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Quality Characterization of Groundwater using Water Quality Index in Surat city, Gujarat, India

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Abstract

Groundwater is a natural resource for drinking water. Like other natural resources, it should be assessed regularly and people should be made aware of the quality of drinking water. The present study is aimed at assessing the water quality index (WQI) for the groundwater of Surat city. This has been determined by collecting 125 groundwater samples from 39 areas of Surat city and subjecting the samples to a comprehensive physicochemical analysis. For calculating the WQI, the following 13 parameters have been considered: pH, total hardness, calcium, magnesium, chloride, nitrate, sulphate, total dissolved solids, iron, boron, and fluorides, COD and DO. The WQI for these samples ranges from 15.93 to 977.86. The high value of WQI has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, and boron in the groundwater. The results of analyses have been used to suggest models for predicting water quality. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption.

Keywords: Groundwater, surat, water quality index, water quality, fluoride.

Introduction

India is endowed with a rich and vast diversity of natural resources, water being one of them. Water is nature's most wonderful, abundant and useful compound. Of the many essential elements for the existence of human beings, animals and plants, water is rated to be of the greatest importance. Without food, human can survive for a number of days, but water is such an essential that without it one cannot survive. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries[1]. Groundwater is an important source of water supply throughout the world. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties[2-5]. Its development and management plays a vital role in agriculture production, for poverty reduction, environmental sustenance and sustainable economic development. In some areas of the world, people face serious water shortage because groundwater is used faster than it is naturally replenished. Human development and population growth exert many and diverse pressures on the quality and the quantity of water resources and on the access to them. Water quality monitoring and assessment is the foundation of water quality management; thus, there has been an increasing demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables[6,7]. The Physico-chemical study could help in understanding the structure and function of particular water body [8-10].

Monitoring of ground water regime is an effort to obtain information on ground water levels and chemical quality through representative sampling. Due to inadequate supply of surface waters, most of the people in India are depending mainly on groundwater resources for drinking and domestic, industrial, and irrigation uses. Innumerable large towns and many cities in India derive water supply from groundwater for different uses through municipality network and also from large number of private boreholes. About one billion people are directly dependent upon groundwater resources in Asia alone, and In India, most of the population is dependent on groundwater as the only source of drinking water supply. The groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become polluted and created health problems. In recent years, because of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposals, the rate of discharge of the pollutants into the environment is far higher than the rates of their purification[11]. The dependence on groundwater has increased tremendously in recent years in many parts of India. Hence, physico-chemical analysis of water is important to assess the quality of groundwater in any basin and/or urban area that influences the suitability of water for domestic, irrigation, and industrial needs. Because of the importance of groundwater in drinking and in other uses, its environmental aspects such as contamination transport have been significantly studied. Many researchers have focused on hydro chemical characteristics and contamination of groundwater in different basins as well as in urban areas that resulted due to anthropogenic intervention mainly by agricultural activities and industrial and domestic wastewater[12, 13]. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water[14].

As per the latest estimate of Central Pollution Control Board, about 29,000 million litre/day of wastewater generated from class-I cities and class-II towns out of which about 45% (about 13000 MLD) is generated from 35 metro-cities alone. The collection system exists for only about 30% of the wastewater through sewer line and treatment capacity exists for about 7000 million litre/day. Thus there is a large gap between generation, collection and treatment of wastewater. A large part of un-collected, un-treated wastewater finds its way to either nearby surface water body or accumulated in the city itself forming cesspools. In almost all urban centres cesspools exist. These cesspools are good breeding ground for mosquitoes and also source of groundwater pollution. The wastewater accumulated in these cesspools gets percolated in the ground and pollute the groundwater. Also in many cities/towns conventional septic tanks and other low cost sanitation facilities exists. Due to non-existence of proper maintenance, these septic tanks become major source of groundwater pollution. In many urban areas groundwater is only source of drinking. Thus, a large population is at risk of exposed to water borne diseases.

