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Original Research Paper

# Alterations in Physicochemical Characteristics of Drinking Water Collected From Some Areas of Ahmedabad City

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## ABSTRACT

Due to urbanization and human activities, the groundwater sources are depleting in terms of quantity and quality in Indian cities. The present study is associated with tap water quality of municipal and tube well sources evaluated from 36 samples collected from 17 areas of Ahmedabad city. Samples were analysed for various physicochemical characteristics by standard methods. The data suggest that most of the samples have total hardness, chlorinity and salinity within the highest desirable limit of GPCB or BIS. Most of the samples have high amount of calcium and magnesium hardness above the highest desirable limit but less than maximum permissible limit. Five samples were having magnesium hardness even above the maximum permissible limit of GPCB standards. The water quality index (WQI) calculated from five parameters has shown that almost all the samples have the index value more than 100 suggesting that drinking water is unsafe. Most of the water samples studied (75%) were hard waters in terms of total hardness. Pearson correlation matrix suggests that total hardness has highly significant positive correlation with rest of the parameters studied. The calcium hardness has significant correlation with chlorinity and salinity. The magnesium hardness showed a positive correlation with chlorinity and salinity. Compared to municipal sources using Student's t-test analysis, the tube-well source has higher values of total hardness ($P<0.001$), magnesium hardness ($P<0.001$), chlorinity ($P<0.05$) and salinity ($P<0.05$). Proper water treatment, especially for tube well water is necessary.

## INTRODUCTION

Freshwater is one of the basic necessities for the sustenance of life. Rapid population growth, urbanization and industrialization have led to a greater demand of water from an increasingly smaller supply of water resources in the country (Tyagi et al. 2002, Asadi et al. 2007, Khandwala & Suthar 2007, Shah et al. 2008).

Water pollution is a serious problem in India as almost 70% of its surface water resources like rivers, streams, ponds, lakes and groundwater reserves are already contaminated. The industrial sector is related with 3% of annual withdrawals of water in India, but it has considerable contribution to water pollution in urban areas. The domestic sector is responsible for the majority of the wastewater generation in India. Cumulative data from 22 largest cities in the country reflect that they produce over 7267 million litres of domestic wastewater per day (Rao & Mamatha 2004).

Water is not only a vital environmental factor to all forms of life, but it has also a great role to play in socio-economical development of human population. Huge amount of money and efforts have been spent by the municipalities, industries and government during the last four decades to enhance the quality of water for domestic and industrial consumption and to reduce its pollution (Dwivedi & Pathak 2007). We must take proper measures for water resources management. Otherwise, we have to face a national catastrophe in the future. The proper water policy is lacking and there is uncontrolled development of water resources in India due to short-term economic objectives and political expediency (Borah et al. 2008). Our previous studies (Suthar et al. 2008a-d) and Verma et al. (2008) showed that various areas of Ahmedabad city have poor drinking water quality. Hence, the present study was carried out as a part of continuous monitoring.

## MATERIALS AND METHODS

The present study is associated with water quality evaluated from 17 areas of Ahmedabad city of Gujarat state (Fig. 1). Ahmedabad is the largest city in Gujarat state located on the bank of Sabarmati river. It is located at 23.03°N and 72.58°E. Total 36 tap water samples were collected from municipal and tube well sources in the morning and labelled appropriately. Samples were analysed for various physicochemical characteristics by standard methods (Sunilkumar & Ravindranath 1998). The colour, taste and odour were reported by direct seeing, smelling and tasting the water sample before chemical analysis. The chemical parameters analysed were total hardness, calcium hardness, magnesium hardness, chlorides and salinity. The data were compared with Gujarat Pollution Control Board (GPCB) drinking water standards as per Kapila & Mehta (2006). These standards are same as IS: 10500 of Bureau of Indian Standards for parameters studied (Shankar & Balasubramanya 2008). The data were analysed statistically by calculating mean, range (minimum and maximum values), correlation matrix and Student's t-test. Water quality index (WQI) was calculated based on GPCB standards. The classification of groundwaters based on total hardness was adapted from Vennila et al. (2008).

### Water Quality Index (Wqi)

Water quality index (WQI) is a very useful and efficient method for assessing and communicating the information on overall quality of water. To determine suitability of water for drinking purposes, WQI is computed as per various researchers (Sinha & Saxena 2006, Asadi et al. 2007, Dwivedi & Pathak 2007).

