CHAPTER 4: HYDRO-GEO CHEMISTRY

4.1 INTRODUCTION

Land and water are critical natural resources that sustain human life and the lives of all other creatures on our planet. Groundwater is one of the primary sources of water for human consumption, agriculture and industrial uses.. Determination of physical and chemical quality of water is essential for assessing its suitability for various purposes. Generally, the quality of groundwater depends on the composition of recharge water, the interaction between the water and the soil, the soil-gas interaction, the rock with which it comes into contact in the unsaturated zone, the residence time, and reactions that take place within the aquifer(Freeze, A.R. and Cherry, J.A., 1979; Hem, J.D. 1989; Hounslow, A.W., 1995; Fetter Jr., C.W., 2000)Groundwater quality in a region is largely determined by both natural processes (dissolution and precipitation of minerals, groundwater velocity, quality of recharge water, and interaction with other types of water aquifer) and anthropogenic activities. The natural chemical quality of groundwater is generally good, but elevated concentrations of a number of constituents can cause problems for water use. The geochemistry of groundwater data gives crucial evidence to the geologic history of rocks and indications of groundwater recharge, movement, and storage(Walton, W.C. 1970; Todd, D.K. and Mays, L.W., 2005; Thilagavathi et al, 2014).

Rapid growth of urban population, development of agriculture and industrial activities especially in hard rock terrains caused an intense increase in water consumption. Hydrogeochemical processes are influenced by many factors, such as geogenic factors (i.e., rock-water interaction) and anthropogenic activities (i.e., agricultural, industrial and domestic activities) (Hounslow, A.W., 1995). Recent research showed the importance of investigating the impacts of various factors on hydrogeochemistry. Groundwater contribution in rural areas for drinking purpose is about 88%, where water treatment and transport do not exist]. By understanding the chemistry of groundwater, we can determine its usefulness for domestic and agricultural purposes. If the quality of ground water is good then it can yield better crops under good soil and water management practices. Factors like the quality of water, soil type, salt tolerance characteristics of plants, climate and drainage decides the suitability of irrigation water in agriculture sector

Hydrogeochemistry use the water's chemistry and isotopic composition as a forensic tool to find out where groundwater has been and what has happened to it along its journey. This information provides a broad, more regionally extensive understanding of groundwater systems . z Furthermore, this improved knowledge can be used to create more comprehensive management and conservation plans, and more equitable groundwater/surface water regulations. There are major, minor, and trace solutes in groundwater!

Major (> 5 mg/l) Ca, Mg, Na, HCO 3, SO 4, Cl, Si, Minor (0.01-10 mg/l) B, Fe, NO 3, NH 4, K, Sr, Mn, Trace (<0.01mg/l)

Assessment of the hydrochemical characteristics of water and aquifer hydraulic properties is important for groundwater planning and management in the study area. Generally, the motion of groundwater along its flow paths below the ground surface increases the concentration of the chemical species (Domenico and Schwartz 1990;

Freeze and Cherry 1979; Kortasi 2007). Groundwater is the purest form of water sourced from natural resources and is usually clear, colorless and remains relatively at constant temperature. Therefore, it is normally superior to surface water in terms of sanitary consideration. But groundwater has higher salt contents than surface water because slowly moving water remains in contact with sub-strata for longer periods. Hence, the groundwater chemistry could reveal important information on the geological history of the aquifers as well as the suitability of groundwater for domestic and agricultural purposes. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes (Schiavo et al. 2006; Subramani et al. 2005). Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry (Aghazadeh and Mogaddam 2010; Hossein 2004). Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interaction. Such factors and their interactions result

Geochemical processes occurring within the groundwater and reactions with aquifer minerals have a profound effect on water quality. Hydro-geo-chemical composition of groundwater can also be indicative of its origin and history of the passage through underground materials with which water has been in contact. Groundwater contains dissolved minerals from the soil layers through which it passes. It may also contain some harmful contaminants through the process of seepage from the surface water and biological activities. On the other hand, the surface water contains a lot of organic matter, mineral nutrients and other contaminants brought by run-off from agriculture fields, fertilizers, pesticides, soil particles, waste chemicals from industries and sewage of cities and rural areas. The water bodies are continuously subjected to a dynamic state of change with respect to lithological characteristics and geo-climatic conditions. This dynamic balance in the aquatic system is upset by human activities, resulting in pollution. Trace element studies of groundwater have attracted researchers for a variety of reasons; their significance related to public health problems, their need in relation to plant growth and the mechanism oof metal transport in aqueous environment.

The study of quantity of water alone is not sufficient to solve the water management problems because its uses for various purposes depend on its quality. Hence, the hydrogeochemical character of groundwater and groundwater quality in different aquifers over space and time have proven to be important in solving the problems (Atwia et al 1997; Ballukraya and Ravi 1999; Ramappa and Suresh 2000). Similar studies were done by Lakshmanan et al (2003); Mondal and Singh (2004); Das Brijraj and Kaur (2007); Singh Abhay et al (2007) and Sadashivaiah et al (2008).

Researchers (e.g. Kortatsi et al. 2008; Yidana et al. 2008, BanoengYakubo et al. 2009; Nag and Ray 2015) have applied different methodologies to understand the sources of variation in the quality of surface and groundwater basins in India.

The competition for water resources has gained importance in recent years, not only in India but also in many places of the world. The development of human societies and industry result in bioenvironmental problems; pollution puts the water, air and soil resources at risk (Milovanovic 2007). Groundwater has become the major source of water supply for domestic, industrial and agricultural sectors of many countries and groundwater chemistry depends on the quality of recharged water, atmospheric precipitation, inland surface water and sub-surface geochemical processes. In recent years, many cities of developing countries are experiencing rapid demographic growth due to rural exodus. Urbanization and the unregulated growth of the population have altered the local topography and drainage system directly which affect both quality and quantity of the groundwater (Vasanthavigar et al. 2010). Temporal changes in the origin and constitution of the recharged water, hydrological and human factors frequently cause periodic changes in groundwater chemistry and quality (Milovanovic 2007; Sreedevi 2004).

Jain and Sharma (2000) made an attempt to develop regression equation to predict the groundwater quality of Sagar district, Madhya Pradesh. From the study it is understood that the water quality had significant correlation co-efficient with electrical conductivity.

Guruprasad and Satyanarayana (2004) investigated the groundwater quality of Sarada river basin. Physical and Chemical parameter were monitored to check the suitability of water for human use. The results of the given work reveals that most of the parameters in the subbasin were above the standard limits given by the WHO, ISI and ICMR

Bhuddhi et al (2004) conducted the survey of the groundwater quality of the Pithampur area and it was found that water quality was good before the establishment of industries. The major problem indicated by the residents were related to health and crop yield. It was also observed that the groundwater quality of oldest industrial region of the area was not affected.

Deepali Sohani et al (2004) carried out a study on quality of groundwater near industrial area at Jalgaon (Maharashtra). The Physico-Chemical parameters were determined (before and after rainy seasons) for the parameters such as pH, Hardness, Alkalinity, Dissolved Oxygen, Total Solids, Chlorides, Sulphate, Nitrate, Iron, etc., of 7 sampling sites. Water Quality Index indicated that water is not suitable for direct use and consumption and they were categorized as slightly polluted.

Shankar and Balasubramanya (2008) evaluated the water quality indices for groundwater of Whitefield industrial area in Bangalore which was determined by collecting 35 samples in and around the industrial area. Water quality index was calculated based on 10 parameters. The WQI ranged from 11.58 to 495.07 with an average of 69.95. The analysis revealed that the groundwater samples in general can be considered to be fit for Human consumption.

Ramakrishnaiah et al (2009) assessed the quality of groundwater using water quality index for Tumkur taluk in Karnataka state of India. Calculation of the water quality index was based on 12 parameters and the range of WQI was between 89.21 and 660.56. The high value of WQI was mainly due to high values of Iron, Nitrate, Total dissolved solids, Hardness Fluorides, Bicarbonate and Manganese. The authors concluded that the groundwater of the area needs some degree of treatment before consumption.

Fig 4.1 (a) On Site Groundwater testing with Sr. Geologist, Kuldeep Singh Bist, Bhuj Division.

Fig 4.1 (b) Groundwater testing on site through HANNA DISK 2 kit.

4.2 METHODOLOGY

1. Data collection related water quality from CGWB, District Lab Bhuj and Data Centre Gandhinagar.
2. Identifying and Mapping the obtained locations of tubewells/wells of water quality data from various govt. departments in the field through GPS and ArcGIS software.
3. Joining the attributes of water quality data to their respective tubwells/Wells in the point map created in the step 2.
4. Query analysis for Separation of the pre-earthquake and post-earthquake data
5. Generation of various water quality maps based on the IDW interpolation technique in ArcGIS software.
6. Reclassification of the maps based on the Indian Quality standards (IS 10500 standards) in terms of desirable, permissible and above permissible limits for better understanding.
7. Generation of Durov, Piper and Gibbs diagrams.
8. Map interpretation and final results.

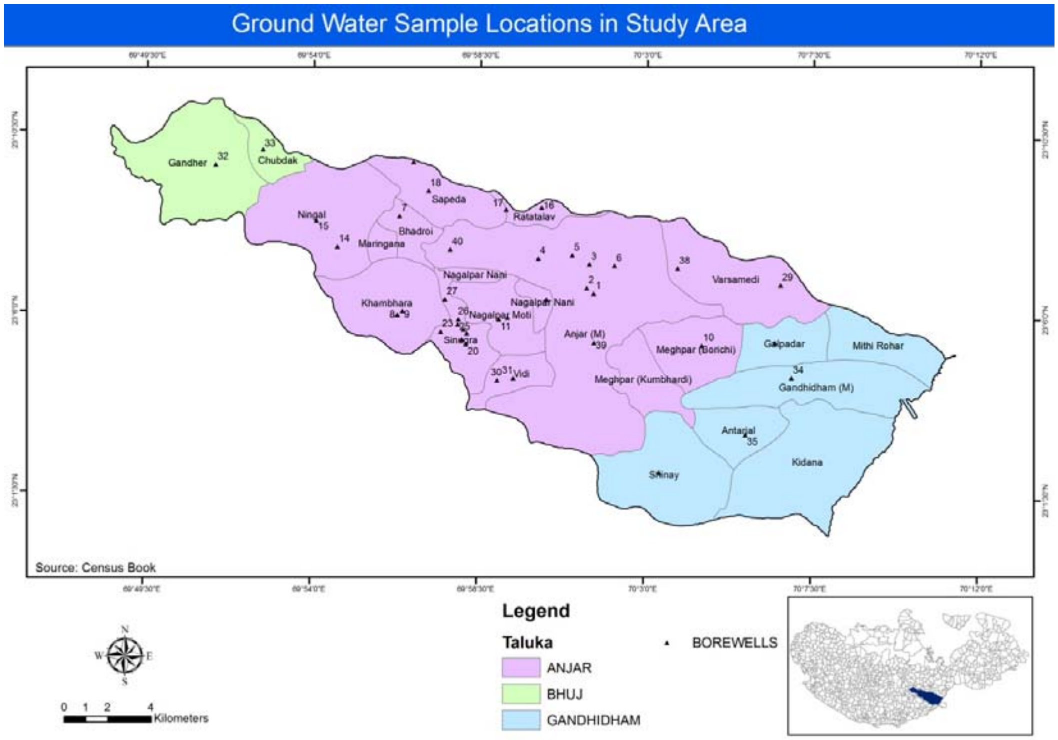

Fig. 4.2 Location of Borewells considered for water sample

4.3 WATER QUALITY ANALYSIS FOR PRE MONSOON (2009)

Table 4.1 Pre-monsoon (2009) Water Quality Parameters

Chemical Parameters	**Maximum**	**Minimum**	**Average**	**Std Dev**	**Skewness**	**Kurtosis**
pH	**8.340**	**6.660**	**7.703**	**0.431**	**-0.785**	**0.025**
Nitrate (mg/l)	153.00	0.70	25.87	33.97	2.14	4.85
Fluoride (mg/l)	2.750	0.080	1.061	0.649	0.837	0.762
Iron (mg/l)	1.780	0.010	0.517	0.433	1.141	1.334

CO3 (mg/l)	998.400	48.000	213.751	184.396	2.542	8.333
Turbidity (NTU)	10	1	5	2	1	1
TDS (mg/l)	6348	600	1687	1460	2	3
Hardness (mg/l)	846	87	405.6486	205.3351	0.642969	-0.56338
Calcium (mg/l)	229	22	76	51	1.0	1
Magnisium (mg/l)	142	11	48.83	31.45	1.19	0.93
Chlorides (mg/l)	2550	136	595	567	2	3
Sulphate (mg/l)	370	20	117.56	90.13	1.29	1.27
Alkalinity (mg/l)	457	140	249	81	1	1
Sodium (mg/l)	944.000	156.000	365.378	193.375	1.060	0.667
Phosphate (mg/l)	1.300	0.010	0.278	0.383	1.569	1.247
Potash (mg/l)	15.000	1.100	6.243	3.865	1.434	3.499
HCO3 (mg/l)	2030.080	97.600	492.980	360.819	2.376	8.155

4.3.1 pH

pH is one of the most common water quality tests performed. pH indicates the sample's acidity but is actually a measurement of the potential activity of hydrogen ions (H+) in the sample. pH measurements run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids. Solutions with a pH above 7.0, up to 14.0 are considered bases or an indication of alkalinity. All organisms are subject to the amount of acidity of stream water and function best within a given range. Water generally becomes more corrosive with decreasing pH; however, excessively alkaline water also may be corrosive.

The pH scale is logarithmic, so everyone-unit change in pH actually represents a ten-fold change in acidity. In other words, pH 6.0 is ten times more acidic than pH 7.0; pH 5 is one hundred times more acidic than pH 7.0.

Factors that affect the pH of water:

The pH of a body of water is affected by several factors. One of the most important factors is the bedrock and soil composition through which the water moves, both in its bed and as groundwater. Some rock types such as limestone can, to an extent, neutralize the acid while others, such as granite, have virtually no effect on pH.

Another factor which affects the pH is the amount of plant growth and organic material within a body of water. When this material decomposes carbon dioxide is released. The carbon dioxide combines with water to form carbonic acid. Although this is a weak acid, large amounts of it will lower the pH.

A third factor which determines the pH of a body of water is the dumping of chemicals into the water by individuals, industries, and communities. Remember - something as "harmless" as shampoo rinse water is actually a chemical brew and can affect the pH along with other chemical parameters of water. Many industrial processes require water of exact pH readings and thus add chemicals to change the pH to meet their needs. After use, this altered pH water is discharged as an effluent, either directly into a body of water or through the local sewage treatment plant.

A fourth factor which affects pH is the amount of acid precipitation that falls in the watershed. Acid rain is caused by nitrogen oxides (NOx) and sulfur dioxide (SO2) in the air combining with water vapor. These pollutants are primarily from automobile and coal-fired power plant emissions. Acid rain is responsible for many of our first order streams becoming acidic. Serious problems can occur in spring when streams receive a massive acid dose as acidic snows melt.

A fifth factor stems from coal mine drainage. Iron sulfide, a mineral found in and around coal seams, combines with water to form sulfuric acid. This acid, ferrous oxide (known as "yellow boy"), and huge quantities of silt are the major pollutants from coal mining. Combined with the problem of acid rain, the pH of some stream waters can be drastically lowered.

pH level within Study area:

The level of pH varied between 6.660 to 8.340, ranging between slightly acidic to the alkaline condition (Fig.4.3). The mean of pH in groundwater was 7.703 indicating a normal condition. Standard deviation (0.431) suggests that sample data are very close to each other. The skewness value (-0.785) is approximately equal to 0, thus the curve is symmetrical. kurtosis is (0.025) platykurtic. This may also indicate flatter distribution of data.

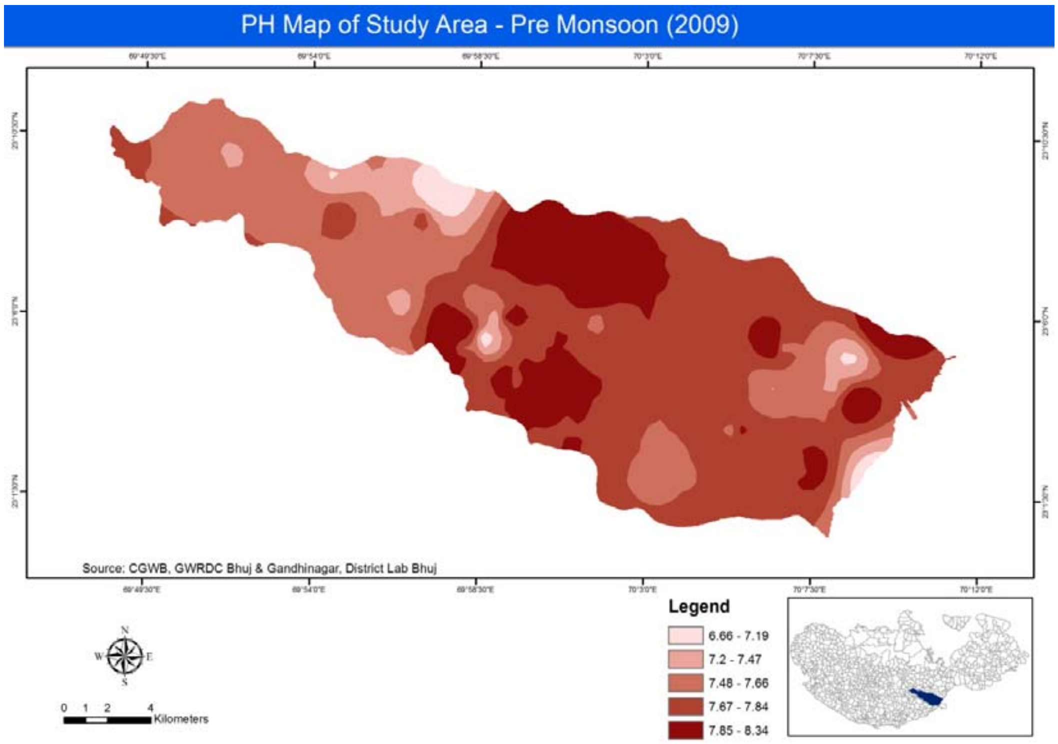

Fig. 4.3 pH Map of Study Area Pre Monsoon 2009

4.3.2 Nitrate

In water, nitrate has no taste or scent and can only be detected through a chemical test. The desirable concentration for nitrate in drinking water in india is 45 milligrams per litre (mg/l) while the permissible limit is less than 100 mg/l.

Nitrate is usually introduced into groundwater through widespread or diffuse sources, commonly called non-point sources, which can be hard to detect. These sources can include, Leaching of chemical fertilizers, Leaching of animal manure, Groundwater pollution from septic and sewage discharges.

Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern because it can harm infants by reducing the ability of blood to transport oxygen.

Nitrate Level within study area:

Concentration of Nitrate above the permissible limit in the study area is found near the coastal area of Gandhidham taluka. Standard deviation (33.97) suggests that sample data are farther to each other. The skewness value (2.14) thus the curve is skewed. kurtosis (4.85) suggests its leptokurtic.

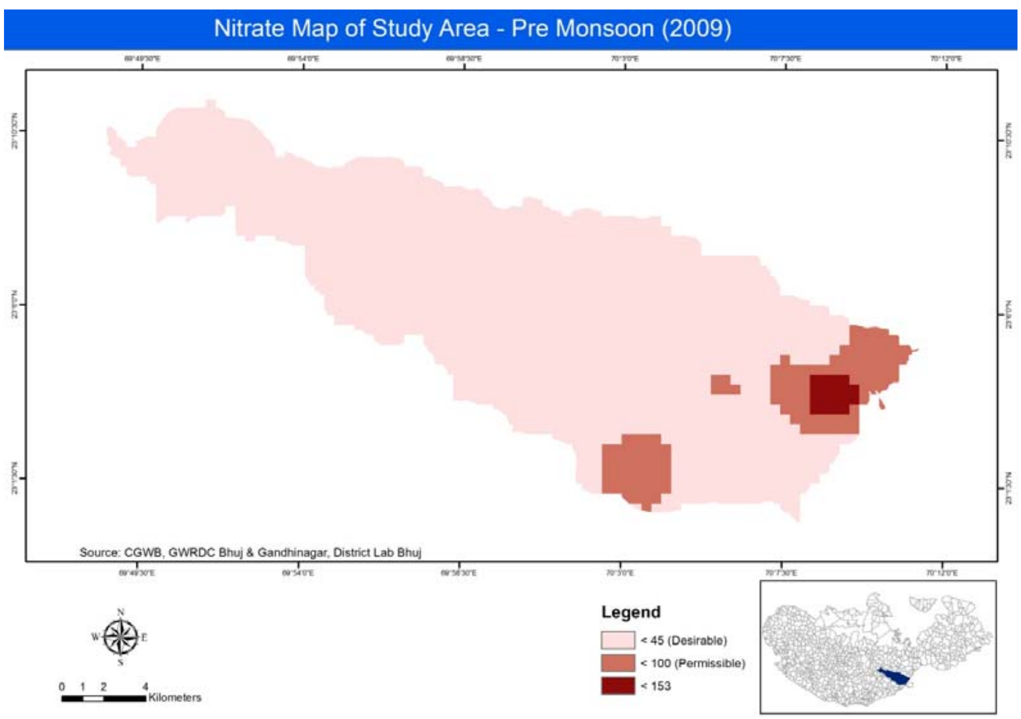

Fig. 4.4 Nitrate Map of Study Area Pre Monsoon 2009

4.3.3 Fluoride

Fluoride is found in all natural waters at some concentration. Seawater typically contains about 1 mg/l while rivers and lakes generally exhibit concentrations of less than 0.5 mg/l. In groundwaters, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. Concentrations in water are limited by fluorite solubility, so that in the presence of 40 mg l calcium it should be limited to 3.1 mgl (Hem, 1989). It is the absence of calcium in solution which allows higher concentrations to be stable. High fluoride concentrations may therefore be expected in groundwaters from calcium-poor aquifers and in areas where fluoride-bearing minerals are common. Fluoride concentrations may also increase in groundwaters in which cation exchange of sodium for calcium occurs (Edmunds and Smedley, 1996).

High groundwater fluoride concentrations associated with igneous and metamorphic rocks such as granites and gneisses have been reported from India and other countries.

Fluoride Level within study area:

In the study area many places in Anjar like Anjar town, Sinugra, Meghpar Borichi, varsamedhi as well as many villages in Gandhidham has been reported to have fluoride levels higher than the permissible limits. Where as northern parts of Anjar (M) and some part of Ningal village were found to have fluoride level less than the desired limit of 0.6 ppm. Fluoride concentration less than 0.6 ppm results in dental caries and dental motling (Rao and Venkateshwarulu 2000). Standard deviation (0.649) suggests that sample data are very close to each other. The skewness value

(0.837) is approximately equal to 0, thus the curve is symmetrical. kurtosis is (0.762) platykurtic.

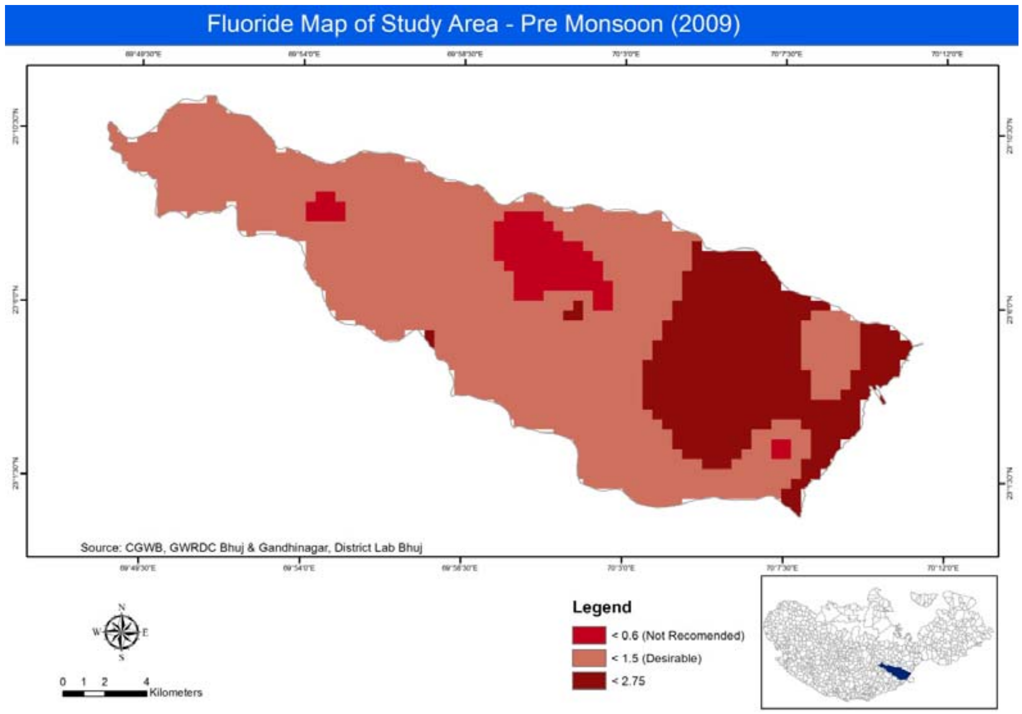

Fig. 4.5 Fluoride Map of Study Area Pre Monsoon 2009

4.3.4 Iron

As water percolates through the Earth, it dissolves minerals that are in the soil such as iron, manganese, calcium and magnesium just to name a few. Because the geology of the Earth varies from one region to another, so does ground water. Ground water supplies may have a little iron or extremely high amounts of iron. It may be naturally soft or so hard that it is virtually unusable for domestic purposes. It may be acidic or very alkaline. Out of all of these variables, which are a direct result of the geology of any particular region, iron can be the most troublesome for water use. Iron is considered to be one of the most unstable minerals in our ground water supply.

The effects of iron in a water supply are numerous. Iron will stain fixtures, water-using appliances or surfaces that the iron-laden water contacts. These stains may vary from a light yellow to a red or light brown color. Iron can give water a metallic taste that may be considered unpalatable. Iron may provide odors that are undesirable for domestic use. Iron can foul water softeners and water-using appliances, and it can plug water pipes or heat exchangers. While none of these effects are hazardous to humans, water processing or the environment, they cause consumers to spend hundreds and even thousands of dollars to clean and maintain appliances, homes and factories every year.

Iron Levels within study area

Iron in the study area above the permissible limit is found in various parts in Anjar taluka mostly in the villages like Sinugra, Vidi, Ningal, Anjar town and locally various other places in small traces. Standard deviation (0.433) suggests that sample data are very close to each other. The skewness value is 1.141 thus the curve is skewed. kurtosis is (0.762) platykurtic.

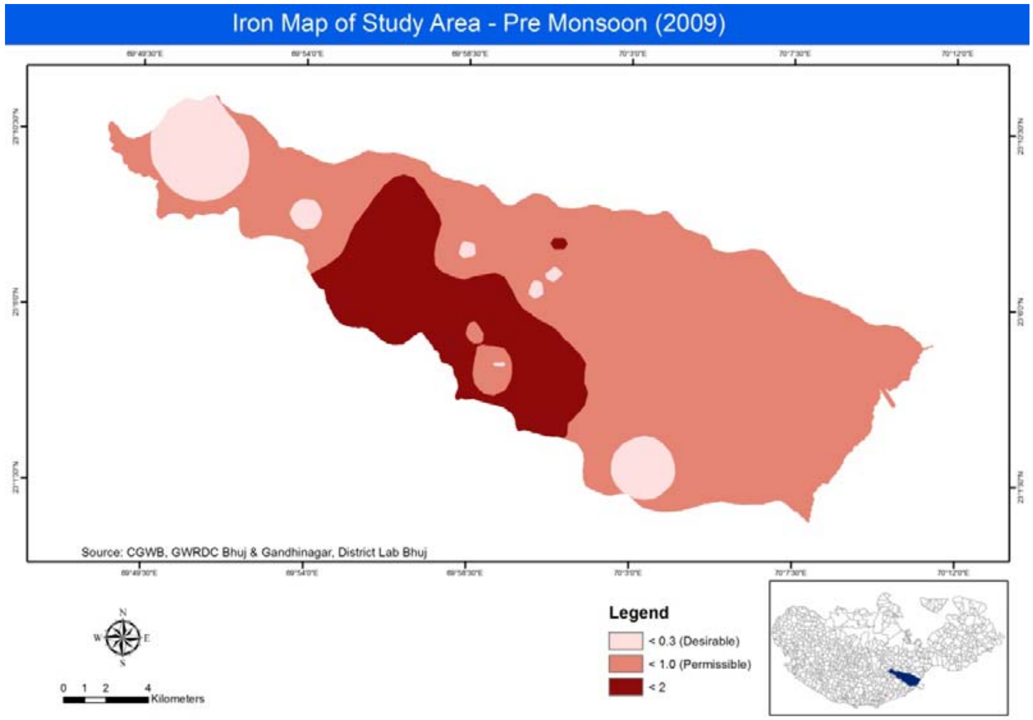

Fig. 4.6 Iron Map of Study Area Pre Monsoon 2009

4.3.5 Carbonate

The carbon dioxide that is dissolved by naturally circulating waters appears in chemical analysis principally as bicarbonate and carbonate ions.

Carbonate that follows this path represents a linkage between the carbon cycle and the hydrologic cycle. The large supply of atmospheric carbon dioxide is partly intercepted by photosynthesizing vegetation. They convert it to cellulose starch and related carbohydrates. These products are later reduced via respiration to carbon dioxide and water with a release of stored energy. The concentration of carbonates in natural waters is a function of dissolved carbon dioxide, temperature, pH, cations and other dissolved salts.

Most surface streams contain less than 200 mg/l Carbonate and Bicarbonate, but in ground water somewhat higher concentrations are not uncommon. Concentrations over 1,000 mg/l sometimes occur in waters which are low in calcium and magnesium and especially where processes releasing carbon dioxide such as sulfate reduction are occurring in the ground water reservoir.

Many of the carbonates are quite insoluble in water, generally more so than the chlorides, nitrates or sulfates. There is a tendency for certain carbonate salts to be removed by precipitation or absorption. In more calcareous environments, the circulation of water rich in carbon dioxide may produce solutions that are highly supersaturated when exposed to the air. Such solutions may deposit large quantities of calcium carbonate as travertine near their points of discharge.

Carbonate level within the study area

Carbonate level are relatively higher on the Anjar town and varsamedhi village area. There are no range specification available in Indian bureau of standards pertaining to the desirable and permissible limits of CO_3 level in water. Standard deviation (184.396) suggests that sample data are far from each other. The skewness value is 2.542 thus the curve is skewed. kurtosis is (8.333) leptokurtic.

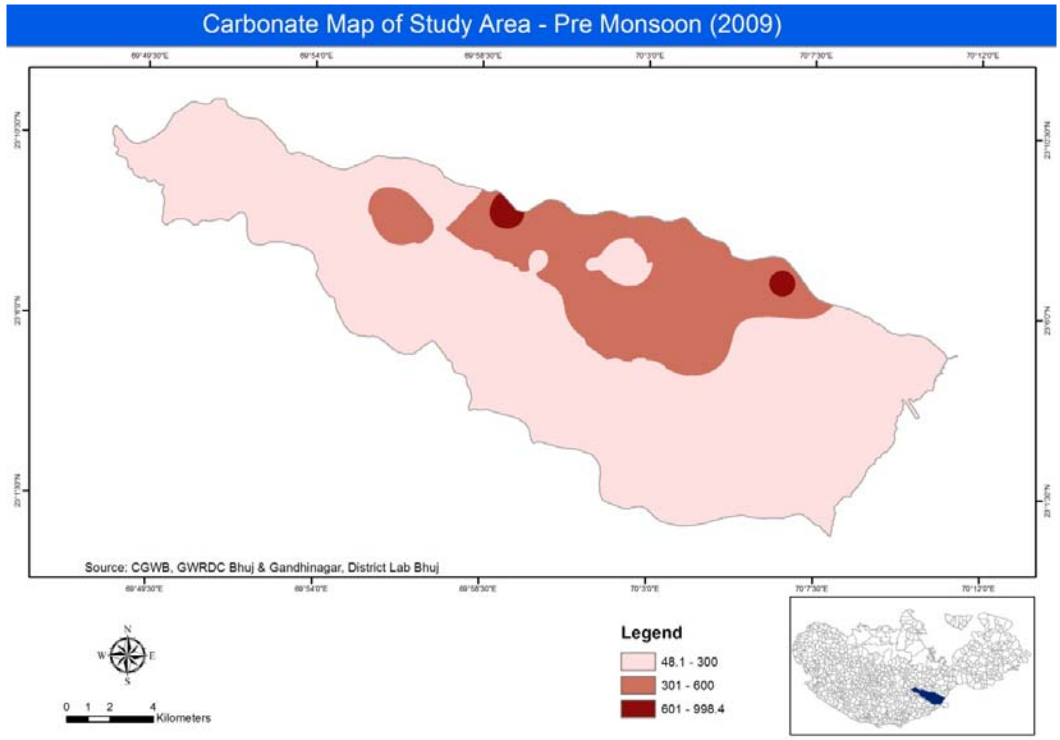

Fig. 4.7 Carbonate Map of Study Area Pre Monsoon 2009

4.3.6 Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher is the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms. Turbidity makes water cloudy or opaque.

Turbidity and water quality: High concentrations of particulate matter affect light penetration and productivity, recreational values, and habitat quality, and cause lakes to fill in faster. In streams, increased sedimentation and siltation can occur, which can result in harm to habitat areas for fish and other aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For this reason, turbidity readings can be used as an indicator of potential pollution in a water body.

Turbidity and human health: Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the United States and the world. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. The particles of turbidity provide "shelter" for microbes by reducing their exposure to attack by disinfectants. Microbial attachment to particulate material has been considered to aid in microbe survival. Fortunately, traditional water treatment processes have the ability to effectively remove turbidity when operated properly. (Source: EPA)

Turbidity level within the study area

Turbidity level within the study area are well within the permissible level. Standard deviation (2.0) suggests that sample data are far from each other. The skewness value is 1 thus the curve is skewed. kurtosis is (1.0) platykurtic.

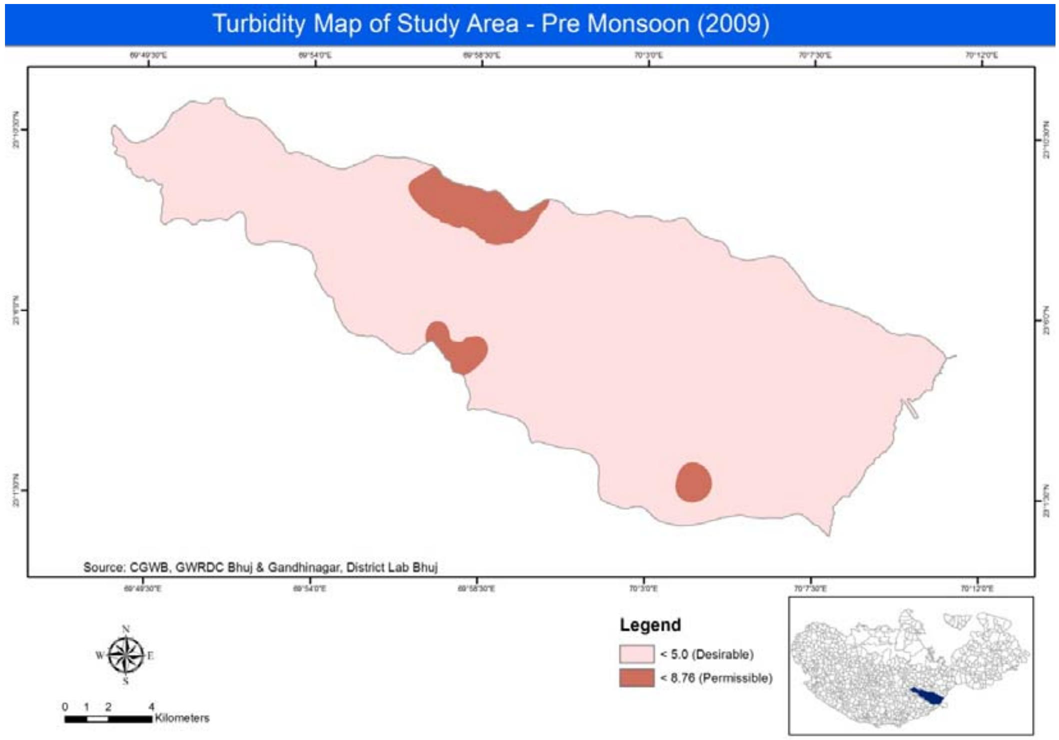

Fig. 4.8 Turbidity Map of Study Area Pre Monsoon 2009

4.3.7 TDS

One basic measure of water quality is the Total Dissolved Solids (TDS), which is the total amount of solids, in mg/l. The concentration of dissolved matter in water is given by weight of the material on evaporation of water to dryness followed by heating for one hour at 180°C. Measuring the electrical conductance of groundwater sample can make a rapid determination of TDS. Conductance is preferred rather than its reciprocal resistance, because it increases with salt content. Specific Electric conductance defines the conductance of a cubic centimeter of water at a standard temperature of 25°C. An increase of 1°C increases conductance by about 2 percent.