Study Area: The current st***udy area is Surat city (figure-***1), located 306 km south of state capital Gandhinagar, and is situated on the left bank of the Tapti River (Tapi), the centre being around 22 km (14 miles) from its mouth. Surat is one of the cleanest cities of India and is also known by several other names like "THE SILK CITY", "THE DIAMOND CITY", "THE GREEN CITY", etc. This city is endowed with 605 medium and large scale industries and 41,300 small scale industries. Industrial development in Surat city could be attributed to the presence of a large number of diamond processing, textiles and chemical and petrochemical industries.

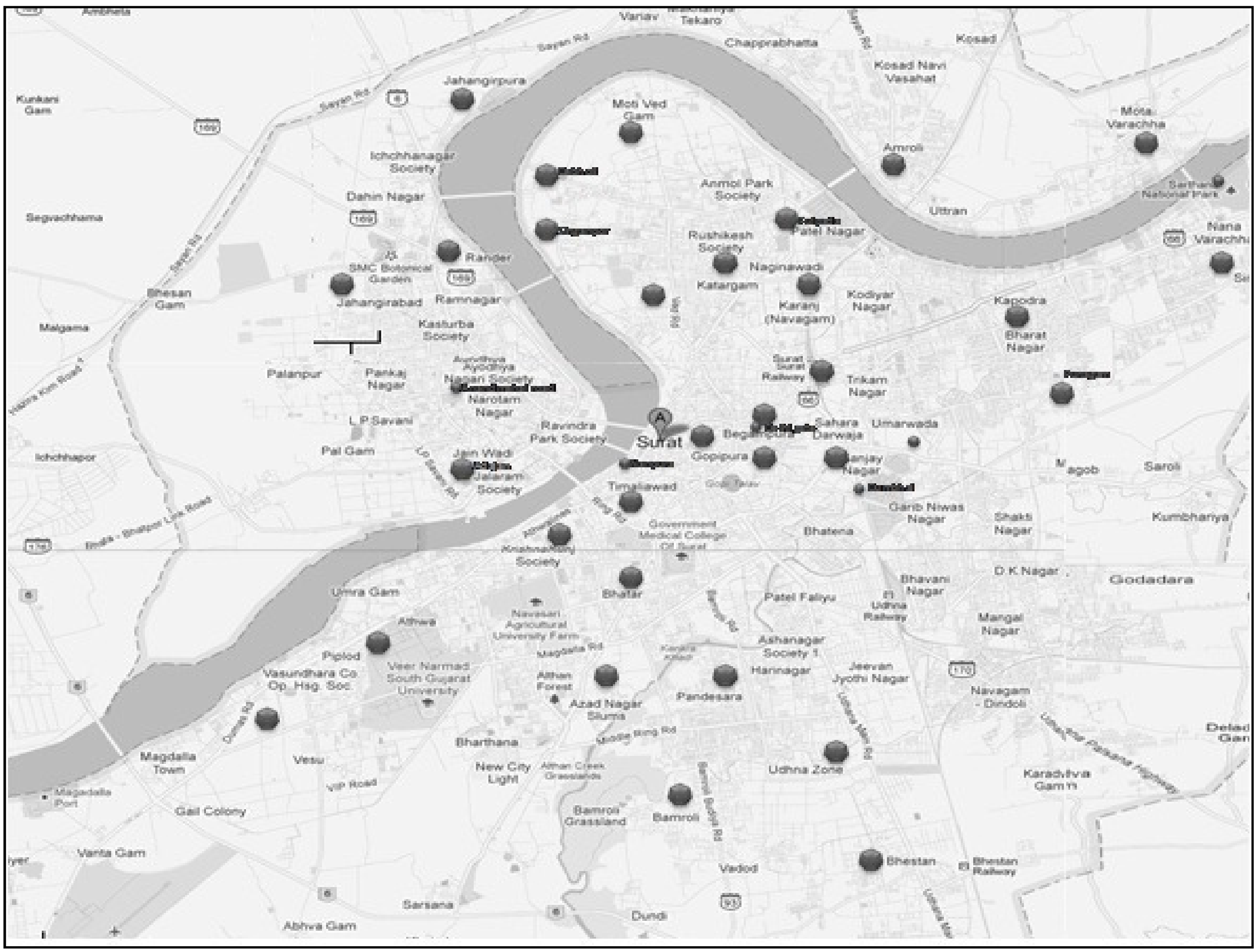

Figure-1
Map of study area (Surat City) [dots indicate sampling points]

