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Suitability of drinking water sources of developmental blocks of Dehradun using Water Quality Index (WQI)

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Abstract

To ensure safe water supply in accordance with meeting out quality criteria for drinking and domestic needs, the present study was undertaken to assess the suitability of 32 drinking water sources of 4 developmental blocks of Dehradun for drinking purpose during pre and post-monsoon seasons of the year 2017. The obtained water quality data of drinking water sources was further applied for the calculation of weighted arithmetic Water Quality Index (WQI). Most of the water sources during pre-monsoon season were graded as 'A' with good quality due to having low WQI values. However, two sites were found of 'B' class, another two were classified as 'C' grade owing to higher WQI values and thus, categorized as having poor water quality. One sampling site was recorded with highest WQI value (92.32) and its water quality was found very poor for drinking purpose. During post-monsoon season, all analyzed water sources showed low WQI values, which indicates 'A' class i.e. excellent water quality. The higher WQI values during pre-monsoon season have been inferred owing to higher calcium, magnesium and iron concentrations assessed during the study.

Keywords: WQI, Pre-monsoon, Post-monsoon and Dehradun.

1. Introduction

The consumption of safe drinking water provides survival as well as life support to the human and living organisms for growth, while poor quality of water leads to adverse health effects. The water quality of an aquatic ecosystem depends on physical, chemical and biological characteristics of its surrounding environment **[1-2]**. If once the water quality of a water body degrades, then it is very difficult to retain its quality. The water quality assessment is an effective tool to get the critical information about natural or anthropogenic processes occurring near the region **[3]**.

Various anthropogenic factors like population growth, urbanization, industrialization and advanced agricultural practices are responsible for the deterioration in water quality. The water quality of available water sources is continuously being depleted due to intensification of such unplanned and unmanaged human driven activities **[4-7]**.

The population of Dehradun district of Uttarakhand, India is facing the problem of drinking water scarcity due to increased population, civilization and industrialization **[5, 8]**. Besides water quantity, the quality is also being depleted during distribution system of water supply due to malfunctioning of treatment plants, lack of advanced treatment technologies, unplanned developmental activities, application of inorganic fertilizers, leakage from old pipes and huge quantities of municipal solid waste. In addition to these issues, seasonal fluctuation, erosion, slope factor, open defecation, abundance of calcium and magnesium rich rocks, etc. are also responsible for deterioration of water quality in the region. Their entry into adjacent surface and ground water bodies might indicate the improper discharge of toxic pollutants and pathogenic micro-organisms **[9]**. Hence, water quality deterioration has become a major 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 **[10-21]**. The WQI is one of the most effective tools being used in getting information about the water quality for drinking purpose to the concerned departments, policy makers and decision makers **[22]**. 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.

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. Materials and Methods

2.1 Study Area

A total of 4 blocks namely Sahaspur, Vikasnagar, Raipur and Doiwala of Dehradun district were selected for the present study. In each block, 8 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 32 sampling sites (D-1 to D-32) are given under **Table 1**.

2.2 Collection of Water Samples

The water samples were collected through grab sampling method during pre-monsoon (April- May) and post-monsoon season (October-November) of the year 2017. 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.

2.3 Analysis Procedure of Water Samples

The analyses of collected water samples for various physico-chemical characteristics were carried out by adopting BIS **[24]** and APHA **[23]** 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 iron were analyzed in the laboratory.

2.4 Interpretation of Water Quality Data

2.4.1 Water Quality Index (WQI). 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 32 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 **[29-30, 17, 31-33]**. 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:

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

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.

