

Ground Water Quality Assessment through WQIs

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Abstract

The large scale industrial growth has caused serious concerns regarding the susceptibility of groundwater contamination due to discharge the waste. So, it is necessary to access the quality of groundwater. Water Quality Indices aim at giving a single value to water quality of a source reducing numerous parameters into a simpler expression and enabling easy interpretation of monitoring data. In the present study, attempts are made to define bore well water quality in terms of different Water Quality Indices (WQIs). Water samples have been taken for 16 bore wells from Vishrambag area of Sangli. In the present work for calculating WQIs, 12 significant parameters have been considered Viz. pH, electrical conductivity, total dissolved solids, total alkalinity, and total hardness. In order to determine the potability of bore well water Indian Standard Drinking Water specification IS10500: 2012 has been adopted in the present study. The study of physicochemical and biological characteristics of the bore well water sample suggests that the bore well water is not suitable for drinking as it is. Particularly, treatments for hardness removal and disinfection are inescapable.

Keywords:WQI, bore well water, WAWQI, NSFQI, BCWQI, CCMEWQI.

Introduction

Recent research conducted showed that there is an increase in the demand for freshwater due to rapid growth of population as well as the accelerated pace of industrialization in the last few decades. This demand has led to the use of ground water not only for its wide spread occurrence and availability but also for its consistent good quality which makes it ideal supply of drinking water and today more than half the world's population depends on ground water for survival. But because of the large scale industrial growth has caused serious concerns regarding the susceptibility of groundwater contamination due to discharge of waste materials. Waste materials near factories are subjected to reaction with percolating rain water and therefore reach the aquifer system and as such degrade the groundwater quality. Contaminants also find their way into ground water through activities like seepage of municipal landfills, septic tank effluents etc. [2, 10]. So, it is necessary to assess the quality of ground water.

Water Quality Index (WQI) is an important technique for demarcating groundwater quality and its suitability for drinking purpose. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. WQI utilizes the water quality data and helps in the modification of the policies, which are formulated by various environmental monitoring agencies. It has been realized that the use of individual water quality variable in order to describe the water quality for common public is not easily understandable. WQI has the capability to reduce the bulk of the information into a single value to express the data in a simplified and logical form. It takes information from a number of sources and combines them to develop an overall status of a water system. They increase the understanding ability of highlighted water quality issues by the policy makers as well as for the general public as users of the water resources [10].

Initially, WQI was developed by Horton (1965) in United States by selecting 10 most commonly used water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. and has been widely applied and accepted in European, African and Asian countries. The assigned weight reflected significance of a parameter for a particular use and has considerable impact on the index. Furthermore, a new WQI similar to Horton's index has also been developed by the group of Brown in 1970.

According to previous study different National and International Agencies involved in Water Quality assessment and pollution control defines water quality criteria for different uses considering different indicator parameters, so there are numerous WQIs specific to a region [2]. Some of the important Water Quality Indices which are generally used: Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) and British Columbia Water Quality Index (BCWQI) [10]. There is no single universally accepted WQI. So, the various Water Quality Indices need to be assessed and it is necessary to develop the most suitable WQI which can be used widely. The present work is proposed to assess Bore well water quality. The attempts are made here to define Bore well water quality in terms of different Water Quality Indices and also to find inferences of these WQIs.