Table-1
Parameters studied

Parameters	Instrument used	Method adopted
pH	Digital pH Meter	Recorded by pH meter
Conductivity	Digital Conductivity Meter	Recorded by Conductivity meter
Total solids	Hot plate	Evaporation method (S.K, Maiti)
Total dissolved solids	Digital Meter	Recorded by TDS meter
Chloride	-	Argentometric Titrimetric method
Alkalinity	-	Neutralising with standard HCI (S.K,Maiti)
Acidity	-	Neutralising with standard NaOH (S.K,Maiti)
Total Hardness	-	EDTA titration (S.K,Maiti)
Calcium Hardness	-	EDTA titration (S.K,Maiti)
Magnesium Hardness	-	EDTA titration (S.K,Maiti)
Phosphate	UV-VIS Spectrophotometer	Colorimetric Stannous chloride method (S.K,Maiti)
Sulphate	UV-VIS Spectrophotometer	Colorimetric Turbidimetric method (S.K,Maiti)
Nitrate	UV-VIS Spectrophotometer	Colorimetric PDA method (S.K,Maiti)
Iron	UV-VIS Spectrophotometer	Colorimetric method (S.K,Maiti)
Fluride	UV-VIS Spectrophotometer	Colorimetric SPANDS method (APHA)
Boron	UV-VIS Spectrophotometer	Colorimetric Carmine method (S.K,Maiti)
Salinity	Digital meter	Recorded by Salinity meter
Resistivity	Digital meter	Recorded by Resistant meter

Environmental Profile: Topography/Location: 72.38° to 74.23° East (Longitude) 21.0° to 21.23° North (Latitude). **Population:** 4.99 Million (As per 2001 Census), 4,786,002 (2010)

Climate: Surat has a Tropical monsoon climate, moderated strongly by the Arabian Sea. The summer begins in early March and lasts till June. April and May are the hottest months, the average temperature being 30 °C. Monsoon begins in late June and the city receives about 800 mm of rain by the end of September, with the average temperature being around 28 °C during those months. October and November see the retreat of the monsoon and a return of high temperatures till late November. Winter starts in December and ends in late February, with average temperatures of around 22 C, and little rain.

Material and Methods

Experimental: 125 water samples were collected from bore wells of thirty nine area of Surat City. Samples were collected in polythene bottles and analyzed for various water quality parameters as per standard procedures (table-1). The experimental values were compared with standard values recommended by World Health Organization (WHO) and Indian standards for drinking purposes. The calculation of Water Quality Index (WQI) was done by Weighted Arithmetic Index method. The statistical analyses such as mean, standard deviation (SD), correlation and regression of obtained data were carried out using Microsoft offices excel 2007.

Water Quality Index: Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programmes. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics[15]. Water quality index provide information on a rating scale from zero to hundred. Higher value of WQI indicates better quality of water and lower value shows poor water quality.

For computing WQI three steps are followed. In the first step, each of the all parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (table-2). The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium which is given the minimum weight of 1 as magnesium by itself may not be harmful. In the second step, the relative weight (Wi) is computed from t he following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (1)$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.
Calculated relative weight (Wi) values of each parameter are also given in table-2

Table-2
Relative weight (Wi) values of each parameter

Parameters	Indian Standard	Weight (wi)	Relative weight (Wi)
pH	6.5-8.5	4	0.1053
Sulphate	200-400	4	0.1053
Flouride	1-1.5	4	0.1053
Nitrate	1- 45	5	0.1316
Iron	0.3-1.0	4	0.1053
Boron	1-5	2	0.0526
Total H	300-600	2	0.0526
Ca+2H	75-200	2	0.0526
Mg+2H	30-100	2	0.0526
Chloride	250-1000	3	0.0789
TDS	500-2000	4	0.1053
DO	6	2	0.0526
TOTAL		**38**	**1.0000**

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result multiplied by 100

$$\mathrm{qi} = \left(\frac{\mathrm{Ci}}{\mathrm{Si}}\right) * 100 \qquad \textbf{(2)}$$

Where,
qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS[16].

