Assessment of Groundwater quality using Water Quality Index

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Abstract

Fifty sampling stations have been identified and water samples were collected from June to May 2008, to know the groundwater quality of Greater Visakhapatnam city using Water Quality Index. The samples were analyzed for the physico-chemical parameters like Temperature, pH, Conductivity, Total dissolved solids, Dissolved Oxygen, Hardness, Calcium, Magnesium, Alkalinity, Chloride and Nitrate. The range of Water Quality Index is 28 to 267. Sample stations 33, 42, 43, and 45-47 come under excellent water quality and 4, 11-14, 18, 21, 26-28, 31, 36, 37, 38, 40, and 44 belong good water quality. The sample stations 5-8, 15, 22, 23, 34, and 41 are poor water quality. Sample station 3 has very poor water quality. Salt water intrusion has also been assessed using various parameters. According to $Cl^-/(CO_3^{2-} + HCO_3^-)$ and TA/TH ratios, the sample stations 2 and 3 are not useful for human consumption.

Keywords: Ground Water, Water Quality Parameters, Water Quality Index, Salt Water Intrusion

1. Introduction

The ground water quality is normally characterized by different physico-chemical characteristics. These parameters change widely due to the various types of pollution, seasonal fluctuation, groundwater extraction, etc. Hence a continuous monitoring on groundwater becomes mandatory in order to minimize the groundwater pollution and have control on the pollution-caused agents.

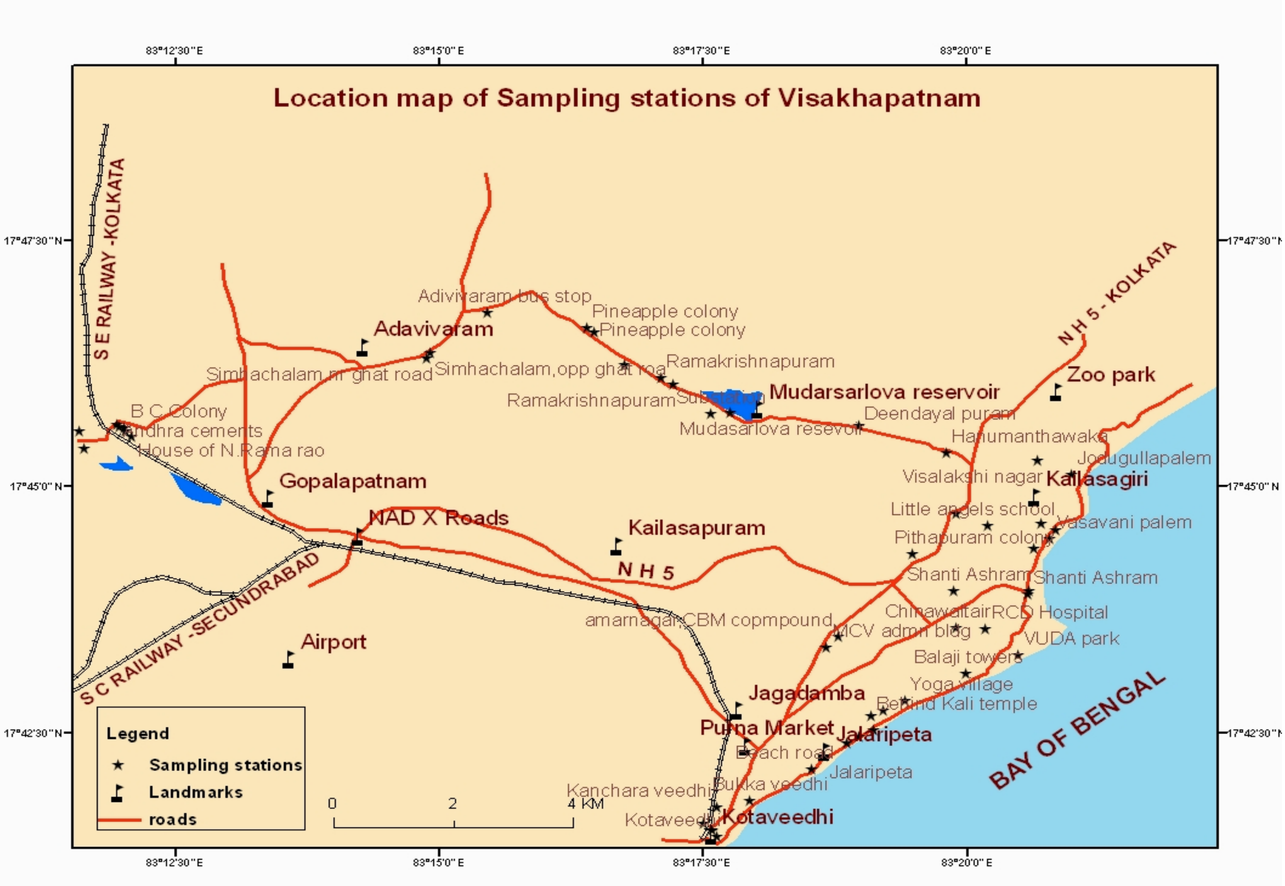
Visakhapatnam is a town started gaining importance when East India Company came here in 1682 A.D. It became municipality in 1858 A.D. The city is located on the east coast of India, abutting Bay of Bengal and located between the longitude 83°17’ and latitude 17°65’ (Fig. 1). The population of the city is 19,00,000. Visakhapatnam is the one of the fast developing cities in India. Day by day the population of the city is rapidly increasing, so for drinking and other regular activities the people are depending on ground water and extracted much ground water. Recently Visakhapatnam Municipal Corporation, adjoining Gajuwaka municipality and some suburban are merged together to form Greater Visakhapatnam Municipal Corporation (GVMC). In order to know the groundwater quality of the city, we have identified 48 sampling stations, in which 34 are bore wells, 14 are open wells.

