/L in post-monsoon season thus a variability of 0.7 g/L observed. The area affected by the salinization (>2 g/L) also registers an increase from 86 percent (pre-monsoon) to 99 per cent (post-monsoon) period. Mineral dissolution is found to be responsible for overall groundwater salinization with contribution of 97 per cent, declined to 86 per cent in post monsoon.

Nikolaou *et. al*. (2020) collected the water samples (n = 890) from private wells in agricultural areas were analyzed from 2009 to 2018 to determine various physicochemical properties. The results indicated that sodium, chloride and sulphate were found to be the predominant ions in groundwater. All samples evaluated were suitable for irrigation in terms of soil sodicitation and soil infiltration rate.

Singh *et al.* (2020) collected 50 groundwater samples from Udham Singh Nagar district, Uttarakhand and analysed for pH, HCO_3^- , CO_3^{-2} , Cl^- , SO_4^{-2} , NO_3^- , Ca^{+2}, Mg^{+2}, Na^+ and K^+ . To assess the groundwater quality for irrigation purpose, parameters like SAR, SSP, RSC, MH, PI and chloroalkaline index CAI values have been calculated. In USSL diagram, most of the groundwater samples fall in the C_2S_1 category and were safe for irrigation purpose. Only seven groundwater samples fall in the C_3S_1category, indicating medium to high salinity which is safe for irrigation purpose for all types of soils but with limited care of exchangeable sodium. On the basis of RSC, all groundwater samples were observed to be suitable for irrigation purpose.

Shyamala *et al.* (2021) was conducted in the study area of Coimbatore district by collecting 60 samples from the agricultural belt. The groundwater is neutral to alkaline in character with pH varying from 6.70 to 9.02 among the mean of 7.37.The EC was observed in upstream parts of the study area. Water quality for irrigation is determined by several key components like EC, TDS, RSC, CAI &CAII,SAR, %Na, KR, MH, PI and SSP. In total, six samples were found to be with high salinity hazard. The mean value of SAR was found to be 5.24, maximum sample falls under C_2S_1 to C_4S_1 category as per USSL salinity diagram.

2.2 QUALITY OF UNDERGROUND WATER

Das *et al.* (1991) collected 97 water samples from Orissa to judge suitability for irrigation purpose. The quality rating of these waters indicated that 8 samples from wells, 3 from perennial stream/canals and 7 from ponds were unsuitable for irrigation purpose. Special attentions are to be given while irrigating these waters.

The compositions of groundwater of 8 different wells were evaluated at coconut plantation farm GAU, Mahuva (Girdhar, 1991). It was observed that EC of these wells varies from 1.9 to 9.3 dS/m and SAR ranges from 5 to 3.15. These waters are also rich in Na^+ followed by $Mg^{+2}$and Ca^{+2}, where as Cl^- is the dominant anion.

An investigation was undertaken by Lal *et al.* (1998) to determine the quality of underground water of non-command area of Bikaner district in Rajasthan, their effect on soil properties and to categorize them for their suitability for irrigation. The water is mostly Na-Mg-Ca type with dominance of Cl followed by CO_3,HCO_3. EC of soil was significantly and positively correlated with EC of irrigation water.

Yadav (1999) studied the chemical composition and quality of irrigation water samples were collected from 64 villages of Mahendragarh district. The cations and anions viz., Ca^{+2}, Mg^{+2}, Na^+ , K^+ ,CO_3^{--}, HCO_3^-, Cl^- and SO_4^- in irrigation water were varied from 0.25-26.25, 0.0-80.00, 0.28-234.00, 0.01-2.10, 0.0-10.00, 0.0-29.60, 0.0-203.00 and 0.0-57.10 me/L with mean values of 3.19, 4.73, 3.15, 0.25, 0.78, 7.08, 21.48 and 3.70 me/L, respectively.

Subramani *et al.* (2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu and they also found the abundance of the major cations is as follows: $Na^+ > Ca^{+2} > Mg^{+2} > K^+$. The concentrations of various cations such as Na^+ (mg/L) 4 to 304 with an average 97, K^+ (mg/L) 2 to 34 with an average 9.71, Ca^{2+} (mg/L) 10 to 176 with an average 63, Mg^{2+} (mg/L) 2 to 243 with an average 63 mg/L and also the major

anions is as follows: $Cl^- > HCO_3^- > SO_4^{-2} > NO_3^- > CO_3^{-2}$. They found concentration of various anions such as Cl^- (mg/L) 7 to 1163 with an average 259, HCO_3^- (mg/L)18 to 275 with an average 153, CO_3^{2-} (mg/L) 0 to 90 with an average 16, SO_4^{2-} (mg/L) 0 to 173 with an average 49 in water samples.

Kishor *et al*. (2006) assessed the 70 tube wells water, distributed in different villages of Rajgarh tehsil of Churu district, Rajasthan. Data revealed that the pH of irrigation water varied from 8.0 to 9.1, EC ranged between 1.70 to 14.10 dS/m. Cations Ca^{+2}, Mg^{+2}, Na^+ and K^+ of irrigation waters ranged from 0.70 - 8.6, 2.3 - 55.8, 10.6 - 84.2 and 0 - 20.5 me/L, respectively. Anions Cl^-, SO_4^{-2}, CO_3^{-2} and HCO_3^- in these irrigation waters varied from 7.0 - 131.8, 1.0 - 13.3, 0.2 - 3.5 and 2.7 -13.0 me/L, respectively.

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh. They obtained concentration of cations in water samples such as Ca^{+2}varied from 0.67 to 6.29 (3.49) , Mg^{+2} from 0.23 to 0.59 (0.42), Na^+ from 0.59 to 1.59 (1.03), K^+ from 0.93 to 2.95 (1.66) mg/L and found concentration of anions such as HCO_3^- varied from 6.25 to 11.50 (8.07), Cl^- from 2.38 to 7.75 (5.13) me/L.

Singh *et al*. (2006) investigated the quality of soil and underground water samples collected from 60 tube wells distributed at 60 sites of non-command area of Degana tehsil, Nagaur district, Rajasthan. They observed that the water was mostly Na-Mg-Ca type with dominance of chlorides followed by carbonate and bicarbonates. The pH of soils varied from 8.0 to 9.4 and EC of the soils varied from 0.14 to 1.64 dS/m. Only 8.3 per cent of the water samples are good quality.

Jalail and Merrikhpour (2007) reported that sodium (Na^+) in poor quality irrigation water participate in ion exchange processes results in the displacement of base cations into solution and a raised concentration in groundwater. The sandy soil showed the high risk for nutrients transfer into groundwater in concentrations exceeding the groundwater quality standard. Irrigation with poor quality water, which is generally more sodic and saline than regional groundwater increases the rate of sodification and salinization of shallow groundwater.

Shahid *et al*. (2008) found that maximum number of underground water samples of Juana block in districtJind had EC between 1 and 2 dS/m. Sodium was the dominant cation followed by calcium and magnesium.

Ramkumar *et al*. (2010) collected the groundwater samples from Vedaraniyam region, Tamilnadu and analyzed the parameters (pH, EC, Total dissolved solids, Total

hardness, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Cl^{-}, SO_4^{-2}, HCO_3^{-} and NO_3^{-}) in order to understand the hydro geochemistry of the water. The results of analysis were interpreted with geology and geomorphology of the area and also by various geochemical diagrams such as Piper tri linear plot and USSL classification diagram. Suitability of this water for its utility was vaerified using Indian standards.

Saini *et al*. (2010) studied on groundwater quality status of Amber tehsil, Jaipur district, Rajasthan. The pH value in study area were found from 7.29 to 9.32, electrical conductivity (EC) ranged from 898 to 3762 mmhos/cm and TDS from 578 to 3360 mg/L. The calcium hardness ranged from 8.01 to 304.60 mg/L. Alkalinity was in the range of 150 to 519 mg/L. Total hardness varied from 64 to 1304 mg/Land magnesium from 5.32 to 132.59 mg/L. Chloride varied from 17.04 to 1482.48 mg/L and fluoride from 0.29 to 3.33 mg/L. Most of the parameters were found to be slightly higher than the IS (Indian standard) permissible limits.

Tank and Chandel (2010) collected underground water sample from eleven stations of Jaipur city during monsoon season and were analyzed for physico-chemical parameters such as pH, EC, Ca^{+2}, Mg^{+2}, SO_4^{-2}, CO_3^{-2}, HCO_3^{-}, Na^{+}, Cl^{-}, nitrate and fluoride. The calculated values percentage sodium indicate that the water for irrigation uses is excellent to good quality.

Mahadevaswamy (2011) studied on quality of groundwater of Nanjangud taluka of Mysore district of Karnataka. Based on water samples collected and analysed from 50 locations, the hydro-geochemical facies in the area are found to be dominated by sodium-bicarbonate.

Obiefuna and Sheriff (2011) found the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes. They found concentration of cations like sodium (mg/L) 0.03 - 97 with mean 7.13, potassium (mg/L) 4 -12.10 with mean 7.35, calcium (mg/L) 18.07-73.76 with mean 34.17, magnesium (mg/L) 7.78 - 58.98 with mean 30.13 mg/L in water samples.

The groundwater quality of Babalgaon Latur was assessed by Mulla *et al*. (2012). They collected water samples from four sampling sites and their physico-chemical parameters such as pH, conductivity, chloride, sulphate, temperature and TDS were estimated. They found that in some cases water quality was good but some of the parameters were above the permissible limit such as pH, Cl^{-} and TDS.

Patel *et al*. (2012) studied the underground water quality of different landforms of Meghal Irrigation Command area of Southern Saurashtra region of Gujarat. They

observed low pH, EC, water soluble Mg^{+2}, Na^{+}, CO_3^{-2}, HCO_3^{-}, Cl^{-}, SSP and SAR at higher elevation than in lower elevation.

An investigation was carried out by Vasanthavigar *et al.* (2012) in sub basin of Thirumanimuttar in Tamil Nadu on groundwater quality for determining its suitability for agricultural purposes. They found concentration of Ca^{+2} from 16.0-228.0 (mg/L), Mg^{+2} from 10.5-158.40 (mg/L), Na^{+} from 0.80-1497.0 (mg/L), K^{+} from 0.80-497.0 (mg/L) in the water samples. The order of concentration of major cations is Na^{+}> Ca^{+2}>Mg^{+2}>K^{+} and The concentration of various anions in water samples as HCO_3^{-} 73.22 - 893.84, Cl^{-} 86.85 - 1,602.27 and SO_4^{-2} 0.01 - 126.8. The order of abundance of anion concentration is HCO_3>Cl^{-}>NO_3^{-}.

Yadav *et al*. (2012a) were analyzed 200 water samples from running tube wells in Bawal tehsil of district Rewari (Haryana) and categories 14, 4, 4, 62 and 16 per cent were found good, marginal, saline, sodic and saline-sodic in nature, respectively.

Yadav *et al*. (2012b) conducted a study during pre and post monsoon seasons of the year 2011 in Rajsamand district of Rajasthan to assess spatio-temporal changes in the groundwater quality and found that the nature of groundwater of Rajsamand district is Na-Mg-Ca and CI-HCO_3-SO_4 type. The spatio-temporal variations were observed in water quality parameters which indicated that there is perceptible improvement in quality of groundwater in post monsoon season.

Ashraf*et al.* (2013) collected 296 advisory water samples from tehsil Layyah during previous three years (2009-10 to 2011-12). The results showed that out of 296 water samples, 114 (38 per cent) water samples were fit, 79 (27 percent) were marginally fit and 103 (35 per cent) were found unfit for irrigation purposes. The analysis data showed that, 95 unfit water samples had electrical conductivity higher than permissible limit (>1250 uS/cm), 12 samples were found with high SAR (>10 mmol/l) and 47 samples had high RSC (>2.5 me/L).

Gandhi (2013) studied evaluation of soil and water resources of the soils of Girnartoposequence of South Saurashtra region. The pH and EC ranged from 7.66 to 7.99 and 0.21 to 4.53 dS/m with the overall mean value of 7.75 and 1.83 dS/m, respectively. The proportion of water soluble cations in saturation extract observed in decreasing order of Na^{+}> Mg^{+2}> Ca^{+2}> K^{+} whereas, water soluble anions were in order of CI^{-}> HCO_3^{-}> CO_3^{-2}. However, EC, soluble cations, water soluble anions increased gradually with decreasing elevation.

Narsimha *et al*. (2013) collected 18 groundwater samples from Hanmakonda area, Warangal district (Andhra Pradesh) and analyzed forvarious physical and chemical parameters, such as, EC, pH, TDS, Na^{+}, K, Ca^{+2}, Mg^{+2},HCO_3^{-} and CO_3^{-2}, Sodium adsorption ratio, sodium percentage, residual sodium carbonate, Kelly's index and magnesium hazard were calculated based on the analytical results. Majority of the samples (78 per cent) belong to C3-S1, water class, indicating water with high salinity and low sodium.

Dhiman (2014) analyzed 27 underground water samples from Rajkot district and reported that 70.37 percent sites have $(Ca^{+2} + Mg^{+2}) > HCO_3^{-}$ indicating as base exchanged-hardened waters, while remaining 29.63 per cent samples have $HCO_3^{-}>$ $(Ca^{+2} + Mg^{+2})$, which may be referred as base exchanged-softened waters.

Sreedevi *et al*. (2016) evaluated the status of groundwater quality and its suitability for agriculture on the basis of calculated water quality indices in thirty six groundwater samples in Gooty Mandal, Anantapur District of Andhra Pradesh. The results showed that 10 ground water samples in the study area were near-neutral to weakly alkaline in nature. The order of major dominance of cations in groundwater is $Na^{+}>Ca^{+2}> Mg^{+2}> K^{+}$ and the anions is $HCO_3^{-}>Cl^{-}> CO_3^{-2}> NO_3^{-}> SO_4^{-2}$.

Verma *et al*. (2016) studied the quality of groundwater of Sabour block, Bhagalpur district of Bihar. The mean value of pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-} and Cl^{-} are found to be 7.26, 0.69, 38.98, 34.20, 16.92, 1.19 and 0.02 respectively.

Apraj *et al*. (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results showed that the sodium concentration in irrigation water samples from Palghar tehsil varied from 4.98 to 109.26 me/L with a mean value of 31.92 me/L and that from Dahanu tehsil 6.14 to 104.70 me/L with a mean value of 29.12 me/L. Among all the cations Na^{+} was dominant in water followed by Ca^{+2}, $Mg^{+2}$and K^{+} and showed that the concentration of carbonate varied from 0.0 to 6.0 me/L with a mean value of 1.02 me/L from Palghar tehsil, while in Dahanu tehsil it was varied from 0.0 to 6.0 me/L with a mean value of 2.50 me/L. There were no carbonate contents in majority of water samples. The order of anions in samples is $Cl^{-}> HCO_3^{-}> SO_4^{-2}> CO_3^{-2}$.

Jebastina and Arulraj (2017) assessed the quality of ground water assessment of Coimbatore District, Tamil Nadu (India) for its suitability for drinking and irrigational purposes by it's hydro-chemical parameters. Seventy eight groundwater samples were collected within the study area during post monsoon season of the year 2011. The

samples were tested for the physical and chemical parameters. Based on the study, it was found that most of the samples are suitable for irrigation purpose.

Kumar *et al*. (2017) examined the quality of groundwater in Rewari block of Rewari district of Haryana, India. Total 143 groundwater samples from running tube wells from the block were analyzed during 2013-2014 for ionic concentration of CO_3^{-2}, HCO_3^-, $C1^-$, SO_4^{-2}, NO_3^-, F^-, Ca^{+2}, Mg^{+2}, Na^+ and K^+. According to AICRP classification of water samples were found to be in good, marginal saline, saline, high SAR saline, marginal alkali, alkali and highly alkali, respectively.

Rao (2018) studied groundwater samples from Prakasam district of Andhra Pradesh. He found the concentration of Ca^{+2} in between 55 and 90 (mg/L) with a mean of 65.67 mg/L while that of Mg^{+2} from 42 to 105 (mg/L) with a mean of 76.87 mg/L, Na^+ concentration from 185 to 823 mg/L with a mean of 444.73 mg/L and K^+ concentration observed to be low, which ranged from 12 to 121 with a mean of 54.33 mg/L in water samples and total anions like bicarbonate, chloride, sulphate. The HCO_3^- content is observed to be 480–1025 mg/L with a mean of 731.33 mg/L, Cl in between 215 and 1060 mg/L with a mean of 568.83 mg/L and SO_4^{2-} content is observed to be 22–125 mg/L with a mean of 71.47 mg/L in water samples.

Rawat *et al*. (2018) focused on the evaluation of the suitability of water of forty-four fixed bore wells of Kanchipuram district, Tamil Nadu. The R_1 and R_2 indices show that groundwater of the study area is Na^+ - SO_4^{-2} and deep meteoric percolation type. Majority of the wells are fall under moderate to unsuitable category of water for irrigation purposes.

Evaluation of groundwater quality for irrigation is crucial in arid and semi arid regions by Singh *et al*. (2018), obseved that pH ranged from 7.25 - 9.25 and the concentration of cations viz., Ca^{+2}, Mg^{+2}, Na^+ and K^+ varied from 0.40 - 3.00, 1.10 - 11.00, 3.20 - 53.10, 0.06 - 1.00, me/L, respectively. Likewise, the concentration of anions viz., CO_3^{-2}, HCO_3^-, Cl^-, SO_4^{-2} and NO_3^{-2} varied from 0 - 2.90, 1.00 - 8.10, 2.00 - 28.80, 0.28 - 30.08 and 0 - 0.90 me/L, respectively.

Yadav *et al*. (2018) studied on quality status in different blocks of Sonbhadra district, Uttar Pradesh and analizedphysico-chemical parameters of groundwaterof quality based on pH, EC, TDS, Cations like Na^+, K^+, Ca^{+2}, Mg^{+2}, Anions like CO_3^{-2} and HCO_3^-. The majority of groundwater samples on the basis of salinity (EC) wee found to be medium to high salinity class.

Kumari and Rai (2020) evaluated the hydrochemistry of groundwater in Southern Haryana. According to the USSL classification more than 85 percent of the samples fall under C_3S_1, C_3S_2, C_4S_1, C_4S_2 classes of irrigation water indicating very high salinity which is alarming considering the use of this water for irrigation.

Nagarajan *et al*. (2020) conducted a geo-spatial study for groundwater sampling for water quality assessment to determine the suitability of water for drinking and irrigation purpose. For this study, five villages around AEC & RI, Kumulur, Trichy, Tamil Nadu were selected. For the assessment of groundwater quality, samples from 53 locations were collected from sources like open well, bore well and hand pump. The different physico-chemical data of above analysis were used for the computation of three Water Quality Index (WQI) for drinking (WQI1 & WQI2) and irrigation (WQI3) needs. In WQI3, 96% samples fall under the permissible category and 4 per cent samples *i.e*. 0.44 km^2 area, fall under the very poor and unsuitable category, which needs treatment before usage for irrigation.

2.3 INTER-RELATIONSHIP BETWEEN DIFFERENT PROPERTIES OF UNDERGRONUD WATER

Maniwal and Timbadia (2000) studied the irrigation water samples of Amreli district and analysed that EC and pH of irrigation water had significant and positive correlation with EC (r= 0.745**) and pH (r= 0.895**) of soil.

Prasad and Prasad (2001) observed that EC and pH of irrigation water highly significantly correlated with ECe(r= 0.914**) and pH (r= 0.394**) of soil. Similarly, SAR was also correlatd positively and significantly with SAR of soil (r = 0.386**).

Kabaria (2004) studied on the correlation between the different properties (EC, pH, RSC, SSP and SAR) of well/tube well waters of Amreli district. The data indicate that EC was negatively correlated with pH (r= -0.1827**) of irrigation water. Highly significant positive correlations between EC and SSP (r= 0.3951**) and SAR (r= 0.8201**) of irrigation water were observed. Which indicate the SSP and SAR of irrigation waters increase with increasing the EC of irrigation waters. The pH of irrigation waters were highly significantly positively correlated with RSC (r=0.7259**) and SSP (r= 0.3957**). The RSC of irrigation water significant correlated with SSP (r= 0.4535**) and SAR (r= 0.2272**) of water. A highly significant correlation (r= 0.7637**) was observed between SSP and SAR of irrigation water.

Subramani *et al.* (2005) examined the groundwater quality in Tamil Nadu, India's Chithar River Basin. They observed a connection of 0.0159 between pH and EC, 0.8188 between EC and Na^{+}, and 0.9319 between SO_4^{-2} and Na^{+}.

In Moradabad, India, groundwater parameters were observed to be correlated by Navneet and Sinha (2010). They observed a connection of 0.900 between EC and pH, 0.885 between EC and Ca^{+2}, and 0.918 between EC and Cl.

Khan and Kumar (2012) conducted a correlation analysis on the ground water in Tamil Nadu, India's Tiruchengode taluka in the Namakkal district. They observed a link between EC and Ca^{+2} (R=0.920), EC and Chloride (R=0.969). The correlation coefficient's value ranges from -1 to +1.

Vaiyampatti Village's groundwater was researched by Khan *et al.* (2012) in the Tiruchirappalli District. The results showed that the range for all water quality measures were between 0.003 and 0.870 and that there was only a minor association between pH and chloride (r= -0.533).

Bhoopathi *et al.* (2014) studied groundwater quality in Nacharam area of Ranga reddy district, Andhra Pradesh. They found that the correlation between pH and EC is -0.01, EC and Ca^{+2} is -0.13, Na^{+} and K^{+} is 1.0.

Choudhary *et al.* (2016) reported the ground water quality in the part of central India and they concluded that the correlation between Cl^{-} and SO_4^{-2} is -0.01, K^{+} and Ca^{+2} is -0.05, Ca^{+2} and Mg^{+2} is 0.93.

CHAPTER - III

MATERIALS AND METHODS

The general features of north Saurashtra Agro climatic Zone region *viz,* geographic location, physiography, geology, climate, soil, vegetation and cropping pattern are described below.

3.1 GENERAL INFORMATION OF NORTH SAURASHTRA AGRO CLIMATIC ZONE

3.1.1 Geographic location

The north Saurashtra Agro climatic Zone region is a peninsular region in the northwest of Gujarat state located on the Arabian Sea coast, with a total area of 49,345.43 sq.km. It is located on the West Coast of India in Gujarat. It covers one-third of the state's geographical area comprising the southwestern part of the state with 7 districts and 48 talukas (Fig. 3.1).

3.1.2 Relief or physiography

The north Saurashtra Agro climatic Zone is traditionally known as part of *Kathiawar* peninsula. It lies on the west and is surrounded by the Arabian Sea on its three sides. This peninsula subdivided into three regions, namely, the Coastal Plain including the Island offshore, the Plains and the Hills on the basis of topography, climate, geology, soils and natural vegetation. Its central mass is an elevated highland with hills. The Girnar and Gir hills are most prominent. The land slopes gently down towards the coast from the central mass. A narrow strip of coastal plain surrounds the peninsula.

3.1.3 Geology

The geographical formation of north Saurashtra Agro climatic Zone region is of volcanic origin; hence the soils of north Saurashtra Agro climatic Zone with the excetion of a few strips are derived from trap basalt rock. However, the volcanic effusions and spread lava followed by denudation have resulted in the creation of a basaltic topography. The black cotton and medium black soils which are shallow and susceptible to erosion in the undulating areas in the interior of the areas due to rain. The soil along costal belt are however, deeper and plainer but to their lowness get inundated by the ingress of sea water.

3.1.4 Climate and rainfall

The north Saurashtra Agro climatic Zone has a tropical wet and dry climate with three different seasons, including a monsoon season from July to October, a hot summer from March to June and a mild winter from November to February. The region experiences harsh weather conditions, with temperatures ranging from 28 °C to 43 °C in the summer and 10 °C to 25 °C in the winter. The entire north Saurashtra Agro Climatic Zone region is prone to drought and dry land and the distribution of rainfall has been widely erratic and inconsistent. Rainfall in this area is caused by depressions and low pressure systems that form over the Bay of Bengal during the monsoon season and move from north to northwest. The monsoon usually commences by the middle of June and withdraws by the middle of September. About 10-15 per cent of the annual rainfall is received in June, nearly 40 per cent in July, 30 per cent in August and 10-20 per cent in September.

3.1.5 Soils

The following are the main soil types generally founds in north Saurashtra Agro climatic Zone.

- Medium black soils (Trap Basalt)
- Shallow black soils (Sandstone)
- Stony soils (Trap basalt)
- Coastal shallow soils
- Deep black soils (Trap basalt)
- Coastal deep soils
- Marine soil

The region of the north Saurashtra Agro climatic Zone has a variety of characteristics, including an uneven, rocky (basaltic) land surface that is crossed by mountain ranges and ridges and trap pean dykes. The majority of soils are made up of enormous, weathered Deccan trap rock, which is impermeable and yields little. The soils of the talukas of Bhavnagar, Amreli, Jamnagar, Dwarka and Morbi districts are located close to the Arbian Sea's coast, which causes the development of coastal alluvial soil, coastal deposit soil and soils with a medium to dark black colour.

3.1.6 Natural vegetation

Sr. No.	Common Name	Botanical Name
Trees and Shrubs		
1	Pipal	*Populous ciliate*
2	Neem	*Azadirechta indica*
3	Khijdo	*Prosopis cineraria*
4	Baval	*Acacia arabica*
5	Piludi	*Salvadora persica*
6	Akado	*Calotropis procera*
7	Aval	*Cassia auricuata*
8	Samadi	*Euphorbia nerifollia*
9	Kerda	*Capparis decidua*
10	Khakhro	*Butea momosperma*
11	Gorusambali	*Pithecellobium duica*
12	Mithosaragvo	*Moringa olefera*
13	Vad	*Ficus bengalem*
14	Kantadothor	*Euphorbia nivadia*
15	Saru	*Casuarinas equisetifolia*
16	Amaltas	*Cassia fistula*
17	Ber (chania)	*Zizyphusnummularia*
18	Desi baval	*Acacia nilotica*
19	Jipto	*Triumfetta rotundifolia*
20	Bordi	*Ziziphus rotandifolia*
21	Gandobaval	*Prosopis juliflora*
22	Su-babul	*Leucaena leucocephala*
23	Glyricidia	*Glyricidia maculate*
24	Sitaphal	*Anona squamosal*
25	Amla	*Emblica officinalis*
26	Bamboo	*Dendrocalamusstrictus*
27	Gulmohar	*Delonix regia*
28	Gunda	*Cordial myxa*
29	Citrus	*Citrus aurantifolia*

30	Aritha	*Sepindusmukorossi*
31	Ambli	*Tamarindus indica*
32	Karanj	*Pongamia pinnata*
33	Shatur	*Morus alba*
34	Sargvo	*Moringa oleifera*
35	Mango	*Mangifera indica*
36	Mangrove	*Rhizophora mangle*
37	Sugar apple	*Annona squamosa*
38	Bael	*Aegle marmelos*
39	Baheda	*Terminalia bellirica*
Grasses and Weeds		
1	Phulni	*Vernonincinaria*
2	Dharo	*Cynodondectylon*
3	Pardesibhangro	*Argemonmaxicana*
4	Barru	*Sorghum halphense*
5	Dhatura	*Datura stramonium*
6	Kala bhangro	*Eciyptaerecta*
7	Gokhru	*Tridex procumbens*
8	Hazar dana	*Phyllanthus niruri*
9	Dudheli	*Euphorbia macrophylla*
10	Chidho	*Cyprus rotandus*
11	Zinzavo	*Dicanthiumannulatum*
12	Amarbel	*Cuscutareflexa*
13	Darudi	*Argemonannulatum*
14	Gaderdi	*Xanthium strumarium*
15	Nori	*Ipomoea reptans*
16	Nagphani	*Opuntia dillenia*
17	Jangalijoot	*Corcorusfascicularis*
18	Baghnakhi	*Martyniadiandra*
19	Asthma plant	*Euphorbia hirta*
20	Khaki weed	*Alternanthera pungens*

3.1.7 Agriculture

The main field crops in the region of the north Saurashtra Agro climatic Zone are groundnut, cotton, wheat, bajra, castor, jowar, maize, sesame and cumin. The main fruit crops are mango, coconut, citrus, sapota, guava and ber and the main vegetable crops are onion, cucurbits, brinjal, okra, tomato and cluster beans. Oilseeds (groundnut, sesame and castor) made up 51.52 per cent of the total gross cropped area, while cotton (33.87 per cent) and other food grains came in second and third (19.47 per cent). Other important crops grown in the region are spices (2.14 per cent), fruits (mango 0.88 per cent and sapota 0.26 per cent) and vegetables (brinjal 0.63 per cent and okra 0.37 per cent).

3.1.8 Cropping pattern

The major field crops cultivated in *kharif* season are groundnut, cotton, jowar, pulses and castor while wheat, gram, onion and garlic are important *rabi* crops. Jowar is grown both as *rabi* and *kharif* crop. In bhal area *rabi* crop (durum wheat) is raised on conserved soil moisture. Major intercropping systems followed in the area are: groundnut+ castor (3:1), groundnut+ Pigeonpea (3:1), groundnut+ sesamum (6:3).

3.2 Collection of water samples

The ten underground water samples are collected from wells/bore wells of each 48 talukas of seven districts of north Saurashtra Agro climatic zone of Gujarat. Total 480 water samples were collected from 48 talukas during the summer season of year 2021.

Table 3.1: District wise talukas of north Saurashtra Agro climatic Zone

S. N.	Districts	Talukas (48)
1)	Rajkot (08)	Rajkot, Paddhari, Lodhika, Jam Kandona, Kotda-Sangani, Jasdan, Vinchhiya, Gondal
2)	Devbhoomi Dwarka (04)	Dwarka, Bhanvad, Kalyanpur, Jam-Khambhaliya
3)	Morbi (05)	Morbi, Tankara, Halvad (Zone V), Wankaner, Maliya-Miyana
4)	Surendranagar (10)	Surendranagar, Chuda, Chotila, Dhrangadhra, Lakhtar, Limbdi, Muli, Patli, Sayla and Thangadh
5)	Amreli (08)	Amreli, Babra, Dhari, Khambha, Kunkavav, Lathi, Lilia, Savarkundla
6)	Bhavnagar (07)	Bhavnagar, Gariadhar, Jesar, Palitana, Sihor, Umrala, Vallabhipur (Zone VIII).
7)	Jamnagar (06)	Jamnagar, Jam Jodhpur, Jodiya, Dhrol, Lalpur, Kalavad

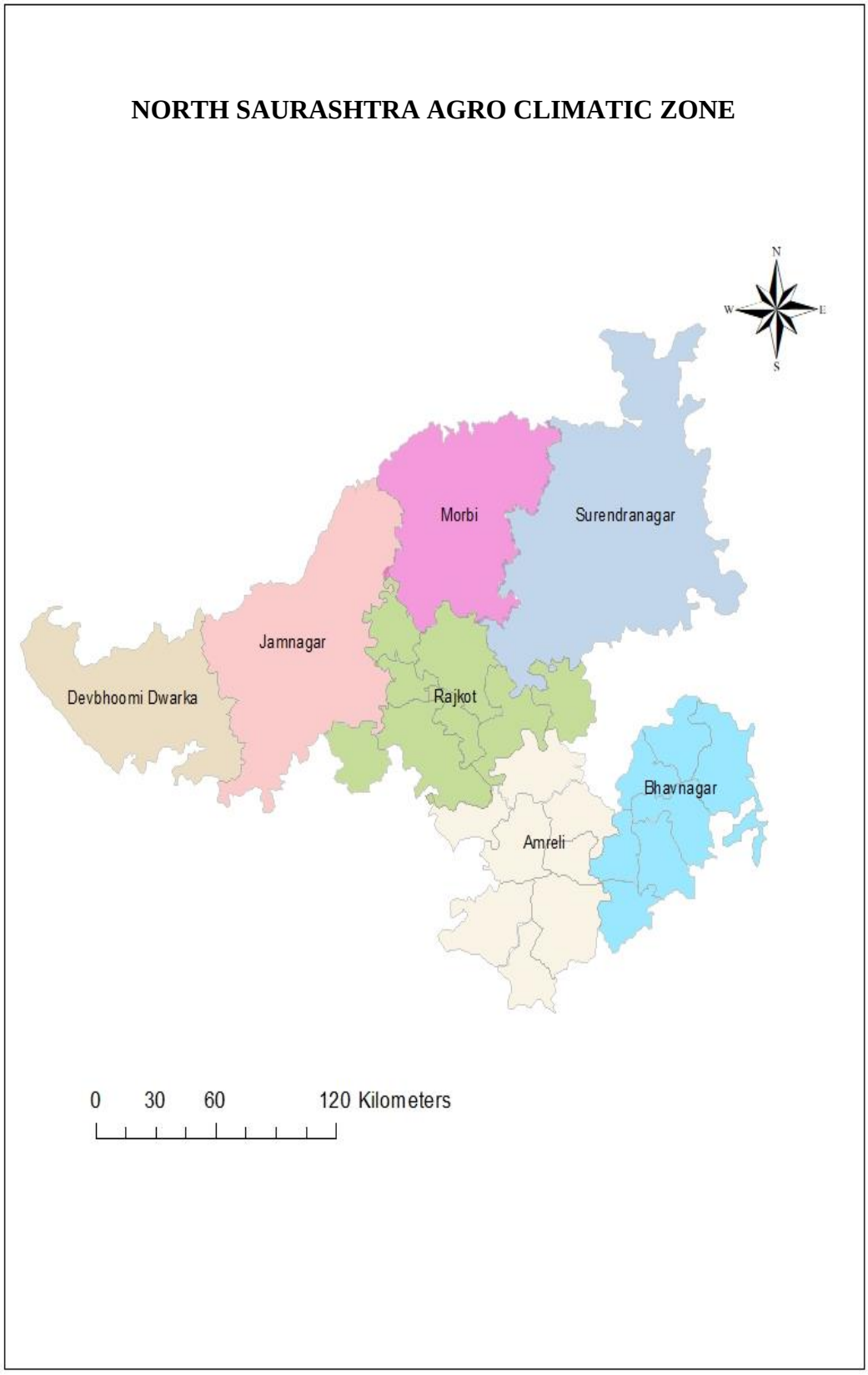

Fig 3.1: Map of north Saurashtra Agro climatic Zone in Gujarat state

3.2.1 PREPARATION OF WATER SAMPLES

Bore well/well is the potential source of irrigation water. The water samples were collected by using GPS and were analyzed for various quality parameters. The standard procedures were applied to analyze the samples for various quality parameters.

By using standard procedure (Richards, 1954) water samples were collected in clean plastic bottles of one liter capacity and tightly screwed and were brought to the laboratory for further analysis. Collected underground water samples were brought to the laboratory on same day and proper labeling was carried out on each sample as given below:

1. Name of the farmer and address
2. Source of water
3. Date of sampling

Collected water samples were stored in refrigerator and analysis was carried out on the next day. The standard methods of analysis as described by Jackson (1973) and Richards (1954) were employed throughout the investigation.

3.3 CHEMICAL ANALYSIS OF WATER SAMPLES

Table 3.2: Methods used for analysis of underground water

S.N.	Characteristics	Method	Reference
1	pH	pH meter	Richard (1954)
2	EC	Conductivity meter	Richard (1954)
3	CO_3^{-2} & HCO_3^-	Titration with sulphuric acid	Reitemeir (1943)
4	Cl^-	$AgNO_3$ precipitation method	Richards (1954)
5	SO_4^{-2}	Turbidimetric method	Chesnin and Yien (1950)
6	Na^+	Flame photometrically method	Richards (1954)
7	K^+	Flame photometrically method	Richards (1954)
8	Ca^{+2}	Versenate (EDTA) Titration method	Chang & Bray (1951)
9	Mg^{+2}	Versenate (EDTA) Titration method	Chang & Bray (1951)

3.3.1 Water pH

Water pH determined by glass electrode using pH meter (Richards, 1954).

3.3.2 Electrical conductivity (EC)

EC of water samples was measured by Conductivity meter (Elico CM Conductivity meter) having a predetermined cell constant and expressed in dS/m. The free ions in the water conduct electricity, so the water electrical conductivity depends on the concentration of ions.

3.3.3. Determination of water soluble cations in water samples

Sodium (Na^+)

It was determined by flame photometrically as per Richards (1954). The results are expressed in me/L.

Potassium (K^+)

Potassium content in irrigation water was determined by flame photometrically as per Richards (1954). The results are expressed in me/L.

Calcium (Ca^{+2})

Calcium in irrigation water was determined by using EDTA, sodium hydroxide, murexide and ammonium purpurate as indicator as described by Chang & Bray (1951). The results are expressed in me/L

Magnesium (Mg^{+2})

Magnesium in irrigation water was determined by using EDTA, ammonium hydroxide-ammonium chloride buffer and EBT as indicator as described by Chang & Bray (1951). The results are expressed in me/L.

3.3.4Determination of water soluble anions in water samples

Sulphate (SO_4^{-2})

Sulphate content in water samples was determined by the turbidimetric method using spectrophotometer at 420 nm wavelength as described by Chesnin and Yien (1950). The results are expressed in me/L.

Carbonate (CO_3^{-2})

Carbonate in irrigation water was determined by using standard sulphuric acid and phenophthalin as indicator as described by Reitemeir (1943). The results are expressed in me/L.

Bicarbonate (HCO_3^-)

Bicarbonate in irrigation water was determined by using standard sulphuric acid and methyl orange as indicator as described by Reitemeir (1943). The results are expressed in me/L.

Chloride (Cl^-)

Chloride in irrigation water was determined by using standard silver nitrate and potassium chromate as indicator as described by Richards (1954). The results are expressed in me/L.

The following water quality indices were calculated by standard formulas for categories purpose.

1. **Soluble Sodium Percentage (SSP)**

$$SSP = \frac{Na^+ + K^+}{Ca^{+2} + Mg^{+2} + Na^+ + K^+} x100$$

(Concentration of all cations are in me/L)

2. **Sodium Adsorption Ratio (SAR)**

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

(Concentration of all cations are in me/L)

3. **Residual Sodium Carbonate (RSC)**

$$RSC = (CO_3^{-2} + HCO_3^-) - (Ca^{+2} + Mg^{+2})$$

(All ionic concentrations are in me/L)

4. **Residual Sodium Bicarbonate (RSBC)**

$$RSBC = HCO_3^- - Ca^{+2}$$

(All ionic Concentrations are in me/L)

The following water quality cations and anions calculated by formulas for categories pupose.