3. 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 32 water sources of 4 blocks of Dehradun district for drinking purpose during pre and post monsoon seasons of the year 2017 is discussed hereunder in detail:

3.1 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 32 drinking water sources of Dehradun district, 27 were found suitable owing to 'A' grade (WQI<25) and thus, status of water quality was described as excellent. The WQI values fluctuated between 2.44 at site D-28 and 18.72 at D-32 site among 27 water sources. Besides, two sampling sites D-20 and D-21 were found with 'B' grade. Hence, the water quality status of these sources was defined as good. Similarly, two study sites namely D-23 and D-26 were evaluated to have 'C' grade due to having higher WQI values e.g. 65.94 and 65.95, respectively and therefore, categorized with poor water quality. Besides, only one sampling site i.e. D-15 had highest WQI value (92.32), thus its water quality was found to be very poor for drinking purpose. Further, the percentage of calculated WQI values under different classes during pre-monsoon season for an overall comprehensive picture is shown through **Figure 1**, with respective contribution of four grades.

The higher WQI values and hence, very poor quality of drinking water at D-15 site may be ascribed due to higher content of calcium, magnesium and iron 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]**.

3.2 WQI Values during Post-monsoon Season

Contrary to the obtained results of WQI values during pre-monsoon season, all the WQI values were found to be lower (WQI<25). Therefore, all 32 water sources were graded 'A' and their water quality was explained as excellent for drinking purpose. Among these 32 water sources, D-3 site has recorded lowest WQI value (0.68) and highest WQI as 3.42 was found at D-32 site.

The overall results of WQI during pre and post monsoon seasons of 2017 clearly indicate the suitability of almost all analyzed 32 water sources for drinking and domestic purposes.

4. 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 2017. 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 32 drinking water sources of 4 developmental blocks of Dehradun district during pre-monsoon season, 27 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-15 has recorded highest WQI value (92.32), 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 2017, it is inferred that except D-15 site, and D-23 and D-26 (with

precaution) rest of the drinking water sources can be used for supply of drinking water to local population.

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Table 1: Description of Drinking Water Sites of Dehradun during Pre and Post Monsoon Seasons, 2017

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	D-2	30°17'22.4"	077°55'07.5"	583
3		JeevaRadi (Main Tubewell)	D-3	30°17'55.1"	077°56'12.1"	572
4		Sailok Colony	D-4	30°17'21.8"	077°56'08.7"	598
5		Malam	D-5	30°17'41.0"	077°53'56.4"	591
6		Mohammad Nagar	D-6	30°22'50.5"	077°55'032"	516
7		Shankarpur	D-7	30°23'23.6"	077°49'13.9"	480
8		Shankarpur (Vyayamshala)	D-8	30°23'2.72"	077°49'30.3"	488
9	Vikasnagar	Jasee wala	D-9	30°25'14.5"	077°74'64.1"	456
10		Bansipur	D-10	30°26'40.7"	077°44'30.2"	446
11		Babughad	D-11	30°27'55.0"	077°45'583"	461
12		Jalkal	D-12	30°28'48.0"	077°76'31.2"	460
13		Lachman pur	D-13	30°28'28.5"	077°46'51.1"	466
14		Jonrasi Basti	D-14	30°29'00.8"	077°46'33.4"	459
15		Mahuwala	D-15	30°29'14.5"	077°48'49.6"	484
16		Bhuguwala	D-16	30°27'44.8"	077°47'58.6"	479
17	Raipur	Kasherwala	D-17	30°27'44.8"	077°47'58.6"	688

18		Ajadnagar	D-18	30°19'26.4"	078°03'44.8"	687
19		Shakti Vihar	D-19	30°19'32.3"	078°03'41.0"	668
20		Upper Badrish Colony	D-20	30°18'26.6"	078°04'14.7"	651
21		Vani Vihar	D-21	30°19'11.5"	078°04'25.2"	665
22		Neembuwala	D-22	30°21'01.7"	078°00'52.9"	689
23		Sanjay Colony	D-23	30°18'12.0"	078°03'44.1"	639
24		Nehru C.3	D-24	30°18'04.6"	078°03'18.2"	661
25.	Doiwala	Dandi	D-25	30°10'42.3"	078°13'44.7"	565
26.		Raipur	D-26	30°10'53.7"	078°12'42.5"	559
27.		Ghanuled	D-27	30°10'34.0"	078°12'37.6"	374
28.		Ranipokhri	D-28	30°10'53.7"	078°07'27.3"	478
29.		Lachchhiwala	D-29	30°11'44.3"	078°07'32.6"	497
30.		Missarwala	D-30	30°11'01.8"	078°07'29.3"	488
31.		Missarwala Kalan	D-31	30°11'06.3"	078°07'18.8"	491
32.		Missarwala Khurd	D-32	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