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$\mathrm{SIi} = \mathrm{Wi} \times \mathrm{qi} \qquad \textbf{(3)}$$

$$\mathrm{WQI} = \_\mathrm{SIi} \qquad \textbf{(4)}$$

Where, SIi is the subindex of ith parameter, qi is the rating based on concentration of i^{th} parameter, n is the number of parameters.

The computed WQI values are classified into five types, “excellent water” to “water, unsuitable for drinking”.

Results and Discussion

The pH of the groundwater samples are neutral or close to it as they all range from 7 to 7.5 which are within the permissible limits 6.5- 8.5 given by Indian Standards, also complies with standard 0f 7-8 given by WHO[17]. One of the main objectives in controlling pH is to produce water that minimizes corrosion or incrustation. These processes, which can cause considerable damage to the water supply systems, result from complex interactions between pH and other parameters, such as dissolved solids, dissolved gasses, hardness, alkalinity, and temperature. There is also a progressive decrease in the efficiency of chlorine disinfection processes with increasing pH levels.

The **Conductivity** of the ground water in Surat ranges from 1.40 - 744.7μs. Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. Water with high mineral content tends to have higher conductivity, which is a general indication of high dissolved solid concentration of the water[18]. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems.

Sulphate concentration in collected groundwater samples is ranged from 5-7 mg/l as in the permissible limit of 200mg/l as per Indian standards and 250mg/L as per WHO Standards. Maximum concentration found in ground water sample collected from Nanpura which is 6.4mg/L. Minimum Concentration is 5.03mg/L found in ground water sample of Bhagal Chowk. Sulfates are discharged into water from textile mills[19].

Phosphate are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate. Phosphate itself does not have notable adverse health effects. However, phosphate levels greater than 1.0mg/L may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed before distribution. Phosphate level in ground water samples collected are in the range of 0.04-0.13mg/L. Phosphate is present only in 8 Ground water samples out of 125 Samples which are from Hirabag (Anand nagar Party plot), Kapodara (P.P.Savani School, Sagar Soc., Spinnig mill Shriji Soc., Swaminarayan temple, Mamta park, Sadhana School, Inter jwell Kamal park Soc. mg/L). Phosphorus is an essential nutrient for human and animal life. It is fundamental to growth, maintenance, and repair of all body tissues, and is necessary, along with calcium and magnesium, for proper growth and formation of bones in infants and children. Sufficient phosphorus intake is important throughout life to ensure the proper balance of essential minerals in order to promote remineralization of bones and teeth to keep them in a healthy state.

The levels of **Flouride** in the groundwater samples ranged from 0.35-7.62 mg/L which exceeds the permissible limit of 1 mg/L as per Indian standards as well as WHO Standards. Flouride is absent in 117 ground water samples out of 125 samples, thus it is present in only 8 ground water samples collected from Ashwanikumar, Fulpada, Kapodara, Katargam, Majuragate, Nanavarachha, Puna road, Sarthana, Udhana. The variation of fluoride is dependent on a variety of factors such as amount of soluble and insoluble fluoride in source rocks, the duration of contact of water with rocks and soil temperature, rainfall, oxidation- reduction process[20]. Easy accessibility of circulating water to the weathered products during irrigation dissolves and leaches the minerals, including fluorine, contributing flouride to the surface water and groundwater. Data available from the ministry of water resources, concerning ground water quality scenario, reveals that 18 of Gujarat's 26 districts have fluoride content above the permissible limit. Gujarat ranks 5th among the 19 states in high fluoride content in ground water. The districts that have such excessive fluoride content include Ahmedabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dahod, Junagadh, Kutch, Mehsana, Narmada, Panchmahals, Patan, Rajkot, Sabarkantha, Surat, Surendranagar and Vadodara[7]. The study on Fluoride Contamination in Groundwater of Patan District, Gujarat, India reveals that, the fluoride concentration was beyond permissible limit at all the villages, when correlated with the analysis reports, the health complaints from the survey indicated that the most common complaints viz., body pain, knee pain and back pain were prevalent among people who consumed water containing excess fluoride in Patan district[20]. The presence of small quantities of fluoride in drinking water may prevent tooth decay. Fluoride is poisonous at high levels, and while dental fluorosis (mottled teeth) is easily recognized, skeletal damage may not be clinically obvious until advanced stages have occurred. Often, ground waters will contain more than 1.0 ppm, and in these cases, the water should probably be deflouridated for drinking.