Material and Methods

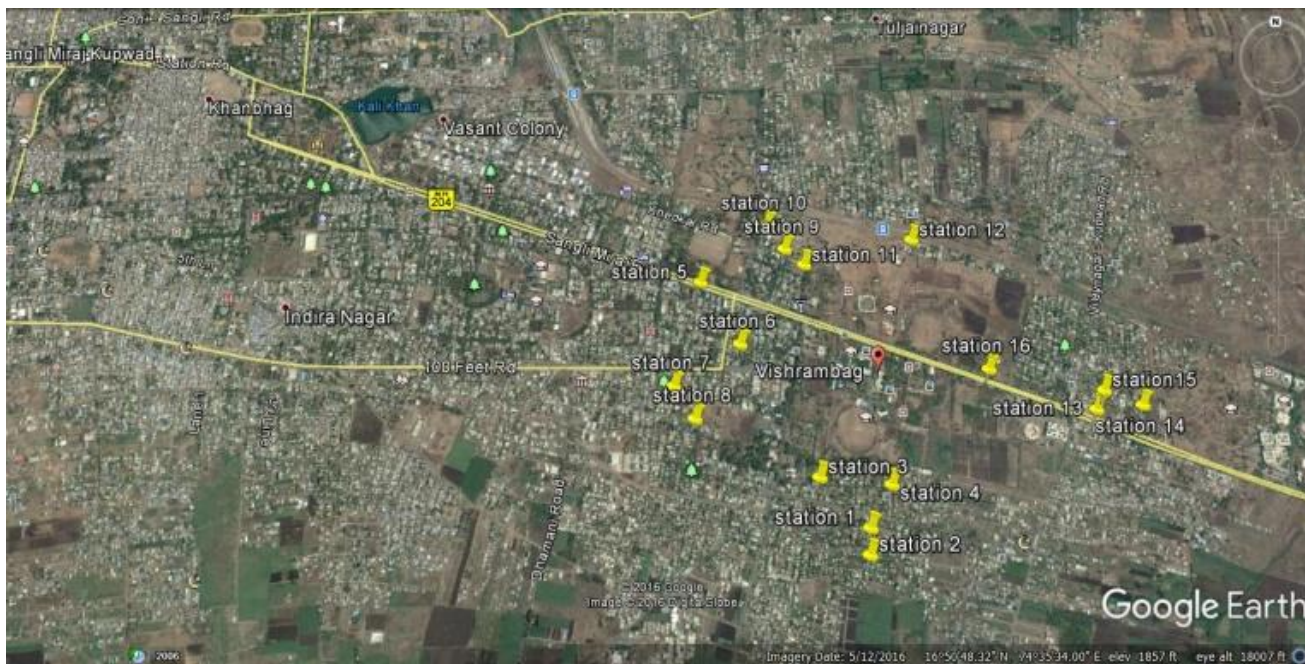


Figure 1: Study area and Sampling locations in Vishrambag, Sangli.
 (Source: Google Earth)

To evaluate nature of the ground water in the Vishrambag area, water samples were collected from bore wells at sixteen different sites-four sites each in north, south, east and west, to cover the whole area. The samples were analyzed as per standard methods for Physico-Chemical and biological parameters namely: pH, conductivity, total alkalinity, total hardness, calcium, magnesium, turbidity, total dissolved solids, chloride, fecal coliforms and nitrate.

Sampling and testing plan

Grab sampling method is adopted for study. Plastic containers are used for collection and storage of water. All samples are stored in 1 lit capacity containers. Container is washed twice with water from respective sampling location. Container is washed once with mild acid and thrice with tap water after use. Sampling is done for winter season, Sampling duration – 1 P.M to 5 P.M. Samples were analyzed as per standard methods for physico-chemical and bacteriological parameters. Results are compared with standards prescribed by IS 10500:2012.

Methods

Weighted Arithmetic Water Quality Index (WAWQI)

Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables [12, 13]. The method has been widely used by the various scientists and the calculation of WQI was made by using the following equation:

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$Q_i = 100 \left[\frac{V_i - V_o}{S_i - V_o} \right]$$

Where,

V_i = Estimated concentration of ith parameter in the analyzed water

V_o = Ideal value of this parameter in pure water

$V_o = 0$ (except for pH =7.0 and DO = 14.6 mg/l)

S_i = Recommended standard value of ith parameter

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{S_i}$$

Where,

K = Proportionality constant and can also be calculated by using the following equation:

$$K = \frac{1}{\sum \frac{1}{S_i}}$$

The rating of water quality according to this WQI is given below:

Table 1: Water Quality Rating

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

National Sanitation Foundation Water Quality Index (NSFWQI)

A usual water quality index method was developed by paying great rigor in selecting parameters, developing a common scale and assigning weights. The attempt was supported by the National Sanitation Foundation (NSF) and therefore as NSFWQI in order to calculate WQI of various water bodies critically polluted. The proposed method for comparing the water quality of various water sources is based upon nine water quality parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids. The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by,

$$WQI = \sum_{i=1}^n Q_i W_i$$

Where,

Q_i = Sub-index for ith water quality parameter

W_i = Weight associated with ith water quality parameter;

n = Number of water quality parameters.

Table 2: Water quality rating according to NSFWQI

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

British Columbia Water Quality Index (BCWQI)

British Columbia water quality index was developed by the Canadian Ministry of Environment in 1995 as increasing

index to evaluate water quality. This index is similar to Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) where water quality parameters are measured and their violation is determined by comparison with a predefined limit. It provides possibility to make a classification on the basis of all existing measurement parameters.

To calculate final index value the following equation is used:

$$BCWQI = 100 - \left(\sqrt{\frac{F_1^2 + F_2^2 + \left(\frac{F_3^2}{3}\right)}{1.453}} \right)$$

The number 1.453 was selected to give assurance to the scale index number from zero to 100. It is important to note that repeated samplings and increasing stations increase the accuracy of British Columbia index. Disadvantages of this method are that this index does not indicate the water quality trend until it deviates from the standard limit and due to usage of maximum percentage of deviation.

Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI)

The Canadian Council of Ministers of the Environment (CCME) has developed a Water Quality Index (WQI) to simplify the reporting of complex and technical water quality data. The CCME WQI is a science-based communication tool that tests multi-variable water quality data against specified water quality benchmarks determined by the user. The WQI mathematically combines three measures of variance (scope, frequency and magnitude) to produce a single unit less number that represents overall water quality at a site relative to the benchmark chosen. The end result is a single unit-less number from 0 to 100, where a score of 100 indicates that all variables were at or below the selected benchmarks during all monitoring time. The Canadian Water Quality Index (CWQI) equation is calculated using three factors as follows:

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

Where: F_1 = Represent Scope: The percentage of variables that exceed the guideline or the number of variables whose objectives are not met.

$$F_1 = [\text{No. of failed variables} / \text{Total no of variables}] * 100;$$

F_2 Represent Frequency: The percentage of individual tests within each variable that exceeded the guideline or the frequency by which the objectives are not met

$$F_2 = [\text{No of failed tests} / \text{Total no of tests}] * 100;$$

F_3 Represent Amplitude: The extent to which the failed test exceeds the guideline or the amount by which the objectives are not met

Excursion = [Failed test value/Objective]-1

$$F_3 = \left[\frac{nse}{0.01 nse + 0.01} \right]$$

Normalized sum of excursions (*nse*) = $\sum_{i=1}^n \frac{\text{excursions}}{\text{No of tests}}$

The constant, 1.732, is a scaling factor (square root of three) to ensure the index varies between 0 and 100.

