Studies on water quality index (WQI) of ground water of Surat City, India

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Abstract

The city of Surat is a fast developing subtropical city situated between 20.58°′N and 72.54°′E. The need of water is increasing continuously. The water is obtained through river,-reservoir-canals- and ground water. Most of the industries and residential buildings procure their water from the underground source. Present work includes the hydrological parameters of the ground water samples obtained from 10 different spots viz. Piplod, Bhatar, Citylight, Adajan, Sachin, Pandesara, Varachha, Kadodara, Palsana and Hajira. From each sampling station, samples were collected for the year 2009 (Once a month). Samples were analyzed for various physico-chemical parameters. Water Quality Index (WQI) was determined on the basis of various parameters and Water Rating was done by Water Rating System adapted by Canadian Council for Ministry of the Environment (CCME). The parameters responsible for poor WQI were analyzed further by statistically also. WQI of sampling station Piplod was 58.64, Bhatar – 72.06, Citylight – 71.39, Adajan – 60.30, Sachin – 32.54, Pandesara – 41.14, Varachha – 36.41, Kadodara – 72.81, Palsana – 65.44 and Hajira – 60.67. WQI of different locations indicate that six sampling spots are not suitable for human consumption. 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. Even than millions of people is consuming water in the fast developing city – Surat.

Keywords: water quality parameters, water quality index (WQI), correlation coefficient, regression analysis.

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1 Introduction

Water is essential for the survival of any form of life. The three percent of global fresh water is large enough to meet the requirements of man for millions of years etc., Water pollution is a phenomenon that is characterized by the deterioration of its quality as a result of various human activities. In India only 12% of people get good drinking water (Kudesia [1]). Inadequate management of water resources directly or indirectly resulted in the degradation of hydrological environment (Karnath, [2]). Therefore, a continuous periodical monitoring of water quality is necessary so that appropriate steps may be taken for water resource management practices. In the present study out of ten sampling sites 5 sampling sites namely Piplod, Bhatar, Citylight, Adajan, Varachha are densely populated and ground water is being over exploited. Rest of the 5 sampling sites are industrial as well as residential region of Surat City and mostly depend upon ground water for their daily and industrial requirement. The present investigation was carried out to calculate the Water Quality Index (WQI) in order to assess the suitability of water for consumption by human population and domestic animals.

2 Material and methods

Ten sampling stations were selected for water quality analysis namely Piplod, Bhatar, Citylight, Adajan, Sachin, Pandesara, Varachha, Kadodara, Palsana and Hajira region of Surat City, India.

Samples for analysis were collected in sterilized bottles using the standard procedure for Grab (or) Catch samples in accordance with standard methods of APHA [3]. The analysis of various Physico – Chemical parameters namely Colour, Odour, Turbidity, pH, Temperature, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Alkalinity (TA), Total Hardness (TH), Chloride (Cl), Iron (Fe), Fluoride (F), Sodium (Na), Calcium (Ca), Magnesium (Mg), Sulphate (SO_4), Nitrate(NO_3), Nitrite (NO_2), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform (TC), Fecal Coliform (FC), and heavy metals like Chromium (Cr), Arsenic (As), Lead (Pb) and Cadmium (Cd) etc. were carried out as per the standard methods of APHA [3]. All the chemicals and reagents used were of analytical grade.

2.1 Water Quality Index

Water Quality Index (WQI) for all the sampling sites was also calculated by using CCME-WQI formula and Water Rating was done by Water Rating System adapted by Canadian Council for Ministry of the Environment (CCME) [4].
The CCME Water Quality Index takes the eqn (1) form:

$$WQI = 100 - \left\{ \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right\} \quad (1)$$

where:

- *Scope (F_1)* - number of variables not meeting water quality objectives
- *Frequency (F_2)* - the number of times the objectives are not met
- *Amplitude (F_3)* - the extent to which objectives exceeded.

Scope (F_1) represents the percentage of variables that depart from their objectives at least once, relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{Number of Failed Variables}}{\text{Total Number of Variables}} \right) \times 100 \tag{2}$$

Frequency (F_2) represents the percentage of failed individual tests:

$$F_2 = \left(\frac{\text{Number of Failed Tests}}{\text{Total Number of Tests}} \right) \times 100 \tag{3}$$

Amplitude (F_3) is an asymptotic capping function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right) \tag{4}$$

The data were analyzed statistically to identify those parameters which are responsible for variation in Water Quality Index (WQI). To identify those parameters we have done correlation analysis, testing of hypothesis, factor analysis and regression Analysis by using SPSS (Statistical Package for Social Science). This was done collectively for all the sampling sites.