In the ground water of Surat City, **Nitrate** is varies from 0.01-0.55 mg/L which complies with the permissible limit of 45 mg/L as per Indian standards and 50 mg/L as per WHO Standards. Nitrates themselves are relatively nontoxic. Nitrogen essential component of amino acids, and therefore all proteins and nucleic acids, and therefore needed for all cell division and reproduction. Enzymes are specialized proteins, and serve to lower energy requirements to perform many tasks inside plants. Nitrogen is contained in all enzymes essential for all plant functions. However, when swallowed, they are converted to nitrites that can react with hemoglobin in the blood, oxidizing its divalent iron to the trivalent form and creating methanoglobin. Thus Nitrate compounds can prevent hemoglobin from binding with oxygen at levels above the permissible limit. Thus the drinking water that is contaminated with nitrates can prove fatal especially to infants as it restricts the amount of oxygen that reaches the brain causing the 'blue baby' syndrome. Sources of nitrate contamination in Surat may include septic tanks and municipal sewage treatment systems. The ability of nitrate to enter well water depends on the type of soil and bedrock present, and on the depth and construction of the well[21].

Iron concentration in the groundwater samples are varies from 0 to 7.17 mg/L which exceeds the permissible limit of 0.3 mg/L as per Indian standards and 0.1 mg/L as per WHO Standards. Three areas which show very high concentration of iron in water are Ashwanikumar, Jahangirpura, Udhna having iron concentration 59.06mg/L, 24.37mg/L, 61.7mg/L respectively. The ground water samples exhibited high Iron contamination which is an indication of the presence ferrous salts that precipitate as insoluble ferric hydroxide and settles out as rusty silt. High concentration of iron is may contributed by industrial estate located at the sampling site, Iron is an essential element in human nutrition**.** Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and cause undesirable tastes. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coat in piping[22].

The values of **Boron** in the groundwater samples are range from 0.44-16.13mg/L which exceeds the permissible limit of 1-5 mg/L as per Indian standards and 0.6-1 mg/L as per WHO Standards. Maximum concentration is found in ground water sample collected from Nanavarachha, which is 16.13mg/L this may due to domestic waste water likage because this is very usual problem over there. Minimum concentration is 0.44mg/L found in ground water sample of L.H.RD. Because of the lack of human data and the limited amount of animal data, the EPA has classified boron as "not classifiable as to human carcinogenicity" in 1994.

Total Hardness varies from 16-2630 mg/L as CaCO3. The hardness values for the study area are found to be high for almost all locations and determined to fall above the desirable limit of WHO specification and Indian standards. According to Sawyer and McCarty's classification for hardness, water samples (10.26%) collected from Moth Bhagal, Dummas RD, Dumbhal, and Athwalines, falls under soft class. 33.33% samples fall under the moderately hard class and 56.42% samples fall under the hard class and very hard class (table-7)[23]. Maximum concentration is found in water sample collected from Ring RD, which is 2630mg/L. Minimum concentration is 16mg/L found in water sample of Parle Point (SCET College). Hardness is caused by polyvalent metallic ions dissolved in water, which in natural water are principally magnesium and calcium. So the adverse effects of such hard water are i. Soap consumption by hard water cause economic loss to water, ii. $MgSO_4$ has laxative effects in person unaccustomed to it, iii. precipitation by hard water adhere to the surface of tubs and sinks and may stain clothing, dishes and other items[24].

