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Water quality indices as indicators for potable water

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ABSTRACT

The present study intended to calculate water quality indices (WQIs) for six different areas of Batlagundu, Dindigul District in order to ascertain the quality of water for public consumption and other domestic purposes. This paper deals with the study on the influence of environmental parameters on the water quality. In this study, five WQIs have been determined on the basis of 24 physico-chemical parameters. The parameters, namely, temperature, pH, sulphate, potassium, nitrate, phosphate, DO, BOD and COD were within the permissible limits of BIS and WHO while other parameters such as turbidity, total dissolved solids, electrical conductivity, total hardness, total alkalinity, calcium, magnesium, chloride, nitrite, fluoride, sodium and iron were found to exceed the limit. Results of WQIs indicated that the quality of water was deteriorated by natural and anthropogenic sources. The aforesaid study showed that the groundwater of the above-selected sampling sites was not safe for human consumption but could be used for domestic purpose after purification.

Keywords: Water quality index; Batlagundu; Quality rating; Physico chemical parameters

1. Introduction

Water is a dynamic renewable resource. Its availability with good quality and adequate quantity is very important for human life and other purposes. India is endowed with rich and vast diversity of natural resources, "water" being one of them. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries [1]. There is something very beautiful about water, not just aesthetically, but also intellectually. Water is not just the mirror of the environment, it also reflects the society around it and accumulates all the "sins" of humanity. Today, water demand for domestic, agricultural and industrial purposes is mostly fulfilled from ground water than that of surface water. The ground water is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste causes the ground water to become polluted and create health problems.

In developing countries, about 1.8 million people, mostly children, die every year as a result of water related diseases [2]. Therefore, the water quality is considered as an important factor to judge the environment changes which are strongly associated with social and economic development [3]. Water quality can be defined as a conventional ensemble of physical, biological and bacteriological features that are

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expressed as values and allow for the framing in a certain category, which expresses the possibility of its anthropogenic usage to meet a certain purpose. The water quality is difficult to evaluate for large number of samples each containing concentrations for many parameters [4].

Water quality index (WQI) is a very useful and efficient method for assessing the suitability of water quality. The WQI is a dimensionless number with values ranking between 0 and 100. This numerical index can be used as a management tool in water quality assessment. The WQI first developed by Horton [5] is basically a mathematical means of calculating a single value from multiple test results. After Horton, a number of workers all over the world developed WQI based on rating of different water quality parameters. Basically, WQI attempts to provide a mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality [6]. The different statistical approaches were followed for analysing water quality data based on rank order of observations and factor analysis [7,8]. After a detailed literature review and a keen study of the different types of water quality indices (WQIs), the one which is most commonly used and perceived is discussed here.

In general, WQIs incorporate data from multiple water quality parameters into a mathematical equation that rates the quality of groundwater through this study.

2. Area of study and sampling sites

Batlagundu is a block of Dindigul District. It is geographically located at Longitude and Latitude is 77˚45´ 33.84´´E and 10˚9´ 55.80´´N with an average elevation of 320 m (1,049 feet). In the 2001 India census, Batlagundu had a population of 22,007. The main occupation of this study area is agriculture. The sources of water supply in the area are hand pumps, bore holes and dug wells. The precipitation which is the sole source of ground water recharges in the study area is very low due to less rain fall. The area is very humid (86%) and warm with an average temperature 22˚C. In order to determine WQI of ground water, the samples were collected from six sampling stations of Batlagundu. The description of sampling sites is given below.

2.1. Station 1 (S_1)

Nilakottai is located 10 km away from study area. Longitude and latitude of this station is 77˚51´ 11.60´´E and 10˚9´ 53.01´´N, respectively. As of 2001 India census, Nilakottai had a population of 19,630. There are many industries like food processing industries, textile mills, perfume industries and spinning mills around Nilakottai. Groundwater sample (S_1) is collected near perfume industry.

2.2. Station 2 (S_2)

Mallanampatti is located 6 km away from study area. It is located at 77˚45´ 40.24´´E longitude and 10˚ 10´ 0.32´´N latitude. Groundwater sample (S_2) is collected near Primary Health Centre.

2.3. Station 3 (S_3)

Usilampatti road, Anna nagar is located 2 km away from study area. It is located at 77˚45´ 41.99´´E longitude and 10˚11´ 9.98´´N latitude. Groundwater sample (S_3) is collected near land fill.

