Analysis of ground water quality using water quality index: A case study of Dehradun District, Uttarakhand, India

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The water quality index (WQI) is an important parameter for determining the drinking water quality for the end users. The study for the same has been carried on the groundwater by collecting 16 groundwater samples from 4 blocks during pre-monsoon (April- May) and post-monsoon season (October-November) of the year 2018 of Dehradun District, India. In order to develop WQI the samples were subjected to a comprehensive physicochemical and biological analysis of 11 parameters such as pH, calcium, magnesium, chloride, nitrate, sulphate, total dissolved solids, fluorides, turbidity, total hardness and alkalinity. Geographical information system has been used to map the sampling area. The coordinates in terms of latitude and longitude of the sampling locations were recorded with the help of global positioning system. In this study 81% water samples were found good quality and 19% water samples falls under oderately poor category. The water quality index ranges from 01.07 to 94.58. The higher WQI values during premonsoon season have been inferred owing to higher calcium and magnesium concentrations assessed during the study. Therefore there is a need of more treatment before usage and also required to protect that area from contamination.

Keywords: Ground Water, Water Quality Index, GIS, Physico Chemical Analysis

1. Introduction

Groundwater is a good sources of fresh water supply throughout the world. The ground water quality is still important to the community, therefore it is important to ensure its high quality at all time so that the consumer health is not compromised. Groundwater resources are affected in principle by three major activities. First of these activities is excessive use of fertilizers and pesticides in agricultural areas. The second one is untreated/partially treated wastewater to the environment. Finally, excessive pumping and improper management of aquifers result**[1-3]**. According to WHO organization, about 80% of all the diseases in human beings are caused by water. High rates of mortality and morbidity due to water borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater**[4]**. The quality of water is defined in terms of its physical, chemical and biological parameters. Its development and management plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development. In India, most of the population is dependent on groundwater as the only source of drinking water supply**[5-6]**. WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy-makers. The advent of satellite technology and geographical information system (GIS) has made it very easy to map of the sampling area. GIS has wide application in water quality mapping using which informative and user-friendly maps can be obtained**[7- 8]**. Hence, water quality deterioration has become amajor concern related to water supply particularly in capital city Dehradun of Uttarakhand state to cater its mass population along with floating tourists. The quality related issues are most prominent especially during summer season owing to drying of drinking water sources and rainy season due to high turbidity. The water quality index (WQI) is an index that reflects the composite influence of a variety of water quality parameters**[9-20]**. Several water quality indexes namely Weighted Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI), etc are being used for suitability assessment of water sources for drinking purpose **[21-22]**.The WAWQI is commonly used for water quality evaluation of various water bodies to check the suitability for drinking purpose. Several studies on the evaluation of water quality for drinking purpose have been carried out by many researchers. However, none of these studies give a comprehensive picture for major drinking water sources of all the developmental blocks of

Dehradun district of Uttarakhand, India about suitability of their water quality for drinking purpose with effect of seasonal variation. Therefore, frequent water quality monitoring of drinking water sources of Dehradun, which is also capital city of Uttarakhand is essential in order to protect its mass population from waterborne diseases and to develop appropriate preventive measures, in case of contamination.

2. Study area

DehraDun, is the interim capital of Uttarakhand, a state in India. Located in the Garhwal region, it lies 236 kilometres(147 mi) north of India's capital Dehli . Dehradun is located in the Doon Valley on the foothills of the Himalayas nestled between the river Ganges on the east and the river Yamuna on the west. It is located at a latitude of 29 °58' N and 31°2'N and longitudes 77° 34' E and 78° 18'E . This district consists of six community development blocks — Vis, Chakrata, Kalsi, Vikasnagar, Sahaspur, Raipur and Doiwala — 17 towns and 764 villages. Out of these 746 villages are inhabited; 18 are uninhabited with a population of 1, 698,560. The total area of Dehradun Disrict is about 3,088 square kilometer with 1,477 square kilometer of forest. The water supply in the area is done through overhead tanks, tube wells, trunks and other supply lines.