1. **Na^+ (me/L)** $= \frac{Na^+ \text{ (ppm)}}{\text{Equivalent weight of } Na^+ (23)}$

2. **K^+ (me/L)** $= \frac{K^+ \text{ (ppm)}}{\text{Equivalent weight of } K^+ (39)}$

3. **Ca^{+2} (me/L)** $= \frac{\text{Reading (X)} * \text{Normality of EDTA (0.01)} * 1000}{\text{Aliquot taken (10 ml)}}$

Where, X = _____ ml of 0.01 N EDTA required for titration of Ca^{+2}

4. **Mg^{+2} (me/L)** = $\frac{\text{Reading (Y - X) * Normality of EDTA (0.01) * 1000}}{\text{Aliquot taken (10 ml)}}$

Where, Y = _____ ml of 0.01 N EDTA required for titration of Ca^{+2} + Mg^{+2}

(Y - X) = _____ ml of 0.01 N EDTA required for titration of Mg^{+2}

5. **CO_3^{-2} (me/L)** = $\frac{\text{Reading (2X) * Normality of } H_2SO_4 \text{ (0.01) * 1000}}{\text{Aliquot taken (10 ml)}}$

Where, X = _____ ml of 0.01 N H_2SO_4 required to neutralize half of the amount of CO_3^{-2} present in 10 ml of aliquot

6. **HCO_3^{-2} (me/L)** = $\frac{\text{Reading (Y - X) * Normality of } H_2SO_4 \text{ (0.01) * 1000}}{\text{Aliquot taken (10 ml)}}$

Where, Y = _____ ml of 0.01 N H_2SO_4 required to neutralize the remaining half amount of CO_3^{-2} and the whole amount of HCO_3^- present in 10 ml of aliquot

(Y - X) = _____ ml of 0.01 N H_2SO_4 required to neutralize HCO_3^- present in 10 ml of aliquot

7. **Cl^- (me/L)** = $\frac{\text{Reading (Z) * Normality of } AgNO_3 \text{ (0.02) * 1000}}{\text{Aliquot taken (10 ml)}}$

Where, Z = _____ ml of 0.02 N $AgNO_3$ required for titration of Cl^-

8. **SO_4^{-2} (me/L)** = $\frac{SO_4^{-2} \text{ (ppm) * Final volume (25 ml)}}{\text{Aliquot taken (5 ml) * Equivalent weight of } SO_4^{-2} \text{ (48.03)}}$

3.4 RATING USED FOR WATER QUALITY APPRAISAL

Table 3.3: Classification of irrigation water according to Electrical conductivity (Richard, 1954)

EC (dS/m)	Symbol	Salinity class
0 - 0.25	C_1	Low
0.25 - 0.75	C_2	Medium
0.75 - 2.25	C_3	High
2.25 - 5.00	C_4	Very high

Table 3.4: Classification of irrigation water according to Residual Sodium Carbonate (Eaton, 1950)

RSC (me/L) value	Class
< 1.25	Safe
1.25 - 2.50	Marginal
> 2.50	Unsafe

Table 3.5: Classification of irrigation water according to Sodium Adsorption Ratio (Richard, 1954)

SAR value	Symbol	Class
0 – 10	S_1	Low Na water
10 – 18	S_2	Medium Na water
18 – 26	S_3	High Na water
> 26	S_4	Very high Na water

Table3.6: Classification of irrigation water according to Soluble Sodium Percentage (Richard, 1954)

SSP	Class
< 60	Good
> 60	Fair

Table3.7: Classification of irrigation water according to Chloride (Schofield and Headley, 1936)

Chloride (me/L)	Class
0 – 4	Excellent
4 – 7	Good
7 – 12	Permissible
12 – 20	Doubtful
> 20	Unsafe

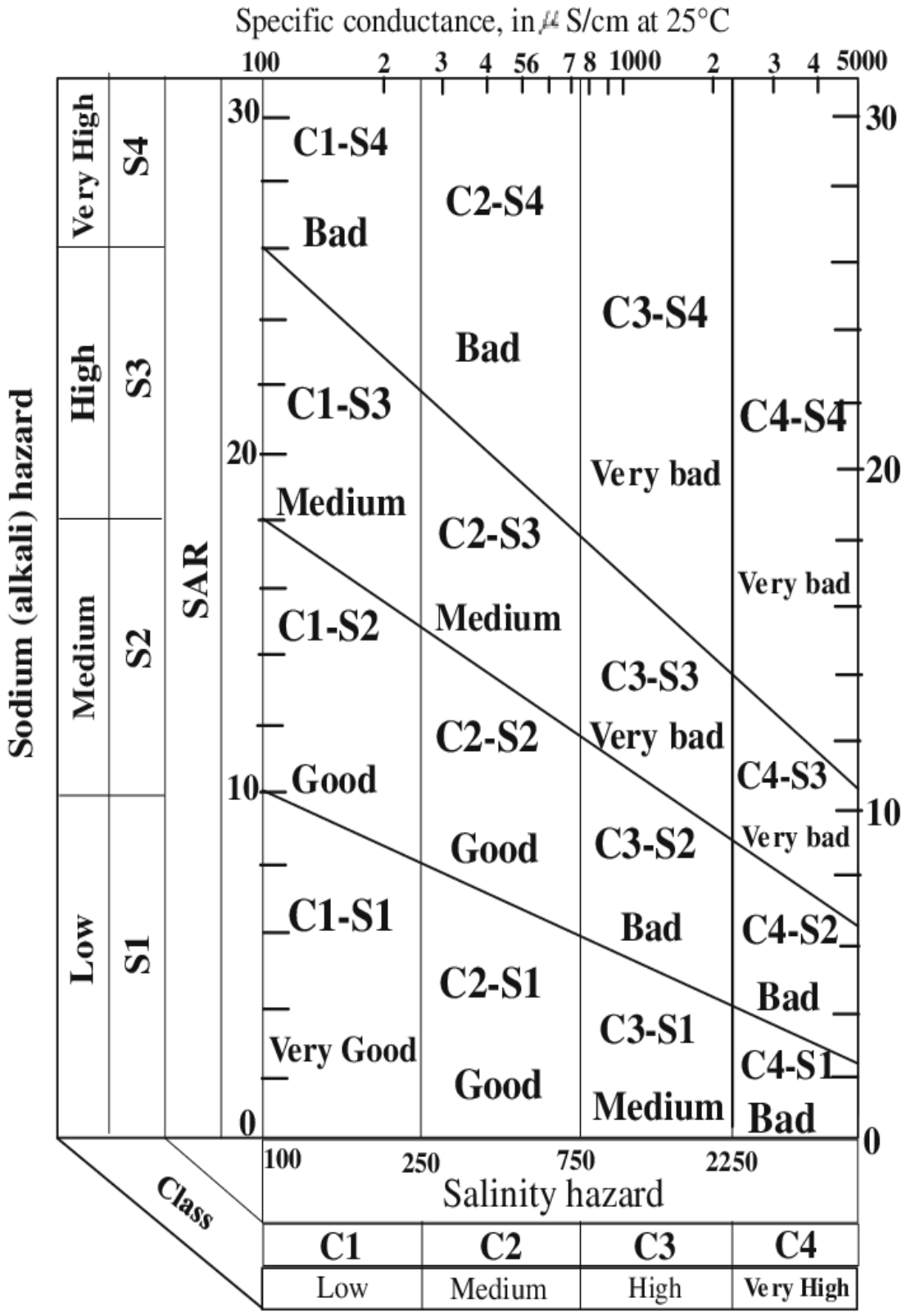

Fig. 3.2: Semi-logarithmic USSL diagram for classification of underground water (Richards, 1954)

3.5 STATISTICAL ANALYSIS:

The correlation between water quality parameters and soil properties were worked out as per the standard method given by Panse and Sukhatme (1967).

Also Correlation and Regression was calculated as described by Steel and Torrie (1980).

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CHAPTER - IV

RESULTS AND DISCUSSION

Our main goal is to assess the quality of underground water resources of north Saurashtra Agro climatic Zone. Total 480 samples of subsurface water were taken for this purpose from the farmer's field of north Saurashtra Agro climatic Zone farmer's fields. The information on the water samples taken from cultivated areas of several districts of the north Saurashtra Agro climatic Zone using tube wells or underground wells.

The following subheads are where the investigation's results are listed

4.1 QUALITY OF UNDERGROUND WATER

4.1.1 pH

4.1.2 Soluble cations

4.1.3 Soluble anions

4.2 SALINITY AND SODICITY INDICES OF UNDERGROUND WATER

4.2.1 Electrical conductivity (EC)

4.2.2 Soluble sodium percentage (SSP)

4.2.3 Sodium absorption ratio (SAR)

4.2.4 Residual sodium carbonate (RSC)

4.2.5 Residual sodium bicarbonate (RSBC)

4.2.6 Evaluation of underground water quality

4.3 INTERRETIAONSHIP BETWEEN PROPERTIES OF UNDERGROUND WATER

4.1 QUALITY OF UNDERGROUND WATER

Total 480 underground well/tube well water samples, 10 from each taluka, were taken from the fields in order to present a water quality assessment. Samples of irrigation water were examined for pH, cations (Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}) and anions (CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2}) an assessment of the water quality was made using the EC and SAR values recommended by the USDA. Table 4.9 to 4.24 provide the distribution of water sample cations and anions for each taluka, while the range and

mean values for EC, pH, RSC, RSBC, SSP and SAR are provided in Table from 4.1 to 4.8.

4.1.1 pH

The north Saurashtra Agro climatic Zone's waterways were generally alkaline. The pH range of the water at north Saurashtra was 6.62 to 8.96, with a mean value of 7.75 (Table 4.8). The findings (Table 4.1 to 4.7) showed that the samples of Thangadh taluka in Surendranagar district had the lowest mean pH value (7.14) while the samples of Lilia taluka in Amreli district had the highest mean pH value (8.33).

The water sample of Rajkot district recorded a high pH of 8.96 and a low pH of 6.62. While the entire mean value of pH was 7.49 and among all taluka of Rajkot district highest mean observed in Lodhika (7.94). The Maximum pH (8.74) and minimum pH (6.79) were both discovered in the Jamnagar district. While all taluka of Jamnagar highest mean reported in Jodiya (7.73) and average pH across all samples was 7.52. The highest pH (8.70) and minimum pH (7.70) were both discovered in the all over Devbhoomi Dwarka district. While the entire mean pH value was 8.23. The highest mean among all talukas observed in Bhanvad (8.32).

In Morbi district out of all talukas the highest pH value mean observed in Tankara (8.21). The maximum pH (8.72) and the minimum pH (6.90) were both discovered in the Morbi district. While the entire mean pH value was 7.97. The maximum pH (8.96) and minimum pH (6.84) were observed in the Surendranagar district. While the entire mean pH value was 7.65 and highest mean 8.29 observed in Lakhtar taluka of Surendranagar district. The greatest pH (8.70) and the minimum pH (6.71) were both observed in the Amreli district and highest mean value of pH 8.33 was observed in Lilia taluka of Amreli, while overall mean pH was 7.71. The maximum pH (8.54) and minimum pH (6.70) were both found in the Bhavnagar district. While the entire mean pH value was observed 8.00. Jesar taluka observed highest mean value (8.30) of Bhavnagar district.

Similar findings were also reported by Kabariya (2004) for the Gujarat district of Amreli, by Verma *et al*. (2003) for the Charu district (Rajasthan), by Hadiyal (2005) for the Porbandar district, by Sojitra (2010) for the Junagadh district and by Rajput and Polara for the Bhavnagar area (2013).

Table 4.1: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Rajkot district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Rajkot	7.22-8.11	0.79-1.66	36.54-57.51	0.70-1.63	0.00-1.81	0.94-4.11
	7.61	1.30	47.75	1.08	0.25	2.09
Paddhari	7.30-7.76	1.71-4.08	41.85-64.17	0.99-3.17	0.00-0.80	1.85-4.92
	7.49	2.20	54.07	1.73	0.09	3.06
Lodhika	7.53-8.96	0.89-1.95	55.84-60.83	1.11-1.92	0.00-0.22	1.22-1.97
	7.94	1.43	50.48	1.31	0.01	1.91
Jam Kandorna	7.01-7.81	0.79-2.07	45.74-76.40	0.76-2.52	0.00-0.90	0.99-2.50
	7.36	1.22	58.28	1.53	0.27	1.81
Kotda Sangani	7.03-8.23	0.76-2.44	42.89-67.94	0.82-2.25	0.01-0.30	0.99-3.54
	7.40	1.51	56.68	1.56	0.11	2.31
Jasdan	7.12-7.90	1.15-2.25	32.39-63.21	0.62-2.31	0.00-0.08	1.60-4.10
	7.45	1.59	52.92	1.47	0.01	2.61
Vinchhiya	7.09-7.90	0.82-2.90	46.01-72.06	0.89-2.45	0.01-1.09	1.10-5.00
	7.34	1.64	57.31	1.64	0.21	2.43
Gondal	6.62-7.68	0.96-4.45	48.06-70.59	0.91-3.40	0.00-0.58	0.40-6.60
	7.34	2.38	58.05	1.92	0.15	3.28
Overall	6.62-8.96	0.76-4.45	32.39-76.40	0.62-3.40	0.00-1.81	0.40-6.60
	7.49	1.66	54.60	1.52	0.14	2.46

Table 4.2: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Jamnagar district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Jamnagar	6.79-7.71	1.11-4.25	53.12-87.54	1.19-7.23	0.06-0.56	1.10-5.10
	7.39	2.45	70.80	3.68	0.24	2.10
Jam-Jodhpur	6.98-7.94	0.86-5.20	43.18-90.89	0.85-10.56	0.00-0.90	0.20-3.30
	7.54	1.83	62.23	2.76	0.28	2.01
Jodiya	7.48-8.01	1.18-3.96	63.99-88.19	1.73-7.48	0.00-0.87	1.33-5.20
	7.73	2.81	79.71	5.05	0.36	2.40
Dhrol	7.09-8.74	0.75-4.72	50.75-83.39	0.90-7.00	0.00-0.70	0.60-3.20
	7.61	1.94	62.43	2.41	0.23	1.95
Lalpur	6.89-8.02	0.66-4.22	34.69-88.92	0.62-8.60	0.00-0.10	0.90-3.90
	7.47	1.42	58.20	2.10	0.22	1.94
Kalavad	7.15-7.66	0.95-3.87	44.51-89.55	0.89-8.57	0.00-1.41	0.90-3.25
	7.40	1.64	61.87	2.35	0.33	1.82
Overall	6.79-8.74	0.66-5.20	34.69-90.89	0.62-10.56	0.00-1.41	0.20-5.20
	7.52	2.01	65.87	3.06	0.28	2.04

Table 4.3: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Devbhoomi Dwarka district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Dwarka	7.90-8.40	0.63-4.05	58.43-87.13	1.11-7.38	0.00-0.11	1.69-1.02
	8.20	2.21	78.18	4.25	0.02	1.23
Bhanvad	8.14-8.47	0.87-1.69	55.86-75.44	1.12-2.92	0.00-0.03	0.86-1.55
	8.32	1.21	69.59	2.07	0.01	1.12
Kalyanpur	7.70-8.70	3.11-5.12	85..16-88.21	6.58-8.22	0.00-0.02	1.07-2.27
	8.13	3.94	86.98	7.31	0.01	1.70
Jam-Khambhaliya	8.00-8.40	0.74-1.52	60.41-73.19	1.25-2.33	0.00-0.46	0.66-1.41
	8.26	1.05	67.72	1.79	0.05	1.10
Overall	7.70-8.70	0.63-5.12	55.86-88.21	1.11-8.22	0.00-0.46	0.66-2.27
	8.23	2.10	75.62	3.85	0.02	1.29

Table 4.4: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Morbi district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Morbi	7.00-8.48	1.05-3.23	57.29-85.09	1.24-5.68	0.00-0.20	1.05-2.03
	8.01	2.64	80.34	4.67	0.02	1.38
Tankara	7.91-8.72	1.42-2.01	75.88-83.11	2.88-4.30	0.00-0.02	0.77-1.36
	8.21	1.76	78.65	3.38	0.01	1.11
Halvad	7.23-8.33	1.31-3.02	78.11-85.68	3.01-5.42	0.00-0.62	0.87-1.83
	7.88	2.03	81.29	4.05	0.07	1.24
Wankaner	6.90-7.80	1.77-3.16	78.55-86.16	3.22-6.04	0.00-0.02	1.27-1.55
	7.54	2.61	82.91	4.96	0.01	1.39
Maliya-Miyana	7.37-8.60	1.01-3.21	72.50-84.89	2.01-5.53	0.00-0.14	1.02-2.09
	8.20	2.33	79.73	4.18	0.03	1.38
Overall	6.90-8.72	1.01-3.23	57.29-86.16	1.24-6.04	0.00-0.62	0.77-2.09
	7.97	2.27	80.58	4.25	0.03	1.30

Table 4.5: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Surendranagar district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Surendra-nagar	7.86-8.63	1.04-2.05	72.27-83.13	2.34-4.13	0.00-0.10	0.85-1.73
	8.25	1.46	77.79	3.03	0.02	1.22
Chuda	6.91-8.60	0.68-3.67	56.76-83.62	1.02-6.09	0.00-1.10	1.02-3.55
	7.74	1.82	69.94	2.86	0.13	1.65
Chotila	6.96-7.68	0.65-6.54	58.73-86.14	1.02-6.74	0.00-0.10	1.05-2.85
	7.26	2.82	79.80	4.81	0.03	1.85
Dhrangadhra	7.66-8.78	0.83-3.87	54.93-88.82	1.23-8.06	0.00-0.20	1.06-2.48
	8.04	2.64	76.47	4.70	0.04	1.80
Lakhtar	7.93-8.57	1.05-1.82	66.88-80.41	1.90-3.70	0.00-0.91	1.03-1.77
	8.29	1.46	75.03	2.78	0.10	1.38
Limbdi	6.93-8.00	0.65-2.81	49.04-85.11	0.78-5.56	0.00-0.02	0.78-2.75
	7.49	2.01	73.26	3.54	0.00	1.54
Muli	7.14-7.95	1.11-3.54	57.13-84.73	1.36-6.02	0.00-0.78	1.28-2.89
	7.34	2.47	78.70	4.33	0.15	2.02
Sayla	7.14-7.95	1.11-3.14	59.39-80.12	1.39-4.78	0.00-0.04	1.13-2.66
	7.34	2.39	76.06	3.76	0.01	2.01
Thangadh	6.84-7.43	0.76-4.61	58.53-86.90	1.14-7.59	0.00-0.18	1.06-2.65
	7.14	2.53	80.44	4.74	0.03	1.63
Patli	7.08-8.96	0.59-2.81	60.32-90.78	1.17-7.83	0.00-0.22	0.78-2.16
	7.65	1.64	74.41	3.39	0.03	1.31
Overall	6.84-8.96	0.59-6.54	49.04-90.78	0.78-8.06	0.00-1.10	0.78-3.55
	7.65	2.12	76.16	3.79	0.05	1.64

Table 4.6: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Amreli district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Amreli	6.71-8.03	0.90-5.10	41.82-90.79	0.72-10.55	0.00-0.64	1.07-4.35
	7.37	3.03	76.10	5.21	0.13	2.41
Babra	7.05-7.72	0.93-3.28	61.23-78.81	1.44-4.72	0.00-0.16	0.51-2.05
	7.36	1.51	69.19	2.31	0.03	1.19
Dhari	7.09-8.10	0.99-2.48	54.59-81.43	1.18-4.19	0.00-0.13	1.02-2.12
	7.46	1.52	68.28	2.18	0.02	1.38
Khambha	7.90-8.33	0.78-1.47	62.66-73.07	1.43-2.37	0.00-0.14	0.97-1.24
	8.05	1.07	67.73	1.76	0.02	1.07
Kunkavav	7.13-7.68	1.31-3.97	58.37-85.85	1.54-6.00	0.00-0.50	1.13-2.11
	7.41	2.29	74.50	3.72	0.11	1.60
Lathi	6.98-8.00	1.13-4.31	60.51-90.74	1.51-9.50	0.00-0.10	1.02-2.32
	7.38	2.27	74.66	3.82	0.02	1.63
Lilia	7.90-8.70	1.32-2.89	54.99-80.47	1.27-3.98	0.00-0.02	1.50-2.47
	8.33	2.45	74.80	3.55	0.01	2.02
Savarkundla	7.90-8.70	0.94-3.54	51.88-79.79	1.24-4.87	0.00-0.05	1.22-3.55
	8.28	2.03	65.20	2.64	0.02	2.05
Overall	6.71-8.70	0.78-5.10	41.82-90.79	0.72-10.55	0.00-0.64	0.51-4.35
	7.71	2.02	71.15	3.15	0.04	1.67

Table 4.7: Taluka wise range and mean value of pH, EC and different indices of underground water samples of Bhavnagar district in north Saurashtra Agro climatic Zone

Name of taluka	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Bhavnagar	7.70-8.10	1.20-3.58	71.26-80.17	2.14-5.32	0.08-1.85	1.04-3.95
	7.96	2.44	74.98	3.48	0.75	2.78
Gariadhar	6.70-8.20	1.19-3.70	58.58-81.68	1.45-5.60	0.00-1.87	1.20-3.80
	7.60	2.12	70.39	3.01	0.55	2.61
Jesar	8.00-8.50	0.86-1.63	50.07-70.84	0.94-2.51	0.01-0.42	1.30-2.10
	8.30	1.15	62.26	1.63	0.15	1.58
Palitana	7.75-8.54	0.91-2.47	44.62-89.09	1.30-4.96	0.02-1.07	0.74-4.71
	8.18	1.59	67.92	2.50	0.56	2.05
Sihor	7.50-8.10	0.76-3.20	48.53-78.45	0.83-4.54	0.03-1.04	1.27-4.07
	7.92	1.74	64..28	2.30	0.41	2.33
Umrala	7.48-8.34	0.76-3.78	47.72-78.56	0.83-5.09	0.01-0.79	1.09-4.52
	8.01	1.51	57.40	1.76	0.24	2.22
Vallabhipur	7.73-8.16	0.95-2.10	63.82-81.54	1.54-4.08	0.01-1.89	1.06-4.30
	8.04	1.79	74.33	3.09	0.71	2.27
Overall	6.70-8.54	0.76-3.78	44.62-89.09	0.83-5.60	0.00-1.89	0.74-4.71
	8.00	1.76	67.34	2.54	0.48	2.26

Table 4.8: District wise range and mean value of pH, EC and different indices of underground water samples in north Saurashtra Agro climatic Zone

Name of district	pH	EC (dS/m)	SSP (%)	SAR	RSC (me/L)	RSBC (me/L)
Rajkot	6.62-8.96	0.76-4.45	32.39-76.40	0.62-3.40	0.00-1.81	0.40-6.60
	7.49	1.66	54.60	1.52	0.14	2.46
Jamnagar	6.79-8.74	0.66-5.20	34.69-90.89	0.62-10.56	0.00-1.41	0.20-5.20
	7.52	2.01	65.87	3.06	0.28	2.04
Devbhoomi-Dwarka	7.70-8.70	0.63-5.12	55.86-88.21	1.11-8.22	0.00-0.46	0.66-2.20
	8.23	2.10	75.62	3.85	0.02	1.29
Morbi	6.90-8.72	1.01-3.23	57.29-86.16	1.24-6.04	0.00-0.62	0.77-2.09
	7.97	2.27	80.58	4.25	0.03	1.30
Surendra nagar	6.84-8.96	0.59-6.54	49.04-90.78	0.78-8.06	0.00-0.10	0.78-3.55
	7.65	2.12	76.16	3.79	0.05	1.64
Amreli	6.71-8.70	0.78-5.10	41.82-90.79	0.7210.55	0.00-0.64	0.51-4.35
	7.71	2.02	71.15	3.15	0.04	1.67
Bhavnagar	6.70-8.54	0.76-3.78	44.62-89.09	0.83-5.60	0.00-1.89	0.74-4.71
	8.00	1.76	67.34	2.54	0.48	2.26
Overall	6.62-8.96	0.59-5.20	32.39-90.89	0.62-10.56	0.00-1.89	0.20-6.60
	7.75	1.98	69.57	3.09	0.15	1.86

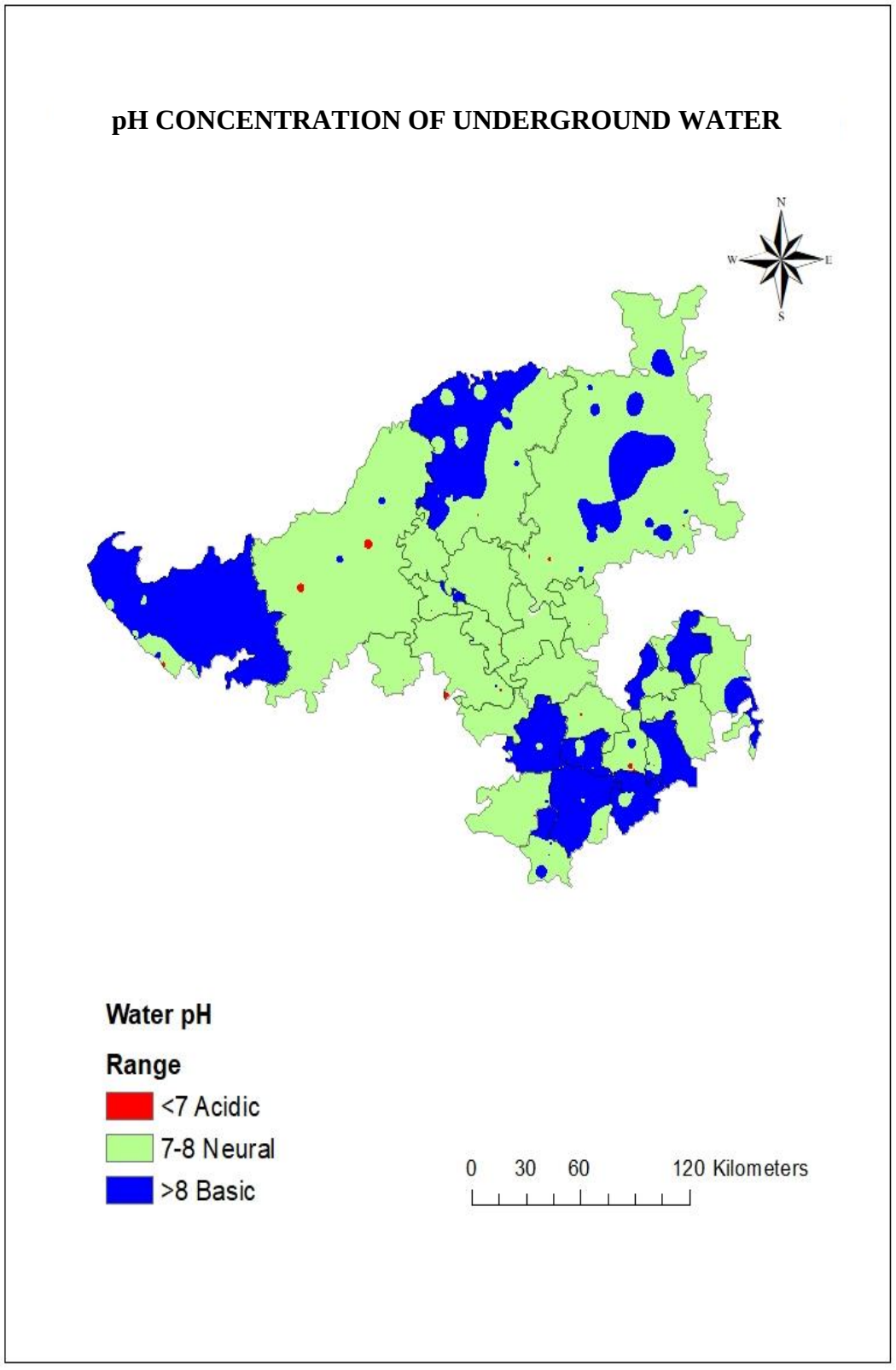

Fig 4.1: pH concentration of underground water in north Saurashtra Agro climatic Zone

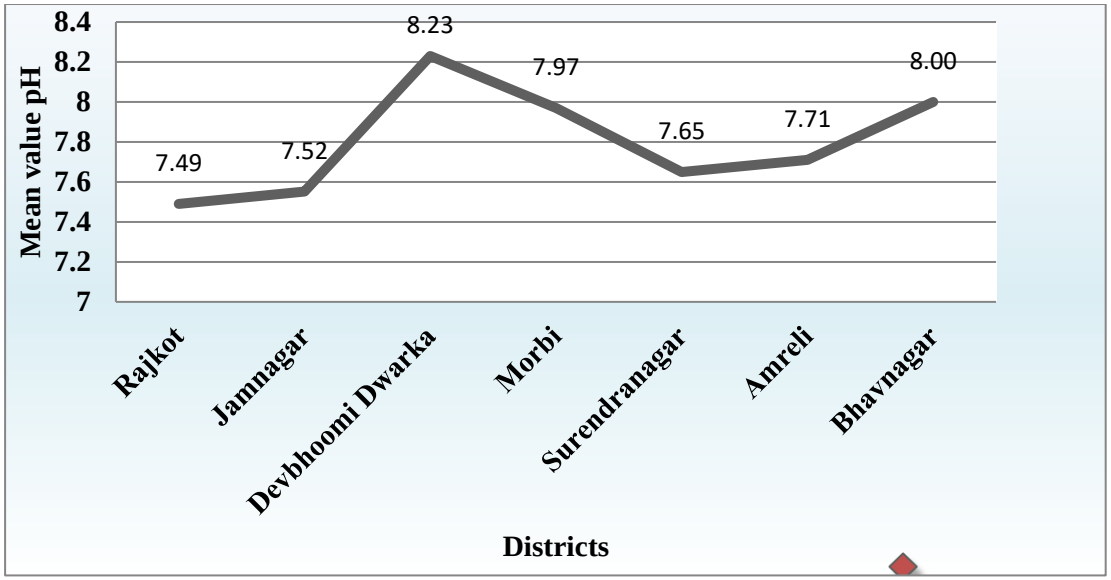

Fig. 4.2: District wise distribution of pH on mean value basis in north Saurashtra Agro climatic Zone

4.1.2 Cations concentration in underground water samples

4.1.2.1 Na^+

The range of the Na^+ value for the water samples from the north Saurashtra Agro climatic Zone (Table 4.16) was 2.08 to 45.30 me/L, with a mean value of 13.15 me/L. The data (Table 4.9 to 4.15) showed that the samples from Rajkot taluka of Rajkot district had the lowest mean value of Na^+ (5.10 me/L) and the samples from Kalyanpur taluka of the Devbhoomi Dwarka district had the highest mean value of Na^+ (32.06 me/L).

Na+ levels varied from the lowest observed value of 2.70 me/L in Rajkot district to the highest recorded value of 26.00 me/L. with a mean value of 7.71 me/L and among all talukas of Rajkot district highest mean value of Na^+ is found in Gondal taluka (11.33 me/L). The largest Na^+ (45.30 me/L) and the lowest Na^+ (2.08 me/L) were found in the Jamnagar district, with the total mean value of Na^+ being 13.60 me/L and highest mean value 22.16 me/L observed in Jodiya taluka in Jamnagar district. The maximum Na^+ value in the Devbhoomi Dwarka district was 41.54 me/L, the lowest Na^+ value was 3.50 me/L and the mean Na^+ value was 15.49 me/L and the highest mean value observed in Kalyanpur (32.06 me/L).

The Na^+ values ranged from 4.56 me/L to 24.75 me/L were observed in the Morbi district and highest Na^+ mean value (19.84 me/L) in Wankaner taluka of Morbi district.

The maximum Na^+ (39.18 me/L) and the minimum Na^+ (2.54 me/L) values were observed in the Surendranagar district with a mean value of 15.66 me/L while the highest mean value of Na^+ was (21.44 me/L) observed in Chotila taluka of Surendranagar. The largest Na^+ (45.25 me/L) and lowest Na^+ (2.88 me/L) values were observed in the Amreli district and average value of Na^+ was 13.39 me/L. The highest mean value of Na^+ (23.12 me/L) was observed in Amreli taluka of Amreli district. The largest Na^+ (29.00 me/L) and lowest Na^+ (2.95 me/L) values were recorded in the Bhavnagar district, where the total mean value of Na^+ was 11.26 me/L and among all talukas of Bhavnagar district highest mean value (16.93 me/L) was observed in Bhavnagar taluka.

The majority of the area under investigation contains a high percentage of Na^+, which suggests that the alkalinity concerns could be dangerous. Similar results were also found in the Porbandar district by Hadiyal (2005), Junagadh district by Sojitra (2010), Bhavnagar district by Rajput and Polara (2013).

4.1.2.2 K^+

The overall K^+ values of the water samples from north Saurashtra Agro climatic Zone were between 0.00 and 0.60 me/L, with a mean value of 0.04 me/L (Table 4.16). The findings (Table 4.9 to 4.15) showed that the samples from Maliya -Miyana taluka in Morbi district had the lowest mean value of K^+ (0.00 me/L) and the samples from Bhavnagar taluka in Bhavnagar district had the highest mean value of K^+ (0.26 me/L).

The Rajkot district observed the highest K^+ value (0.60 me/L) and the lowest K^+ value (0.00 me/L). While the greatest mean value was found in Gondal (0.12 me/L), the total mean value of K^+ was 0.04 me/L. The K^+ was found in the Jamnagar district with a mean value of 0.04 me/L overall, a maximum value of 0.40 me/L and a minimum value of 0.00 me/L. The maximum K^+ value in the Devbhumi Dwarka district was 0.24 me/L, the lowest K^+ value was 0.00 me/L and the average K^+ value was 0.02 me/L.

The K^+ was observed in the district of Morbi with a mean value of 0.01 me/L overall, a maximum value of 0.11 me/L and a minimum value of 0.00 me/L. The Surendranagar district had an average K^+ value of 0.02 me/L, a maximum K^+ value of 0.21 me/L and a minimum K^+ value of 0.00 me/L. The average K^+ value in the Amreli district was 0.06 me/L, the highest K^+ value was 0.30 me/L and the lowest K^+ value was 0.00 me/L. The K^+ was found in the Bhavnagar district with a mean value of 0.10 me/L and a maximum value of 0.60 me/L and minimum value of 0.00 me/L.

Similar findings were also discovered in the Churu district of Rajasthan by Verma *et al*. (2003), the Porbandar district by Hadiyal (2005), the Junagadh district by Sojitra (2010), the Bhavnagar district by Rajput and Polara (2013), the Latur district of Maharashtra by Patil *et al*. (2014).