2.4. Station 4 (S_4)

Anna nagar is located 1 km away from study area. It is located at 77˚45´ 42.39´´E longitude and 10˚ 11´ 10.23´´N latitude. Groundwater sample (S_4) is collected near drainage.

2.5. Station 5 (S_5)

Middle street, Batlagundu is located at77˚45´ 33.84´´E longitude and 10˚9´ 55.80´´N latitude. Groundwater sample (S_5) is collected from residential area.

2.6. Station 6 (S_6)

Periyakulam road, Batlagundu is located 0.5 km away from study area. It is located at longitude 77˚45´ 33.99´´E and 10˚9´ 56.05´´N latitude. Groundwater sample (S_6) is collected near agriculture field.

Six stations are chosen for sample collection in the study area as described in Fig. 1.

3. Materials and methods

In order to determine WQI of ground water, the samples are collected from six sampling stations of Batlagundu for three months period in triplicates. These samples are collected in cleaned and well-dried brown glass bottles with necessary precautions. These bottles are labelled with respect to collecting points, date and time in order to avoid any error between collection and analysis. The sampling stations

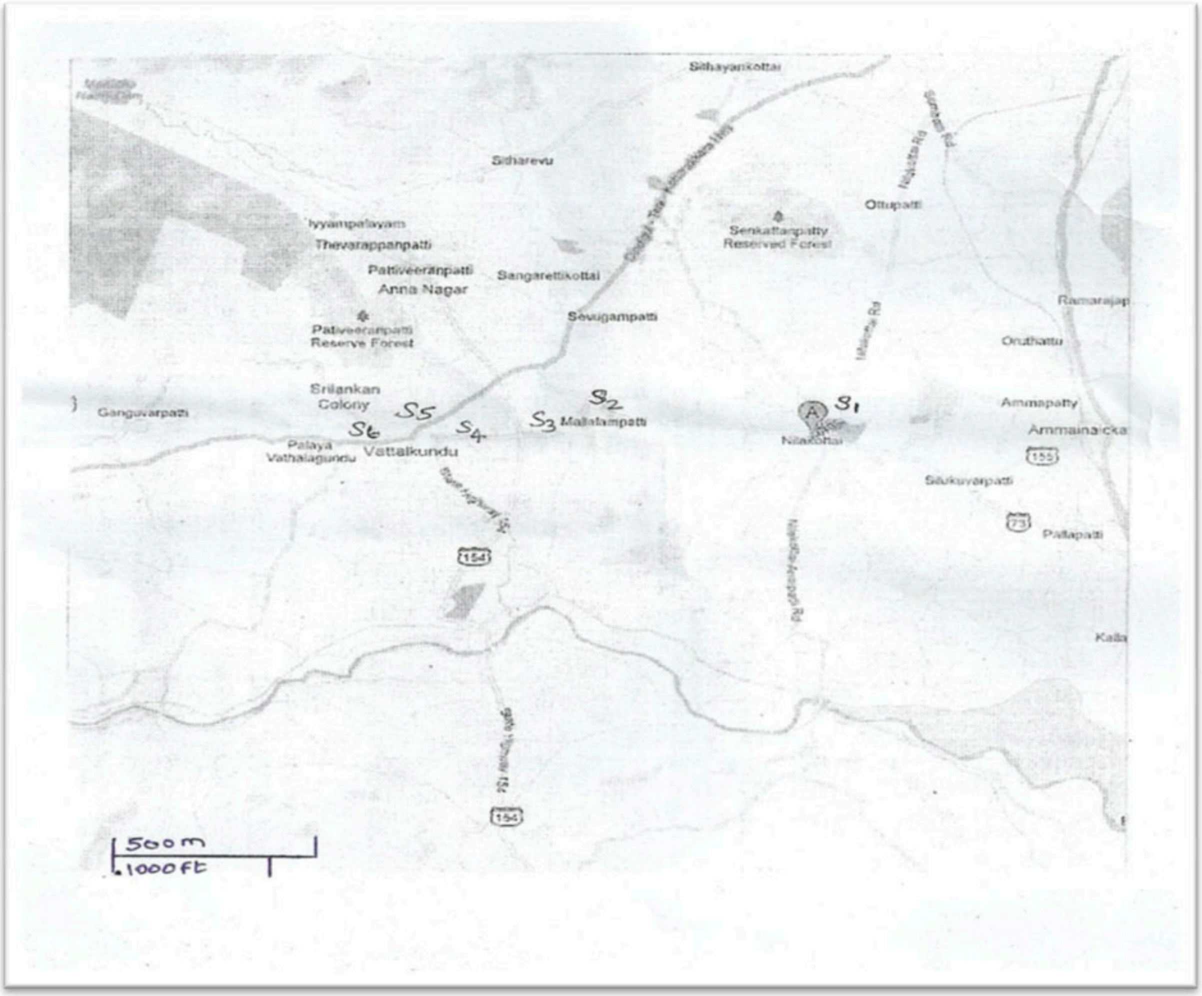

Fig. 1. The map of study area. S_1—Nilakottai, S_2—Mallanampatti, S_3—Anna Nagar, Usilampatti road, S_4—Anna nagar, Batlagundu, S_5—Middle street, Batlagundu, S_6—Periyakulam road Batlagundu.

are selected according to the point and non-point pollution sources mainly from agricultural and minor industrial activities. The collected samples are stored in an icebox and brought to laboratory for determining both physical and chemical parameters. All the chemicals used were AR grade of pure quality. Double distilled water was used for the preparation of all the reagents and solutions. Glass wares were cleaned with HCl followed by distilled water. The water samples were analysed for various water quality parameters as per standard procedures [9–11] given in Tables 1 and 2. The experimental values were compared with standard values recommended by [2,12] are given in Table 3.

4. Water quality index (WQI)

The WQI is a mean to summarise large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner. The WQI has been considered to give criteria for water classification based on the use of standard parameters for water characterisation [13–20]. WQI is a single value indicator to the water quality. It integrates the data pool generated after collecting due weights to the different parameters. WQI is calculated from the point of view of the suitability of ground water for human consumption.