The concept of Water Quality Index (WQI) to represent gradation in water quality was first proposed by Horten [1]. WQI indicates a single number like a grade that expresses the overall water quality at a certain area and time based on several water quality parameters. WQI reflects a composite influence of contributing factors on the quality of water for any water system [2]. WQI a well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. It thus, becomes an important parameter for the assessment and management of ground water [3,4]. Water quality of different sources has been communicated on the basis of calculated water quality indices [5,6].

Rao et al. applied the WQI in the assessment of ground water quality in Meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh, India [7]. Tyagi et al. used the WQI in the study of spatial and temporal water quality trends of the pristine river Kshipra, Madhya Pradesh [8]. WQI was used by Kakati and Sarma in the study of drinking water of Lakshimpur district, Assam [2]. The quality of ground water in Tumkur Taluk, Karnataka state, was assessed by Ramakrishnaiah et al. using

WQI [9]. Swarna Latha et al. used the WQI in water quality assessment at village level, S. Kota, Vizianagaram district [10]. In the assessment and mapping of water pollution indices in Municipal Corporation of Hyderabad, WQI was used by Asadi et al. [11,12].

Figure 1. Location map of sampling stations



2. Materials and Methods

Fifty sampling points (bore wells, open wells and two reservoirs) were selected from different locations in the study area. Sampling was done during 2007 June to 2008 May on monthly basis. Water samples from identified bore wells and open wells were collected in precleaned two liter polythene bottles and were analyzed for 11 parameters, viz., temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total alkalinity (TA), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), and nitrate (NO_3^-). The physico-chemical analysis was carried out as per the standard methods [13]. TDS is calculated indirectly from EC as 0.64×EC (µS/cm) [14]. The carbonate plus bicarbonate is calculated from Alkalinity as 1.31×Alkalinity [15].

3. Results and Discussions

3.1. Water Quality Index [9]

Three steps are followed to calculate WQI. In the first step each of the parameters has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purpose. A maximum weight of 5 has been assigned to nitrate due to its major importance in water quality assessment. In the second step, the relative weight is calculated from the following equation

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

where W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters. Calculated W_i values of the parameter are given in Table 1.

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

$q_i = (C_i – C_{io} / S_i - C_{io}) \times 100$

where C_i is the concentration of each chemical parameter in each water sample in mg/L, C_{io} is the ideal value of the parameter in pure water and S_i is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS. For pH, C_{io} is 7 and $q_i = (C_i – 7)/(S_i - 7)\times 100$. In the case of the remaining parameters the ideal value is 0.

Table 1. Relative Weight of Chemical Parameters

Chemical parameters	Indian standards	Weight	Relative weight (Wi)
pH	6.5-8.5	4	0.1818
Total hardness	300	2	0.0909
Calcium	75	2	0.0909
Magnesium	30	2	0.0909
Chloride	250	3	0.1363
TDS	500	4	0.1818
Nitrate	45	5	0.2272

For calculating the WQI, the sub index (SI) is first determined for each parameter, which is used to determine the WQI as per the following equations.

$SI_i = W_i \times q_i$,

$$WQI = \sum_{i=1}^{n} SI_i$$

SI_i is the sub index of the i^{th} parameter. The calculated WQI values are classified into five types as shown in Table 2.

Table 2. Water Quality Classification based on WQI value

WQI	Water quality
< 50	Excellent
50 - 100	Good
100 - 200	Poor
200 - 300	Very poor

The calculated WQI values are classified in to five types “excellent water” to “water unsuitable for drinking” (Table 2). To know the degree of linear relationship between any two parameters, as measured by the simple correlation coefficient (r) is presented in Table 3.