The water naturally contains a number of different dissolved inorganic constituents. The major cautions are calcium, magnesium, sodium, and potassium. The major anions are chloride, sulphate, carbonate, and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing to TDS. In addition, there may be minor constituents present including iron, manganese, fluoride, boron etc. The TDS content of groundwater may range from 20 ppm in areas of high rainfall to 100000 ppm in some desert brines. Several processes including movement of groundwater through rocks containing soluble mineral matter may cause an increase in the dissolved solids (K. R. Karanth, 1987).

TDS level of the Study area:

The map showing the concentration of TDS is also shown in Fig. 4.9 in the basin. Many places in Gandhidham taluka, namely Galpader, Antarjal, Gandhidham, Bharatnagar, Ganeshnagar, Kidana and Shinay villages are showing the TDS of more than 2000 ppm, which is the indication of brackish water. Villages of Anjar taluka mostly Bhadroi, Malingna, Ningal, few places in Anjar (M) and villages like Meghpar Borichi and Meghpar khumbadi was also found to have TDS level higher than the permissible limits. Standard deviation (1460.0) suggests that sample data are very far from each other. The skewness value is 2.0 thus the curve is skewed. kurtosis is (3.0) which indicates normal distribution.

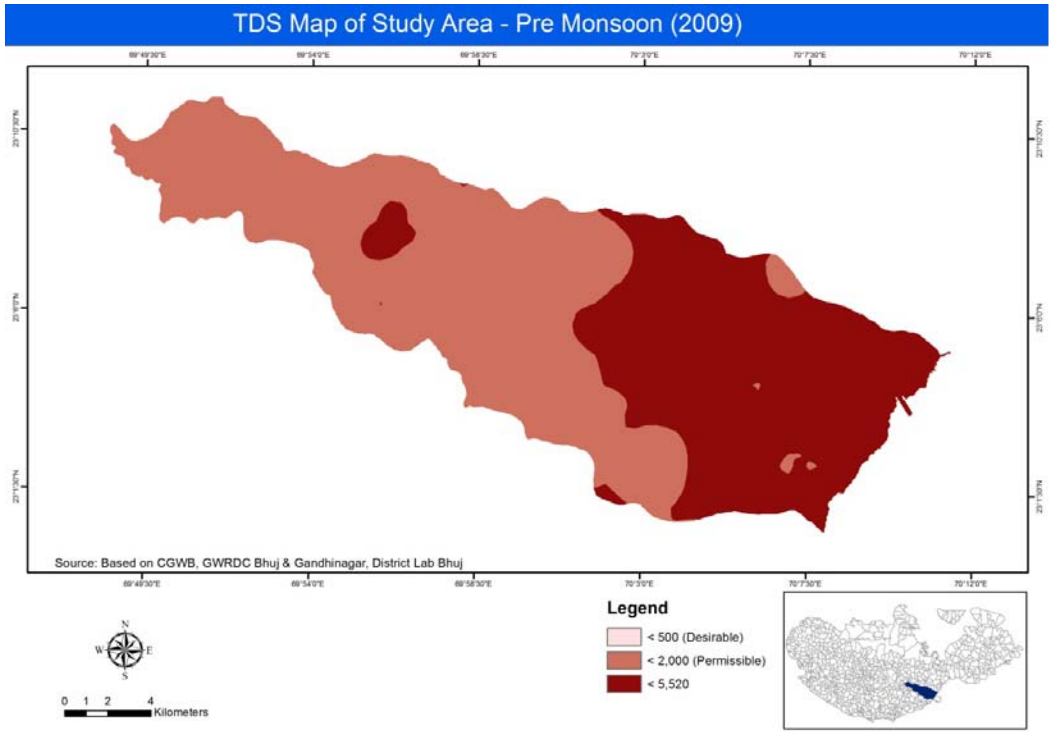

Fig. 4.9 TDS Map of Study Area Pre Monsoon 2009

4.3.8 Hardness

Water that contains high levels of dissolved calcium or magnesium salts, or both, is described as being 'hard'. Other cations such as iron, manganese, aluminium and zinc can also contribute to hardness.

The desirable hardness limit is upto 300 mg/l while permissible limit is 600 mg/l in india.

Hardness is a property of water that is not a health concern, but it can be a nuisance. Hard water can cause mineral build up in plumbing, fixtures, and water heaters, and poor performance of soaps and detergents. Hence Hard water can affect soil, stock and domestic water use, and pipes and equipment.

Effects in Soils: Hardness does not affect plants directly, but hardness caused by bicarbonates can affect soils, thus having an indirect impact on plant growth. A bicarbonate (HCO_3) compound is a soluble compound often found in saline–sodic water. Bicarbonates cause calcium and magnesium from soil and water to precipitate as insoluble carbonates. The relative concentration of sodium in the soil – which remains bonded to the clay particles – therefore increases as a percentage of total exchangeable cations, and increases soil sodicity (see 'Sodicity'). The risk of this occurring is low if the water contains bicarbonates at a concentration of less than 90 mg/l, and high if the concentration is greater than 335 mg/l.

Effect on stock and domestic use: Hard water also leads to poor laundry results. Hard water will not lather with soap until all the calcium and magnesium have reacted, and so more soap needs to be used. The more soap required to produce lather, the harder the water. Domestic or livestock consumption of hard water is generally not a problem unless magnesium salts predominate. Drinking water hard in magnesium could lead to gastrointestinal problems due to the laxative effect of magnesium sulfate, better known as Epsom salts.

Hardness Level within study area:

In the study area it is usually found in Anjar taluka in small patches near Vidi and Anjar town. Standard deviation (205.33) suggests that sample data are very far from each other. The skewness value is 0.6 thus the curve is skewed. kurtosis is (-0.56) which indicates its platykurtic.

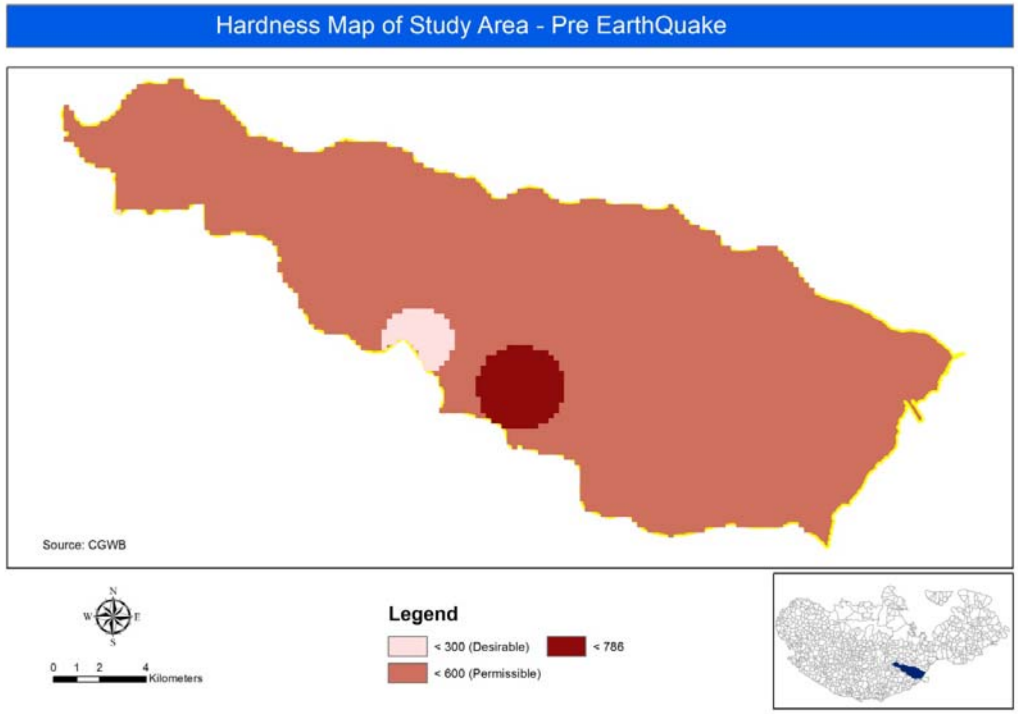

Fig. 4.10 (a) Hardness Map of Study Area Pre Monsoon (Pre Earthquake)

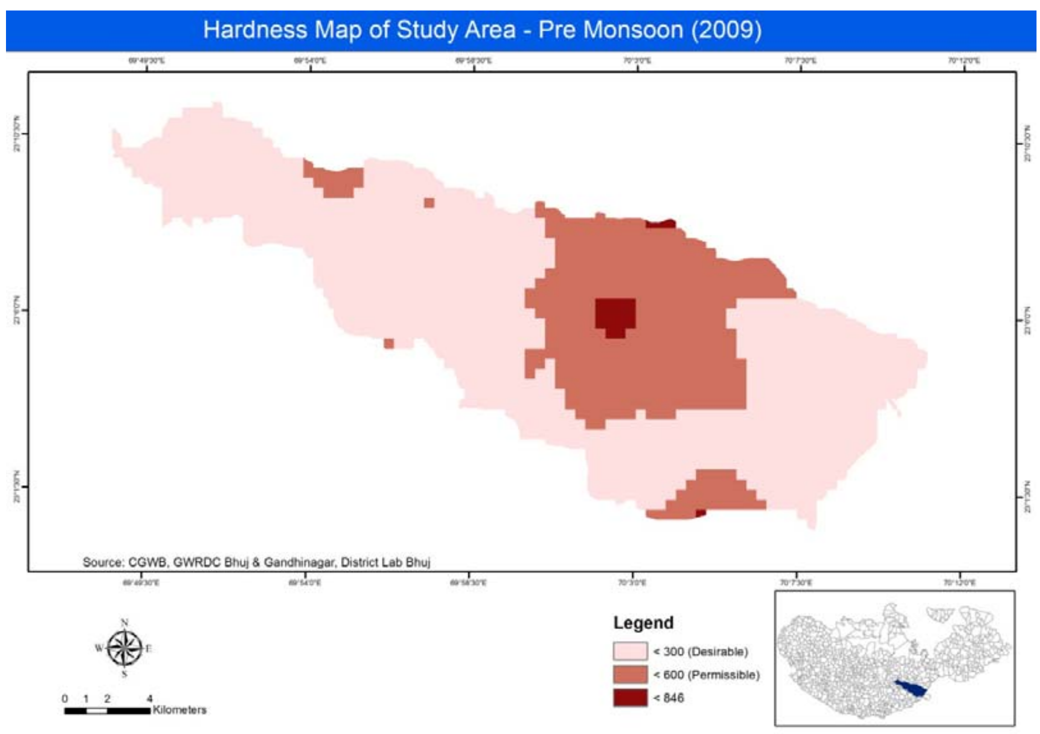

Fig. 4.10 (b) Hardness Map of Study Area Pre Monsoon 2009

4.3.9 Calcium

Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Magnesium is the other hardness determinant.

Calcium often positively affects soil quality and various compounds are applied as a fertilizer.

Calcium is largely responsible for water hardness, and may negatively influence toxicity of other compounds. Elements such as copper, lead and zinc are much more toxic in soft water.

In limed soils calcium may immobilize iron. This may cause iron shortages, even when plenty of iron is present in the soil.

Some environmental effects of water hardness include hardening of domestic equipment, because high temperatures cause carbonate hardness. This may dramatically decrease the lifespan of equipment, and causes an increase of domestic waste. Calcium carbonate interacts with detergents and cleansing agents. Complex formation causes a decrease in detergent efficiency, resulting in requirement for increased detergent application and softener purchases.

Calcium Levels within Study area

In the study area calcium is mostly found within the permissible limits excluding the coastal boundary of Gandhidham taluka. Standard deviation (51.0) suggests that sample data are very far from each other. The skewness value is 1.0 thus the curve is skewed. kurtosis is (1.0) which indicates its platykurtic.

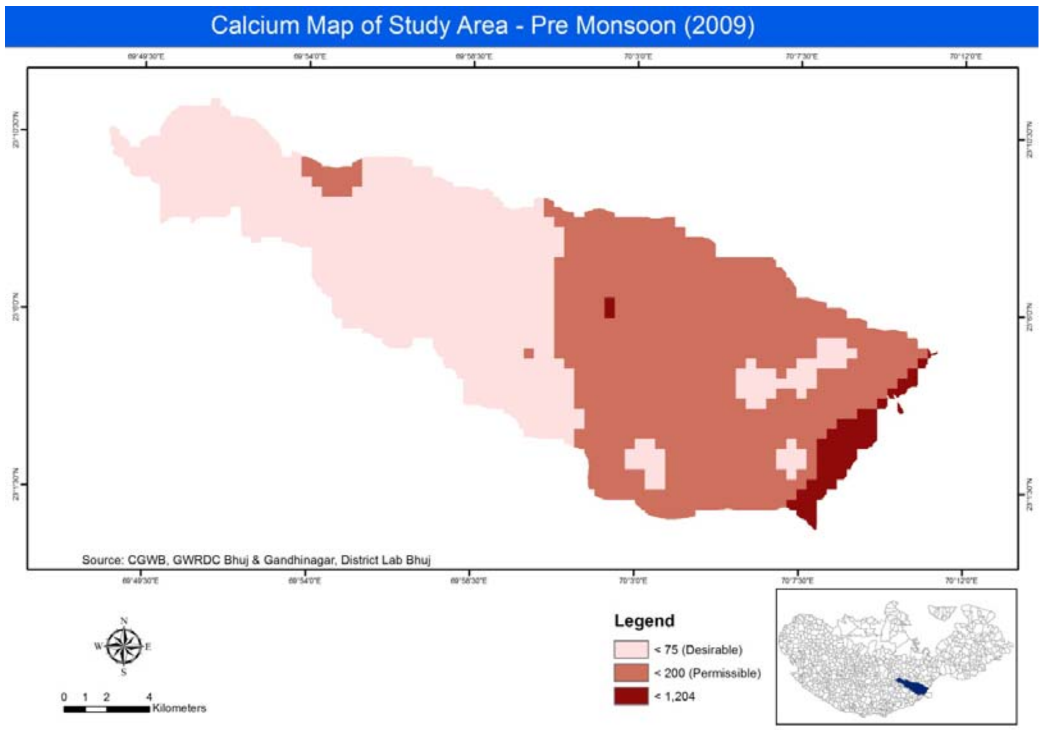

Fig. 4.11 Calcium Map of Study Area Pre Monsoon 2009

4.3.10 Magnisium

Mostly Local rocks are the main source of magnesium in groundwater. As rocks are eroded and transported by rivers as alluvial sediments, they slowly dissolve and release magnesium and other chemicals into the groundwater over time. A small amount of magnesium may also come from the use of agricultural fertiliser.

Magnesium Level within the study area

Because calcium and magnesium are the major constituents responsible for hardness in water, the highest levels of these ions generally occur in ground water with high hardness levels. As expected, the Gandhidham and Anjar taluka have high to median calcium and magnesium levels relative to most of the other areas. Standard deviation (31.45) suggests that sample data are very far from each other. The skewness value is 1.19 thus the curve is skewed. kurtosis is (0.93) which indicates its platykurtic

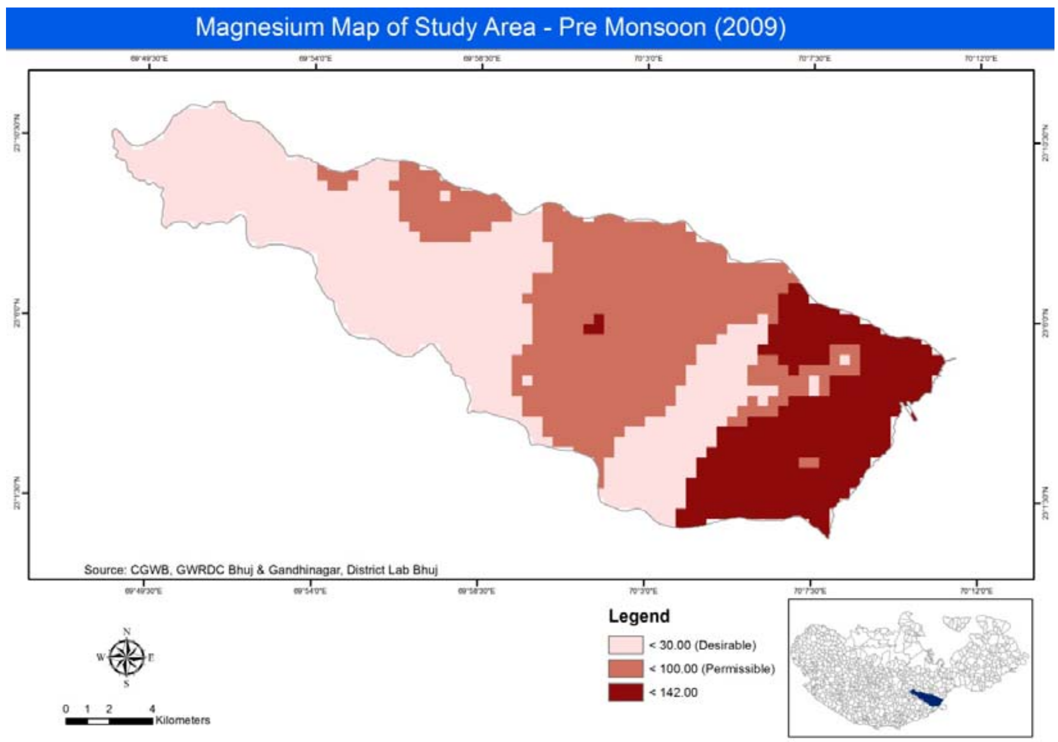

Fig. 4.12 Magnesium Map of Study Area Pre Monsoon 2009

4.3.11 Chlorides

Chlorides are widely distributed in nature as salts of sodium ($NaCl$), potassium (KCl), and calcium ($CaCl_2$).

Environmental fate: Chlorides are leached from various rocks into soil and water by weathering. The chloride ion is highly mobile and is transported to closed basins or oceans.

Chloride can be introduced in surface and groundwater from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas.

Effects On Humans: Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure **(13).** Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion **(4).**

Other Considerations: Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts **(8)**, thus increasing levels of metals in drinking-water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion **(14).** It can also increase the rate of pitting corrosion of metal pipes **(8).**

Conclusions: Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre. No health-based guideline value is proposed for chloride in drinking-water.

Chloride levels within the study area

The mean chloride concentration in several study area was in the range <100 to 2400 mg/litre during pre earthquake data analysis **i.e. 1998-2000**. Evidence of a general increase in chloride concentrations in groundwater and drinking-water has been found towards the gulf of kutch, but exceptions have also been reported in and around Gandhidham area. Aquifers prone to seawater intrusion have been found to contain chloride at concentrations ranging from >1000 to <7400 mg/litre, whereas contaminated wells have been reported to have an average chloride concentration of 350 mg/litre. Chloride levels within desirable limits below 250 mg/litre are found at many areas in villages like Sinugra, Vidi, Nagalpar Moti, Nagalpar Nani, Ningal and Anjar in Anjar taluka. During the pre-earthquake period Gandher and Chubdak village in Bhuj taluka where mostly reported to have chlorides level within the desirable limits i.e. <250 mg/ltr while this has changed to permissible limits i.e <1000 mg/ltr during the recent years. Standard deviation (567.0) suggests that sample data are very far from each other. The skewness value is 2.0 thus the curve is skewed. kurtosis is (3.0) which indicates normal distribution.

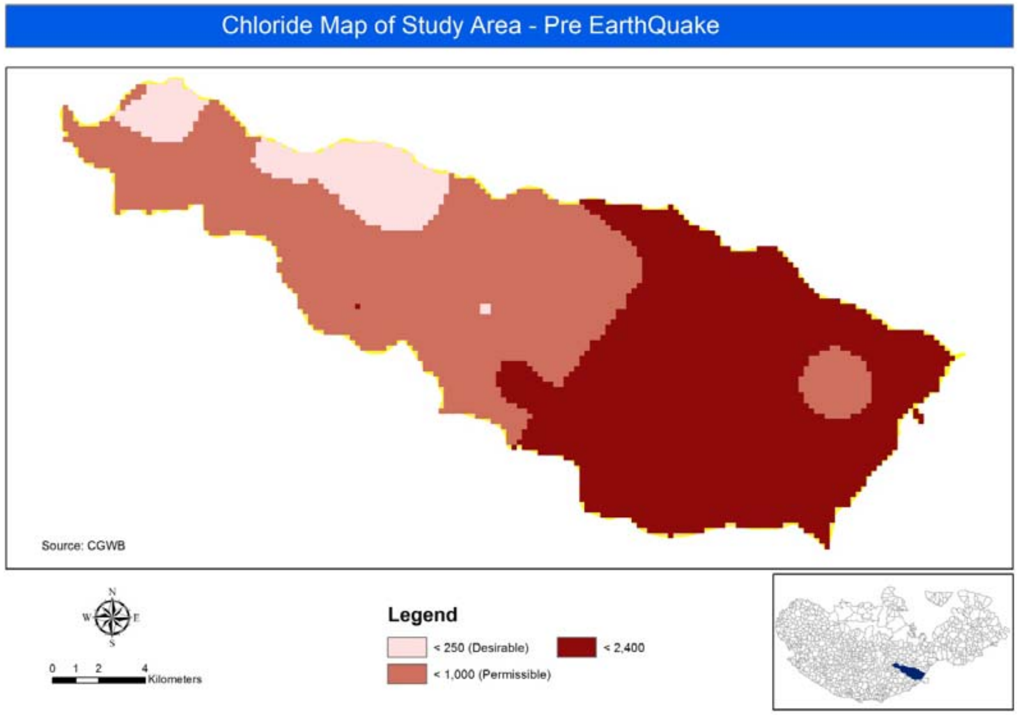

Fig. 4.13 (a) Chloride Map of Study Area Pre Monsoon (Pre Earthquake)

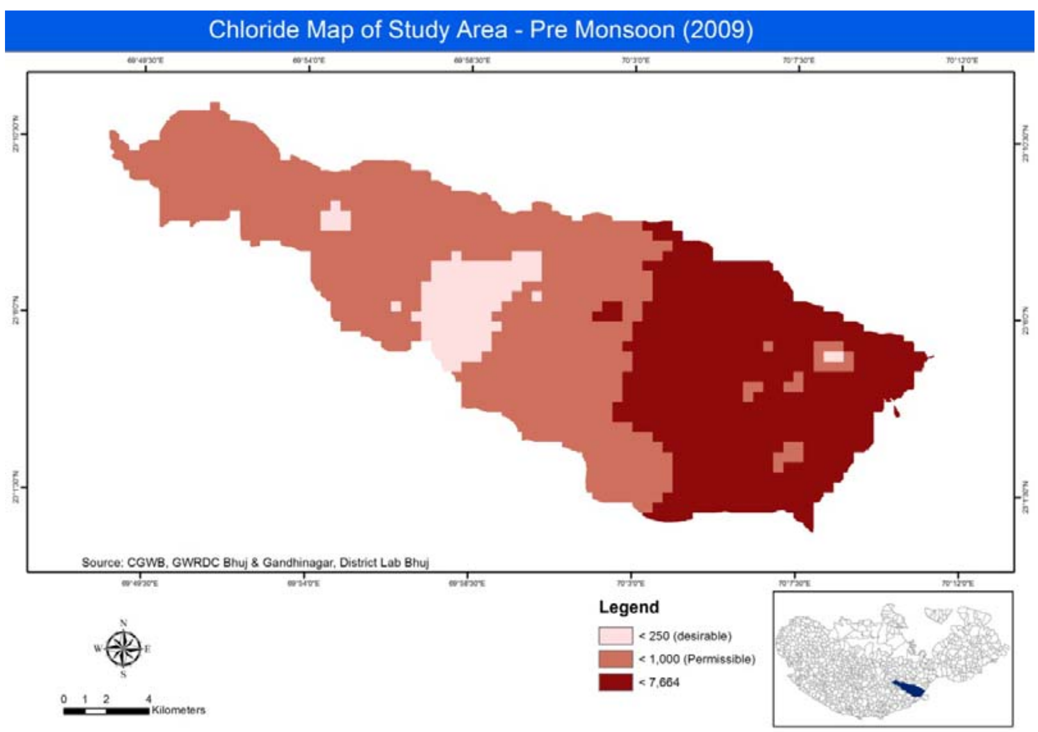

Fig. 4.13 (b) Chloride Map of Study Area Pre Monsoon 2009

4.3.12 Sulphate

Sulfate is second to bicarbonate as the major anion in hard water reservoirs. Sulfates ($SO4--$) can be naturally occurring or the result of municipal or industrial discharges. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals, or of atmospheric deposition. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills. Runoff from fertilized agricultural lands also contributes sulfates to water bodies.

Sulfates are not considered toxic to plants or animals at normal concentrations. In humans, concentrations of 500 - 750 mg/l cause a temporary laxative effect. However, doses of several thousand mg/l did not cause any long-term ill effects. At very high concentrations sulfates are toxic to cattle. Problems caused by sulfates are most often related to their ability to form strong acids which changes the pH. Sulfate ions also are involved in complexing and precipitation reactions which affect solubility of metals and other substances.

Sulphate levels within the study area

Sulphates above the permissible limits are only seen near the coastal area of Gandhidham in the recent survey and was found within the permissible limits during the pre-earthquake time based on the available reports. Standard deviation (90.13) suggests that sample data are very far from each other. The skewness value is 1.29 thus the curve is skewed. kurtosis is (1.27) which indicates its platykurtic.

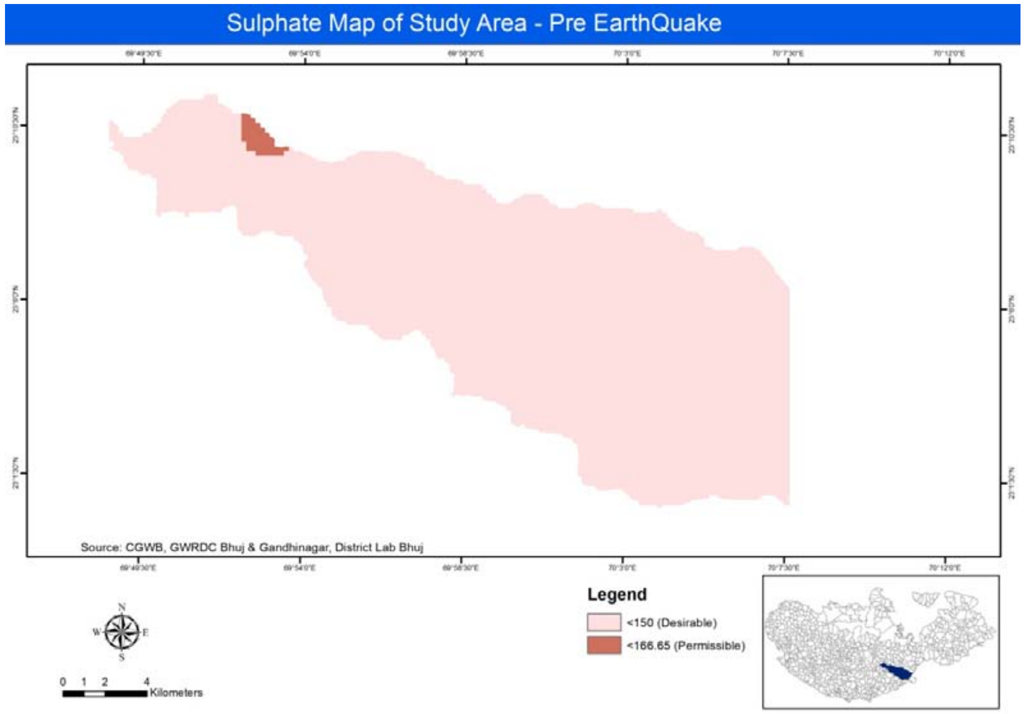

Fig 4.14 (a) Sulphate Map of study area (Pre-Earthquake)

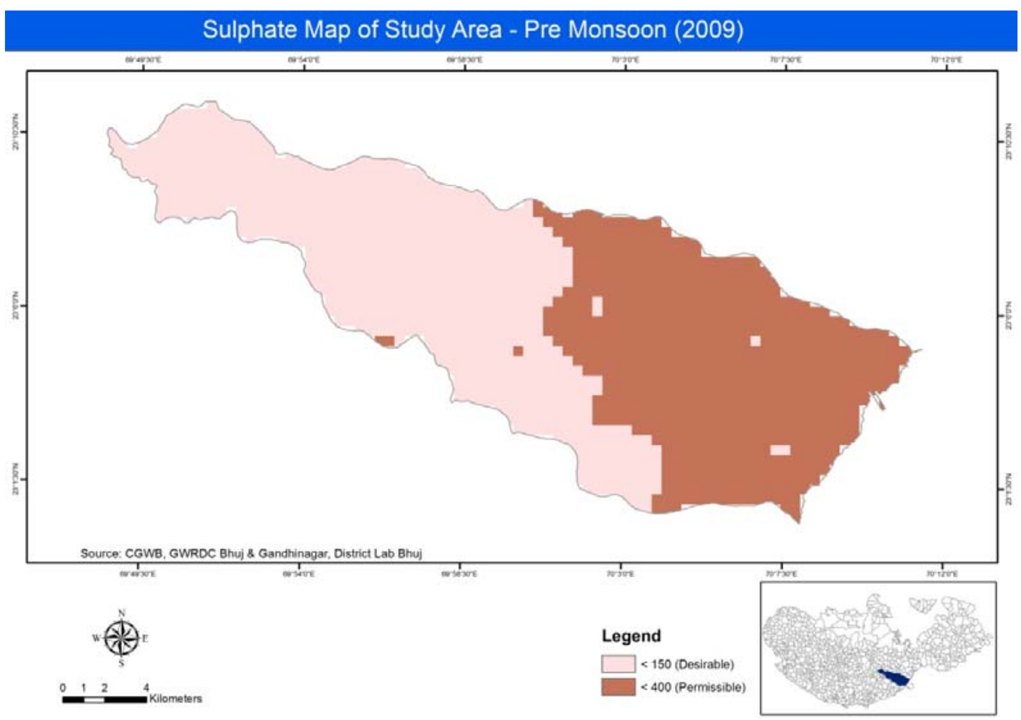

Fig. 4.14 (b) Sulphate Map of Study Area Pre Monsoon 2009

4.3.13 Alkalinity

Alkalinity and pH are related to each other in ways that are obvious, and in other ways that are subtle.

The idea that alkalinity is separate from pH (which is by 'coincidence' called either acid or alkaline) is a myth though pH and alkalinity are two different measurable parameters of water.

Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic. This capacity is commonly known as "buffering capacity. In other words Alkalinity is a measure of the capacity of water to neutralize acids. It measures the presence of carbon dioxide, bicarbonate, carbonate, and hydroxide ions that are naturally present in water. At normal drinking water pH levels, bicarbonate, and carbonate are the main contributors to alkalinity. Normal to high alkalinity implies adequate bicarbonate, while low alkalinity implies that it is in short supply

Alkalinity of natural water is determined by the soil and bedrock through which it passes.

The main sources for natural alkalinity are rocks which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates also may contribute to alkalinity. Limestone is rich in carbonates, so waters flowing through limestone regions or bedrock containing carbonates generally have high alkalinity - hence good buffering capacity.

Conversely, areas rich in granites and some conglomerates and sandstones may have low alkalinity and therefore poor buffering capacity.

High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acid for some plant. If the water is also somewhat acidic, the process would be accelerated. Another aspect of alkalinity is its potential effect on sodium (Na-). Soil or artificial growing media irrigated with alkaline water may, upon drying, cause an excess of available sodium. Several potential problems could result. · The excess available sodium could become directly toxic to some plants · The salinity of the soil could be increased to the point that plant growth is damaged. · Excess sodium could damage the structure of natural soil to the point that air and water infiltration are prevented, and root growth is restricted. Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. However, bicarbonates can be found in water of lower pH. Carbonates become a significant factor as the water pH increases beyond 8.0 and are a dominant factor when the pH exceeds about 10.3. High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3 mg/l (200 ppm) will cause lime (calcium and magnesium carbonate) to be deposited on foliage when irrigated with overhead sprinklers. This may be undesirable for ornamental plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging to many tree species. High water alkalinity can be corrected with acid injection

Alkalinity Level within the study area

Alkalinity is mostly found in the parts of Anjar and Gandhidham talukas in the study area. Standard deviation (81.0) suggests that sample data are very far from each other. The skewness value is 1.0 thus the curve is skewed. kurtosis is (1.0) which indicates its platykurtic.

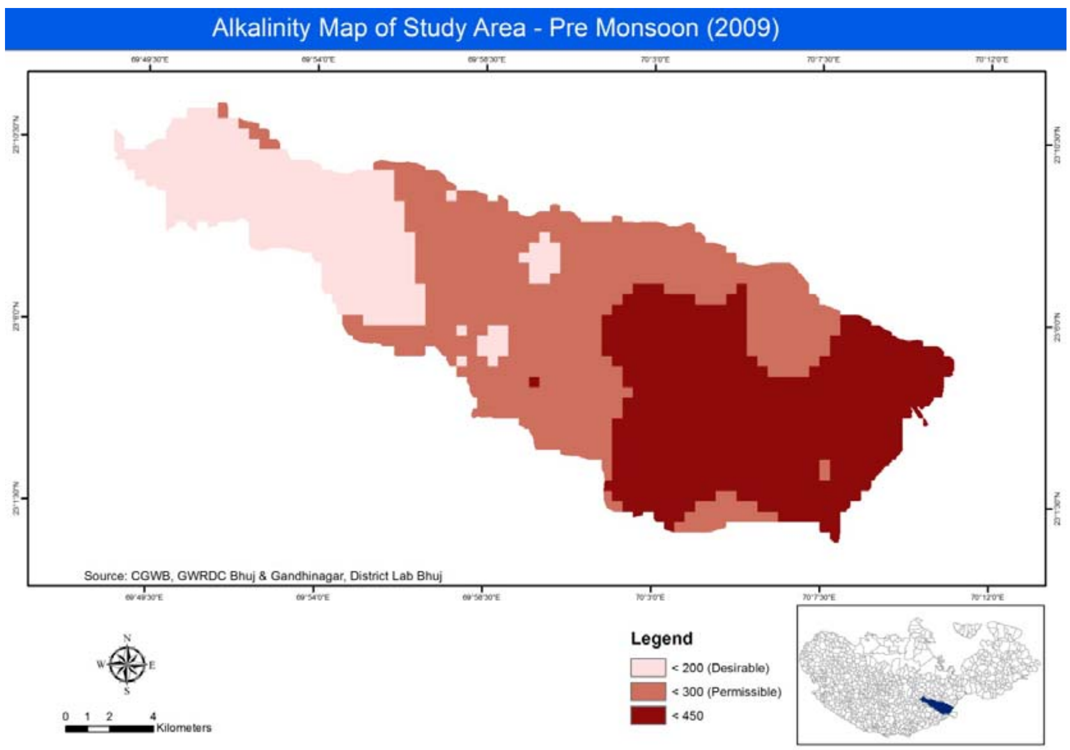

Fig. 4.15 Alkalinity map of study area Pre Monsoon 2009

4.3.14 Sodium

Sodium exists in nearly all irrigation water and is not necessarily a cause for concern unless high concentrations are present. High concentrations (> 70 mg/l) can be detrimental to both turf and soils. Sodium in irrigation water can be absorbed by roots and foliage, and foliar burning can occur if sufficient amounts accumulate in leaf tissue.