4.1. Method: 1

WQI was calculated for assessing the suitability of water for biotic communities and also for drinking purposes. It was done by considering eight important physico-chemical properties using [21,22] standards.

In order to calculate WQI, eight important parameters such as pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), total hard-

Table 1
Water quality parameters units and analytical methods used

S. no.	Parameters	Abbreviation	Units	Analytical methods	Instruments
1.	Temperature	Temp.	℃	Instrumental	Mercury thermometer
2.	Colour	Colour	Pt-Co scale	Visual comparison method	–
3.	Turbidity	Turbidity	NTU	Nephelometric method	Nephelometer
4.	Odour	–	–	–	–
5.	TDS	TDS	mg/L	Filtration and gravimetric method	Temperature controlled oven
6.	EC	EC	μS/cm	Instrumental	Electrometric
7.	pH	pH	pH unit	Instrumental	pH meter
8.	Total hardness	Hardness	mg/L	Digital titrimetric	EDTA titration
9.	Total alkalinity	Alkalinity	mg/L	Digital titrimetric	Neutralising with standard HCl
10.	Calcium	Ca	mg/L	Digital titrimetric	EDTA titration
11.	Magnesium	Mg	mg/L	Digital titrimetric	EDTA titration
12.	Chloride	Cl	mg/L	Digital titrimetric	Argentometric titrimetric method
13.	Sulphate	SO_4	mg/L	Colorimetric turbidimetric method	UV—vis spectrophotometer
14.	Nitrate	NO_3	mg/L	Colorimetric PDA method	UV—vis spectrophotometer
15.	Nitrite	NO_2	mg/L	Diazotisation method	UV—vis spectrophotometer
16.	Fluoride	F	mg/L	Colorimetric SPANDS method	UV—vis spectrophotometer
17.	Sodium	Na	mg/L	Flame photometric method	Flame photometer
18.	Potassium	K	mg/L	Flame photometric method	Flame photometer
19.	Iron	Fe	mg/L	Colorimetric method	UV—vis spectrophotometer
20.	Ammonia	NH_3	mg/L	Nesslerisation method	UV—vis spectrophotometer
21.	Phosphate	PO_4	mg/L	Colorimetric stannous chloride method	UV—vis spectrophotometer
22.	DO	DO	mg/L	Titrimetric method	WinklersIodometric method
23.	Biochemical oxygen demand	BOD	mg/L	5 days incubation, 20℃	Winkler azide method
24	Chemical oxygen demand	COD	mg/L	Potassium dichromate oxidation (open reflux, titrimetric)	Dichromate method

ness, calcium (Ca), magnesium (Mg) and total alkalinity have been selected. Factors which have higher permissible limits are less harmful because they can harm quality of ground water when they are present in very high quantity. So weightage of factor has an inverse relationship with its permissible limits.