Table-3
Classification of water based on hardness by Sawyer and McCarthy

Hardness as CaCO3 (mg/L)	Water quality	Percent
0-75	soft	10.26
75-150	moderately hard	33.33
150-300	hard	28.21
above 300	very hard	28.21

Alkalinity of the samples are in the range of 8-176 mg/L. Maximum concentration is found in ground water sample collected from Udhna is 176 mg/L. Minimum concentration is 8mg/L found in water sample of Ghoddod RD- Turning. Alkalinity is absent in ground water sample of Althan. The alkalinity levels of all the water samples are high thus, resisting acidification of the groundwater samples.

Acidity measured in all water samples do not exceed more than 12mg/L.

Chloride present in ground water samples are in the range of 15.36-1511 mg/L, which exceeds the permissible limit of 250 mg/L as per Indian standards as well as WHO Standards and this obviously affects the taste of the water. Maximum concentration is found in ground water sample collected from Ring RD which is 1511mg/L. Minimum concentration is 15.36mg/L found in ground water sample of Navapura-Bhagal. Another research carried out in Surat City shows the chloride content in the groundwater of surat city is in the range of 432-2360, 418-2440, 371-2344 mg/L for the year 2007,2008,and 2009 respectively[25]. Similarly study of Chemical characteristics of groundwater in and around Surat City, depicts that the chloride content is beyond the permissible limit[24]. This occurs may be due to saline water intrusion. Chlorine enters the body breathed in with contaminated air or when consumed with contaminated food or water. It does not remain in the body, due to its reactivity. Chloride is present in natural waters due to the dissolution of salt deposits, salting of roads, and effluents from chemical industries. Chloride is the most abundant anion in the human body. No evidence has been found suggesting that ingestion of chloride is harmful to humans. Chloride is a widely distributed element in all types of rocks in one or the other form. Its affinity towards sodium is high. Therefore, its concentration is high in ground waters, where the temperature is high and rainfall is less. Soil porosity and permeability also has a key role in building up the chlorides concentration[26].

Total dissolved solids level in ground water is 1-818.8 mg/L which exceeds the permissible limit of 500 mg/L as per Indian standards and 1000 mg/L as per WHO Standards. Maximum concentration is found in ground water sample collected from Ring road, which is 818.8mg/L. Minimum concentration is 1.142 mg/L found in ground water sample of Udhana (Arihant Complex). The term total dissolved solids refer mainly to the inorganic substances that are dissolved in water. The effects of TDS on drinking water quality depend on the levels of its individual components; excessive hardness, taste, mineral depositions and corrosion are common properties of highly mineralized water.

Dissolved Oxygen level in ground water is 2.06-3.7mg/L, Maximum concentration is found in ground water sample collected from Ved Road is 3.7mg/L. Minimum concentration is 2.06mg/L found in ground water sample of Hirabag.

The chemical analyses of the groundwater and the percent compliance with the Indian Standards and WHO are summarized in table-4 and the statistics of water quality parameters of groundwater samples are shown in table-5.

The following regression models have been obtained from the results of analysis of water samples. This shows that the following parameters show linear relationships with each other.

$Ca^{+2} = 0.240TH + 1.311$ ($R^2 = 0.514$)
$Mg^{+2} = 0.759TH - 1.311$ ($R^2 = 0.913$)
$TH = 0.803 Cl^{-} + 126.5$ ($R^2 = 0.300$)
$Cl^{-} = 1.162 Ca^{+2} + 246.6$ ($R^2 = 0.327$)
$TS = 0.941TSS + 175.2$ ($R^2 = 0.946$)

The degree of a linear association between any two of the water quality parameters, as measured by the simple correlation coefficient (r), is presented in table-7. Correlation analysis is useful for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. Hence, it is a helpful tool for the promotion of research. Calcium and chloride are highly interrelated among themselves. This interrelationship indicates that the hardness of the water is permanent in nature.