Sodium Level within the study area

Sodium level near the coastal areas i.e. Gandhidham area are observed to be above the permissible limit. Standard deviation (193.0) suggests that sample data are very far from each other. The skewness value is 1.06 thus the curve is skewed. kurtosis is (0.667) which indicates its platykurtic.

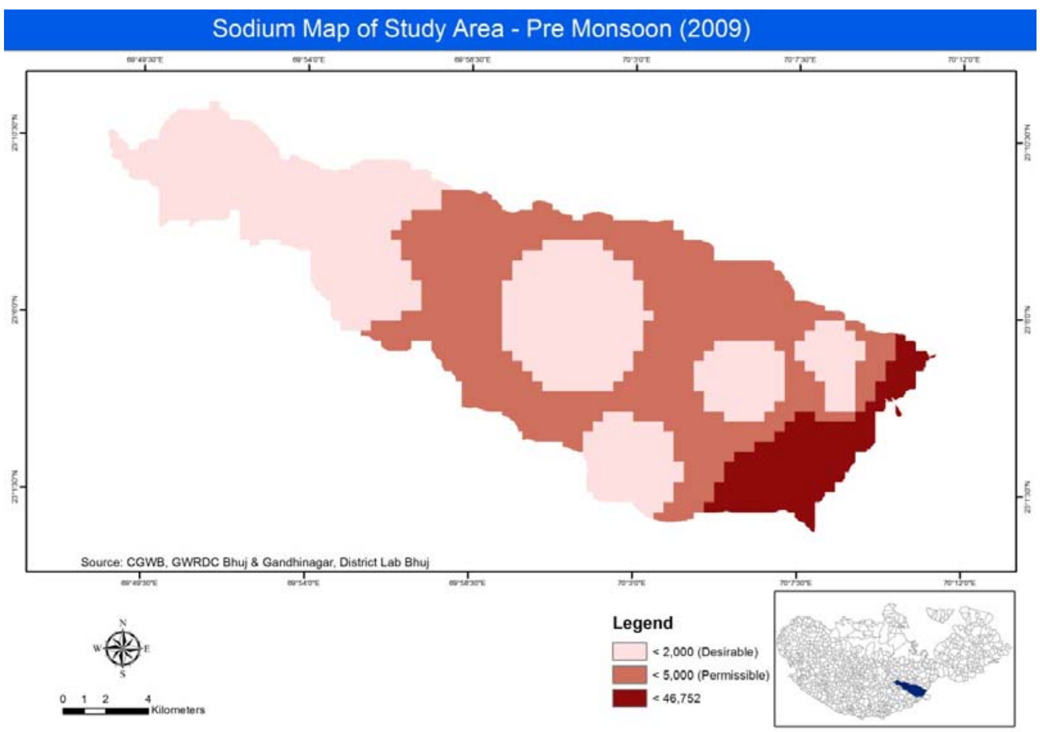

Fig. 4.16 Sodium Map of Study Area Pre Monsoon 2009

4.3.15 Phosphate

Phosphates are chemical compounds containing phosphorus. Phosphorus is a non-metallic element which is necessary for life and is found in rock as inorganic phosphates. As water runs over and through rocks it carries off small amounts of minerals such as calcium, magnesium, and phosphates. Inorganic phosphates are a plant nutrient and are taken in by plants with water and incorporated into organic phosphate compounds. Animals obtain their essential phosphorus from phosphates in water and plant material. Natural waters have a phosphorus concentration of approximately 0.02 parts per million (ppm) which is a limiting factor for plant growth. On the other hand, large concentrations of this nutrient can accelerate plant growth.

Phosphates enter waterways through manmade sources also. The addition of large quantities of phosphates to waterways accelerates algae and plant growth in natural waters; enhancing eutrophication and depleting the water body of oxygen. This can lead to fish kills and the degradation of habitat with loss of species. Large mats of algae can form and in severe cases can completely cover small lakes. As a result, water can become putrid from decaying organic matter. When the concentration of phosphates rises above 100 mg/liter the coagulation processes in drinking water treatment plants may be adversely affected. Manmade sources of phosphate include human sewage, agricultural run-off from crops, sewage from animal feedlots, pulp and paper industry, vegetable and fruit processing, chemical and fertilizer manufacturing, and detergents.

Phosphate within study area

Phosphate level was seen on the higher side in the coastal boundaries on Gandhidham taluka only while in rest of the region within the study area it was found to be within the permissible limits. Standard deviation (0.383) suggests that sample data are very far from each other. The skewness value is 1.569 thus the curve is skewed. kurtosis is (1.247) which indicates its platykurtic.

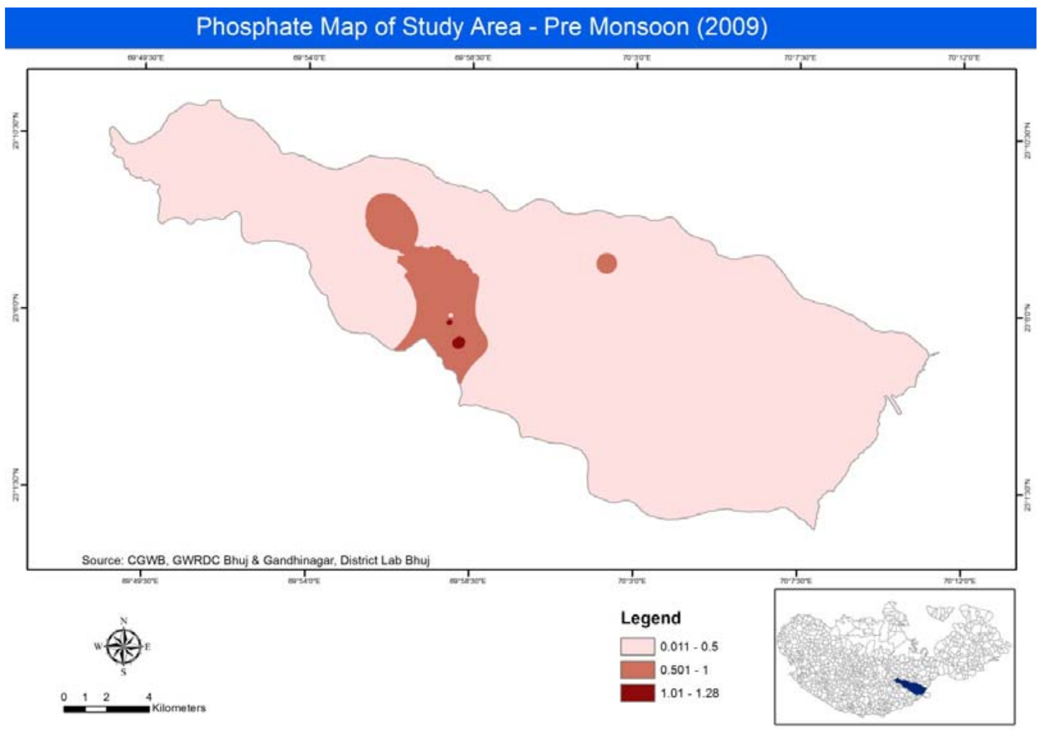

Fig. 4.17 Phosphate Map of Study Area Pre Monsoon 2009

4.3.16 Potash

The concentration of potassium in ground water varied from 1.1 to 15.. mg/l Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. It is more abundant in sedimentary rocks and commonly present in feldspar, mica and other clay minerals. The Bureau of Indian Standards has not included potassium in drinking water standards. Higher potassium content in ground water is indicative of ground water pollution. (CPCB, 2011)

Potash Level within the study area

There are no Indian standards available for potash however Potash level are relatively on the higher side near the coastal area i.e Gandhidham taluka as compared to the other places within the study area. Standard deviation (3.865) suggests that sample data are very far from each other. The skewness value is 1.434 thus the curve is skewed. kurtosis is (3.499) which indicates its leptokurtic.

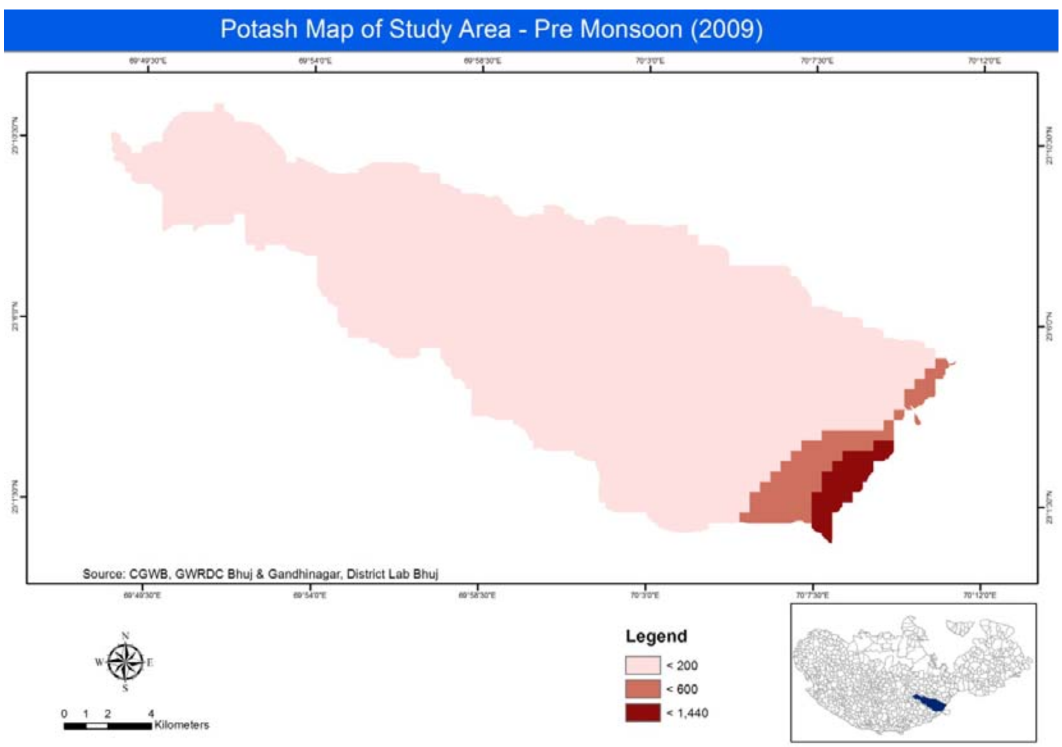

Fig. 4.18 Potash Map of Study Area Pre Monsoon 2009

4.3.17 Bicarbonate

In inorganic chemistry, is an intermediate form in the deprotonation of carbonic acid. It is a polyatomic anion with the chemical formula HCO3

Bicarbonate serves a crucial biochemical role in the physiological pH buffering system.

Bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}) are common constituents of water, and can influence soil properties. If bicarbonate and/or carbonate levels are high (>120 and 15 mg/l, respectively), these ions can react with calcium and magnesium in the soil to form insoluble calcium carbonate and magnesium carbonate (lime). This reaction reduces the amount of free calcium and magnesium in soil, allowing sodium to compete for and occupy negatively-charged exchange sites on clay particles. Excess sodium in clay results in destruction of soil structure and reduced water percolation though the soil profile. This effect is referred to as the sodium permeability hazard.

Bicarbonate Level within the study area

Bicarbonate levels are found to be on the higher side near the villages of Anjar taluka i.e. Meghpar (Borichi), Meghpar Khumbhardi and Anjar (M) and in Gandhidham taluka i.e. Antarjal, Kidana, Gandhidham (M), Galpadar and shinay. Standard deviation (360.819) suggests that sample data are very far from each other. The skewness value is 2.367 thus the curve is skewed. kurtosis is (8.155) which indicates its leptokurtic.

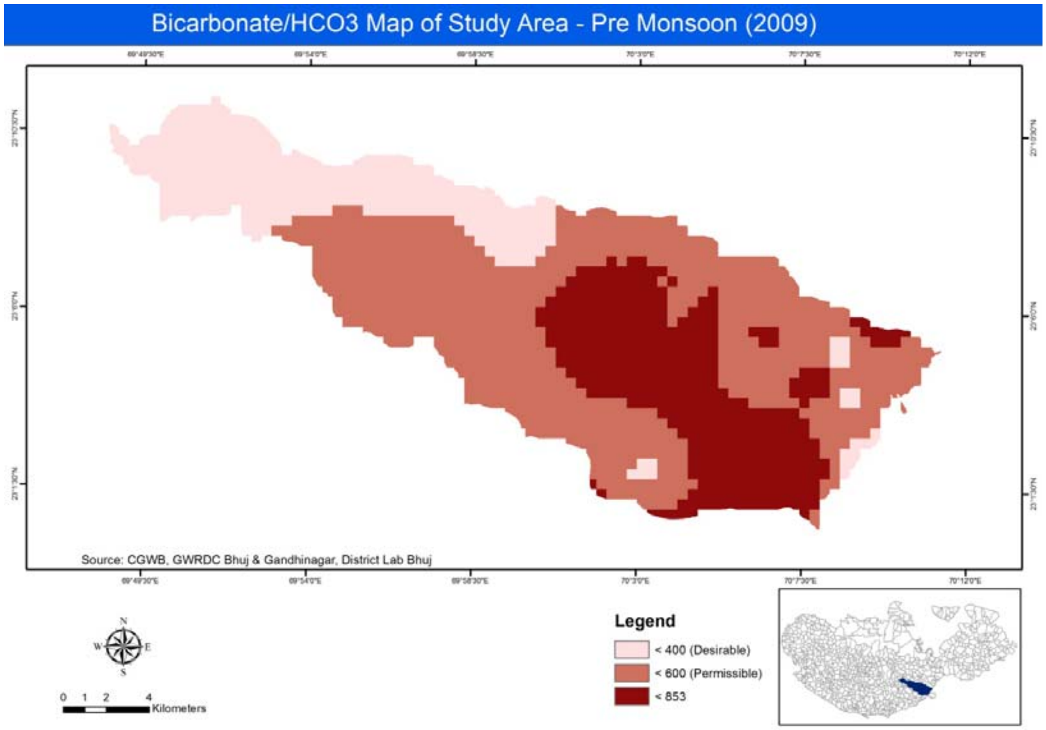

Fig. 4.19 Bicarbonate Map of Study Area Pre Monsoon 2009

Table 4.2 (a) Correlation Matrix of Pre Monsoon 2009

	pH	Nitrate	Fluoride	Iron	CO3	Turbidity	TDS	Hardness	calcium
pH	1	0.121	0.145	-0.19	0.197	0.361	0.234	0.222	0.3
Nitrate	0.121	1	0.233	0.069	.367*	0.077	.370*	.411**	0.25
Fluoride	0.145	0.233	1	0.051	.357*	0.257	.517**	.369*	0.268
Iron	-0.19	0.069	0.051	1	.460**	0.089	0.218	.440**	0.209
CO3	0.197	.367*	.357*	.460**	1	.542**	.631**	.950**	.555**
Turbidity	.361*	0.077	0.257	0.089	.542**	1	0.226	.530**	0.243
TDS	0.234	.370*	.517**	0.218	.631**	0.226	1	.734**	.857**
Hardness	0.222	.411**	.369*	.440**	.950**	.530**	.734**	1	.687**
calcium	0.3	0.25	0.268	0.209	.555**	0.243	.857**	.687**	1
magnesium	0.106	.328*	.511**	.414**	.894**	.567**	.705**	.904**	.595**
chlorides	0.21	.403**	.431**	0.227	.548**	0.203	.967**	.666**	.856**
Sulphate	0.21	.450**	.475**	.355*	.811**	.403**	.820**	.837**	.667**
Alkalinity	.597**	.348*	0.285	0.174	.594**	0.3	.519**	.595**	.473**
Sodium	.405**	0.258	0.28	0.197	.488**	0.211	.474**	.469**	.518**
Phosphate	-.358*	-0.2	0.124	0.135	-0.045	0.134	-0.17	-0.085	-0.265
Potash	0.202	.710**	0.214	0.092	0.267	0.057	.302*	.308*	0.263
HCO3	0.255	.435**	.434**	.396**	.937**	.440**	.841**	.945**	.727**

Table 4.2 (b) Correlation Matrix of Pre Monsoon 2009

	magnesium	chlorides	Sulphate	Alkalinity	Sodium	Phosphate	Potash	HCO3
pH	0.106	0.21	0.21	0.597	0.405	-.358*	0.202	0.255
Nitrate	.328*	.403**	.450**	.348*	0.258	-0.2	.710**	.435**
Fluoride	.511**	.431**	.475**	0.285	0.28	0.124	0.214	.434**
Iron	.414**	0.227	.355*	0.174	0.197	0.135	0.092	.396**
CO3	.894**	.548**	.811**	.594**	.488**	-0.045	0.267	.937**
Turbidity	.567**	0.203	.403**	0.3	0.211	0.134	0.057	.440**
TDS	.705**	.967**	.820**	.519**	.474**	-0.171	.302*	.841**
Hardness	.904**	.666**	.837**	.595**	.469**	-0.085	.308*	.945**
calcium	.595**	.856**	.667**	.473**	.518**	-0.265	0.263	.727**
magnesium	1	.618**	.862**	.415**	.351*	0.045	0.282	.869**
chlorides	.618**	1	.750**	.479**	.457**	-0.159	.330*	.769**
Sulphate	.862**	.750**	1	.512**	.347*	-0.056	.408**	.879**
Alkalinity	.415**	.479**	.512**	1	.614**	-0.284	.414**	.632**
Sodium	.351*	.457**	.347*	.614**	1	-0.193	0.238	.512**
Phosphate	0.045	-0.159	-0.056	-0.284	-0.193	1	-0.129	-0.11
Potash	0.282	.330*	.408**	.414**	0.238	-0.129	1	.318*
HCO3	.869**	.769**	.879**	.632**	.512**	-0.108	.318*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

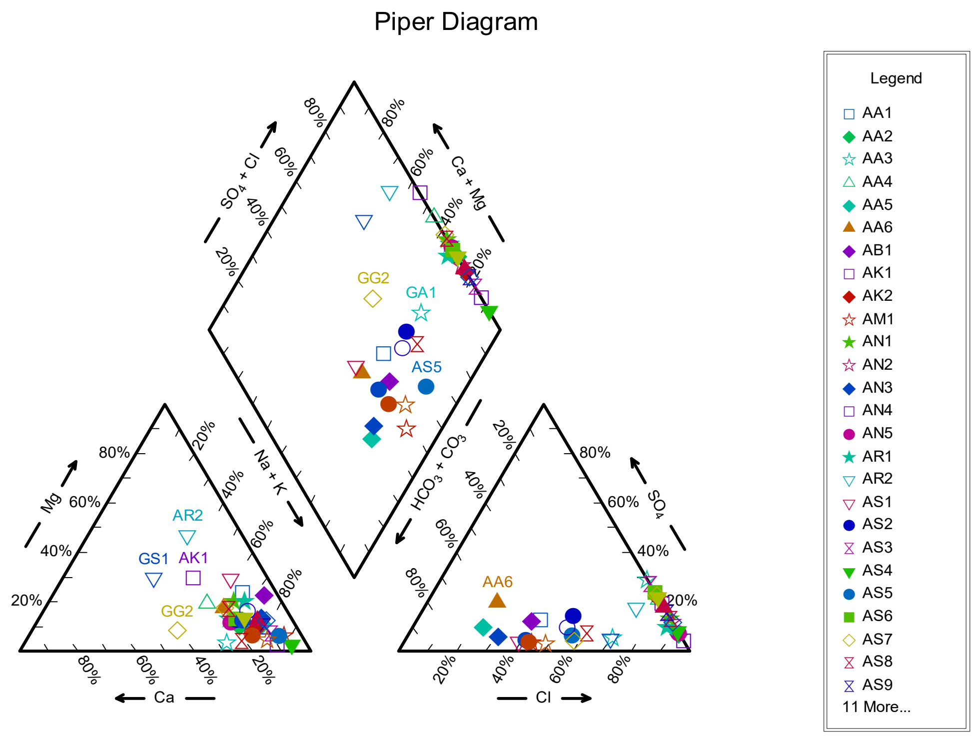

Fig. 4.20 Piper Diagram of Study Area Pre Monsoon 2009

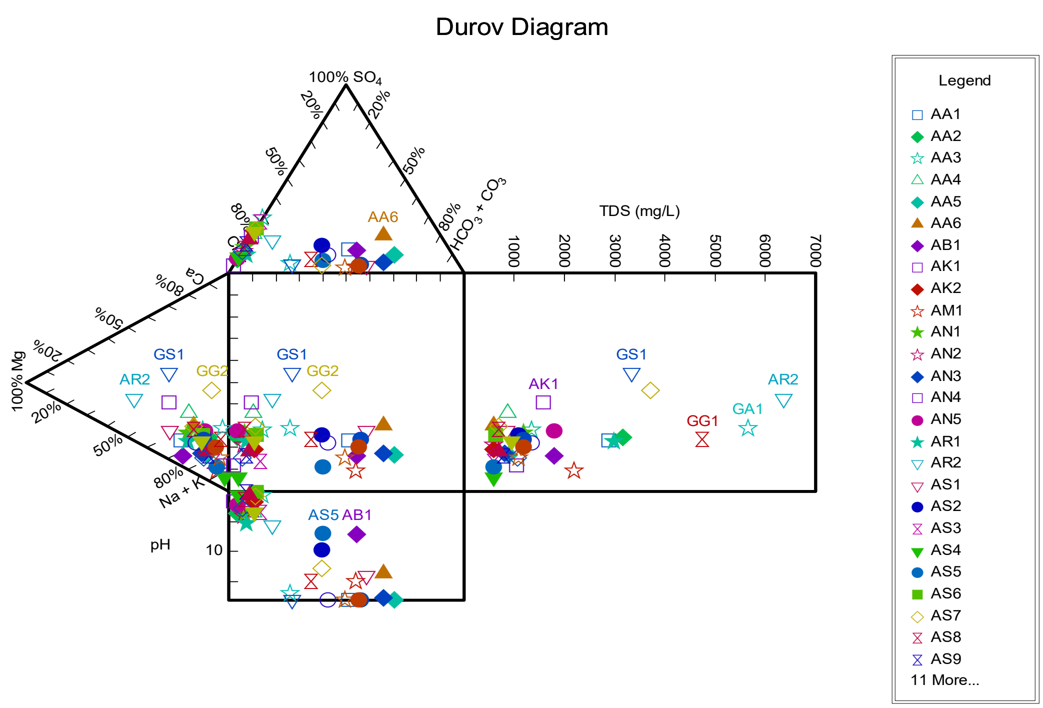

Fig. 4.21 Durov Diagram of Study Area Pre Monsoon 2009

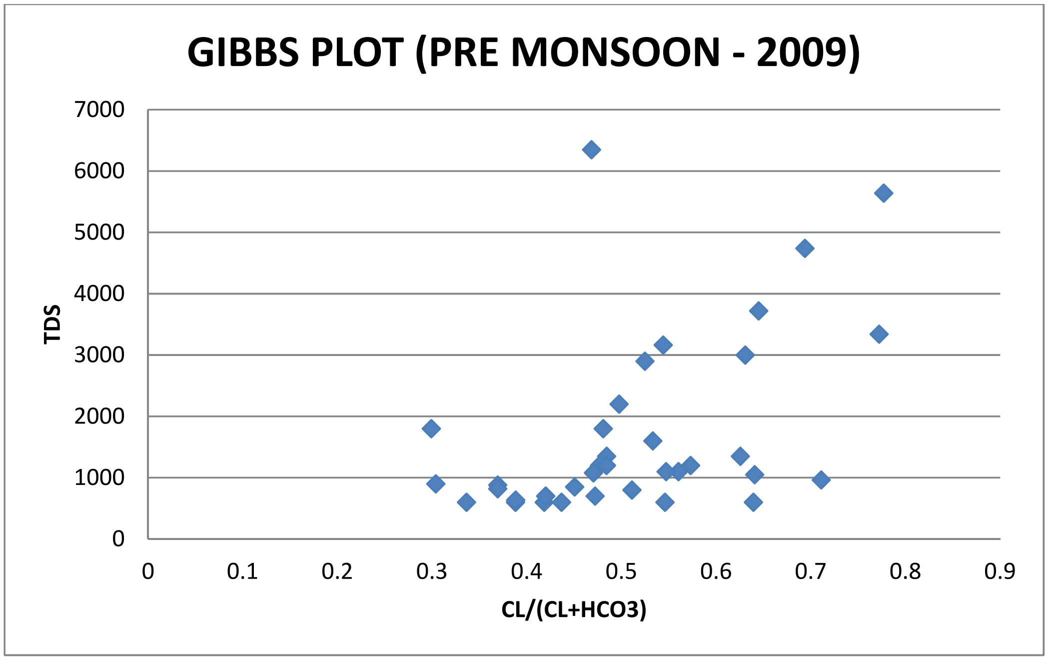

Fig. 4.22 Gibbs Plot of Study Area Pre Monsoon 2009

4.4 WATER QUALITY ANALYSIS FOR POST MONSOON (2009)

Table 4.3 Post Monsoon (2009) Water Quality Parameters

Chemical Parameters	Maximum	Minimum	Average	Std Dev	Skewness	Kurtosis
pH	8.30	6.90	7.72	0.36	-0.42	-0.61
Nitrate (mg/l)	89.0	0.7	23.14	25.78	1.50	1.38
Fluoride (mg/l)	2.30	0.09	1.06	0.59	0.29	-0.11
Iron (mg/l)	1.90	0.06	0.67	0.42	0.75	0.87
Co3 (mg/l)	998.40	48.00	213.75	184.39	2.54	8.33
Turbidity (ntu)	8	1	4	2	0	0
TDS (mg/l)	6200	450	1557	1422	2	4
Hardness (mg/l)	1892	87	452	333	3	9
Calcium (mg/l)	188	25	75	50	1	1
Magnisium (mg/l)	252	11	43	43	4	16
Chlorides (mg/l)	2656	156	631	588	2	3
Sulphate (mg/l)	491	21	117	101	2	4
Alkalinity (mg/l)	488	127	249	81	1	1
Sodium (mg/l)	699.00	115.00	336.59	191.67	1.09	0.54
Phosphate (mg/l)	1.39	0.02	0.30	0.40	1.53	1.23
Potash (mg/l)	12.57	1.00	5.65	3.48	1.26	3.10
HCO3 (mg/l)	2030.08	97.60	492.98	360.82	2.38	8.16

4.4.1 pH

pH level within Study area:

The level of pH varied between 6.9 to 8.3, ranging between slightly acidic to the alkaline condition (Fig.4.23). The mean of pH in groundwater was 7.716 indicating a normal condition and a less deviation of 0.357. Standard deviation (**0.357**) which is near to zero, suggests that sample data are close to each other. The skewness value is **-0.415** thus the curve is negatively skewed. kurtosis is (**-0.607**) which indicates its platykurtic.

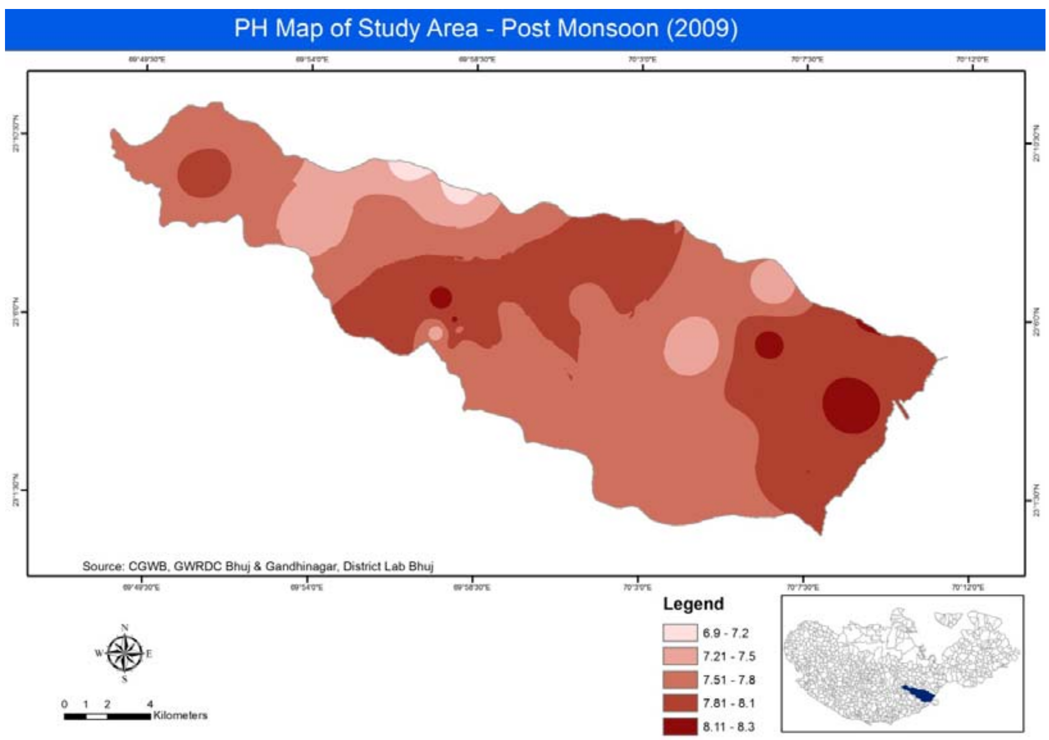

Fig. 4.23 pH Map of Study Area Post Monsoon 2009

4.4.2 Nitrate

Nitrate Level within study area:

Concentration of Nitrate above the permissible limit in the study area is not found anywhere within the study area and also not found near the coastal area of Gandhidham taluka where it was found to be slightly higher in the pre monsoon period. Standard deviation (25.78) suggests that sample data are far from each other. The skewness value is 1.503 thus the curve is skewed. kurtosis is (1.385) which indicates its platykurtic.

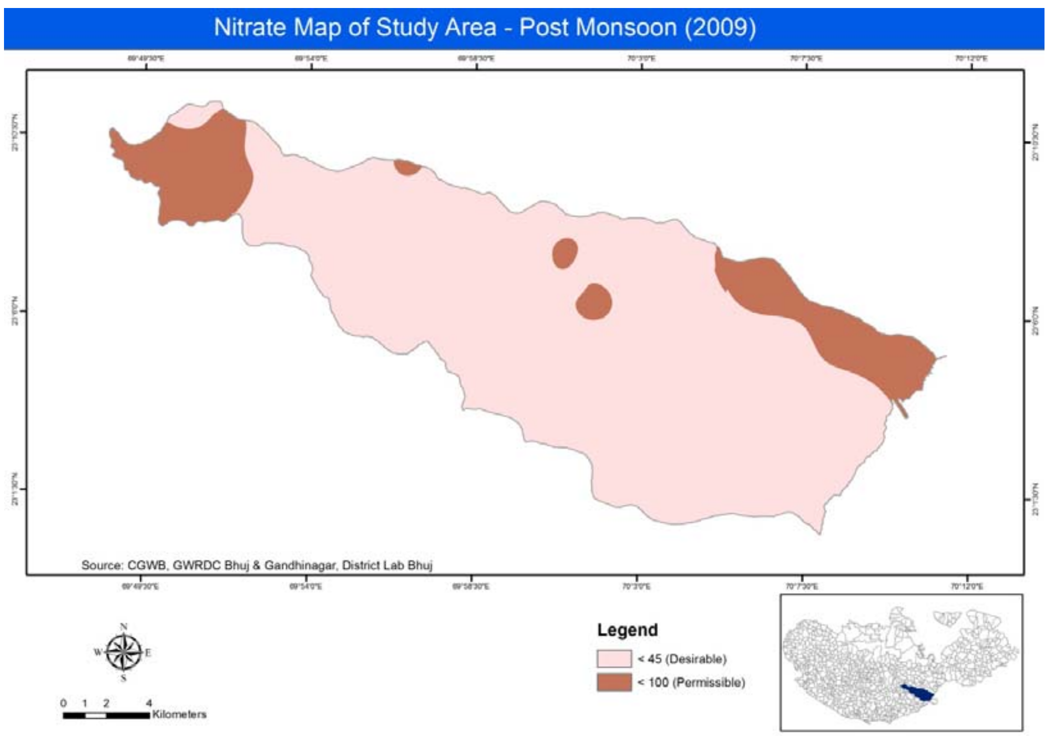

Fig. 4.24 Nitrate Map of Study Area Post Monsoon 2009

4.4.3 Fluoride

Fluoride Level within study area:

Fluoride level were found to be above the permissible limits in the parts of village like Sapeda, Sinugra, Anjar (M) and Vidi of Anjar taluka and Gandhidham, Antarjal and Kidana of Gandhidham taluka. Where as few areas of northern parts of Anjar (M) and some part of Ningal and Khambhara village were found to have fluoride level less than the desired limit of 0.6 ppm. Fluoride concentration less than 0.6 ppm results in dental caries and dental motling (Rao and Venkateshwarulu 2000). Standard deviation (0.585) suggests that sample data are close to each other. The skewness value 0.287 is approximately equal to 0, thus the curve is symmetrical. kurtosis is (-0.105) which indicates its platykurtic.

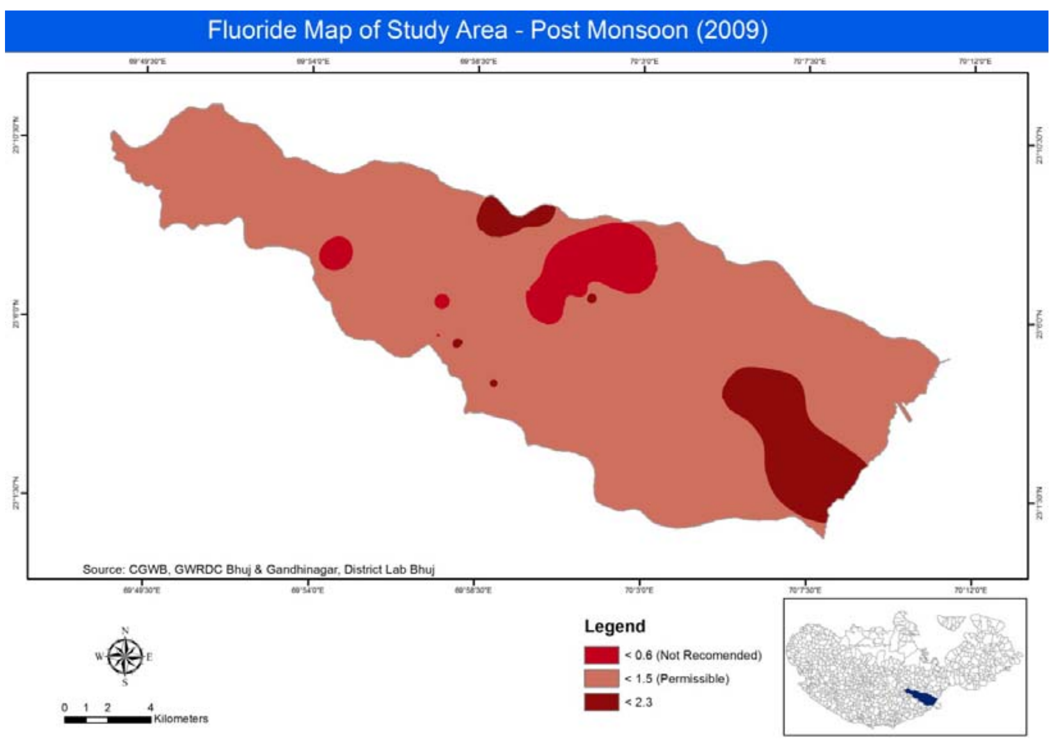

Fig. 4.25 Fluoride Map of Study Area Post Monsoon 2009

4.4.4 Iron

Iron Levels within study area

Iron in the study area above the permissible limit is found in various parts in Anjar taluka mostly in the villages like Vidi, Bhadroi, khambra and Anjar town during the post monsoon period and various other places in small traces locally. Standard deviation (0.416) suggests that sample data are close to each other. The skewness value 0.753 is approximately equal to 0, thus the curve is symmetrical. kurtosis is (0.416) which indicates its platykurtic.

