EVALUATION OF UNDERGROUND WATER QUALITY OF SURAT CITY (INDIA)

Hemangi Desai*, Tasneem Anandwala1 and H. Desai 2

1. TIFAC-CORE in Environmental Engineering, Surat, (INDIA)
2. Sarvajanik College of Engineering and Technology, Surat, (INDIA)

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ABSTRACT

Ninety-five percent of all fresh water on earth is ground water. Ground water is found in natural rock formations. These formations, called aquifers, are a vital natural resource with many uses. High quality of water is essential to the welfare of humans, aquatic ecosystems and industries. The study of water quality draws information from a variety of disciplines including chemistry, biology, mathematics, physics, engineering and resource management. Because of industrial development, leaking underground storage and sewage tanks and municipal landfills, many local areas have experienced significant ground water contamination, which is cause of special concern. This problem needs attention and protective actions to prevent despoliation of the aquifers, because once contaminated it is difficult to decontaminate an aquifer. Efforts have to be made to use physical and chemical principles to explain the factors controlling the quality of ground waters. The present study describes the quality assessment of underground water in different zones of Surat City of Gujarat State, (India), i.e., central, east, west, north, south, south-west and south-east zones of Surat city. The quality of water was examined by analyzing certain parameters, such as: total dissolved solids, turbidity, pH, conductivity, total hardness, calcium hardness, magnesium hardness, total alkalinity and chemical oxygen demand of collected bore samples. Near residential area, total suspended solid, magnesium hardness, total alkalinity and chemical oxygen demand are found to be higher than the permissible limit. Near bank of the river, total suspended solid, total hardness, total alkalinity, total dissolved solid, magnesium hardness, calcium hardness, chloride, total alkalinity and chemical oxygen demand are found to be higher than the permissible limit. Near industrial area, total suspended solid, total alkalinity, total dissolved solid, chloride, calcium hardness, magnesium hardness, total hardness and chemical oxygen demand are found to be higher than the permissible limit. As Dumas village is situated on the coast of Arabian sea, the value of magnesium hardness, total hardness and total alkalinity are higher than the permissible limit.

Key Words: Hardness, COD, Despoliation, Permissible limit.