Five physicochemical parameters, viz. total hardness, calcium hardness, magnesium hardness, chlorinity, and salinity were used to calculate WQI.

**Calculation of unit weight ($W_i$):** For a given pollutant or component of water ($i^{th}$ parameter), if it is more harmful then its recommended standard ($S_i$) for drinking water will have smaller magnitude. So, the unit weight ($W_i$) for the $i^{th}$ parameter is assumed to be inversely proportional to its recommended standard ($S_i$) for the $i^{th}$ parameter. Where, i = 1, 2, 3…, n and n = number of parameters considered for WQI (n = 5 as five parameters studied in the present study). Thus,

$$W_i = K/S_i$$

Where, K = Proportionality constant, $W_i$ = Unit weight for $i^{th}$ parameter, $S_i$ = Drinking water standard (i.e. highest desirable limit) prescribed by GPCB (or BIS) for $i^{th}$ parameter.

The proportionality constant (K) was derived from

$$K = [1/\sum_{i=1}^{n} 1/S_i]$$

These assumed unit weights ($W_i$) for all five water quality parameters used here as given in the last column of Table 1 A.

Fig. 1: Location of sampling points of water sample collecion in Ahmedabad city.

**Calculation of quality rating (qi):** The quality rating ($q_i$) was calculated for the $i^{th}$ parameter using the following formula.

$$q_i = [(V_{actual} - V_{ideal})/(V_{standard} - V_{ideal})] \times 100$$

Where,

$q_i$ = Quality rating of $i^{th}$ parameter

$V_{actual}$ = Actual value of the $i^{th}$ parameter obtained from laboratory analysis

$V_{ideal}$ = Ideal value of $i^{th}$ parameter which can be obtained from the standard tables (here, for all parameters, $V_{ideal}$ is equivalent to zero)

$V_{standard}$ = GPCB standard value of $i^{th}$ parameter (i.e., highest desirable value of $i^{th}$ parameter as per GPCB standards)

**Calculation of subindex:** The subindex (qiWi) has been calculated by multiplying quality rating ($q_i$) and unit weight ($W_i$) of $i^{th}$ parameter.

**Calculation of Water Quality Index (WQI):** The water quality index was calculated by taking the weighted arithmetic mean of the quality rating using following formula adopted by various investigators (Swarnalatha et al. 2007, Dwivedi & Pathak 2007, Shankar & Balasubramanya 2008).

$$WQI = [\Sigma q_i W_i]/[\Sigma W_i]$$

Here, $\Sigma W_i = 1$ was considered. Both the summations were taken from i = 1 to i = n = 5 (i.e., the total number of parameters considered in the present study).

The status of water quality based on WQI was evaluated as per classification adopted by various investigators (Asadi et al. 2007, Shah et al. 2008) as given in Table 1b.

## RESULTS

The physicochemical parameters with their GPCB standards and unit-weights (Wi) are listed in Table 1A. Table 1B gives water quality index and probable status of drinking water for comparison. Table 2 shows samplewise list of physicochemical parameters. Total 36 tap water samples were collected from various areas of Ahmedabad city. The data suggest that most of the samples have total hardness, chlorinity and salinity within the highest desirable limit of GPCB. Most of the samples have high amount of calcium and magnesium hardness above the highest desirable limit but less than maximum permissible limit. Five samples showed magnesium hardness even above the maximum permissible limit of GPCB standards. The water quality index (WQI) showed that almost all the samples were having the index value more than 100 suggesting that drinking water is unsafe as per GPCB standards adopted. Table 3 shows classification of groundwaters based on total hardness. It depicts that 75% of the samples studied were hard waters.

Figs. 1-5 show area-wise mean values of physicochemical characteristics studied. Most of the samples were collected from eastern part of Ahmedabad city with majority of samples from Maninagar (7), Bapunagar (6), Khokhara (5) and Ghodasar (3). The total hardness, chlorinity and salinity of all the areas under the study were within the highest desirable limit of GPCB. Most of the areas have calcium hardness and magnesium hardness above the highest desirable limit. Three areas have the magnesium hardness even above the maximum allowable limits of GPCB.