Table 1: CWQI rating system.

WQI	Rating
95 – 100	Excellent
80 – 94	Good
65 – 79	Fair
45 – 64	Marginal
0 - 44	Poor

3 Results and discussion

The average values of various physico-chemical parameters of different sampling sites of Surat City during the year 2009 is presented in the Table 2 and Table 3.

Table 2: Average values of physico-chemical parameters of various sampling sites of Surat City for the year 2009.

Parameter	Piplod	Bhatar	Citylight	Adajan	Sachin
Colour	Colourless	Colourless	Colourless	Colourless	Colourless
Odor	*	*	*	*	*
Turbidity	0.80	0.71	0.73	0.39	0.922
Temp	27.7	27.63	27.98	28.95	29.27
pH	7.61	7.74	7.13	8.27	8.13
TDS	4200.4	635.75	1326.6	294.41	4456
TSS	255.25	59.42	121.08	509	61.08
DO	2.33	0.89	1.10	3.091	3.73
BOD	1.99	0.20	0.32	ND	1.62
COD	57.92	ND	ND	ND	38.25
Cl	1277.4	60.59	406.08	94.62	1769.4
Hardness	312.42	143.58	354.92	232.33	2498.4
Alkalinity	241	176.41	124.41	159.5	266.25
SO_4	154.17	42.66	73.20	21.86	77.33
NO_3	1.23	1.17	1.45	13.87	0.02
NO_2	0.57	0.47	0.18	2.375	0.40
Na	1244.9	576.66	1182.4	28.375	1353.2
Ca	224.58	165.66	55.91	20.23	235.58
Mg	45.17	75.16	67.58	22.55	345.5
TC	152.67	ND	ND	ND	4230.4
FC	35	ND	ND	ND	1451.6
Fluoride	0.15	0.63	0.775	0.12	1.07
Fe	0.22	0.31	0.69	0.007	0.40
Cr	ND	ND	ND	ND	ND
As	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND

(*) Unobjectionable, (ND) Not Detected.

Table 3: Average values of physico-chemical parameters of various sampling sites of Surat City for the year 2009.

Parameter	Pandesara	Varachha	Kadodara	Palsana	Hajira
Colour	Colourless	Colourless	Colourless	Colourless	Colourless
Odor	*	*	*	*	*
Turbidity	1.35	1.44	1.30	8.90	0.54
Temp	28.79	28.83	28.13	28.1	28.75
pH	7.96	8.33	8.27	8.26	7.725
TDS	6556.83	876.33	1271.41	614.5	360.5
TSS	186.42	25.5	72.33	134.25	35.42
DO	4.86	3.92	4.46	4.20	2.66
BOD	1.94	1.074	1.46	0.91	ND
COD	38.16	13.33	16.58	54.17	ND
Cl	3578.41	108.25	144.08	144.5	80.37
Hardness	3271.58	261.08	330.16	71.25	232.91
Alkalinity	164.25	531.41	380.25	505.08	155.16
SO_4	835.16	61.41	60.5	25.91	13.74
NO_3	0.90	3.50	0.32	3.36	3.10
NO_2	0.3775	1.08	0.095	0.085	0.40
Na	2481	1986.2	1249.4	872.25	24.91
Ca	467.08	35.75	41.75	21.28	25.08
Mg.	622.25	54.67	54.83	11.83	16.87
TC	413.67	394.08	24.08	204.5	ND
FC	132.83	255.08	12.08	67.25	ND
Fluoride	0.17	0.59	0.23	0.13	0.28
Fe	0.14	0.28	0.45	0.13	0.08
Cr	ND	ND	ND	ND	ND
As	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND

(*) Unobjectionable, (ND) Not Detected.

3.1 Colour and odour

In our study at all the sampling sites colour was within its desirable units laid by WHO and odour was unobjectionable.

3.2 pH

The pH value of natural water changes due to the biological activity and industrial contamination. Higher pH includes the formation of trihalomethanes which are toxic (Trivedi and Goel [5]). The pH values of the present investigation were within the WHO standards (6.5–8.5).