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Table 3: Calculated WQI Values of 32 Drinking Water Sites of Dehradun during Pre-Monsoon Season, 2017

S.N.	Block	Code of Sampling Sites	WQI Specification	Calculated WQI Value	Water Quality Grading	Water Quality Status
1	Sahaspur	D-1	0-25	7.25	A	Excellent
2		D-2	0-25	10.60	A	Excellent
3		D-3	0-25	13.98	A	Excellent
4		D-4	0-25	13.54	A	Excellent
5		D-5	0-25	11.03	A	Excellent
6		D-6	0-25	10.77	A	Excellent
7		D-7	0-25	10.93	A	Excellent
8		D-8	0-25	11.51	A	Excellent
9	Vikasnagar	D-9	0-25	10.61	A	Excellent
10		D-10	0-25	13.85	A	Excellent
11		D-11	0-25	7.93	A	Excellent
12		D-12	0-25	13.81	A	Excellent
13		D-13	0-25	17.83	A	Excellent
14		D-14	0-25	11.20	A	Excellent
15		D-15	76-100	92.32	D	Very Poor
16		D-16	0-25	7.99	A	Excellent
17	Raipur	D-17	0-25	2.73	A	Excellent
18		D-18	0-25	12.01	A	Excellent
19		D-19	0-25	2.48	A	Excellent
20		D-20	26-50	26.66	B	Good
21		D-21	26-50	33.35	B	Good
22		D-22	0-25	2.82	A	Excellent
23		D-23	51-75	65.94	C	Poor
24		D-24	0-25	2.71	A	Excellent
25.	Doiwala	D-25	0-25	2.77	A	Excellent
26.		D-26	51-75	65.95	C	Poor
27.		D-27	0-25	3.06	A	Excellent
28.		D-28	0-25	2.44	A	Excellent
29.		D-29	0-25	3.26	A	Excellent
30.		D-30	0-25	3.09	A	Excellent
31.		D-31	0-25	3.00	A	Excellent
32.		D-32	0-25	18.72	A	Excellent

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Table 4: Calculated WQI Values of 32 Drinking Water Sites of Dehradun during Post-Monsoon Season, 2017

S.N.	Block	Code of Sampling Sites	WQI Specification	Calculated WQI Value	Grading	Description of Water Quality Status
1	Sahaspur	D-1	0-25	1.29	A	Excellent
2		D-2	0-25	1.21	A	Excellent
3		D-3	0-25	0.68	A	Excellent
4		D-4	0-25	1.35	A	Excellent
5		D-5	0-25	1.79	A	Excellent
6		D-6	0-25	2.08	A	Excellent
7		D-7	0-25	1.69	A	Excellent
8		D-8	0-25	2.51	A	Excellent
9	Vikasnagar	D-9	0-25	1.95	A	Excellent
10		D-10	0-25	1.97	A	Excellent
11		D-11	0-25	1.99	A	Excellent
12		D-12	0-25	2.17	A	Excellent
13		D-13	0-25	1.87	A	Excellent
14		D-14	0-25	2.32	A	Excellent
15		D-15	0-25	2.35	A	Excellent
16		D-16	0-25	2.08	A	Excellent
17	Raipur	D-17	0-25	1.98	A	Excellent
18		D-18	0-25	2.48	A	Excellent
19		D-19	0-25	2.10	A	Excellent
20		D-20	0-25	2.48	A	Excellent
21		D-21	0-25	2.91	A	Excellent
22		D-22	0-25	2.92	A	Excellent
23		D-23	0-25	3.01	A	Excellent
24		D-24	0-25	2.80	A	Excellent
25.	Doiwala	D-25	0-25	2.14	A	Excellent
26.		D-26	0-25	2.57	A	Excellent
27.		D-27	0-25	2.35	A	Excellent
28.		D-28	0-25	2.44	A	Excellent
29.		D-29	0-25	2.98	A	Excellent
30.		D-30	0-25	2.63	A	Excellent
31.		D-31	0-25	2.78	A	Excellent
32.		D-32	0-25	3.42	A	Excellent