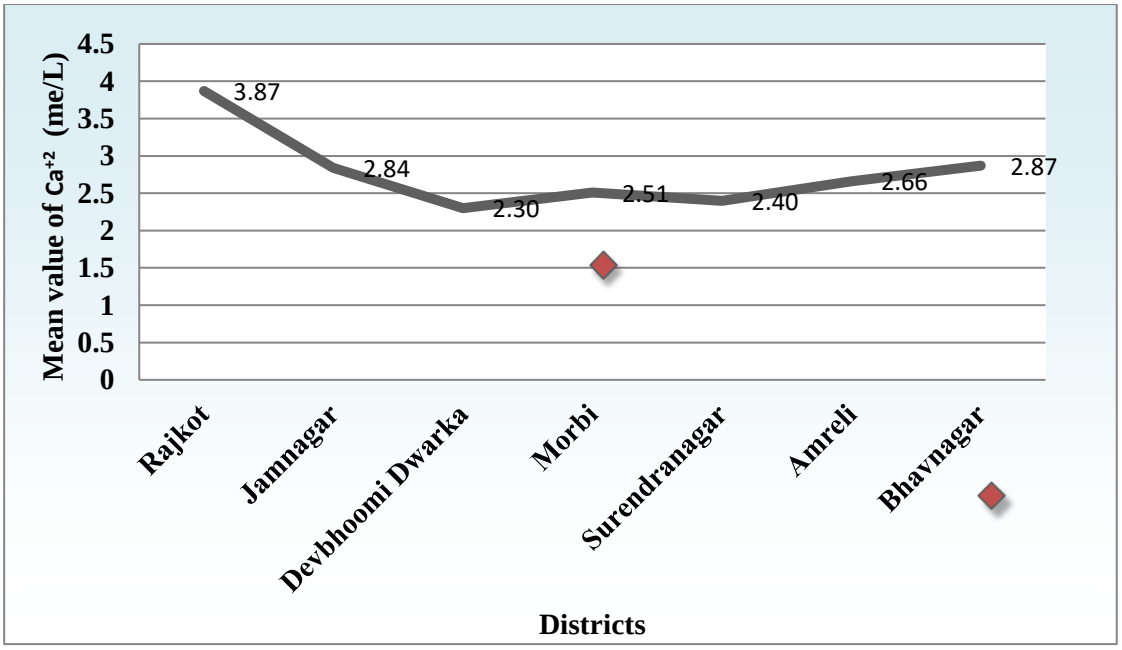

Fig. 4.3: District wise distribution of Ca^{+2} (me/L) on mean value basis in north Saurashtra Agro climatic Zone

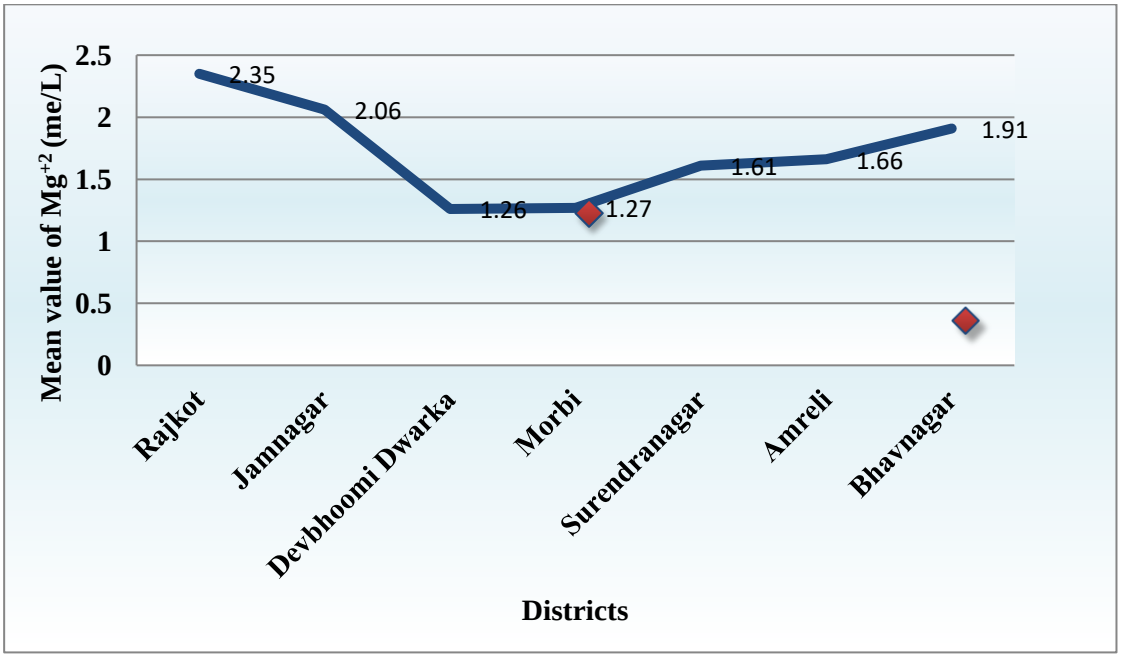

Fig. 4.4: District wise distribution of Mg^{+2} (me/L) on mean value basis in north Saurashtra Agro climatic Zone

Table 4.9: Taluka wise range and mean value of cations of underground water samples of Rajkot district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Rajkot	2.70-7.85	0.00-0.07	1.90-4.90	0.60-2.31
	5.10	0.03	3.68	1.84
Paddhari	5.45-22.50	0.01-0.07	2.90-8.50	1.80-4.90
	10.09	0.03	5.37	2.97
Lodhika	3.90-9.54	0.00-0.05	1.23-5.20	1.20-3.50
	6.09	0.03	3.55	2.13
Jam Kandorna	2.85-12.00	0.01-0.10	1.50-3.70	0.90-2.40
	6.15	0.05	2.57	1.61
Kotda Sangani	3.65-12.90	0.02-0.07	1.11-6.50	0.90-3.24
	7.51	0.04	3.32	2.20
Jasdan	3.20-12.50	0.01-0.04	2.30-4.90	1.60-4.10
	7.36	0.02	3.54	2.60
Vinchhiya	3.74-15.54	0.01-0.08	1.50-6.80	0.90-4.80
	8.05	0.03	3.74	2.22
Gondal	4.05-26.00	0.02-0.60	1.60-12.80	1.20-6.30
	11.33	0.12	5.22	3.22
Overall	2.70-26.00	0.00-0.60	1.11-12.80	0.60-6.30
	7.71	0.04	3.87	2.35

Table 4.10: Taluka wise range and mean value of cations of underground water samples of Jamnagar district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Jamnagar	5.00-36.00	0.00-0.15	2.00-4.70	0.90-5.00
	17.18	0.04	3.34	2.27
Jam Jodhpur	3.59-45.30	0.00-1.90	1.40-4.50	0.80-2.70
	11.91	0.24	2.55	1.96
Jodiya	6.76-34.16	0.01-0.40	1.30-4.87	0.60-5.70
	22.16	0.07	2.64	2.17
Dhrol	3.08-39.00	0.00-0.10	1.60-6.30	1.20-4.27
	12.11	0.03	3.27	2.30
Lalpur	2.08-36.87	0.00-0.14	1.40-4.30	0.30-3.80
	8.47	0.05	2.37	1.72
Kalavad	4.00-34.26	0.00-0.10	1.70-5.70	0.50-2.80
	9.78	0.02	2.87	1.95
Overall	2.08-45.30	0.00-0.40	1.30-6.30	0.30-5.70
	13.60	0.04	2.84	2.06

Table 4.11: Taluka wise range and mean value of cations of underground water samples of Devbhoomi Dwarka district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Dwarka	3.50-32.45	0.00-0.02	1.25-3.15	0.95-1.69
	16.50	0.01	2.25	1.21
Bhanvad	4.00-11.12	0.00-0.24	1.01-2.65	0.85-1.54
	7.32	0.04	2.01	1.11
Kalyanpur	25.64-41.54	0.00-0.06	2.54-4.21	1.06-2.25
	32.06	0.02	3.14	1.69
Jam Khambhaliya	4.05-9.35	0.00-0.04	1.02-2.78	0.65-1.24
	6.10	0.01	1.81	1.04
Overall	3.50-41.54	0.00-0.24	1.01-4.21	0.65-2.25
	15.49	0.02	2.30	1.26

Table 4.12: Taluka wise range and mean value of cations of underground water samples of Morbi district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Morbi	4.56-24.56	0.00-0.08	1.68-3.68	1.10-2.03
	19.50	0.01	2.90	1.36
Tankara	10.31-15.04	0.00-0.02	1.54-2.65	0.75-1.35
	12.25	0.01	2.20	1.11
Halvad	9.06-22.15	0.00-0.11	1.42-3.06	0.84-1.65
	14.96	0.03	2.21	1.17
Wankaner	12.05-24.45	0.00-0.03	2.04-3.21	1.08-1.65
	19.84	0.01	2.59	1.38
Maliya-Miyana	6.05-24.75	0.00-0.01	1.21-3.25	1.01-2.01
	16.97	0.00	2.63	1.35
Overall	4.56-24.75	0.00-0.11	1.21-3.68	0.75-2.0.3
	16.71	0.01	2.51	1.27

Table 4.13: Taluka wise range and mean value of cations of underground water samples of Surendranagar district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Surendranagar	7.12-14.75	0.00-0.02	1.05-2.45	0.84-1.72
	10.35	0.01	1.72	1.20
Chuda	3.15-29.08	0.00-0.04	1.24-3.65	1.01-2.45
	12.39	0.02	2.51	1.52
Chotila	3.09-29.25	0.01-0.21	1.03-3.65	1.05-2.75
	21.44	0.06	2.97	1.82
Dhrangadhra	4.18-32.72	0.00-0.04	1.82-3.67	1.05-2.46
	20.28	0.02	2.80	1.76
Lakhtar	6.45-13.41	0.00-0.02	1.12-2.45	0.85-1.75
	9.95	0.01	1.98	1.28
Limbdi	2.54-21.65	0.00-0.10	1.45-3.12	0.76-2.75
	14.22	0.02	2.32	1.53
Muli	5.56-28.45	0.00-0.12	1.45-3.65	1.28-2.85
	18.73	0.04	2.54	2.03
Sayla	5.28-23.45	0.00-0.02	2.23-3.56	1.12-2.65
	17.01	0.01	2.93	2.00
Thangadh	3.75-39.18	0.00-0.16	1.23-3.65	1.05-3.01
	19.91	0.05	2.36	1.73
Patli	3.16-24.92	0.00-0.01	1.05-3.05	0.76-2.15
	12.37	0.01	1.84	1.28
Overall	2.54-39.18	0.00-0.21	1.03-3.67	0.76-3.01
	15.66	0.02	2.40	1.61

Table 4.14: Taluka wise range and mean value of cations of underground water samples of Amreli district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Amreli	2.88-45.25	0.00-0.30	1.10-4.85	1.30-5.34
	23.12	0.06	2.34	2.45
Babra	5.10-24.01	0.00-0.08	1.72-4.56	0.50-1.95
	9.34	0.04	2.52	1.26
Dhari	4.65-16.58	0.00-0.19	1.60-3.70	1.02-2.12
	8.69	0.04	2.65	1.36
Khambha	4.01-8.45	0.00-0.18	1.06-2.65	0.89-1.23
	5.90	0.05	1.74	1.05
Kunkavav	6.80-28.95	0.00-0.18	2.35-4.20	1.08-2.10
	15.48	0.04	2.89	1.49
Lathi	5.70-37.05	0.00-0.21	2.21-3.23	1.02-2.32
	15.60	0.07	2.73	1.62
Lilia	5.32-18.87	0.00-0.26	2.41-3.54	1.50-2.45
	16.13	0.07	3.13	2.01
Savarkundla	4.65-24.01	0.00-0.28	2.01-4.32	1.21-3.50
	12.63	0.09	3.26	2.03
Overall	2.88-45.25	0.00-0.30	1.06-4.85	0.50-5.34
	13.39	0.06	2.66	1.66

Table 4.15: Taluka wise range and mean value of cations of underground water samples of Bhavnagar district in north Saurashtra Agro climatic Zone

Name of taluka	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Bhavnagar	7.40-28.00	0.01-0.60	1.64-5.03	1.01-3.80
	16.93	0.26	3.42	2.26
Gariadhar	6.04-29.00	0.05-0.14	2.05-4.74	1.00-4.00
	14.09	0.09	3.12	2.27
Jesar	3.50-10.40	0.00-0.51	1.97-2.80	1.04-2.12
	6.25	0.10	2.19	1.47
Palitana	5.60-17.50	0.01-0.20	1.04-6.29	0.47-4.15
	9.91	0.06	2.89	1.69
Sihor	2.95-23.20	0.01-0.54	2.03-4.90	1.05-3.95
	10.72	0.13	2.98	2.10
Umrala	3.00-28.30	0.01-0.04	2.04-3.77	1.05-4.35
	8.39	0.03	2.94	2.06
Vallabhipur	5.40-15.10	0.01-0.25	2.03-3.40	1.02-2.41
	12.53	0.05	2.54	1.56
Overall	2.95-29.00	0.00-0.60	1.04-6.29	0.47-4.35
	11.26	0.10	2.87	1.91

Table 4.16: District wise range and mean value of cations of underground water samples in north Saurashtra Agro climatic Zone

Name of District	Na^{+} (me/L)	K^{+} (me/L)	Ca^{+2} (me/L)	Mg^{+2} (me/L)
Rajkot	2.70-26.00	0.00-0.60	1.10-12.80	0.60-6.30
	7.71	0.04	3.87	2.35
Jamnagar	2.08-45.30	0.00-0.40	1.30-6.30	0.30-5.70
	13.60	0.04	2.84	2.06
Devbhoomi Dwarka	3.50-41.54	0.00-0.24	1.01-4.21	0.65-2.25
	15.49	0.02	2.30	1.26
Morbi	4.56-24.75	0.00-0.11	1.21-3.68	0.75-2.03
	16.71	0.01	2.51	1.27
Surendranagar	2.54-39.18	0.00-0.21	1.03-3.67	0.76-3.01
	15.66	0.02	2.40	1.61
Amreli	2.88-45.25	0.00-0.30	1.06-4.85	0.50-5.34
	13.39	0.06	2.66	1.66
Bhavnagar	2.95-29.00	0.00-0.60	1.04-6.29	0.47-4.35
	11.26	0.10	2.87	1.91
Overall	2.08-45.30	0.00-0.60	1.01-12.80	0.30-6.30
	13.15	0.04	2.81	1.78

4.1.2.1 Ca^{+2}

The overall Ca^{+2} values of the water samples from north Saurashtra Agro climatic Zone were between 1.01 and 12.80 me/L, with a mean value of 2.81 me/L. (Table 4.16). According to the findings (Table 4.9 to 4.15), samples from the Surendranagar taluka of the Surendranagar district had the lowest mean Ca^{+2} value (1.72 me/L) and samples from the Paddhari taluka of Rajkot district had the highest mean Ca^{+2} value (5.37 me/L).

The Highest Ca^{+2} (12.80 me/L) and lowest Ca^{+2} (1.11 me/L) were both observed of the Rajkot district, with the mean value of Ca^{+2} being 3.87 me/L and among all taluka of Rajkot district highest mean value of Ca^{+2} (5.37 me/L) was observed in Padhhari taluka of Rajkot district. The Ca^{+2} was recorded in the Jamnagar district with a mean value of 2.84 me/L, a maximum of 6.30 me/L and a minimum of 1.30 me/L and highest mean value observed in Jamnagar taluka (3.34).

The highest Ca^{+2} (4.21 me/L) and lowest Ca^{+2} (1.01 me/L) values were observed in the Devbhoomi Dwarka district, and the mean Ca^{+2} value overall was 2.30 me/L and Kalyanpur taluka of Devbhoomi Dwarka district observed is (3.14 me/L) highest mean value of Ca^{+2}.Ca^{+2} was recorded in the district of Morbi with a mean value of 2.51 me/L, a maximum value of 3.68 me/L and a minimum value of 1.21 me/L and Morbi taluka it was observed highest mean value of Ca^{+2} (2.90 me/L) in Morbi district. The Ca^{+2} was recorded in Surendranagar district with overall mean value of 2.40 me/L and the highest mean value of Ca^{+2} was observed in Chotila taluka. The overall maximum value of 3.67 me/L and a minimum value of 1.03 me/L of Surendranagar district. The Ca^{+2} level in the Amreli district ranged from a maximum of 4.85 me/L to a minimum of 1.06 me/L, with the overall mean value being 2.66 me/L and highest mean value of Ca^{+2} (3.26 me/L) was observed in Savarkundla taluka of Amreli district. The largest Ca^{+2} (6.29 me/L) and lowest Ca^{+2} (1.04 me/L) values were reported in the Bhavnagar district, where the total mean value of Ca^{+2} was 2.87 me/L and the highest mean value observed in Bhavnagar taluka of Bhavnagar district. The SSP was raised because Ca^{+2} reduced more quickly than Na^{+}.

Similar results were also found in the Churu district (Rajasthan) by Verma *et al*. (2003), Porbandar district by Hadiyal (2005); Junagadh district by Sojitra (2010), Bhavnagar district by Rajput and Polara (2013), in Latur district (Maharashtra) by Patil *et al*. (2014)

4.1.2.2 Mg^{+2}

According to the findings (Table 4.9 to 4.15) samples from Jam Khambhaliya taluka of Devbhoomi Dwarka district had the lowest mean Mg^{+2} value (1.04 me/L) and samples from Gondal taluka of Rajkot district had the highest mean Mg^{+2} value (3.22 me/L).

The Mg^{+2} level in Rajkot district high as 6.30 me/L and as low as 0.60 me/L with overall mean value of 2.35 me/L was observed and the highest mean value of Mg^{+2} (3.22 me/L) is observed in Gondal taluka of Rajkot district. Mg^{+2} levels ranged from a maximum of 5.70 me/L in the Jamnagar district to a minimum of 0.30 me/L. The district's overall mean value of Mg^{+2} was observed 2.06 me/L and highest mean value of Mg^{+2} (2.30 me/L) was observed in Dhrol taluka of Jamnagar district. The maximum Mg^{+2} value in the Devbhoomi Dwarka district was 2.25 me/L and lowest Mg^{+2} value was 0.65 me/L with the average Mg^{+2} value was 1.26 me/L. Among all talukas of Devbhoomi Dwarka highest mean value of Mg^{+2} was 1.69 me/L found in Kalyanpur taluka of Devbhoomi Dwarka.

In Morbi district, the maximum and minimum value 2.03 & 0.75 me/L of Mg^{+2}respectively. The overall mean value of Mg^{+2} was 1.27 me/L and among all talukas of Morbi district highest mean value observed in Wankaner (1.38 me/L). The district of Surendranagar had a mean Mg^{+2} value of 1.61 me/L overall, 3.01 me/L for the highest value and 0.76 me/L for the lowest value and highest mean value of Mg^{+2} was observed in Muli taluka. The Mg^{+2} was detected in Amreli district with a mean value of 1.66 me/L, maximum value of 5.34 me/L and minimum value of 0.50 me/L and highest mean value 2.45 me/L observed in Amreli taluka.

The district of Bhavnagar has a mean Mg^{+2} value of 1.91 me/L, a maximum value of 4.35 me/L and a minimum value of 0.47 me/L and mean value of Mg^{+2} 2.27 me/L recorded highest in Gariyadhar taluka. The Mg^{+2} concentrations in the water samples from north Saurashtra Agro climatic Zone ranged from 0.30 to 6.30 me/L, with a mean value of 1.78 me/L (Table 4.16). The SSP role as the decrease rate of Mg^{+2} was greater than that of Na^{+}.

Similar results were also found by Verma *et al.* (2003) in the Churu district of Rajasthan, Junagadh district of Gujarat by Sojitra (2010), by Rajput and Polara (2013) for Bhavnagar district, by Patil *et al*. (2014) in the Latur district of Maharashtra.

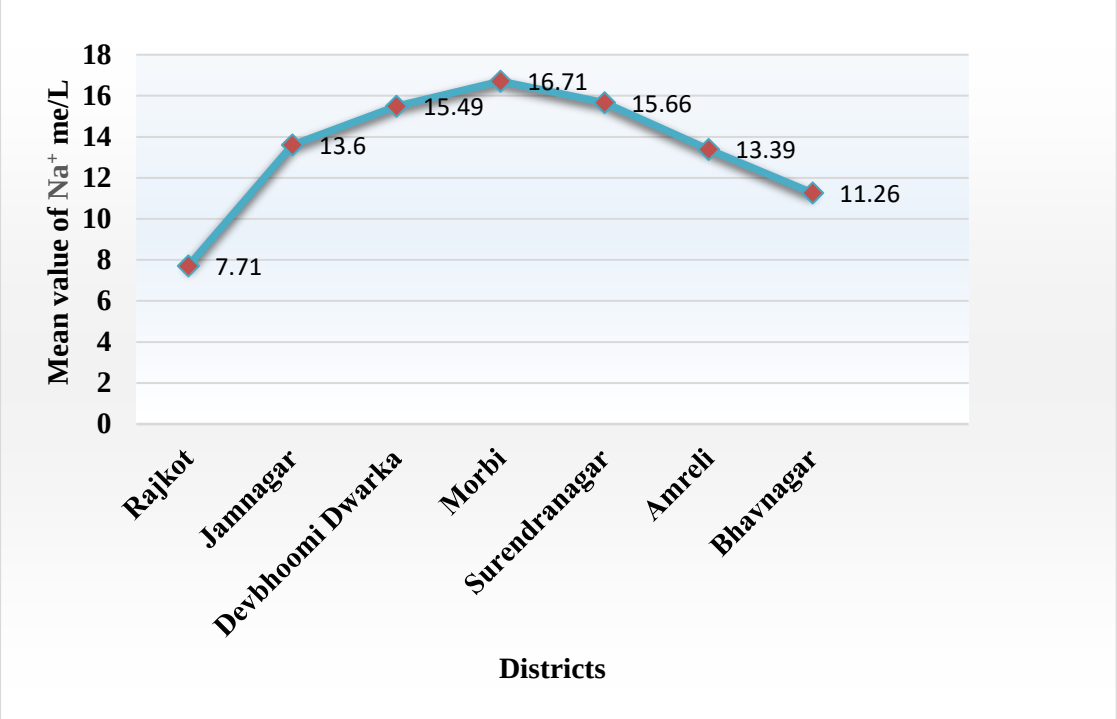

Fig. 4.5: District wise distribution of Na^+ (me/L) on mean value basis in north Saurashtra Agro climatic Zone

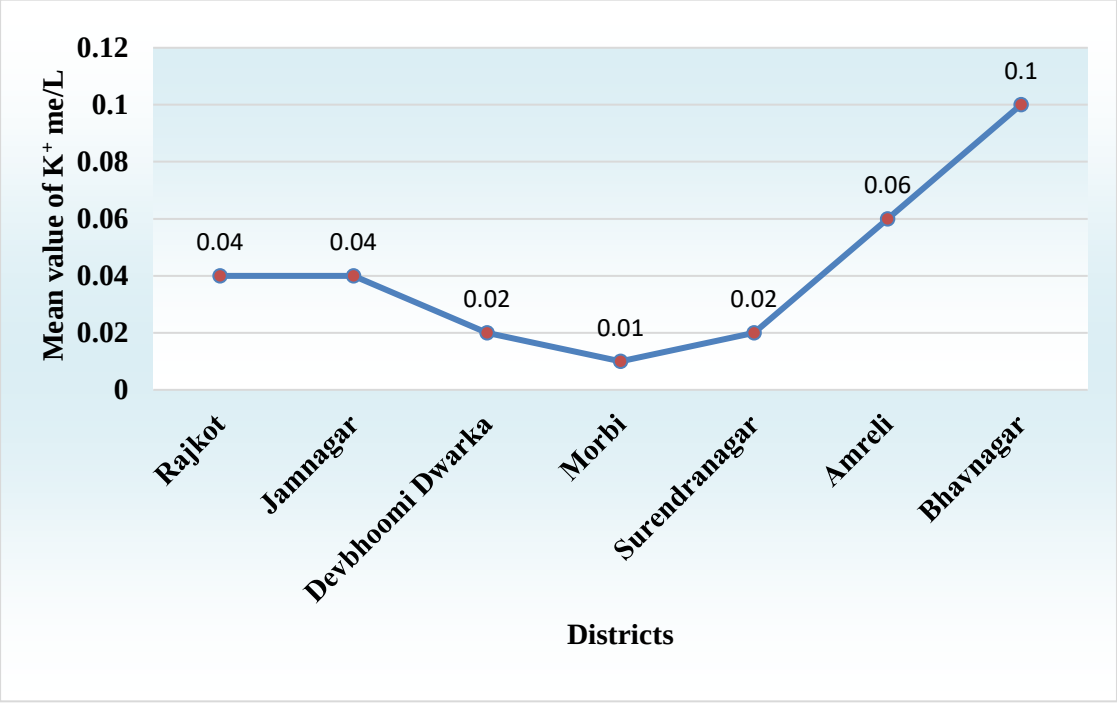

Fig. 4.6: District wise distribution of K^+ (me/L) on mean value basis in north Saurashtra Agro climatic Zone

4.1.3 Anions concentration in underground water samples

Taluka wise range and mean values of different anions present in underground water samples are given in Table 4.17 to Table 4.24.

4.1.3.1. CO_3^{-2}

The CO_3^{-2} concentrations in the water samples from north Saurashtra Agro climatic Zone ranged from 0.00 to 2.30 me/L, with a mean value of 0.07 me/L (Table 4.24). The Dhrol taluka of the Jamnagar district recorded the highest mean CO_3^{-2} value (0.57 me/L) while the majority of the talukas, including Rajkot, Paddhari, Kotda Sagani, Jasdan, Vinchhiya, Dwarka, Bhanvad, Kalyanpur, Jam Khambhaliya, Morbi, Tankara, Halvad, Chuda, Chotila, Limdi, Sayla, Patli, Dhari, Khambha, Kunkavav, Lathi, Lalia, Valiabhipur, Dhrangadhra, Lalpur, Wankaner, Maliya-Miyana, Surendranagar, and Lakhtar recorded the lowest mean CO_3^{-2} (Table 4.17 to Table 4.23).

In the Rajkot district, the average concentration of CO_3^{-2} was 0.02 me/L, the highest concentration was 0.80 me/L and the lowest concentration was 0.00 me/L. In the Devbhoomi Dwarka district, the maximum CO_3^{-2} concentration was 0.00 me/L, the lowest CO_3^{-2} concentration was 0.00 me/L and the average CO_3^{-2} concentration was 0.00 me/L.

The highest and the lowest concentrations 2.30 me/L and 0.00 me/L of CO_3^{-2}, respectively, were recorded in the Jamnagar district, with the mean concentration of CO_3^{-2} being 0.30 me/L. The maximum CO_3^{-2} value in the Morbi district was 0.00 me/L, while the lowest CO_3^{-2} value was also 0.00 me/L, making the total mean value of CO_3^{-2} 0.00 me/L. The largest CO_3^{-2} value (1.20 me/L) and the lowest CO_3^{-2} value (0.00 me/L) were both recorded in the Surendranagar district, whereas the mean CO_3^{-2} value overall was 0.03 me/L.

The maximum value of CO_3^{-2} (1.01 me/L) and minimum value of CO_3^{-2} (0.00 me/L), while the overall mean value of CO_3^{-2} was 0.03 me/L were both found in the Amreli district. The greatest CO_3^{-2} value in the Bhavnagar district was 1.72 me/L, the lowest CO_3^{-2} value was 0.00 me/L and the average CO_3^{-2} value was 0.13 me/L

Similar findings were made by Verma *et al.* (2003) in the Churu district of Rajasthan, by Kabaria (2004) in the Amreli district, by Hadiyal (2005) in the Porbandar district, by Rajput and Polara (2013) in the Bhavnagar district.

4.1.3.2 HCO_3^-

The HCO_3^- concentration in the water samples from north Saurashtra Agro climate Zone ranged from 1.67 to 19.40 me/L, with a mean value of 4.67 me/L (Table 4.24). The HCO_3^- levels ranged from 2.10 me/L to 19.40 me/L in the Rajkot district, with a mean value of 6.34 me/L, while the samples from Gondal taluka in the Rajkot district had the highest mean value of HCO_3^- (8.50 me/L). The HCO_3^- levels ranged from a maximum of 6.41 me/L in the Devbhoomi Dwarka district and minimum of 1.67 me/L, with a mean value of 3.59 me/L (Table 4.18). The samples taken from Jam Kalyanpur taluka in the Devbhoomi Dwarka district had the highest mean value of HCO_3^- (4.84 me/L).

In the Jamnagar district, the average concentration of HCO_3^- was 4.87 me/L, with the highest concentration recorded at 8.30 me/L and the lowest concentration recorded at 2.40 me/L and among all taluka Jamnagar taluka have highest mean value of HCO^-_3 is 5.44 me/L. The highest 5.48 me/L and lowest 2.27 me/L HCO_3^- values were discovered in the Morbi district, respectively, with a mean value of 3.81 me/L, while samples from Morbi taluka in Morbi district had the highest mean value of HCO_3^- 4.28 me/L.

The HCO_3^- levels ranged from 6.80 me/L to 1.83 me/L in the Surendranagar district, with a mean value of 4.04 me/L (Table 4.21), while a samples from Sayla taluka had highest mean value of HCO_3^- 4.94 me/L. The largest HCO_3^- value (7.87 me/L) and the lowest HCO_3^- value (2.03 me/L) were both recorded in the Amreli district, with the mean value of HCO_3^- being 4.33 me/L and highest mean value of HCO_3^- (5.15 me/L) was observed in Lilia taluka of Amreli district.

The HCO_3^- levels ranged from a maximum of 11.00 me/L to a minimum of 1.78 me/L in the Bhavnagar district. The total mean value of HCO_3^- was 5.13 me/L under Bhavnagar district and among all talukas of Bhavnagar district highest value of HCO_3^- (6.20 me/L) in Bhavnagar taluka.

Similar results were also found in the Churu district (Rajasthan) by Verma *et al*. (2003), the Amreli district by Kabaria (2004), the Bhavnagar district (Gujarat) by Rajput and Polara (2013), the Latur district of Maharashtra by Patil *et al*. (2014), the Gir Somnath district of Gujarat by Polara and Chauhan (2015), the Devbhumi Dwarka district by Hadiya and Polara (2017).

Table 4.17: Taluka wise range and mean value of anions of underground water samples of Rajkot district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^{-} (me/L)	Cl^{-} (me/L)	SO_4^{-2} (me/L)
Rajkot	0.00-0.00	2.84-8.61	2.68-7.45	0.13-0.54
	0.00	5.77	4.61	0.24
Paddhari	0.00-0.00	4.75-13.42	4.56-19.50	0.10-2.54
	0.00	8.43	8.84	1.21
Lodhika	0.00-0.20	3.12-7.91	2.50-8.50	0.13-1.38
	0.04	5.67	5.20	0.55
Jam Kandorna	0.00-0.20	2.50-6.10	3.00-10.10	0.04-0.94
	0.06	4.38	5.27	0.25
Kotda Sangani	0.00-0.00	2.10-10.04	3.85-11.98	0.10-1.25
	0.00	5.63	6.47	0.59
Jasdan	0.00-0.00	4.00-8.00	2.80-10.40	0.30-3.63
	0.00	6.15	6.30	1.17
Vinchhiya	0.00-0.00	2.60-10.60	2.50-12.10	0.08-3.63
	0.00	6.16	6.78	0.89
Gondal	0.00-0.80	2.30-19.40	4.04-25.74	0.03-1.58
	0.09	8.50	10.68	0.77
Overall	0.00-0.80	2.10-19.40	2.50-25.74	0.03-3.63
	0.02	6.34	6.77	0.71

Table 4.18: Taluka wise range and mean value of anions of underground water samples of Devbhoomi Dwarka district in north Saurashtra Agro climatic Zone

Name of Taluka	CO_3^{-2} (me/L)	HCO_3^- (me/L)	Cl^- (me/L)	SO_4^{-2} (me/L)
Dwarka	0.00-0.00	2.31-4.84	1.05-31.85	0.54-1.54
	0.00	3.48	15.73	0.94
Bhanvad	0.00-0.00	1.87-3.91	4.01-10.10	0.45-1.12
	0.00	3.13	6.77	0.81
Kalyanpur	0.00-0.00	3.72-6.41	24.67-41.18	0.97-1.65
	0.00	4.84	31.17	1.19
Jam Khambhaliya	0.00-0.00	1.67-4.03	3.85-8.16	0.45-1.45
	0.00	2.91	5.45	0.96
Overall	0.00-0.00	1.67-6.41	1.05-41.18	0.45-1.65
	0.00	3.59	14.78	0.97

Table 4.19: Taluka wise range and mean value of anions of underground water samples of Jamnagar district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^- (me/L)	Cl^- (me/L)	SO_4^{-2} (me/L)
Jamnagar	0.00-1.60	3.10-8.30	5.00-33.00	0.20-4.17
	0.41	5.44	16.21	0.95
Jam Jodhpur	0.00-1.90	2.40-7.80	3.00-43.00	0.10-1.87
	0.24	4.55	11.31	0.67
Jodiya	0.00-1.14	3.50-6.50	7.00-32.00	0.21-3.93
	0.12	5.04	20.90	1.22
Dhrol	0.00-2.30	3.12-7.20	3.20-38.00	0.11-1.95
	0.57	5.22	11.51	0.49
Lalpur	0.00-0.00	2.70-6.40	2.80-34.75	0.09-1.36
	0.00	4.31	8.03	0.40
Kalavad	0.00-1.40	2.70-8.00	4.00-33.00	0.07-0.38
	0.46	4.69	8.74	0.23
Overall	0.00-2.30	2.40-8.30	2.80-43.00	0.07-4.17
	0.30	4.87	12.78	0.66

Table 4.20: Taluka wise range and mean value of anions of underground water samples of Morbi district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^- (me/L)	Cl^- (me/L)	SO_4^{-2} (me/L)
Morbi	0.00-0.00	2.89-5.48	3.05-23.00	1.01-2.23
	0.00	4.28	18.15	1.52
Tankara	0.00-0.00	2.31-3.86	9.54-15.23	0.65-1.76
	0.00	3.31	11.21	1.04
Halvad	0.00-0.00	2.29-4.71	8.04-23.45	0.54-1.05
	0.00	3.45	14.04	0.85
Wankaner	0.00-0.00	3.31-4.76	11.02-23.12	0.65-2.01
	0.00	3.99	18.79	1.12
Maliya-Miyana	0.00-0.00	2.27-5.13	5.12-23.05	0.76-1.32
	0.00	4.01	15.65	1.07
Overall	0.00-0.00	2.27-5.48	3.05-23.45	0.54-2.23
	0.00	3.81	15.57	1.12

Table 4.21: Taluka wise range and mean value of anions of underground water samples of Surendranagar district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^{-} (me/L)	Cl^{-} (me/L)	SO_4^{-2} (me/L)
Surendranagar	0.00-0.00	2.08-4.08	6.45-14.05	0.75-1.25
	0.00	2.94	9.47	1.03
Chuda	0.00-0.00	2.27-6.80	2.64-25.64	0.54-2.05
	0.00	4.16	11.31	1.15
Chotila	0.00-0.00	2.08-6.50	2.10-27.85	0.76-1.85
	0.00	4.82	20.06	1.21
Dhrangadhra	0.00-0.01	2.88-5.78	3.15-30.74	0.40-1.76
	0.00	4.61	18.90	1.24
Lakhtar	0.00-0.00	2.77-4.22	5.46-12.45	0.75-1.47
	0.00	3.36	8.78	1.08
Limbdi	0.00-0.00	2.23-5.87	2.65-20.75	0.45-1.65
	0.00	3.85	13.51	1.03
Muli	0.00-0.60	2.78-6.10	5.08-26.15	0.53-1.81
	0.17	4.56	17.65	1.08
Sayla	0.00-0.00	3.36-6.02	4.65-21.85	0.56-1.83
	0.00	4.94	15.93	1.12
Thangadh	0.00-1.20	2.32-5.66	3.28-36.81	0.54-2.01
	0.12	3.99	18.79	1.25
Patli	0.00-0.00	1.83-5.21	2.41-24.18	0.37-1.27
	0.00	3.15	11.20	0.91
Overall	0.00-1.20	1.83-6.80	2.10-36.81	0.37-2.05
	0.03	4.04	14.56	1.11

Table 4.22: Taluka wise range and mean value of anions of underground water samples of Amreli district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^- (me/L)	Cl^- (me/L)	SO_4^{-2} (me/L)
Amreli	0.00-1.01	3.71-6.20	3.00-44.01	0.18-2.92
	0.17	4.76	22.34	1.19
Babra	0.00-0.98	2.74-5.48	4.62-21.54	0.31-1.28
	0.10	3.71	8.60	0.49
Dhari	0.00-0.00	2.62-5.72	4.65-16.58	0.00-0.03
	0.000	4.03	8.69	0.01
Khambha	0.00-0.00	2.03-3.77	4.25-8.45	0.00-0.02
	0.00	2.80	5.86	0.01
Kunkavav	0.00-0.00	3.81-6.04	6.23-27.65	0.21-1.24
	0.00	4.49	14.60	0.69
Lathi	0.00-0.00	3.56-5.42	5.01-36.75	0.01-0.43
	0.00	4.36	15.65	0.15
Lilia	0.00-0.00	3.92-6.01	6.51-19.85	0.01-0.04
	0.00	5.15	16.59	0.02
Overall	0.00-1.01	2.03-6.20	3.00-44.01	0.00-2.92
	0.03	4.33	13.15	0.32

Table 4.23: Taluka wise range and mean value of anions of underground water samples of Bhavnagar district in north Saurashtra Agro climatic Zone

Name of taluka	CO_3^{-2} (me/L)	HCO_3^- (me/L)	Cl^- (me/L)	SO_4^{-2} (me/L)
Bhavnagar	0.00-1.30	3.08-8.50	5.08-24.70	0.00-3.05
	0.23	6.20	15.23	0.72
Gariadhar	0.00-1.19	4.02-8.00	4.90-26.00	0.00-2.49
	0.21	5.74	13.29	0.27
Jesar	0.00-0.40	3.40-4.90	4.10-9.10	0.00-0.11
	0.04	3.77	6.10	0.02
Palitana	0.00-0.80	1.78-11.00	4.50-16.10	0.00-2.04
	0.20	4.94	8.69	0.21
Sihor	0.00-1.72	3.37-8.50	3.12-22.00	0.00-2.04
	0.17	5.31	10.08	0.42
Umrala	0.00-0.80	3.30-7.90	3.06-26.00	0.00-2.11
	0.08	5.16	7.92	0.21
Vallabhipur	0.00-0.00	3.10-7.10	4.70-14.20	0.00-0.07
	0.00	4.81	11.35	0.02
Overall	0.00-1.72	1.78-11.00	3.06-26.00	0.00-3.05
	0.13	5.13	10.38	0.27

Table 4.24: District wise range and mean value of anions of underground water samples in north Saurashtra Agro climatic Zone

Name of District	CO_3^{-2} (me/L)	HCO_3^{-} (me/L)	Cl^{-} (me/L)	SO_4^{-2} (me/L)
Rajkot	0.00-0.80	2.10-19.40	2.50-25.74	0.03-3.63
	0.02	6.34	6.77	0.71
Devbhoomi Dwarka	0.00-0.00	1.67-6.41	1.05-41.18	0.45-1.65
	0.00	3.59	14.78	0.97
Jamnagar	0.00-2.30	2.40-8.30	2.80-43.00	0.07-4.17
	0.30	4.87	13.31	0.72
Morbi	0.00-0.00	2.27-5.48	305-23.45	0.54-2.23
	0.00	3.81	15.57	1.12
Surendranagar	0.00-1.20	1.83-6.80	2.10-36.81	0.37-2.05
	0.03	4.04	14.56	1.11
Amreli	0.00-1.01	2.03-6.20	3.00-44.01	0.00-2.92
	0.03	4.33	13.15	0.32
Bhavnagar	0.00-1.72	1.78-11.00	3.06-26.00	0.00-3.05
	0.13	5.13	10.38	0.27
Overall	0.00-2.30	1.67-19.40	1.05-44.01	0.00-4.17
	0.07	4.67	12.32	0.72

4.1.3.3 Cl^-

The overall Cl^- values of north Saurashtra Agro climatic Zone water samples were ranged from 1.05 to 44.01 me/L with mean value of 12.32 me/L (Table 4.24). The data (Table 4.17 to 4.23) revealed that the highest value of Cl^- (44.01 me/L) was obtained from the samples of Amreli taluka of Amreli district and the lowest value of Cl^- (1.05 me/L) was found in the samples of Dwarka taluka of Devbhoomi Dwarka district.

In the Rajkot district, the average Cl^- value was 6.77 me/L, the maximum Cl^- value was 25.74 me/L and minimum Cl^- value was 2.50 me/L and the highest mean value of Cl^- 10.68 me/L was observed in Gondal taluka of Rajkot district. The district of Devbhoomi Dwarka had an average Cl^- value of 14.78 me/L, the highest Cl^- value of 41.18 me/L and a lowest Cl^- value of 1.05 me/L

In the Jamnagar district, the mean value of Cl^- 12.78 me/L, the maximum Cl^- value was 43.00 me/L and minimum Cl^- value was 2.80 me/L and among all talukas of Jamnagar having Jodiya taluka highest mean value of Cl^- (20.90 me/L) was found. The Cl^- was observed in Morbi district with a mean value of 15.57 me/L, a maximum value of 23.65 me/L and a lowest value of 3.05 me/L. The highest mean value of the findings (Table 4.18) showed that the samples from the Kalyanpur taluka in Devbhuoomi Dwarka district had the greatest mean value of Cl^- (31.17 me/L), while those from the Rajkot taluka in the Rajkot district had the lowest mean value (4.61 me/L) of Cl^- (Table 4.17).

The maximum 36.81 me/L and minimum 2.10 me/L Cl^- values were found in Surendrnagar district, with mean value of 14.56 me/L. The Cl^- ranged from 3.00 me/L to 44.01 me/L in the Amreli district, with mean value of 13.15me/L and among all talukas Amreli taluka had maximum mean value of Cl^- 22.34 me/L. In the Bhavnagar district, the mean value of Cl^- 10.38 me/L, the maximum Cl^- value was 26.00 me/L, minimum Cl^- value was 3.06 me/L and mean value of Cl^- was 10.38 me/L and among all talukas of Bhavnagar district, in Bhavnagar taluka highest mean value of Cl^- (15.23 me/L) is found

Similar results were also found in the Churu district (Rajasthan) by Verma *et al*. (2003), Porbandar district (Hadiyal, 2005), Junagadh district (Sojitra, 2010), Latur district of Maharashtra (Patil, *et al.,* 2014).