$$W_i \propto \frac{1}{V_i} \text{ or } W_i = \frac{k}{V_i} \quad (1)$$

where k = constant of proportionality, W_i = unit weight factor, V_i = maximum permissible limits as recommended by Indian council of Medical Research/Public Health Environmental engineering Organisation.

Value of k was calculated as $K = \frac{1}{\sum_{i=1}^{8} \frac{1}{V_i}}$ (2)

where

Table 2
Physico chemical changes of ground water samples collected from six different sampling stations

Parameters	BIS	WHO	S_1	S_2	S_3	S_4	S_5	S_6
Temperature in ℃	–	40 ± 5	22.8	22.6	22.5	22.3	22.0	22.9
Colour (Hazen unit)	5.0	15 TCU	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Turbidity (NTU)	5.0	5.0	2.0	5.0	1.0	4.0	6.0	3.0
Odour	Unobjectionable	–	None	None	None	None	None	None
TDS (mg/L)	500	1,000	701	1,472	1,610	1,453	2,130	1,216
EC (μmho/cm)	–	300	1,030	2,164	2,300	2,130	3,132	1,788
pH	6.5–8.5	6.5–8.5	7.9	8.03	7.7	8.1	7.7	7.9
Total hardness (mg/L)	300	500	252	384	900	360	660	288
Total alkalinity (mg/L)	200	–	300	260	400	260	296	232
Calcium (mg/L)	75	–	56	80	200	77	136	61
Magnesium (mg/L)	30	30	27	44	96	40	77	33
Chloride (mg/L)	250	250	96	470	525	450	780	370
Sulphate (mg/L)	200	400	49	119	106	146	125	116
Nitrate (mg/L)	45	10	19	13	10	14	20	10
Nitrite (mg/L)	0.06	–	0.32	0.27	0.3	0.24	0.38	0.22
Fluoride (mg/L)	1.0	1.5	0.6	2.0	0.4	0.4	0.4	0.6
Sodium (mg/L)	–	200	104	272	198	264	336	240
Potassium (mg/L)	–	200	26	78	12	66	84	60
Iron (mg/L)	0.3	0.3	0.71	0.52	0.5	0.61	0.98	0.94
Ammonia (mg/L)	–	–	0.73	0.45	0.3	0.57	0.86	0.36
Phosphate (mg/L)	–	5.0	0.59	0.80	1.0	0.69	0.98	0.69
DO (mg/L)	–	>5	5.5	5.2	6.3	5.6	6.3	6.0
BOD (mg/L)	–	5	2.0	2.0	2.3	2.0	2.0	1.0
COD (mg/L)	–	20	5.0	6.0	6.9	5.0	6.0	4.0

Table 3
Calculated values of BCWQI

Term of the index	Value	Rating of water quality
Scope F_1	58.33	Marginal. Water quality is frequently endangered or deteriorated. Conditions often deviate from natural or desirable levels
Frequency F_2	50.00	
nse	0.736	
Amplitude F_3	42.39	
BCWQI	53.76	

$$\sum_{i=1}^{8}\frac{1}{V_i}=\frac{1}{V_{i(\mathrm{pH})}}+\frac{1}{V_{i(\mathrm{TDS})}}+\frac{1}{V_{i(\mathrm{Hardness})}}+\frac{1}{V_{i(\mathrm{Ca})}}+\frac{1}{V_{i(\mathrm{Mg})}}+\frac{1}{V_{i(\mathrm{Total\ alkalinity})}}+\frac{1}{V_{i(\mathrm{DO})}}+\frac{1}{V_{i(\mathrm{EC})}} \tag{3}$$

The weightage of all the chemical factors were calculated on the basis of this equation.

$$\mathrm{WQI}=W_i\times V_r \tag{4}$$

i.e. WQI is equal to the product of rating (V_r) and unit weight (W_i) of all the factors.