Results

The physico-chemical properties obtained for each sample are presented in Table 3 &4.

Table 3: Characterization of water samples

Samples	pH	Conductivity (µS/cm)	Total Solids (mg/L)	Dissolved Oxygen (% Saturation)	Turbidity (NTU)	Nitrate (mg/L)
Acceptable Limit	6.5-8.5	-	-	-	1	45
S1	7.03	1860	1418	56.46	6.31	3.1
S2	6.93	160	1214	89.39	1.62	0
S3	7.14	3800	2838	88.77	8.73	0
S4	7.0	1780	1360	59.81	1.46	0.2
S5	7.0	2600	1724	83.01	1.25	8.3
S6	6.8	1470	1018	97.06	1.31	3.7
S7	7.02	1900	1558	90.79	1.61	5.0
S8	7.1	1070	768	71.51	1.09	0
S9	7.2	1150	820	76.50	1.23	1.8
S10	7.13	1200	854	76.20	1.56	1.7
S11	7.10	1110	790	77.90	2.29	1.9
S12	7.04	1370	992	77.90	1.02	1.9
S13	6.9	2700	1944	49.32	1.98	0.9
S14	7.01	1760	1320	60.02	1.10	2.9
S15	7.01	2200	1434	68.92	3.25	2.8
S16	7.13	1520	1563	72.79	1.62	0.4

Table 4: Characterization of water samples

Samples	Phosphate (mg/L)	Alkalinity (mg/L)	Chlorides (mg/L)	Hardness (mg/L)	Most Probable Number (No./100mL)	Total Dissolved Solids (mg/L)
Acceptable Limit	-	200	250	200	0	500
S1	0.36	460	241.05	625	23	1395
S2	0.97	235	221.16	460	17	1245
S3	0.98	565	313.11	700	22	2850
S4	0.82	345	318.08	1035	13	1335
S5	0.80	330	437.36	1480	23	1950
S6	0.73	285	164.01	805	26	1102
S7	0.75	265	305.65	1010	21	1425
S8	0.96	260	101.88	625	17	802
S9	0.82	275	106.27	680	13	862
S10	0.84	270	110.12	720	11	900
S11	0.88	260	126.73	570	8	832
S12	0.80	315	171.46	1335	12	1027
S13	0.76	440	342.93	1020	9	2025
S14	0.78	325	300.68	800	7	1320
S15	0.74	325	337.96	790	4	1650
S16	0.74	290	236.07	980	6	1140

Quality of water according to Weighted Arithmetic Water Quality Index (WAWQI):

Table 5: Quality of water according to WAWQI

Sr. No.	Samples	WQI	Status
1	S1	1361	*US
2	S2	864	*US
3	S3	1428	*US
4	S4	672	*US
5	S5	1127	*US
6	S6	1267	*US
7	S7	1050	*US
8	S8	840	*US
9	S9	663	*US
10	S10	585	*US
11	S11	481	*US
12	S12	608	*US
13	S13	511	*US
14	S14	377	*US
15	S15	338	*US
16	S16	355	*US

*US = Unsuitable for drinking purpose

Discussion

Based on the results it was found that most of the parameters exceeds the acceptable limit according to IS: 10500-2012. Hardness and Total Dissolved Solids are much higher than others. According to WAWQI the bore well water is not suitable for drinking purpose while according to NSFQWI the bore well water quality is medium and good. For BCWQI and CCMEWQI one year data is required. Work is still in progress, so these indices are not calculated here.

Conclusions

In NSFQWI the parameters like hardness and total dissolved solids are not considered, that's why it shows medium and good water quality. But for ground water hardness and total dissolved solids are important parameters and in this case they are much higher than acceptable limit. So here NSFQWI can't be applied to determine ground water quality.

As most of the parameters exceed the acceptable limit these water samples are not fit for drinking without proper treatment.

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Quality of water according to National Sanitation Foundation Water Quality Index (NSFWQI):

Table 6: Quality of water according to NSFQWI

Sr. No.	Samples	WQI	Water Quality
1	S1	67	Medium
2	S2	74	Good
3	S3	73	Good
4	S4	68	Medium
5	S5	68	Medium
6	S6	72	Good
7	S7	71	Good
8	S8	71	Good
9	S9	73	Good
10	S10	74	Good
11	S11	75	Good
12	S12	74	Good
13	S13	66	Medium
14	S14	69	Medium
15	S15	73	Good
16	S16	75	Good

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