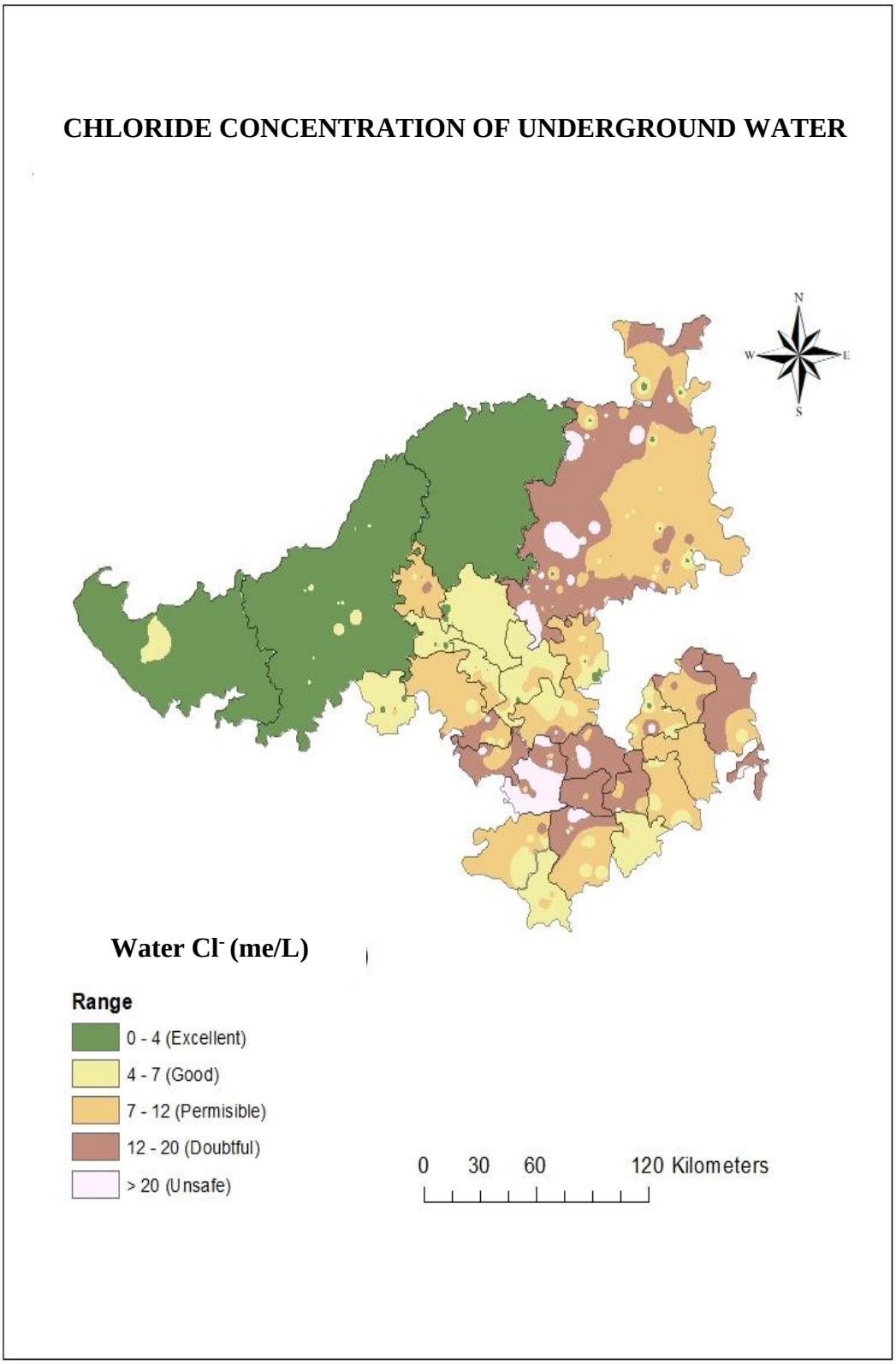

Fig. 4.7: Cl^- concentration (me/L) of underground water in north Saurashtra Agro climatic Zone

4.1.3.4. SO_4^{-2}

The total SO_4^{-2} concentrations in the water samples from north Saurashtra Agro climatic Zone ranged from 0.00 to 4.17 me/L with a mean value of 0.72 me/L (Table 4.24). The data (Table 4.17 to 4.23) showed that the samples from Morbi taluka in Morbi district had the highest mean SO_4^{-2} value (1.52 me/L), while the samples from Dhari & Khambha talukas in Amreli district had the lowest mean of SO_4^{-2} value (0.01 me/L).

The greatest SO_4^{-2} value in Rajkot district was 3.63 me/L, while the lowest SO_4^{-2} value was 0.03 me/L. The total mean value of SO_4^{-2} was 0.71 me/L. The Devbhoomi Dwarka district recorded the highest SO_4^{-2} concentration (1.65 me/L) and lowest SO_4^{-2}concentration (0.45 me/L), with an average SO_4^{-2} concentration of 0.97 me/L.

The largest SO_4^{-2} (4.17 me/L) and lowest SO_4^{-2} (0.07 me/L) values were recorded in the Jamnagar district. The total mean value of SO_4^{-2} was 0.66 me/L The largest SO_4^{-2} value (2.23 me/L) and the lowest SO_4^{-2} value (0.54 me/L) were both found in the Morbi district, whereas the average SO_4^{-2} value was 1.12 me/L.

In the Surendranagar district, the highest SO_4^{-2} value was 2.05 me/L and the lowest SO_4^{-2} value was 0.37 me/L. The detected SO_4^{-2} average value was 1.11 me/L. The maximum SO_4^{-2} value in the Amreli district was 2.92 me/L and minimum SO_4^{-2} value was 0.00 me/L, while average value of SO_4^{-2} was 0.32 me/L. The SO_4^{-2} values in the Bhavnagar district ranged from 0.00 me/L to 3.05 me/L, with an average SO_4^{-2} value of 0.27 me/L.

Similar results were also found in the Churu district (Rajasthan) by Verma *et al.* (2003), for Porbandar district (Hadiya, 2005), for Junagadh district (Sojitra, 2010), for Latur district of Maharashtra (Patil, *et al*., 2014), for Gir Somnath district (Gujarat) by Polara and Chauhan (2015), Hadiya and Polara (2017) for Devbhoomi Dwarka district (Gujarat).

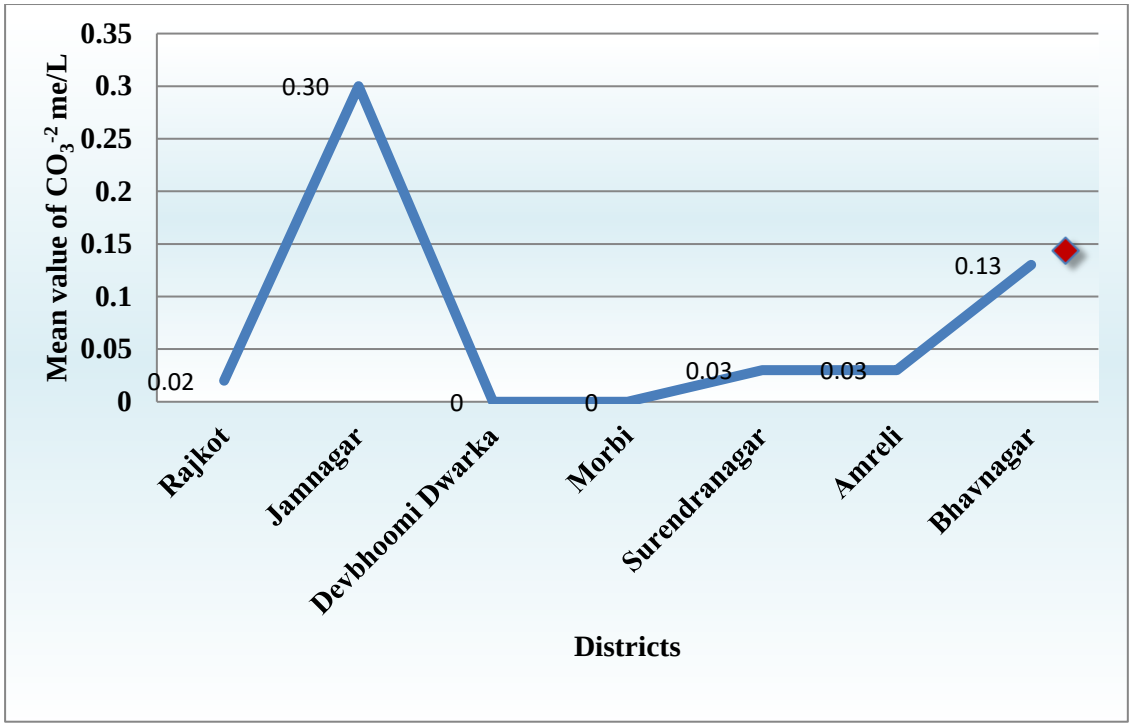

Fig. 4.8: District wise distribution of CO_3^{-2} (me/L) mean value basis in north Saurashtra Agro climatic Zone

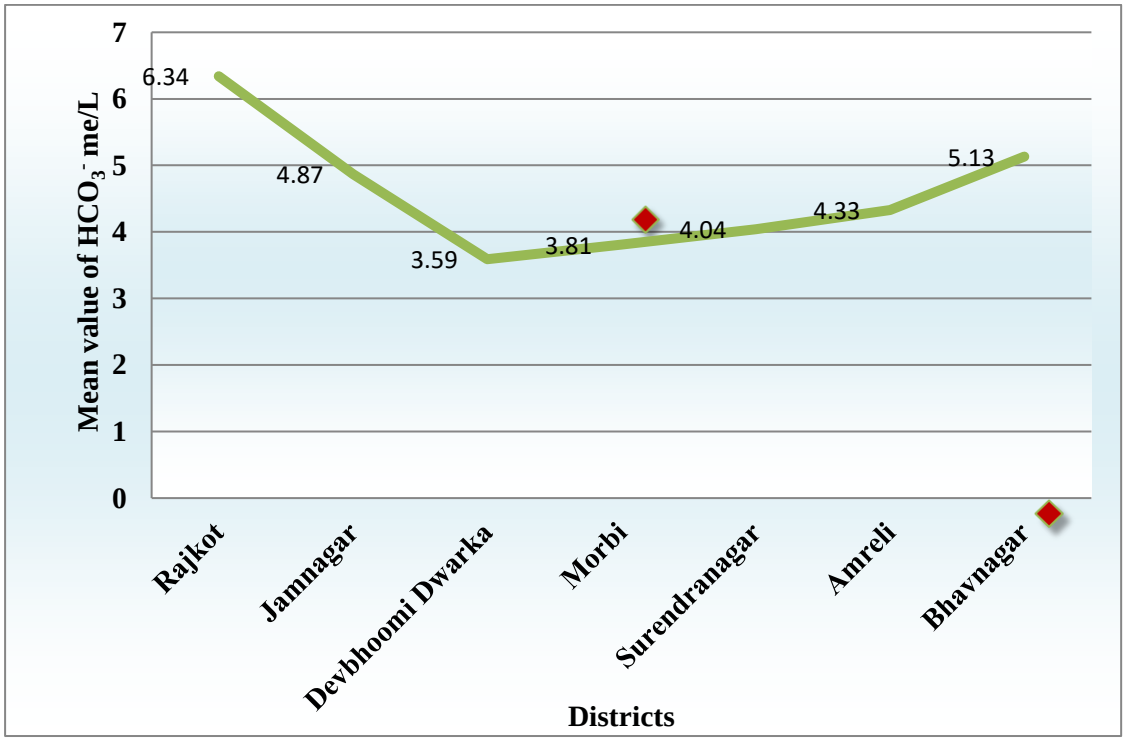

Fig. 4.9: District wise distribution of HCO_3^- (me/L) mean value basis in north Saurashtra Agro climatic Zone

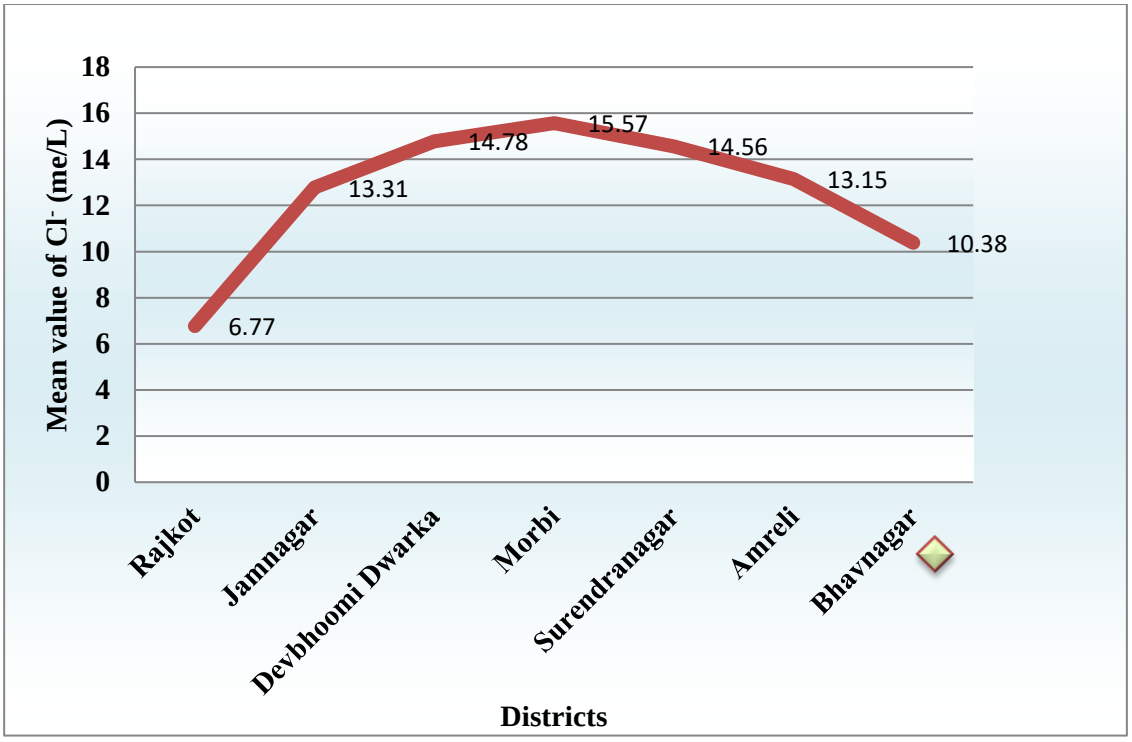

Fig. 4.10: District wise distribution of Cl^- (me/L) mean value basis in north Saurashtra Agro climatic Zone

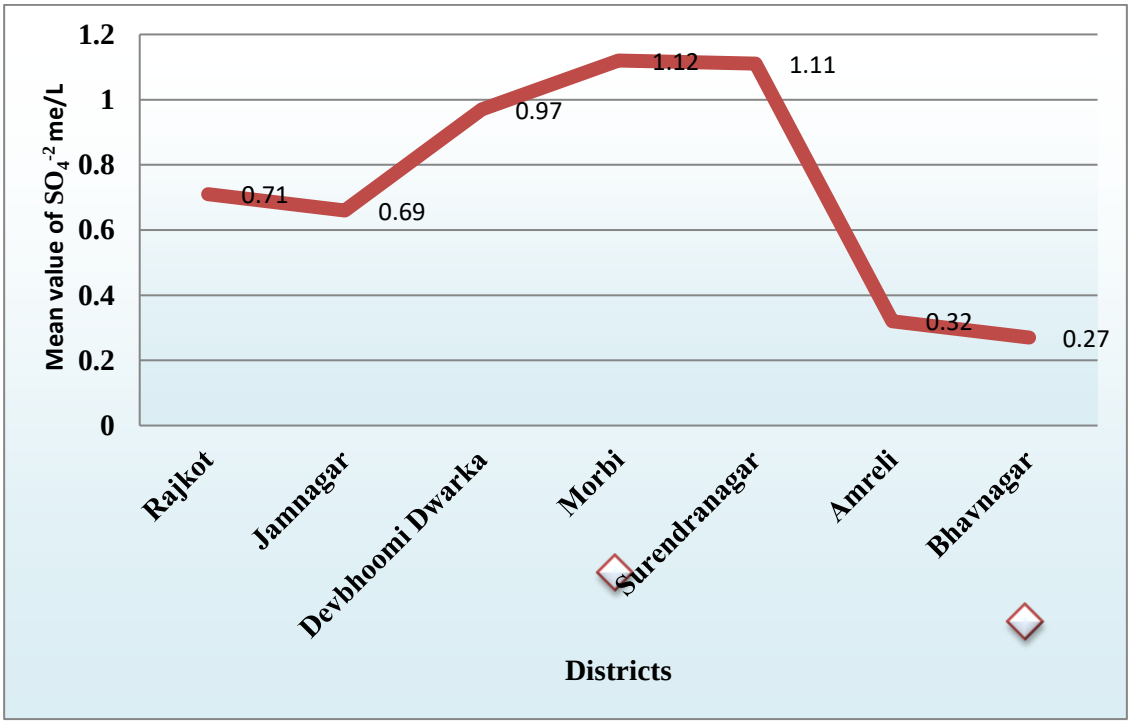

Fig. 4.11: District wise distribution of SO_4^{-2} (me/L) mean value basis in north Saurashtra Agro climatic Zone

4.2 SALINITY AND SODICITY INDICES OF UNDERGROUND WATER

4.2.1 Electrical conductivity (EC)

The average EC of the water samples from north Saurashtra Agro climatic Zone was found to be 1.98 dS/m, ranging greatly from 0.59 to 5.20 dS/m (Table 4.8). The Rajkot district had an average EC value of 1.66 dS/m, a maximum EC value of 4.45 dS/m and a minimum EC value of 0.76 dS/m (Table 4.1). In the Jamnagar district, the overall mean EC value was 2.01 dS/m and the samples discovered the highest EC of 5.20 dS/m and the lowest EC of 0.66 dS/m (Table 4.2). The samples obtained in the Devbhoomi Dwarka district contained with an average EC value of 2.10 dS/m, a maximum EC value of 5.12 dS/m and minimum EC value of 0.63 dS/m

The district of Morbi has an average EC value of 2.27 dS/m, a maximum EC value of 3.23 dS/m and a minimum EC value of 1.01 dS/m (Table 4.4). under sample collected from Surendranagar district has an average EC value of 2.12 dS/m, maximum EC value of 4.61 dS/m and a minimum EC value of 0.59 dS/m (Tables 4.5).

The district of Amreli recorded an average EC value of 2.02 dS/m, a maximum EC value of 5.10 dS/m and a minimum EC value of 0.78 dS/m (Table 4.6). The district of Bhavnagar has an average EC value of 1.76 dS/m, a maximum EC value of 3.78 dS/m and a minimum EC value of 0.76 dS/m (Table 4.7).

The samples taken from Patli taluka in Surendranagar district had the lowest value of EC (0.59 dS/m), whereas Jam Jodhpur taluka in Jamnagar district had the greatest value of EC (5.20 dS/m). The data also showed that samples from Jam Khambhaliya taluka in Devbhoomi Dwarka district had the lowest mean EC value (1.05 dS/m) while samples from Kanyanpur taluka of Devbhoomi Dwarka district had the highest mean EC value (3.94 dS/m).

Most of water samples (62.50 per cent) fell in C_3 class. It indicated that water cannot be used where drainage is restricted and salt tolerant plant grow as well as additional management practices should be followed.

Similar results were also reported for the districts of Porbandar by Hadiyal (2005), Junagadh by Sojitra (2010), Bhavnagar by Rajput and Polara (2013), Latur district of Maharashtra by Patil *et al*. (2014).

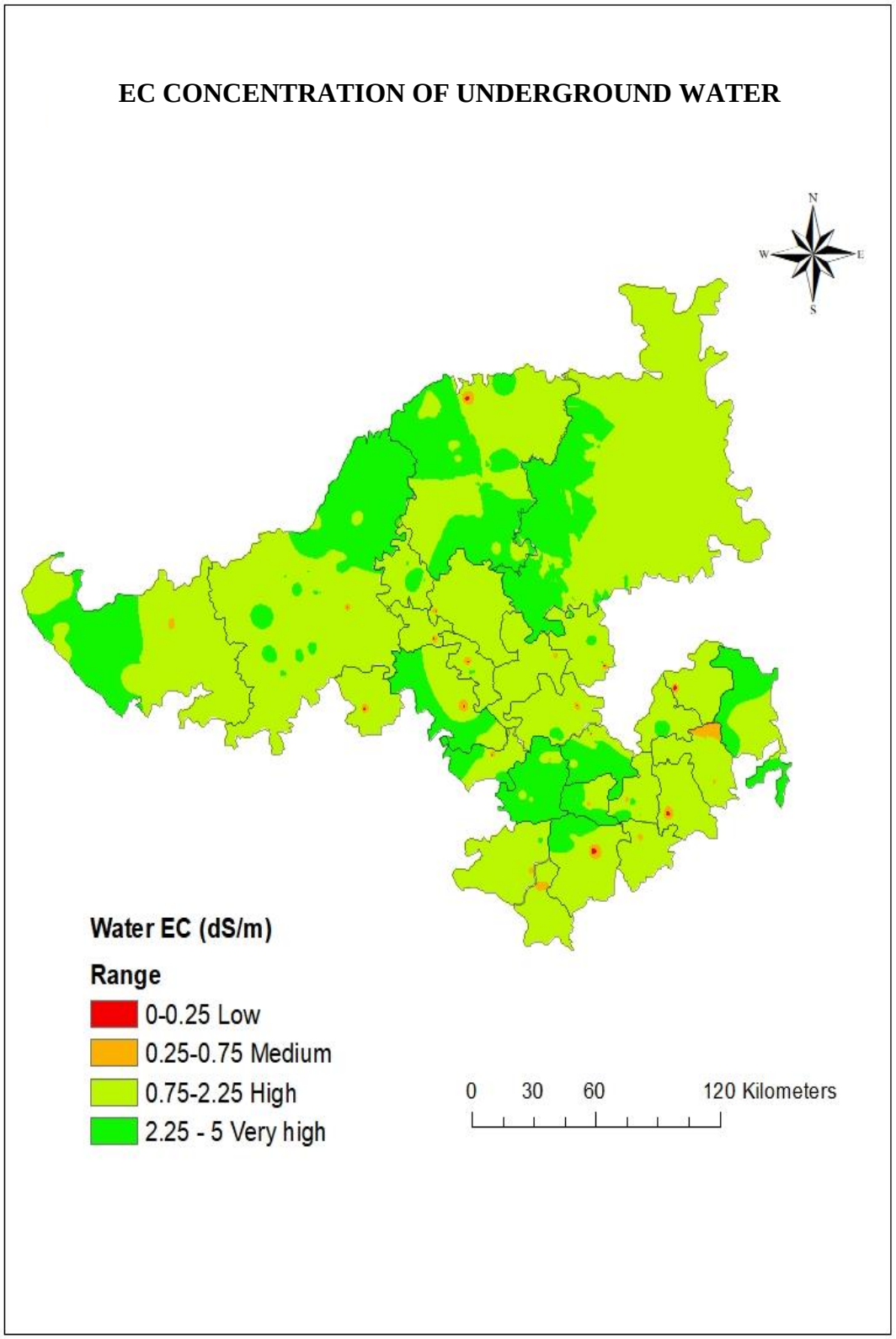

Fig. 4.12: EC concentration (dS/m) of underground water in north Saurashtra Agro climatic Zone

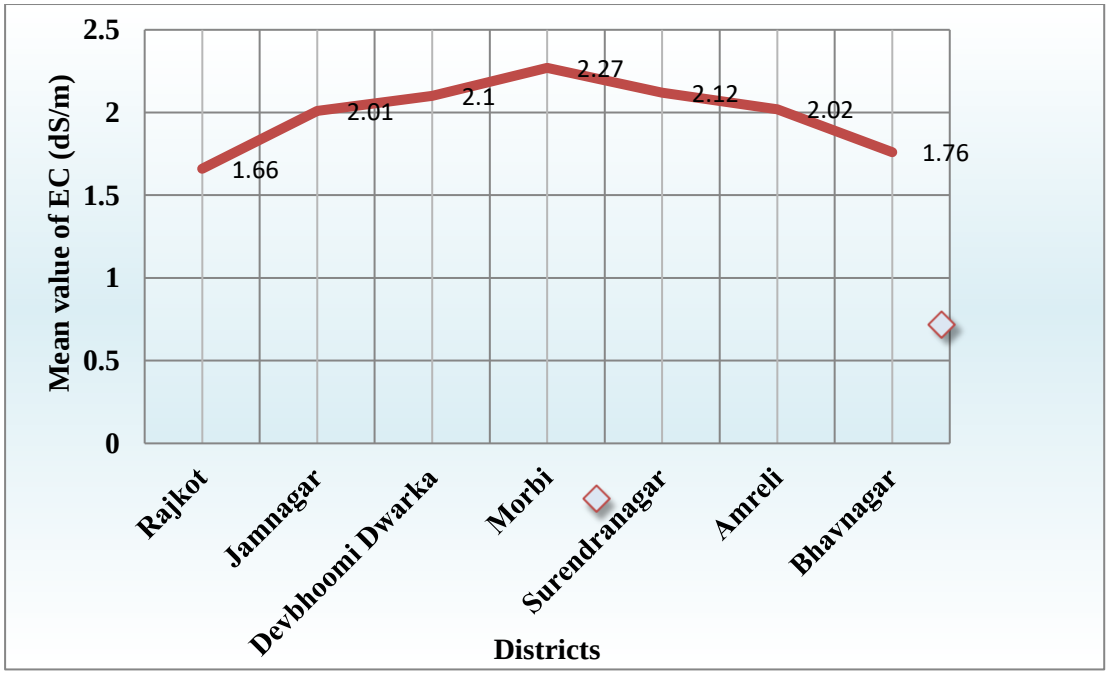

Fig. 4.13: District wise distribution of EC (dS/m) mean value basis in north Saurashtra Agro climatic Zone

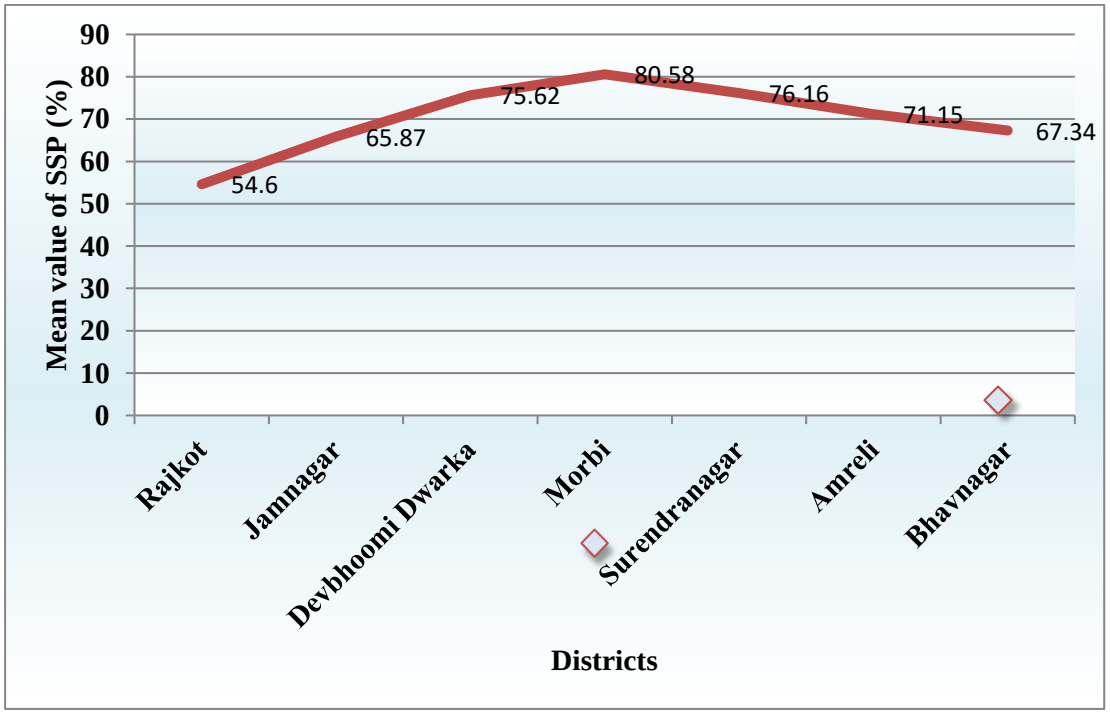

Fig. 4.14: District wise distribution of SSP (%) mean value basis in north Saurashtra Agro climatic Zone

4.2.2 Soluable Sodium percentage (SSP)

The taluka wise range and mean values of SSP are provided in Table 4.1 to 4.7. The percentage distribution of water samples among the various SSP classes (as recommended by the USDA) is shown in Table 3.6.

The SSP in the water samples from north Saurashtra Agro climatic Zone ranged from 32.39 to 90.89 per cent and with a mean value of 69.57 (Table 4.8). The SSP was overall mean value of 54.60 in the Rajkot district, with a maximum value of 76.40 and a lowest value of 32.39 (Table 4.1). The highest per cent SSP value (90.89) and the lowest SSP number (34.69) were found in Jamnagar district with mean value of SSP in per cent (65.87). The largest SSP value (88.21) and the lowest SSP value (55.86) were observed in the Devbhoomi Dwarka district, while the mean SSP value overall was 75.62.

The district of Morbi recorded an average SSP value of 80.58 overall, a maximum SSP of 86.16 and a lowest SSP of 57.29 (Table 4.4). The SSP was observed in Surendranagar district to have an overall mean value of 76.16, a maximum value of 90.78 and a minimum value of 49.04 (Table 4.5). The SSP was found to have an overall mean value of 71.15 in the Amreli district, with a maximum SSP of 90.89 and a minimum SSP of 41.82 (Tabl 4.6). The SSP was determined in Bhavnagar district to have an overall mean value of 67.34, a maximum value of 89.09 and a minimum value of 44.62 (Table 4.7).

The data also showed that Rajkot taluka in the Rajkot district recorded the lowest mean SSP value (47.75) and that Kalyanpur taluka in Devbhoomi Dwarka had the highest mean SSP value (86.98). The majority of the talukas in the north Saurashtra region's water samples have mean SSP values greater than 60, which indicates a fair level of alkali threat in these water samples. These results agree with those from Nilsood *et al*. (1998), Verma *et al*. (2003), Kabaria (2004), Hadiyal (2005), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015) and Hadiya and Polara (2017).

Overall, 40.42 and 59.58 per cent of the samples fell into the good and fair SSP categories, respectively (Table 4.25). The sixty per cent of the water samples had SSP values greater than 60 (Fair class). A fair class of SSP was discovered for around 75.14, 90.00, 98.00, and 95.00 percent of the water samples from the districts of Bhavnagar, Surendranagar, Morbi and Dwarka, respectively. The safe class of SSP was discovered in about 75.00 per cent of the water samples from the Rajkot district.

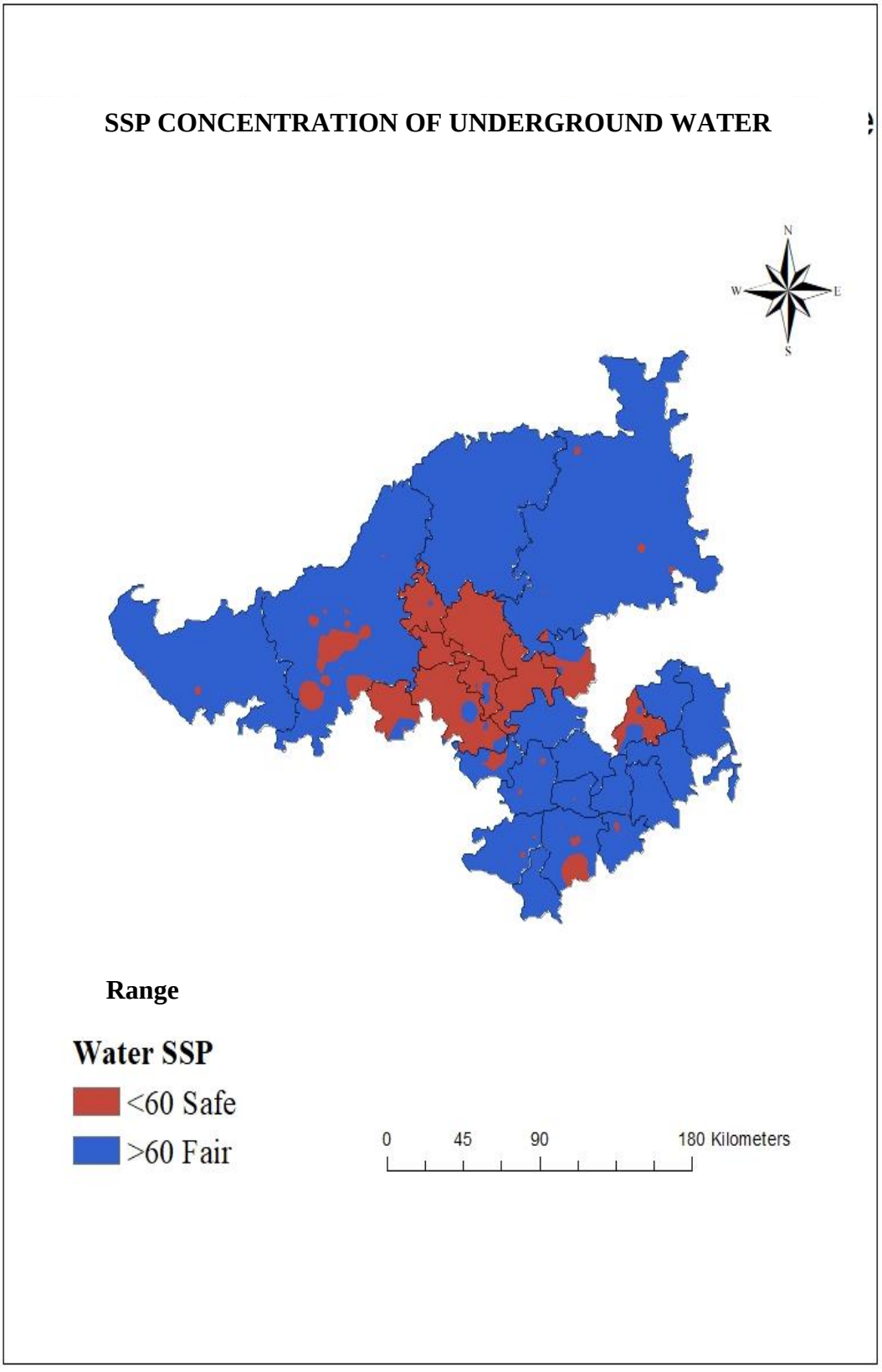

Fig.4.15: SSP concentration (%) of underground water in north Saurashtra Agro climatic Zone

4.2.3 Sodium Adsorption Ratio (SAR)

With studying the alkali dangers of irrigation water requires consideration of the SAR value. As a result, Table 4.1 to 4.7 provided the taluka wise range and mean values of SAR and Distribution of water samples is shown in Tables 4.1 to 4.8 for each SAR class in Table 3.5. (as recommended by USDA).

The range of SAR in the water samples from the north Saurashtra Agro climatic Zone was 0.62 to 10.56, with a mean value of 3.09 overall (Table 4.8). The water samples from Lalpur taluka of Jamnagar district and Jasdan taluka of Rajkot district had the lowest SAR value (0.62) and the water samples from Jam Jodhpur taluka of Jamnagar district had the highest SAR value (10.56). The Rajkot district recorded the highest SAR (3.40) and the lowest SAR (0.60), with a mean SAR value of 1.52 across the board. The highest SAR (10.56) and the lowest SAR (0.62) were both discovered in the Jamnagar district, with the mean SAR overall being 3.06. The highest SAR (8.22) and the lowest SAR (1.11) with a mean value of 3.85, were discovered in the Devbhoomi Dwarka district.

The highest SAR (6.04) and the lowest SAR (1.24), with a mean value of 4.25 were observed in the Morbi district. The maximum SAR (8.06) and the minimum SAR (0.78) were observed in the Surendranagar district, with the total mean SAR being 3.79. The highest SAR (10.55) and lowest SAR (0.72) were observed in the Amreli district, while the mean SAR overall was 3.15. The highest SAR (5.60) and lowest SAR (0.83), with a mean value of 2.54 overall, were found in the Bhavnagar district.

It appears that the majority of samples were classified as S_1, which can be utilised in all soils with little risk of damaging Na level development and crop damage to Na-sensitive plants.

The data also showed that Kalyanpur and Rajkot talukas, respectively, recorded the highest (7.31) and lowest (1.08) mean value of SAR. The mean SAR values in the north Saurashtra Agro climatic Zone were over all less than 10. These results are similar with those of Nilsood *et al*. (1998), Kabaria (2004) for Amreli district, Hadiya (2005) for Porbander, Sojitra (2010) for Junagadh.