In this study, the computed WQI values ranges from 22.55 to 247.17 and therefore, can be categorized into five types “excellent water” to“ water unsuitable for drinking”. Table-5 shows the percentage of water samples that falls under different quality. The high value of WQI at these stations has been found to be mainly from the higher values of iron, sulphate, total dissolved solids, hardness, fluorides, bicarbonate and boron in the groundwater. In 2010 study of chemical characteristics of groundwater in and around Surat City had revealed that the ground water in and around Surat city possesses high concentration of total alkalinity, hardness and chloride. All these factors may pose health hazard on long term and can degrade the quality of drinking water, therefore require to be treated before using for drinking purpose[24]. Another research carried out in 2010 which concluded that groundwater quality of study area Surat City lies in the range of poor to tolerable good but the temporally analysis indicates that such quality fluctuates in its own and even in some of the area it has been found within the range of very poor water[19]. Similarly in 2009 research carried out on water quality index (WQI) of ground water of Surat City, India, they have exposed that out of ten only four sampling spots are in fare condition and not a single spot is having good or excellent WQI and it is not consumable and should not be consumed[27]. Study of ground water quality of Gandhinagar Taluka, Gujarat, India shows that the water quality of bore wells of Gandhinagar taluka is poor for drinking purpose as per Water Quality Index. So, this water can be used for drinking purpose after purification treatment[27]. Besides that physico chemical characterization of ground water of Anand district, Gujarat, India was studied, which concluded that drinking water quality analysis showed dominance of poor and very poor water with good water in some locations[28]. Thus, the presents study and literature reviews depicts that the overall ground water quality is poor and require some pre treatments before use.

Table-4
Comparison of groundwater quality with Indian standards for drinking water and WHO standards

Parameters	Indian Standard	Percentage Compliance	WHO Standard	Percentage Compliance
pH	6.5-8.5	100	7.0-8.0	100
Sulphate(mg/L)	200	100	250	100
Flouride (mg/L)	1	95.2	1	95.2
Nitrate (mg/L)	45	100	50	100
Iron (mg/L)	0.3	13.6	0.1	13.6
Boron (mg/L)	1-5	36.8	0.06-1	36.8
Totah H (mg/L)	300	27.2	100	21.6
Ca+2H (mg/L)	75	64	75	64
Mg+2H (mg/L)	30	4.8	30	4.8
Chloride(mg/L)	250	72	250	72
TDS (mg/L)	500	64.8	1000	86.4
DO (mg/L)	6	100	6	100

Table-5
Normal statistics of water quality parameters of groundwater samples

Parameters	MIN	MAX	AM	MEDIAN	SD
pH	7	7.23	7.07	7	0.09
Sulphate(mg/L)	5.03	6.40	5.53	5.49	0.36
Phosphate(mg/L)	0.04	0.13	0.08	0.08	0.04
Flouride (mg/L)	0.35	7.62	4.02	5.31	2.72
Nitrate (mg/L)	0.01	0.55	0.23	0.20	0.15
Iron (mg/L)	2.5	7.17	4.71	4.56	0.98
Boron (mg/L)	0.44	16.13	7.52	6.74	5.03
Total Hardness (mg/L)	16	2360	431.69	174.27	613.89
Ca+2 Hardness(mg/L)	4	1271	108.13	56.8	208.90
Mg+2 Hardness (mg/L)	16	2204	326.41	118.8	488.04
Alkalinity (mg/L)	8	176	82.71	79.75	39.91
Acidity (mg/L)	4	12	7.21	7.2	2.26
Chloride (mg/L)	53.96	1511	365.89	151.47	415.71
TS (mg/L)	120	7000	1212	706.67	1615
TDS ppm	1.142	818.8	307.51	299.65	199.55
TSS ppm	20.35	6807	1131	578.57	1682
Conductivity	1.40	744.7	378.20	385.35	224.46
NaCl ppm	1.04	703	323.51	300.02	176.16
Res Ohm	1.13	940	485.75	460.19	249.97
DO (mg/L)	2.06	3.70	2.94	3.01	0.37