Table 4 shows Pearson correlation matrix for five parameters. It suggests that total hardness has highly significant positive correlation ($r = 0.656, 0.786, 0.638$ and $0.638$; $P < 0.001$) with rest of parameters studied. The calcium hardness has significant correlation ($r = 0.560, 0.560$; $P < 0.01$) with chlorinity and salinity. The magnesium hardness showed a positive correlation with chlorinity and salinity ($r = 0.445, 0.445$; $P < 0.01$). Chlorinity value had positive correlation with salinity.

Table 5 shows sample source-wise parameters with total values. It suggests that calcium hardness and magnesium hardness were above the higher permissible limit as per GPCB standards. Compared to municipal sources using Student's t-test analysis, the tube-well sources have higher values of total hardness ($P < 0.001$), magnesium hardness ($P < 0.001$), chlorinity ($P < 0.05$) and salinity ($P < 0.05$).

## DISCUSSION

Water used for drinking purpose should be potable. It means that it can be consumed in any desired amount without any adverse effect on health. Water should be free from turbidity, colour and objectionable smell or taste. Good quality water has become a precious commodity. The quality of water is deteriorated by improper waste disposal and carelessness towards the surrounding environment (Jayalakmidevi & Belagadi 2005, Kamraj et al. 2008). There are problems of water availability and water quality.

In the present study, water of all sampling sites was colourless. However, colour of the natural water may be due to the organic matter degradation and presence of algae. Sometimes, it may suggest water pollution due to industrial effluents. In the present study, all sampling waters were devoid of any unpleasant odour and taste. Metals and salts from soil and inorganic substances are responsible to produce taste accompanied by odour in natural water (Garg et al. 2008).

In the present study, samples were having total hardness within highest desirable limits similar to other investigations (Swarnalatha et al. 2007, Shah et al. 2008, Suthar et al. 2008b-d). The hardness of water is due to the presence of certain cations like calcium ($Ca^{+2}$), magnesium ($Mg^{+2}$), aluminium

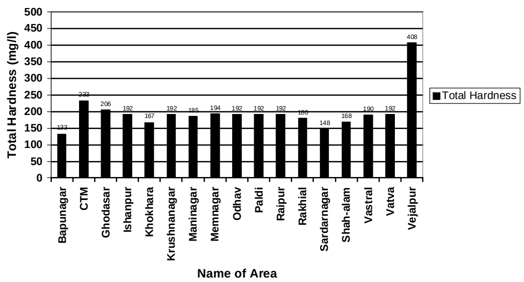


Fig. 2: Mean value of total hardness from selected areas of Ahmedabad city in year 2007.

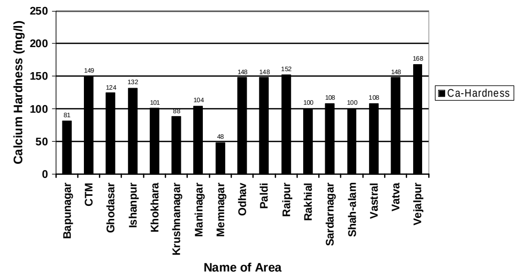


Fig. 3: Mean value of calcium hardness from selected areas of Ahmedabad city in year 2007.

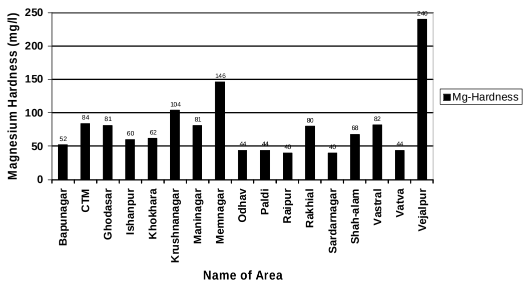


Fig. 4: Mean value of magnesium hardness from selected areas of Ahmedabad city in year 2007.

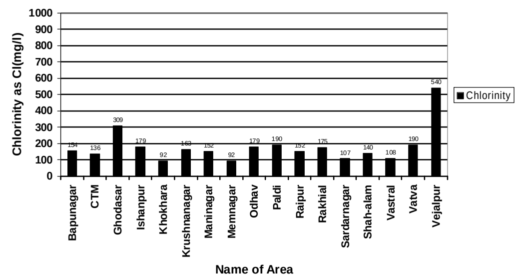


Fig. 5: Mean value of chlorinity from selected areas of Ahmedabad city in year 2007.