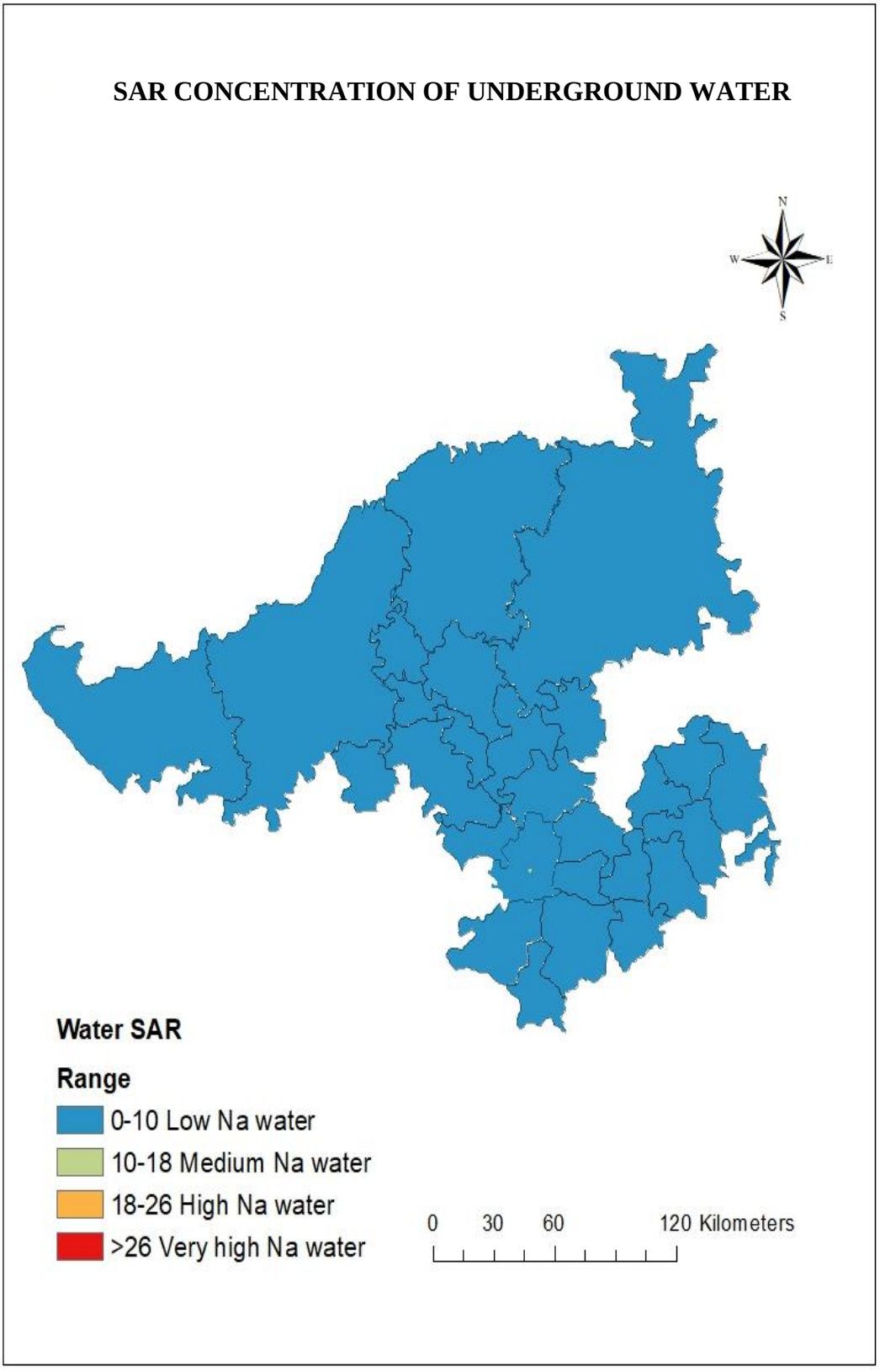

Fig.4.16: SAR concentration of underground water in north Saurashtra Agro climatic Zone

4.2.4 Residual Sodium Carbonate (RSC)

Taluka wise range and mean values of RSC are provided in Table 4.1 to 4.7. The percentage distribution of the water sample in the various RSC classes (as recommended by the USDA) are shown in the Table 3.4. The overall RSC values were between 0.00 to 1.89 me/L with a mean value of 0.15 me/L, under less than 1.25 me/L. In the Vallabhipur taluka of the Bhavnagar district, the highest value of RSC (1.89 me/L) was found.

The RSC was found in Rajkot district at a maximum value of 1.81 me/L and a mean value of 0.14 me/L. The RSC was found to have a maximum value in the Jamnagar district (1.41 me/L), while found mean value was (0.28 me/L). The RSC was observed maximum in the Devbhumi Dwarka district (0.46 me/L), while mean value was observed 0.02 me/L of RSC

The greatest RSC (0.62 me/L) and overall mean value of RSC (0.03 me/L) were recorded in the Morbi district. The largest RSC (1.10 me/L) and overall mean value of RSC (0.05 me/L) were both discovered in the Surendeanagar district. The RSC was found to have a highest value of 0.64 me/L in the Amreli district and overall mean value of 0.04 me/L. The largest RSC (1.89 me/L) and overall mean value of RSC (0.48 me/L) were both observed in the Bhavnagar district. The total RSC mean readings for all talukas of all districts were below the permissible level of 1.25 me/L (Table 4.8)

In the previous studies Kabaria (2004) for Amreli, Hadiyal (2005) for Porbandar as well as those for the Gir Somnath district of Gujarat (Polara and Chauhan, 2015), provide support for the current investigations.

Overall, samples make up 98.54, 1.46, and 0.00 per cent that fall into the safe, marginal and hazardous categories of RSC, respectively (Table 4.25). It indicated that most of the water samples are probably safe for most purpose. Only 1.46 percent of the water samples taken from underground water RSC values between 1.25 and 2.50 and it is indicates mostly used on light texture soil with adequate leaching and application of gypsum.

These suggested that the water from the north Saurashtra Agro climatic Zone underground water was found to be devoid of RSC risks. The findings of Nilsood *et al.* (1998) for the Bhatinda district, Patel (2004) for the Surendranagar district, Kabaria (2004) for the Amreli district, Sojitra (2010) for the Junagadh district, Rajput and Polara (2013) for the Bhavnagar district in agreement with this finding.

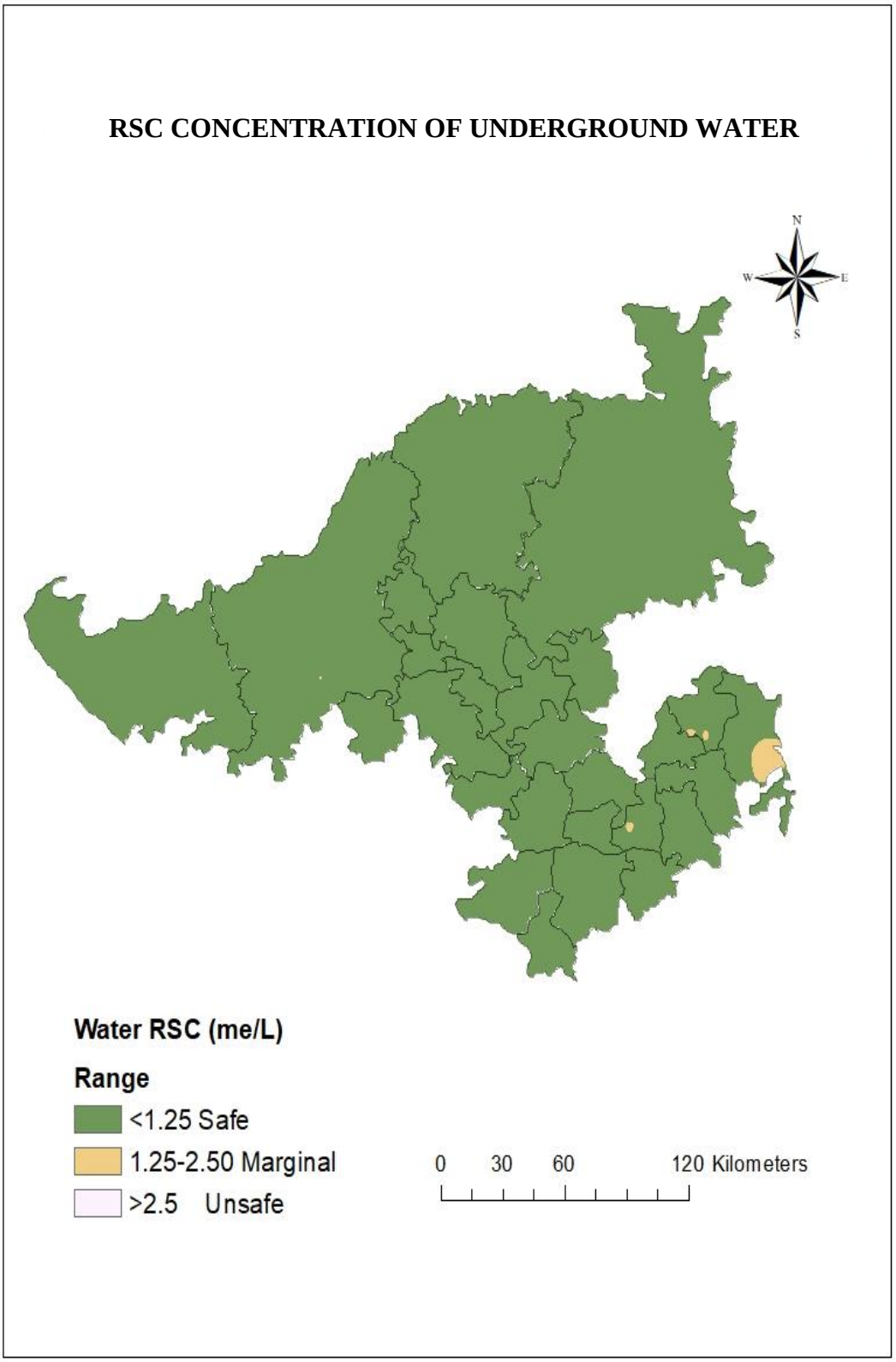

Fig. 4.17: RSC concentration (me/L) of underground water in north Saurashtra Agro climatic Zone

4.2.5 Residual Sodium Bicarbonate Percentage (RSBC)

Table 4.1 to 4.7 provided the taluka wise range and mean values of RSBC. The overall RSBC mean value was 1.86me/L with values ranging from 0.20 to 6.60 me/L (Table 4.8). The Gondal taluka of the Rajkot district had the highest value of RSBC (6.60 me/L).

The largest RSBC (6.60 me/L) and minimum value of RSBC (0.40 me/L), were both observed in Rajkot district, where the overall mean value of RSBC was (2.46 me/L). The highest and lowest RSBC values were recorded in the Jamnagar district 5.20 me/L and 0.20 me/L, respectively. whereas the mean RSBC value was (2.04 me/L). The highest value of RSBC (2.27 me/L) and lowest value of RSBC 0.66 me/L were both reported in the Devbhoomi Dwarka district, while the total mean value of RSC was (1.29 me/L).

The largest RSBC (1.80 me/L) and minimum value of RSBC (1.06 me/L) were both observed in the Morbi district, while the overall mean value of RSBC was (1.30 me/L). The largest RSBC (3.55 me/L) and lowest RSBC (0.78 me/L) value were found in the Surendeanagar district, with the total mean value of RSBC being 1.64 me/ L and highest mean value observed in Muli taluka. The largest RSBC (4.35 me/L) and lowest RSBC value were (0.51 me/L) found in the Amreli district, with the total mean value of RSBC being 1.67 me/L. The district of Bhavnagar had an average RSBC value of 2.26 me/L, a maximum RSC value of 4.71 me/L and a lowest RSBC value of 0.74 me/L.

The previous studies Nilsood *et al*., (1998) for the Bhatinda, Kabaria (2004) for the Amreli district, Hadiyal (2005) for Porbandar provide support for the current investigations.

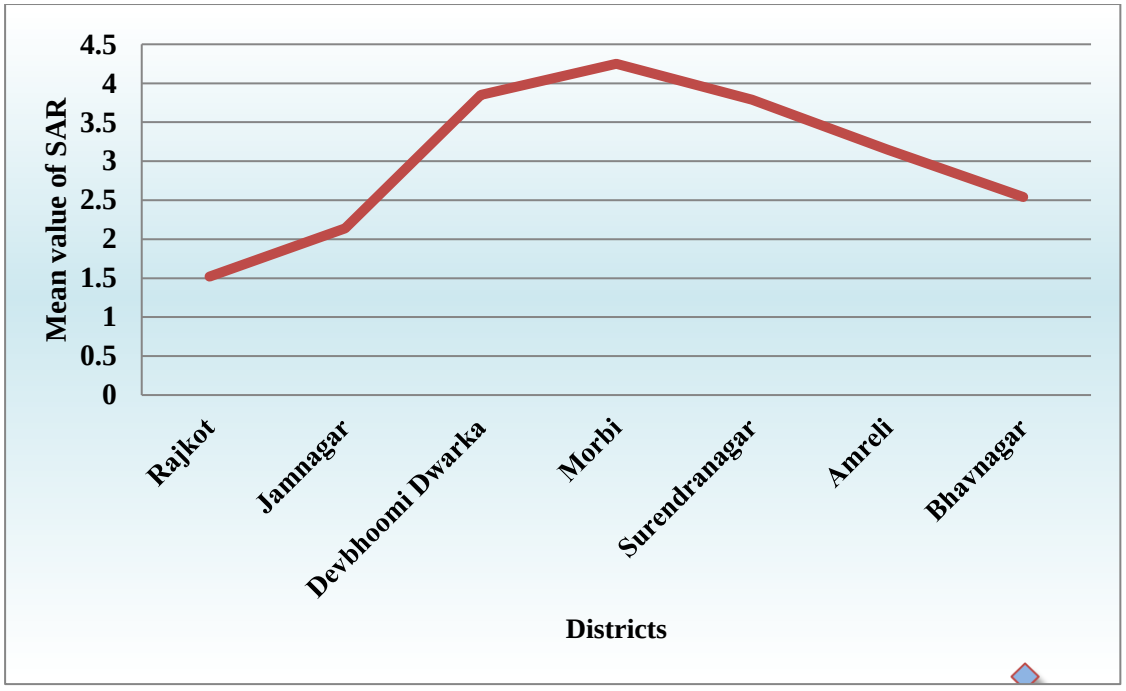

Fig. 4.18: District wise distribution of SAR mean value basis in north Saurashtra Agro climatic Zone

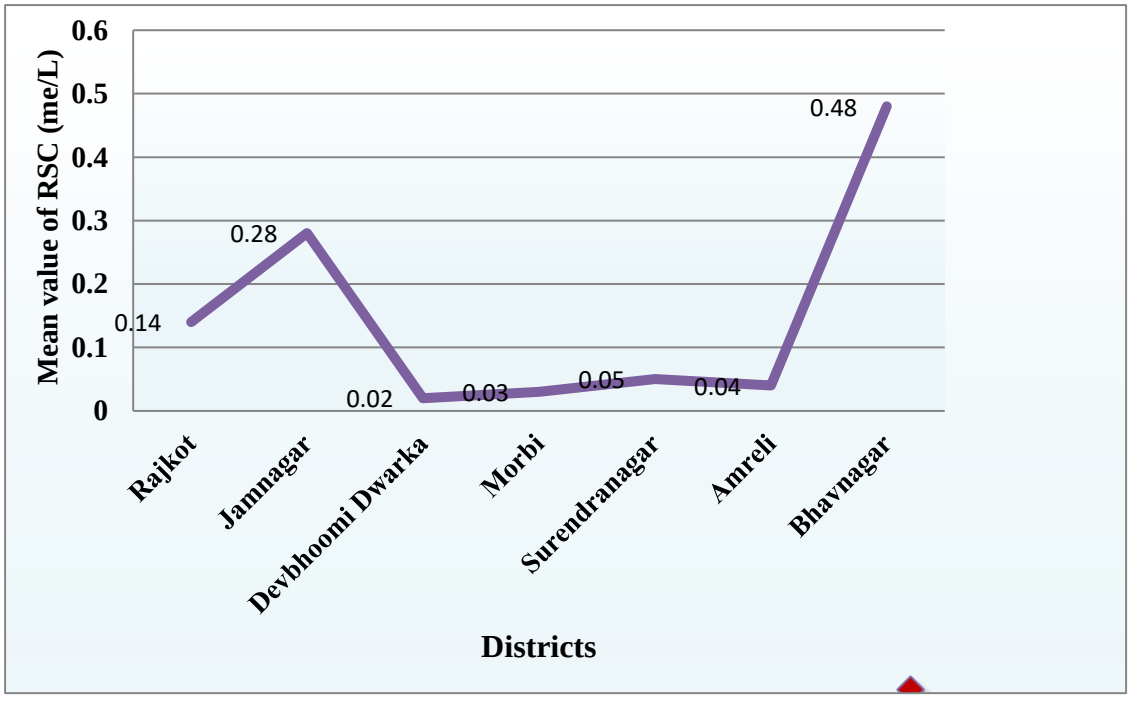

Fig. 4.19: District wise distribution of RSC (me/L) mean value basis in north Saurashtra Agro climatic Zone

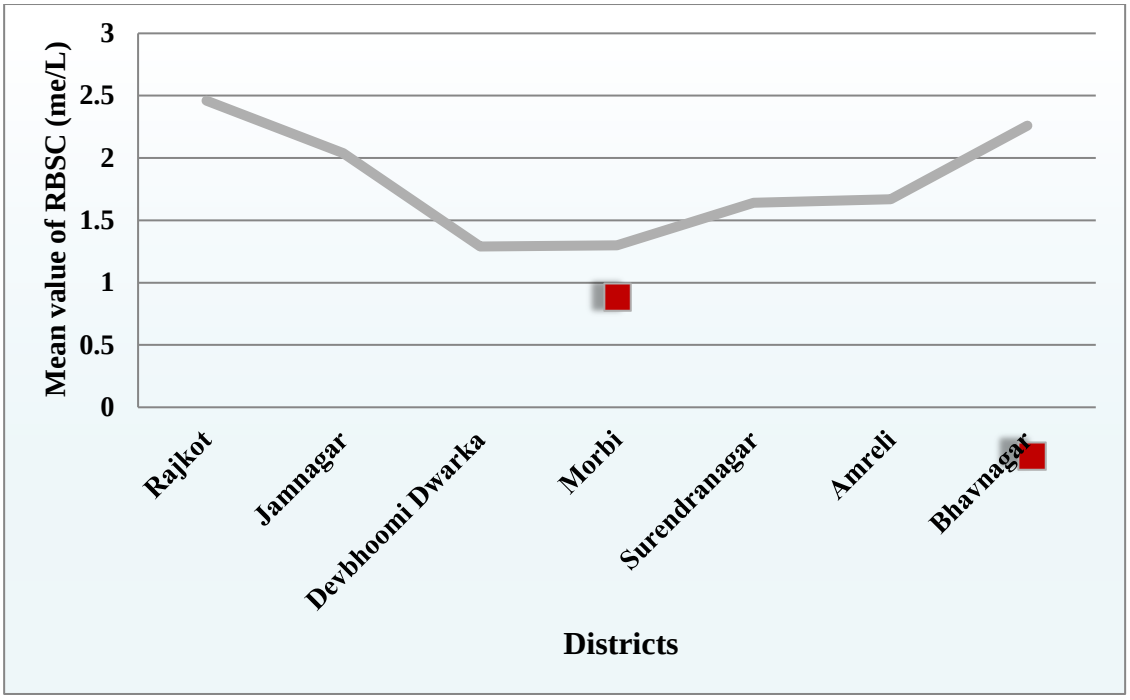

Fig. 4.20: District wise distribution of RSBC (me/L) mean value basis in north Saurashtra Agro climatic Zone

4.2.6 EVALUTION OF UNDERGROUND WATER QUALITY

4.2.6.1 EC (dS/m)

Overall, 0.00, 2.08, 62.50, and 35.42 per cent of the north Saurashtra Agro climatic Zone samples fell into the C_1, C_2, C_3 and C_4 classes of EC, respectively (Table 4.25). The EC values for more than half (62.50 per cent) of the water samples fell between 0.75 and 2.25 dS/m (C_3 class). Approximately 83.75, 75.71, 63.33 and 60.00 per cent of the water samples from the districts of Rajkot, Bhavnagar, Jamnagar and Amreli, respectively, fell under the C_3 category of EC. Therefore, the development of secondary salinization in the soils of the north Saurashtra Agro climatic Zone is caused by the salinity risk of irrigation water.

4.2.6.2 SAR

Overall, the samples fell into the S_1, S_2, S_3 and S_4 classes of SAR, respectively, with 99.58, 0.42, 0.00 and 0.00 per cent, respectively (Table 4.25). Each and Every single water sample had a SAR value of <10 (S_1 class). Non of the samples fit within the SAR classes of S_3 or S_4. The 100 per cent water samples from Rajkot and Devibhoomi Dwarka, 97.75 per cent samples from Amreli to be under S_1 class of SAR to varying degrees (100, 97.75, 100 and 98.33 per cent), respectively. These results

agree with those of Kabaria (2004) for Amreli, Savalia *et al.* (2006), Sojitra (2010) for Junagadh and Rajput and Polara (2013) for Bhavnagar.

4.2.6.3 Water quality with combination of EC and SAR classes

The percentage distribution of underground water samples combination with different classes of EC & SAR are presented in Table 4.26.

C_1S_1 class: out of 480 samples, non of sample fall under under C_1S_1 class. In this class neither salinity nor alkalinity problem for irrigation waters of north Saurashtra Agro climatic Zone.

C_2S_1 class: Total water samples fell into C_2S_1 class have 10 water samples from total 480 samples and 2.08 per cent. The highest 7 samples were observed in Surendranagar district under class C_2S_1. This class has no alkali problem, but salinity is medium and this water can be used with moderately leaching in good quality of water or rain water. Besides, moderate salt tolerance crops should be grown.

C_3S_1 class: Out of the 480 water samples, 300 samples fell under C_3S_1 class. In north Agro climatic Zone, maximum 67 water samples were recorded in Rajkot district and minimum 22 water samples of Devbhoomi Dwarka district. Under C_3S_1 class water have no alkalinity hazard, but have high salinity problem in water. So, this water cannot be used where drainage is restricted and farmers should be raised salt tolerance crops. Besides, additional management practices should be followed.

C_4S_1 class: The total number of 480 water samples 168 samples fell under C_4S_1 class in north Sautrashtra Agro climatic Zone. The highest number (48) water samples of Surendranagar and the lowest (13) in Rajkot district. This class water has no alkali hazard, but indicate very high salinity problem. This water cannot used for irrigation purpose. It can be used occasionally with leaching. Besides, salt tolerant crop should be grown with additional management practices.

C_4S_2 class: From 480 samples only two samples fell under this class. The Jamnagar and Amreli districts contain each one sample of this water class. This class have very high salinity problem (C_4) and medium alkali hazard. Underground water cannot cannot be used for irrigation it can be used concessionally with leaching and salt tolerant crop should be grown with add it on all management practices Alkali risk and salt issue in medium, fine grained soil. This water may come from soils with significant problems.

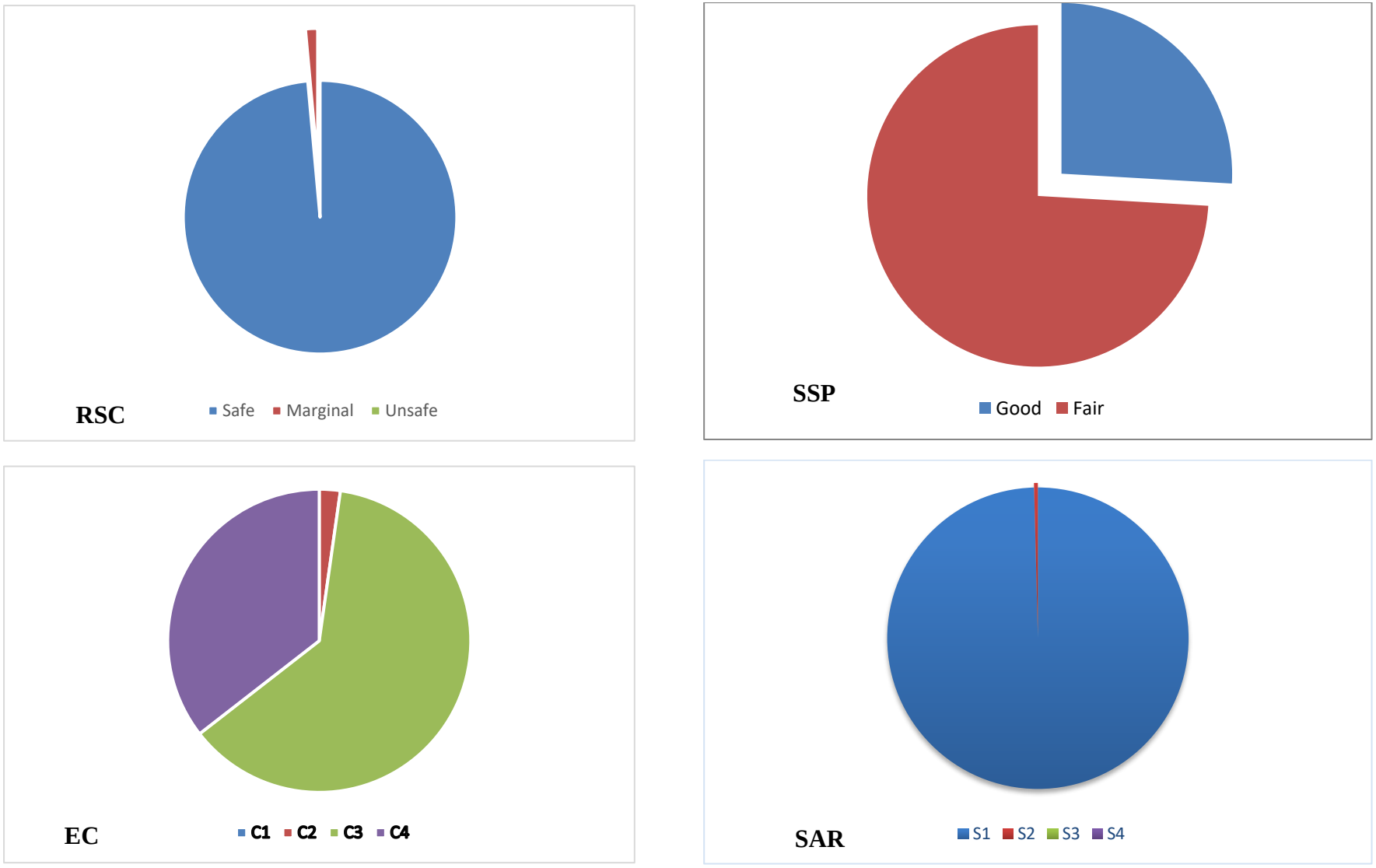

Fig 4.21: Overall percentage of water RSC, SSP, EC and SAR of underground water in north Saurashtra Agro climatic Zone

Table 4.25: Percentage distribution of underground water samples with different EC, SAR, RSC and SSP classes in north Saurashtra Agro climatic Zone

Name of district	EC classes				SAR classes				RSC classes			SSP classes	
	C_1	C_2	C_3	C_4	S_1	S_2	S_3	S_4	Safe	Marginal	Unsafe	Good	Fair
Rajkot	0.00	0.00	83.75	16.25	100	0	0	0	98.25	1.25	0.00	75	25
	(0)	(0)	(67)	(13)	(80)	(0)	(0)	(0)	(79)	(1)	(0)	(60)	(20)
Jamnagar	0.00	1.67	63.33	35	98.33	1.67	0.00	0.00	98.33	1.67	0.00	40.00	60.00
	(0)	(1)	(38)	(21)	(59)	(1)	(0)	(0)	(59)	(1)	(0)	(24)	(36)
Amreli	0.00	0.00	60	40	97.75	1.25	0.00	0.00	100	0.00	0.00	13.75	86.25
	(0)	(0)	(48)	(32)	(79)	(1)	(0)	(0)	(80)	(0)	(0)	(11)	(69)
Bhavnagar	0.00	0.00	75.71	24.29	100	0.00	0.00	0.00	92.86	7.14	0.00	24.29	75.14
	(0)	(0)	(53)	(17)	(70)	(0)	(0)	(0)	(65)	(5)	(0)	(17)	(53)
Morbi	0.00	0.00	54	46	100	0.00	0.00	0.00	100	0.00	0.00	2.00	98
	(0)	(0)	(27)	(23)	(50)	(0)	(0)	(0)	(50)	(0)	(0)	(1)	(49)
Devbhoomi Dwarka	0.00	5.00	55.00	40.00	100	0.00	0.00	0.00	100	0.00	0.00	5.00	95.00
	(0)	(2)	(22)	(16)	(40)	(0)	(0)	(0)	(40)	(0)	(0)	(2)	(38)
Surendranagar	0.00	7.28	45	48	100	0.00	0.00	0.00	100	0.00	0.00	10	90
	(0)	(7)	(45)	(48)	(100)	(0)	(0)	(0)	(100)	(0)	(0)	(10)	(90)
Overall	0.00	2.08	62.50	35.42	99.58	0.42	0	0	98.54	1.46	0	40.42	59.58
	(0)	(10)	(300)	(170)	(478)	(2)	(0)	(0)	(473)	(7)	(0)	(194)	(286)

Table 4.26: Percentage distribution of underground water samples with combination of different classes of EC and SAR (given by Richard, 1954)

Name of classes	Rajkot	Jamnagar	Devbhoomi Dwarka	Morbi	Surendranagar	Amreli	Bhavnagar	Overall
C_1S_1	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_2S_1	(0)	(1)	(2)	(0)	(7)	(0)	(0)	(10)
	0.00	1.67	5.00	0.00	7.00	0.00	0.00	2.08
C_3S_1	(67)	(38)	(22)	(27)	(45)	(48)	(53)	(300)
	83.75	63.33	55.00	54.00	45.00	60.00	75.71	62.5
C_4S_1	(13)	(20)	(16)	(23)	(48)	(31)	(17)	(168)
	16.25	33.33	40.00	46.00	48.00	38.75	24.28	35.00
C_1S_2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_2S_2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_3S_2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_4S_2	(0)	(1)	(0)	(0)	(0)	(1)	(0)	(2)
	0.00	1.67	0.00	0.00	0.00	1.25	0.00	0.42

Table 4.27: Percentage distribution of underground water samples with combination of different classes of EC and SAR (given by Richard, 1954)

Name of classes	Rajkot	Jamnagar	Devbhoomi Dwarka	Morbi	Surendranagar	Amreli	Bhavnagar	Overall
C_1S_3	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_2S_3	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_3S_3	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_4S_3	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_1S_4	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_2S_4	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_3S_4	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_4S_4	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0

*Values in parathesis are number of samples in respective group.

4.3 INTER-RETIAONSHIP BETWEEN DIFFERENT PROPERTIES OF UNDERGROUND WATER

4.3.1 Correlation Study

The correlation among different parameters of water (pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO_3^{-2}, HCO_3^{-}, Cl^{-}, SO_4^{-2}) and with different parameters (pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2}) were worked out and presented in Table 4.28. The examination of correlation of values were indicates that the highly significant positive relation of Cl^{-} with Na^{+} (r=0.994**), Cl^{-}(r=0.962**). Similarly, all the above properties were also correlated Na^{+} with EC (r= 0.968**). Whereas, Ca^{+2} was significant correlated with EC (r=0.474**), Mg^{+2} (r=0.657**), Na^{+} (r = 0.261**), K^{+}(r=0.112*), Hco_3^{-2} (r=0.931**), Cl^{-} (r=0.249**), SO_4^{-2}(r=167**). In case of Mg, the highly positively significant correlated with HCO_3^{-}(r = 0.850**), Na^{+}(r = 0.280**), CO_3^{-2} (r =0.231**), Cl^{-} (r = 0.269**), RSBC (r= 0.920**), SAR (r =0.068), RSC (r = 0.056) and SO_4 (r = 0.187**), Obviously, the Na was significantly correlated with (Table 4.4.1….) HCO_3^{-}(r = 0.283**), Cl^{-}(r = 0.994**), SSP (r= 0.772**), SAR (r= 0.964**), RSBC (r=0.249**) and SO_4^{-2} (r=0.527**).

Available K also significantly correlated with HCO_3^{-} (r = 0.139**) and RSC (r = 0.243**) as well as RSBC (r = 0.144**). Available CO_3^{-2} also significantly correlated with RSC (r = 0.243**) and Cl^{-} (r=0.076). Available HCO_3^{-} significantly correlated with Cl^{-} (r = 0.266**), RSC (r=0.188**), RSBC (r= 0.867**) and SO_4^{-2} (r=0.177**). Available Cl significantly correlated with SO_4^{-2} (r=0.474**), SSP (r=0.766**), SAR (r= 0.960**) and RSBC (r=0.229**). Available SO4 significantly correlated with SSP (r = 0.415**), SAR (r=0.502**), and RSBC (r=0.151**). Available SSP significantly correlated with SAR (r=0.868**). Available RSC significantly correlated with RSBC (r=0.311**).

The SAR significantly correlated with RSBC(r=0.052). Similar results were also obtained by Patel (2004). Almost similar relationships were also obtained by Yadav (1999), Prasad and Prasad (2001).

Table 4.28: Correlation co-efficient among different properties of underground water in north Saurashtra Agro climatic Zone

	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{-2}	HCO_3^{-2}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC	RSBC
pH	1	--	--	--	--	--	--	--	--	--	--	--	--	--
EC	-0.073	1	--	--	--	--	--	--	--	--	--	--	--	--
Ca^{+2}	-0.156**	0.474**	1	--	--	--	--	--	--	--	--	--	--	--
Mg^{+2}	-0.201**	0.475**	0.657**	1	--	--	--	--	--	--	--	--	--	--
Na^{+}	-0.033	0.968**	0.261**	0.280**	1	--	--	--	--	--	--	--	--	--
K^{+}	0.016	0.074	0.112*	0.066	0.056	1	--	--	--	--	--	--	--	--
CO_3^{-2}	-0.083	0.107*	0.115*	0.231**	0.083	0.009	1	--	--	--	--	--	--	--
HCO_3^{-2}	-0.184**	0.497**	0.931**	0.850**	0.283**	0.139**	0.073	1	--	--	--	--	--	--
Cl^{-}	-0.024	0.962**	0.249**	0.269**	0.994**	-0.060	-0.076	0.266**	1	--	--	--	--	--
SO_4^{-2}	-0.088	0.519**	0.167**	0.187**	0.527**	-0.061	-0.055	0.177**	0.474**	1	--	--	--	--
SSP	0.109*	0.644**	0.193**	-0.188**	0.772**	0.009	-0.028	0.205**	0.766**	0.415**	1	--	--	--
SAR	0.021	0.882**	0.060	0.068	0.964**	0.020	0.030	0.063	0.960**	0.502**	0.868**	1	--	--
RSC	-0.033	0.014	0.067	0.056	0.09	0.243**	0.263**	0.188**	0.026	0.144**	0.00	0.11	1	--
RSBC	-0.180**	0.416**	0.626**	0.920**	0.249**	0.144**	0.00	0.867**	0.229**	0.151**	-0.17**	0.052	0.311**	1

* Significant at 5 per cent level
** Significant at 1 per cent level

4.3.2 Regression

Linear regression equations were worked out for predicting from SAR, RSC and SSP the measured EC, pH and SAR of irrigation water regression equation were computed (Table 4.28). The highly significant correlation coefficient (r) values were obtained between EC of irrigation water and SAR of irrigation water in overall samples (Table 4.27). Highly significant correlation coefficient between EC and SAR (r = 0.882**) and between SAR and SSP (r = 0.868**) were observed. Negative correlation were obtained between pH and RSC (r = -0.033).

Table 4.29: Regression equation of EC with SAR, pH with RSC and SAR with SSP of underground water samples in north Saurashtra Agro climatic Zone.

Sr No	**No. of Sample**	**Regression equation (y = a + bx)**	**Per cent of Variance (R_2)**	**Correlation coefficient (r)**
1	480	EC =0.599 + 0.445 SAR	0.778	0.882**
2	480	pH =7.742 -0.064 RSC	0.01	-0.033
3	480	SAR= -5.998 + 0.130 SSP	0.754	0.868**

CHAPTER-V

SUMMARY AND CONCLUSIONS

Groundwater is the most significance source of supplemental irrigation water supply. Crops requires various water qualities for sustained agricultural growth, so analysis of the groundwater is necessary before effective management and ground water quality monitoring is required. With this goal in mind, undertook a study in 2020-2021 titled "Evaluation of underground water quality in north Saurashtra Agro climatic Zone" was conducted in the Department of Soil Science and Agricultural Chemistry at the College of Agriculture, JAU, Junagadh. The north Saurashtra Agro climatic Zone including 7 districts in which 48 talukas are involves. In this view, around taken total 480 water samples from the each talukas taken 10 samples.

These water sample were analysed in laboratory for different parameters such as pH, EC, total cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}) and total anions (CO_3^{-2}, HCO_3- , Cl^{-}, SO_4^{-2}). The values of SAR and RSC were worked out by the formula given by the Richards (1954). Form the water samples EC were also worked out by the formula given by Eaton (1950).

5.1 Quality, salinity and sodicity of underground water in north Saurashtra Agro climatic Zone

1. The groundwater samples from different sources were collected from north Saurashtra Agro climatic Zone and assessed for their chemical parameters. The analysis were performed according to the standard methods for groundwater samples (Richards, 1954). The groundwater samples were classified into different categories of EC, SAR, SSP and RSC values. According to EC value (water classified into 4 classes C_1, C_2, C_3 and C_4), SAR values (water classified into S_1, S_2, S_3 and S_4), SSP values (water classified into 2 classes good and fair) and RSC values (water classified into 3 classes are safe, marginal and unsafe).

2. In the north Saurashtra Agro climatic Zone, total 480 water samples the pH ranged from neutral to alkaline (6.62 to 8.96), with a mean value of 7.75, while their EC values ranged from 0.59 to 5.20 dS/m. Out of 480 samples 60.83 per cent were found to have a pH between 7.5 and 8.5, whereas 34.58 percent of the samples had a pH below 7.5.

3. The frequency distribution of underground well/tube well water samples in relation to EC showed that overall 0, 2.08, 62.50 and 35.42 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively.

4. The relative proportion of cations sodium ion is dominant followed by calcium, magnesium and potassium. In different wells/tube well, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} varied from 1.01 to 12.80, 0.30 to 6.30, 2.08 to 45.30 and 0.00 to 0.60 with mean value of 2.81, 1.78, 13.15 and 0.04 me/L, respectively.

5. Among the different anions chloride is dominant followed by bi-carbonate, sulphate, carbonate. In different wells / tube wells water samples Cl^{-}, HCO_3^{-}, CO_3^{-2} and SO_4^{-2} varied from 1.05 to 44.01, 1.67 to 19.40, 0.00 to 2.30 and 0.00 to 4.17 me/L with mean value of 12.32, 4.67, 0.07 and 0.72 me/L, respectively.

6. The overall residual sodium carbonate values ranged from 0.00 to 1.89 with a mean value of 0.15 me/L. Overall 98.54, 1.46 and 0 per cent samples were found under safe, marginal and unsafe classes of RSC, respectively. The highest mean value (0.75 me/L) and lowest mean value (0.00 me/L) were found in Bhavnagar and Limbdi taluka, respectively.

7. The overall mean value of sodium adsorption ratio observed it was 3.09 and varied from 0.62 to 10.56. The lowest (0.62) and highest (10.56) SAR values were reported in samples collected from Jasdan (Rajkot) and Jam Jodhpur (Jamnagar) talukas, respectively. Overall 99.58, 0.42, 0.00 and 0.00 per cent samples fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively.

8. The overall mean value of soluble sodium percentage was 69.57, which varied from 32.39 to 90.79. The highest mean value (86.98) was recorded in Kalyanpur taluka in Devbhoomi Dawrka whereas the lowest value (47.75) in Rajkot taluka. Overall 40.42 and 59.58 per cent samples fall under good and fair classes of SSP, respectively.

5.2 Inter-relationship between different properties of underground water in north Saurashtra Agro climatic Zone

The highest significant positive relations were observed between EC with SSP and SAR. These indicate that SSP and SAR increase with increasing EC. The SSP was significantly and positively correlated with SAR. The studies showed that there is a need to use underground water with caution. The Na^{+} is highest significant with SAR and Cl^{-}.