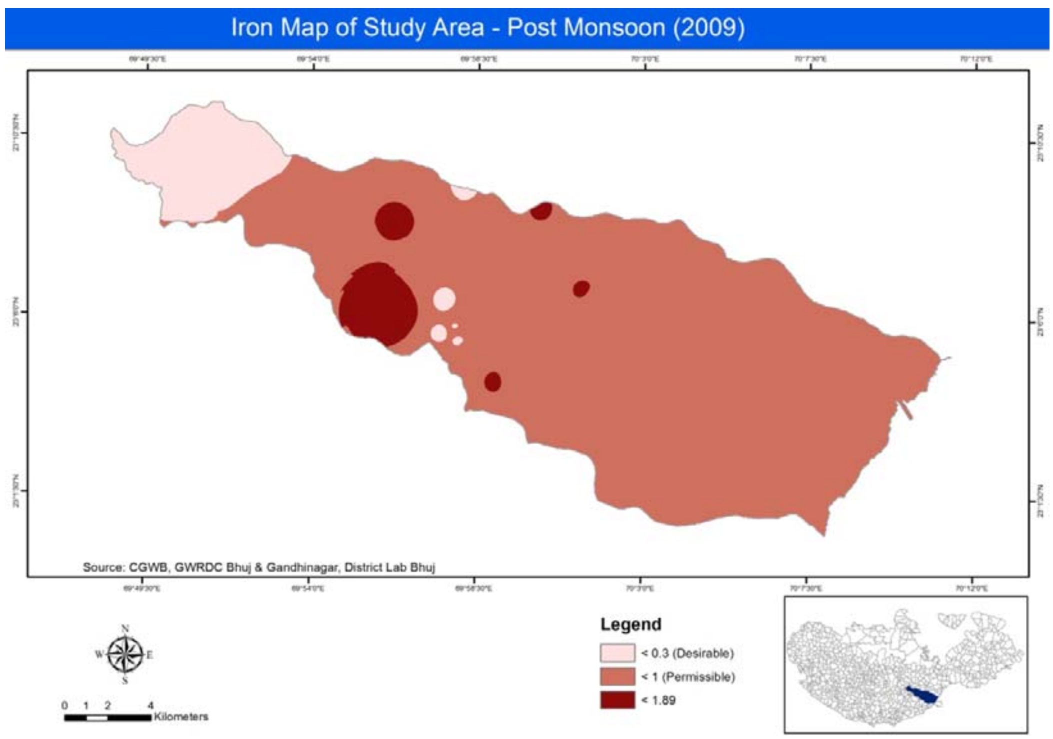

Fig. 4.26 Iron Map of Study Area Post Monsoon 2009

4.4.5 Carbonate

Carbonate level within the study area

Carbonate level are relatively higher on the Anjar town and Sapeda village area. There are no range specification available in Indian bureau of standards pertaining to the desirable and permissible limits of CO3 level in water. Standard deviation (184.396) suggests that sample data are far from each other. The skewness value is 2.542 thus the curve is skewed. kurtosis is (8.333) which indicates its leptokurtic.

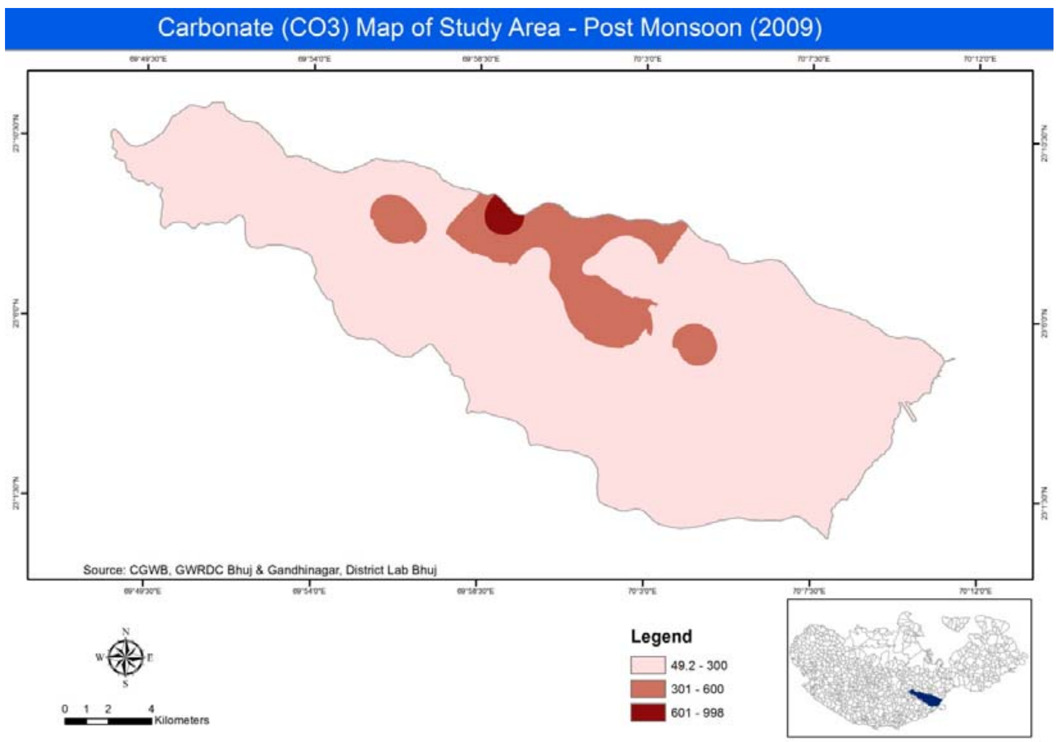

Fig. 4.27 Carbonate Map of Study Area Post Monsoon 2009

4.4.6 Turbidity

Turbidity level within the study area

Turbidity level within the study area are well within the permissible level. Standard deviation (2.0) suggests that sample data are not close to each other. The skewness value is 0.0 thus the curve is symmetrical. kurtosis is (0.0) which indicates its platykurtic.

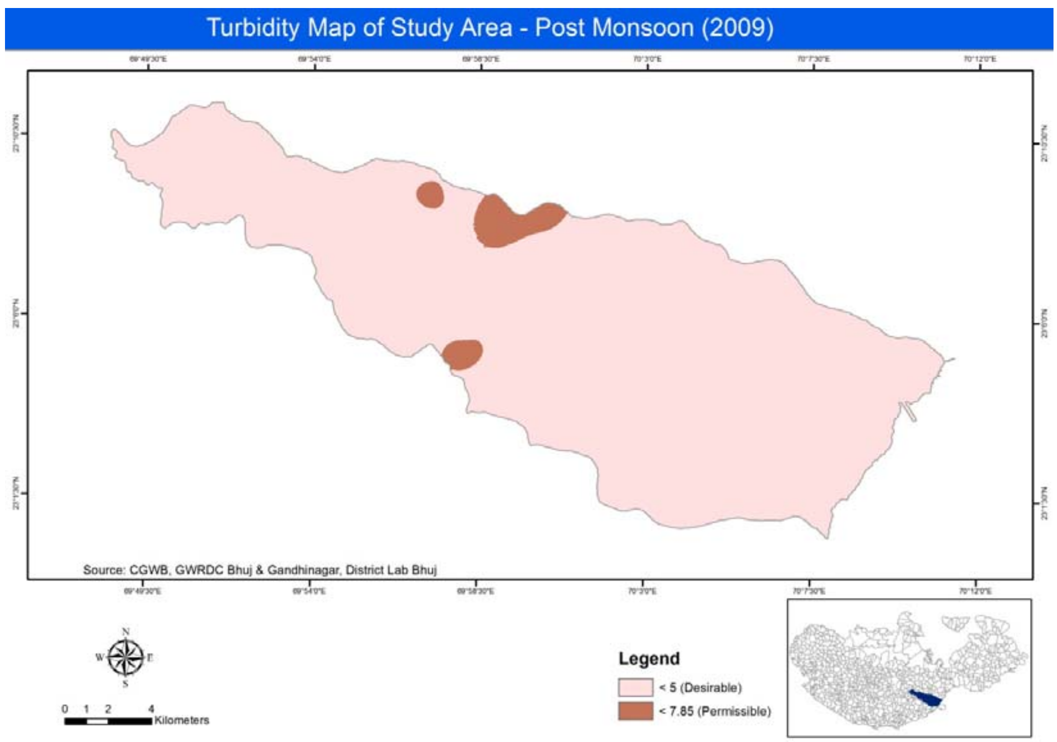

Fig. 4.28 Turbidity Map of Study Area Post Monsoon 2009

4.4.7 TDS

TDS level of the Study area:

The map showing the concentration of TDS is also shown in Fig. 4.29 in the basin. Few places, namely Galpader, Antarjal, Gandhidham, Bharatnagar, Ganeshnagar, Kidana and Shinay villages are showing the TDS of more than 2000, which is the indication of brackish water even during the post monsoon seasons. Standard deviation (1422) suggests that sample data are far from each other. The skewness value is 2.0 thus the curve is skewed. kurtosis is (4.0) which indicates its leptokurtic.

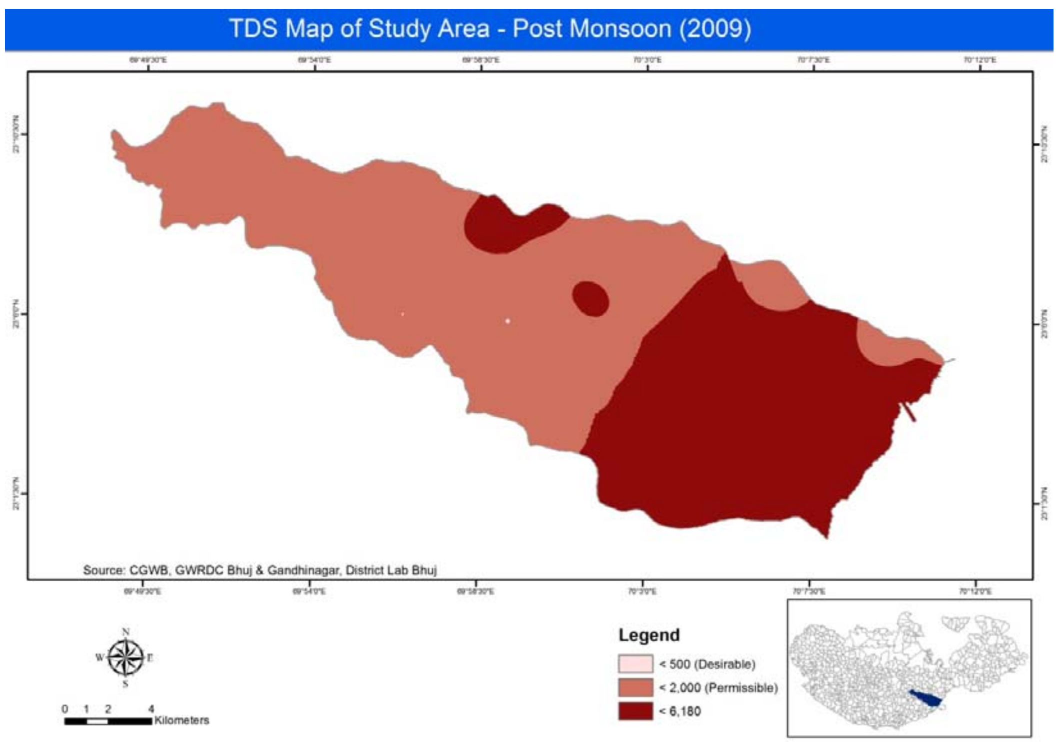

Fig. 4.29 TDS Map of Study Area Post Monsoon 2009

4.4.8 Hardness

Hardness Level within study area:

Hardness is usually found above the permissible limit in the villages of Bhadroi, Sapeda, Anjar (M) and Meghpar khumbhardi of Anjar taluka and in Kidana and shinay of Gandhidham taluka. . Standard deviation (333) suggests that sample data are far from each other. The skewness value is 3.0 thus the curve is skewed. kurtosis is (9.0) which indicates its leptokurtic.

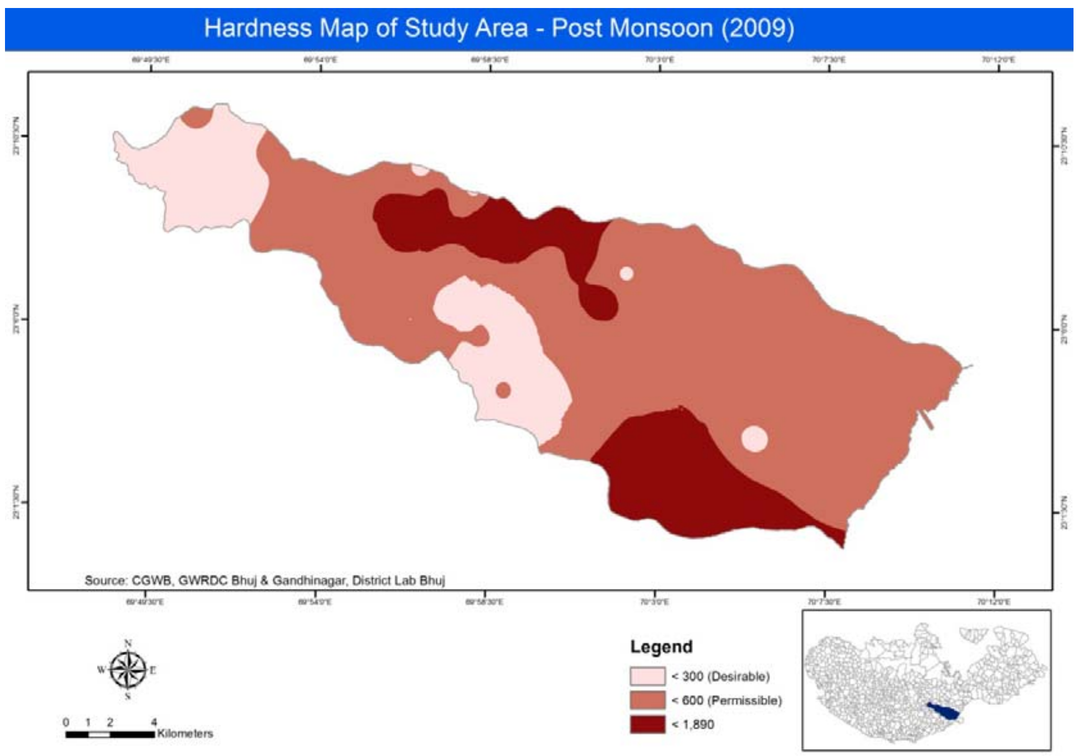

Fig. 4.30 Hardness Map of Study Area Post Monsoon 2009

4.4.9 Calcium

Calcium Levels within Study area

In the study area calcium is mostly found within the permissible limits in the post monsoon season. Standard deviation (50) suggests that sample data are far from each other. The skewness value is 1.0 thus the curve is symmetrical. kurtosis is (1.0) which indicates its platykurtic.

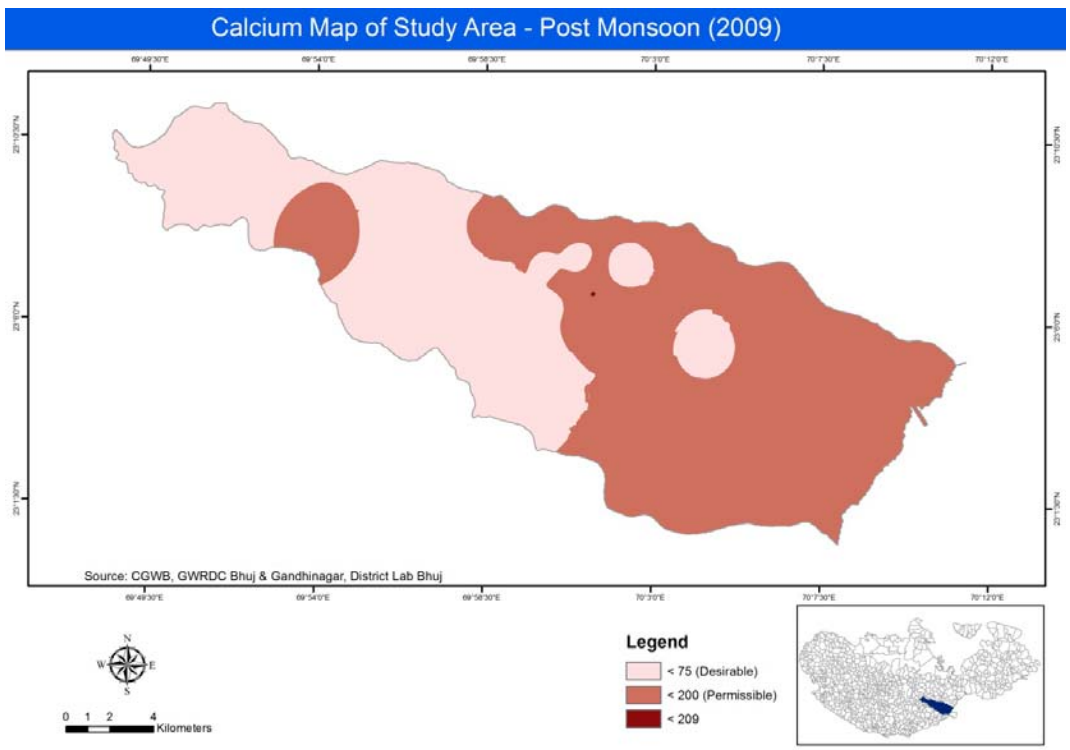

Fig. 4.31 Calcium Map of Study Area Post Monsoon 2009

4.4.10 Magnesium

Magnesium Level within the study area

Because calcium and magnesium are the major constituents responsible for hardness in water, the highest levels of these ions generally occur in ground water with high hardness levels. Sapeda and Anjar (M) of Anjar taluka have slightly higher than the permissible limits of magnesium levels relative to most of the other areas. Standard deviation (43) suggests that sample data are far from each other. The skewness value is 4.0 thus the curve is skewed. kurtosis is (16.0) which indicates its leptokurtic.

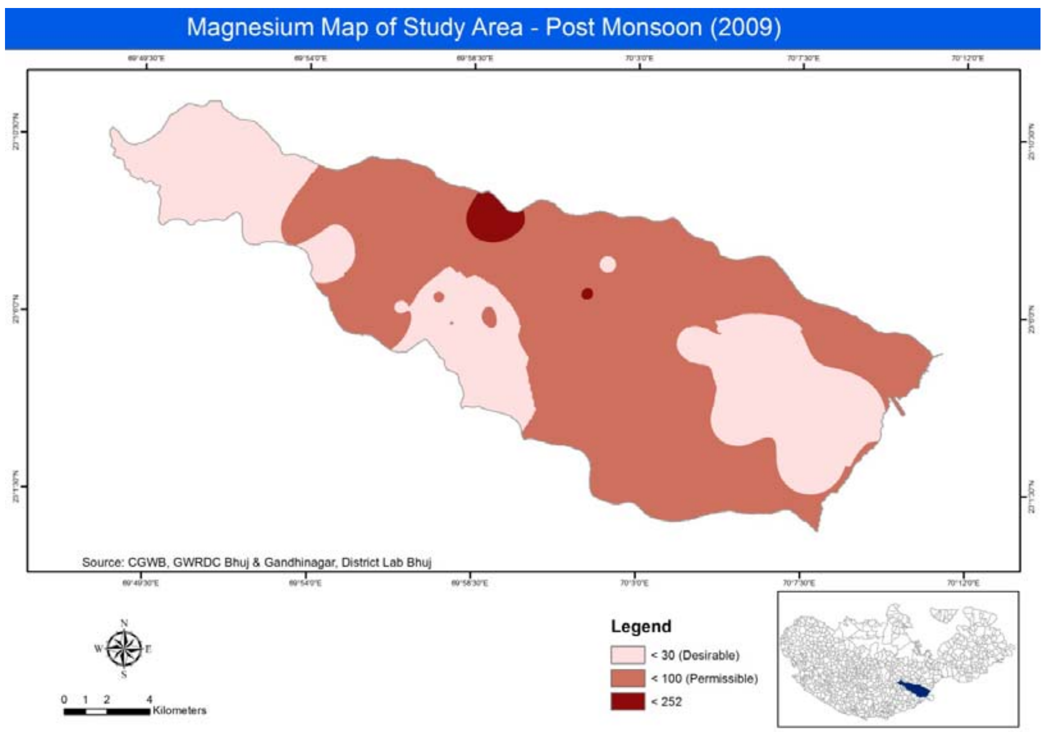

Fig. 4.32 Magnesium Map of Study Area Post Monsoon 2009

4.4.11 Chlorides

Chlorides Level within the study area

Chlorides are found to be higher than the permissible limits in Sapeda and Anjar (M) of Anjar and most part of the Gandhidham taluka within the study area. Standard deviation (588) suggests that sample data are far from each other. The skewness value is 2.0 thus the curve is skewed. kurtosis is (3.0) which indicates normal distribution.

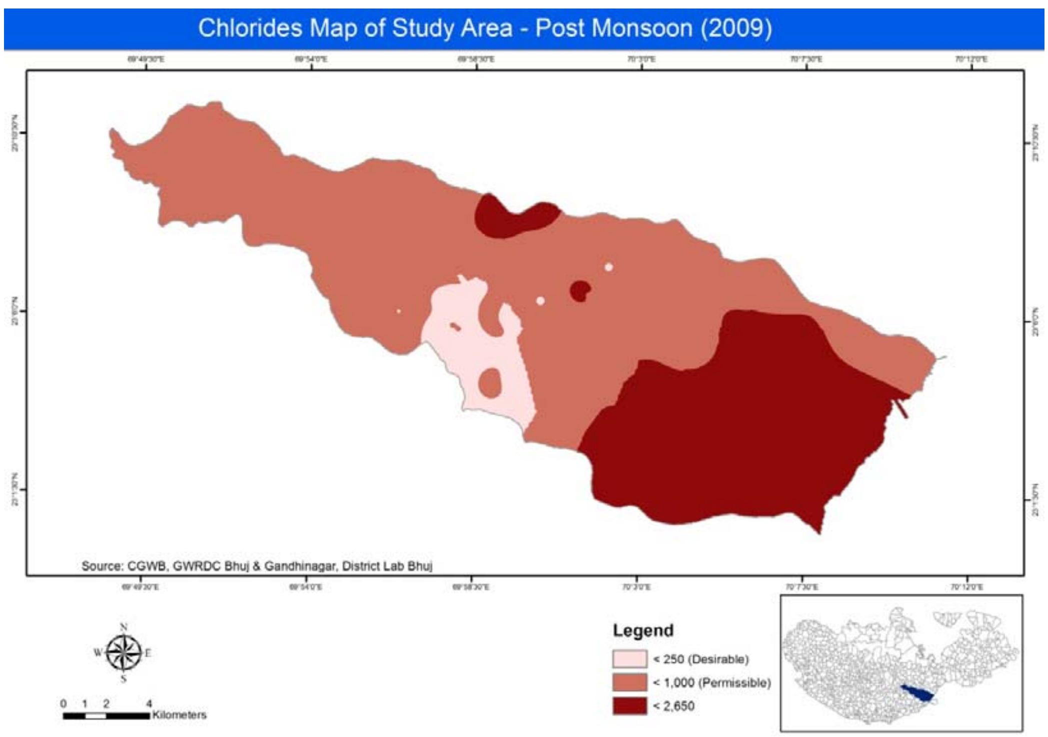

Fig. 4.33 Chlorides Map of Study Area Post Monsoon 2009

4.4.12 Sulphate

Sulphate levels within the study area

Sulphates above the permissible limits are only seen near few patches in Sapeda village during the post monsoon season while it is mostly within the permissible limits in rest of the region. Standard deviation (101) suggests that sample data are far from each other. The skewness value is 2.0 thus the curve is skewed. kurtosis is (4.0) which indicates its leptokurtic.

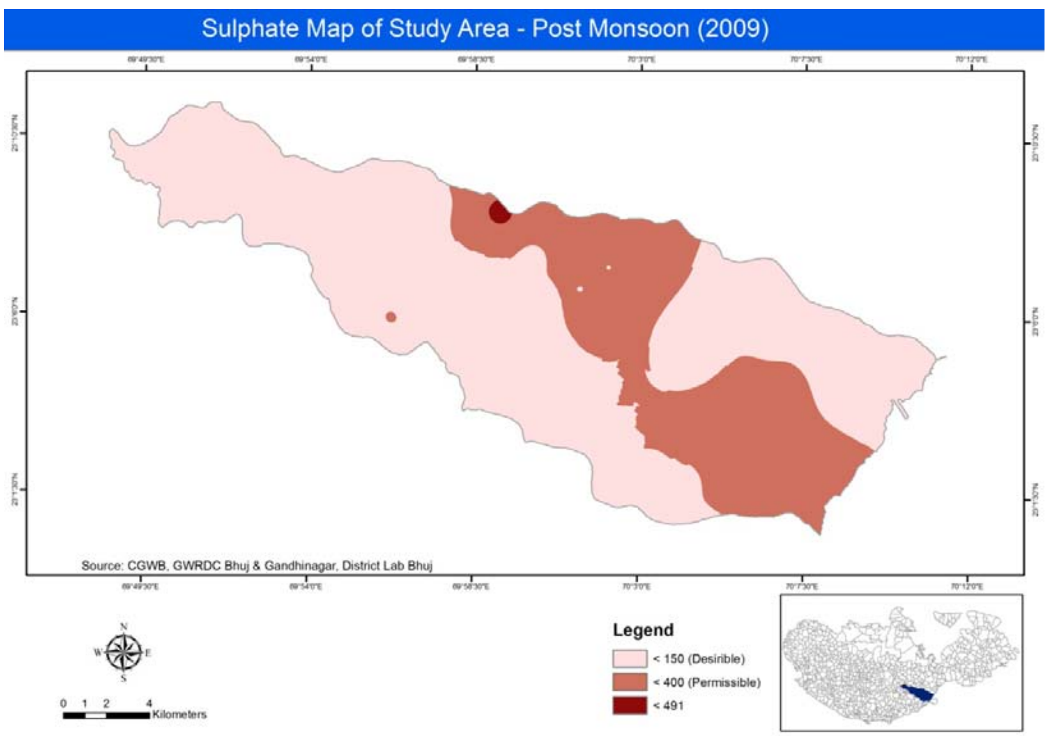

Fig. 4.34 Sulphate Map of Study Area Post Monsoon 2009

4.4.13 Alkalinity

Alkalinity Level within the study area

Alkalinity is mostly above the permissible limits in the villages of bhdroi, Vidi, Anjar (M) and beghpar Borichi of Anjar taluka and Antarjal, Kidana and Gandhidham (M) of Gandhidham taluka. Standard deviation (81) suggests that sample data are far from each other. The skewness value is 1.0 thus the curve is symmetrical. kurtosis is (1.0) which indicates its platykurtic.

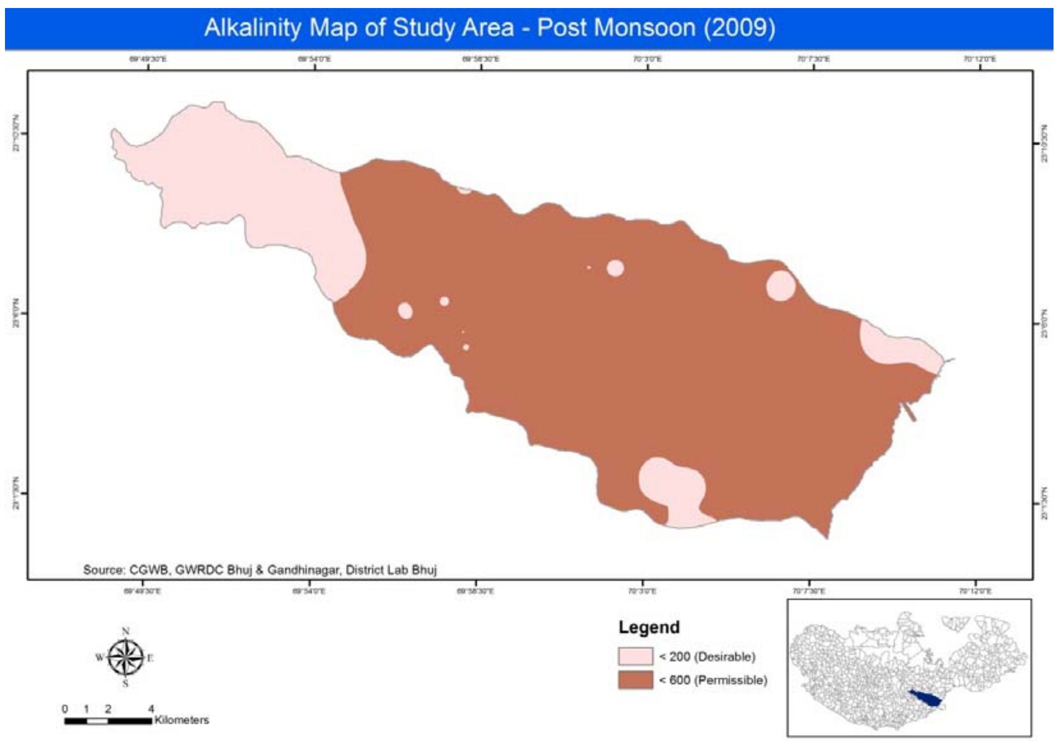

Fig. 4.35 Alkalinity Map of Study Area Post Monsoon 2009

4.4.14 Sodium

Sodium Level within the study area

Sodium level was found to be in the permissible limits within study area. Standard deviation (191.667) suggests that sample data are far from each other. The skewness value is 1.089 thus the curve is symmetrical. kurtosis is (0.535) which indicates its platykurtic.

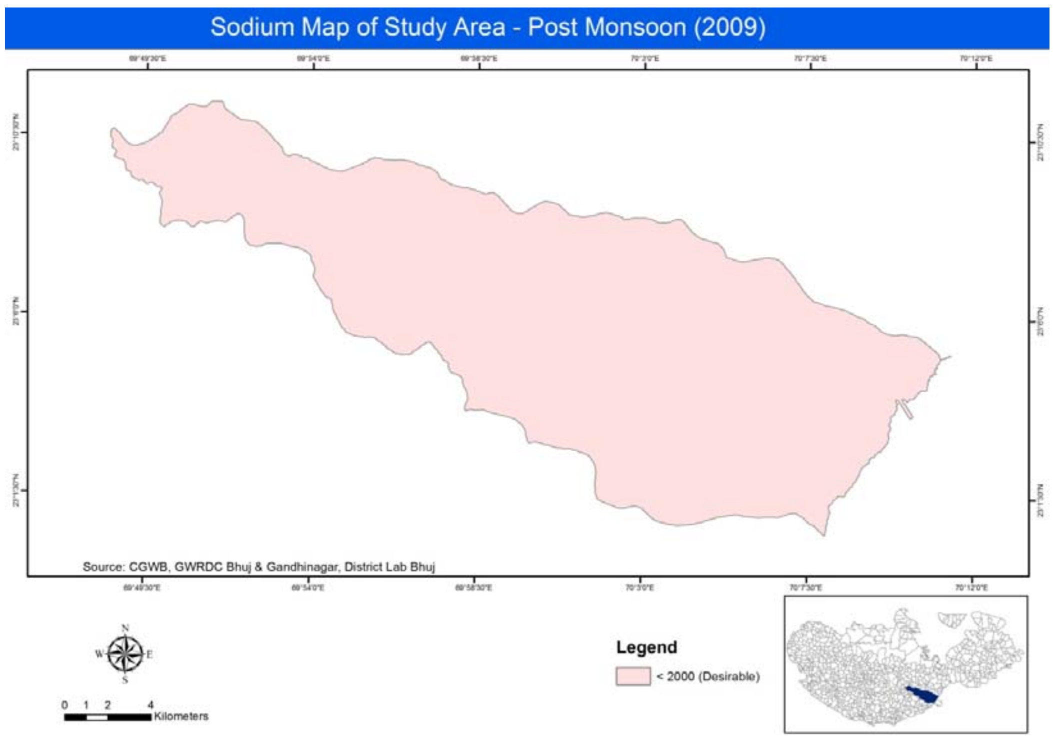

Fig. 4.36 Sodium Map of Study Area Post Monsoon 2009

4.4.15 Phosphate

Phosphate level within the study area

Phosphate level was found to be in the permissible limits at most of the places within the study area except Sinugra village of Anjar. Standard deviation (0.400) suggests that sample data are close to each other. The skewness value is 1.53 thus the curve is skewed. kurtosis is (1.229) which indicates its platykurtic.

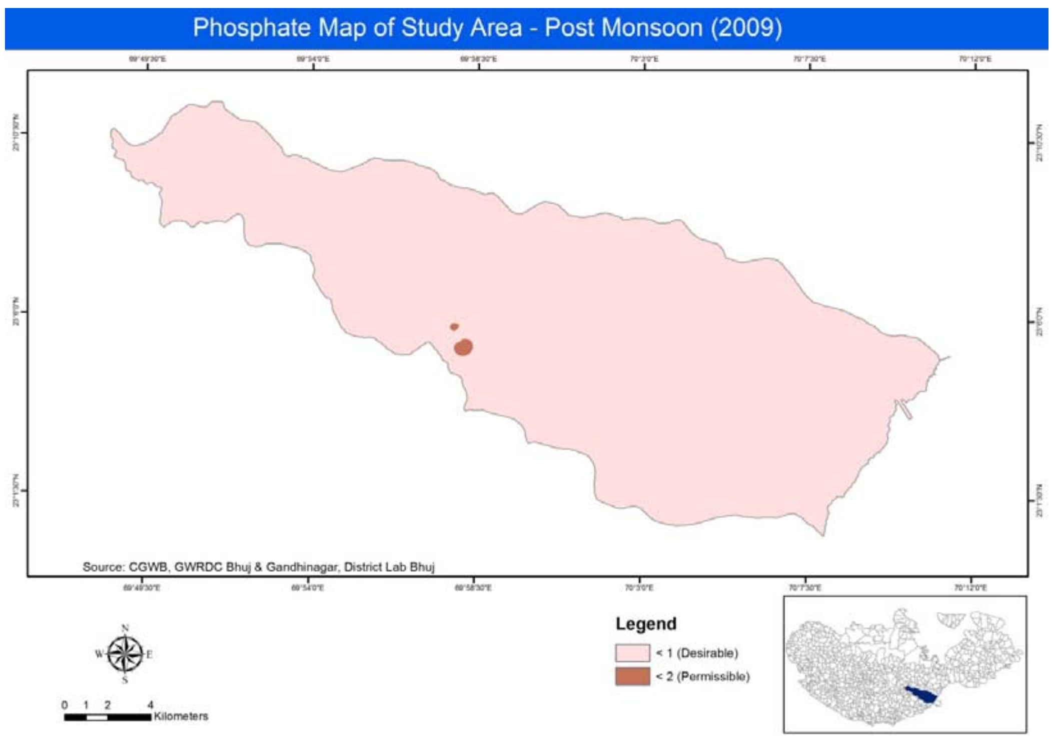

Fig. 4.37 Phosphate Map of Study Area Post Monsoon 2009

4.4.16 Potash

Potash Level within the study area

There are no Indian standards available for potash however Potash level are relatively on the higher side in few small patches within Anjar (M) and near the coastal area i.e Gandhidham taluka as compared to the other places within the study area. Standard deviation (3.482) suggests that sample data are far from each other. The skewness value is 1.259 thus the curve is skewed. kurtosis is (3.099) which indicates its leptokurtic.