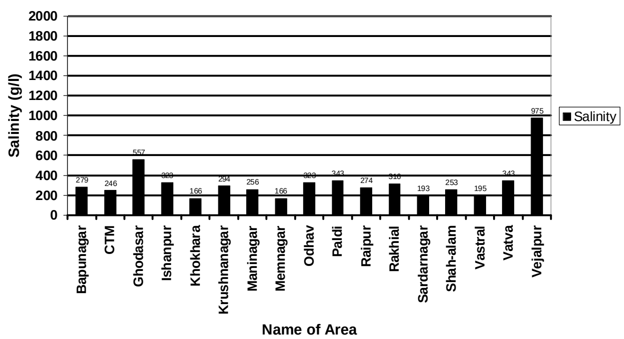


Fig.6: Mean value of salinity from selected areas of Ahmedabad city in year 2007.

($Al^{+3}$), iron ($Fe^{+3}$) and manganese ($Mn^{+2}$) and anions like bicarbonates ($HCO_3^{-1}$), sulphates ($SO_4^{-2}$), chlorides ($Cl^{-1}$), nitrates ($NO_3^{-1}$), etc. which are in the dissolved state.

In the present study, samples were having high amount of calcium and magnesium hardness similar to other studies (Gupta et al. 1994, Swarnalatha et al. 2007, Shah et al. 2008, Suthar et al. 2008a,c,d). Calcium is a common constituent of natural water. It plays important role in biological systems. Source of calcium is the leaching rocks. High concentration of calcium is not desirable in washing, laundering and bathing. Magnesium is another common constituent of natural water. It is a beneficial metal ion but toxic at higher concentration. Salts of magnesium have a laxative and diuretic effect. Its high concentration reduces the utility of water for domestic use (Garg et al. 2008, Joshi & Seth 2008).

Table 1a: Water quality parameters, their GPCB standards, Bureau of Indian Standards (BIS : 2003) standards and assigned unit weights.

| Parameters | Standard ($S_i$) (Highest Desirable Limit-HDL) | Maximum Permissible limit (MPL) | Unit weights ($W_i$) |
|---|---|---|---|
| Total Hardness | 300 | 600 | 0.0592898 |
| Calcium hardness | 75 | 200 | 0.2371592 |
| Magnesium hardness | 30 | 90 | 0.5938982 |
| Chlorinity | 250 | 1000 | 0.0711477 |
| Salinity | - (450#) | - (1800#) | 0.0395265 |
| $\Sigma W_i$ | | | 1 |

#Calculated from chlorinity value; '-' represents no standard prescribed by GPCB.

Table 1b: Status of water quality based on Water Quality Index (WQI).

| WQI value | Status |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very poor |
| Above 100 | Unsuitable for drinking |

Chloride is one of the major anions found in natural water. But, high concentration of chlorides in drinking water can impart salty taste that most people find objectionable, and it may increase the corrosiveness of water (Sundar & Mohanraj 2008). Chloride content above the permissible limits can cause serious health problems to the consumers. In the present study, concentration of chlorides was within the approved GPCB standards for safe drinking water contrary to the earlier reports (Suthar et al. 2008a-d). However, Swarnalatha et al. (2007) and Borah et al. (2008) also reported chlorides within permissible limits in other parts of India.

Water quality index is one of the most effective ways to communicate water quality information to the public and policy makers. A water quality index (WQI) may be defined as a rating reflecting the composite influence of a number of water quality parameters on the overall quality of water (Shankar & Balasubramanya 2008). The numerical value of the water quality index implies that the water under consideration is fit for human consumption if its WQI is less than 100. Moreover, the larger the WQI value, the water is considered to be more polluted. In the present study, WQI values exceeded 100 in all samples collected. Similarly, other investigators (Guru Prasad 2003, Sinha & Saxena 2006, Ramakrishnaiah et al. 2009) also reported high WQI values in other parts of India. It is considered that the water samples studied were unfit for potable purpose without suitable treatment. In the present study, the major factor for higher WQI values in most of the samples may be the higher calcium and magnesium hardness. Shah et al. (2008) also found poor water quality by WQI due to hardness and chlorides.