5.3 Conclusion

Based on survey work of underground waters of north Saurashtra Agro climatic Zone, it was concluded that amongst the 480 samples analysed, almost half of the samples from farmer's fields were high saline waters (EC 0.75 to 2.25 dS/m). This is indicative of the potential development of saline soil in this region. Therefore, the salt affected soils of this region were mostly due to secondary salinization. The pH of most of the samples (60.83%) ranged from 7.5 to 8.5, which is suitable for irrigation in most of the soils and crops.

In the different underground water cations, sodium is the dominant ion and decreasing concentrations order of: $Na^+ > Ca^{+2} > Mg^{+2} > K^+$. Among the different anions, Cl^- is dominant and decreasing concentrations order of: $Cl^- > HCO_3^- > SO_4^{-2} > CO_3^{-2}$. Range of RSC in majority of the samples (98.54%) was below 1.25 me/L, which is safe for irrigation purpose. Similarly, range of SAR was 0.62 to 10.56 in most samples (99.58%), which is good quality for irrigation. According to USSL classification of underground water, majority of samples fell under C_3S_1 class, which indicates problem of high salinity in underground waters. In the case of SSP, 59.58 per cent samples were found unsafe for irrigation (SSP>60) which might be due to higher concentration of Na^+ ion in underground water. It can be suggested to use good quality of irrigation waters or rain water with moderate leaching. Besides, drip irrigation system for applying irrigation water to the crops and holistic management practices should be implemented for sustainable agriculture in north Agro climatic Zone.

5.4 Suggestion for further work:

1. Groundwater quality monitoring will be useful to prevent future deterioration of soil quality in the regions with poor water quality.
2. The effects of low-quality water should be observed in the soil throughout a range of time periods. Making appropriate management procedures for the impacted areas would be made easier manage to this.
3. To evaluate potential crop damage from soil salinity and alkalinity, routine groundwater monitoring should be conducted.

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Appendix I: General description of soil samples collected from different districts of north Saurashtra Agro climatic Zone
(1) Rajkot district:

Sr. No.	Name of Farmer	Village	Logitude (N)	Latitude (E)	Source of under ground water
JAM-KANDORANA					
1	Jentibhai Devjibhai Dedkiya	Khajurada	70.39264007	21.88546658	Well
2	Mansukhbhai Haribhai Vekariya	Rodhel	70.41418383	21.8589137	Well
3	Babubhai Gopalbhai Ajudiya	Vaibhavnagar	70.42374107	21.88405699	Well
4	Manishbhai Babubhai Chovatiya	Jasapar	70.484813	21.88812109	Well
5	Kanajibhai Vallabhbhai Baldha	Jam-Kandorana	70.48479669	21.87686035	Well
6	Dharmeshbhai Girdharbhai Lunagariya	Boriya	70.50612466	21.92783351	Well
7	Panchaji Kalugi Jadav	Belda	70.52324577	21.92985208	Well
8	Ajitsinh Takhubha Padhiyar	Mota-Dudhivadar	70.49831383	21.84797582	Well
\9	Rajeshbhai Khimajibhai Ranpariya	Nana-Dudhivadar	70.49472688	21.83567504	Well
10	Chandubhai Gordhanbhai Vasoya	Raydi	70.47426347	21.82210711	Well
GONDAL					
11	Nitinbhai Vallabhbhai Gondaliya	Sultanpur	70.85322191	21.77120398	Well
12	Kurjibhai Kanjibhai Kothiya	Bhandaria	70.72634391	21.80422142	Well
13	Parbarbhai Nanjibhai Khachriya	Khambhalida	70.72492066	21.78487479	Well
14	Rakeshbhai Raghavbhai Kachhadiya	Ransiki	70.92356261	21.76271698	Well

15	Vinubhai Kanjibhai Devani	Derdi-Kumbhaji	70.97192425	21.75098926	Tube Well
16	Parshotambhai Vallabhbhai Chovatiya	Moti-Khilori	70.97544531	21.80702738	Well
17	Babubhai Kalubhai Mangrolia	Meta-Khambhaliya	70.96696137	21.81336872	Well
18	Janakbhai Gandubhai Kapadiya	Kamadhiya-Keshwala	70.94560511	21.82771857	Tube Well
19	Ashokbhai Vallabhbhai Chovatiya	Shrinathgadh	70.89069149	21.88026949	Tube Well
20	Rajubhai Kalariya	Moviya	70.86718337	21.89570247	Well
KOTDA SANGANI					
21	Gordhanbhai Bhimajibhai Khunt	Kotda-sangani	70.82551635	21.99869604	Well
22	Tinubhai Jadeja	Khareda	70.83810247	22.01804361	Tube Well
23	Raghubhai Vaghasiya	Rajpara	70.8743537	22.06310024	Well
24	Rambhai Mankad	Ardoi	70.80042732	22.10051292	Well
25	Dhirubhai Punabhai Patoliya	Rajgadh	70.88554483	22.02612324	Well
26	Rushirajsinh Pradhumansinh Jadeja	Manekwada	70.90196784	22.02780842	Well
27	Raghuvirsinh Danubha Jadeja	Panch – Talawada	70.92822673	22.0494192	Well
28	Chanabhai Dudabhai Hirpara	Mota – mandva	70.92874306	22.02856966	Well
29	Mukundbhai Lavabhai Gajera	Ramod	70.93712795	21.97551169	Well
30	Vallabhbhai Jivrajbhai Padaliya	Karmal – Pipaliya	70.97624155	21.99641324	Well
VINCHHIYA					
31	Bhimabhai Danabhai Chauhan	Fulzar	71.32518738	22.08887339	Well
32	Jadavbhai Muljibhai Makawana	Som-pipaliya	71.35718504	22.06960847	Well
33	Govindbhai Arjanbhai Charoliya	Modhuka	71.40054462	22.08529492	Tube Well

34	Bhagwanbhai Govindbhai Makawana	Bandhali	71.41984303	22.08212549	Well
35	Rohitbhai Sarmabhai Kasotiya	Vanala	71.46061063	22.06079422	Well
36	Bhupatbhai Nathubhai Sorthiya	Sanala	71.46851596	22.05010171	Well
37	Vashrambhai Gandabhai Sankaliya	Bhadali	71.45187206	22.02669224	Well
38	Gordhanbhai Kadvabhai Kehla	Janda-Khanjewadia	71.40888672	22.14750689	Well
39	Jivabhai Lalubhai Olakiya	Kandhewalia	71.38920621	22.18305176	Well
40	Dipakbhai Bhanubhai Rajpara	Vinchiya	71.38915151	22.20086257	Well
JASDAN					
41	Girdharbhai Pragjibhai Sakariya	Ishwariya	71.01469899	21.97366798	Well
42	Rameshbhai Karshanbhai Chavda	Kanpar	71.02418811	21.9451093	Well
43	Chaturbhai Gordhanbhai Gadhani	Santhali	71.01945656	21.93029271	Tube Well
44	Sanjaybhai Vekariya	Juna-pipaliya	71.07872761	21.9268859	Well
45	Punabhai Vaghasiya	Jivapar	71.09250454	21.93674979	Well
46	Kantibhai Rokad	Panchvada	71.11251229	21.97252419	Tube Well
47	Bhikhabhai Bavaliya	Aatkot	71.16828399	22.01697728	Well
48	Vallabhbhai Rupabhai Chapadiya	Khanda-Hadmatiya	71.25487747	22.07660907	Well
49	Rajubhai Manjibhai Bavaliya	Hadmatiya	71.25509521	22.08014786	Well
50	Madhubhai Jivarajbhai Chayani	Jasdan	71.21890874	22.03137378	Well
PADDHARI					
51	Lalbhai N. Aahir	Khandheri	70.71172049	22.35760825	Well
52	Hirenbhai Rawatbhai Sonara	Nyara	70.71174733	22.35835389	Well

53	Dineshbhai Valjibhai Sanandiya	Taraghadia	70.68485152	22.3764718	Well
54	Pavanbhai Rangani	Rampar	70.63616492	22.39927299	Tube Well
55	Alpeshbhai Gopalbhai Rathod	Paddhari	70.61936467	22.42659528	Well
56	Lakhabhai Trangaliya	Vanapari	70.57845519	22.43689521	Well
57	Girirajsinh Jayubha Jadeja	Chanol	70.58368399	22.43902031	Tube Well
58	Jitendrabhai Vashrambhai Talapada	Moviya	70.61463206	22.43489158	Well
59	Rameshbhai Limbabhai Talapada	Adbalaka	70.62133894	22.43416189	Well
60	Ramjibhai Khimjibhai Parmar	Nava Naranaka	70.70195891	22.37205857	Well
LODHIKA					
61	Ghanshyambhai Jayantibhai Ramani	Jashvantpur	70.7457118	22.2296072	Well
62	Devshibhai Dhanabhai Desai	Pal	70.75008924	22.20413545	Tube Well
63	Nagjibhai Laxmanbhai Zapda	Dholara	70.75373129	22.22242013	Well
64	Bhaveshbhai Nagjibhai Sorathiya	Ravki	70.73823308	22.20251305	Well
65	Sanjaybhai Muljibhai Ramani	Khambha	70.7255348	22.15289301	Well
66	Kantaben Jayantibhai Ramani	Makhavad	70.6933338	22.15124102	Tube Well
67	Lakhabhai Kurjibhai Ramani	Chibhda	70.68187014	22.15652205	Well
68	Lavajibhai Gangdasbhai Meghani	Sangnava	70.69095869	22.13367816	Well
69	Ramjibhai Aambabhai Pansuriya	Lodhika	70.63592863	22.14009521	Well
70	Babubhai Mohanbhai Hirani	Taravada	70.69582371	22.17565641	Well
RAJKOT					
71	Raghubhai Meghani	Mavadi-(02)	70.76102821	22.24724348	Tube Well

72	Kanjibhai Mohanbhai Parmar	Vejagam	70.72714463	22.3033254	Well
73	Jitubhai Dholakiyawala	Ghanteshwar	70.73073323	22.34519699	Well
74	Naranbhai Rudabhai Morya	Vajdi	70.71172832	22.357621	Well
75	Bhalabhai Jethabhai Makawana	Mota-mava	70.73425034	22.25765279	Tube Well
76	Damajibhai Jivarajbhai Dobariya	Kankot	70.75135526	22.24498912	Well
77	Vallabhbhai Khodabhai Sorathiya	Mavadi-(03)	70.77295938	22.244176	Well
78	Khodabhai Laxmanbhai Sorathiya	Rajkot	70.76568057	22.25185149	Well
79	Manishbhai Devabhai Sorathiya	Mavadi-(01)	70.75473506	22.24545102	Well
80	Amrutbhai Mohanbhai Sorathiya	Rajkot	70.76291792	22.23704416	Well

(2) Amreli district:

AMRELI					
81	Ghanshyambhai Dhirubhai Kasvala	Mota Bhandariya	71.11	21.55	Well
82	Jignaben Himanshubhai Kilavat	Jadiya	71.08	21.54	Well
83	Parsotambhai Dhirubhai Katharotiya	Kerala	71.03	21.53	Tube Well
84	Mansukhbhai Devjibhai Gondaliya	Babapur	71.11	21.52	Well
85	Haribhai Savjibhai Parmar	Gavadaka	71.15	21.54	Well
86	Ranchhodbhai Bhurabhai Sojitra	Nava Khijadiya	71.17	21.56	Well
87	Samatbhai Sathiya	Nana Machiyala	71.23	21.67	Well
88	Dineshbhai Kachhadiya	Mota Machiyala	71.23	21.69	Well
89	Dhanjibhai Parsotambhai Mangaroliya	Jasvantgadh	71.22	21.71	Well

90	Valjibhai Jiyalbhai Naloda	Chital	71.22	21.75	Well
KUNKAVAV					
91	Ukabhai Sambhubhai Patodiya	Amrapar	71.02	21.62	Well
92	Premjibhai Rajubhai Vekariya	Kunkavav	70.98	21.67	Tube Well
93	Pravinbhai Premjibhai Jiyani	Ujala	70.96	21.69	Well
94	Ranchhodbhai Bachubhai Thumar	Vavdi	70.98	21.71	Well
95	Jagdishbhai Laljibhai Kundariya	Anida	70.93	21.68	Well
96	Rameshbhai Bhimajibhai Bhuva	Khajuri Pipaliya	70.91	21.71	Tube Well
97	Vijaybhai Kalabhai Pipaliya	Targhari	70.92	21.71	Well
98	Jentibhai Vasrambhai Khanpara	Khajuri	70.90	21.71	Well
99	Govindbhai Anandbhai Kothiya	Megha Pipaliya	70.90	21.74	Well
100	Pravinbhai Dhanajibhai Vaishnav	Suryapratap gadh	70.92	21.68	Well
BABRA					
101	Rajubhai Babubhai Karad	Bhiladi	71.25	21.76	Well
102	Hareshbhai Karasanbhai Der	Ingorana	71.26	21.79	Well
103	Parsotambhai Manajibhai Karadiya	Babra	71.29	21.83	Well
104	Nareshbhai Goradhanbhai Siyani	Charakha	71.25	21.87	Tube Well
105	Dhirubhai Vipulbhai Khunt	Untvad	71.23	21.91	Well
106	Virakabhai Bijalbhai Gadiya	Kotadapitha	71.21	21.94	Well
107	Jagdishbhai Vallabhbhai Sojitra	Chamaradi	71.23	21.86	Well
108	Babubhai Bhikhabhai Kachela	Khakhariya	71.33	21.88	Well
109	Mulajibhai Jatapara	Kariyana	71.35	21.895	Well

110	Goradhanbhai Bavaji	Isvariya	71.37	21.91	Well
LATHI					
111	Ashokbhai Yadeshbhai Der	Chavand	71.40	21.80	Well
112	Chhaganbhai Manajibhai Desai	Karkoliya	71.41	21.79	Well
113	Bhailalbhai Bavachandbhai Kothiya	Virpur	71.41	21.77	Tube Well
114	Jethabhai Haribhai Sachani	Nana Rajkot	71.43	21.76	Tube Well
115	Ghelabhai Ukabhai Randholiya	Rampar	71.45	21.75	Well
116	Bavachandbhai Mavajibhai Barad	Tajpar	71.46	21.73	Well
117	Shamajibhai Valabhai Vadher	Bhurakhiya	71.46	21.73	Well
118	Dandagiri Bapu (mandir)	Lathi	71.38	21.70	Well
119	Sardulbhai Narsibhai Japadiya	Toda	71.35	21.70	Well
120	Girdharbhai Manajibhai Dhakecha	Kerala	71.34	21.68	Well
DHARI					
121	Ranga Bhila Kakdiya	Chalada	71.19	21.38	Tube Well
122	Rajdeepbhai Mangalubhai Vala	Vavdi	71.19	21.35	Tube Well
123	Hiteshbhai Chhaganbhai Gajera	Dharagani	71.21	21.33	Well
124	Chandubhai Nagajibhai Chovatiya	Lakhapadar	71.16	21.29	Well
125	Vinubhai Chhaganbhai Bhimani	Nagadhra	71.16	21.29	Well
126	Mansukhbhai Gordhanbhai Sabhaya	Madhupur	71.13	21.27	Well
127	Devachandbhai Naranbhai Chodavadiya	Virpur	71.15	21.27	Tube Well
128	Kalubhai Bhikhubhai Vasoya	Devada	71.14	21.23	Well
129	Devasibhai Dayabhai Ribadiya	Ramapara	71.12	21.299	Well

130	Mansukhbhai Bhagavanbhai Sabhaya	Hudali	71.14	21.35	Well
LILIYA					
131	Maheshbhai Karshanbhai Bhuva	Saladi	71.33	21.56	Well
132	Manupari Diyalpari Goswami	Godhavadar	71.35	21.54	Well
133	Kanubhai Arajanbhai Shingala	Mota Liliya	71.37	21.54	Well
134	Babbhai Nathabhai Bhalala	Nana Liliya	71.39	21.49	Tube Well
135	Rameshbhai Nanajibhai Bhalala	Vaghaniya	71.40	21.52	Well
136	Babbhai Khumal	Sedhavadar	71.42	21.49	Well
137	Babbhai Rambhai Jadav	Krankach	71.44	21.47	Tube Well
138	Bharatbhai Khimajibhai Chhodiya	Loki	71.38	21.50	Well
139	Parabatbhai Bhikhabhai Chhodaiya	Loka	71.38	21.50	Well
140	Mavajibhai Kanajibhai Mavani	Bhensavadi	71.37	21.49	Tube Well
SAVARKUNDLA					
141	Khodabhai Ranchhodbhai Laheri	Juna Savar	71.39	21.46	Well
142	Babubhai Bachubhai Kanani	Khadakala	71.34	21.43	Well
143	Chetanbhai Dilubhai Pipaliya	Bhuva	71.33	21.39	Tube Well
144	Pravinbhai Natubhai Jani	Savar Kundala	71.32	21.38	Well
145	Punabhai Tank	Mota Zinzuda	71.37	21.32	Tube Well
146	Giradharbhai Virajibhai Dudhat	Nana Zinzuda	71.39	21.33	Well
147	Vinubhai Dayabhai Baladha	Pithavadi	71.42	21.34	Well
148	Naranbhai Bhikhabhai Kacchadiya	Charakhadiya	71.29	21.39	Well
149	Vinubhai Kathadbhai Hadiya	Goradaka	71.40	21.22	Well

150	Ranabhai Bhurabhai Hadiya	Vijapadi	71.48	21.21	Well
KHAMBHA					
151	Pravinbhai Nagajibhai Vadodariya	Anida	71.20	21.25	Tube Well
152	Lalubhai Mohanbhai Tanti	Ingorana	71.20	21.23	Well
153	Kanubhai Bhikhabhai Dhorajiya	Nana Visavadar	71.20	21.21	Well
154	Rajubhai Dhohabhai Bhuva	Nanudi	71.21	21.18	Well
155	Bharatbhai Goradhanbhai	Khambha	71.23	21.15	Well
156	Valakubhai Mulubhai Magani	Chakarava	71.24	21.12	Well
157	Dulabhbhai Khodabhai Hirani	Pipalava	71.22	21.10	Tube Well
158	Kishorbhai Dhirubhai Amreliya	Khadadhar	71.22	21.09	Well
159	Babubhai Vaghani	Borala	71.20	21.07	Tube Well
160	Amrutbhai Aogadbhai Bhuva	Babarpara	71.19	21.04	Well

(3) Surendranagar district:

LIMBADI					
161	Gadhvi Mansurbhai Ranabhai	Borana	71.3939	22.30337	Well
162	Patel Hirabhai Ashokbhai	Panjari	71.47262	22.31846	Well
163	Dabhi Savjibhai	Choraniya	71.50419	22.34297	Well
164	Madahar Nanjibhai Karshanbhai	Urdi	71.49409	22.33303	Tube Well
165	Zala Shaktisinh Jashubhai	Bhoika	71.52296	22.31155	Well
166	Jadeja Balveersinh Jayrajsinh	Khmabhlav	71.54248	22.3259	Well
167	Mkavana Rakeshsinh Ramsinh	Samala	71.76304	22.63802	Well

168	Dalvadi Ghanshyambhai Prabhabhai	Vachalapara	71.69535	22.25666	Well
169	Patel Gangarambhai Gandabhai	Katariya	71.90383	22.58264	Tube Well
170	Dodiya Ntavarsinh Prabhatsinh	Anandpar	71.76262	22.56826	Well
CHUDA					
171	Zala Dilipsinh Chandubha	Chuda	71.40323	22.29343	Well
172	Jampdiya Dineshbhai Savabhai	Laliyad	71.43182	22.24446	Well
173	Vaghela Thakarsinh Ramji	Gokharvala	71.43245	22.29199	Well
174	Dabhi Tapubhai Lavjibhai	Bhagupur	71.44792	22.27273	Tube Well
175	Metaiyala Harjibhai Hematbhai	Karmad	71.43374	22.25532	Well
176	Mithapara Rameshbhai Manjibhai	Vejalka	71.43177	22.24271	Well
177	Thalvaniya Prabhubhai Harkhabhai	Jobala	71.45192	22.25271	Tube Well
178	Zala Tinbha	Karol	71.38387	22.3141	Well
179	Makvana Natavarsinh Narayanbhai	Mojidad	71.48426	22.28237	Well
180	Mandalia Laljibhai Jethabhai	Sejakpar	71.47315	22.28464	Tube Well
CHOTILA					
181	Harijan Rupabhai Polabhai	Moldi	70.44935	21.50793	Well
182	Madahar Bhushbhai Harjihai	Sangani	71.24169	22.44783	Tube Well
183	Dabhi Dineshbhai Somabhai	Magharikhada	71.16211	22.20228	Well
184	Meniya Bharatbhai Hakabhai	Sapar	71.18237	22.29487	Well
185	Meniya Vanrajbhai Popatbhai	Kandhasar	71.15254	22.27313	Well
186	Jambukiya Raghubhai Khemabhai	Rajvad	71.15659	22.27453	Tube Well

187	Meniya Ramsinhbhai Chaganbhai	Nana Kandhasar	71.14255	22.27847	Well
188	Saravadiya Devrajbhai Devsinhbhai	Navagam	71.11169	22.26469	Tube Well
189	Khvada Mangabhai Alabhai	Nava	71.12534	22.29009	Well
190	Chudasamsa Pruthvirajsinh	Chotila	71.11471	22.25245	Well
SAYLA					
191	Kalapara Dhanabhai Chandubhai	Kalapara	71.21586	22.31266	Tube Well
192	Klapara Smajibhai Popatbhai	Dheduki	71.19427	22.29597	Well
193	Khichhadaia Manshukhai Kukabhai	Hadala	71.19659	22.19653	Well
194	Dabhi Dhirabhai Ramabhai	Tedhuki	71.19506	22.30571	Well
195	Solanki Ratansinh Jilubha	Doliya	71.2128	22.31125	Well
196	Mer Ghanshyambhai Raghabhai	Vakhatpar	71.24277	22.31444	Well
197	Makvana Ishvarbhai Devjibhai	Ghosal	71.24522	22.30656	Tube Well
198	Khachhar Vanrajbhai Kathadbhai	Madargadh	71.24498	22.2948	Well
199	Jograna Rajubhai Valubhai	Jashapar	71.25264	22.29316	Well
200	Durgadash Laljibhai	Zayla	71.28234	22.3251	Well
MULI					
201	Shardiya Manshukhbhai Maiyabhai	Jepar	71.12587	22.43404	Well
202	Vaghela Ajitsinh Bachubha	Virpar	71.13364	22.46226	Well
203	Jejariya Premjibhai Merabahi	Velala	71.17553	22.46352	Tube Well
204	Sapara Jayantibhai Hindubhai	Vaddhrra	71.15294	22.463	Well
205	Vaghela Digvijaysinh Samarsinh	Khampaliya	71.18788	22.44568	Well

206	Sormiya Bhratbhai Govindbhai	Gadhdha	71.44877	22.63782	Well
207	Rabari Devabhai Rupabahi	Dudhai	71.20321	22.41104	Well
208	Dangar Pratapbahi Dhirubhai	Ramparda	71.21527	22.39567	Tube Well
209	Parmar Dilipsinh Gambhirsinh	Muli	71.27526	22.38354	Well
210	Parmar Bopalal Bharatsinh	Sekhapur	71.3343	22.42246	Tube Well
THANGADH					
211	Bharvad Hamirbhai Gelabhai	Gugaliyana	71.13449	22.32298	Well
212	Degama Jinaben Narsinhbhai	Jmaavali	71.13828	22.32563	Well
213	Chavda Bhupatbhai Narsinhbhai	Amrapar	71.22488	22.36153	Well
214	Golkar Madhabhai Motibhai	Navagam	71.10392	22.37535	Well
215	Badurbhai Bhagatbhai	Thangadh	71.12356	22.37003	Tube Well
216	Karelia Surabhai Kumalbhai	Kanpar	71.12358	22.3778	Well
217	Zala Babubhai Danabhai	Vijaliya	71.11324	22.39311	Well
218	Charadiya Chanabhai Mohanbhai	Tarnetar	71.12771	22.40215	Well
219	Sardiya Jigabhai Sanabhai	Ranipat	71.12564	22.40585	Well
220	Zala Jaydipsinh Ranjitsinh	Kanpar	71.33947	22.55139	Tube Well
SURENDRANAGAR					
221	Gagjibhai Devabhai	Kothariya	71.43376	22.45469	Tube Well
222	Sindiv Prabhabhai Karsanbhai	Anindra	71.65592	22.82849	Well
223	Herma Chandubhai	Bakathali	71.60548	22.7755	Well
224	Mandva Kishorbhai	Dudhrej	71.62526	22.73302	Well

225	Parmar Dilubha	Kherali	71.60356	22.6903	Well
226	Gohil Shaktibhai Manubhai	Thoriyali	71.38387	22.3141	Well
227	Dodiya Bhupatsinh Banesinh	Nana Kerala	71.4429	22.40105	Tube Well
228	Bhutiya Ajitbhai Abubhai	Memka	71.48358	22.48222	Well
229	Pitroda Rajubhai	Ratanpar	71.37181	22.4224	Well
230	Panechada Mansukhbhai Gandabhai	Wadhvan	71.63193	22.71235	Well
LAKHTAR					
231	Patel Ngarbhai Aamthubhai	Jamar	71.45506	22.17751	Well
232	Bavaliya Narsingbhai Vitthalbhai	Lakhtar	71.46598	22.50454	Well
233	Kanabhai Karshanbhai	Aadalsar	71.50608	22.53499	Well
234	Aswinbhai Jaysinhbhai	Lilapur	71.466	22.50524	Tube Well
235	Rmnikbhai Devsibhai	Larkhadiya	71.46128	22.53013	Well
236	Parmar Pratapbhai Jaysingbhai	Sadad	71.42312	22.54589	Well
237	Zala Lavjibhai Mnubhai	Vana	71.46153	22.53794	Well
238	Zala Ajaysinh	Chahad	71.52258	22.52352	Tube Well
239	Golani Himmatbhai Soghalbhai	Pedhda	71.90338	22.56506	Well
240	Laxmanbhai Ghelabhai	Bhalala	71.77639	22.82256	Well
PATLI					
241	Chavda Ajitbhai Ramanbhai	Malvan	71.43437	23.32792	Well
242	Chavda Prabhabhai Muljibhai	Bajana	71.46299	23.83222	Tube Well
243	Rabari Laljibhai Berar	Patdi	71.47323	23.9583	Well

244	Patel Asvinkumar Jivrajbhai	Salvas	71.50126	23.10906	Well
245	Bhuva Dipakbhai Laljibhai	Joravarpuara	71.57278	23.11365	Well
246	Rabari Raghubhai Bachubhai	Surajpura	71.80642	23.17886	Well
247	Tardiya Rajubhai Devabhai	Jarvala	71.4834	23.19475	Well
248	Patel Manikbhai Somabhai	Gediya	71.72287	23.01013	Tube Well
249	Rthvai Maheshbhai Somabhai	Odu	71.68474	23.22829	Well
250	Harijan Mohanbhai Rajabhai	Malvan	71.3937	23.3118	Well
DHANGADHRA					
251	Kaiyla Harjibhai Pran	Metahn	71.3937	22.5848	Well
252	Zala Paratapbhai Ramanbhai	Mnpur	71.41137	23.83514	Well
253	Koli Dhanjibhai	Chuli	71.21239	23.01266	Tube Well
254	Ghanshyambhai Narsinhbhai	Soladi	71.26363	22.59566	Well
255	Zala Shaktisinh	Rajpar	71.21239	23.12062	Well
256	I. K. Jadeja	Dhrangadhra	71.27211	23.49883	Well
257	Zala Vanrajsinh N.	Satapar	71.26301	23.73992	Well
258	Dalvadi Ghnashyambhai Devji	Virendragadh	71.41517	23.07298	Well
259	Zala Bhratsinh	Thuthuwada	71.44422	23.00372	Well
260	Mahadev Kalyan	Dudapur	71.54747	23.10311	Well

(4) Bhavnagar district:

GARIYADHAR					
261	Kamabhai Naranbhai Avaya	Luvari	71.56417	21.46389	Well
262	Karamsinhbhai Mohanbhai Ghelani	Dhasa	71.582	21.454	Well

263	Vinubhai Vallubhabhai Gjelani	Gujarda	71.583	21.454	Well
264	Ghelubha Sujansinh Sarviya	Ganeshgadh	71.61	21.449	Tube Well
265	Pravinbhai Kakdiya	Rupavati	71.66	21.472	Well
266	Sambhubhai Lavabhai Dhaduk	Samadhiyari	71.64917	21.45528	Well
267	Kanjibhai Lavabhai Dhaduk	Bhandariya	71.62528	21.47861	Tube Well
268	Jivanbhai Lavjibhai Goyani	Pasegam	71.58611	21.53167	Well
269	Vinubhai lavjibhai Goyani	Parvadi	71.63139	21.5725	Well
270	Bhartbhai Govindbhai Gajera	Gariyadhar	71.56972	21.53778	Well
PALITANA					
271	Govindbhai Jivrajbhai Gajera	Chhatapra	71.4724	21.3059	Tube Well
272	Bhimjibhai bhavanbhaivaholiya	Vadal	71.5025	21.292	Well
273	Vasudevsinh Kripalsinh Sarviay	Hathasni	71.72083	21.43917	Well
274	Raghuveersinh Ranubha Sarviya	Hastgiri	71.82194	21.51278	Well
275	Hasanbhai Kashambhai Sandhi	Dungarpur	71.81111	21.46639	Well
276	Ghohabhai Gilabhai Bhadarka	Jariya	71.72889	21.70639	Well
277	Karamsinhbhai Mohanbahi Chavada	Dedarda	71.71889	21.49	Tube Well
278	Hirabhai Sababhai Makvana	Kanjarda	71.74306	21.48361	Tube Well
279	Gohil Harpalsinh M.	Lapadiya	71.5529	21.2657	Well
280	Gohil Pradumansinh M.	Metha	71.5614	21.2613	Well
SIHOR					
281	Malubha Natubha Gohil	Aniyari	72.0125	21.59694	Well

282	Parbatsinh Natubha Gohil	Bhamgadh	71.5635	21.0118	Well
283	Maldevsinh Natubha Gohil	Varal	71.585	21.313	Well
284	Vikramsinh Natubha Gohil	Thara	71.6914	21.33	Well
285	Pravinsinh Natubha	Thoradi	72.18917	21.64528	Tube Well
286	Dipubha Lakhubha Gohil	Kanad	71.93306	21.65028	Well
287	Gaba Meabhai Ulava	Tana	71.97556	21.6575	Well
288	Devsinhbhai Meramanbhai Ulava	Bordi	71.5816	21.3019	Well
289	Narsang Ukabahi Mori	Kajavadar	71.97	21.65139	Tube Well
290	Sursangbhai Umjibhai	Sihor	71.94833	21.71694	Well
BHAVNAGAR					
291	Gobarbhai Merabhai Chavda	Alapar	72.144	21.352	Well
292	Rameshbhai Valabhai	Kotda	72.10889	21.96528	Well
293	Rameshbhai Chandubhai	Vavdi	72.18111	21.6175	Well
294	Amarben Deshurbhai	Kardej	72.025	21.75583	Tube Well
295	Kanksinh Ghanshyamsinh Gohil	Nava Ratnpara	72.27667	21.64556	Well
296	AshoksinhJethubhaGohil	Gundala	71.95204	21.55111	Well
297	Rajendrsinh Sahdevsinh Gohil	Budhel	72.0902	21.4138	Tube Well
298	Hitendrsinh Rajendrsinh Gohil	Malpar	72.1102	21.3957	Well
299	Rushirajsinh Bhimdevsinh Gohil	Kanpar	71.5248	21.5831	Well
300	Sukhdevsinh Nirmalsinh Gohil	Italiya	71.92028	21.97806	Tube Well
VALLABHIPUR					
301	Lakirajsinh Sukhdevsinh Gohil	Chada	71.4437	21.58	Well

302	Harishchandsinh Ghanshyamsinh Gohil	Dared	71.74111	21.97444	Well
303	JAU Farm	Vallbhipur	71.5236	21.5301	Well
304	Vanrajsinh Vajeshinh Gohil	Patana	71.945	22.05167	Well
305	Pravinbhai Bhagvanjibhai Munjani	Pati	71.87194	21.86972	Tube Well
306	Amsinhbhai Kalubhai Mathukiya	Bhojpara	72.0001	21.4512	Tube Well
307	Pravinaben Chaganbhai Vaghasiya	Meghavadar	71.5018	21.5151	Well
308	Dayabhai Mayabhai Ahir	Melana	71.77361	21.96694	Well
309	Gohil Jagatsinh	Pipali	71.87083	21.89528	Well
310	Gohil Ranjubha Natubha	Vallbhipur	71.88861	21.88889	Tube Well
UMRALA					
311	Jaypalsinh Narendrasinh Gohil	Malpara	71.79167	21.77556	Well
312	Shivrajsinh Narendrasinh Gohil	Hadiyad	71.78944	21.91111	Well
313	Manharsinh	Dedakdi	71.72139	21.80694	Well
314	Narendrasinh Bharatsinh Gohil	Iswariya	71.79667	21.74139	Well
315	Digvijaysinh	Vadod	71.74361	21.91472	Tube Well
316	Sandeepsinh	Reva	71.80722	21.76389	Well
317	Nandirajsinh Samratsinh Gohil	Dhola	71.70944	21.90111	Tube Well
318	Raghuveersinh Bharatsinh Gohil	Limda	71.63472	21.79611	Well
319	Vijaysinh Ranjubha Gohil	Ranghola	71.67444	21.75944	Well
320	Lakhubha	Dadava	71.75306	21.87556	Tube Well

JESAR					
321	Elaba Hardevsinh Sarvaiya	Mota Bhamodara	71.60833	21.37389	Tube Well
322	Kanubhai Melabhai Kamliya	Selana	71.62417	21.39167	Well
323	Jagdishbhai Labhubhai Koradiya	Pipavadli	71.60028	21.375	Well
324	Hirenbhai Jadavbhai Kachhi	Katarodi	71.60833	21.35889	Well
325	Badukbhai Madhubhai Desai	Jadakla	71.62083	21.37306	Well
326	Bhavsangbhai Jivrajbhai	Pa	71.63833	21.36278	Tube Well
327	Dhanjibhai Ranchodbhai Chavda	Jeshar	71.66389	21.36444	Well
328	DhakarsinhBhai Ukabhai Parmar	Jeshar	71.66806	21.36306	Well
329	Surabhai Dhirubhai Parmar	Delpa	71.65556	21.40833	Tube Well
330	Govindbhai Popatbhai Zalavadiya	Santinagar	71.76278	21.52139	Well

(5) Jamnagar district:

JAMNAGAR					
331	Chaganbhai Mudjibhai Parmar	Jam-Vanthali	70.32	22.43	Well
332	Juvansinh Deepsinh Jadeja	Motilakhani	70.3	22.47	Well
333	Jagabhai Naranbhai Jani	Khilosh	70.31	22.5	Well
334	Maheshbhai Khimjibhai Vashjadiya	Falla	70.28	22.52	Tube Well
335	Ombhai Sanjaybhai Modi	Jambuda	70.2	22.51	Well
336	Jagdishbhai Chanan	Vavdi	70.02	22.09	Well
337	Milan Gordhanbhai Nanda	Dadiya	70.08	22.39	Well
338	Hemantbhai Der	Chela	70.05	22.38	Well
339	Lakha Parbat Khuti	Changa	70.03	22.35	Well

340	Miteshbhai Bhalodiya	Changa	70.02	22.32	Well
JAM-JODHPUR					
341	Anilbhai Bavanjibhai Bhadaniya	Valasan	70.07	22	Well
342	Jayeshbhai Hashrajbhi Chovtani	Dhrafa	70.08	22.04	Well
343	Nileshbhai Jamanbhai Dadhaniya	Shethvadala	70.07	22.02	Well
344	Hardashbhai Mirshinhbhai Gagiiya	Samana	70.09	22.06	Tube Well
345	Rajubhai Dadhaniya	Veral	70	22.02	Well
346	Girishbhai Vashantbhai Sutariya	Jamvadi	70.18	22.07	Well
347	Sanjaybhai Boghabhai Surela	Jamjodhpur	70	22	Tube Well
348	Laxmanbhai Jivabhay Nagash	Bavishikotada	70.04	22	Well
349	Jethabhai Madanbhai Kanet	Mevasha	70.16	22	Well
350	Girdharbhai Samjibhai Abhagi	Narmala	70.15	22.09	Well
JODIYA					
351	Munabhai Popatsinh Vaghela	Balachadi	70.21	22.6	Well
352	Devabhai Patel	Limbula	70.29	22.61	Well
353	Maganbhai Khodabhi Kasundra	Khiri	70.13	22.34	Well
354	Bhavanbahi Kamabhai Sondarva	Kunad	70.28	22.64	Well
355	Rajeshbhai Chanabahi Sondarva	Badnpar	70.29	22.64	Well
356	Hiteshbhai Hirjibhai Nakum	Alada	70.3	22.67	Well
357	Ganeshbhai Parshotambhai Nakum	Jodiya	70.18	22.42	Well
358	Bhagvanjibhai Vasarambhai Bhalodiya	Jodiya	70.18	22.41	Well
359	Mangnbhai Jadvbhai Ghetiya	Badra	70.31	22.6	Well

360	Danjibhai Chanabhai Pethadiya	Lakhatar	70.36	22.65	Well
KALAVAD					
361	Ambabhai Devrajbhai Trada	Bhavbhi-Khijadiya	70.26	22.03	Tube Well
362	Jitubha Sujaji Jadeja	Toda	70.23	22.03	Well
363	Vrjlalbhai Meghajibhai Akbari	Rinari	70.22	22.06	Well
364	Pankajbhai Devrajbhai Pansuriya	Sarvaniya	70.22	22.1	Tube Well
365	Jadeja Majbutsinh Bapalal	Machhhalivad	70.16	22.09	Well
366	Jadeja Sukhdevsinh Bapalal	Khakhriya	70.16	22.1	Well
367	Mansukhbhai Bachubhai Sangani	Sanala	70.2	22.11	Tube Well
368	Vithalljibhai Bavanjibhai Rokadiya	Kalavad	70.21	22.22	Well
369	Dhirajlal Khimjibhai Vasoya	Haripar	70.36	22.24	Well
370	Vijaybhai Nathabhai Sakhiya	Vodisang	70.35	22.27	TubeWell
DHROL					
371	Mukeshbhai Becharbhai Dalsaniya	Dhrol	70.39	22.61	Well
372	Dineshbhai Bhagvanjibhai Nakum	Dhrol	70.44	22.55	Well
373	Daramsinhbhai mudjibhai Santoki	Vakiya	70.23	22.33	Well
374	Ashokbhai Bhagvanjibhai Getiya	Soyal	70.21	22.33	Tube Well
375	Pravinbhai Narjimbhai Mistri	Sanosara	70.3	22.27	Well
376	Nandarambhai gurjibhai Kansagra	Dangra	70.2	22.31	Tube Well
377	Kiranben Bipinbhai Kathrotiya	Nathuvadala	70.21	22.35	Well
378	Prabhaben Gordhanbhai Kagathra	Nathuvadala	70.21	22.34	Tube Well
379	Jasuben Hareshbhai kagathra	Majeth	70.21	22.37	Well