$$W_i\times V_r=W_{i(\mathrm{pH})}\times V_{r(\mathrm{pH})}+W_{i(\mathrm{TDS})}\times V_{r(\mathrm{TDS})}+W_{i(\mathrm{Hardness})}\times V_{r(\mathrm{Hardness})}+W_{i(\mathrm{Ca})}\times V_{r(\mathrm{Ca})}+W_{i(\mathrm{Mg})}\times V_{r(\mathrm{Mg})}+W_{i(\mathrm{Total\ alkalinity})}\times V_{r(\mathrm{Total\ alkalinity})}+W_{i(\mathrm{DO})}\times V_{r(\mathrm{DO})}+W_{i(\mathrm{EC})}\times V_{r(\mathrm{EC})} \tag{5}$$

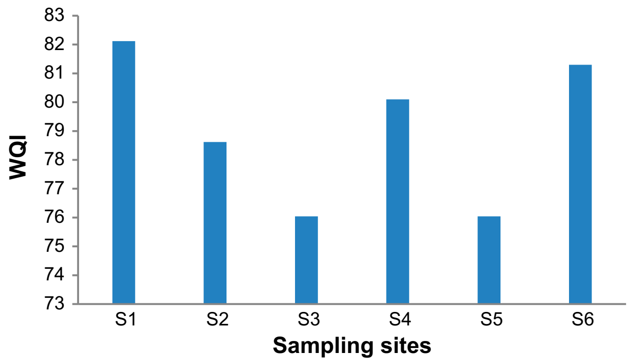

Fig. 2. WQI of different sampling sites at Batlagundu.

The results of WQI using above-mentioned equation based on Tiwari and Mishra [23] is shown in Fig. 2.

4.2. Method 2

4.2.1. Method: 2a

WQIs are calculated in two steps. The raw analytical results for the selected water quality variables having different units of measurements are transformed into unit less sub-index values [15]. This can be done by transforming each parameter into 0 to 100 scale [13] using sub-index curves. The sub-index curves may be linear, nonlinear, segmented-linear and segmented nonlinear [24]. These sub-indices are then averaged (typically using some type of averaging function) to give a WQI value [16] applying suitable weighting factors that reflects the importance of each parameter as an indicator of the water quality [13]. To get the access of water quality using minimum number of parameters, [13] used DO, turbidity and conductivity and calculated the minimum WQI.

$$\mathrm{WQI} = K\sum_{i=1}^{3}\frac{C_i P_i}{3} \tag{6}$$

The different parameters that were used in the evaluation process, as well as their relative weights and the normalisation factors were adopted from various literatures: [13,16,25–27].

4.2.2. Method: 2b

Five important parameters are chosen to calculate WQI such as temperature, pH, DO, TDS and EC.

$$\mathrm{WQI} = K\sum_{i=1}^{5}\frac{C_i P_i}{5} \tag{7}$$

4.2.3. Method: 2c

The equation for the WQI is proposed by Pesce and Wunderlin [13] is:

$$\mathrm{WQI} = K\frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \tag{8}$$

where, n is the total number of parameters, C_i is the value assigned to parameter i after normalisation and P_i is the relative weight assigned to a parameter that has the most importance for aquatic life preservation (e.g. DO) and value of 1 assigned to the parameter that has a smaller impact (e.g. chloride). K is a subjective constant, the value of which ranges from 0.25 (for highly contaminated water) to 1 (for water without apparent contamination). Thus, in this work, such as in other studies reported [27], the WQI was calculated using $k = 1$ in all the cases to account only for the variation due to measured parameters as:

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \tag{9}$$

The WQI calculated for all sampling sites using Eqs. (6) and (7) were found to be excellent and for the Eq. (9) is found to be medium. The WQI values for all the three equations are compared and it is given in Fig. 3

4.3. Method: 3

The WQI equation was developed in two steps. The first was ranking water quality variables according to their significance. The variables included in the calculation of WQI are DO, total phosphates, turbidity and specific conductivity. Second, several forms were tested to give DO the highest weight followed by total