* Author for correspondence
INTRODUCTION

A well that yields plenty of water doesn’t mean you can go ahead and just take a drink. Because water is such an excellent solvent, it can contain lots of dissolved chemicals. And since groundwater moves through rocks and subsurface soil, it has a lot of opportunity to dissolve substances as it moves. For that reason, groundwater will often have more dissolved substances than surface water will. Also, groundwater is not as easily contaminated as surface water, but once it is contaminated, it is much more difficult to clean up because of its relative inaccessibility. The quality of groundwater in some regions may be changing as a result of human activities. Groundwater is less susceptible to bacterial pollution than surface water because the soil and rocks through which groundwater flows screen out most of the bacteria. Bacteria, however, occasionally find their way into groundwater, sometimes in dangerously high concentrations. But freedom from bacterial pollution alone does not mean that the water is fit to drink. Even though the ground is an excellent mechanism for filtering out particulate matter, such as leaves, soil, and bugs, dissolved chemicals and gases can still occur in large enough concentrations in groundwater to cause problems. Also, many unseen dissolved mineral and organic constituents are present in groundwater in various concentrations. Most are harmless or even beneficial; though occurring infrequently, others are harmful, and a few may be highly toxic. Determination of the groundwater and surface water quality in the vicinity of coal mine has been evaluated and interpreted the quality of water. The effect of disposal of urea plant effluent on the quality of groundwater analyzed for pH, total dissolved solid, total suspended solid, Cl, F, chemical oxygen demand, biochemical oxygen demand, Fe, Zn, Pb, Cu, Cr, Cd, Mn, and As. Results showed the quality of underground water was below standard due to having a higher quantity of total dissolved solids than permissible.\(^1\) Variation of the environmental tritium content as well as in the chemical composition of both major cations (Na, K, Ca, Mg) and major anions (Cl, SO\(_4\), HCO\(_3\)) between different groundwater in the studied area reflect the high degree of in homogeneity of the aquifer and different recharging conditions due to permeability of the water bearing formation. The chemical water type of the El-Dabaa groundwater is sodium sulphate (Na\(_2\)SO\(_4\)) and the SAR values illustrate the suitability of these groundwater for agricultural purposes.\(^2\) Detail problems of regional ground subsidence due to pumping in opencast mine areas and problems of estimation of seepage forces in saturated or unsaturated loose rocks with an isotropic conductivities and in fissured hard rocks with conductivities characterized by a tensor.\(^3\) With the integration of the geologic and hydrologic data and analytic results was the most precise method of sampling of underground water is the low flow one.\(^4\) (1) There were obvious temporal and spatial changes of groundwater quality during the past 22 years. (2) Concentrations of NH\(_4^+\), SO\(_4^{2-}\), NO\(_3^-\), NO\(_2^-\), Cl\(^-\), and the pH value, total hardness, total alkalinity increased significantly, in which NH\(_4^+\), NO\(_3^-\), and NO\(_2^-\) of groundwater exceeded the drinking water standards as a result of non-point pollution caused by the expansion of cultivated land and mass use of the fertilizer and pesticide. (3) Oppositely, Ca\(^{2+}\) and HCO\(_3^-\) showed an obvious decline.
trend due to forest reduction and degradation and stony desertification. Meantime, there was a dynamic relation between the groundwater quality change and the land use change. The effect of nitrogen fertilizer application on nitrate leaching and contamination of underground and surface waters in a continuously cropped lowland area of South Western Nigeria has indicated a high potential for nitrate leaching. Natural groundwater less protected from the impact of acid atmospheric precipitation is in a worse ecological condition, which is confirmed by observations in Northern and Western Europe and other regions of the world. The influence of the human activities (intense farming) and that of the climate changes (temperature rise 1°C) in the hydrological cycle in terms of qualitative and quantitative impact on the groundwater resources. The high salinity of the river especially during summer periods and the intense farming activities played a crucial role for the quality degradation of the aquifer. The impacts of land use from commercial, industrial and domestic activities on groundwater quality are investigated. The water quality was investigated with respect to bacteriological and physico-chemical parameters. The seasonal variation in quality variables in individual wells is likely to be greater than the seasonal variation in the aquifers, which emphasizes the vulnerability of the wells. The chemical characteristics of leachate derived from domestic refuse has been studied. Migration of inorganic and organic substances to the groundwater table is possible, and these results suggest that a cautious approach to landfill site selection should be taken, although soil depth to water table and dilution characteristics of the underlying groundwater must also be considered. Drought prone areas and sites exposed to domestic or municipal wastes are most heavily polluted. Major water problems are due to fecal and non-fecal contamination, high TDS, conductivity and salt content. Use of water for drinking or agricultural purposes from such wells and hand pumps without treatment may expose population to higher health risk. Physicochemical quality of groundwater in industrial areas of zinc smelter plants, ore-mining industries, steel plants, thermal power plants, tanneries, distilleries and heterogeneous group of industries in India has been under taken. The pollution with respect to NO$_3^-$, Cl$^-$, and F$^-$ is mainly attributed to the extensive use of fertilizers and large-scale discharge of municipal wastes into the open drainage system of the area. The source of the pollution is effluent from industries. The effluent is discharged in a stream flowing through the area in the injection wells, pollutants have entered into the aquifer through system and flowed farther in the eastern direction. Geochemical modeling showed that potentially toxic heavy metals might exist largely in the forms of MSO$_4^{2-}$ and M$^{2+}$ in pore water of SAL metallurgical waste. The groundwater near the landfill site was characterized as not potable and not suitable for irrigation water. Furthermore, this study presents the application of the hydrologic evaluation of landfill performance (HELP) model for the determination of the yearly leakage from the base of the landfill after the final capping. An increase in the concentration of pollutants in downstream groundwater over that observed in upstream boreholes. Krigeing distributions and contour patterns show general similarity except for minor variations.
and are controlled by morphology, lithology, fracture pattern, rainfall, and groundwater flow direction. In general TDS, EC, Ca\(^{2+}\), HCO\(_3^-\), Cl\(^-\), TH, and Alkalinity show very similar behaviour in their spatial distribution from wetter to drier regions of the study area.