3. Sampling and analysis

3.1 Collection of Water Samples

A total of 4 blocks namely Sahaspur, Vikasnagar, Raipur and Doiwala of Dehradun district were selected for the present study. In each block, 4 drinking water sources were identified for assessment of suitability of their drinking water. The details of water sampling sites, sampling site code, their GPS co-ordinates and elevation above mean sea level of each of the 16 sampling sites (D-1 to D-16) are given under **Table 1**. The water samples were collected through grab sampling method during pre-monsoon (April- May) and post-monsoon season (October-November) of the year 2018. All water samples were taken in clean and sterilized Tarson (high-density polyethylene) bottles after 2-3 times rinsed with the water samples. The collection of water samples, their preservation and transportation to the laboratory were carried out as per APHA**[23]** protocols and methods. Water samples for the analysis of various metals/ metal ions were collected in acid leached sterilized Tarson bottles and preserved by adding ultrapure grade nitric acid (2 ml/L) to reduce the pH below 2. All collected water samples were stored in ice box and brought to the laboratory by maintaining the cold chain at 4°C and analyzed within specified period as per **APHA [23]** guidelines.

3.2 Analysis Procedure of Water Samples

The analyses of collected water samples for various physico-chemical characteristics were carried out by adopting APHA**[23]** and BIS**[24]** protocols and methodologies. A total of eleven water quality parameters were analyzed and used for the determining weighted arithmetic WQI values at each drinking water source. Two water quality parameters namely pH and turbidity were analyzed on-site, while remaining nine variables viz. total hardness, alkalinity, chloride, Total Dissolved Solids (TDS), calcium, magnesium, sulphate, nitrate and fluoride were analyzed in the laboratory.

3.3 Interpretation of Water Quality Data

The main purpose of WQI is to change the complex water quality data set into an understandable and usable information by which common people can know the current status of water sources in a particular region**[25-27]**. The WQI is an important data assessment tool for the conversion of complex hydro-chemical data set into simplest and usable form to effectively convey the information to general public, policy makers and decision makers. It is an indicator of water quality, which reveals the composite influence of number of water quality parameters and is useful in determining suitability of water of any water body for drinking purpose. The water quality can be classified into various grades, which indicate the status of water quality. The concept of WQI for usefulness of representing the grading of water quality was first time introduced by Horton**[28]**. The WQI denotes a single number, which expresses the overall condition of water quality in any water body. In present study, the weighted arithmetic WQI was calculated to assess the suitability of 16 drinking water sources of 4 blocks of Dehradun on the basis of water quality data of 11 parameters. The WQI values were calculated by adopting the procedures and equations described in various studies **[29-33]**. The weighted arithmetic index method was used for calculation of WQI by using the following equation (1) **[31, 34, 10, 35]**:

$$WQI = \Sigma\, WiQi / \Sigma\, Wi \quad \ldots\ldots(1)$$

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

$$Wi = k / Si \quad \ldots\ldots(2)$$

Where, k is proportionality constant and can be calculated as under:

$$k = \frac{1}{\sum \frac{1}{Si}}$$

Si = Standard permissible limit of i^{th} water quality parameter.

The quality rating (Qi) of equation (1) is calculated as given under:

$$Qi = 100\,[(Vo - Vi / Si - Vi)] \quad \ldots\ldots(3)$$

Where, Vi = Ideal value of i^{th} water quality parameter in pure water and

Vo = Observed value of i^{th} water quality parameter.

All ideal values are taken as zero for drinking water except pH=7.0. The description of water quality status according to WQI is given in **Table 2 [36]** with different grades A-E based on WQI values ranging from 0 to >100 for describing suitability of water for drinking purpose.

4. Results and Discussion

The obtained water quality data was applied for the calculation of WQI. Based on calculated weighted arithmetic WQI values during pre and post monsoon seasons **(Tables 3 & 4)**, the suitability of 16 water sources of 4 blocks of Dehradun district for drinking purpose during pre and post monsoon seasons of the year 2018 and Eleven Physicochemical parameters is discussed here under in detail:

4.1 WQI Values during Pre-monsoon Season

Most of the drinking water sources were found to be suitable due to low calculated WQI values during the study of pre-monsoon season. Out of 16 drinking water sources of Dehradun district, 11 were found suitable owing to 'A' grade (WQI<25) and thus, status of water quality was described as excellent. Besides, two sampling sites D-10 and D- 11 were found with 'B' grade. Hence, the water quality status of these sources was defined as good. Similarly, two study sites namely D-12 and D-14 were evaluated to have 'C' grade due to having higher WQI values e.g. 68.37 and 64.49, respectively and therefore, categorized with poor water quality. Besides, only one sampling site i.e. D-8 had highest WQI value (94.58), thus its water quality was found to be very poor for drinking purpose. With respective contribution of four grades. The higher WQI values and hence, very poor quality of drinking water at D-8 site may be ascribed due to higher content of calcium and magnesium during the study period. The possible cause of the occurrence of higher iron and turbidity in surface water sources may be the discharge of industrial and consumer wastes. Besides these activities, mixing of untreated as well as partially treated domestic and municipal sewages also contributed up to large extent. In addition to these human driven activities, acidic rain can also breakdown the soil, which causes land erosion and subsequently releases metals/ metal ions adjacent water bodies viz. in streams, lakes and rivers **[37-39]**.

4.2 WQI Values during Post-monsoon Season

Contrary to the obtained results of WQI values of post-monsoon season to pre-monsoon season, all the WQI values were found to be lower (WQI<25). Therefore, all 16 water sources were graded 'A' and their water quality was explained as excellent for drinking purpose. Among these 16 water sources, D-5 site has recorded lowest WQI value (1.08) and highest WQI as 4.25 was found at D-16 site.

The overall results of WQI during pre and post-monsoon seasons of 2018 clearly indicate the suitability of almost all analyzed 16 water sources for drinking and domestic purposes.

4.3 Physicochemical Parameters

4.3.1 pH

It plays an important role in clarification process and disinfection of drinking water. For effective disinfection with chlorine, the pH should preferably be less than eight, however, lower-pH water (<7) is more likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking water and adverse effect on its taste and appearance. Bureau of Indian Standard (BIS) has prescribed permissible limit of pH to be 6.5–8.5. The pH value of groundwater samples in the present study has been analysed and it lies in the range 7.13–8.18.

4.3.2 Turbidity

Recent research establishes a correlation between gastro-intestinal infections with high turbidity and turbidity events in distribution. The turbidity of the collected samples has been observed in the range 0.16–2.33 NTU. BIS has prescribed 1 NTU as the acceptable limit and 5 NTU as the permissible limit in absence of alternate source of drinking water. In the present study, all of the samples were well within the acceptable limit.

4.3.3 TDS

The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent (less than 300 mg/l), good (300–600 mg/l), poor (900–1,200 mg/l) and unacceptable (>1,200 mg/l). BIS has prescribed 500 mg/L as the acceptable limit and 2,000 mg/L as the permissible limit for TDS for the water to be used for drinking purpose. In present study, the TDS concentration of analysed samples lies in the range of 168–1470 mg/L .

4.3.4 Total hardness

In fresh water sources, hardness is mainly due to presence of calcium and magnesium salts. Temporary hardness more than 200 mg/L as $CaCO_3$ may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. Water with hardness less than 100 mg/l may, in contrast, have a low buffering capacity and will be more corrosive for water pipes. BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total hardness in absence of alternate source of drinking water. The hardness of groundwater samples in the study area is found to be in the range 58 – 672 mg/L as $CaCO_3$. The hardness value is found to be 672 mg/L as Ca CO3 which is exceeding the permissible limit of 600 mg/L.

4.3.5 Calcium

Analysis of calcium has also been carried out in all the samples in present study. The BIS limit for calcium is 75 mg/l as acceptable limit and 200 mg/L as permissible limit for drinking water. The concentration of all the samples is well within the permissible limit of 200 mg/l. However, the concentration of magnesium in sample number D-8 is found to be 352.5 mg/L which is greater than the permissible limit.

4.3.6 Magnesium

Magnesium is another important parameter that has been analysed in all the samples taken in the present study. The BIS limits the magnesium concentration of 30 mg/l as acceptable value and 100 mg/l as a permissible value for drinking water. . Only 75 % of the total samples has been found to be within the acceptable limit. However, the concentration of magnesium in sample number D-8 is found to be 258.7 mg/l which is greater than the permissible limit prescribed by BIS.