3.3 Turbidity

In the year 2009, turbidity ranged within its desirable limits. It was highest at Palsana region (8.90 NTU) and lowest at Adajan region (0.39 NTU).

3.4 Temperature

Temperature of water is basically important because it affects bio-chemical reactions in aquatic environment. A rise in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the tastes and odours [6]. The average temperature of the present study ranged from 27.63–28.83°C. It was highest at Varachha region and lowest at Bhatar region.

3.5 TDS and TSS

The Total Dissolved Solid in ground water was detected exceeding its desirable limit at almost all the sampling sites. At Piplod 4200.4 mg/l, Bhatar 635.75 mg/l, Citylite 1326.6 mg/l, Adajan 294.41 mg/l, Sachin 4456 mg/l, Pandesara 6556.83 mg/l, Varachha 876.33 mg/l, Kadodara 1271.41 mg/l, Palsana 614.5 mg/l and Hajira 360.5 mg/l. Higher values of TDS indicate that the ground water is being affected by industrialisation and urbanisation.

In case of ground water TSS should not be present but in our study at all the sampling sites TSS was detected, which shows that the water is being affected by anthropogenic activities.

3.6 Dissolved oxygen (DO)

It is an important parameter which is essential to the metabolism of all aquatic organisms that posses aerobic respiration (Moundiotiya et al. [7]). Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophs (Shanthi et al. [8]). Oxygen can be rapidly removed from the waters by discharge of oxygen demanding wastes. The DO values obtained in the present study was less than its desirable limits (5 mg/l). In our study at all the sampling sites values of DO was less than 5 mg/l which indicates the presence of oxygen demanding wastes in the water body.

3.7 COD and BOD

BOD and COD are the parameters used to assess the pollution of surface water and ground waters. Values obtained for both the parameters (BOD and COD) in the present study were within permissible levels [6]. At Hajira, Adajan, Bhatar, Citylight regions COD was not detected throughout in the year 2009. BOD was not detected at Hajira and Adajan regions. At rest of the sites it was within permissible limit.

3.8 Chlorides

The higher concentration of Cl is considered to be an indicator of higher pollution due to higher organic waste of industrial origin. Presence of chlorides above the required acceptable limits can also be used as an indicator of pollution by seepage of domestic sewage [9]. In our study values of chlorides was higher at Piplod, Citylight, Sachin and Pandesara region. It was 1277.4 mg/l, 406.08 mg/l, 1769.4 mg/l and 3578.41 mg/l respectively.

3.9 Hardness

Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing ions are Calcium, Magnesium Bicarbonate, Carbonate, Chloride and Sulphates. In our study at Pandesara and Sachin region values were exceeding its desirable limit. It was 2489.4 mg/l and 3271.58 mg/l at Sachin and Pandesara respectively. At rest of the sampling sites it was within permissible limit.

3.10 Alkalinity

Alkalinity value less than 100mg/l is desirable for domestic use. However, in large quantities it imparts bitter taste to water. In the present investigation the total alkalinity of the water samples were found in the range 124.41 to 531.41 mg/l at Citylight and Varachha region respectively.

3.11 SO_4, NO_2, NO_3

In our study values of SO_4, NO_2, and NO3 were found within the permissible limits of WHO [10].

3.12 Sodium (Na) calcium (Ca) and magnesium (Mg)

Sodium (Na) was higher at all the sampling sites except Hajira and Adajan region. Calcium was higher at Pandesara region only and it was 467.08 mg/l. Magnesium (Mg) was detected higher at Pandesara and Sachin region.

3.13 Total Coliform (TC) and Fecal Coliform (FC)

TC and FC was not detected at Hajira, Bhatar, Citylight, and Adajan region. It was higher in amount at Sachin, Piplod, Pandesara and Varachha region, which indicates that the ground water is being contaminated due to various human activities [10].

3.14 Fluoride (F) and iron (Fe)

Fluoride was detected higher than its desirable limit at Sachin (1.07 mg/l). It was within its limits at all the other sampling sites. Iron was detected 0.31 mg/l, 0.40 mg/l and 0.45 mg/l at Bhatar, Sachin and Kadodara region respectively, which is slightly higher than its prescribed limit.

3.15 Heavy metals

In our study the heavy metals like Arsenic (As), Cadmium (Cd), Lead (Pb) and Chromium (Cr) were not at all detected from any sampling site.