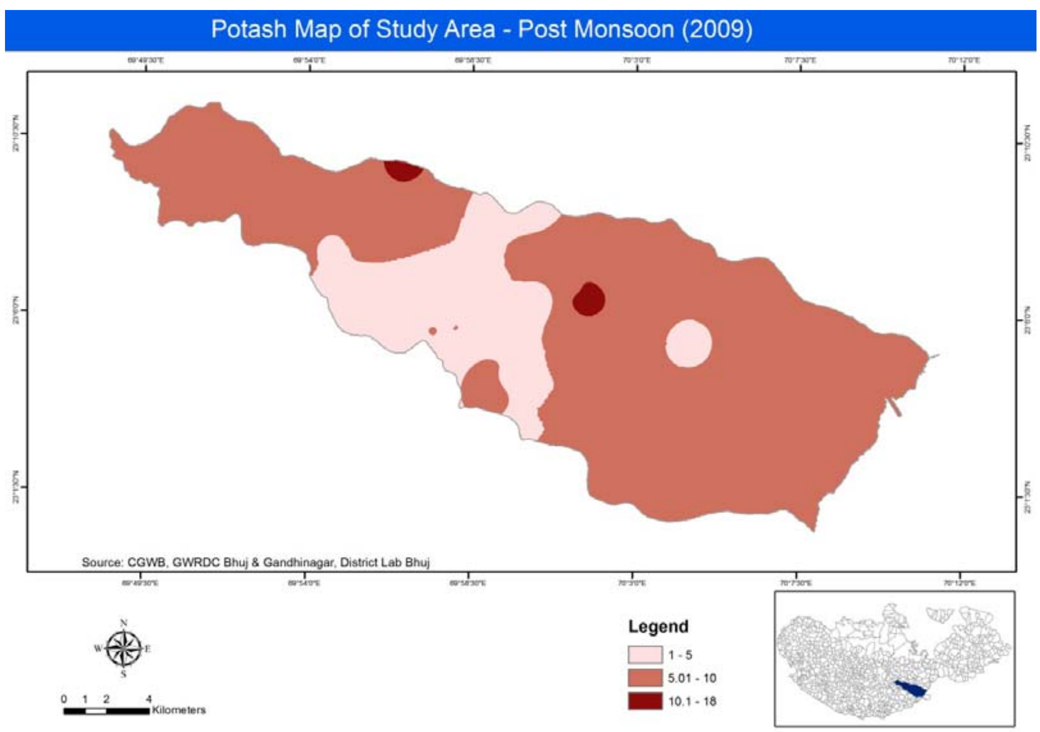

Fig. 4.38 Potash Map of Study Area Post Monsoon 2009

4.4.17 Bicarbonate

Bicarbonate Level within the study area

Bicarbonate levels are found to be on the higher side near the villages of Anjar taluka i.e. Meghpar (Borichi), Meghpar Khumbhardi and Anjar (M), Sapeda and in Gandhidham taluka i.e. Antarjal, Kidana, Gandhidham (M), Galpadar and shinay. Standard deviation (360.819) suggests that sample data are far from each other. The skewness value is 2.376 thus the curve is skewed. kurtosis is (8.155) which indicates its leptokurtic..

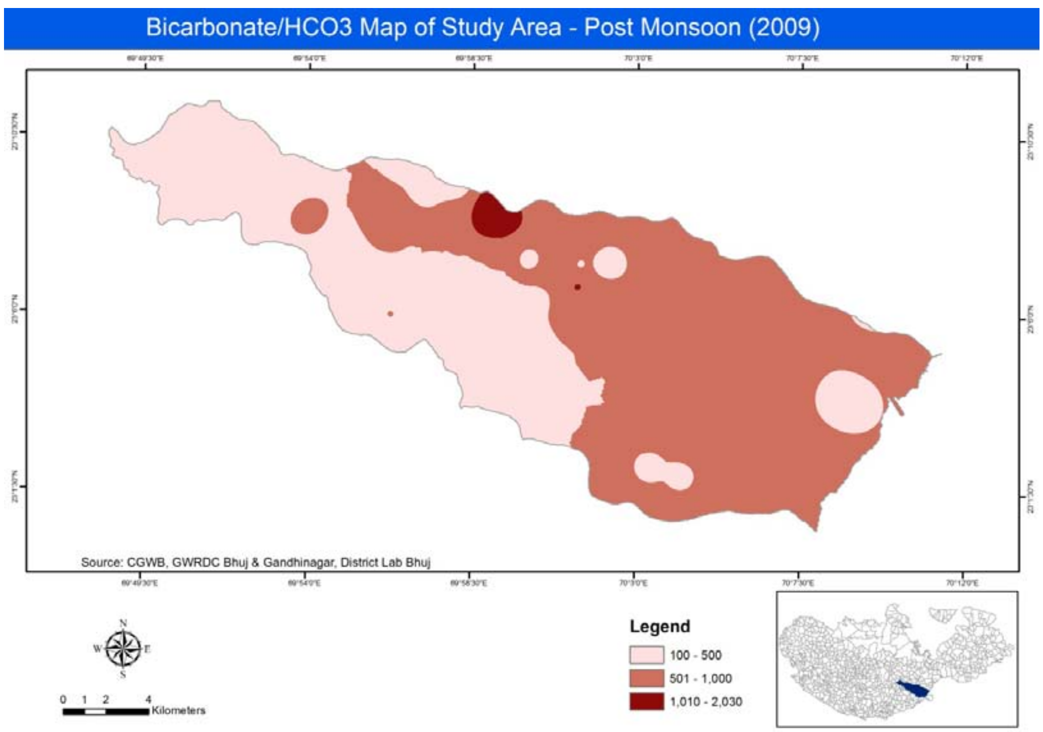

Fig. 4.39 Bicarbonate Map of Study Area Post Monsoon 2009

Table 4.4 (a) Correlation Matrix of Post Monsoon 2009

	pH	Nitrate	Fluoride	Iron	CO3	Turbidity	TDS	Hardness	calcium
pH	1	0.159	.343*	0.043	0.21	.467**	0.22	0.251	.307*
Nitrate	0.159	1	0.245	0.125	.365*	0.069	.351*	.363*	0.271
Fluoride	.343*	0.245	1	0.086	.353*	0.277	.566**	.427**	.337*
Iron	0.043	0.125	0.086	1	.458**	0.147	0.265	.468**	.313*
CO3	0.21	.365*	.353*	.458**	1	.452**	.621**	.923**	.538**
Turbidity	.467**	0.069	0.277	0.147	.452**	1	0.17	.479**	0.213
TDS	0.22	.351*	.566**	0.265	.621**	0.17	1	.715**	.840**
Hardness	0.251	.363*	.427**	.468**	.923**	.479**	.715**	1	.662**
calcium	.307*	0.271	.337*	.313*	.538**	0.213	.840**	.662**	1
magnesium	0.148	.345*	.463**	.400**	.890**	.512**	.697**	.927**	.610**
chlorides	0.212	.398**	.493**	.318*	.547**	0.152	.962**	.646**	.868**
Sulphate	0.23	.457**	.474**	.316*	.771**	.344*	.809**	.768**	.666**
Alkalinity	.593**	.349*	.411**	.338*	.594**	0.285	.507**	.562**	.457**
Sodium	.360*	0.245	.341*	.327*	.485**	0.239	.406**	.423**	.491**
Phosphate	-.363*	-0.23	-0.065	-0.03	-0.03	0.128	-0.13	-0.024	-0.222
Potash	0.211	.732**	0.235	0.158	0.221	0.008	0.276	0.247	0.266
HCO3	-0.07	0.245	0.237	0.252	.900**	0.022	.759**	.875**	.629**

Table 4.4 (b) Correlation Matrix of Post Monsoon 2009

	magnesium	**chlorides**	**Sulphate**	**Alkalinity**	**Sodium**	**Phosphate**	**Potash**	**HCO3**
pH	0.148	0.212	0.23	.593**	.360*	-.363*	0.211	-0.07
Nitrate	.345*	.398**	.457**	.349*	0.245	-0.225	.732**	0.245
Fluoride	.463**	.493**	.474**	.411**	.341*	-0.065	0.235	0.237
Iron	.400**	.318*	.316*	.338*	.327*	-0.033	0.158	0.252
CO3	.890**	.547**	.771**	.594**	.485**	-0.031	0.221	.900**
Turbidity	.512**	0.152	.344*	0.285	0.239	0.128	0.008	0.022
TDS	.697**	.962**	.809**	.507**	.406**	-0.131	0.276	.759**
Hardness	.927**	.646**	.768**	.562**	.423**	-0.024	0.247	.875**
calcium	.610**	.868**	.666**	.457**	.491**	-0.222	0.266	.629**
magnesium	1	.624**	.818**	.427**	.354*	0.027	0.253	.793**
chlorides	.624**	1	.753**	.478**	.405**	-0.149	.332*	.658**
Sulphate	.818**	.753**	1	.512**	.334*	-0.09	.415**	.767**
Alkalinity	.427**	.478**	.512**	1	.567**	-0.264	.374*	.503**
Sodium	.354*	.405**	.334*	.567**	1	-0.158	0.192	0.309
Phosphate	0.027	-0.149	-0.09	-0.264	-0.158	1	-0.148	-0.28
Potash	0.253	.332*	.415**	.374*	0.192	-0.148	1	0.055
HCO3	.793**	.658**	.767**	.503**	0.309	-0.283	0.055	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

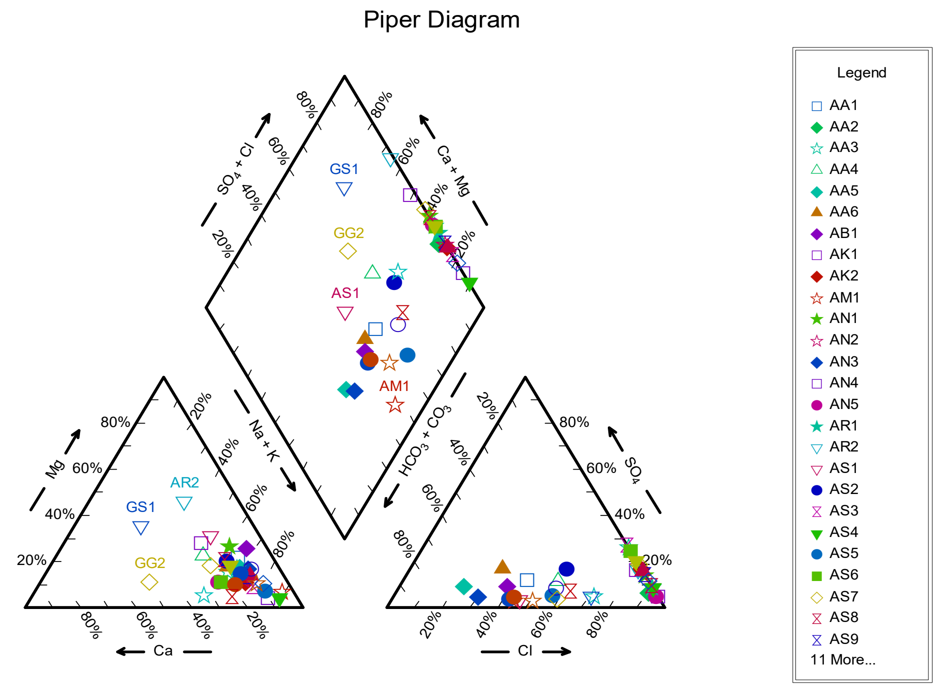

Fig. 4.40 Piper Diagram of Study Area Post Monsoon 2009

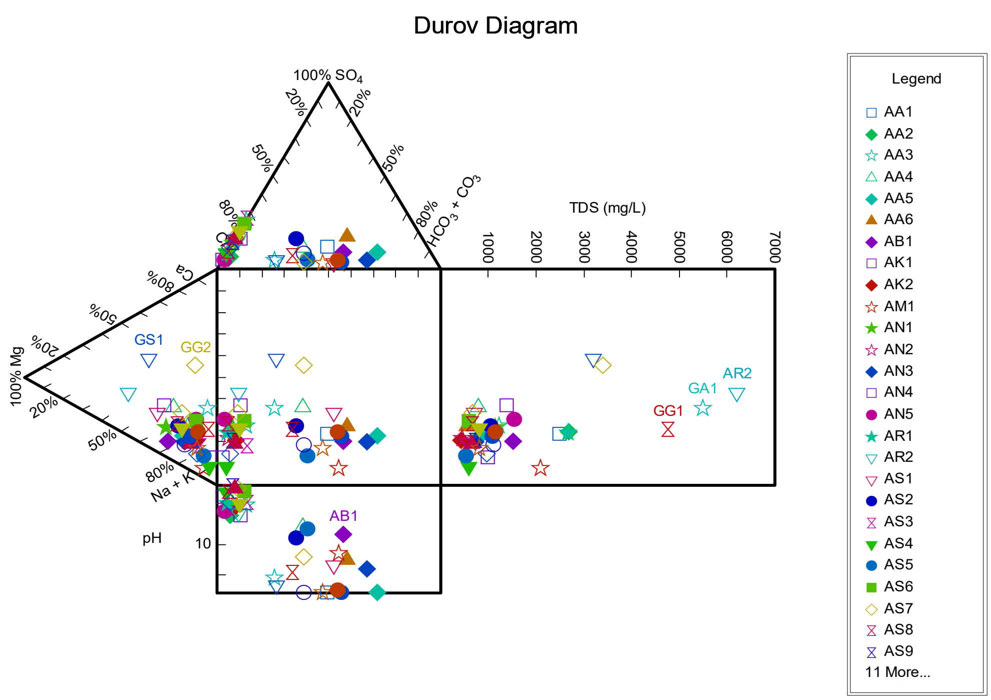

Fig. 4.41 Durov Diagram of Study Area Post Monsoon 2009

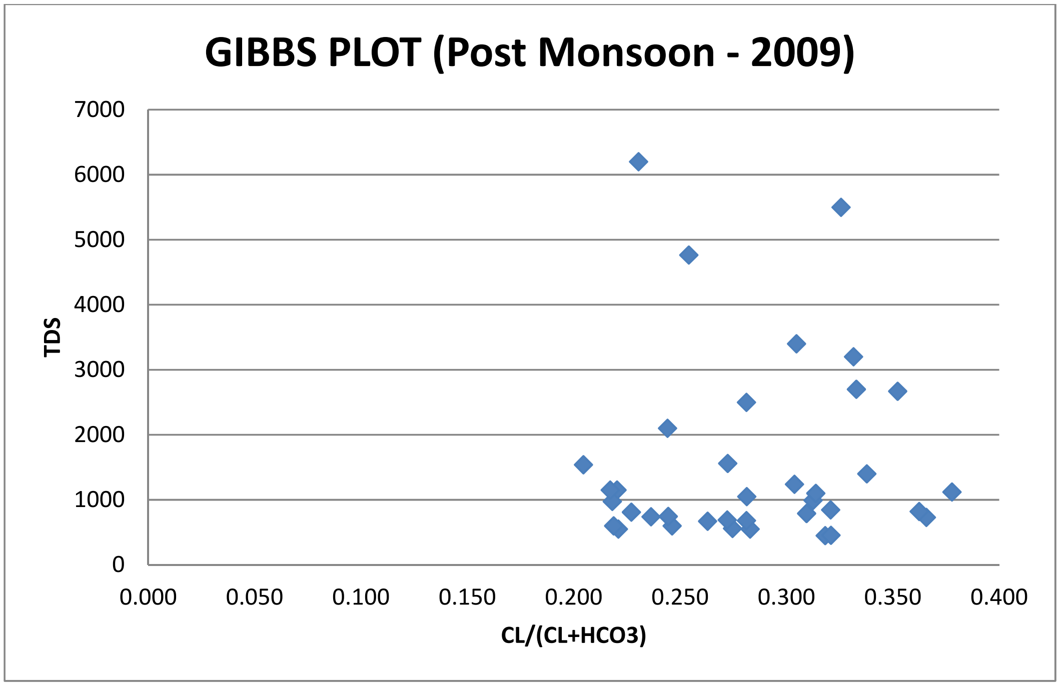

Fig. 4.42 Gibbs Plot of Study Area Post Monsoon 2009

4.5 WATER QUALITY ANALYSIS FOR PRE-MONSOON 2015

Table 4.5 Pre-monsoon Water Quality Parameters (2015)

Chemical Parameters	**Maximum**	**Minimum**	**Average**	**Std Dev**	**Skewness**	**Kurtosis**
pH	8.30	7.22	7.56	0.32	1.66	1.48
Nitrate (mg/l)	120.00	0.88	28.08	46.48	1.32	-0.15
Fluoride (mg/l)	1.50	0.30	1.22	0.35	-1.26	0.94
Tds (mg/l)	4280.00	280.00	1743.60	1152.31	1.26	0.73
Hardness (mg/l)	952.00	150.00	424.00	204.72	0.94	0.89
Calcium (mg/l)	240.00	32.00	106.25	50.56	1.07	1.26
Magnisium (mg/l)	182.00	19.00	69.75	39.62	1.63	2.81
Chlorides (mg/l)	1242.00	52.00	528.8	310.19	0.81	0.03
Sulphate (mg/l)	244.00	4.00	73.00	61.95	1.56	1.95
Alkalinity (mg/l)	502.00	152.00	304.50	106.05	0.47	-0.87

4.5.1 pH

pH level within Study area:

The level of pH varied between 7.22 to 8.30, ranging between slightly acidic to the alkaline condition (Fig.4.43). The mean of pH in groundwater was 7.56 indicating a normal condition. Standard deviation (0.32) suggests that sample data are very close to each other. The skewness value (1.66) indicates that the curve is skewed. kurtosis is (1.48) platykurtic. This may also indicate flatter distribution of data.

Comparatively the groundwater seems to be more alkaline towards Vidi, shinay, some parts of Gandhidham (M), meghar Borichi and Meghpar khumbardi and many parts of Anjar and Bhuj.

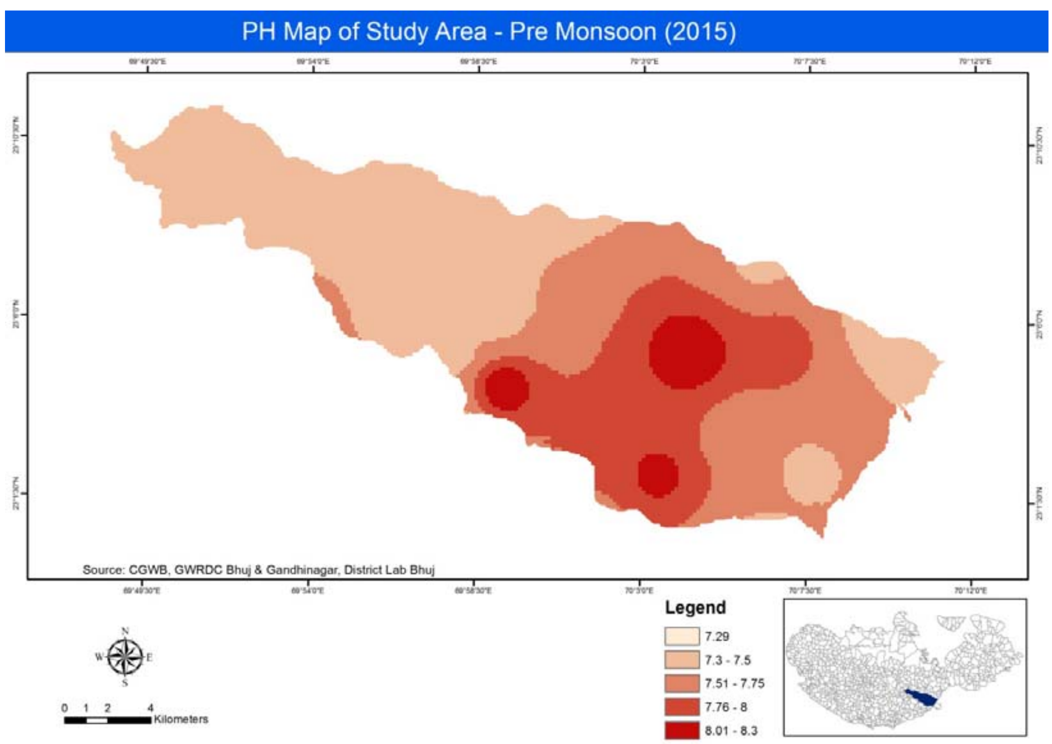

Fig. 4.43 pH Map of Study Area Pre Monsoon 2015

4.5.2 Nitrate

Nitrate Level within study area:

Standard deviation (46.48) suggests that sample data are farther to each other. The skewness value (1.32) indicates that the curve is skewed. kurtosis (-0.15) suggests its platykurtic.

Gandhidham taluka and especially villages of shinay, Kidana and Antarjal have Nitrate level higher then the permissible limits while most parts o Anjar and Bhuj have Nitrate level within the desirable and permissible limits of Indian standards.

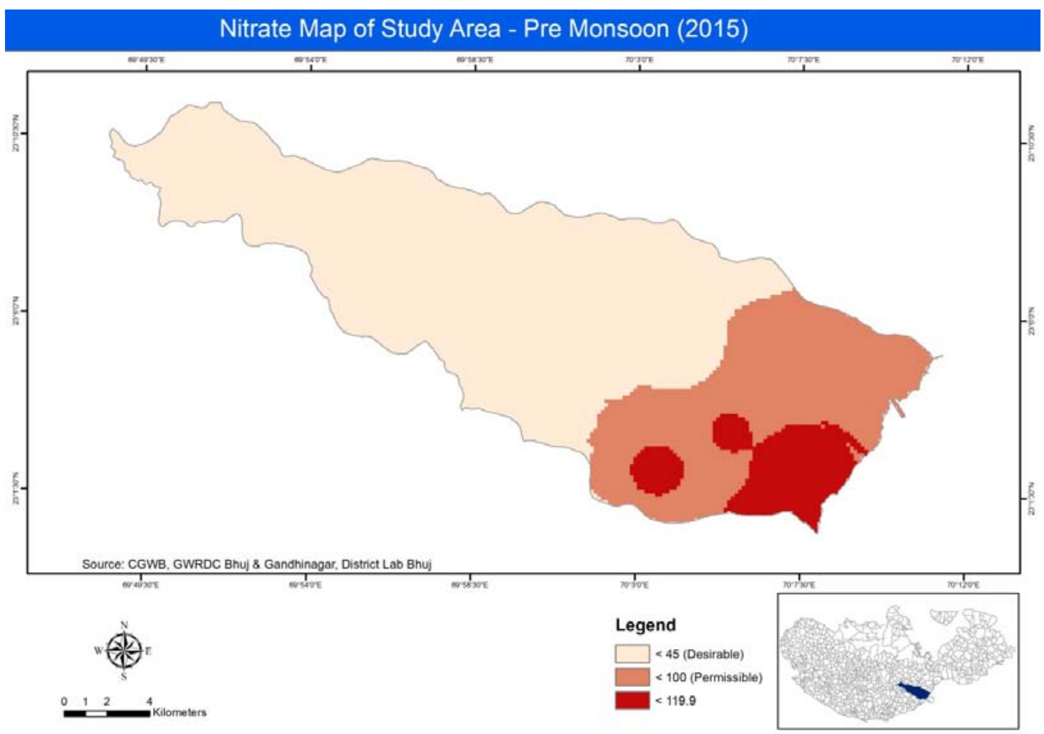

Fig. 4.44 Nitrate Map of Study Area Pre Monsoon 2015

4.5.3 Fluoride

Fluoride Level within study area:

Standard deviation (0.35) suggests that sample data are very close to each other. The skewness value (-1.26) is approximately equal to 0, thus the curve is symmetrical. kurtosis is (0.94) which indicates its platykurtic.

Except few parts of Kidana area most of the area of the study area have fluoride level within the permissible limits of Indian standards.

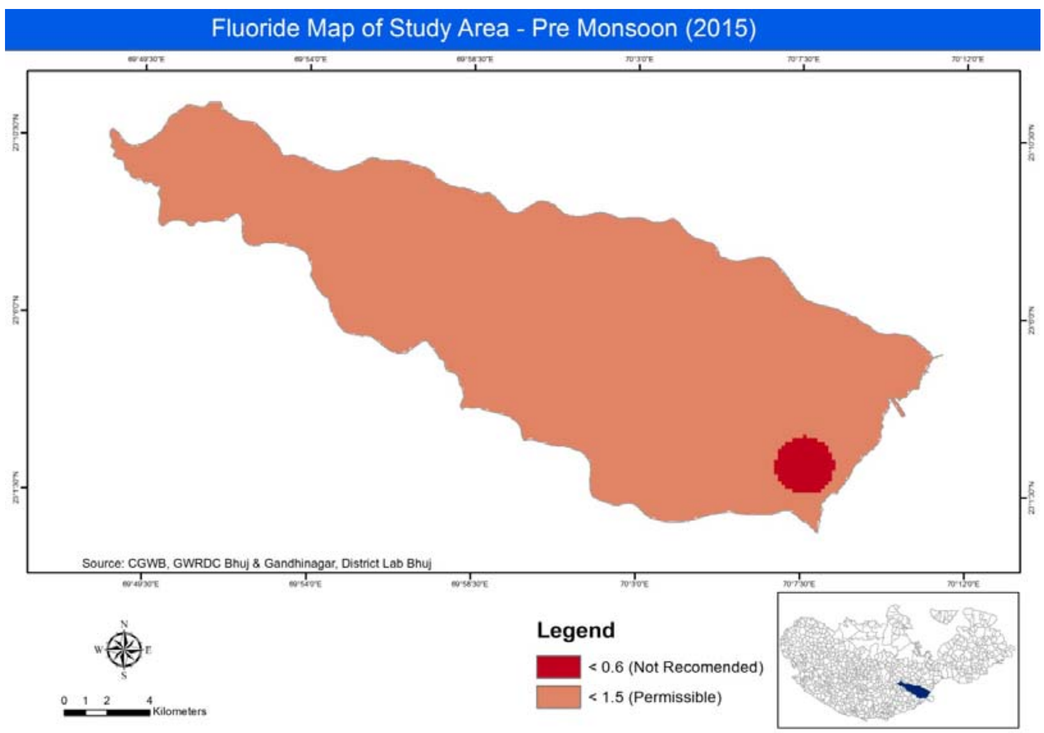

Fig. 4.45 Fluoride Map of Study Area Pre Monsoon 2015

4.5.4 TDS

TDS level of the Study area:

Standard deviation (1152.0) suggests that sample data are very far from each other. The skewness value is 1.26 thus the curve is skewed. kurtosis is (0.73) which indicates its platykurtic.

Most of the taluka of Gandhidham like Galpader, Antarjal, Gandhidham(M), Bharatnagar, Ganeshnagar, Kidana and Shinay villages are showing the TDS of more than permissible limits i.e. 2000 ppm, which is the indication of brackish water including few areas of Meghpar Borichi and Meghar Khumbhardi of Anjar taluka.

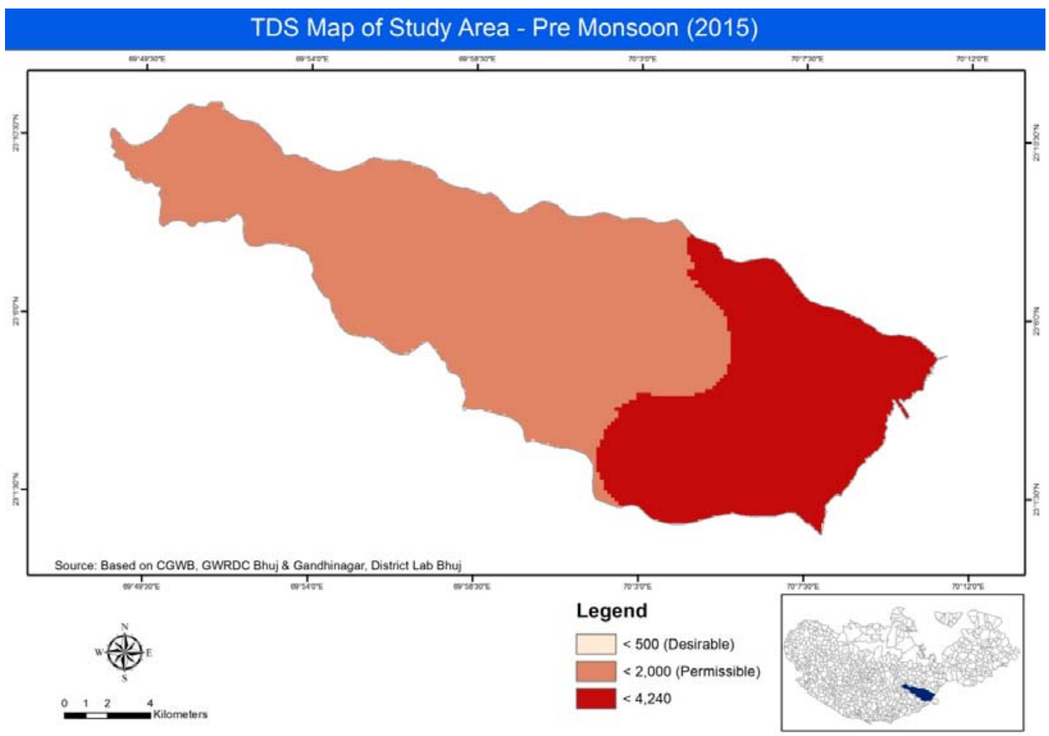

Fig. 4.46 TDS Map of Study Area Pre Monsoon 2015

4.5.5 Hardness

Hardness Level within study area:

Standard deviation (204.72) suggests that sample data are very far from each other. The skewness value is 0.94 thus the curve is skewed. kurtosis is (0.89) which indicates its platykurtic.

Mostly the parts of Anjar taluka like khambra, varsamedi and parts of Anjar town seem to have Hardness level higher than the permissible limits of Indian standards.

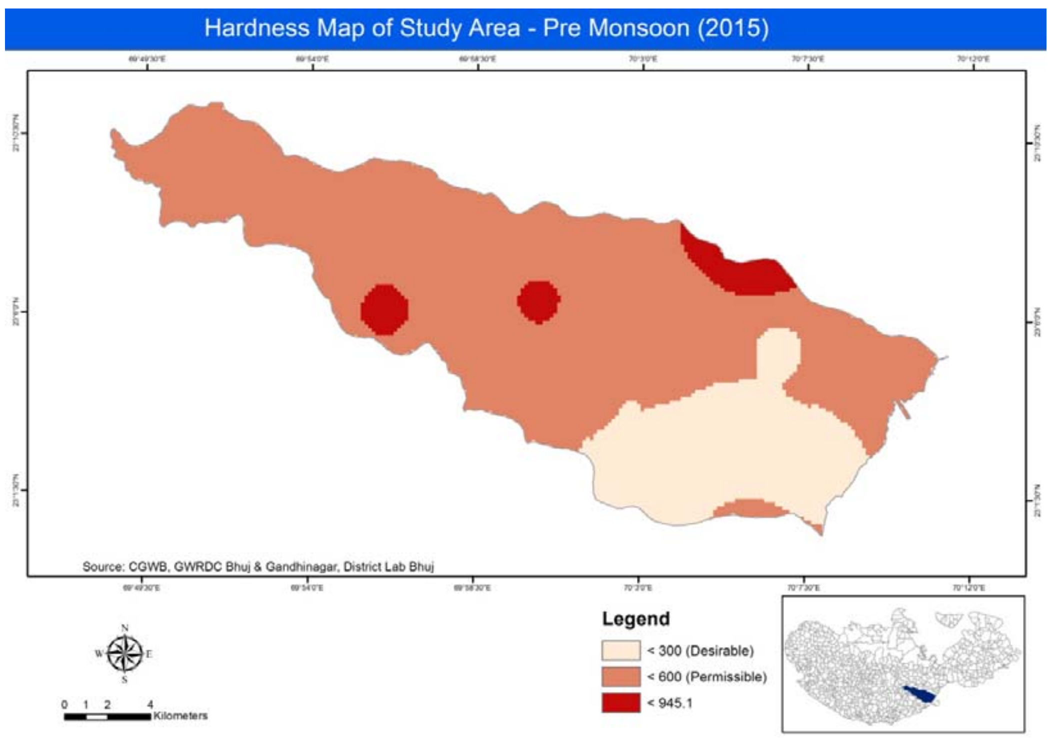

Fig. 4.47 Hardness Map of Study Area Pre Monsoon 2015

4.5.6 Calcium

Calcium Levels within Study area

Standard deviation (50.560) suggests that sample data are very far from each other. The skewness value is 1.07 thus the curve is skewed. kurtosis is (1.26) which indicates its platykurtic.

Calcium level higher than the permissible limits are found only in the parts of Kidana village within the study area while rest of the study area seem to be within the permissible limits of Indian standards.

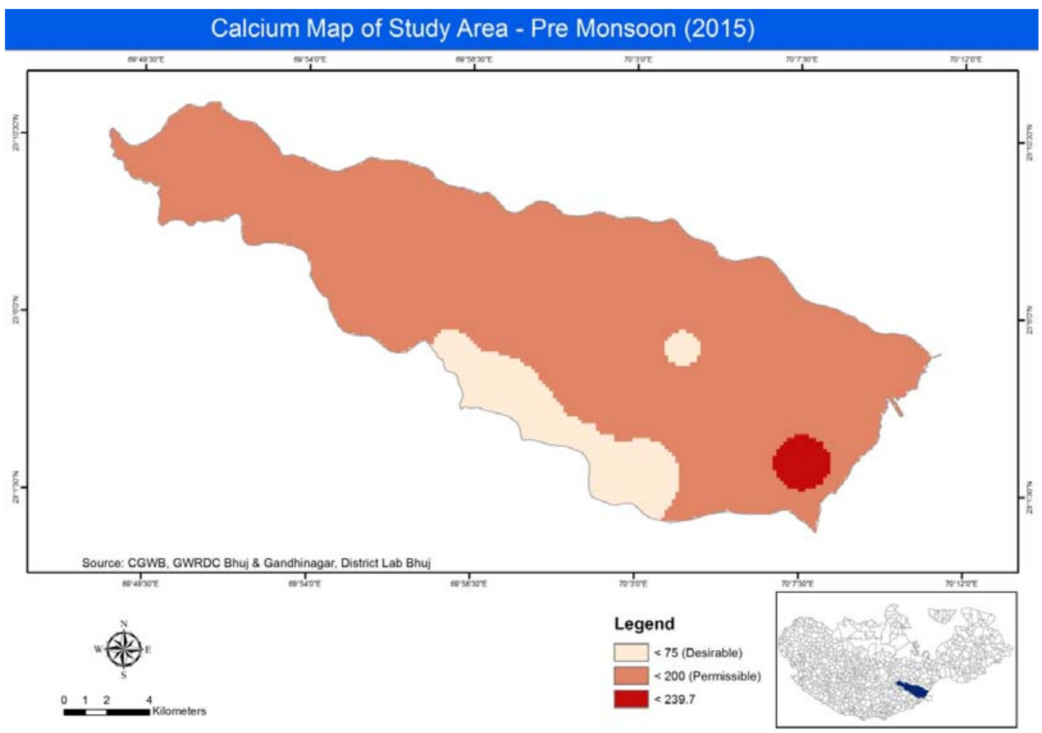

Fig. 4.48 Calcium Map of Study Area Pre Monsoon 2015

4.5.7 Magnesium

Magnesium Level within the study area

Standard deviation (39.62) suggests that sample data are very far from each other. The skewness value is 1.63 thus the curve is skewed. kurtosis is (2.81) which indicates its platykurtic.

Few parts of Gandhidham and Anjar taluka like Varsamedi, Galpadar, Gandhidham (M) and Kidana have high magnesium levels relative to most of the other areas.