The aim of this paper is to present data, obtained using APHA Standard methods, which measures total dissolved solids, total suspended solid, turbidity, pH, dissolved oxygen, sulphate, chloride, nitrate, fluoride, calcium hardness, magnesium hardness, total hardness, total alkalinity and chemical oxygen demand, to check the present quality of underground water in industrial area, residential area, near water and sewage treatment plant, near sea, river and lake with respect to pre-monsoon and post-monsoon season to check the variation, whether the temperature changes have the potential to influence the quality of underground water.

**METHODOLOGY**

Samples were collected through the chain of custody from eleven selected stations (zone of Surat city) using a pre-cleaned plastic canes in May (pre-monsoon) and November (post-monsoon) during 2007 as shown in Table 1 and Fig.1. Surat is located at 21.112°North altitude and 72.814°East latitude. Total Dissolved solids, total suspended solids, dissolved oxygen, chloride, calcium hardness, magnesium hardness, total hardness, total alkalinity and chemical oxygen demand were measured using APHA Standards methods of water and wastewater examination. Turbidity was measured using turbidity meter. pH was measured using pH meter. Sulphate was measured using spectrophotometer. Nitrate and fluoride was measured using HACH make spectrophotometer (DR/2400).

![Fig. 1: Location map of sampling sites of different zones in Surat city.](image-url)
Table 1: Location chart

<table>
<thead>
<tr>
<th>Zone</th>
<th>Location</th>
<th>Area</th>
<th>Source of water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central zone</td>
<td>Begumpura</td>
<td>Residential area</td>
<td>Bore well</td>
</tr>
<tr>
<td>East zone</td>
<td>Sarthena</td>
<td>Near water treatment plant</td>
<td>Bore well</td>
</tr>
<tr>
<td>West zone</td>
<td>Jahangirpura</td>
<td>Near water treatment plant</td>
<td>Bore well</td>
</tr>
<tr>
<td>North zone</td>
<td>Katargam G.I.D.C.</td>
<td>Industrial (textile)</td>
<td>Bore well</td>
</tr>
<tr>
<td>North zone</td>
<td>Singanpore</td>
<td>Near sewage treatment plant</td>
<td>Bore well</td>
</tr>
<tr>
<td>South zone</td>
<td>Pandesara G.I.D.C.</td>
<td>Industrial (textile)</td>
<td>Bore well</td>
</tr>
<tr>
<td>South-west zone</td>
<td>Ambika Niketan</td>
<td>Near river Tapi</td>
<td>Bore well</td>
</tr>
<tr>
<td>South-west zone</td>
<td>SICE Section (SCET College)</td>
<td>Near river Tapi</td>
<td>Bore well</td>
</tr>
<tr>
<td>South-west zone</td>
<td>Piplod Jakatnaka</td>
<td>Near lake</td>
<td>Bore well</td>
</tr>
<tr>
<td>South-west zone</td>
<td>Dumas Village</td>
<td>Near sea-cost</td>
<td>Bore well</td>
</tr>
<tr>
<td>South-east zone</td>
<td>Limbayat</td>
<td>Industrial (textile)</td>
<td>Bore well</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

The temperature ranged from 26-27°C (pre-monsoon) and 23-24°C (post-monsoon).