380	Kanjariya Chadresh Vasrambhai	Neshda	70.19	22.36	Tube Well
LALPUR					
381	Saileshbhai Ashokbhai Arathiya	Khatiya	70.12	22.17	Well
382	Parshbhai Kariya	Mota Pachashra	70.11	22.21	Well
383	Dharnarajbhai laxmanbhai Suva	Vadpachasra	70.11	22.22	Tube Well
384	Kishorsinh Jaysinh Jadeja	Gula	70.1	22.24	Well
385	Girdharbhai Ukabhai Ghadiya	Pipartoda	70.09	22.26	Tube Well
386	Hiralal Ratilal Raytha	Moti Veraval	70.08	22.36	Well
387	Mohan Pancha Marakna	Haripar	70.09	22.1	Well
388	Damjibhai Khodabhai Kothiya	Arikhana	69.99	22.24	Tube Well
389	Dalsukhbhai Parbatbhai Solanki	Dharampur	69.89	22.12	Well
390	Babubhai Harshadbhai Barad	Sanosri	70.06	22.11	Well

(6) Devbhoomi Dwarka district:

BHANVAD					
391	Rana Mandan	Gundala	69.405	22.0049	Well
392	Suka Sarman Gondalia	Gunda	69.683	21.876	Tube Well
393	Kanbhai Samatbhai Banta	Timdi	69.792	21.876	Well
394	Sanjaybhai Tapubhai Gundhadiya	Ghumali	69.773	21.892	Tube Well
395	Nathabhai Parbatbhai Pipalia	Bhanvad	69.777	21.905	Well
396	Jentibhai Gokalbhai Parmar	Bhanvad	69.756	21.929	Tube Well
397	Lakhman aakand pipalia	Rupamota	69.737	21.951	Well
398	Khimaji Gova Gorfad	Jamrojivada	69.729	21.968	Well

399	Musabhai Jusabbhai Igoda	Ranarotivada	69.721	21.979	TubeWell
400	Nagabhai Naranbhai Karmur	Fat	69.669	22.024	Well
JAM-KHAMBHALIA					
401	Devakandbhai Naranbhai karmur	Moti khokhri	69.662	22.064	Well
402	Jivabhai Jethabhai Mapada	Juna tathiya	69.656	22.107	Well
403	Vinubhai Hamirbhai Bharvad	Laliya	69.646	22.139	Tube Well
404	Jagabhai Bhimabhai Bharvad	Mambh	69.645	22.143	Well
405	Ramaben Rameshbhai Kanjaria	Ramnagar	69.636	22.189	Well
406	Kantilal Hirabhai Hadiyal	Harsadpur	69.627	22.211	Tube Well
407	Vinubhai Kumbhar	Jamkhambhadia	69.61	22.207	Well
408	Pabubhai Bharabahi Gadhvi	Kuvadia	69.588	22.209	Well
409	Govindbhai Pababhai Dethriya	Anshthar	69.556	22.211	Tube Well
410	Bhimshibhai Hardalbhai karangiya	Vadtar	69.533	22.207	Well
KALYANPUR					
411	Mohanbhai Godkanbahi Parmar	Juvanpur	69.359	22.164	Tube Well
412	Ramjibhai Khimabhai Hadiyal	Ran	69.331	22.169	Well
413	Nebhabhai Vaghshibhai Kantodiya	Mahadevia	69.279	22.174	Tube Well
414	Munubhai Palabahi Suva	Ranjatpur	69.206	22.19	Well
415	Palabhai Naranbhai Karmur	Gurgadh	69.198	22.194	Well
416	Govabhai Bhapabhai Chavda	Bhogat	69.249	21.985	Well
417	Masri Markhibhai Karmur	Navdra	69.256	21.972	Tube Well

418	Pamiben Bhulabhai Nakum	Nandana	70.03	22.003	Well
419	Nileshbhai Somabhai Babaria	Lamba	69.279	21.95	Well
420	Valiben Ramabhai	Gangadi	69.307	21.913	Well
DWARKA					
421	Dashrathbhai Bakubhai Parmar	Charkala	69.111	22.203	Well
422	Hamirbhai Meramanbhai Karngiya	Tumpani	69.111	22.225	Well
423	Savdasbhai Nakubhai Madam	Tumpani	69.123	22.24	Tube Well
424	Chavda Sumat Vatshibhai	Murvel	69.111	22.261	Well
425	Jashabha lakhubha Shobhaniya	Nageshwar	69.101	22.337	Well
426	Ludabha Ranmalbha Sumaniya	Kalapar	69.054	22.307	Well
427	Ashabha Devubha Ker	Gorija	69.044	22.169	Tube Well
428	Khetabhai Virabhai Varmal	Okhamadhi	69.113	22.087	Tube Well
429	Dula Pabu Beratiya	Kuranga	69.169	22.054	Well
430	Hardal Rayabhai Kariya	Ariyana	70.54	23.01	Well

(7)Morbi district:

MORBI					
431	Koriya Shivlal Dayabhai	Kantipur	70.68	22.85	Well
432	Sarojben Chandulal	Gorkhijadiya	70.79	22.87	Well
433	Patel Vinodbhai Devshibhai	Khakhrada	70.75	22.88	Well
434	Kavadiya Chandulal Devshibhai	Jepur	70.77	22.87	Well
435	Loriya Karamshibhai Bhagvanjibhai	Hajnadi	70.8	22.88	Well
436	Gadara Manshukh Dharamshibhai	Dharmpur	70.83	22.86	Well

437	Virsodiya Jasuben Valamjibhai	Laxminagar	70.83	22.89	Well
438	Charola Ashokbhai Madhavjibhai	Amreli	70.83	22.85	Tube well
439	Sarathava Vasant Ratanshibhai	Bagathava	70.73	22.85	Well
440	Bhimani Khantim Maganbhai	Khanpar	70.71	22.9	Well
MALIYA-MIYANA					
441	Saradava Laljibhai L.	Motabhela	70.69	23.02	Well
442	Premji Nathabhai	Sarvad	70.7	22.99	Tube Well
443	Kangad Ravatbhai Polabhai	Nanibarar	70.7	23.03	Well
444	Kangad Polabhai Lakhmanbhai	Jashapar	70.72	23.05	Tube Well
445	Ramji Ravji Bhomnak	Juna Ghantila	71.03	23.12	Well
446	Revabhai Khodabhai Saradva	Bhavpar	70.65	23.06	Well
447	Dhirubhai Ranabhai Balra	Vagharva	70.81	23.05	Tube Well
448	Iqbalbhai B. Dalal	Maliya	70.76	23.09	Well
449	Ganeshbhai P. Patel	Manaba	70.87	23.07	Well
450	Odhvji Naranbhai Vaghdiya	Nana Bhela	70.8	22.99	Tube Well
TANKARA					
451	Rangpariya Chandrashekhar Dhanjibhai	Dhunda	70.73	22.72	Well
452	Rajnetia Jitedra Ramjibhai	Nesda	70.7	22.68	Well
453	Hemat Nanjibhai	Hirapar	70.72	22.61	Well
454	Makanbhai Dayabhai	Savdi	70.66	22.6	Tube Well
455	Dhethi Ganeshbhai Arjanbhai	Saraya	70.68	22.6	Tube Well

456	Boriya Pravinbhai Jivrajbhai	Lakhdhirgadh	70.73	22.66	Well
457	Gauriben Maganbhai Kamariya	Jabalpur	70.74	22.63	Well
458	Chamrashibhai Karshanbhai Koringa	Lakhdhirgadh	70.75	22.67	Well
459	Balji Gangaram Bhimni	Vagadh	70.87	22.65	Well
460	Bhagvanji Amarashi Dalsaniya	Medhpar (Zala)	70.67	22.66	Well
HALVAD					
461	Marvaniya Pranjivanbhai	Mathku	71.05	22.84	Well
462	Pranjivanbhai	Chamli	71.04	22.85	Tube Well
463	Panara Jayshukhlal Kanjibhai	Manekvada	71.06	22.77	Well
464	Dethariya Chandrakant Harjibhai	Tikar	71.18	23.02	Well
465	Patel Veljibhai Mahadevjibhai	Gokudiya	71	23	Well
466	Patel Kantilal Bhudarbhai	Juna Devadiya	71	23.01	Tube Well
467	Vasudev Pragjibhai Dalvadi	Chanradva	71.02	22.93	Well
468	Jayantilal Valjibhai	Shivpur	71.08	22.89	TubeWell
469	Jethabhai Nanjibhai Katotara	Susvav	71.09	22.99	Well
470	Keshubhai Charola	Saranbhda	71.09	23.01	Well
WANKANER					
471	Bada Rehmatben Mohmad	Kerada	71	22.5	Tube Well
472	Shersiya Mahmadbhai Aamadbhai	Jodhpur	70.82	22.56	Well
473	Khorjiya Nurmamad Haji	Tithva	70.88	22.58	Tube Well
474	Kadivar Alavadi Mimanji	Valasan	70.87	22.55	Well
475	Kanabar Kapilbhai	Ratidevdi	70.92	22.63	Well

476	Badi Usman Ahmad	Samadhiyada	71.07	22.5	Well
477	Mathukiya Rasul Hasanbhai	Garida	71.05	22.5	Well
478	Parasara Ibrahim Jalal	Sindhavadar	70.89	22.55	Well
479	Shersiya Ismail Alibhai	Didhaliya	71.05	22.58	Well
480	Kharasara Usman Ahmad	Panchdwarka	70.88	22.58	Tube Well

Appendix II: Sample wise cations, anions and different water quality indices of underground water samples of nouth Saurashtra Agro climatic Zone

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
1	7.29	1.5	3.6	2.1	7.25	0.06	0	5.7	6.45	0.17	56.19	1.52	0	2.1
2	7.1	1.06	2.8	1.5	4.76	0.04	0	4.5	4.05	0.4	52.75	1.15	0.2	1.7
3	7.39	0.79	2.1	1.4	2.85	0.1	0.2	3.51	3	0.08	45.74	0.76	0.21	1.41
4	7.61	0.88	2.25	1.41	3.32	0.1	0	3.67	3.2	0.06	48.31	0.87	0.01	1.42
5	7.01	2.07	3.6	2.4	12	0.04	0	6.1	10.1	0.94	66.74	2.45	0.1	2.5
6	7.36	1.37	2.9	1.9	7.12	0.02	0	5.4	5.91	0.54	59.80	1.62	0.6	2.5
7	7.81	0.87	1.76	1.4	3.3	0.01	0	3.54	3.1	0.08	51.16	0.93	0.38	1.78
8	7.1	1.11	1.5	0.9	6.9	0.03	0.2	3.1	4.6	0.04	74.28	2.23	0.9	1.6
9	7.33	1.4	3.7	2.1	6.08	0.06	0	5.8	6.04	0.17	51.42	1.26	0	2.1
10	7.6	1.17	1.51	0.94	7.9	0.03	0.2	2.5	6.2	0.04	76.40	2.52	0.25	0.99
11	7.16	4.4	12.8	6.3	17.65	0.02	0	19.4	16.76	0.56	48.06	2.02	0.3	6.6
12	7.34	2.89	4.9	3.6	11.1	0.05	0	8.5	9.8	1.58	56.74	1.90	0	3.6
13	6.62	2.87	5.4	3.6	14.75	0.04	0	9.1	13.4	1.52	62.17	2.46	0.1	3.7
14	7.64	1.21	3.1	1.9	5.2	0.08	0	5	5.1	0.46	51.36	1.16	0	1.9
15	7.68	1.2	1.6	1.2	6.7	0.02	0	3.2	6.4	0.03	70.59	2.00	0.4	1.6
16	6.92	1.44	3.2	1.9	7.2	0.04	0	5.1	7.02	0.65	58.67	1.59	0	1.9
17	7.58	3.18	7.8	4.5	15	0.28	0	12.3	14	1.08	55.40	2.14	0	4.5
18	7.46	4.45	8.4	6.2	26	0.02	0	14.7	25.74	0.54	64.06	3.40	0.1	6.3
19	7.49	1.18	3.12	1.8	4.05	0.6	0.1	5.4	4.04	0.8	48.59	0.91	0.58	2.28
20	7.5	0.96	1.9	1.2	5.69	0.03	0.8	2.3	4.5	0.46	64.85	1.62	0	0.4
21	7.29	2.13	4.1	2.9	11.7	0.03	0	7.2	11	0.77	62.63	2.21	0.2	3.1
22	8.23	1.1	2.8	2.1	3.65	0.03	0	5.01	3.85	0.81	42.89	0.82	0.11	2.21

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
23	7.23	0.99	2.4	1.8	4.69	0.07	0	4.3	3.9	0.15	53.13	1.14	0.1	1.9
24	7.17	0.96	2.3	1.6	4.1	0.05	0	3.91	4.1	0.13	51.55	1.04	0.01	1.61
25	7.47	2.44	5.1	3.1	12.9	0.02	0	8.4	11.98	1.25	61.17	2.25	0.2	3.3
26	7.03	2.41	6.5	3.24	12.7	0.03	0	10.04	6.49	1.25	56.65	2.03	0.3	3.54
27	7.64	0.99	2.1	1.7	4.89	0.04	0	3.82	3.9	0.15	56.47	1.25	0.02	1.72
28	7.34	0.76	1.11	0.9	4.2	0.06	0	2.1	4.2	0.1	67.94	1.48	0.09	0.99
29	7.41	2.18	3.9	2.9	11.2	0.03	0	6.81	10.8	0.77	62.29	2.15	0.01	2.91
30	7.19	1.14	2.9	1.8	5.08	0.03	0	4.71	4.5	0.54	52.09	1.17	0.01	1.81
31	7.9	1.3	2.5	1.8	6.78	0.02	0	4.31	7.3	0.61	61.26	1.63	0.01	1.81
32	7.22	2.15	5.1	2.8	10.45	0.01	0	8	9.45	1.33	56.97	1.86	0.1	2.9
33	7.57	0.95	3	1.4	3.74	0.01	0	4.4	3.12	0.08	46.01	0.89	0	1.4
34	7.13	2.03	4.6	2.4	10.6	0.08	0	7	9.6	0.71	60.41	2.00	0	2.4
35	7.23	2.48	5.6	4.8	10.45	0.02	0	10.6	6.7	3.63	50.17	1.62	0.2	5
36	7.34	0.93	2.6	1.4	3.74	0.01	0	4.4	3.2	0.08	48.39	0.94	0.4	1.8
37	7.43	0.82	1.9	1.02	3.86	0.01	0	4.01	2.5	0.31	57.00	1.13	1.09	2.11
38	7.09	2.9	6.8	3.25	15.54	0.07	0	10.1	12.1	1.24	60.83	2.45	0.05	3.3
39	7.27	1.04	1.5	0.9	6.18	0.01	0	2.6	5.3	0.35	72.06	1.99	0.2	1.1
40	7.24	1.75	3.75	2.4	9.2	0.02	0	6.2	8.5	0.6	59.99	1.85	0.05	2.45
41	7.28	1.32	3.21	1.91	6.02	0.02	0	5.2	5.9	0.3	54.12	1.33	0.08	1.99
42	7.57	1.34	3.5	1.8	6.6	0.01	0	5.3	5.1	0.63	55.50	1.43	0	1.8
43	7.74	2.22	4.1	3.2	12.5	0.04	0	7.3	10.4	1.9	63.21	2.31	0	3.2
44	7.9	1.27	4.2	2.5	3.2	0.01	0	6.7	2.8	0.6	32.39	0.62	0	2.5
45	7.12	1.15	2.3	1.7	5.2	0.01	0	4	5.1	0.73	56.57	1.30	0	1.7
46	7.36	2.25	4.9	3.05	11.4	0.02	0	8	7.8	3.63	58.96	2.02	0.05	3.1

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
47	7.48	2.09	3.2	4.1	10.21	0.04	0	7.3	7.8	1.91	58.40	1.89	0.00	4.1
48	7.36	1.37	3.6	1.6	5.24	0.02	0	5.2	6.8	0.65	50.29	1.15	0.00	1.6
49	7.24	1.21	2.6	3.5	4.3	0.02	0	6.1	3.4	0.67	41.46	0.87	0.00	3.5
50	7.4	1.72	3.8	2.6	8.93	0.02	0	6.4	7.9	0.65	58.31	1.76	0.00	2.6
51	7.3	2.23	6.8	3.1	8.17	0.05	0	9.9	6.65	1.77	45.36	1.30	0.00	3.1
52	7.37	2.19	6.2	3.4	8.94	0.02	0	9.6	7.2	1.23	48.28	1.44	0.00	3.4
53	7.48	2.27	6.3	3.8	9.1	0.04	0	10.1	7.5	1.27	47.51	1.43	0.00	3.8
54	7.59	4.08	8.5	4.1	22.5	0.07	0	13.4	19.5	2.1	64.17	3.17	0.80	4.9
55	7.76	1.6	4.9	2.7	5.45	0.02	0	7.6	4.56	0.94	41.85	0.99	0.00	2.7
56	7.37	1.49	3.1	2.1	6.54	0.02	0	5.2	6.7	0.1	55.78	1.43	0.00	2.1
57	7.44	1.48	2.9	1.9	6.6	0.01	0	4.82	6.21	0.5	57.93	1.51	0.02	1.92
58	7.57	3.52	8.5	4.9	16.85	0.04	0	13.42	14.75	2.54	55.76	2.30	0.02	4.92
59	7.47	1.42	2.9	1.8	7.2	0.02	0	4.75	6.4	1.06	60.57	1.66	0.05	1.85
60	7.55	1.71	3.6	1.9	9.5	0.05	0	5.5	8.94	0.58	63.46	2.03	0.00	1.9
61	8.96	1.03	2.43	1.45	4.1	0.05	0	3.9	3.4	0.13	51.68	1.04	0.02	1.47
62	8.18	1.52	4.6	2.1	5.76	0.03	0	6.71	5.9	0.2	46.36	1.11	0.01	2.11
63	7.81	1.83	5.2	2.7	7.1	0.01	0	7.91	7.2	0.15	47.37	1.26	0.01	2.71
64	7.82	1.95	3.7	3.5	9.53	0.04	0	7.2	7.1	1.38	57.07	1.78	0.00	3.5
65	7.86	0.91	1.23	2.1	3.9	0.07	0.2	3.13	2.6	0.65	54.38	1.07	0.00	1.9
66	7.87	1.89	4.2	1.97	9.54	0.04	0	6.17	8.5	1.38	60.83	1.92	0.00	1.97
67	7.96	0.89	1.9	1.2	3.9	0.02	0.2	3.12	2.5	0.5	55.84	1.11	0.22	1.22
68	7.59	1.6	4.8	1.9	6.8	0.05	0	6.71	5.73	0.67	50.55	1.31	0.01	1.91
69	7.53	1.23	3.5	2.1	4.9	0	0	5.62	4.01	0.19	46.67	1.04	0.02	2.12
70	7.77	1.43	3.9	2.3	5.4	0.01	0	6.2	5.1	0.24	46.60	1.08	0.00	2.3

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
71	6.80	8.31	62.21	0.21	2.00	3.50	0.00	6.50	58.00	3.33	91.90	37.51	1.00	4.50
72	2.62	7.51	20.33	0.05	3.10	2.40	0.00	3.83	21.00	0.91	78.74	12.26	0.00	0.73
73	7.08	7.97	63.00	0.15	6.20	0.54	0.56	5.10	60.21	4.17	90.36	34.32	0.00	0.00
74	2.07	7.87	13.29	0.02	3.80	1.30	0.00	4.30	14.00	0.44	72.29	8.32	0.00	0.50
75	4.20	7.01	33.32	0.04	5.61	1.50	0.00	6.20	34.20	0.73	82.43	17.6	0.00	0.59
76	2.76	7.45	17.95	0.01	3.20	5.00	0.00	7.30	19.20	0.43	68.65	8.86	0.00	4.10
77	1.43	7.59	7.02	0.01	3.85	1.20	0.00	3.90	9.00	0.21	58.19	4.42	0.00	0.05
78	2.10	7.34	15.72	0.02	2.70	1.40	0.00	3.85	15.80	0.29	79.33	10.98	0.00	1.15
79	1.53	7.38	6.32	0.31	3.12	2.60	0.00	6.10	7.00	0.17	53.70	3.74	0.38	2.98
80	1.25	7.27	7.10	0.00	3.20	1.50	0.00	3.19	7.40	0.54	60.17	4.63	0.00	0.00
81	8.00	1.03	2.73	1.64	4.05	0.00	0.67	3.80	4.20	0.19	48.10	0.97	0.10	1.07
82	7.27	3.09	2.60	2.40	24.00	0.00	0.00	5.01	22.45	1.05	82.76	5.37	0.01	2.41
83	6.90	4.44	1.10	3.81	37.12	0.06	0.00	4.93	36.45	1.65	88.33	8.38	0.02	3.83
84	7.71	4.55	4.85	1.30	34.54	0.30	0.00	6.20	33.85	2.92	85.00	6.96	0.05	1.35
85	7.70	1.91	1.92	2.04	13.01	0.13	0.00	4.60	12.45	0.64	76.84	3.27	0.64	2.68
86	6.71	5.10	2.62	1.98	45.25	0.07	0.00	4.90	44.01	1.87	90.79	10.55	0.30	2.28
87	7.24	3.53	1.40	5.34	25.25	0.02	1.01	5.75	24.25	1.30	78.94	4.86	0.02	4.35
88	8.03	0.90	1.50	2.52	2.88	0.01	0.00	4.16	3.00	0.18	41.82	0.72	0.14	2.66
89	7.15	2.22	2.10	1.60	17.05	0.03	0.00	3.71	16.00	1.04	82.19	4.43	0.01	1.61
90	6.99	3.57	2.60	1.90	28.07	0.00	0.00	4.50	26.75	1.05	86.18	6.62	0.00	1.90
91	7.17	2.73	2.85	1.30	20.15	0.02	0.00	4.65	19.25	1.24	82.94	4.95	0.50	1.80
92	7.68	1.57	2.90	1.16	8.95	0.00	0.00	4.25	8.75	0.57	68.79	2.22	0.19	1.35
93	7.53	1.69	3.20	2.10	7.98	0.01	0.00	5.30	7.92	0.46	60.12	1.73	0.00	2.10
94	7.53	1.31	2.90	1.95	6.80	0.00	0.00	5.01	6.23	0.21	58.37	1.54	0.16	2.11

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
95	7.55	1.53	2.70	1.12	8.65	0.00	0.00	3.83	8.20	0.35	69.37	2.21	0.01	1.13
96	7.44	3.97	4.20	1.80	28.95	0.12	0.00	6.04	27.65	1.06	82.89	5.91	0.04	1.84
97	7.30	2.85	2.35	1.35	22.07	0.18	0.00	3.81	20.03	1.06	85.74	5.74	0.11	1.46
98	7.27	2.98	2.41	1.50	23.71	0.02	0.00	3.92	21.05	1.04	85.85	6.00	0.01	1.51
99	7.13	2.62	2.45	1.54	19.01	0.01	0.00	4.00	18.45	0.59	82.66	4.76	0.01	1.55
100	7.51	1.60	2.90	1.08	8.54	0.03	0.00	4.08	8.45	0.35	68.29	2.14	0.10	1.18
101	7.05	1.90	2.50	1.95	12.45	0.00	0.00	4.55	11.84	0.54	73.67	2.95	0.10	2.05
102	7.25	3.28	4.56	1.90	24.01	0.02	0.98	5.48	21.54	1.28	78.81	4.72	0.00	0.92
103	7.55	1.53	2.98	1.10	9.09	0.05	0.00	4.09	9.01	0.57	69.14	2.25	0.01	1.11
104	7.18	1.15	2.50	0.50	6.20	0.06	0.00	3.01	6.50	0.39	67.60	1.79	0.01	0.51
105	7.72	1.13	2.10	1.03	7.65	0.08	0.00	3.13	5.78	0.42	71.18	2.16	0.00	1.03
106	7.26	1.06	1.85	1.04	5.64	0.08	0.00	3.05	5.08	0.32	66.43	1.66	0.16	1.20
107	7.31	1.10	2.30	1.10	5.30	0.07	0.00	3.40	4.87	0.41	61.23	1.44	0.00	1.10
108	7.28	1.24	2.60	1.23	6.75	0.05	0.00	3.83	6.01	0.33	63.97	1.72	0.00	1.23
109	7.44	0.93	1.72	1.01	5.10	0.02	0.00	2.74	4.62	0.31	65.22	1.54	0.01	1.02
110	7.54	1.77	2.10	1.72	11.23	0.00	0.00	3.82	10.72	0.32	74.62	2.87	0.00	1.72
111	7.74	2.61	2.21	1.42	19.21	0.01	0.00	3.65	19.23	0.31	84.11	5.04	0.02	1.44
112	7.63	1.13	2.54	1.02	5.70	0.00	0.00	3.56	5.01	0.43	61.56	1.51	0.00	1.02
113	7.12	1.48	3.01	1.30	7.98	0.00	0.00	4.32	8.23	0.26	64.93	1.92	0.01	1.31
114	7.43	2.31	2.45	1.32	17.45	0.00	0.00	3.78	17.04	0.21	82.23	4.49	0.01	1.33
115	7.42	2.35	3.10	2.32	14.87	0.07	0.00	5.42	16.42	0.12	73.38	3.19	0.00	2.32
116	7.09	2.37	3.23	1.90	15.21	0.06	0.00	5.13	16.23	0.14	74.85	3.36	0.00	1.90
117	8.00	1.59	3.12	2.10	7.85	0.15	0.00	5.32	7.85	0.01	60.51	1.72	0.10	2.20
118	6.98	4.31	2.45	1.35	37.05	0.18	0.00	3.80	36.75	0.02	90.74	9.50	0.00	1.35

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
119	7.17	2.68	2.45	1.65	19.23	0.21	0.00	4.12	18.26	0.01	82.58	4.75	0.02	1.67
120	7.25	1.91	2.70	1.80	11.42	0.00	0.00	4.50	11.45	0.03	71.73	2.69	0.00	1.80
121	7.46	2.47	3.60	1.45	16.24	0.00	0.00	5.05	16.58	0.01	76.28	3.61	0.00	1.45
122	7.23	1.37	2.91	2.12	6.45	0.04	0.00	5.03	6.23	0.03	56.34	1.44	0.00	2.12
123	8.10	1.20	2.50	1.02	6.98	0.05	0.00	3.65	5.20	0.01	66.64	1.86	0.13	1.15
124	7.72	2.21	2.35	1.30	16.01	0.00	0.00	3.65	16.02	0.02	81.43	4.19	0.00	1.30
125	7.25	2.48	3.70	2.01	15.87	0.06	0.00	5.72	15.64	0.00	73.61	3.32	0.01	2.02
126	7.24	1.03	2.50	1.40	4.67	0.02	0.00	3.90	4.72	0.01	54.59	1.18	0.00	1.40
127	7.09	0.99	1.60	1.02	4.65	0.19	0.00	2.62	4.65	0.02	64.88	1.44	0.00	1.02
128	7.55	1.03	2.03	1.02	5.40	0.00	0.00	3.06	5.40	0.01	63.91	1.55	0.01	1.03
129	7.49	1.27	2.80	1.23	6.54	0.00	0.00	4.03	6.48	0.02	61.87	1.63	0.00	1.23
130	7.47	1.17	2.50	1.05	6.12	0.00	0.00	3.56	5.97	0.01	63.29	1.62	0.01	1.06
131	8.04	2.44	3.54	2.32	16.23	0.01	0.00	5.86	16.10	0.03	73.48	3.35	0.00	2.32
132	8.40	2.24	2.41	1.50	15.75	0.26	0.00	3.92	17.21	0.01	80.37	3.98	0.01	1.51
133	7.90	2.65	3.10	2.03	18.00	0.00	0.00	5.13	18.00	0.02	77.82	3.97	0.00	2.03
134	8.30	2.74	3.50	2.31	18.87	0.00	0.00	5.82	18.65	0.04	76.46	3.91	0.01	2.32
135	8.40	1.32	2.92	1.50	5.32	0.08	0.00	4.42	6.51	0.01	54.99	1.27	0.00	1.50
136	8.63	2.66	3.10	2.12	16.87	0.01	0.00	5.23	16.45	0.02	76.38	3.69	0.01	2.13
137	8.10	2.28	2.56	1.60	16.02	0.06	0.00	4.16	17.12	0.01	79.45	3.93	0.00	1.60
138	8.32	2.54	3.20	2.05	17.84	0.08	0.00	5.26	18.01	0.01	77.34	3.89	0.01	2.06
139	8.55	2.89	3.54	2.45	18.54	0.05	0.00	6.01	19.85	0.02	75.63	3.79	0.02	2.47
140	8.70	2.69	3.45	2.21	17.87	0.12	0.00	5.67	18.01	0.04	76.07	3.76	0.01	2.22
141	8.26	3.25	4.01	2.05	23.00	0.01	0.00	6.10	24.00	0.04	79.15	4.67	0.04	2.09
142	8.35	3.54	4.32	3.50	24.01	0.25	0.00	7.87	25.04	0.01	75.62	4.29	0.05	3.55

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
143	8.30	1.30	2.98	2.01	6.45	0.28	0.00	5.01	6.45	0.02	57.42	1.44	0.02	2.03
144	8.60	3.21	3.87	2.21	24.01	0.00	0.00	6.09	24.65	0.00	79.79	4.87	0.01	2.22
145	8.40	1.83	3.45	1.65	9.65	0.00	0.00	5.10	9.25	0.03	65.42	2.14	0.00	1.65
146	7.90	1.13	2.54	1.56	5.03	0.08	0.00	4.13	5.45	0.01	55.48	1.24	0.03	1.59
147	8.10	0.94	2.01	1.21	4.65	0.06	0.00	3.23	4.65	0.02	59.39	1.30	0.01	1.22
148	8.70	2.53	3.45	2.21	17.21	0.04	0.00	5.67	17.23	0.03	75.29	3.62	0.01	2.22
149	8.30	1.36	3.05	2.45	5.87	0.06	0.00	5.50	5.98	0.01	51.88	1.25	0.00	2.45
150	7.90	1.24	2.96	1.45	6.45	0.16	0.00	4.43	6.35	0.01	59.98	1.54	0.02	1.47
151	8.33	0.92	1.21	1.04	5.23	0.00	0.00	2.25	5.24	0.02	69.92	1.74	0.00	1.04
152	8.08	0.98	1.34	1.05	5.12	0.00	0.00	2.39	4.95	0.00	68.18	1.66	0.00	1.05
153	8.00	0.78	1.06	0.97	4.01	0.00	0.00	2.03	4.54	0.01	66.39	1.41	0.00	0.97
154	8.04	1.06	2.06	1.23	5.45	0.07	0.00	3.30	5.08	0.01	62.66	1.50	0.01	1.24
155	8.01	0.86	1.45	0.97	4.56	0.01	0.00	2.45	4.52	0.01	65.38	1.47	0.03	1.00
156	7.90	1.47	2.21	1.05	8.45	0.08	0.00	3.26	7.54	0.00	72.35	2.34	0.00	1.05
157	8.10	1.25	2.65	1.12	6.45	0.00	0.00	3.77	6.87	0.01	63.11	1.66	0.00	1.12
158	7.90	1.21	2.21	1.05	7.25	0.16	0.00	3.26	7.15	0.02	69.45	2.01	0.00	1.05
159	7.92	1.35	2.05	1.13	8.45	0.18	0.00	3.18	8.45	0.01	73.07	2.37	0.00	1.13
160	8.18	0.78	1.12	0.89	4.05	0.00	0.00	2.15	4.25	0.01	66.83	1.43	0.14	1.03
161	7.13	2.45	2.31	1.26	19.45	0.01	0.00	3.57	18.21	1.05	84.50	5.15	0.00	1.26
162	7.79	2.58	2.48	1.36	19.07	0.00	0.00	3.85	18.75	0.98	83.24	4.87	0.01	1.37
163	8.00	2.78	2.54	1.28	20.45	0.01	0.00	3.83	20.75	1.05	84.27	5.23	0.01	1.29
164	7.87	2.81	1.78	2.01	21.65	0.02	0.00	3.79	20.06	1.08	85.11	5.56	0.00	2.01
165	6.93	0.78	1.45	0.76	4.05	0.04	0.00	2.23	3.45	0.85	64.92	1.36	0.02	0.78
166	7.87	0.65	1.65	1.01	2.54	0.02	0.00	2.67	2.65	0.45	49.04	0.78	0.01	1.02

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
167	7.21	0.76	2.01	1.12	3.05	0.10	0.00	3.13	2.75	0.65	50.16	0.86	0.00	1.12
168	7.33	2.39	2.78	1.23	18.07	0.03	0.00	4.01	16.75	1.65	81.86	4.51	0.00	1.23
169	7.36	2.44	3.05	2.54	17.05	0.01	0.00	5.59	16.12	1.12	75.32	3.61	0.00	2.54
170	7.36	2.47	3.12	2.75	16.85	0.00	0.00	5.87	15.65	1.45	74.16	3.48	0.00	2.75
171	7.34	0.89	1.65	1.05	4.65	0.02	0.00	2.71	4.56	0.63	63.36	1.41	0.01	1.06
172	8.16	1.76	3.10	2.42	10.45	0.01	0.00	5.53	10.05	0.75	65.46	2.22	0.01	2.43
173	7.57	3.67	3.25	2.45	29.08	0.02	0.00	6.80	25.64	1.98	83.62	6.09	1.10	3.55
174	8.05	0.92	1.87	1.01	5.12	0.01	0.00	2.89	4.45	0.95	64.04	1.51	0.01	1.02
175	7.42	0.69	1.24	1.03	3.87	0.00	0.00	2.27	3.49	0.54	63.03	1.28	0.00	1.03
176	7.39	3.45	3.65	1.68	26.58	0.01	0.00	5.34	24.56	2.05	83.30	5.76	0.01	1.69
177	7.99	1.81	2.86	1.26	12.06	0.04	0.00	4.13	11.05	1.06	74.60	2.97	0.01	1.27
178	6.91	0.68	1.38	1.02	3.15	0.00	0.00	2.50	2.64	0.65	56.76	1.02	0.10	1.12
179	8.00	1.16	2.45	1.12	5.89	0.02	0.00	3.58	5.16	1.06	62.34	1.56	0.01	1.13
180	8.60	3.12	3.65	2.15	23.05	0.03	0.00	5.80	21.45	1.85	79.92	4.79	0.00	2.15
181	7.28	2.57	2.95	1.65	18.65	0.01	0.00	4.65	18.63	1.21	80.22	4.35	0.05	1.70
182	7.68	0.65	1.03	1.05	2.94	0.02	0.00	2.08	2.10	0.76	58.73	1.02	0.00	1.05
183	7.02	3.43	3.21	1.95	27.65	0.03	0.00	5.16	24.85	1.54	84.29	6.09	0.00	1.95
184	6.96	3.02	3.65	2.15	22.45	0.06	0.00	5.81	20.26	1.85	79.51	4.66	0.01	2.16
185	7.24	3.21	3.25	2.45	24.06	0.05	0.00	5.71	22.35	1.06	80.88	5.04	0.01	2.46
186	7.14	3.45	3.65	2.75	26.23	0.15	0.00	6.50	24.15	1.18	80.48	5.18	0.10	2.85
187	7.14	3.54	3.06	1.65	29.25	0.02	0.00	4.71	27.85	1.02	86.14	6.74	0.00	1.65
188	7.26	3.02	3.38	2.14	22.45	0.01	0.00	5.59	21.54	1.12	80.27	4.78	0.07	2.21
189	7.46	2.86	2.85	1.34	21.85	0.21	0.00	4.21	21.05	1.05	84.04	5.34	0.02	1.36
190	7.42	2.48	2.68	1.06	18.83	0.01	0.00	3.75	17.82	1.34	83.44	4.87	0.01	1.07

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
191	7.14	2.97	3.12	2.65	20.75	0.00	0.00	5.78	19.45	1.02	78.24	4.32	0.01	2.66
192	7.25	1.85	2.23	1.12	12.31	0.01	0.00	3.36	12.05	0.56	78.62	3.36	0.01	1.13
193	7.25	2.65	3.01	2.37	18.65	0.02	0.00	5.38	18.54	1.15	77.63	4.02	0.00	2.37
194	7.26	1.11	2.34	1.27	5.28	0.00	0.00	3.62	4.65	0.74	59.39	1.39	0.01	1.28
195	7.37	2.83	3.42	2.17	20.45	0.01	0.00	5.61	18.63	1.31	78.54	4.32	0.02	2.19
196	7.39	3.14	3.56	2.45	23.45	0.02	0.00	6.02	21.05	1.83	79.61	4.78	0.01	2.46
197	7.19	2.25	2.75	1.89	17.08	0.01	0.00	4.68	16.05	1.03	78.65	3.96	0.04	1.93
198	7.34	2.91	3.08	2.54	22.65	0.00	0.00	5.62	21.85	1.16	80.12	4.78	0.00	2.54
199	7.27	1.38	2.35	1.18	9.06	0.00	0.00	3.54	7.81	1.07	71.96	2.41	0.01	1.19
200	7.95	2.76	3.45	2.37	20.45	0.01	0.00	5.83	19.24	1.34	77.85	4.24	0.01	2.38
201	7.14	2.97	2.15	2.61	21.85	0.02	0.50	5.04	20.45	1.42	82.13	5.01	0.78	2.89
202	7.25	1.85	1.85	1.28	15.05	0.00	0.00	3.13	14.25	0.53	82.78	4.25	0.00	1.28
203	7.25	2.12	2.65	1.85	16.05	0.03	0.00	4.51	14.65	1.06	78.13	3.78	0.01	1.86
204	7.26	1.11	2.05	2.13	5.56	0.01	0.00	4.19	5.08	0.54	57.13	1.36	0.01	2.14
205	7.37	3.45	3.65	2.85	26.85	0.12	0.50	6.10	25.45	1.35	80.58	5.27	0.10	2.45
206	7.39	3.14	3.18	2.38	23.45	0.01	0.10	5.47	24.06	1.05	80.84	4.97	0.01	2.29
207	7.19	2.25	2.85	1.75	16.85	0.03	0.00	4.61	15.24	0.94	78.58	3.93	0.01	1.76
208	7.34	2.91	2.65	1.53	23.15	0.04	0.00	4.18	22.45	1.12	84.73	5.66	0.00	1.53
209	7.27	1.38	1.45	1.32	10.04	0.08	0.00	2.78	8.75	1.02	78.51	3.02	0.01	1.33
210	7.95	3.54	2.95	2.63	28.45	0.04	0.60	5.59	26.15	1.81	83.62	6.02	0.61	2.64
211	7.19	4.61	3.65	3.01	39.18	0.01	1.20	5.64	36.81	2.01	85.47	7.59	0.18	1.99
212	7.05	1.66	1.54	1.05	12.62	0.00	0.00	2.61	11.24	1.64	82.97	3.92	0.02	1.07
213	6.84	2.31	2.64	1.38	18.43	0.02	0.00	4.02	16.85	1.25	82.11	4.60	0.00	1.38
214	7.43	2.06	2.16	1.83	15.24	0.03	0.00	4.01	13.95	1.05	79.28	3.81	0.02	1.85