4.3.7 Alkalinity

Alkalinity in the water may be due to hydroxides, carbonates and bicarbonates. BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total alkalinity as $CaCO_3$ in absence of alternate source of drinking water. In present study, the alkalinity of all samples lies between 106 and 221 mg/l. sample number D-12 is found to be 221 mg/l which is greater than the permissible limit prescribed by BIS for water used for drinking purpose.

4.3.8 Chlorides

Some common chloride compounds found in natural water are sodium chloride (NaCl), potassium chloride (KCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). Taste thresholds for the chloride anion depend on the associated cations and the concentration ranges from 200 to 300 mg/l for sodium, potassium and calcium chloride. Based on taste threshold, BIS has prescribed 250 mg/l as the acceptable limit and 1,000 mg/l as the permissible limit for chloride. Chloride level in 87.5 % samples was well within the acceptable limit and chloride level in all the samples were within permissible limit prescribed by BIS.

4.3.9 Sulphate

The most common form of sulphur in well-oxygenated water is sulphate. The presence of sulphate in drinking water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste thresholds have been found to range from 250 mg/l for sodium sulphate to

1,000 mg/L for calcium sulphate. BIS has prescribed 200 mg/l as the acceptable limit and 400 mg/L as the permissible limit. Sulphate concentration of groundwater samples in the study area lies in the range of 14 mg/l –386 mg/l. Sulphate concentration in all the samples is found to be within the acceptable limit prescribed by BIS for drinking water.

4.3.10 Nitrate

Nitrate (NO_3) is found naturally in the environment and is an important plant nutrient. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation. The presence of nitrate in drinking water is a potential health hazard when present in large quantities. The combination of nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic. The maximum allowable nitrate concentration as per BIS for drinking water is 45 mg/L as NO_3. The concentration of nitrate in groundwater samples of the study area ranges between 2.2 and 23.8 mg/l and is found to be well within the desirable limit prescribed by BIS.

4.3.11 Fluoride

Fluoride is found in all natural type of waters at different concentrations. The fluoride concentration in water is limited by fluorite solubility, so that in the presence of 40 mg/L calcium it should be limited to 3.1 mg/L. It is the absence of calcium in solution which allows higher concentrations to be stable. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis. BIS has prescribed 1 mg/l as the acceptable limit and 1.5 mg/l as the permissible limit for fluoride. The fluoride concentration of all groundwater samples in present study is in the range 0–1.20 mg/l . It is found that Fluoride concentration in 93% of total samples is well within the acceptable limit prescribed by BIS.

5. Conclusion

The water quality of drinking water sources on the basis of Water Quality Index (WQI) by analyzing physico-chemical characteristics of capital of Uttarakhand, Dehradun has been determined during pre and post monsoon seasons of the year 2018. Present study was carried out to assess the suitability of drinking water sources of Dehradun for drinking purpose on the basis of analyzed water quality data. Out of analyzed 16 drinking water sources of 4 developmental blocks of Dehradun district during pre-monsoon season, 11 were found excellent owing to lower WQI values and thus, water quality was graded as ‘A’. Whereas, two sites were found with ‘B’ grade i.e. good water quality. However, two study sites were classified as ‘C’ grade and categorized under poor water quality. Moreover, only one sampling site i.e. D-8 has recorded highest WQI value (94.58), thus its water quality was found to be very poor for drinking purpose. Contrary to this, all analyzed drinking water sources during post-monsoon season had observed low WQI values, which signify excellent water quality and grade ‘A’. On the basis of combined results during pre and post monsoon seasons of 2018, it is inferred that except D-8 site, and D-12 and D-14 (with precaution) rest of the drinking water sources can be used for supply of drinking water to local population. The rain water harvesting structures should be installed to restore the ground water aquifers for improvement of ground water resources in order to maintain the quality and quantity of ground water reservoir and thus diluting the higher concentration of chemical constituents and dissolved salts. Public awareness program should be begun to enhance the knowledge and awareness to save water pollution on human being around their dweller.