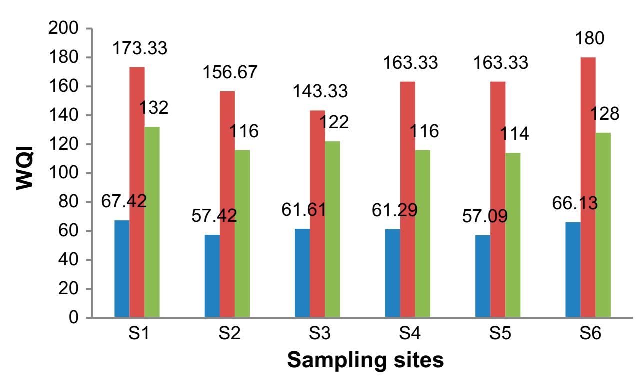

Fig. 3. Comparison of WQIs using method 2.

phosphorus. The per cent saturation reflects the temperature effect. Turbidity and specific conductance were given the least influence. A final form was selected that keeps the index in a simple equation and a reasonable numerical range. The logarithm was used to give small numbers that are easily used by the management decision-makers, the stake-holders and general public as well.

In the final form, the powers of the variables were chosen for the WQI based on the effect of each variable on water conditions. For example, higher values of total phosphorus will be very harmful for health and aquatic life. The forms of total phosphorus in the index formula were chosen to give strong responses to these effects.

On the other hand, turbidity and specific conductance have linear effects, which are less sensitive for changing the values of the variables, in the index formula. This is because; turbidity would not be very dangerous unless it is associated with a higher level of disease causing micro-organisms that will make faecal coli form higher as well in the formula.

To calculate this index, there is no need to standardise the variables. The calculations are further simplified through the elimination of sub-indices (percent of ideal situation of each variable). The index was proposed by Said et al. [28] is:

$$\mathrm{WQI} = \log\left[\frac{(\mathrm{DO})^{1.5}}{(3.8)^{\mathrm{TP}}(\mathrm{Turb})^{0.15} + 0.14(\mathrm{SC})^{0.5}}\right] \tag{10}$$

where DO is the dissolved oxygen (% oxygen saturation), Turb is the turbidity (nephelometric turbidity units [NTU]), TP is the total phosphates (mg/L)and SC is the specific conductivity in (MS/cm at 25˚C).

Fig. 4 shows the values of WQI using Eq. (10) proposed by Said et al. [28].

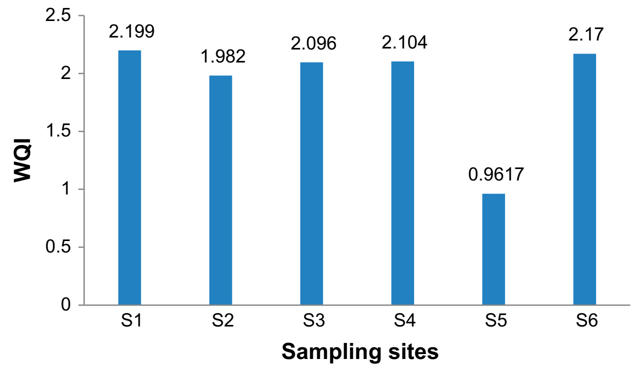

Fig. 4. Results of WQI for all six sampling sites.

4.4. Method: 4

An index is a mean device to reduce a large quantity of data down to a simplest form [29]. In India, the NSF WQI is being used by CPCB, with a slight modification in weights [30,31].

The NSF WQI is expressed mathematically as:

$$\text{NSF WQI} = \sum_{i=1}^{p} W_i I_i \tag{11}$$

where I_i is the sub index of ith parameter, W_i = weight (in terms of importance) associated with water quality parameter and P = number of water quality parameters. NSF WQI and modified weights by CPCB as depicted in Fig. 5.

4.5. Method: 5

4.5.1. British Columbia water quality index (BCWQI)

BCWQI was developed by CCME [32] as increasing index to evaluate water quality. This index is similar to CCME WQI 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 parameters. The BCWQI model consists of three measures of variance from selected water quality objectives (scope; frequency; amplitude).

Scope (F_1):	The number of variables whose objectives are not met.
Frequency (F_2):	The frequency by which the objectives are not met.
Amplitude (F_3):	The amount by which the objectives are not met.