In the present study, samples from tube well have higher hardness and chlorinity compared to municipal source. Higher hardness and chlorinity suggest possibilities of groundwater pollution, which may be due to sewage or industrial source. The groundwater sources, once get polluted, the effects of pollutants may persist for longer periods. Areas in the eastern part of Ahmedabad city have industrial belt with residential blocks. Therefore, proper disposal of industrial effluents with periodical monitoring of groundwater, especially in the industrial belt is necessary otherwise alarming situ-

Table 2: Physicochemical parameters of water samples collected from different areas of Ahmedabad city (Samplewise listing).

| No. | Area | Sample | TH | CH | MH | Chlorinity | Salinity | WQI |
|---|---|---|---|---|---|---|---|---|
| 1 | Bapunagar | Municipal | 168 | 100 | 68 | 175 | 316 | 231.94 |
| 2 | Vastral | Municipal | 190 | 108 | 82 | 108 | 195 | 253.96 |
| 3 | Khokhara | Municipal | 117 | 72 | 45 | 72 | 130 | 148.29 |
| 4 | Maninagar | Municipal | 180 | 100 | 80 | 175 | 316 | 258.03 |
| 5 | Maninagar (E) | Tubewell | 216 | 84 | 132 | 56 | 101 | 340.60 |
| 6 | Ghodasar | Municipal | 192 | 112 | 80 | 312 | 563 | 289.82 |
| 7 | Ghodasar | Municipal | 192 | 112 | 80 | 312 | 563 | 289.82 |
| 8 | Raipur | Municipal | 192 | 152 | 40 | 152 | 274 | 193.49 |
| 9 | Rakhial | Municipal | 180 | 100 | 80 | 175 | 316 | 258.03 |
| 10 | Maninagar (E) | Municipal | 216 | 84 | 132 | 56 | 101 | 340.60 |
| 11 | Odhav | Municipal | 192 | 148 | 44 | 179 | 323 | 205.18 |
| 12 | Bapunagar | Municipal | 100 | 60 | 40 | 179 | 323 | 151.27 |
| 13 | Khokhara | Municipal | 180 | 108 | 72 | 103 | 186 | 231.28 |
| 14 | Bapunagar | Municipal | 180 | 112 | 68 | 139 | 251 | 231.38 |
| 15 | Maninagar | Municipal | 104 | 48 | 56 | 139 | 251 | 172.4 |
| 16 | Sardarnagar | Municipal | 148 | 108 | 40 | 107 | 193 | 162.47 |
| 17 | Bapunagar | Municipal | 100 | 60 | 40 | 179 | 323 | 151.27 |
| 18 | Vatva | Municipal | 192 | 148 | 44 | 190 | 343 | 207.24 |
| 19 | Maninagar | Municipal | 192 | 148 | 72 | 190 | 343 | 262.57 |
| 20 | Paldi | Municipal | 192 | 148 | 44 | 190 | 343 | 207.24 |
| 21 | Khokhara | Municipal | 180 | 108 | 80 | 92 | 166 | 245.04 |
| 22 | Khokhara | Municipal | 180 | 108 | 40 | 92 | 166 | 165.98 |
| 23 | Ishanpur | Municipal | 192 | 112 | 80 | 179 | 323 | 264.94 |
| 24 | Ishanpur | Municipal | 192 | 152 | 40 | 179 | 323 | 198.54 |
| 25 | Krushnanagar | Tubewell | 192 | 88 | 104 | 163 | 294 | 301.79 |
| 26 | Bapunagar | Municipal | 148 | 108 | 40 | 163 | 294 | 172.94 |
| 27 | Maninagar | Tubewell | 172 | 108 | 64 | 224 | 404 | 236.52 |
| 28 | Bapunagar | Municipal | 104 | 48 | 56 | 92 | 166 | 163.61 |
| 29 | Vejalpur | Tubewell | 408 | 168 | 240 | 540 | 975 | 709.06 |
| 30 | Maninagar | Municipal | 233 | 149 | 84 | 312 | 563 | 317.52 |
| 31 | Khokhara | Municipal | 180 | 108 | 72 | 100 | 181 | 230.72 |
| 32 | Ghodasar | Tubewell | 233 | 149.2 | 84 | 302 | 545 | 315.72 |
| 33 | CTM | Tubewell | 233 | 149.2 | 84 | 136 | 246 | 284.67 |
| 34 | Memnagar | Municipal | 194 | 48 | 146 | 92 | 166 | 359.27 |
| 35 | Maninagar (E) | Municipal | 140 | 112 | 28 | 64 | 116 | 130.39 |
| 36 | Shah-alam | Municipal | 168 | 100 | 68 | 140 | 253 | 225.40 |
| | Within HDL | | 35 | 06 | 01 | 31 | 31 | - |
| | Between HDL and MPL | | 1 | 30 | 30 | 05 | 05 | - |
| | Above MPL | | - | - | 05 | - | - | - |
| | Total samples | | 36 | 36 | 36 | 36 | 36 | - |
| | HDL | | 300 | 75 | 30 | 250 | 450 | - |
| | MPL | | 600 | 200 | 90 | 1000 | 1800 | - |