Depending upon the above physic-chemical parameters Water Quality Index (WQI) was find out by using CCME-WQI formula and Water Rating was done by Water Rating System adapted by Canadian Council for Ministry of the Environment (CCME). Table 4 shows the CCME-WQI of various sampling sites of Surat.

Table 4: WQI of sampling sites of Surat City for the year 2009.

Sampling site	WQI	Rating
Hajira	60.67	Marginal
Piplod	58.64	Marginal
Bhatar	72.06	Fair
Citylight	71.39	Fair
Adajan	60.30	Marginal
Sachin	32.54	Poor
Pandesara	41.14	Poor
Varachha	36.41	Poor
Kadodara	72.81	Fair
Palsana	65.44	Fair

Table 4 indicate that out of 10 sampling sites four sampling sites namely Bhatar, Citylight, Kadodara and Palsana is having fair water quality, which means water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. Three sampling sites namely Hajira, Piplod, Adajan is having marginal water quality, which means water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels. Three sampling sites Sachin, Pandesara and Varachha are having poor water quality as per CCME-WQI, which indicates that water quality is almost always threatened or impaired; conditions usually depart

from natural or desirable levels. Here we can see that not a single site is having good or excellent water quality.

In our statistical analysis out of 28 parameters 10 parameters were found statistically significant namely TDS, BOD, COD, Cl, Hardness, Na, Ca, Mg, TC and FC, which means water quality is significantly being affected by these10 variables.

Out of 28 variables only using statistically significant variables, Regression model was fitted for Water Quality Index (WQI). Backward regression analysis was done in which Hardness, COD, BOD variables were removed and TDS, Cl, Na, Ca, Mg and FC were used as explanatory variable to the WQI as dependent variable.

Here, the calculated p value 0.001 is less than alpha value (0.05), which implies that the group of explanatory variables shows a statistically significant relationship with the dependent variable. This means that the most affecting variables are TDS, Cl, Na, Ca, Mg and FC and first preference should be given to these variables to maintain the water quality. If the same situation remains as it is, then the Water Quality Index is suppose to be 67.539 with Standard Deviation 17.986 and minimum and maximum values will be 36.14 and 91.052 respectively.

4 Conclusion

From the present observations, it can be concluded that water quality of ground water of Surat City is under severe stress of pollution due to the unplanned industrialization and urbanization.

The water is not suitable for drinking purpose of human and domestic animals, washing or at some places for the industrial use also. In order to save these ground water resources from further deterioration, effective pollution control measures must be taken in the near future.

A government commitment is needed along with cohesive academic research centered on ground water pollution as a problem, so that its importance may be understood, and so that conservation as a principle may be accepted by administrators. The Water Quality Indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and water quality management department or section.

References

[1] Kudesia, V. P., *Water pollution*, Pragathi Prakashan, Meerut, India pp 1-12, 1980.

[2] Karnath, K. R., Hydrogeology. Tata McGraw Hill publishing company Ltd., New Delhi, 1989.

[3] APHA, Standard methods for the examination of water and waste water, *20th ed. American Public Health Assoc. Washington.* (1998).

[4] (CCME) Canadian Council of Ministers of the Environment. *Canadian Environmental Quality Guidelines.* Winnipeg, Manitoba (1999).

[5] Trivedi R.K. and Goel P.K., *Chemical and Biological methods for water pollution studies.* Environment Publications pp .215, 1986.
[6] BIS, *Standards for water for drinking and other purpose,* Bureau of Indian Standards, New Delhi, 1983.
[7] Moundiotiya C., Sisodia R., M. Kulshreshtha, and A.L. Bhatia. A case study of the Jamwa Ramgarh wetland with special reference to physical and chemical properties of water and its environs. Journal of Environmental Hydrology Vol. 12, Paper 24, 2004
[8] Shanthi. K, Ramasamy P., and Lashmanperumalsamy. *Hydrological study of Singanallur Lake at Coimbatore,* Nature Environment & Pollution Technology, 1(2), 97-101, 2002.
[9] ICMR, "Manual of standards of quality for drinking water supplies". Special report series No.44, 2nd edition, 1975.
[10] WHO, World Health Organization. *WHO Guidelines for Drinking Water Quality*. *2nd edn.* WHO, Geneva, 1995.