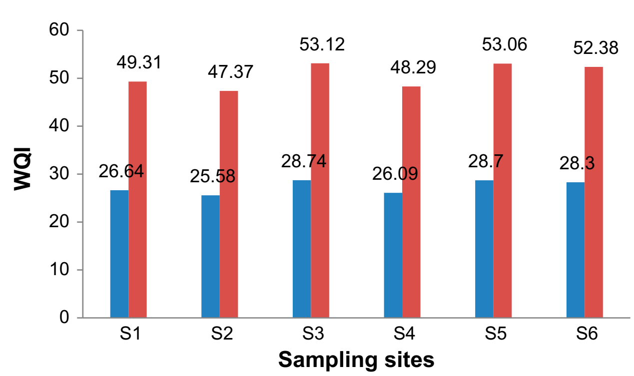

Fig. 5. Comparison of NSF WQI and CPCB WQI.

The measure for scope (F_1) is calculated as follows:

$$F_1 = [\text{number of failed variables/total number of variables}] \times 100 \tag{12}$$

The measure for frequency (F_2) is calculated as follows:

$$F_2 = [\text{number of failed tests /total number of tests}] \times 100 \tag{13}$$

The measure for amplitude (F_3) is calculated as follows:

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows:

When the test value must not exceed the objective:

$$\text{Excursion}_1 = [\text{failed test value/objective}] - 1 \tag{14}$$

For the cases in which the test value must not fall below the objective:

$$\text{Excursion}_2 = [\text{objective/failed test value}] - 1 \tag{15}$$

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}}{\text{No. of tests}} \tag{16}$$

$$F_3 = \left[\frac{\text{nse}}{0.01\text{nse} + 0.01}\right] \tag{17}$$

To calculate final index value, the following equation is used:

$$\text{BCWQI} = \left[\frac{\sqrt{F_1^2 + F_2^2 + \left(\frac{F_3}{3}\right)^2}}{1.453}\right] \tag{18}$$

The number 1.453 was selected to give assurance to the scale index number from zero to 100. It is important to note that respected 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, it cannot determine the number of with drawls above the maximum limit of standard.

The BCWQI is calculated using 12 parameters are tabulated in Table 3.

5. Results and discussion

In this study, the physico-chemical parameters such as temperature, pH, sulphate, nitrate, phosphate, DO, BOD and COD are within the permissible limits described by WHO, BIS standards [2,12]. But other parameters such as turbidity, TDS, EC, total hardness, total alkalinity, calcium, magnesium, chloride, nitrate, nitrite, fluoride, sodium and iron were found to exceed the limits. The turbidity recorded in all sampling sites were found to be within the limits except S_5 indicates the turbidity is associated with more suspended materials and bacteriological contamination. EC of water is direct function of its TDS [33]. Hence, it is an index to represent the total concentration of soluble salts in water [34]. In present investigation, the EC of the ground water samples varied between 1,030–3,132 μS/cm. The permissible limit for TDS for drinking water is 500 mg/L. The range of TDS levels in the study area is 701–2,130 mg/L. The highest concentration of TDS was found to be 2,130 mg/L at the sampling site S_5 due to dense residential area and due to intensive irrigation in that area. High concentrations of TDS in ground water affect persons who are suffering from kidney and heart diseases [35].

The hardness values for the study area were observed as high for the sampling sites S_2(384), S_3(900), S_4(360) and S_5(660) than the permissible limits of BIS [12] specification. Hardness below 300 mg/L is considered potable, but beyond this limit produces gastrointestinal irritation [22]. Higher concentration of calcium and magnesium in the sampling sites S_2, S_3, S_4 and S_5 also reflected the concentration of total hardness in the same sampling sites. The range of total alkalinity in all the sampling sites was 232–400 mg/L. These values exceed the permissible limit of BIS. The hydroxides, carbonates and bicarbonates released from limestone, sedimentary rocks, carbonate rich soils, cleaning agents and domestic solid waste contribute to high alkalinity [36]. Chloride concentration was observed as high for all sampling sites except S_1. Soil porosity and permeability has a key role in increasing the concentration of chloride. The fluoride content in this study area ranged from 0.4 to 2.0. The sampling site S_2 was found to be higher concentration than the permissible limit of BIS [12] causes fluorosis. Sodium concentration was observed as high for the sampling sites S_2, S_4, S_5 and S_6 due to high rate of mineralisation in the sediments, increasing sodium into the nutrient pool there by making more sodium to solubilise. The permissible limit of iron is 0.3 mg/L in drinking water is defined by WHO, BIS standards [2,12]. Iron is an essential trace element for the human body. However, a high concentration of iron in water stains laundry and plumbing fixtures. In present investigation, iron concentration was found to be high for all the sampling sites.