The samples were collected and analysed in the year 2007-08.
Units of measurements: Total hardness (as $CaCO_3$) mg/L; Calcium hardness (as Ca) mg/L; Magnesium hardness (as Mg) mg/L; Chlorinity (as Cl) mg/L; Salinity g/L; Abbreviations: TH = Total Hardness; CH = Calcium Hardness; MH = Magnesium Harndess; HDL = Highest desirable limt; MPL = Maximum permissible limit.

ations may arise. In addition, government and non-government agencies should setup immediate and long term quality monitoring programs. Proper water treatment is necessary, especially for tube well source to be used as potable water.

Table 3: Classification of groundwaters based on total hardness.

| Total Hardness as $CaCO_3$ (mg/L) | Water Class | Number of Samples in present study | Percentage (%) |
|---|---|---|---|
| Less than 75 | Soft water | 00 | 00.00 |
| Between 75 to 150 | Moderately Hard water | 08 | 22.22 |
| Between 150 to 300 | Hard water | 27 | 75.00 |
| Above 300 | Very Hard water | 01 | 02.78 |
| Total | | 36 | 100 |

The classification is as given in Vennila et al. (2008), Units of measurements for Total hardness (as $CaCO_3$) mg/L

Table 4: Pearson correlation matrix for the physico-chemical parameters studied.

| | Total Hardness | Ca-Hardness | Mg-Hardness | Chlorinity | Salinity |
|---|---|---|---|---|---|
| Total Hardness | 1 | 0.656 | 0.786*** | 0.638*** | 0.638*** |
| Ca-Hardness | 0.656*** | 1 | 0.069 | 0.506** | 0.506** |
| Mg-Hardness | 0.786*** | 0.069 | 1 | 0.445** | 0.445** |
| Chlorinity | 0.638*** | 0.506** | 0.445** | 1 | 1.000*** |
| Salinity | 0.638*** | 0.506** | 0.445** | 1.000*** | 1 |

**Correlation is significant at the 0.01 level (two tailed) ($P < 0.01$)
***Correlation is highly significant at the 0.001 level (two tailed) ($P < 0.001$)

Table 5: Sample source-wise list of physicochemical parameters studied.

| Sample source | No. of Samples studied | Total Hardness | Ca-Hardness | Mg-Hardness | Chlorinity (Chlorides) | Salinity |
|---|---|---|---|---|---|---|
| Municipality | 30 | 170.61 ± 6.370 (100-233) | 106.03 ± 5.818 (48-152) | 64.70 ± 4.895 (28-146) | 154.56 ± 12.392 (56-312) | 279.00 ± 22.367 (101-563) |
| Tube-well | 6 | 242.36 ± 34.541*** (172-408) | 124.40± 14.557 (84-168) | 118.00 ± 26.143*** (64-240) | 236.78 ± 69.436* (56-540) | 427.51± 125.332* (101-974) |
| Total | 36 | 182.56 ± 8.766 (100-408) | 109.56 ± 5.455 (48-168) | 73.58 ± 6.640 (28-240) | 168.28 ± 15.738 (56-540) | 303.77 ± 28.407 (101-974) |

Values are Mean ± SEM.; The value in parenthesis represents range having minimum and maximum value for each parameter studied; Student's t-test (Comparing Municipal source with tubewell source data) *$P < 0.05$; ***$P < 0.001$

## CONCLUSION

From the present study, it can be concluded that the drinking water quality in selected area of Ahmedabad city in year 2007 is altered in terms of various physicochemical parameters studied. The quality should be maintained as per recommended standards at least in case of potable water. On other hand, the urban citizens should wisely use the water resources. There is need of continuous monitoring of water quality in study area. Proper water treatment, especially for tube well water before supply is necessary.

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