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
215	6.91	1.84	1.96	1.54	11.85	0.01	0.00	3.51	12.65	0.67	77.21	3.17	0.01	1.55
216	6.95	0.76	1.65	1.05	3.75	0.06	0.00	2.71	3.28	0.54	58.53	1.14	0.01	1.06
217	7.29	3.61	2.87	2.16	29.05	0.07	0.00	5.03	28.05	1.65	85.27	6.48	0.00	2.16
218	7.21	3.56	3.01	2.65	28.78	0.12	0.00	5.66	27.15	1.38	83.62	6.05	0.00	2.65
219	7.19	1.43	1.23	1.08	11.14	0.16	0.00	2.32	10.04	1.01	83.03	3.66	0.01	1.09
220	7.30	3.45	2.85	1.53	29.05	0.00	0.00	4.39	27.84	1.28	86.90	6.94	0.01	1.54
221	8.21	1.76	1.76	1.05	13.85	0.00	0.00	2.81	12.85	1.25	83.13	4.13	0.00	1.05
222	8.43	1.24	1.18	1.31	9.02	0.00	0.00	2.50	8.01	1.03	78.37	2.86	0.01	1.32
223	8.43	1.31	1.37	1.07	9.65	0.01	0.00	2.45	9.45	0.75	79.83	3.09	0.01	1.08
224	8.37	1.45	2.06	1.28	9.57	0.00	0.00	3.35	8.75	1.05	74.13	2.62	0.01	1.29
225	8.54	1.24	1.94	1.31	8.45	0.02	0.00	3.35	6.75	1.12	72.27	2.34	0.10	1.41
226	8.63	1.74	2.45	1.34	11.45	0.01	0.00	3.79	10.73	0.85	75.15	2.94	0.00	1.34
227	7.86	2.05	2.35	1.72	14.75	0.00	0.00	4.08	14.05	1.12	78.37	3.66	0.01	1.73
228	7.87	1.62	1.82	1.05	12.05	0.00	0.00	2.87	11.04	0.94	80.76	3.56	0.00	1.05
229	8.00	1.10	1.05	1.02	7.54	0.00	0.00	2.08	6.45	1.12	78.46	2.62	0.01	1.03
230	8.11	1.04	1.24	0.84	7.12	0.01	0.00	2.09	6.57	1.05	77.42	2.47	0.01	0.85
231	8.10	1.28	2.11	1.45	8.05	0.01	0.00	3.56	6.25	1.24	69.36	2.13	0.00	1.45
232	7.93	1.05	1.85	1.04	6.45	0.00	0.00	2.89	5.46	0.85	69.06	1.90	0.00	1.04
233	8.30	1.35	2.45	1.65	8.27	0.01	0.00	4.10	6.78	1.12	66.88	2.04	0.00	1.65
234	8.03	1.12	1.12	0.85	7.94	0.02	0.00	2.88	6.07	1.07	80.16	2.83	0.91	1.76
235	8.37	1.45	1.65	1.14	9.73	0.00	0.00	2.81	9.02	1.02	77.72	2.91	0.02	1.16
236	8.57	1.75	2.37	1.65	12.45	0.01	0.00	4.05	10.85	0.75	75.61	3.10	0.03	1.68
237	8.49	1.56	1.74	1.02	11.32	0.01	0.00	2.77	10.24	1.12	80.41	3.41	0.01	1.03
238	8.34	1.82	2.13	1.15	13.41	0.00	0.00	3.28	12.45	1.32	80.35	3.70	0.00	1.15

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
239	8.35	1.76	2.45	1.75	12.45	0.00	0.00	4.22	10.45	1.47	74.77	3.04	0.02	1.77
240	8.46	1.46	1.94	1.05	9.45	0.00	0.00	3.01	10.25	0.85	75.96	2.73	0.02	1.07
241	7.24	2.40	2.65	1.83	18.45	0.00	0.00	4.48	17.45	1.04	80.46	4.36	0.00	1.83
242	7.27	2.34	2.61	1.43	17.28	0.00	0.00	4.05	15.76	1.16	81.05	4.30	0.01	1.44
243	8.43	1.98	1.67	1.23	16.17	0.01	0.00	3.12	14.08	0.73	84.80	4.75	0.22	1.45
244	7.63	2.81	3.05	2.15	22.76	0.01	0.00	5.21	20.67	1.27	81.41	4.99	0.01	2.16
245	7.27	1.24	1.58	1.04	8.67	0.00	0.00	2.62	8.19	1.06	76.79	2.68	0.00	1.04
246	8.96	2.81	1.46	1.07	24.92	0.00	0.00	2.54	24.18	0.46	90.78	7.83	0.01	1.08
247	7.08	0.69	1.28	1.06	3.73	0.01	0.00	2.35	3.07	0.37	61.51	1.22	0.01	1.07
248	7.39	0.59	1.05	0.76	3.16	0.00	0.00	1.83	2.41	0.83	63.58	1.17	0.02	0.78
249	7.86	0.72	1.43	1.05	3.76	0.01	0.00	2.49	2.76	1.06	60.32	1.19	0.01	1.06
250	7.32	0.84	1.57	1.18	4.76	0.00	0.00	2.76	3.45	1.08	63.38	1.44	0.01	1.19
251	8.47	2.76	1.82	1.05	22.59	0.01	0.00	2.88	21.76	1.03	88.73	6.67	0.01	1.06
252	8.78	3.76	2.83	1.29	32.72	0.01	0.00	4.12	30.74	1.65	88.82	8.06	0.00	1.29
253	7.78	3.87	3.06	2.45	31.58	0.03	0.00	5.52	30.15	1.76	85.16	6.73	0.01	2.46
254	7.69	3.46	2.76	2.46	27.19	0.00	0.00	5.24	25.82	1.18	83.89	5.95	0.02	2.48
255	7.66	3.08	3.25	2.19	23.84	0.00	0.00	5.46	21.73	1.42	81.42	5.11	0.02	2.21
256	7.95	3.46	3.67	2.09	28.18	0.02	0.00	5.78	26.08	0.97	83.04	5.87	0.02	2.11
257	8.10	0.83	1.85	1.06	4.18	0.01	0.01	3.01	3.15	1.08	59.01	1.23	0.11	1.16
258	7.84	1.17	2.80	1.5	5.20	0.04	0.00	4.50	4.70	0.40	54.93	1.25	0.20	1.70
259	8.26	1.25	2.76	1.76	6.52	0.02	0.00	4.54	5.12	1.18	59.13	1.53	0.02	1.78
260	7.89	2.76	3.24	1.76	20.75	0.01	0.00	5.01	19.75	1.76	80.59	4.64	0.01	1.77
261	7.70	3.70	3.60	3.10	29.00	0.10	0.00	7.40	26.00	2.49	81.28	5.60	0.70	3.80
262	8.20	2.37	2.90	1.20	18.20	0.08	0.00	4.10	19.20	0.00	81.68	4.49	0.00	1.20

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
263	8.01	1.62	2.90	2.50	8.98	0.08	0.00	5.40	8.67	0.01	62.66	1.93	0.00	2.50
264	7.34	1.43	2.90	2.02	7.50	0.11	0.00	5.60	6.35	0.02	60.73	1.69	0.68	2.70
265	7.32	1.30	3.16	1.16	6.04	0.07	0.00	5.30	4.90	0.01	58.58	1.45	0.98	2.14
266	6.80	2.30	3.09	2.89	16.00	0.05	0.00	6.10	15.04	0.00	72.86	3.27	0.12	3.01
267	6.70	2.27	2.80	2.50	15.00	0.05	0.00	5.40	16.37	0.01	73.96	3.26	0.10	2.60
268	7.80	2.80	4.74	4.00	17.70	0.14	1.19	8.00	16.00	0.08	67.12	2.99	0.45	3.26
269	8.16	2.20	3.10	2.31	15.00	0.06	0.00	6.05	15.00	0.07	73.57	3.22	0.64	2.95
270	8.00	1.19	2.05	1.00	7.50	0.14	0.90	4.02	5.34	0.00	71.47	2.15	1.87	1.97
271	8.11	2.47	3.97	2.31	17.50	0.06	0.00	6.90	16.10	0.00	73.66	3.49	0.62	2.93
272	8.10	1.04	2.70	1.00	5.90	0.06	0.00	4.02	4.50	0.01	61.70	1.53	0.32	1.32
273	8.41	1.85	2.91	1.93	11.50	0.04	0.60	5.10	10.70	0.00	70.45	2.61	0.86	2.19
274	8.51	1.73	2.76	1.71	10.50	0.04	0.60	4.40	10.20	0.00	70.22	2.48	0.53	1.64
275	8.54	1.57	1.04	0.47	12.20	0.13	0.80	1.78	9.50	0.00	89.09	4.96	1.07	0.74
276	8.10	1.10	2.22	1.54	6.16	0.02	0.00	4.10	5.28	0.00	62.17	1.59	0.34	1.88
277	8.03	0.98	2.32	1.25	6.68	0.20	0.00	3.59	5.58	0.00	65.84	1.77	0.02	1.27
278	7.75	0.91	2.21	1.25	5.60	0.01	0.00	4.10	5.40	0.01	61.85	1.51	0.64	1.89
279	8.08	2.25	6.29	4.15	8.37	0.04	0.00	11.00	7.64	0.00	44.62	1.30	0.56	4.71
280	8.12	2.00	2.52	1.25	14.70	0.01	0.00	4.40	12.00	2.04	79.60	3.79	0.63	1.88
281	8.10	0.99	2.30	1.54	4.68	0.02	0.00	4.10	4.25	0.00	55.04	1.19	0.26	1.80
282	7.90	0.98	2.10	1.60	4.90	0.01	0.00	3.90	4.90	0.01	57.03	1.27	0.20	1.80
283	8.00	0.76	2.10	1.05	2.95	0.02	0.00	3.37	3.12	0.00	48.53	0.83	0.22	1.27
284	7.90	1.75	2.52	1.20	12.50	0.18	0.00	4.40	9.10	2.04	77.32	3.24	0.68	1.88
285	8.00	1.61	2.03	3.95	9.20	0.23	0.00	6.10	8.76	0.00	61.19	1.88	0.12	4.07
286	8.10	1.51	3.10	2.10	8.20	0.02	0.00	5.50	8.05	0.15	61.25	1.80	0.30	2.40

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
287	7.90	1.74	2.52	1.95	12.06	0.08	0.00	4.50	9.45	2.04	73.09	2.85	0.03	1.98
288	7.90	1.80	4.06	2.02	8.50	0.15	1.72	5.40	9.32	0.00	58.72	1.72	1.04	1.34
289	7.50	3.09	4.12	2.40	23.20	0.54	0.00	7.32	22.00	0.00	78.45	4.54	0.80	3.20
290	7.90	3.20	4.90	3.20	21.00	0.04	0.00	8.50	21.80	0.00	72.20	3.69	0.40	3.60
291	8.04	2.95	5.03	3.12	20.30	0.09	0.00	8.50	18.00	0.00	28.54	26.50	29.50	71.44
292	7.90	2.60	3.58	2.16	17.20	0.50	0.00	6.50	16.20	1.41	23.44	24.11	26.00	75.51
293	7.80	3.58	4.42	2.51	28.00	0.01	0.00	7.40	23.00	3.05	34.94	33.45	35.80	80.17
294	7.90	2.50	3.58	2.14	17.00	0.50	0.00	5.80	16.20	1.41	23.22	23.41	25.00	75.37
295	8.10	2.42	3.49	2.01	16.00	0.60	0.00	5.70	16.10	1.30	22.10	23.10	24.20	75.11
296	7.90	2.96	4.45	3.12	20.40	0.09	0.00	8.40	18.70	0.00	28.06	27.10	29.60	73.02
297	8.10	1.49	2.04	1.60	9.60	0.05	1.30	3.08	7.20	0.00	13.29	11.58	14.90	72.61
298	8.07	1.28	1.64	1.01	8.40	0.47	0.00	4.50	7.10	0.00	11.52	11.60	12.80	77.00
299	8.09	1.20	1.90	1.10	7.40	0.04	0.00	4.80	5.08	0.00	10.44	9.88	12.00	71.26
300	7.70	3.45	4.05	3.80	25.00	0.24	1.00	7.30	24.70	0.00	33.09	33.00	34.50	76.28
301	7.73	2.05	2.70	1.22	14.80	0.03	0.00	4.80	14.20	0.00	18.75	19.00	20.50	79.09
302	8.15	2.00	2.40	1.02	15.10	0.01	0.00	4.30	14.10	0.00	18.53	18.40	20.00	81.54
303	8.10	0.95	2.03	1.06	5.40	0.05	0.00	3.50	4.70	0.04	8.54	8.24	9.50	63.82
304	8.10	2.04	3.10	1.40	14.80	0.03	0.00	4.80	14.20	0.07	19.33	19.07	20.40	76.72
305	8.12	1.86	2.13	1.45	13.60	0.03	0.00	3.59	12.50	0.00	17.21	16.09	18.60	79.20
306	8.16	2.05	3.40	2.34	13.90	0.25	0.00	6.12	12.00	0.01	19.89	18.13	20.50	71.14
307	7.90	1.84	2.10	1.50	13.50	0.02	0.00	4.00	13.00	0.00	17.12	17.00	18.40	78.97
308	7.97	0.98	2.04	1.02	5.70	0.06	0.00	3.10	5.80	0.05	8.82	8.95	9.80	65.31
309	8.01	2.10	2.80	2.41	13.50	0.02	0.00	7.10	11.00	0.00	18.73	18.10	21.00	72.18
310	8.11	2.06	2.70	2.21	15.00	0.01	0.00	6.80	12.00	0.00	19.92	18.80	20.60	75.35

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
311	7.48	1.16	2.90	2.21	4.90	0.03	0.00	5.20	4.65	0.00	10.04	9.85	11.60	49.10
312	7.56	1.06	2.10	1.60	4.70	0.01	0.00	3.80	4.80	0.00	8.41	8.60	10.60	56.00
313	7.91	3.78	3.38	4.35	28.30	0.02	0.00	7.90	26.00	2.11	36.05	36.01	37.80	78.56
314	8.34	0.76	2.21	1.05	3.00	0.01	0.00	3.30	3.06	0.00	6.27	6.36	7.60	48.01
315	8.25	1.76	3.77	2.22	10.20	0.04	0.00	6.50	8.50	0.00	16.23	15.00	17.60	63.09
316	8.21	1.30	3.10	1.45	6.40	0.03	0.00	5.20	6.11	0.00	10.98	11.31	13.00	58.56
317	8.12	0.78	2.04	1.40	3.10	0.04	0.00	3.50	3.10	0.00	6.58	6.60	7.80	47.72
318	8.10	1.16	3.10	2.05	4.80	0.03	0.00	5.16	4.65	0.00	9.98	9.81	11.60	48.40
319	8.20	1.84	3.46	2.22	11.00	0.04	0.00	5.7	11.20	0.00	16.72	16.90	18.40	66.03
320	7.96	1.50	3.29	2.02	7.45	0.04	0.80	5.3	7.10	0.00	12.80	13.20	15.00	58.52
321	8.50	1.63	2.16	2.12	10.40	0.00	0.40	3.9	9.10	0.00	14.68	13.40	16.30	70.84
322	8.31	0.96	2.20	1.30	3.50	0.01	0.00	3.7	4.30	0.00	7.01	8.00	9.60	50.07
323	8.26	1.23	2.06	1.60	7.80	0.02	0.00	3.67	7.90	0.00	11.48	11.57	12.30	68.12
324	8.00	1.14	1.97	1.45	6.80	0.12	0.00	3.45	7.20	0.00	10.34	10.65	11.40	66.92
325	8.30	0.98	2.18	1.20	4.10	0.16	0.00	3.8	4.20	0.00	7.64	8.00	9.80	55.76
326	8.23	1.10	2.06	1.23	6.50	0.51	0.00	3.6	4.50	0.11	10.30	8.21	11.00	68.06
327	8.31	1.30	2.30	1.25	7.30	0.05	0.00	3.7	7.10	0.04	10.90	10.84	13.00	67.43
328	8.36	0.86	2.10	1.04	4.30	0.04	0.00	3.4	4.10	0.00	7.48	7.50	8.60	58.02
329	8.46	1.13	2.10	1.50	6.50	0.12	0.00	3.61	6.90	0.00	10.22	10.51	11.30	64.77
330	8.30	1.19	2.80	2.01	5.33	0.01	0.00	4.9	5.70	0.00	10.15	10.60	11.90	52.61
331	6.79	2.54	2.30	2.70	18.60	0.04	1.21	3.86	18.73	0.27	78.85	4.16	0.07	1.56
332	7.61	1.18	3.10	0.90	6.14	0.01	0.00	4.30	5.40	0.30	60.59	1.54	0.30	1.20
333	7.11	2.83	3.20	5.00	17.79	0.01	0.00	8.30	19.20	0.43	68.46	3.11	0.10	5.10
334	7.71	2.48	2.00	1.00	21.00	0.07	0.00	3.10	20.00	1.58	87.54	6.06	0.10	1.10

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
335	7.50	4.15	3.56	2.15	34.56	0.15	0.56	5.71	29.45	4.17	85.87	7.23	0.56	2.15
336	7.21	4.25	3.86	2.56	36.00	0.03	0.36	6.40	33.00	1.29	84.88	7.10	0.34	2.54
337	7.50	2.31	4.70	3.60	12.50	0.00	1.60	7.20	11.20	0.30	60.10	2.17	0.50	2.50
338	7.41	2.10	4.10	2.00	12.27	0.03	0.40	6.00	12.80	0.27	66.85	2.48	0.30	1.90
339	7.56	1.50	3.90	1.00	7.89	0.01	0.00	5.00	7.30	0.70	61.72	1.78	0.10	1.10
340	7.51	1.11	2.64	1.80	5.00	0.03	0.00	4.50	5.00	0.20	53.12	1.19	0.06	1.86
341	7.67	1.90	4.50	2.40	9.70	0.01	0.00	7.80	8.15	0.21	58.46	1.85	0.90	3.30
342	7.75	1.10	2.80	2.20	3.80	0.00	0.00	5.20	3.00	0.10	43.18	0.85	0.20	2.40
343	6.98	3.26	2.60	2.45	25.80	0.00	0.00	5.20	24.87	1.87	83.63	5.74	0.15	2.60
344	7.39	1.08	2.03	1.70	5.15	0.06	0.00	4.10	4.85	0.29	58.28	1.33	0.37	2.07
345	7.59	1.08	2.90	1.80	5.01	0.01	1.90	3.10	3.00	0.58	51.65	1.16	0.30	0.20
346	7.40	1.01	2.00	0.80	4.31	0.00	0.50	2.40	7.00	0.26	60.62	1.29	0.10	0.40
347	7.79	0.86	1.40	1.60	4.43	0.02	0.00	3.30	4.00	0.23	59.73	1.28	0.30	1.90
348	7.70	1.01	2.50	2.00	3.59	0.01	0.00	4.50	4.20	0.12	44.44	0.85	0.00	2.00
349	7.17	1.80	2.10	2.70	12.00	0.05	0.00	5.00	11.00	1.20	71.51	2.74	0.20	2.90
350	7.94	5.20	2.62	1.98	45.30	0.07	0.00	4.90	43.00	1.87	90.79	10.56	0.30	2.28
351	8.01	1.18	1.86	1.95	6.76	0.01	0.00	3.90	7.00	0.21	63.99	1.73	0.09	2.04
352	7.82	3.49	2.03	1.99	30.00	0.01	0.00	4.45	27.00	1.70	88.19	7.48	0.43	2.42
353	7.76	3.46	1.30	5.70	27.18	0.02	1.14	6.50	24.86	1.86	79.53	5.14	0.64	5.20
354	7.48	3.94	1.70	3.85	34.16	0.02	0.00	5.70	29.84	3.93	86.03	7.25	0.15	4.00
355	7.52	3.96	4.67	0.60	33.06	0.40	0.00	6.00	32.00	1.11	86.39	7.20	0.73	1.33
356	7.77	2.60	2.98	1.00	21.11	0.13	0.00	4.85	19.00	1.30	84.22	5.29	0.87	1.87
357	7.86	1.50	3.10	1.50	8.50	0.01	0.10	4.50	9.00	0.34	64.91	1.98	0.00	1.40
358	7.76	2.39	2.04	1.30	18.79	0.03	0.00	3.50	19.40	0.48	84.93	5.14	0.16	1.46

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
359	7.69	3.18	2.60	2.30	25.00	0.01	0.00	5.20	24.87	1.05	83.62	5.65	0.30	2.60
360	7.62	2.40	4.10	1.50	17.00	0.04	0.00	5.80	16.00	0.22	75.27	3.59	0.20	1.70
361	7.42	1.19	3.10	2.00	5.40	0.01	1.20	4.00	4.20	0.35	51.47	1.20	0.10	0.90
362	7.27	1.10	2.40	2.60	4.00	0.01	0.00	5.00	4.00	0.07	44.51	0.89	0.00	2.60
363	7.66	1.30	3.20	2.00	5.30	0.00	0.00	5.30	5.10	0.13	50.48	1.16	0.10	2.10
364	7.15	1.10	1.70	0.50	7.20	0.02	0.65	2.96	4.70	0.19	76.65	2.43	1.41	1.26
365	7.22	1.40	2.00	2.43	8.00	0.10	0.00	4.50	8.27	0.19	64.64	1.90	0.07	2.50
366	7.53	1.30	3.40	2.00	5.80	0.00	0.67	4.80	5.40	0.17	51.79	1.25	0.07	1.40
367	7.33	3.87	2.50	1.50	34.26	0.00	1.40	3.50	33.00	0.32	89.55	8.57	0.90	1.00
368	7.39	2.12	5.70	2.80	8.76	0.00	0.68	8.00	8.15	0.18	50.75	1.50	0.18	2.30
369	7.42	2.10	2.90	2.80	13.00	0.00	0.00	6.15	9.00	0.38	69.52	2.72	0.45	3.25
370	7.63	0.95	1.80	0.90	6.11	0.01	0.00	2.70	5.60	0.33	69.39	1.86	0.00	0.90
371	8.15	1.50	3.50	1.90	7.49	0.00	0.00	5.60	7.40	0.15	58.11	1.61	0.20	2.10
372	7.19	4.72	3.50	4.27	39.00	0.01	1.17	6.70	38.00	1.17	83.39	7.00	0.10	3.20
373	7.12	2.30	4.60	3.70	12.00	0.00	1.80	7.20	11.00	0.30	59.11	2.08	0.70	2.60
374	7.16	3.50	4.90	2.36	26.30	0.02	0.36	7.01	23.76	1.95	78.38	4.88	0.11	2.11
375	7.09	2.24	6.30	2.90	9.46	0.02	2.30	6.90	9.45	0.43	50.75	1.56	0.00	0.60
376	8.02	0.75	1.70	1.20	3.08	0.10	0.00	3.18	3.20	0.13	52.30	0.90	0.28	1.48
377	7.95	0.75	1.60	1.30	3.80	0.00	0.00	3.12	3.20	0.14	56.72	1.12	0.22	1.52
378	7.32	1.40	2.80	1.50	8.50	0.01	0.10	4.30	7.90	0.34	66.43	2.05	0.10	1.50
379	7.32	1.33	1.70	2.43	7.12	0.10	0.00	4.40	8.00	0.17	63.61	1.75	0.27	2.70
380	8.74	0.87	2.10	1.40	4.30	0.06	0.00	3.80	3.20	0.11	55.47	1.15	0.30	1.70
381	7.07	0.98	2.74	1.80	3.57	0.02	0.00	4.55	3.12	0.31	44.16	0.84	0.01	1.81
382	7.40	0.88	1.40	1.60	4.43	0.02	0.00	3.30	4.00	0.23	59.73	1.28	0.30	1.90

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
383	7.30	1.20	2.60	3.80	3.40	0.00	0.00	6.40	3.80	0.09	34.69	0.67	0.00	3.80
384	7.51	1.09	1.70	3.80	3.32	0.07	0.00	5.60	3.00	0.11	38.13	0.71	0.10	3.90
385	7.55	0.97	1.80	0.90	6.11	0.01	0.00	2.70	6.00	0.33	69.39	1.86	0.00	0.90
386	7.76	1.02	2.03	1.70	5.11	0.06	0.00	4.10	4.15	0.29	58.09	1.32	0.37	2.07
387	7.35	1.93	4.30	0.30	11.72	0.14	0.00	5.60	11.00	0.31	72.05	2.73	1.00	1.30
388	6.89	4.22	3.90	0.70	36.87	0.06	0.00	5.00	34.75	1.36	88.92	8.60	0.40	1.10
389	8.02	1.25	1.60	1.40	8.10	0.04	0.00	3.01	7.64	0.78	73.07	2.34	0.01	1.41
390	7.83	0.66	1.60	1.20	2.08	0.10	0.00	2.80	2.80	0.15	43.78	0.62	0.00	1.20
391	8.35	0.87	2.06	1.14	4.00	0.05	0.00	3.22	4.01	0.68	55.86	1.12	0.02	1.16
392	8.20	1.23	2.12	1.54	6.54	0.01	0.00	3.67	7.05	1.06	64.15	1.71	0.01	1.55
393	8.45	1.69	2.54	1.08	11.12	0.00	0.00	3.64	9.65	0.78	75.44	2.92	0.02	1.10
394	8.47	1.57	2.64	1.10	10.28	0.04	0.00	3.74	10.10	0.45	73.40	2.66	0.00	1.10
395	8.40	1.21	2.08	1.05	7.63	0.24	0.00	3.13	7.06	0.65	71.55	2.16	0.00	1.05
396	8.18	1.37	2.65	1.23	8.25	0.01	0.00	3.91	7.54	1.01	68.04	2.09	0.03	1.26
397	8.24	1.06	1.85	0.85	6.05	0.00	0.00	2.71	5.19	0.89	69.14	1.84	0.01	0.86
398	8.30	0.90	1.01	0.85	5.12	0.01	0.00	1.87	5.19	0.68	73.39	1.88	0.01	0.86
399	8.14	1.30	2.01	1.26	8.06	0.00	0.00	3.27	7.45	1.12	71.14	2.23	0.00	1.26
400	8.42	0.89	1.16	1.01	6.10	0.01	0.00	2.17	4.50	0.76	73.79	2.07	0.00	1.01
401	8.24	4.69	4.02	2.23	35.85	0.01	0.00	6.25	35.45	1.65	85.16	7.17	0.00	2.23
402	8.70	5.12	4.21	2.18	41.54	0.06	0.00	6.41	41.18	1.54	86.68	8.22	0.02	2.20
403	8.56	3.65	2.75	1.24	29.45	0.00	0.00	3.99	28.25	0.97	88.07	7.37	0.00	1.24
404	7.80	4.01	3.45	1.67	32.65	0.00	0.00	5.12	31.65	1.21	86.44	7.21	0.00	1.67
405	8.10	3.90	2.54	2.06	32.67	0.05	0.00	4.61	31.65	1.08	87.67	7.62	0.01	2.07
406	8.00	3.85	2.65	1.65	31.45	0.00	0.00	4.30	31.05	1.12	87.97	7.58	0.00	1.65

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
407	7.80	3.65	2.75	1.36	30.75	0.00	0.00	4.12	29.12	1.05	88.21	7.58	0.01	1.37
408	8.26	4.21	3.67	2.25	34.45	0.01	0.00	5.94	32.65	1.18	85.34	7.08	0.02	2.27
409	8.15	3.11	2.65	1.06	25.64	0.02	0.00	3.72	24.67	1.03	87.37	6.66	0.01	1.07
410	7.70	3.24	2.74	1.21	26.15	0.00	0.00	3.95	26.02	1.05	86.88	6.58	0.00	1.21
411	8.24	4.69	4.02	2.23	35.85	0.01	0.00	6.25	35.45	1.65	85.16	7.17	0.00	2.23
412	8.70	5.12	4.21	2.18	41.54	0.06	0.00	6.41	41.18	1.54	86.68	8.22	0.02	2.20
413	8.56	3.65	2.75	1.24	29.45	0.00	0.00	3.99	28.25	0.97	88.07	7.37	0.00	1.24
414	7.80	4.01	3.45	1.67	32.65	0.00	0.00	5.12	31.65	1.21	86.44	7.21	0.00	1.67
415	8.10	3.90	2.54	2.06	32.67	0.05	0.00	4.61	31.65	1.08	87.67	7.62	0.01	2.07
416	8.00	3.85	2.65	1.65	31.45	0.00	0.00	4.30	31.05	1.12	87.97	7.58	0.00	1.65
417	7.80	3.65	2.75	1.36	30.75	0.00	0.00	4.12	29.12	1.05	88.21	7.58	0.01	1.37
418	8.26	4.21	3.67	2.25	34.45	0.01	0.00	5.94	32.65	1.18	85.34	7.08	0.02	2.27
419	8.15	3.11	2.65	1.06	25.64	0.02	0.00	3.72	24.67	1.03	87.37	6.66	0.01	1.07
420	7.70	3.24	2.74	1.21	26.15	0.00	0.00	3.95	26.02	1.05	86.88	6.58	0.00	1.21
421	8.40	0.63	1.25	0.95	3.50	0.01	0.00	2.31	1.05	0.85	61.47	1.18	0.11	1.06
422	8.39	4.05	3.15	1.69	32.45	0.02	0.00	4.84	31.85	1.21	87.03	7.38	0.00	1.69
423	8.37	2.44	2.65	1.12	17.52	0.01	0.00	3.78	18.05	0.79	82.30	4.51	0.01	1.13
424	8.25	2.62	2.75	1.35	18.54	0.01	0.00	4.10	19.25	0.65	81.90	4.58	0.00	1.35
425	8.40	1.39	2.13	1.16	8.25	0.01	0.00	3.31	8.04	0.81	71.52	2.27	0.02	1.18
426	8.10	1.54	1.45	1.02	11.25	0.01	0.00	2.47	10.18	0.85	82.01	3.58	0.00	1.02
427	7.90	2.34	2.45	1.21	18.24	0.00	0.00	3.68	15.65	1.54	83.29	4.77	0.02	1.23
428	8.16	0.75	1.45	1.04	3.50	0.00	0.00	2.49	3.05	0.54	58.43	1.11	0.00	1.04
429	7.90	3.20	2.65	1.34	26.05	0.00	0.00	4.01	25.65	0.89	86.72	6.52	0.02	1.36
430	8.12	3.15	2.54	1.25	25.65	0.00	0.00	3.80	24.54	1.25	87.13	6.59	0.01	1.26

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
431	7.85	3.12	3.65	1.23	22.05	0.08	0.00	4.88	20.65	2.23	81.93	4.99	0.00	1.23
432	8.05	3.23	3.68	1.45	24.56	0.01	0.00	5.13	23.00	1.23	82.73	5.42	0.00	1.45
433	8.01	3.08	3.21	1.65	23.65	0.00	0.00	4.86	22.31	1.06	82.95	5.36	0.00	1.65
434	7.98	2.85	2.76	1.21	22.65	0.00	0.00	3.97	21.65	1.54	85.09	5.68	0.00	1.21
435	7.00	1.05	2.35	1.05	4.56	0.00	0.00	3.40	3.05	1.74	57.29	1.24	0.00	1.05
436	8.10	3.12	3.45	2.03	23.05	0.00	0.00	5.48	21.03	1.45	80.79	4.92	0.00	2.03
437	8.40	2.18	2.01	1.25	15.78	0.00	0.00	3.27	14.65	1.65	82.88	4.37	0.01	1.26
438	8.48	1.68	1.68	1.01	12.03	0.01	0.00	2.89	11.08	1.01	81.74	3.67	0.20	1.21
439	8.15	3.05	3.15	1.23	23.05	0.00	0.00	4.38	21.05	2.05	84.03	5.51	0.00	1.23
440	8.04	3.04	3.08	1.45	23.65	0.00	0.00	4.54	23.00	1.21	83.92	5.56	0.01	1.46
441	8.55	2.10	2.67	1.23	14.65	0.00	0.00	3.90	12.24	1.05	78.98	3.71	0.00	1.23
442	8.60	2.35	2.45	1.23	18.05	0.00	0.00	3.68	15.12	1.32	83.06	4.70	0.00	1.23
443	7.50	1.54	2.65	1.01	9.65	0.00	0.00	3.67	8.45	1.16	72.50	2.52	0.01	1.02
444	7.37	1.67	2.54	1.05	10.65	0.00	0.00	3.60	9.12	1.24	74.79	2.81	0.01	1.06
445	8.28	2.65	2.86	1.12	20.05	0.00	0.00	4.01	18.85	1.06	83.44	5.03	0.03	1.15
446	8.41	3.01	3.12	2.01	21.85	0.00	0.00	5.13	21.85	1.24	80.99	4.82	0.00	2.01
447	8.43	3.21	3.25	1.75	24.75	0.00	0.00	5.01	23.05	1.04	83.19	5.53	0.01	1.76
448	8.49	2.75	2.65	1.06	20.85	0.00	0.00	3.80	20.21	0.76	84.89	5.41	0.09	1.15
449	7.84	1.01	1.21	1.05	6.05	0.01	0.00	2.27	5.12	0.85	72.84	2.01	0.01	1.06
450	8.49	3.04	2.92	1.95	23.16	0.01	0.00	5.01	22.45	1.00	82.63	5.25	0.14	2.09
451	8.18	2.01	2.01	1.05	15.04	0.02	0.00	3.06	15.23	1.05	83.11	4.30	0.00	1.05
452	7.98	1.65	2.15	1.06	10.31	0.00	0.00	3.21	10.08	0.65	76.26	2.88	0.00	1.06
453	7.91	1.82	2.31	1.16	12.65	0.00	0.00	3.47	11.54	0.87	78.47	3.40	0.00	1.16
454	8.10	2.01	2.45	1.06	14.65	0.01	0.00	3.51	12.65	1.54	80.68	3.91	0.00	1.06

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
455	8.18	1.96	2.65	1.21	12.45	0.02	0.00	3.86	11.87	1.76	76.36	3.17	0.00	1.21
456	8.42	1.71	2.05	1.35	12.05	0.01	0.00	3.41	9.54	1.28	78.01	3.27	0.01	1.36
457	7.98	1.66	2.25	1.25	11.01	0.00	0.00	3.51	10.06	0.98	75.88	2.94	0.01	1.26
458	8.12	1.42	1.54	0.75	10.65	0.01	0.00	2.31	10.01	0.65	82.32	3.52	0.02	0.77
459	8.72	1.73	2.35	1.06	12.54	0.02	0.00	3.42	11.00	0.76	78.65	3.40	0.01	1.07
460	8.46	1.65	2.25	1.12	11.14	0.01	0.00	3.38	10.08	0.86	76.79	3.03	0.01	1.13
461	7.65	3.02	3.06	1.65	22.15	0.03	0.00	4.71	23.65	0.75	82.48	5.10	0.00	1.65
462	7.23	2.45	2.23	1.06	19.67	0.02	0.00	3.29	19.05	0.85	85.68	5.42	0.00	1.06
463	8.03	1.94	1.95	1.02	14.05	0.01	0.00	2.97	13.21	0.62	82.56	4.08	0.00	1.02
464	7.98	1.78	2.21	1.19	13.21	0.00	0.00	3.42	11.05	1.02	79.53	3.58	0.02	1.21
465	7.83	1.87	2.23	1.21	13.21	0.01	0.00	3.45	12.32	0.87	79.35	3.56	0.01	1.22
466	8.33	2.25	2.32	1.25	18.14	0.02	0.00	3.57	16.75	0.97	83.57	4.80	0.00	1.25
467	8.07	1.73	2.18	1.21	12.05	0.05	0.00	4.01	9.87	0.86	78.11	3.27	0.62	1.83
468	8.00	1.31	1.42	0.84	9.06	0.08	0.00	2.29	8.04	0.54	80.18	3.01	0.03	0.87
469	7.98	1.92	2.12	1.06	14.01	0.11	0.00	3.18	13.05	1.05	81.62	3.93	0.00	1.06
470	7.73	2.04	2.35	1.21	14.05	0.01	0.00	3.56	13.45	0.96	79.80	3.72	0.00	1.21
471	7.26	2.12	2.12	1.35	15.47	0.00	0.00	3.47	14.01	1.07	81.68	4.15	0.00	1.35
472	7.53	3.16	3.21	1.54	23.65	0.01	0.00	4.76	23.12	0.73	83.28	5.43	0.01	1.55
473	7.58	2.56	2.54	1.65	18.65	0.03	0.00	4.21	18.56	0.89	81.68	4.56	0.02	1.67
474	6.90	2.93	2.68	1.08	22.85	0.02	0.00	3.78	21.45	1.02	85.88	5.89	0.02	1.10
475	7.62	2.16	2.41	1.41	14.25	0.01	0.00	3.84	14.01	0.72	78.87	3.65	0.02	1.43
476	7.80	1.77	2.04	1.25	12.05	0.00	0.00	3.31	11.02	0.65	78.55	3.32	0.02	1.27
477	7.53	2.71	2.65	1.32	21.15	0.03	0.00	3.98	20.05	1.16	84.21	5.31	0.01	1.33
478	7.78	2.86	2.56	1.21	23.45	0.02	0.00	3.78	21.75	2.01	86.16	6.04	0.01	1.22

Lab. No.	pH	EC (dS/m)	Cations in me/L				Anions in me/L				Indices			
			Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	SSP	SAR	RSC (me/L)	RSBC (me/L)
479	7.65	2.78	2.65	1.35	22.45	0.01	0.00	4.01	21.85	1.65	84.88	5.61	0.01	1.36
480	7.74	3.01	3.05	1.65	24.45	0.00	0.00	4.71	22.05	1.28	83.88	5.64	0.01	1.66