Inter seasonal variation of the WQI is in the range of 28 to 267 and 24% of water bodies are excellent in premonsoon and post monsoon seasons and 18% of water bodies are excellent in monsoon season. In premonsoon, monsoon and post monsoon seasons about 58%, 62%, and 60% of water bodies are in good quality respectively. 16%, 14%, and 12% of water bodies are poor water bodies in premonsoon, monsoon and postmonssoon seasons respectively. The remaining 2%, 6%, and 4% of water bodies are very poor water bodies in premonsoon, monsoon and post monsoon seasons respectively. In monsoon and post monsoon season 16% and 48% of water bodies are in excellent and good water bodies, respectively.

Table 3. Correlation matrix of various ground water parameters

	pH	Cond.	DO	Hard.	Ca^{2+}	Mg^{2+}	Alk.	NO_3^-	Cl^-	TDS
pH	1									
Cond.	0.18	1								
DO	0.39	-0.03	1							
Hard.	0.04	0.91	-0.01	1						
Ca^{2+}	0.03	0.88	0.01	0.96	1					
Mg^{2+}	0.05	0.81	-0.06	0.91	0.83	1				
Alk.	0.18	0.51	-0.04	0.34	0.27	0.37	1			
NO_3^-	0.09	0.59	0.30	0.56	0.53	0.41	0.15	1		
Cl^-	0.17	0.95	-0.02	0.86	0.87	0.80	0.35	0.46	1	
TDS	0.14	0.97	-0.10	0.94	0.91	0.87	0.56	0.53	0.93	1

The eight sample stations with sampling station #18, 35, 41, 44, 45, and 47-49 are in excellent water quality in all the seasons. About 21 sample stations with sample station numbers 1, 10-14, 16, 19-27, 37, 39, 40, 42, and 50 are good water bodies in all seasons. About four and one sample station with sample station numbers 5, 7, 9, 36, and 3 are poor water and very poor water bodies in all seasons respectively. The very poor water quality is due to the high WQI values in the parameters (Hardness, Calcium, Magnesium, Chloride, Nitrate and Total Dissolved Solids). The poor water quality is due to the high values of WQI in TDS, Nitrate and Chloride parameters. The excellent and good water bodies are useful for drinking and all purpose, but the poor water and very poor water bodies are not suggestible for use of regular human activities.

3.2. Assessment of Salt Water Intrusion

Salt water contamination may be identified by the relative concentration of some of the characteristic ions of sea water such as chlorides, sodium and magnesium. Revelle recommended the $Cl^-/(CO_3^{2-} + HCO_3^-)$ ratio as a criterion to evaluate the salt water intrusion [16]. The second parameter suggested for identification of salt water contamination is total alkalinity/total hardness ratio (TA/TH) [17]. An excess of TA over TH indicated the presence of sodium bicarbonate. In case waters show the existence of free sodium bicarbonate (TA/TH = 1), it may be presumed that the waters might not have been contaminated with sea water since the sea waters are full of sodium chloride and sulphates of calcium and magnesium. The third parameter that recommended for identification of salt water contamination is Ca^{2+}/Mg^{2+} ratio, since magnesium is present in seawater in much greater concentration than calcium. Ca^{2+}/Mg^{2+} value of seawater is 0.18. The fourth parameter is Cl^-/Na^+ ratio. In sea water Cl^- is the abundant ion. The Cl^-/Na^+ ratio in sea water is more than unity (1.17) [17]. However, these parameters are to be adjudged carefully in the light of variable country rocks which also contribute to the anomalies in the ratios. The degree of concentration is assessed by Simpson (1946) [18]. In the present study $Cl^-/(CO_3^{2-} + HCO_3^-)$ ratio values of 1.902, 1.604 and 1.616 are observed at sample station #2, 3, and 9. These sampling stations may be moderately contaminated ground water. If TA/TH ratio is equal to unity then there is no contamination. In the present study the sampling stations 4, 11-13, 18-21, 23-29, 31, 32, 33, 35, 38, 39, 42, 43, and 45-48 have above more than unity and the remaining have less than unity. These sampling stations are influenced by the geological factors (land and rocks). Hence they are showing less than one ratio value. The low value of Ca^{2+}/Mg^{2+} ratio (0.18) indicates the seawater contamination, but in the present study no sampling station is showing such a small value.

4. Conclusion

To know the ground water quality of selected areas in GVMC, we have identified 14 open wells, 34 bore wells, and two reservoirs. After analysis of various physico-chemical parameters, we observe the range of WQI from 28 to 267. The highest values of WQI are observed at sampling stations 2, 3 (> 200). The high value of WQI at these stations has been found to be mainly from the higher values of Hardness, Calcium, Magnesium, Chloride, Nitrate and Total dissolved solids. The ratio's ($Cl^-/(CO_3^{2-}$ $+HCO_3^-$ and TA/TH) also indicate the contamination of ground water with sea water. Hence these two sampling stations are not useful for human consumption.

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