Min-Minimum, Max-Maximum, AM-Arithmetic mean, SD-Standard deviation

Table-6
Water quality classification based on WQI value

WQI Value	Water Quality	Percent of Water Samples
<50	Excellent	10.3
50-100	good water	56.4
100-200	poor water	30.8
200-300	very poor water	2.6
>300	Water unsuitablefor drinking	0

Table-7
Correlation coefficient matrix of water quality parameters

	pH	Sulphate	Phosphate	Flouride	Nitrate	Iron	Boron	Total Hardness	Ca+2 H	Mg+2 H	Alkalinity	Acidity	Chloride	TS	TDS	TSS	Conductivity	NaCl	Resistivity	DO
pH	1																			
Sulphate	0.15	1																		
Phosphate	0.42	0.22	1																	
Flouride	0.23	0.06	0.45	1																
Nitrate	-0.02	0.14	0.05	0.33	1															
Iron	-0.01	0.19	0.11	-0.07	-0.08	1														
Boron	-0.05	-0.09	0.11	0.09	-0.02	0.06	1													
Total Hardness	0.11	0.35	-0.17	-0.13	-0.08	0.13	0.22	1												
Ca+2 H	0.24	0.40	-0.09	-0.06	0.21	-0.01	-0.002	**0.72**	1											
Mg+2 H	0.03	0.27	-0.18	-0.13	-0.19	0.18	0.28	**0.96**	0.48	1										
Alkalinity	-0.07	0.41	0.08	-0.01	-0.05	0.41	0.23	0.17	-0.04	0.23	1									
Acidity	0.09	-0.003	0.07	-0.05	0.09	0.33	0.08	-0.004	0.11	-0.05	0.13	1								
Chloride	-0.20	**0.68**	-0.26	-0.21	0.16	0.16	0.01	**0.55**	**0.57**	0.45	0.47	0.03	1							
TS	-0.22	0.32	-0.13	-0.16	-0.07	-0.02	0.27	0.27	0.10	0.30	0.38	-0.27	0.47	1						
TDS	0.28	-0.19	0.30	0.33	0.17	-0.09	0.03	-0.54	-0.37	-0.52	0.01	0.001	-0.52	-0.29	1					
TSS	-0.14	0.33	-0.14	-0.17	-0.11	0.01	0.27	0.36	0.12	0.40	0.41	-0.27	0.47	**0.97**	-0.33	1				
Conductivity	0.02	-0.39	0.23	0.11	-0.12	-0.10	-0.18	-0.61	-0.44	-0.58	-0.33	-0.27	-0.58	-0.22	0.32	-0.26	1			
NaCl	0.32	-0.12	0.13	0.22	0.29	-0.10	-0.06	-0.18	0.12	-0.28	0.01	-0.11	-0.24	-0.37	0.42	-0.33	0.03	1		
Resistivity	0.03	-0.27	0.18	0.07	-0.14	0.12	-0.09	-0.36	-0.31	-0.33	-0.23	-0.19	-0.37	-0.41	0.25	-0.40	0.32	0.12	1	
DO	0.17	-0.21	0.02	0.28	0.03	-0.30	-0.21	-0.13	0.02	-0.17	-0.24	0.001	-0.20	-0.17	0.25	-0.20	0.03	0.22	0.003	1

Conclusion

The WQI for 125 Ground water samples ranges from 22.55 to 247.17 almost 33.3 percent of the samples exceeded 100, the upper limit for drinking water. The high value of WQI at these stations has been found to be mainly from the higher values of iron, total dissolved solids, hardness, chloride and manganese in the groundwater. About 30.8% of water samples are poor in quality and 2.6 percent of water samples are of very poor quality and should not use directly for drinking purpose. As per the classification based on water quality index 66.7% of ground water samples are of good quality and suitable for drinking purpose in which 56.4% ground water samples shows good quality of water and 10.3% sample shows excellent quality of ground water. In this part, the groundwater quality may improve due to inflow of freshwater of good quality during rainy season. Calcium and chloride are significantly interrelated and indicates that the hardness of the water is permanent in nature. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

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