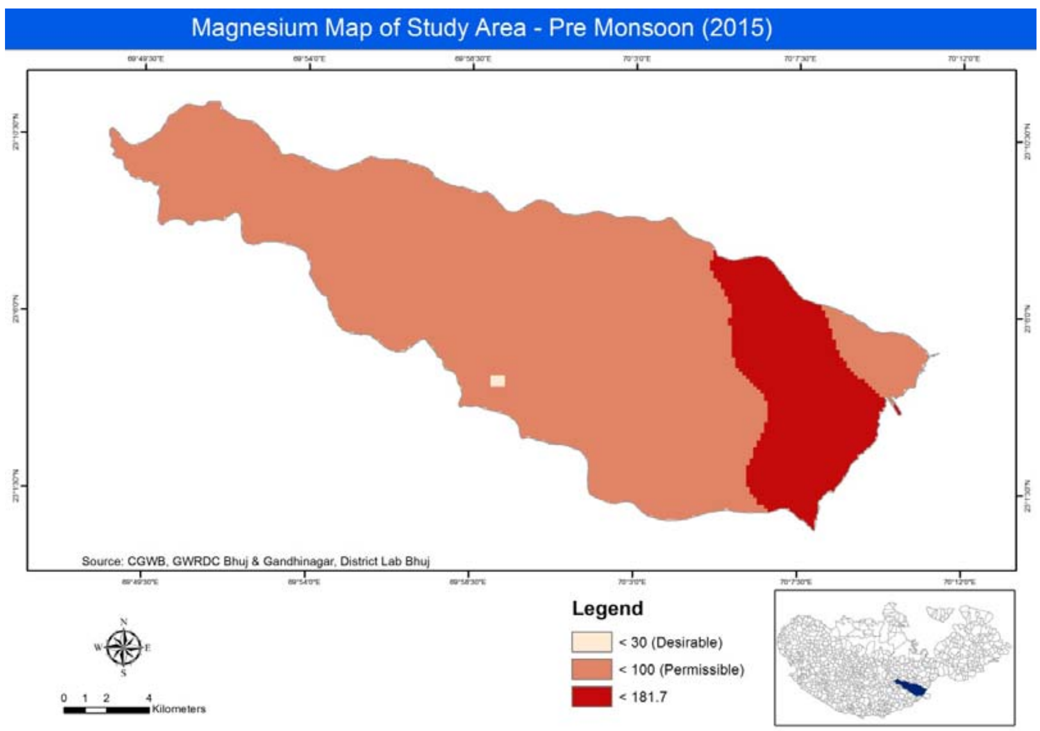

Fig. 4.49 Magnisium Map of Study Area Pre Monsoon 2015

4.5.8 Chloride

Chloride levels within the study area

Standard deviation (528.8) suggests that sample data are very far from each other. The skewness value is 0.81 thus the curve is skewed. kurtosis is (0.03) which indicates its platykurtic.

Most of the high chloride levels are found in the Gandhidham taluka of the study area while rest of the study area are in the range of permissible limit of the indian standards.

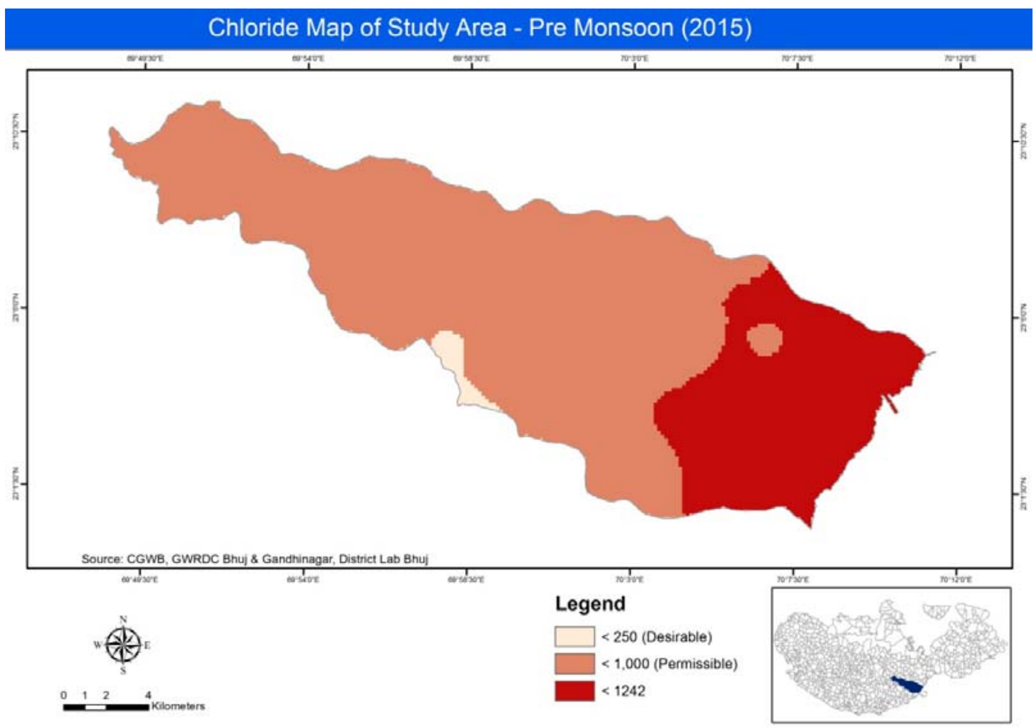

Fig. 4.50 Chloride Map of Study Area Pre Monsoon 2015

4.5.9 Sulphate

Sulphate levels within the study area

Standard deviation (61.95) suggests that sample data are very far from each other. The skewness value is 1.56 thus the curve is skewed. kurtosis is (1.95) which indicates its platykurtic.

Sulphates within the permissible limits are seen near the coastal area of Gandhidham like Kidana, Mithi Rohar and Gandhidham (M)while it is within the desirable limits in the rest of the study area.

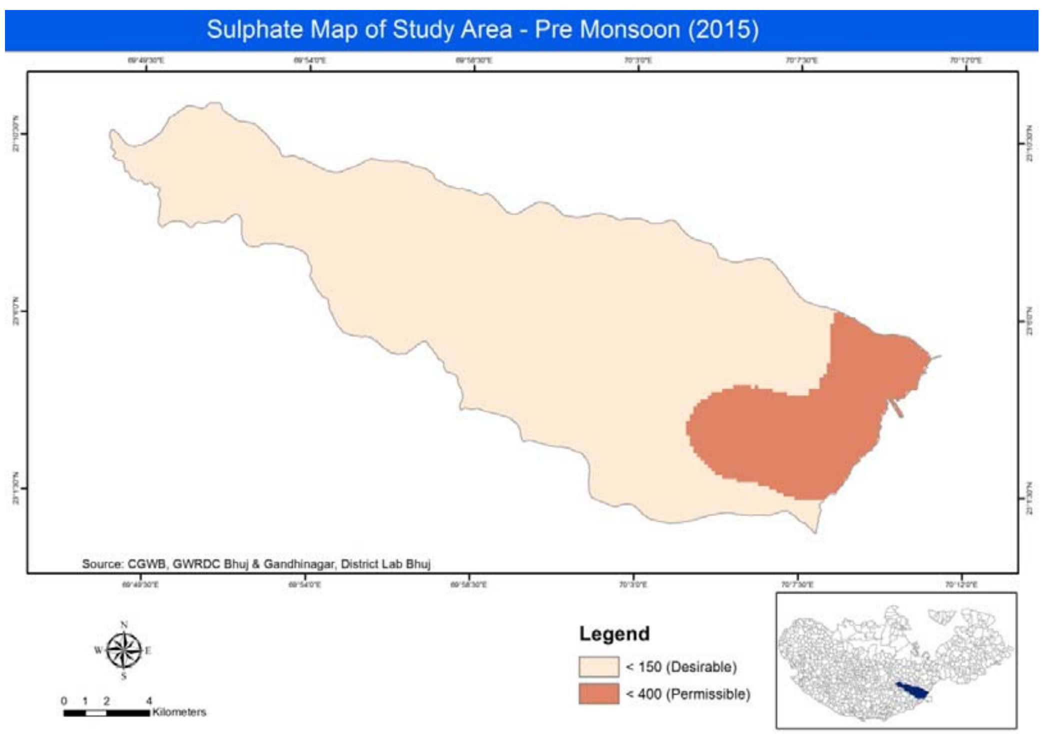

Fig. 4.51 Sulphate Map of Study Area Pre Monsoon 2015

4.5.10 Alkalinity

Alkalinity Level within the study area

Standard deviation (106.05) suggests that sample data are very far from each other. The skewness value is 0.47 which is close to 0, thus the curve is symmetrical. kurtosis is (-0.87) which indicates its platykurtic.

Alkalinity is found well within the permissible limits of in Bhuj, Anjar and Gandhidham talukas. Ningal, Khambra, Malingna and Bhadroi have Alkalinity within Desirable limits according to Indian standards.

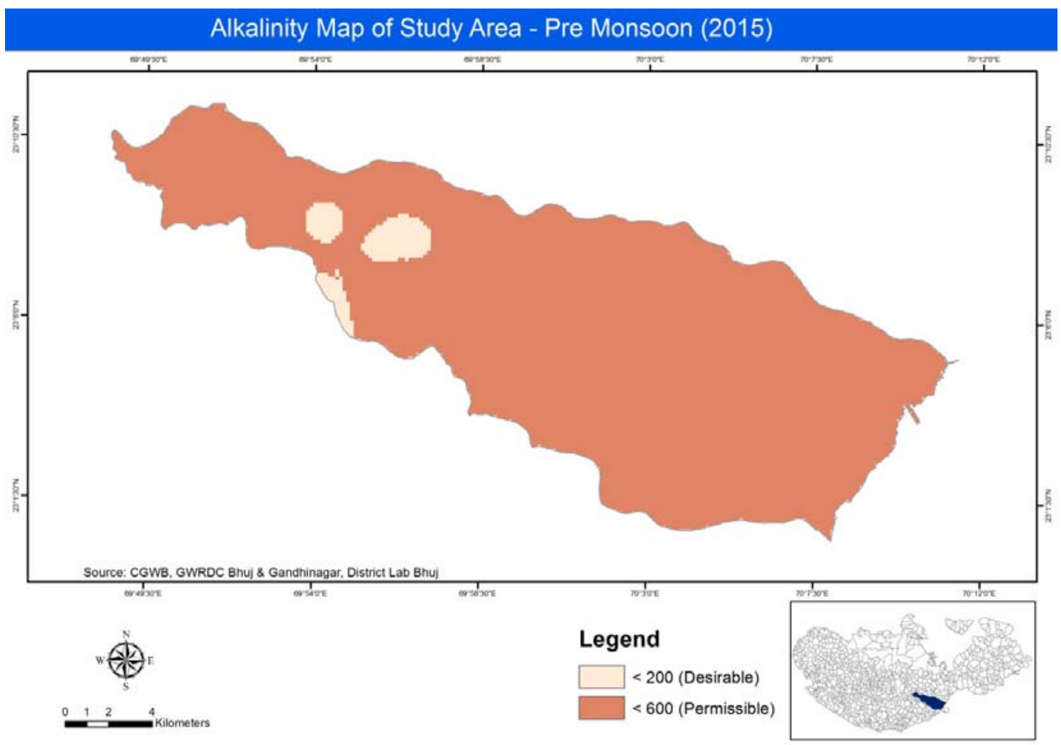

Fig. 4.52 Alkalinity Map of Study Area Pre Monsoon 2015

Table 4.6 (a) Correlation Matrix of Pre Monsoon 2015

Correlations						
	TDS	Hardness	Calcium	Magnessium	Chloride	Sulphate
TDS	1	-.182	.547*	.677**	.787**	.787**
Hardness	-.182	1	.348	.117	-.254	-.259
Calcium	.547*	.348	1	.830**	.438	.626**
Magnessium	.677**	.117	.830**	1	.351	.535*
Chloride	.787**	-.254	.438	.351	1	.830**
Sulphate	.787**	-.259	.626**	.535*	.830**	1
Nitrate	.858**	-.579**	.373	.538*	.704**	.851**
Fluorides	-.558*	.479*	-.170	-.367	-.403	-.321
Alkalinity	.539*	-.091	.296	.252	.567**	.404
pH	.005	-.313	-.266	-.062	-.229	-.039

Table 4.6 (b) Correlation Matrix of Pre Monsoon 2015

Correlations				
	Nitrate	Fluorides	Alkalinity	pH
TDS	.858**	-.558*	.539*	.005
Hardness	-.579**	.479*	-.091	-.313
Calcium	.373	-.170	.296	-.266
Magnessium	.538*	-.367	.252	-.062
Chloride	.704**	-.403	.567**	-.229
Sulphate	.851**	-.321	.404	-.039
Nitrate	1	-.574**	.406	.194
Fluorides	-.574**	1	-.260	.129
Alkalinity	.406	-.260	1	.294
pH	.194	.129	.294	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

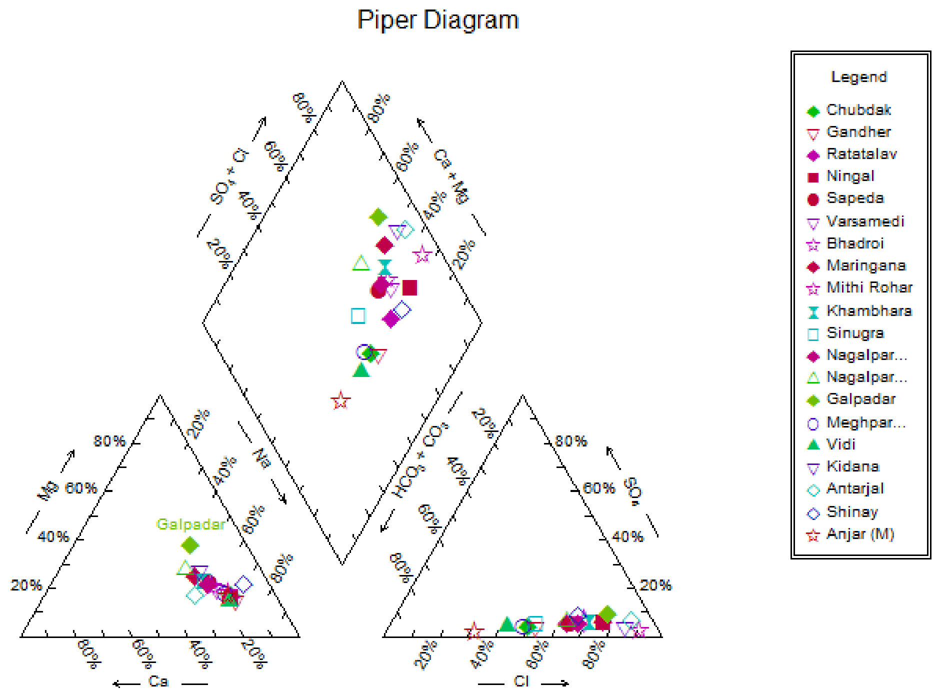

Fig. 4.53 Piper Diagram of Study Area Pre Monsoon 2015

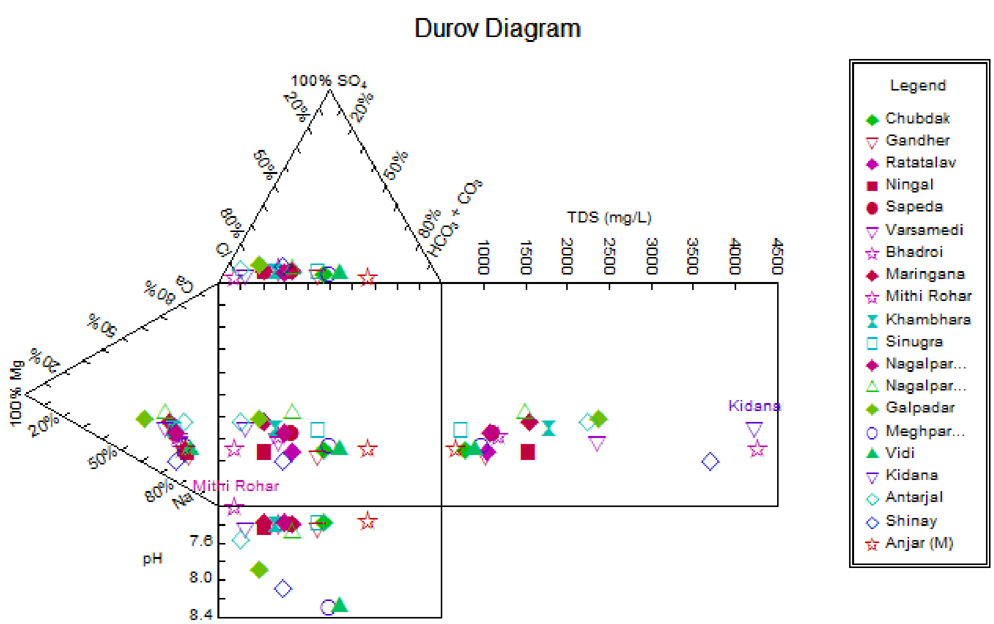

Fig. 4.54 Durov Diagram of Study Area Pre Monsoon 2015

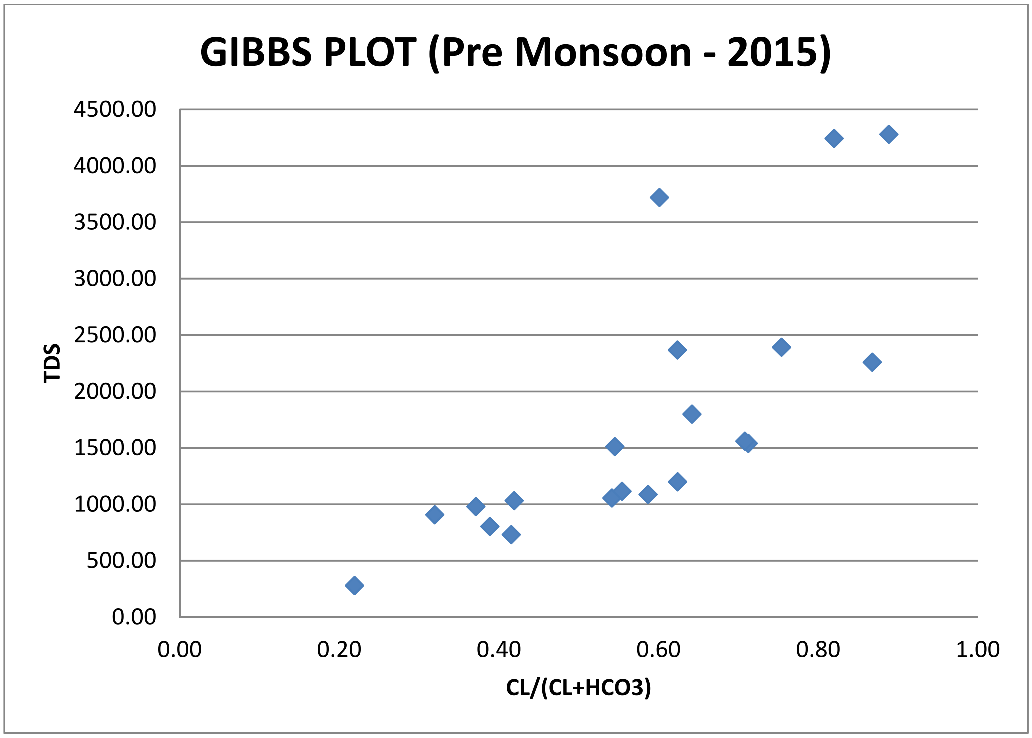

Fig. 4.55 Gibbs Plot of Study Area Pre Monsoon 2015

4.6 WATER QUALITY ANALYSIS FOR POST MONSOON 2015

Table 4.7 Post Monsoon Water Quality Parameters (2015)

Chemical Parameters	Maximum	Minimum	Average	Std Dev	Skewness	Kurtosis
pH	8.48	7.20	7.53	0.28	2.01	5.94
Nitrate (mg/l)	254.00	22.00	54.35	66.21	1.54	2.66
Fluoride (mg/l)	1.40	0.16	0.66	0.35	0.46	-0.75
TDS (mg/l)	4656.00	191.00	1967.67	1342.63	0.71	-0.61
Hardness (mg/l)	1380.00	88.00	374.38	261.32	3.07	11.51
Calcium (mg/l)	255.00	19.00	101.67	67.00	1.42	1.21
Magnisium (mg/l)	181.00	10.00	67.62	48.12	1.31	0.85
Chlorides (mg/l)	1680.00	48.00	696.48	541.26	0.82	-0.88
Sulphate (mg/l)	500.00	6.00	139.81	115.91	1.83	4.05
Alkalinity (mg/l)	460.00	80.00	250.67	106.25	0.72	-0.29

4.6.1 pH

pH level within Study area:

The level of pH varied between 8.48 to 7.2, ranging between slightly acidic to the alkaline condition (Fig.4.56). The mean of pH in groundwater was 7.53 indicating a normal condition. Standard deviation (**0.28**) which is near to zero, suggests that sample data are close to each other. The skewness value 2.01 thus the curve is skewed. kurtosis is (**5.94**) which indicates its leptokurtic.

pH tends to be more alkaline towards the Gandher and Chubdak village of Bhuj taluka compared to the rest of the study area.

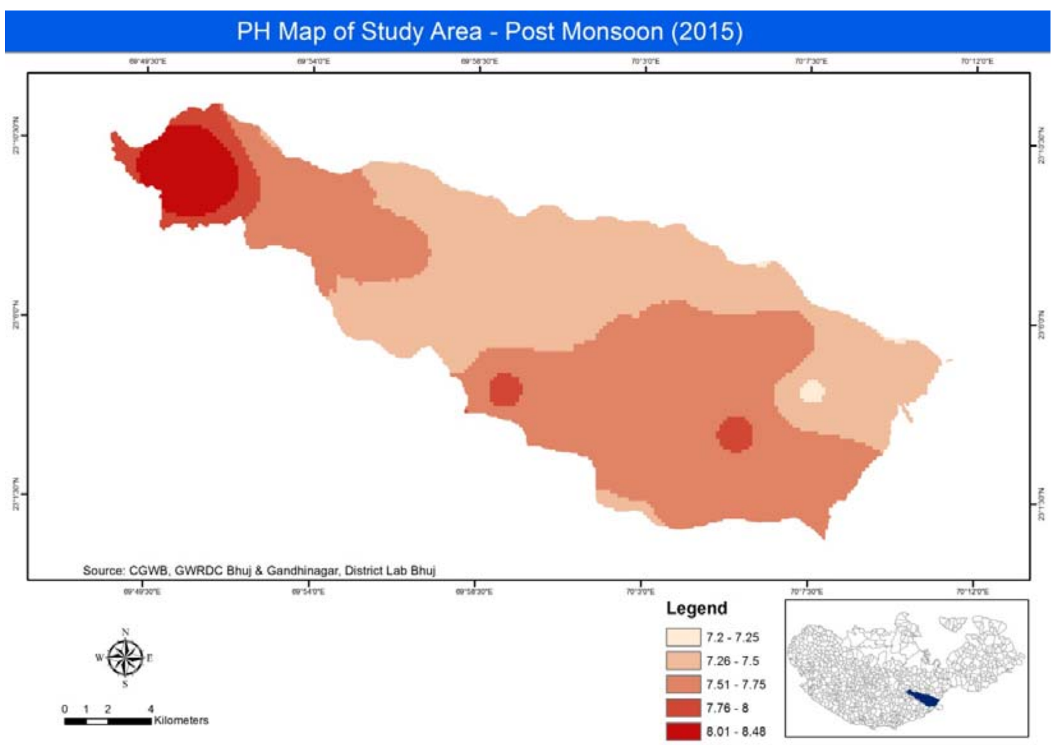

Fig. 4.56 pH Map of Study Area Post Monsoon 2015

4.6.2 Nitrate

Nitrate Level within study area:

Concentration of Nitrate above the permissible limit in the study area is not found anywhere within the study area and also not found near the coastal area of Gandhidham taluka where it was found to be slightly higher in the pre monsoon period. Standard deviation (66.21) suggests that sample data are far from each other. The skewness value is 1.54 thus the curve is skewed. kurtosis is (2.66) which indicates its platykurtic.

Nitrate level more than the permissible limits are found to be more towards the coastal areas o Gandhidham taluka like Kidana, Mithi Rohar and Gandhidham (M). While parts of Shinay, Galpadar, Varsamedi are found to be within the permissible limits. Rest of the study area like most parts of Anjar and Bhuj are well within the desirable limits of Indian standards.

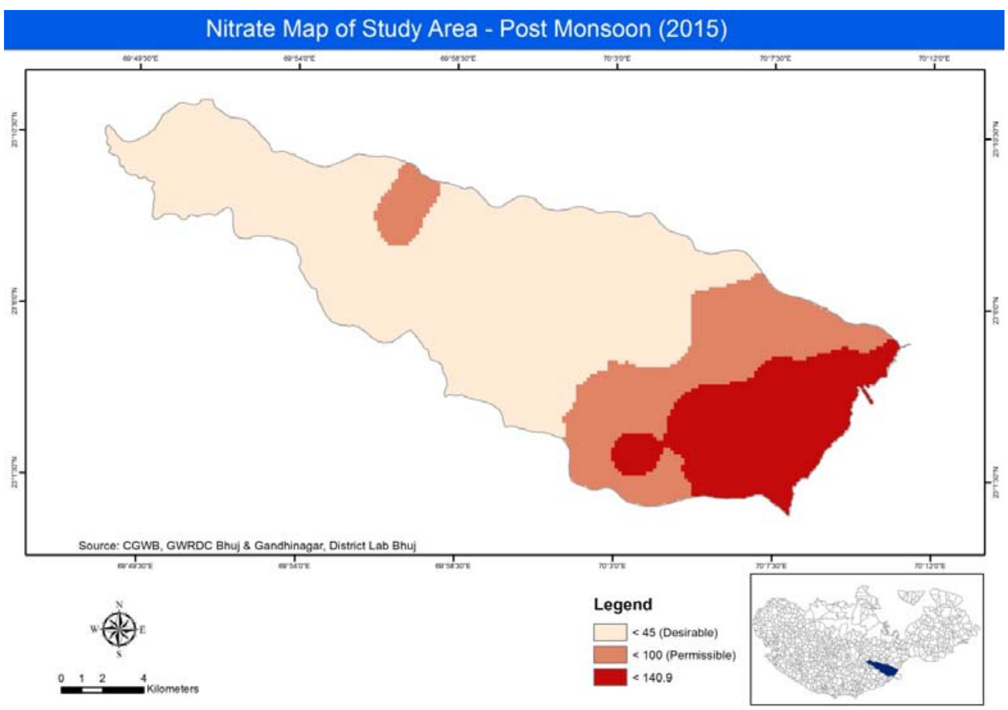

Fig. 4.57 Nitrate Map of Study Area Post Monsoon 2015

4.6.3 Fluoride

Fluoride Level within study area:

Standard deviation (0.35) suggests that sample data are close to each other. The skewness value 0.46 is approximately equal to 0, thus the curve is symmetrical. kurtosis is (-0.75) which indicates its platykurtic.

Fluoride in found to be below the minimum level of <0.6 mg/l in most of the part of Anjar taluka in the post monsoon periods while rest of the areas are within the permissible limits according to the Indian standards.

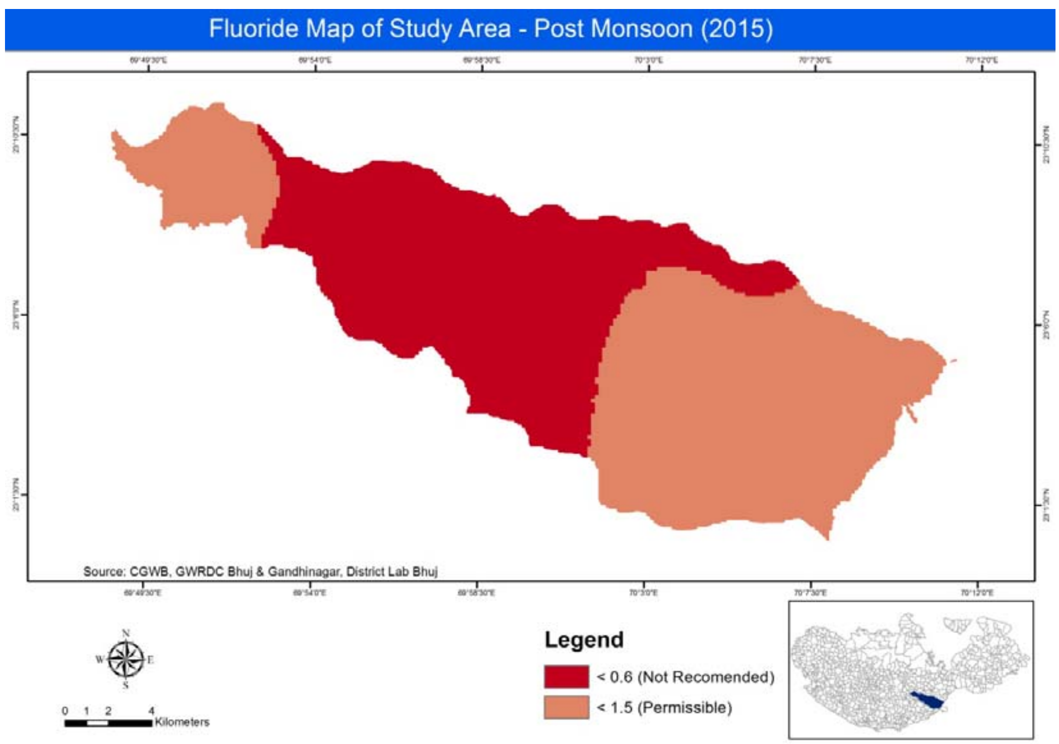

Fig. 4.58 Fluoride Map of Study Area Post Monsoon 2015

4.6.4 TDS

TDS level of the Study area:

Standard deviation (1342.63) suggests that sample data are far from each other. The skewness value is 0.7 which is close to zero thus the curve is symmetrical. kurtosis is (-0.61) which indicates its platykurtic.

During the post monsoon season the TDS levels of most of the part of Bhuj and Gandhidham taluka are found to have the TDS level higher than the permissible limits of Indian Standards, while that of Anjar taluka are within the permissible limits.

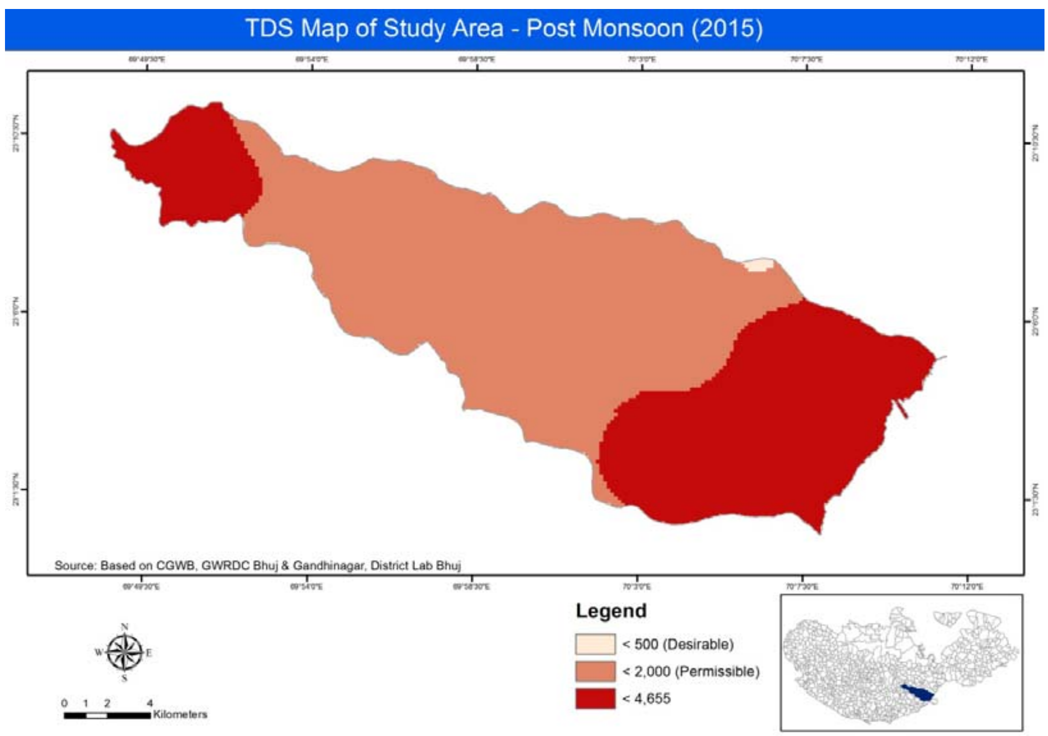

Fig. 4.59 TDS Map of Study Area Post Monsoon 2015

4.6.5 Hardness

Hardness Level within study area:

Standard deviation (261.32) suggests that sample data are far from each other. The skewness value is 3.07 thus the curve is skewed. kurtosis is (11.51) which indicates its leptokurtic.

During the post monsoon period the only area found to have the hardness level higher than the permissible limits are that of Gandher and Chubdak village of Bhuj taluka. While rest of the study are have hardness level either within the permissible limits or desirable limits.

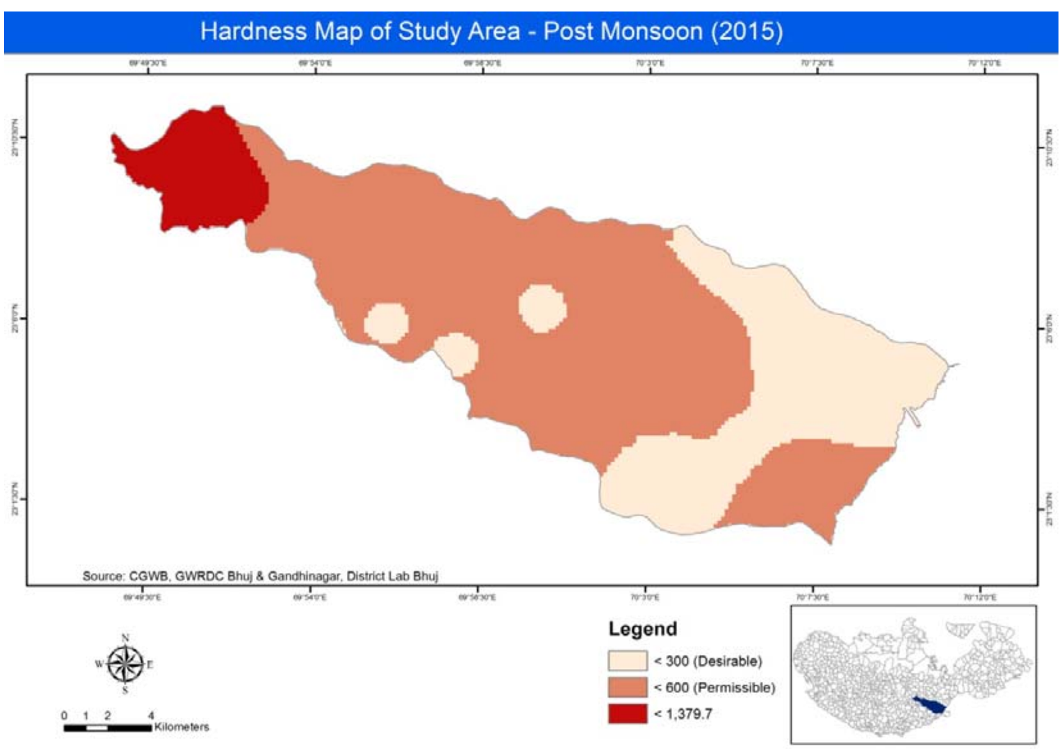

Fig. 4.60 Hardness Map of Study Area Post Monsoon 2015

4.6.6 Calcium

Calcium Levels within Study area

Standard deviation (67.0) suggests that sample data are far from each other. The skewness value is 1.42 thus the curve is skewed. kurtosis is (1.21) which indicates its platykurtic.