Here, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, DO = Dissolved Oxygen, SO₄²⁻ = Sulphate, Cl⁻ = Chloride, NO₃⁻ = Nitrate, F⁻ = Fluoride, Ca H = Calcium Hardness, Mg H = Magnesium Hardness, TH = Total Hardness, TA = Total Alkalinity, COD = Chemical Oxygen Demand.
Table 2: Parameters of various sources for underground water quality of Surat city for the month of May ’07

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Sources</th>
<th>T D S mg/l</th>
<th>T S S mg/l</th>
<th>Turbidity NTU</th>
<th>pH</th>
<th>T H mg/l</th>
<th>D O^2 mg/l</th>
<th>S O_4^2- mg/l</th>
<th>C l- mg/l</th>
<th>N O_3- mg/l</th>
<th>F- mg/l</th>
<th>C a H mg/l</th>
<th>M g H mg/l</th>
<th>C O-D+ mg/l</th>
<th>IS Requirement Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Begumpura</td>
<td>640</td>
<td>5</td>
<td>8.24</td>
<td>190</td>
<td>8.2</td>
<td>0.24</td>
<td>279.99</td>
<td>0.8</td>
<td>39.99</td>
<td>8.0</td>
<td>300</td>
<td>250</td>
<td>200</td>
<td>600</td>
</tr>
<tr>
<td>2.</td>
<td>Sarthana</td>
<td>1448</td>
<td>16</td>
<td>8.04</td>
<td>600</td>
<td>9.7</td>
<td>1.0</td>
<td>279.94</td>
<td>0.6</td>
<td>190</td>
<td>2.0</td>
<td>430</td>
<td>300</td>
<td>200</td>
<td>600</td>
</tr>
<tr>
<td>3.</td>
<td>Jahanagipa</td>
<td>714</td>
<td>16</td>
<td>8.25</td>
<td>500</td>
<td>9.5</td>
<td>0.75</td>
<td>414.91</td>
<td>0.7</td>
<td>100</td>
<td>0.5</td>
<td>500</td>
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<td>600</td>
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<td>4.</td>
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<td>474</td>
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<td>8.13</td>
<td>450</td>
<td>9.5</td>
<td>0.5</td>
<td>99.98</td>
<td>0.8</td>
<td>-</td>
<td>0.5</td>
<td>190</td>
<td>250</td>
<td>10</td>
<td>600</td>
</tr>
<tr>
<td>5.</td>
<td>Singanpore</td>
<td>1776</td>
<td>6</td>
<td>8.27</td>
<td>420</td>
<td>9.3</td>
<td>1.5</td>
<td>194.96</td>
<td>0.8</td>
<td>360</td>
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<td>300</td>
<td>400</td>
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<tr>
<td>6.</td>
<td>Pandesara G.I.D.C.</td>
<td>23986</td>
<td>144</td>
<td>7.76</td>
<td>11,350</td>
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<td>11097.50</td>
<td>1.4</td>
<td>5150</td>
<td>0.5</td>
<td>6200</td>
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<td>600</td>
<td>600</td>
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<td>7.</td>
<td>Ambika Niketan</td>
<td>6820</td>
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<td>8.</td>
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<td>0.6</td>
<td>-</td>
<td>0.6</td>
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<td>120</td>
<td>120</td>
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<td>9.</td>
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<td>8.6</td>
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<td>0.5</td>
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<td>400</td>
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<td>-</td>
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<td>-</td>
<td>0.6</td>
<td>130</td>
<td>270</td>
<td>480</td>
<td>60</td>
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</tbody>
</table>

* Generally, TSS should not be present in drinking water.

^ Tolerance limits for Public water supplies. IS: 2296-1974 40% of the saturation value or 3 mg/l, the higher value is desirable.

+ Generally, COD is not measured in water used for drinking purpose. But due to increased industrialization and Urbanization, it has been measured just to check the chemical contamination in underground water.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Sources</th>
<th>TDS mg/l</th>
<th>TSS mg/l</th>
<th>Turbidity NTU</th>
<th>pH</th>
<th>TTH mg/l</th>
<th>D ° mg/l</th>
<th>SO₄²⁻ mg/l</th>
<th>Cl⁻ mg/l</th>
<th>NO₃⁻ mg/l</th>
<th>F⁻ mg/l</th>
<th>Ca H mg/l</th>
<th>Mg H mg/l</th>
<th>TA mg/l</th>
<th>CO₂ D+ mg/l</th>
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<td>1.</td>
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<td>640</td>
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<td>-</td>
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<td>0.1</td>
<td>0.29</td>
<td>80</td>
<td>110</td>
<td>440</td>
<td>80</td>
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<td>1200</td>
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<td>0.52</td>
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<td>60</td>
</tr>
</tbody>
</table>