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Table 1: Description of Drinking Water Sites of Dehradun during Pre and Post Monsoon Seasons, 2018

S.N.	Block	Sampling site	Code of Sampling Sites	Latitude	Longitude	Elevation above Mean Sea Level (m)
1	Sahaspur	Manaksidh	D-1	30°17'22.2"	077°55'07.3"	590
2		JeevaRadi (Main Tubewell)	D-2	30°17'55.1"	077°56'12.1"	572
3		Malam	D-3	30°17'41.0"	077°53'56.4"	591
4	Vikasnagar	Shankarpur	D-4	30°23'23.6"	077°49'13.9"	480
5		Jasee wala	D-5	30°25'14.5"	077°74'64.1"	456
6		Babughad	D-6	30°27'55.0"	077°45'583"	461
7		Lachman pur	D-7	30°28'28.5"	077°46'51.1"	466
8		Mahuwala	D-8	30°29'14.5"	077°48'49.6"	484
9	Raipur	Kasherwala	D-9	30°27'44.8"	077°47'58.6"	688

10	Doiwala	Upper Badrish Colony	D-10	30°18’26.6”	078°04’14.7”	651
11		Vani Vihar	D-11	30°19’11.5”	078°04’25.2”	665
12		Sanjay Colony	D-12	30°18’12.0”	078°03’44.1”	639
13.		Dandi	D-13	30°10’42.3”	078°13’44.7”	565
14.		Raipur	D-14	30°10’53.7”	078°12’42.5”	559
15.		Ghanuled	D-15	30°10’34.0”	078°12’37.6”	374
16.		Missarwala Khurd	D-16	30°10’58.3”	078°07’40.5”	474

Table 2: Standard Rating of Water Quality as per WQI Values for Determining Suitability for Drinking Purpose

S.N.	WQI Classification	Water Quality Grading	Water Quality Rating
1.	0-25	A	Excellent
2.	26-50	B	Good
3.	51-75	C	Poor
4.	76-100	D	Very Poor
5.	Above 100	E	Unsuitable for Drinking Purpose

Table 3: Calculated WQI Values of 16 Drinking Water Sites of Dehradun during Pre-Monsoon Season, 2018

S.N.	Block	Code of Sampling Sites	WQI Specification	Calculated WQI Value	Water Quality Grading	Water Quality Status
1	Sahaspur	D-1	0-25	11.48	A	Excellent
2		D-2	0-25	15.69	A	Excellent
3		D-3	0-25	14.68	A	Excellent
4		D-4	0-25	10.93	A	Excellent
5	Vikasnagar	D-5	0-25	10.61	A	Excellent
6		D-6	0-25	05.48	A	Excellent
7		D-7	0-25	17.83	A	Excellent
8		D-8	76-100	94.58	D	Very Poor
9	Raipur	D-9	0-25	01.07	A	Excellent
10		D-10	26-50	26.66	B	Good
11		D-11	26-50	33.35	B	Good
12		D-12	51-75	68.37	C	Poor
13.	Doiwala	D-13	0-25	03.48	A	Excellent
14.		D-14	51-75	64.49	C	Poor
15.		D-15	0-25	06.49	A	Excellent
16.		D-16	0-25	19.36	A	Excellent

Table 4: Calculated WQI Values of 16 Drinking Water Sites of Dehradun during Post-Monsoon Season, 2018

S.N.	Block	Code of Sampling Sites	WQI Specification	Calculated WQI Value	Grading	Description of Water Quality Status
1	Sahaspur	D-1	0-25	02.28	A	Excellent
2		D-2	0-25	01.62	A	Excellent
3		D-3	0-25	02.06	A	Excellent
4		D-4	0-25	02.69	A	Excellent
5	Vikasnagar	D-5	0-25	01.08	A	Excellent
6		D-6	0-25	01.99	A	Excellent
7		D-7	0-25	02.49	A	Excellent

8	Raipur	D-8	0-25	02.47	A	Excellent
9		D-9	0-25	01.98	A	Excellent
10		D-10	0-25	02.48	A	Excellent
11		D-11	0-25	03.14	A	Excellent
12		D-12	0-25	03.24	A	Excellent
13.	Doiwala	D-13	0-25	02.14	A	Excellent
14.		D-14	0-25	02.25	A	Excellent
15.		D-15	0-25	03.75	A	Excellent
16.		D-16	0-25	04.25	A	Excellent