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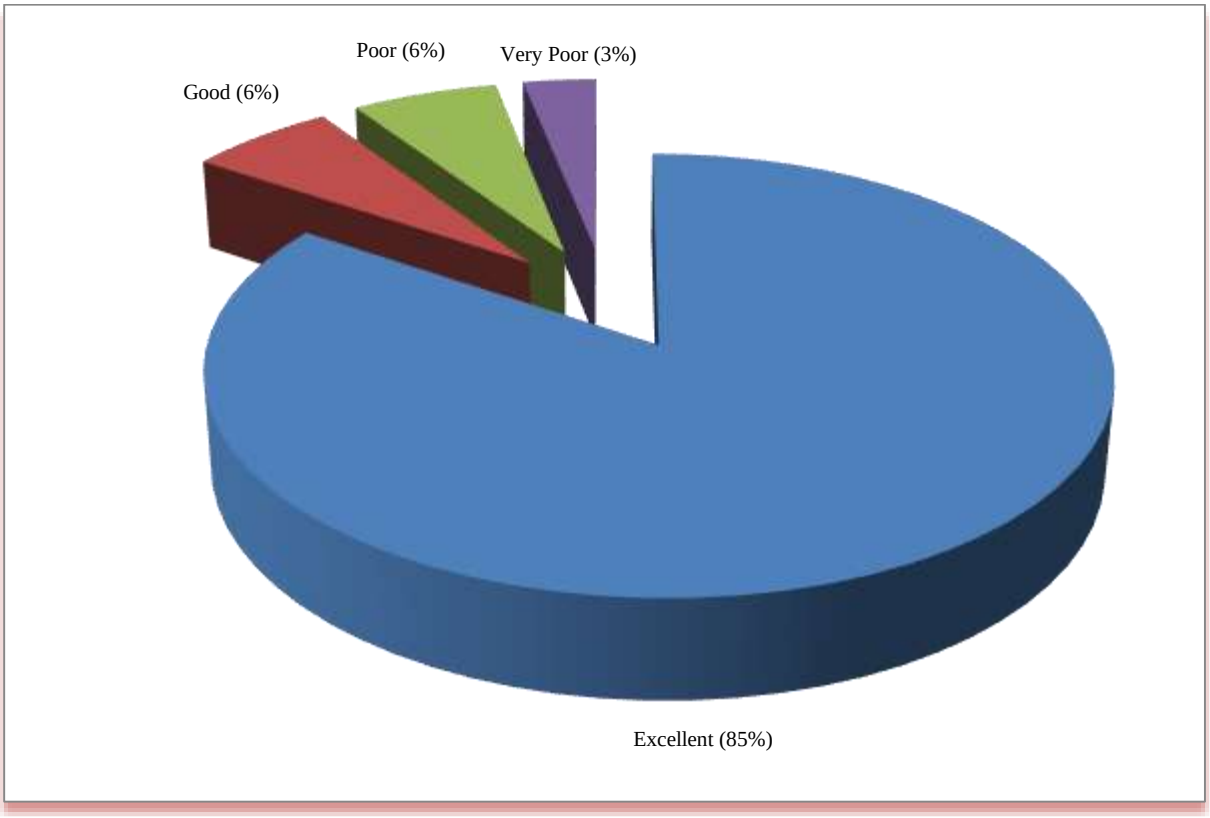

Figure 1: Distribution of Drinking Water Sites According to WQI Values during Pre-Monsoon Season-2017