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Total Dissolved Solids, Total Suspended Solids, Turbidity, pH, Dissolved Oxygen, Sulphate, Chloride, Nitrate, Fluoride, Calcium Hardness, Magnesium Hardness, Total Hardness, Total Alkalinity and Chemical Oxygen are very important characteristics to be maintained in its permissible limits for drinking purpose. These parameters of different location are shown in Table. 2 and Table 3. The studies showed that at Begumpura, total dissolved solids, pH, calcium and magnesium hardness are within the permissible limits. Chemical oxygen demand is detected. Total suspended solids is present above the permissible limit, which may be explained in terms of the wastewater that may percolate enough down to underground water reservoirs, accumulates enough and stands for a long time have contaminated underground potable water. Turbidity is nil. Dissolved oxygen is above the desirable limit. Sulphate, chloride, nitrate, fluoride, total hardness and total alkalinity are under the required limits.

At Jahangirpura, total dissolved solids, pH, chloride, fluoride and calcium hardness are within the permissible limits. Total suspended solid is present above the permissible limit. Turbidity is nil. Dissolved oxygen is above the desirable limit. Also, dissolved oxygen is decreasing in the month of Nov’07 due to the increase in chloride, calcium, magnesium and total hardness in the month of Nov’07. Sulphate and nitrate are under the required limit. Magnesium hardness is up to the limit in the month of May’07 but above the limit in the month of Nov’07. Total hardness and total alkalinity are within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07. Chemical oxygen demand is detected.

At Ambika Niketan, total dissolved solids, magnesium hardness and total hardness are above the permissible limits. Total suspended solid is present above the permissible limit. Turbidity is nil. Dissolved oxygen is higher than the desirable limit. Sulphate, nitrate and fluoride are under the required limit. Chloride and calcium hardness are above the permissible limit in the month of May’07 but within the permissible limit in the month of Nov’07. Total alkalinity is within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07. Chemical oxygen demand is detected.

At SCET College, Athwalines, total dissolved solids, calcium hardness, magnesium hardness, total hardness and total alkalinity are within the permissible limits. Turbidity is nil. Total suspended solid is present above the permissible limit. Dissolved oxygen is higher than the desirable limit. Also, dissolved oxygen is decreasing in the month of Nov’07 due to the increase in chloride content in the month of Nov’07. Sulphate, chloride, nitrate and fluorde are under the required limit. Chemical oxygen demand is detected.

The variation in groundwater is due to the increased or decreased inflow of domestic waste of specific constituents through the different aquifers in the underground water as the source is located in residential area.
At Piplod Jakatnaka, total dissolved solids, pH, chloride, calcium hardness, magnesium hardness and total alkalinity are within the permissible limit. Turbidity and chemical oxygen demand is nil. Total suspended solid is present above the permissible limit. Dissolved oxygen is higher than the desirable limit. Sulphate, nitrate and fluoride are under the required limit. Total hardness is within the permissible limit in the month of May’07 but under the limit in the month of Nov’07.

The variation in characteristics of groundwater is due to the increased or decreased intake of industrial waste through the different aquifers present in the groundwater-table, as this source is located very near to river Tapi – within the range of 1 km (due to the presence of pollutants).

**Total Dissolved Solids**

![Graph showing Total Dissolved Solids for different sources in May'07 and Nov'07.]

**Fig. 2**: Comparison of TDS of various sources for underground water of Surat city in different season.

**Total Suspended Solids**

![Graph showing Total Suspended Solids for different sources in May'07 and Nov'07.]

**Fig. 3**: Comparison of TSS of various sources for underground water of Surat city in different season.
**Fig. 4**: Comparison of Chloride of various sources for underground water of Surat city in different season.

**Fig. 5**: Comparison of Total Hardness of various sources for underground water of Surat city in different season.
Fig. 6: Comparison of Total Alkalinity of various sources for underground water of Surat city in different season.