In the study area calcium is mostly found within the permissible limits in the post monsoon season except few patches in the villages of Bhuj like Gandher and Chubdak and Kidana village of Gandhidham taluka. Many parts of Villages of Anjar taluka like Varsamedi, Anjar (M), Khambra, Sinugra, Nagalpar Moti and Nagalpar Nani and Sapeda tend to have calcium levels within the desirable levels of Indian standards.

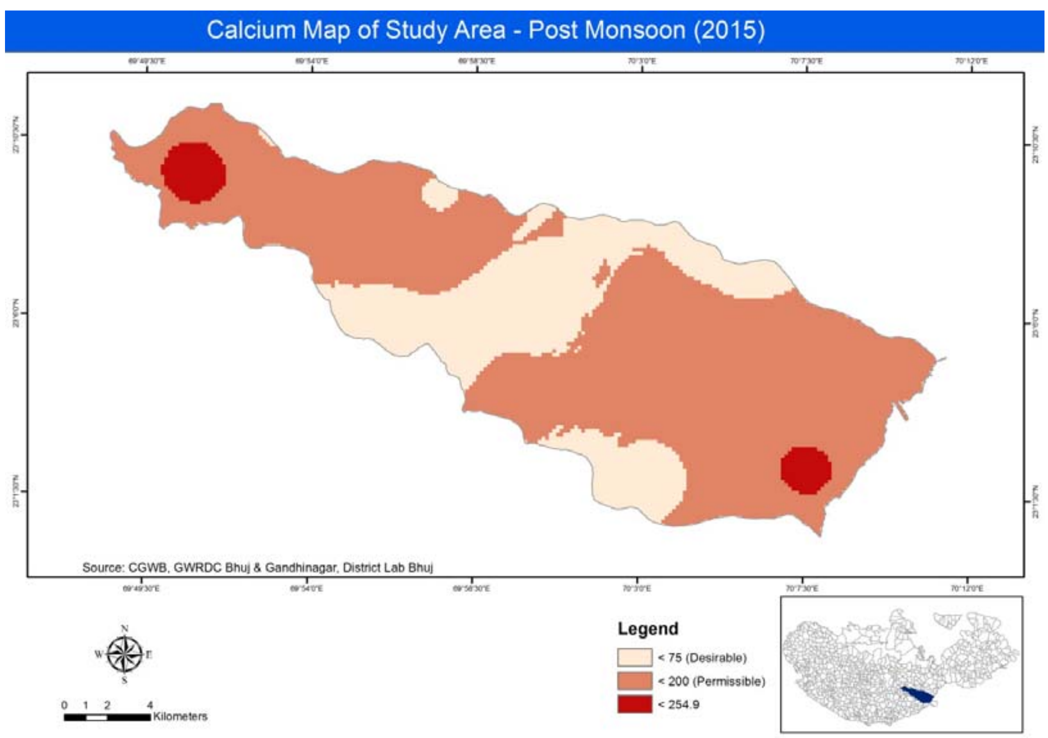

Fig. 4.61 Calcium Map of Study Area Post Monsoon 2015

4.6.7 Magnesium

Magnesium Level within the study area

Standard deviation (48.12) suggests that sample data are far from each other. The skewness value is 1.31 thus the curve is skewed. kurtosis is (0.85) which indicates its platykurtic.

Most of the parts of Gandher and Chubdak within the study area and major part of the Kidana, Gandhidham and Galpadar village have Magnesium levels higher than the permissible limit of Indian standards.

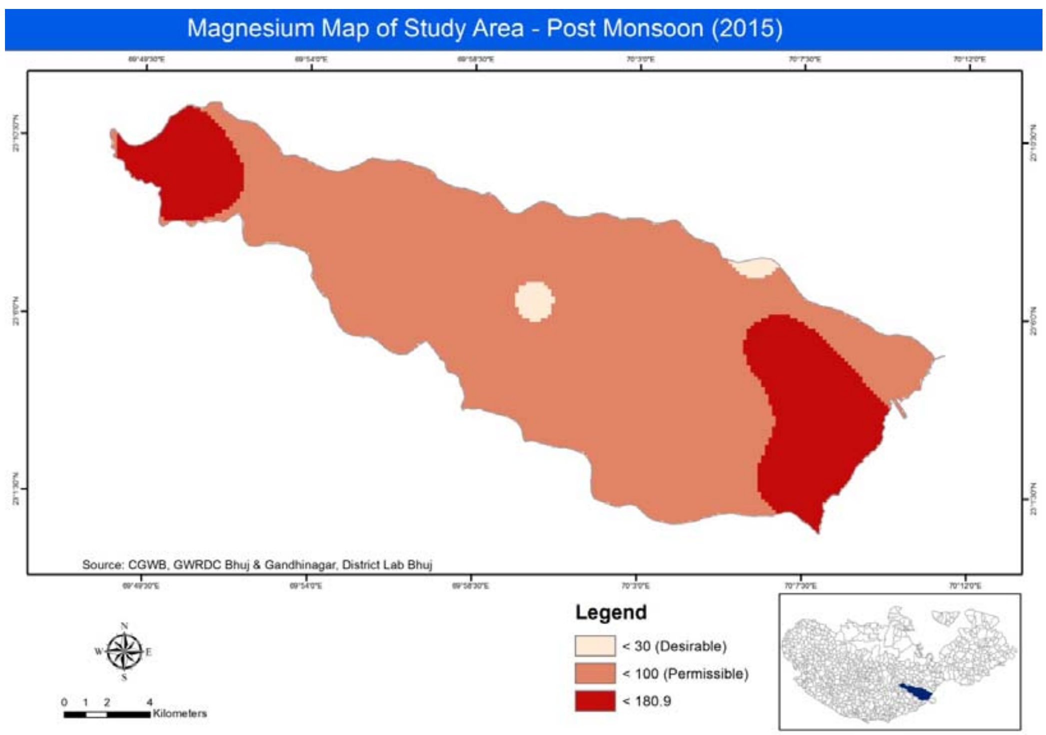

Fig. 4.62 Magnesium Map of Study Area Post Monsoon 2015

4.6.8 Chlorides

Chlorides Level within the study area

Standard deviation (696.48) suggests that sample data are far from each other. The skewness value is 0.82 thus the curve is skewed. kurtosis is (-0.88) which indicates normal platykurtic.

During the post monsoon periods, Gandher, Chubdak villages of Bhuj taluka and most of the parts of villages of Gandhidham taluka like Kidana, Gandhidham (M), Galpadar, Mithi Rohar tend to have chloride level higher than the permissible limit of Indian standards, while most of the villages of Anjar taluka seem to have chloride level within the permissible limits.

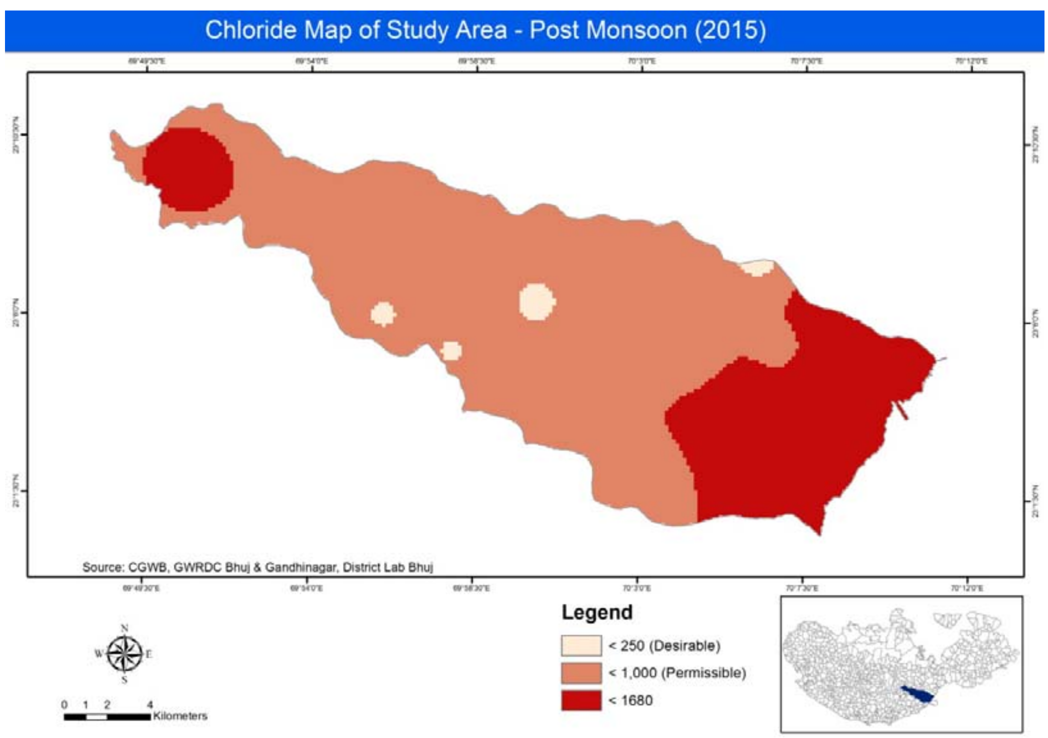

Fig. 4.63 Chloride Map of Study Area Post Monsoon 2015

4.6.9 Sulphate

Sulphate levels within the study area

Standard deviation (115.91) suggests that sample data are far from each other. The skewness value is 1.83 thus the curve is skewed. kurtosis is (4.05) which indicates its leptokurtic.

Sulphates level above the permissible limits are only seen near few patches of Gandher village of Bhuj taluka during the post monsoon season while it is mostly within the permissible limits in rest of the region.

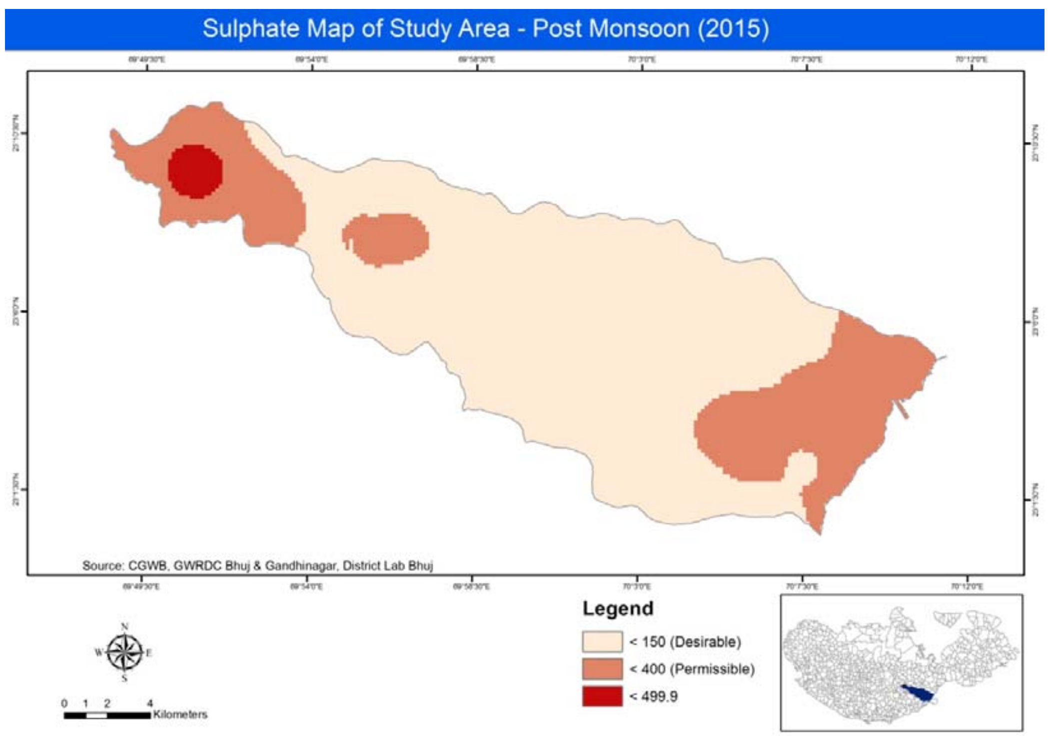

Fig. 4.64 Sulphate Map of Study Area Post Monsoon 2015

4.6.10 Alkalinity

Alkalinity Level within the study area

Standard deviation (106.25) suggests that sample data are far from each other. The skewness value is 0.72 thus the curve is symmetrical. kurtosis is (-0.29) which indicates its platykurtic.

Alkalinity is mostly within the permissible limits in whole of the study area during the post monsoon season.

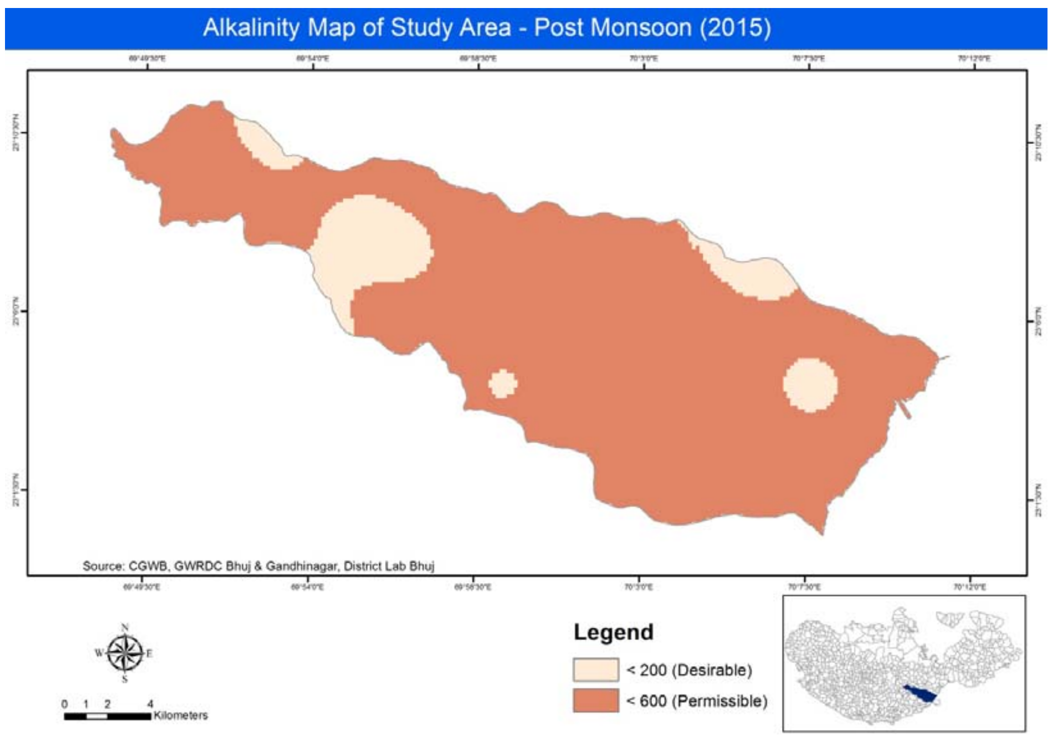

Fig. 4.65 Alkalinity Map of Study Area Post Monsoon 2015

Table 4.8 (a) Correlation Matrix of Post Monsoon 2015

Correlations						
	TDS	PH	Hardness	Calcium	Magnesium	Chloride
TDS	1	.489*	.419	.796**	.779**	.670**
PH	.489*	1	.817**	.649**	.557**	.119
Hardness	.419	.817**	1	.625**	.524*	.096
Calcium	.796**	.649**	.625**	1	.813**	.462*
Magnesium	.779**	.557**	.524*	.813**	1	.369
Chloride	.670**	.119	.096	.462*	.369	1
Sulphate	.849**	.689**	.718**	.822**	.656**	.471*
Nitrate	.632**	-.081	-.245	.484*	.344	.474*
Fluoride	.719**	.265	.171	.477*	.625**	.538**
Alkalinity	.219	.105	.097	.153	.105	.520*

Table 4.8 (b) Correlation Matrix of Post Monsoon 2015

Correlations				
	Sulphate	Nitrate	Fluoride	Alkalinity
TDS	.849**	.632**	.719**	.219
PH	.689**	-.081	.265	.105
Hardness	.718**	-.245	.171	.097
Calcium	.822**	.484*	.477*	.153
Magnesium	.656**	.344	.625**	.105
Chloride	.471*	.474*	.538**	.520*
Sulphate	1	.356	.521*	.016
Nitrate	.356	1	.463*	.117
Fluoride	.521*	.463*	1	.249
Alkalinity	.016	.117	.249	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

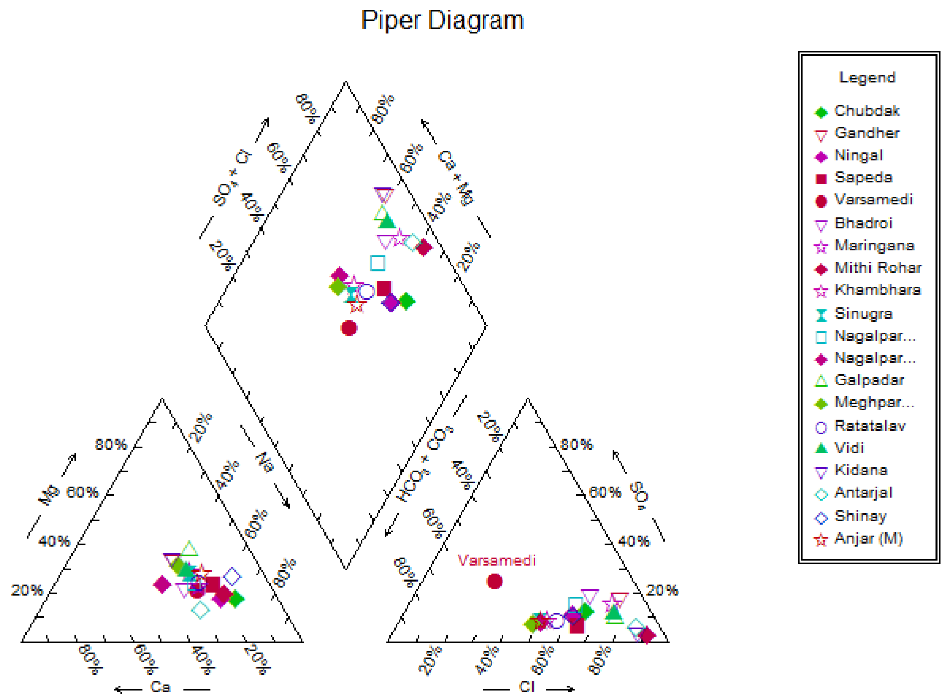

Fig. 4.66 Piper Diagram of Study Area Post Monsoon 2015

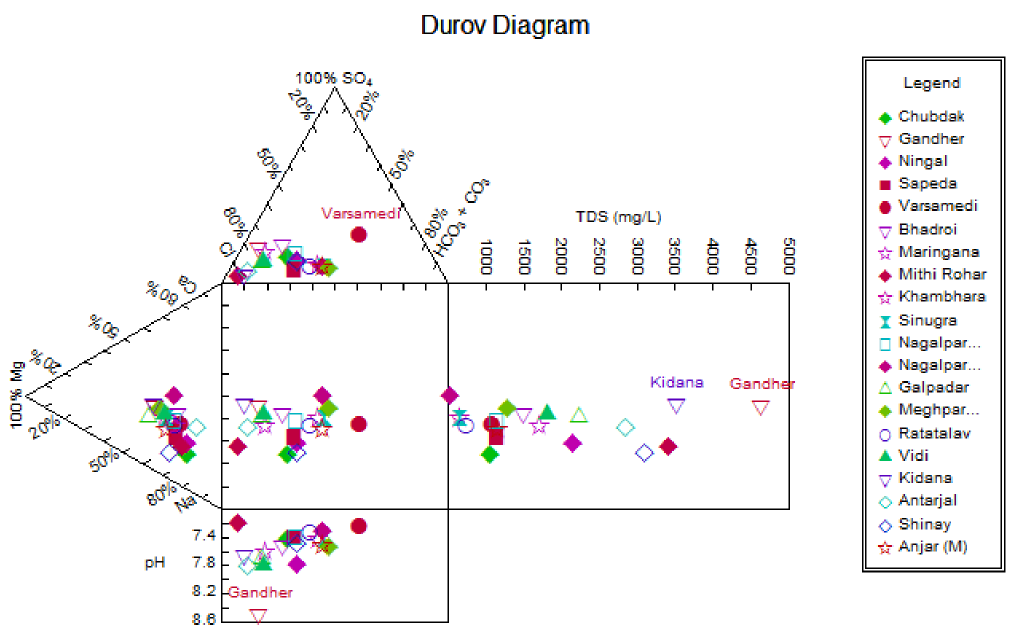

Fig. 4.67 Durov Diagram of Study Area Post Monsoon 2015

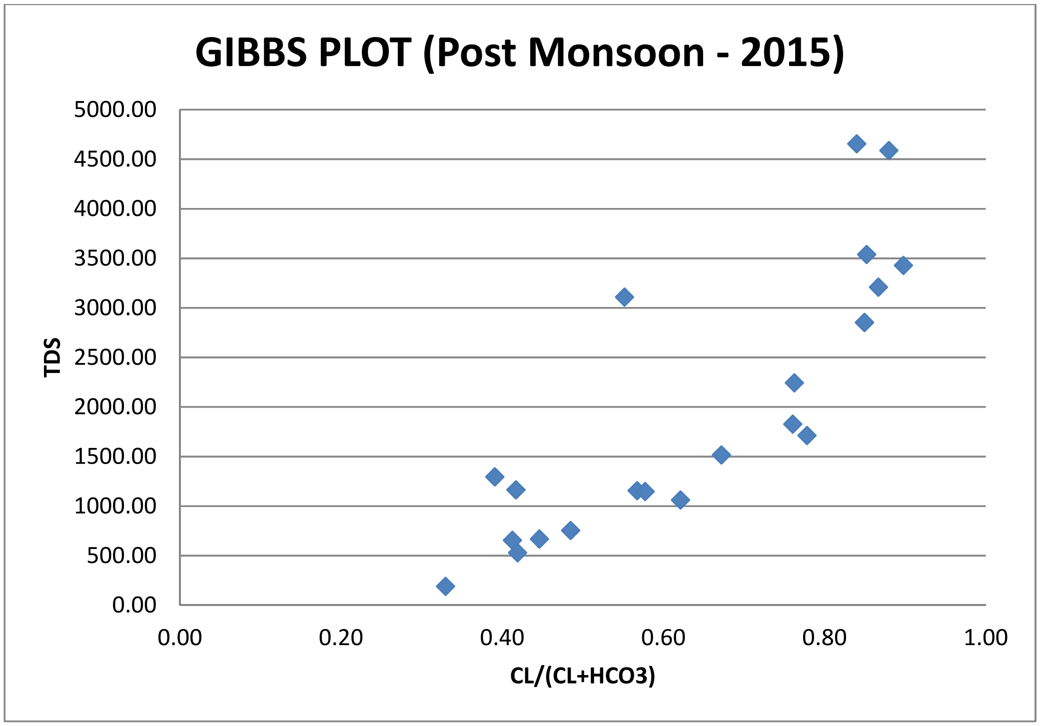

Fig. 4.68 Gibbs Plot of Study Area Post Monsoon 2015

4.7 WATER QUALITY ANALYSIS FOR PRE-MONSOON 2016

Table 4.9 Pre-monsoon Water Quality Parameters (2016)

Chemical Parameters	Maximum	Minimum	Average	Std Dev	Skewness	Kurtosis
pH	8.10	7.00	7.53	0.35	0.10	-1.43
Nitrate (mg/l)	162.00	2.22	47.81	55.46	0.91	-0.52
Fluoride (mg/l)	1.38	0.28	0.71	0.32	0.35	-0.45
Tds (mg/l)	4879.00	476.00	1856.80	1231.21	1.10	0.30
Hardness (mg/l)	496.00	184.00	310.90	91.44	0.60	-0.51
Calcium (mg/l)	212.00	43.00	95.45	40.46	1.26	2.32
Magnisium (mg/l)	128.00	18.00	48.75	26.59	1.62	3.12
Chlorides (mg/l)	1125.00	128.00	558.10	331.93	0.47	-1.25
Sulphate (mg/l)	398.00	6.00	163.55	97.49	0.99	0.78
Alkalinity (mg/l)	455.00	180.00	264.05	83.05	1.11	0.15

4.7.1 pH

pH level within Study area:

The level of pH varied between 8.1 to 7.0, ranging between slightly acidic to the alkaline condition (Fig.4.69). The mean of pH in groundwater was 7.53 indicating a normal condition. Standard deviation (0.35) suggests that sample data are very close to each other. The skewness value (0.10) is approximately equal to 0, thus the curve is symmetrical. kurtosis is (-1.43) platykurtic.

pH level is found to be comparatively more alkaline in the Gandhidham taluka in the premonsoon season of 2016 than the rest of the area in the study area.

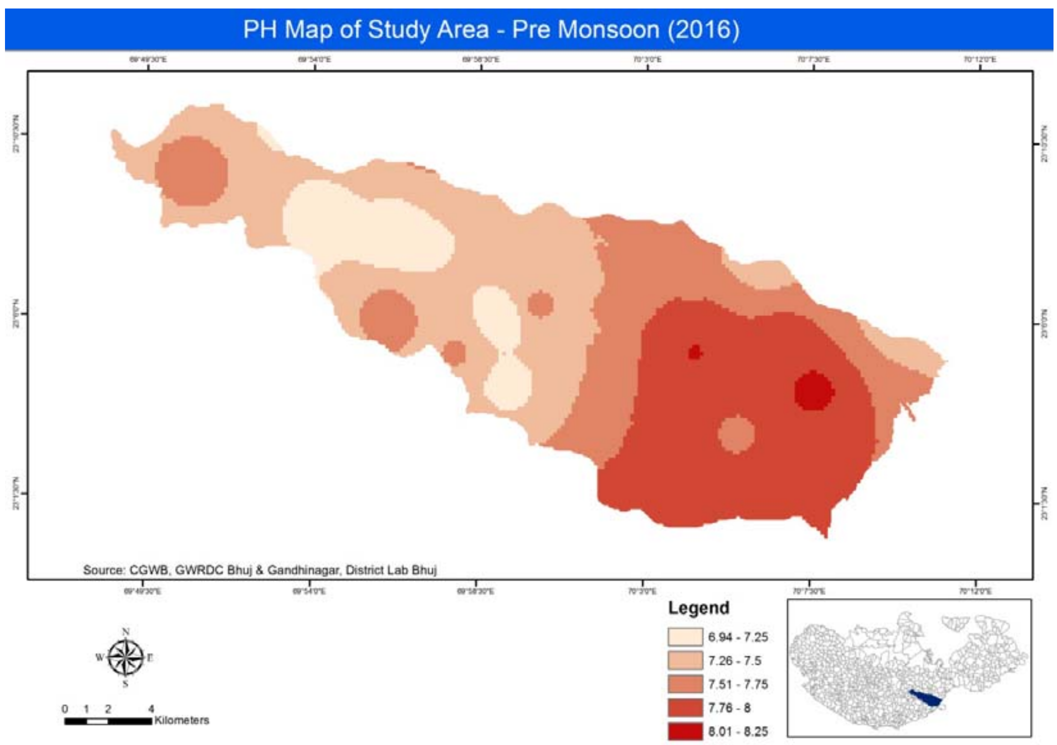

Fig. 4.69 pH Map of Study Area Pre Monsoon 2016

4.7.2 Nitrate

Nitrate Level within study area:

Standard deviation (55.46) suggests that sample data are farther to each other. The skewness value (0.91) thus the curve is skewed. kurtosis (-0.52) suggests its platykurtic.

Concentration of Nitrate level above the permissible limit in the study area is found mostly in the coastal area of Gandhidham taluka like Kidana and Shinay.

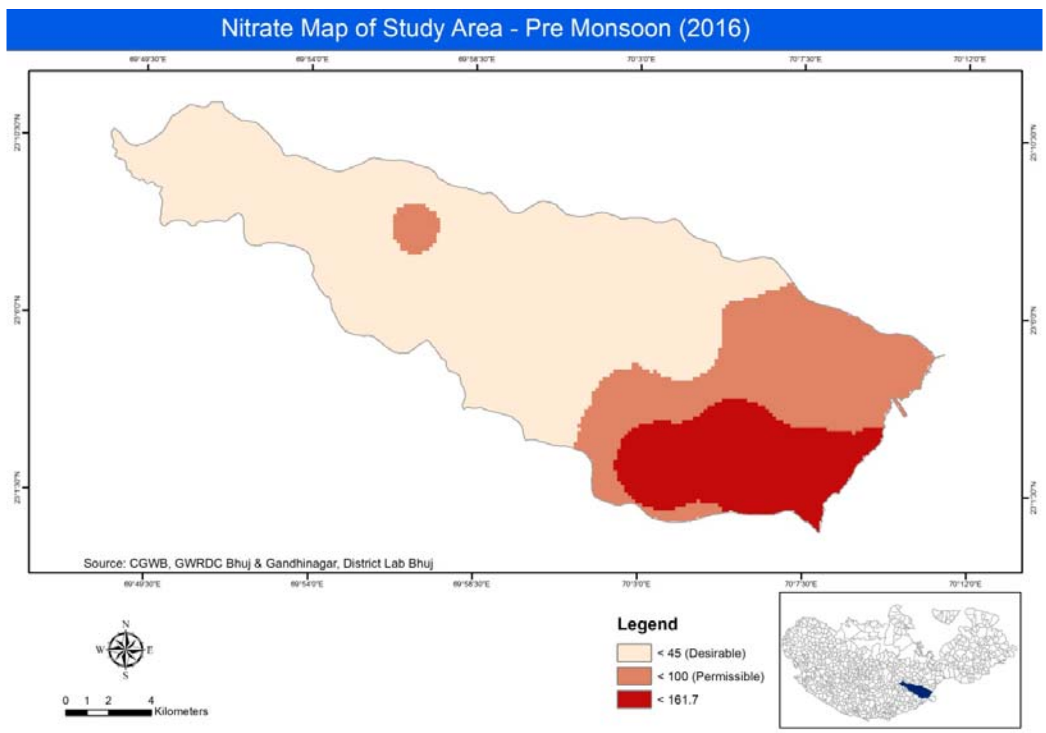

Fig. 4.70 Nitrate Map of Study Area Pre Monsoon 2016

4.7.3 Fluoride

Fluoride Level within study area:

Standard deviation (0.32) suggests that sample data are very close to each other. The skewness value (0.35) is approximately equal to 0, thus the curve is symmetrical. kurtosis is (-0.45) platykurtic.

Many villages in Anjar taluka like Anjar (M), Vidi, Sinugra, Khambhara, Meghpar Borichi, Malingna, Varsamedhi as well as Kidana village in Gandhidham has been reported to have fluoride levels below permissible limits of 0.6 ppm.

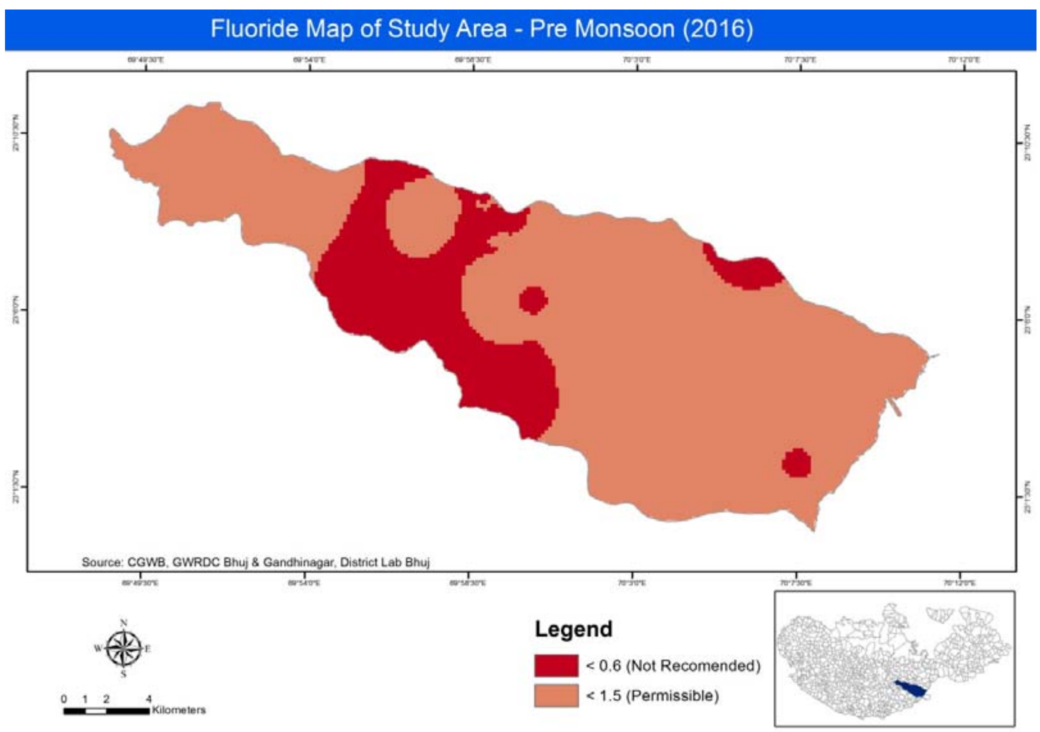

Fig. 4.71 Fluoride Map of Study Area Pre Monsoon 2016

4.7.4 TDS

TDS level of the Study area:

Standard deviation (1231.0) suggests that sample data are very far from each other. The skewness value is 1.1 thus the curve is skewed. kurtosis is (0.3) platykurtic.

Few villages, namely Galpader, Antarjal, Gandhidham, Bharatnagar, Ganeshnagar, Kidana and Shinay villages of Gandhidham taluka are showing the TDS level higher than the permissible limits which is the indication of brackish water. Rest of the study area have TDS level within the permissible limits of Indian standards.

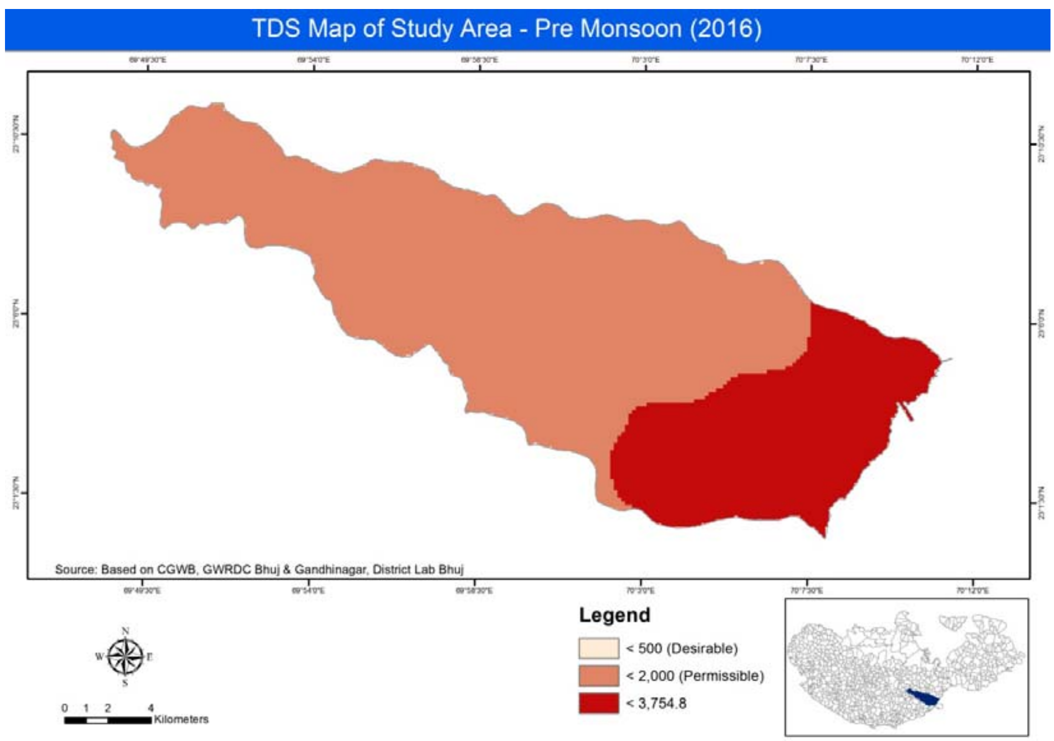

Fig. 4.72 TDS Map of Study Area Pre Monsoon 2016

4.7.5 Hardness

Hardness Level within study area:

Standard deviation (91.44) suggests that sample data are very far from each other. The skewness value is 0.60 thus the curve is close to symmetrical. kurtosis is (-0.51) which indicates its platykurtic.