WQI is a composite assessment of different parameters which determine whether the water can be used for drinking purposes. The Water quality index calculated using [20,21] gave the following results. The DO level is mostly responsible for the variations occurring in the WQI values. In present investigation, DO values was fluctuated between 5.2 and 6.3 which altered rating factor and had direct implication on the WQI values. The WQI values for the sampling sites ranged from 76.04 to 82.12. Higher values of WQI indicates that the water is very much clear and free from any impurities and showed that the water is in good condition to support the biotic communities. The similar observation has been made previously by Akkaraboyina and Raju [37]. The WQI was used to classify overall water quality as excellent, good, medium, bad and very bad using method 2. The water quality of all six sampling sites was excellent and the highest score was obtained using Eq. (6) and Eq. (8), while the water quality was medium using Eq. (9). From this, it is concluded that analysis of minimum number of parameters (3 and 5) for all sampling sites showed as excellent and maximum number of parameters (17) showed as medium water quality. Our results are in concordance with those obtained by Jafari et al. [38].

The formula proposed by Said et al. [28] gives a values of WQI for the sampling sites S_1(2.199), S_3(2.096), S_4(2.104) and S_6(2.17) which indicates that the water is good in just one simple step. For other sampling sites S_2(1.982) and S_5(0.9617) indicates that the water is marginal and poor, respectively. The WQI values ranged from 3 to 2, the water is good and it can be used for drinking purpose, and less than 2, the water cannot be used for certain beneficial uses such as drinking and other domestic purposes. This index can be used to assess water quality for general uses. However, it cannot be used in making regulatory decisions. From Fig. 5, it was observed that for all six sampling sites, the WQI was found to exist between 25.58 and 28.70 and the sampling sites were described as bad to very bad according to NSF WQI, and for the same sampling sites for CPCB WQI was found to have variation. The sampling sites S_3, S_4, S_5 and S_6 were described as medium to good, whereas the other sampling sites such as S_1 and S_2 were consid-

Table 4
Consolidated WQI results

Method	S1		S2		S3		S4		S5		S6	
	WQI	Quality	WQI	Quality	WQI	Quality	WQI	Quality	WQI	Quality	WQI	Quality
1	82.12	Good	78.62	Good	76.04	Good	80.10	Good	76.04	Good	81.30	Good
2a	67.42	Medium	57.42	Medium	61.61	Medium	61.29	Medium	57.09	Medium	66.13	Medium
2b	173.33	Excellent	156.67	Excellent	143.33	Excellent	163.33	Excellent	163.33	Excellent	180	Excellent
2c	132	Excellent	116	Excellent	122	Excellent	116	Excellent	114	Excellent	128	Excellent
3	2.199	Acceptable	1.982	Marginal	2.096	Marginal	2.104	Marginal	0.9617	Poor	2.17	Marginal
4 (NSF WQI)	26.64	Bad to very bad	25.58	Bad to very bad	28.74	Bad to very bad	26.09	Bad to very bad	28.70	Bad to very bad	28.30	Bad to very bad
4 (CPCB)	49.31	Bad	47.37	Bad	53.12	Medium to good	48.29	Bad	53.06	Medium to good	52.38	Medium to good
5						53.76- Marginal						

ered as bad. BCWQI is used for the determination of overall water quality of study area. The analysis of BCWQI rated that the water quality for drinking water as marginal and indicates water quality is frequently endangered or deteriorated. This may reflect the discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial effluents and agricultural runoff.

6. Conclusion

The values of WQI for all the five methods are consolidated in Table 4. WQIs are valuable tools to communicate information and they need reinforcement and guidance on specific uses. The water quality rating at all the sampling sites clearly showed that the status of the water body was degraded and unsuitable for drinking purpose. It has been concluded that discharging of domestic and other anthropogenic activities was the main factors for contaminating the study area.

7. Application of the present work

This study throws light on the ground water quality status in different areas of Batlagundu. WQI may be used as a tool to convey the information to the public and governmental decision-makers regarding the quality of water and to take up necessary measures so as to maintain the quality and life of the ground water.

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