Fig. 7: Comparison of COD of various sources for underground water of Surat city in different season.
At Katargam G.I.D.C., total dissolved solids, pH, magnesium hardness and total hardness are within the permissible limits. Turbidity is nil. Total suspended solid is present above the permissible limit. Dissolved oxygen is higher than the desirable limit. Also, dissolved oxygen is decreasing in the month of Nov’07 due to the increase in chloride, magnesium and total hardness in the month of Nov’07. Sulphate, chloride, nitrate and fluoride are under the required limit. Total alkalinity is within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07.

The higher value of total suspended solids and total alkalinity reflects the increased industrial activities in Katargam G.I.D.C. as there are numbers of textile mills.

At Singanore, total dissolved solids, pH, calcium hardness, magnesium hardness and total hardness are within the permissible limits. Turbidity is nil. Total suspended solids is present above the permissible limit. Dissolved oxygen is higher than the desirable limit. Also, dissolved oxygen is decreasing in the month of Nov’07 due to the increase in chloride, magnesium and total hardness in the month of Nov’07. Sulphate, nitrate and fluoride are under the required limit. Chloride is under the required limit in the month of May’07 but within the permissible limit in the month of Nov’07. Total alkalinity is within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07. Chemical oxygen demand is detected.

The higher value of total dissolved solid, total suspended solids, chloride, calcium hardness, magnesium hardness, total hardness and total alkalinity reflects the increased industrial activities in Pandesara G.I.D.C. as there are numbers of textile units and dyeing house.

At Limbayat, total dissolved solids, pH, calcium hardness, magnesium hardness and total hardness are within the permissible limits. Turbidity is nil. Total suspended solid is present above the permissible limit. Dissolved oxygen is higher than the desirable limit. Also, dissolved oxygen decreases in the month of Nov’07 due to the increase in the chloride. Calcium hardness, magnesium hardness and total hardness in the month of Nov’07. Sulphate, chloride, fluoride and nitrate are under the required limit. Total alkalinity is within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07. Chemical oxygen demand is detected.

The higher value of total suspended solids and total alkalinity reflects the increased industrial activities in Limbayat as there are numbers of textile mills, which may discharge the untreated water, percolating into the underground forming lechates that makes the water unfit for drinking purpose.
At Dumas Village, total dissolved solids, pH, chloride and magnesium hardness are within the permissible limit. Turbidity and chemical oxygen is nil. Total suspended solid is present above the permissible limit. Dissolved oxygen demand is higher than the desirable limit. Also, dissolved oxygen is decreasing in the month of Nov’07 due to the increase in chloride, calcium hardness, magnesium hardness and total hardness in the month of Nov’07. Sulphate, nitrate and fluoride are under the required limit. Total hardness is up to the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07. Total alkalinity is within the permissible limit in the month of May’07 but above the permissible limit in the month of Nov’07.

As Dumas village is situated on the coast of Arabian sea the value of magnesium hardness, total hardness and total alkalinity are higher than the permissible limit. It can be explained in the terms of intrusion of salty water / brine under the ground through aquifers.

**Fig. 8**: Comparison of characteristics of underground water of Singanpore, Surat in different seasons.

**Fig. 9**: Comparison of characteristics of underground water of Pandesara G.I.D.C., Surat in different seasons.
Fig. 10: Comparison of characteristics of underground water of Ambika Niketan, Surat in different seasons.

Fig. 11: Comparison of characteristics of underground water of SICE Section (SCET College), Surat in different seasons.

CONCLUSION

The underground water of all eleven sources may be unfit for drinking purpose with reference to the selected fourteen parameters. The underground water of all the sources except Pandesara G.I.D.C. and Ambika Niketan may be used for other recreational purposes like irrigation, fish culture, industrial cooling, etc. with reference to the selected fourteen parameters. Thus, due to some anthropological activities like industry, the discharged industrial effluents percolate and enter the groundwater. As a
result, it contaminates groundwater, which is best for drinking, the value of parameters according to different standards (WHO, ISI, etc.) is found higher than permissible limit. So, if one wishes to use such groundwater as potable water, specific treatment has to be decided.

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