Hardness levels are within the permissible and desirable limits of Indian standards in whole of the study area.

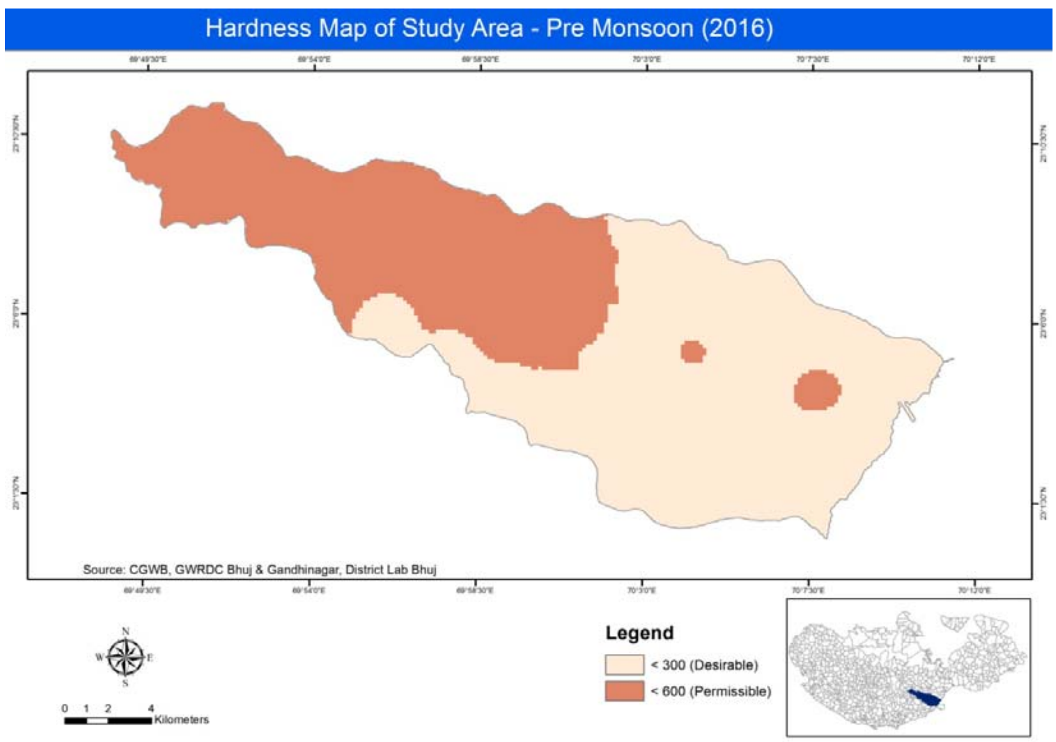

Fig. 4.73 Hardness Map of Study Area Pre Monsoon 2016

4.7.6 Calcium

Calcium Levels within Study area

Standard deviation (40.46) suggests that sample data are very far from each other. The skewness value is 1.26 thus the curve is skewed. kurtosis is (2.32) which indicates its platykurtic.

Calcium is mostly found within the permissible and desirable limits within the study area excluding the coastal villages of Gandhidham taluka like Kidana, Mithi Rohar and Gandhidham (M).

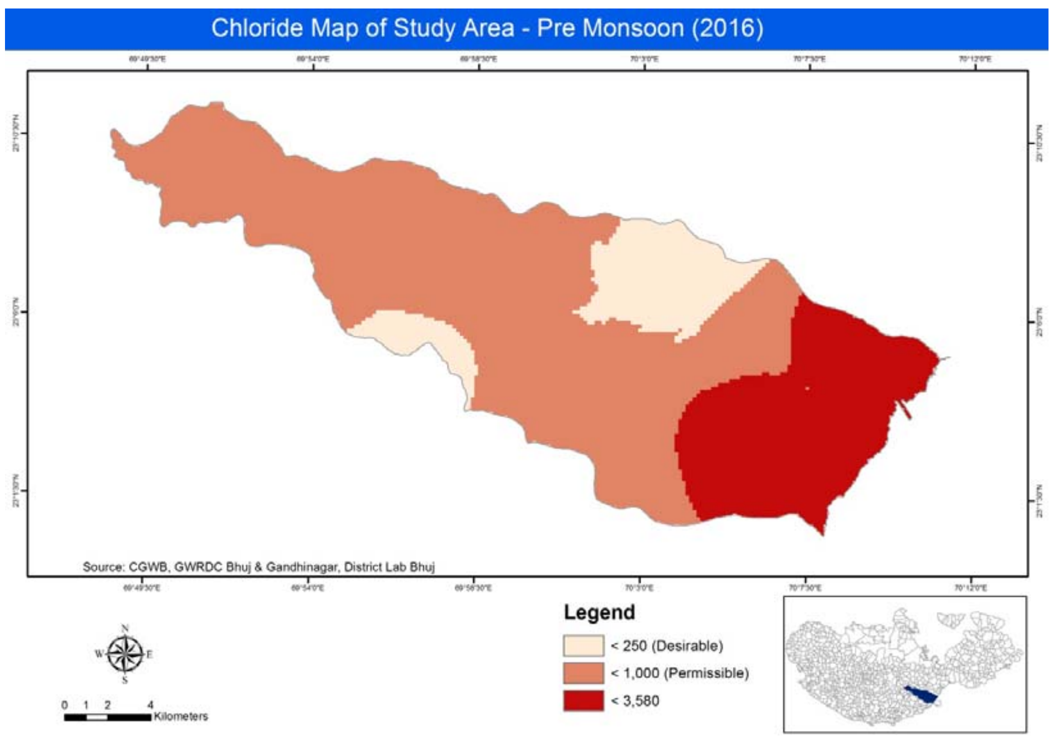

Fig. 4.74 Chloride Map of Study Area Pre Monsoon 2016

4.7.7 Magnesium

Magnesium Level within the study area

Standard deviation (26.59) suggests that sample data are very far from each other. The skewness value is 1.62 thus the curve is skewed. kurtosis is (3.12) which indicates its platykurtic.

Magnesium level is mostly found within the permissible and desirable limits within the study area excluding the coastal area of Kidana village of Gandhidham taluka.

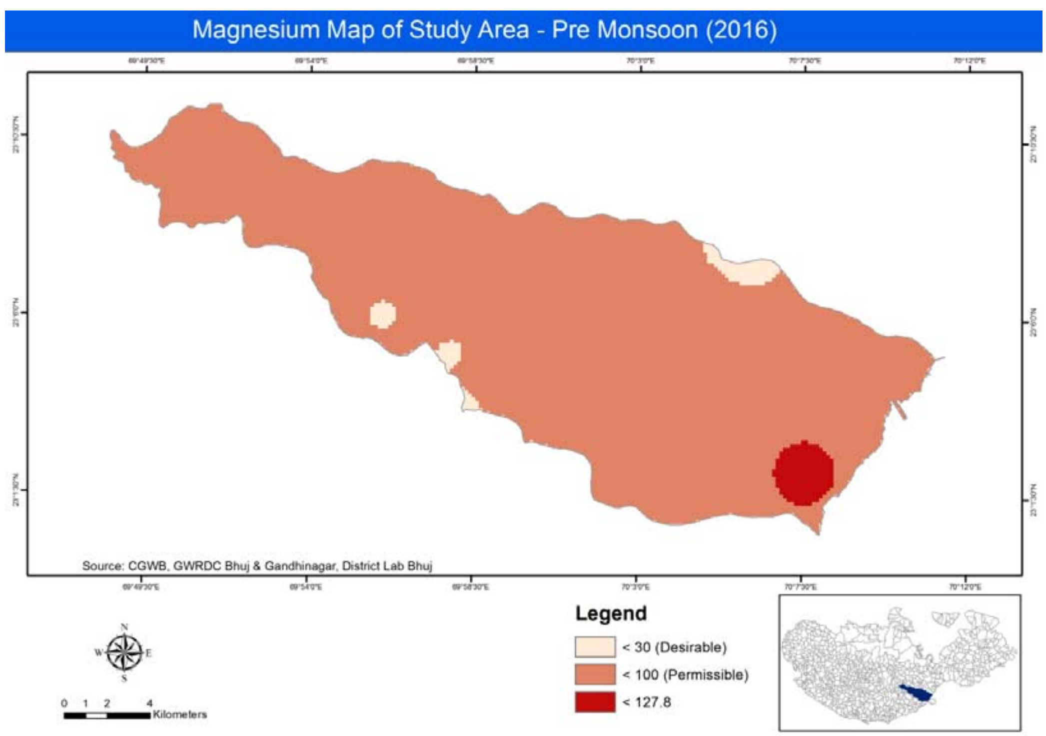

Fig. 4.75 Magnesium Map of Study Area Pre Monsoon 2016

4.7.8 Chloride

Chloride levels within the study area

Standard deviation (558.1) suggests that sample data are very far from each other. The skewness value is 0.47 thus the curve is close to zero hence it is symmetrical. kurtosis is (-1.25) platykurtic.

Chloride level is mostly found within the permissible and desirable limits within the study area excluding the coastal villages of Gandhidham taluka like Kidana, Mithi Rohar and Gandhidham (M).

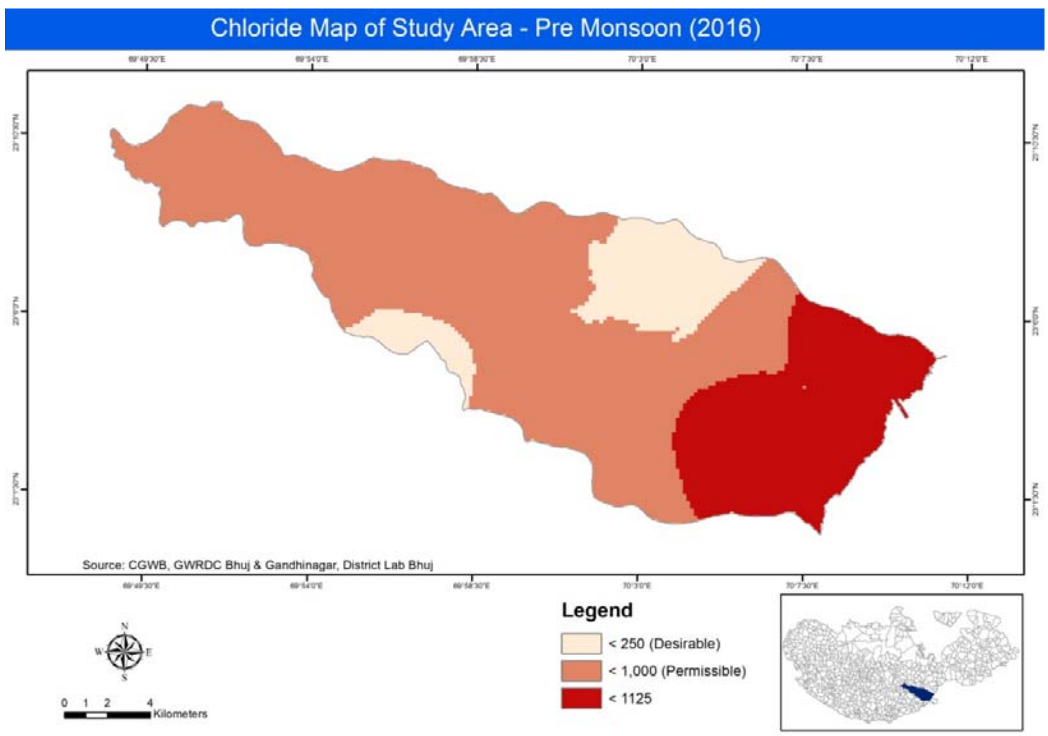

Fig. 4.76 Chloride Map of Study Area Pre Monsoon 2016

4.7.9 Sulphate

Sulphate levels within the study area

Standard deviation (97.49) suggests that sample data are very far from each other. The skewness value is 0.99 thus the curve is skewed. kurtosis is (0.78) which indicates its platykurtic.

Sulphate level are found to be within the permissible and desirable limits in whole of the study area according to Indian standards.

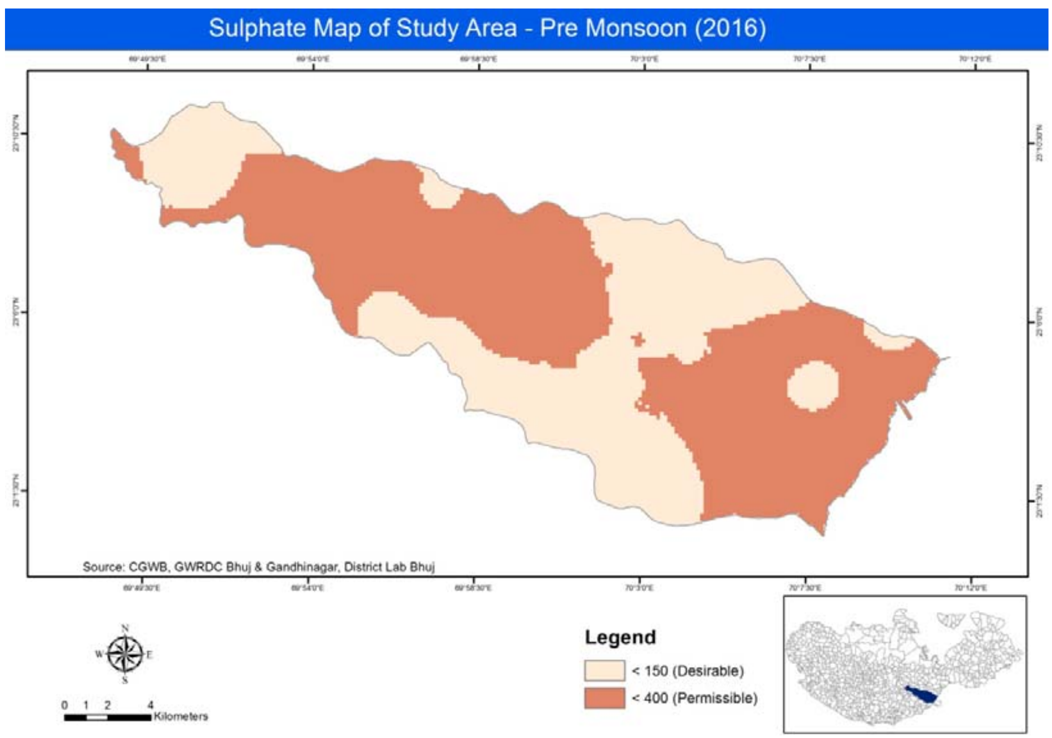

Fig. 4.77 Sulphate Map of Study Area Pre Monsoon 2016

4.7.10 Alkalinity

Alkalinity Level within the study area

Standard deviation (83.05) suggests that sample data are very far from each other. The skewness value is 1.11 thus the curve is skewed. kurtosis is (0.15) which indicates its platykurtic.

Alkalinity levels are found to be within the permissible and desirable limits in whole of the study area with respect to Indian standards.

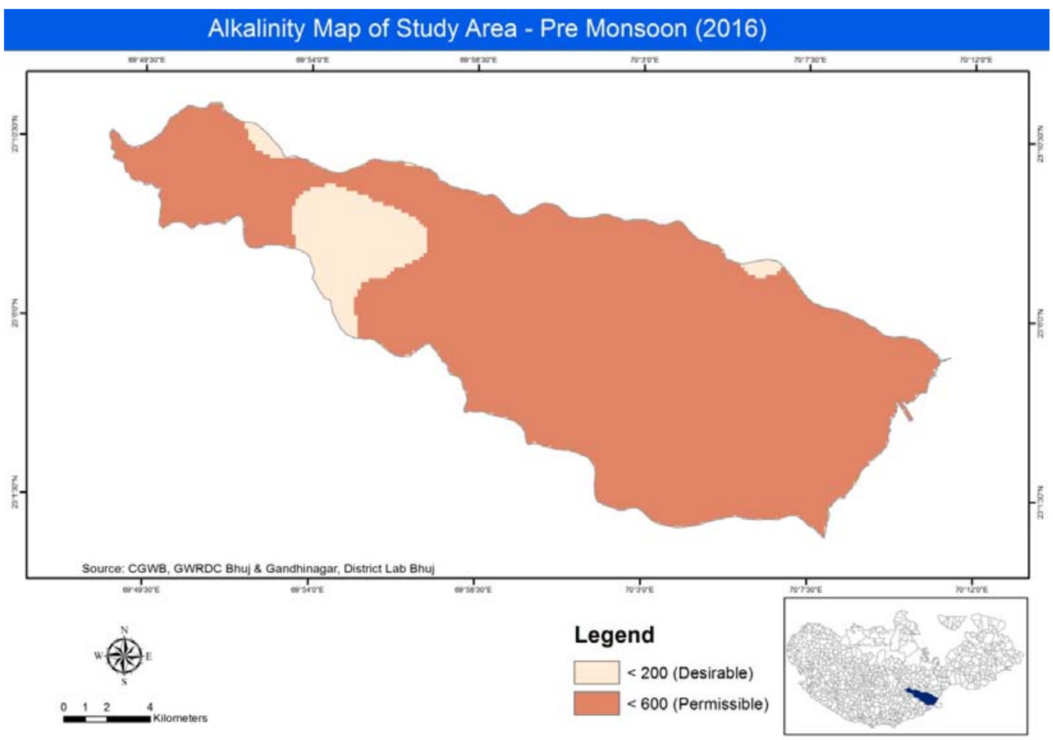

Fig. 4.78 Alkalinity Map of Study Area Pre Monsoon 2016

Table 4.10 (a) Correlation Matrix of Pre Monsoon 2016

Correlations						
	TDS	PH	Hardness	Calcium	Magnesium	Chloride
TDS	1	.084	-.049	.825**	.738**	.664**
PH	.084	1	-.491*	.208	.060	.042
Hardness	-.049	-.491*	1	-.042	-.045	-.228
Calcium	.825**	.208	-.042	1	.802**	.647**
Magnesium	.738**	.060	-.045	.802**	1	.622**
Chloride	.664**	.042	-.228	.647**	.622**	1
Sulphate	.315	-.258	.484*	.458*	.363	.207
Nitrate	.820**	.300	-.274	.704**	.587**	.490*
Fluoride	.383	.264	.143	.348	.117	.215
Alkalinity	.444*	.094	-.309	.353	.474*	.636**

Table 4.10 (b) Correlation Matrix of Pre Monsoon 2016

Correlations				
	Sulphate	Nitrate	Fluoride	Alkalinity
TDS	.315	.820**	.383	.444*
PH	-.258	.300	.264	.094
Hardness	.484*	-.274	.143	-.309
Calcium	.458*	.704**	.348	.353
Magnesium	.363	.587**	.117	.474*
Chloride	.207	.490*	.215	.636**
Sulphate	1	.017	.166	.005
Nitrate	.017	1	.379	.328
Fluoride	.166	.379	1	.284
Alkalinity	.005	.328	.284	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

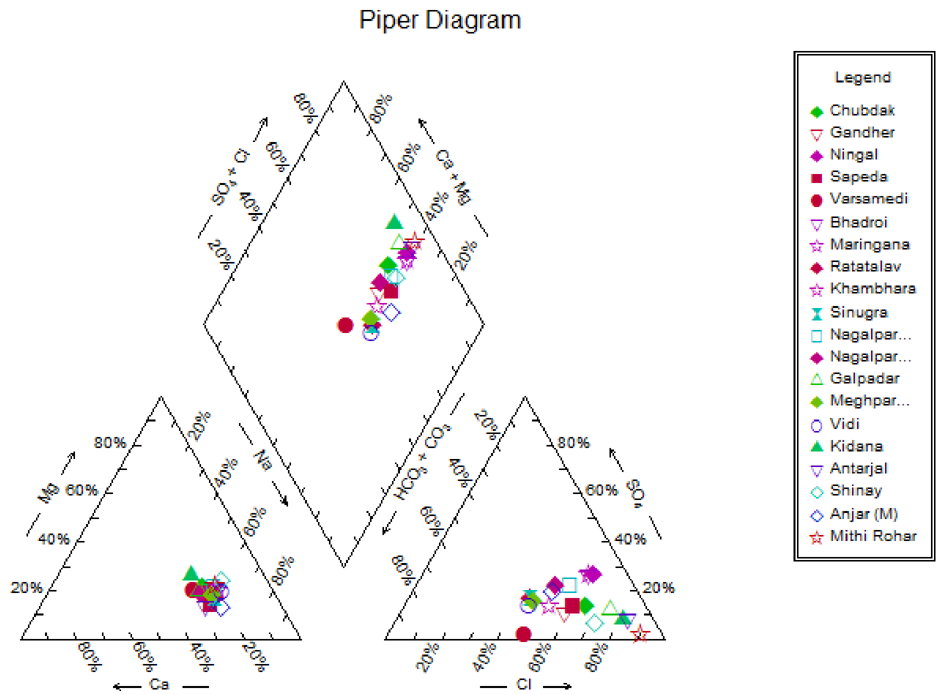

Fig. 4.79 Piper Diagram of Study Area Pre Monsoon 2016

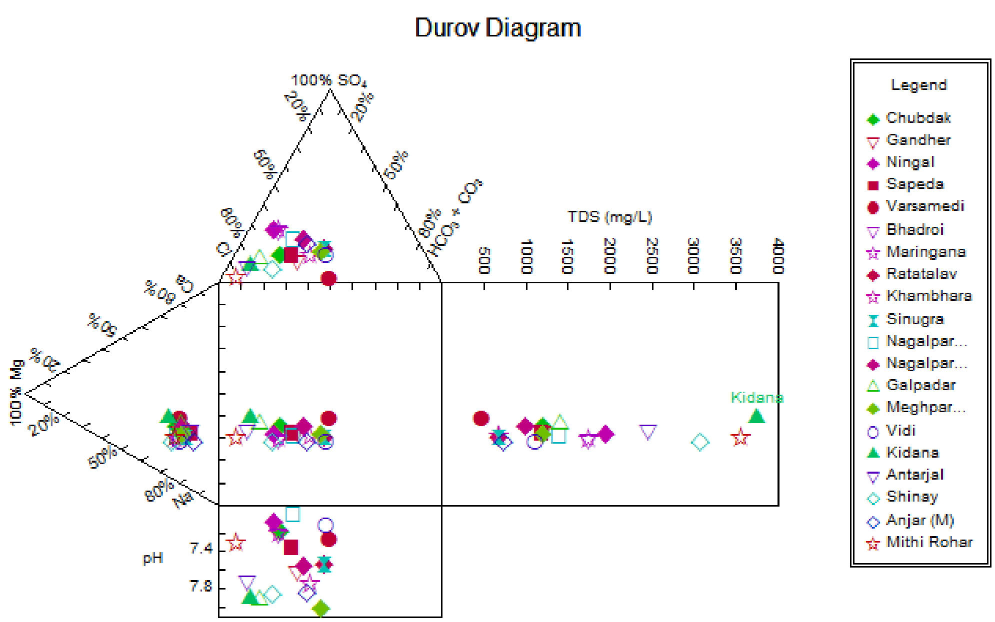

Fig. 4.80 Durov Diagram of Study Area Pre Monsoon 2016

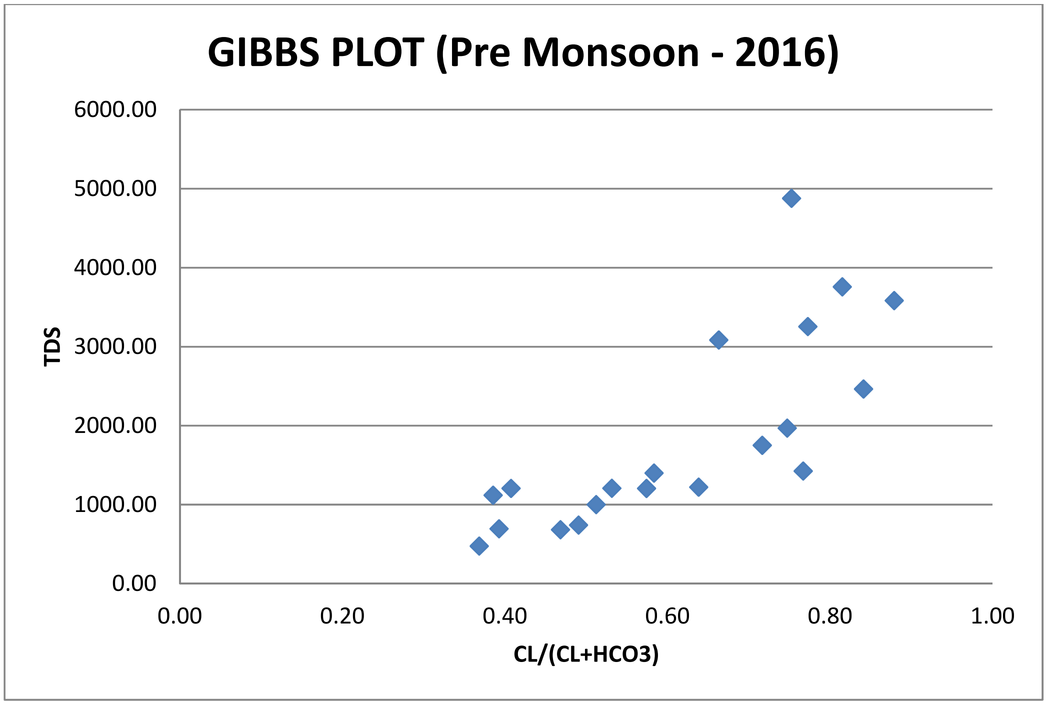

Fig. 4.81 Gibbs Plot of Study Area Pre Monsoon 2016

4.8 COMPARISION OF VARIOUS GROUNDWATER QUALITY PARAMETERS FOR THE PRE MONSOON PERIOD OF 2009, 2015 & 2016

pH: pH was found in the range of 6. to 8.34 in 2009 while it was in the range of 7.2 to 8.3 and 7.0 to 8.1 in 2015 and 2016 respectively. It was mostly found to more alkaline towards the central part of the study area in Anjar taluka during the 2009 while it was more towards the Vidi, shinay and Meghpar Borichi, khumbardi and Gandhidham during the 2015 and 2016.

Nitrate: Nitrate was found in the range of 0.7 mg/l to 153 mg/l during the year 2009 and 0.88 mg/l to 120 mg/l and 2.22 mg/l to 162 mg/l during the year 2015 and 2016 respectively. Gandhidham is the only taluka having the concentration of the Nitrate level higher than the permissible limits consistantly during the year 2009 asa well as 2015 and 2016, while it was found to be within the permissible limits in rest of the study area.

Fluoride: Fluoride level was found in the range of 0.08 mg/l to 2.75 mg/l in 2009 while it was within the range of 0.3 mg/l to 1.5 mg/l and 0.28 mg/l to 1.38 mg/l during the 2015 and 2016 respectively. The high concentration of fluoride was only found during the year 2009 at many places in Anjar taluka like Anjar town, Sinugra, Meghpar Borichi, varsamedhi as well as many villages in Gandhidham taluka like Antarjal, mithi rohar, Gandhidham (M) and Kidana, while it was within the permissible limits in rest of the area. At many places like in northern parts of

Anjar (M) and some part of Ningal village were found to have fluoride level less than the desired limit of 0.6 ppm in 2009. Most part of Anjar taluka was found to have fluoride level less than 0.6 ppm in 2015 while many villages in Anjar taluka like Anjar (M), Vidi, Sinugra, Khambhara, Meghpar Borichi, Malingna, Varsamedhi as well as Kidana village in Gandhidham has been reported to have fluoride levels below permissible limits of 0.6 ppm.

TDS: TDS was found in the range of 600 ppm to 6348 ppm in 2009 and 280 to 4280 ppm and 476 ppm to 4879 ppm in 2015 and 2016 respectively. TDS is mostly found to have levels higher than the permissible in the coastal villages of Gandhidham taluka in all the years. During the year 2009 Villages of Anjar taluka mostly Bhadroi, Malingna, Ningal, few places in Anjar (M) and villages like Meghpar Borichi and Meghpar khumbadi were found to have TDS level higher than the permissible limits. However the same villages showed TDS level within the permissible limits during the year 2015 and 2016.

Hardness: Hardness level ranges from 87 mg/l to 846 mg/l during the year 2009, while it ranges from 150 to 952 mg/l to 184 to 496 mg/l during the year 2015 and 2016.while the hardness level was found on the higher side of the permissible limits at few places in Anjar town during the pre-earthuake periods, 2009 and 2015 it found to have hardness level within the permissible limits during the pre monsoon period of 2016.

Calcium: calcium level ranges from 22 mg/l to 229 mg/l in the year 2009, while it ranges from 32 mg/l to 240 mg/l and 43 mg/l to 212 mg/l in the year 2015 and 2016 respectively. Calcium level were within the range of permissible limits in most of the part of the study area during all the three time periods i.e. 2009, 2015 and 2015 except few coastal areas of Gandhidham taluka.

Magnisium: Magnisium in 2009 ranges from 11 mg/l to 142 mg/l, while it ranges from 19 mg/l to 182 mg/l and 18 mg/l to 128 mg/l in 2015 and 2016 respectively. Changes in the concentration level above the permissible limits can be observed in Kidana, Gandhidham (M), Mithi Rohar and Galpadar of Gandhidham taluka during all the study years while it was found to within the permissible limits in rest of the places of Anjar and Bhuj talukas.

Chloride: Chloride in 2009 ranges from 136 mg/l to 2550 mg/l, while it ranges from 52 mg/l to 1242 mg/l and 128 mg/l to 1125 mg/l in 2015 and 2016 respectively. Changes in the concentration level above the permissible limits can be observed in Kidana, Gandhidham (M), Mithi Rohar and Galpadar of Gandhidham taluka during all the study years while it was found to within the permissible limits in rest of the places of Anjar and Bhuj talukas except Meghpar Borichi, Meghpar khumbardi and versamedhi in 2009.

Sulphate: sulphate levels in 2009 ranges from 20 mg/l to 370 ppm, while it ranges from 4 mg/l to 244 ppm and 6 mg/l to 398 ppm during the year 2015 and 2016.

Sulphate level were found within the permissible limits during all the 3 study periods within entire study area.

Alkalinity: Alkalinity during the year 2009 ranges from 140 mg/l to 457 mg/l, while it ranges from 152 mg/l to 502 mg/l and 180 mg/l to 455 mg/l during the year 2015 and 2016. Alkalinity was mostly found to be above the permissible limits in Gandhidham taluka and at few places in Anjar taluka like Meghpar Borichi, Meghpar Khumbardi, Varsamedhi and Anjar (M) during the year 2009 while it was found to be within the permissible limits in entire study area during the year 2015 and 2016.

4.9 COMPARISION OF VARIOUS GROUNDWATER QUALITY PARAMETERS FOR THE POST MONSOON PERIOD OF 2009 & 2015

pH: pH was found in the range of 6.9 to 8.3 in 2009 while it was in the range of 7.2 to 8.48 in 2015. It was mostly found to more alkaline towards Gandhidham taluka in 2009 while it was more alkaline towards Bhuj taluka during 2015.

Nitrate: Nitrate was found in the range of 0.7 mg/l to 89 mg/l during the year 2009 and 22 mg/l to 254 mg/l during the year 2015. Gandhidham is the only taluka having the concentration of the Nitrate level higher than the permissible limits during the year 2015, while it was found to be within the permissible limits in entire study area during 2009 in post monsoon season.

Fluoride: Fluoride level was found in the range of 0.09 mg/l to 2.3 mg/l in 2009 while it was within the range of 0.16 mg/l to 1.4 mg/l during the 2015. The high concentration of fluoride was found during the year 2009 at few places in Anjar taluka like ratatalav as well as many villages in Gandhidham taluka like Antarjal, Gandhidham (M) and Kidana, while it was within the permissible limits in rest of the area. At many places like in northern parts of Anjar (M) and some part of Ningal village were found to have fluoride level less than the desired limit of 0.6 ppm in 2009. Most part of Anjar taluka was found to have fluoride level less than 0.6 ppm in 2015 even during post monsoon season.

TDS: TDS was found in the range of 450 ppm to 6200 ppm in 2009 and 191 ppm to 4656 ppm in 2015. TDS is mostly found to have levels higher than the permissible in the coastal villages of Gandhidham taluka in all the years even during the post monsoon season. During the year 2009 Villages of Anjar taluka mostly few places in Anjar (M) and villages like ratatalav, Meghpar Borichi and Meghpar khumbadi were found to have TDS level higher than the permissible limits. However the village ratatalav showed TDS level within the permissible limits during the year 2015 while villages of Bhuj under study area like Gandher and Chubdak showed TDS levels higher than the permissible limits in post monsoon season in 2015.

Hardness: Hardness level ranges from 87 mg/l to 1892 mg/l during the year 2009, while it ranges from 88 mg/l to 1380 mg/l during the year 2015. while the hardness level was found on the higher side then the permissible limits at few places in Anjar town, Ratatalav, Sapeda, Ningal and Bhadroi in 2009, it found to have hardness level above the the permissible limits in Gandher and Chubdak villages of Bhuj taluka during the post monsoon season of 2015.

Calcium: calcium level ranges from 25 mg/l to 188 mg/l in the year 2009, while it ranges from 19 mg/l to 255 mg/l in the year 2015. Calcium level were within the range of permissible limits in entire study area during 2009, while it showed increase in the concentration levels in post monsoon period of 2015 in Kidana which falls in the coastal areas of Gandhidham taluka as well and Gandher village of Bhuj taluka.

Magnisium: Magnisium in 2009 ranges from 11 mg/l to 252 mg/l, while it ranges from 10 mg/l to 181 mg/l in post mon soon 2015. Changes in the concentration level above the permissible limits can be observed in Ratatalav and Sapeda villages of Anjar in 2009 while its concentration level was above the permissible limits in Kidana, Gandhidham (M), Mithi Rohar of Gandhidham taluka as well as Gandher and Chubdak villages of Bhuj taluka in post monsoon 2015.

Chloride: Chloride in 2009 ranges from 156 mg/l to 2656 mg/l, while it ranges from 48 mg/l to 1680 mg/l in post monsoon of 2015.Changes in the concentration level above the permissible limits can be observed in almost all the villages of Gandhidham taluka as well as ratataav and Sapeda villages of Anjar taluka in 2009 while its concentration level was above the permissible limits in Kidana, Gandhidham (M), Mithi Rohar and Galpadar of Gandhidham taluka and Gandher and Chubdak villages of Bhuj taluka in post mon soon 2015.

Sulphate: Sulphate levels in 2009 ranges from 21 mg/l to 491 mg/l, while it ranges from 6 mg/l to 500 mg/l during the post monsoon season of 2015. Sulphate level were found within the permissible limits in almost entire study area during both the years except a small patch in Ratatalav of Anjar taluka in 2009 and Chubdak village of Bhuj taluka in post monsoon 2015.

Alkalinity: Alkalinity during the year 2009 ranges from 127 mg/l to 488 mg/l, while it ranges from 80 mg/l to 460 mg/l during the year 2015. Alkalinity was mostly found to be within the permissible limits in entire study area during both the study periods i.e. year 2009 and 2015.

4.10 CONCLUSION

The primary objective of this study was to evaluate changes in groundwater water quality obtained at different time and at different seasons within the study area. From this study we can get a clear idea about the future trends and changes that might be necessary in maintaining the existing water quality. The differences in the water quality may also get affected based on the changes in the type of landuse and agricultural practices existing at a particular location over the period of time.

From the study it can be concluded that the quality of groundwater within the study area varies with space and time. However this study helped in understanding the overall trend of groundwater quality existing during the earlier as well as recent time in post monsoon and Pre monsoon seasons.

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