Water quality categorization using WQI in rural areas of Haridwar, India

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Abstract

The present study was carried out for assessment of ground water quality in rural areas of district Haridwar. This study would provide baseline data for ground water management. For this purpose, Groundwater is indispensable for continuity of life and sustainability of environment. It is needed in almost every sphere of human activity. Hence, this study is aimed to assessing the ground water quality in Haridwar district, Uttarakhand, India, with respect to drinking and irrigation uses. Groundwater samples were collected from 6 different sites to evaluate the ground water quality. Overall, the physico-chemical parameters of groundwater in the study area were found under permissible limit proposed by WHO and BIS. In order to assist the interpretation of the water status of hydric resource, the Water Quality Index (WQI) was considered. This index depict the technical information in description of the water quality status, highlighting the effectiveness of its use and guiding the decision-making process when necessary. Water Quality Index (WQI) values for all sites indicates that the water quality of ground water is in excellent class (WQI<50) and suitable for drinking and irrigation purposes. This research offered the need of an effective evaluation of the ground water quality and its utility for human health.

Keywords: Groundwater quality | Water quality index | Irrigation and drinking suitability | Haridwar

Introduction

Water is the basic requirements of all life on Earth. The origin of life has been attributed is water along with other basic elements water the source of life is passionate. Too passionate to manage excess of, it leads to flood and lack of its results in drought and famine. It must be remembered that any natural or manmade activity on the surface of the earth will have it’s for most impact on the quality and quantity of water this will be taken into the biosphere systems and ultimately lead to hydrological

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The increase in population and urbanization necessitates growth in the agricultural and industrial sectors which demand for more fresh water (Matta et al. 2014). When surface water is the non-available mode the alternative is to depend on groundwater. The dependability on groundwater has reached an all-time high in recent decades due to reasons such as unreliable supplies from surface water due to vagaries of monsoon, increase in demand for domestic, agricultural and industrial purposes. This has resulted in over exploitation all over the country and in certain places it has reached critical levels like drying up of aquifers (Matta et al., 2015).

Best medicine available to mankind, animals and plants are clean water. At the dawn of civilization, settlements were built along river banks. Population size was less. Surface water was the main resource. Gradually, exponential rise in population size led to pollution and depletion of river water (Matta et al. 2016). People took recourse in groundwater believing that it is safe in all respects. From quenching thirst, washing, cleaning, use for agriculture to operation of high-power industries, groundwater plays a very vital role. This indispensable resource is a victim of over-exploitation, pollution and exhaustion. Rate of groundwater development and management is not at par with rate of utilization. Presently, India is the biggest user of groundwater for agriculture in the world (Shah, 2009). Ground water protection against contamination by the human activities is one of the most important tasks of environmental awareness on a world wide scale. If the groundwater reservoir is left unchecked, the minor contamination can damage the whole reservoir with the passage of time (Kamboj, 2012).

Aquifer waters suffer from pervasive contamination. Unlike rivers, the damage is generally irreversible. Rate of groundwater renewal is very slow in comparison with that of surface water. Since water in aquifers moves through Earth at snail’s pace, the pollutants continue to accumulate. So the amount of clean water available is diminishing. The hydrochemistry of groundwater depends on source of groundwater itself, ion-exchange process, interaction with aquifer material (Mercado, 1985; Matta et al. 2018a, b). There are various physico-chemical parameters which play a vital role regarding the quality of groundwater for consumption and irrigation purposes (Matta et al., 2017; Matta, 2010; Matta et al., 2015). If the concentration of any parameter is above the prescribed limit [WHO, 2011; BIS, 2012]. Assessment of ground water quality and monitoring of its different parameters is essential for particularly water from those sources which serve as drinking water sources to the mankind. According to World Health Organization (WHO), there were estimated 4 billion cases of diarrhea and 2.2 million deaths annually. The consumption of unsafe water has been implicated as one of the major causes of the disease most gradual deterioration of water quality was resulted by the increase in human population and urbanization (WHO, 2004).

The present work aims at assess the groundwater quality of rural areas of Haridwar district and hence determining its suitability for drinking and irrigation purposes. So these rural areas need to be
continuously monitored to get the long-term sustainability.

Study Area

Present study was conducted in Haridwar district, Uttarakhand. The covered area of Haridwar district is 2360 sq.km. with 29.580 N latitude and 78.130 E longitude and at an elevation of 249.7 m above the sea level. The regional climatic condition lies within the range of about -2 0C to 44 0C temperature. In 2011, the vegetation, water, urban and barren area is about 277.70, 9.56, 693.47 and 11.74 sq.km. respectively (Mishra nad Kumar, 2015). The population of Haridwar district is around 1,927,029 (District Census, 2011). For the study eleven different sites demarcated at Haridwar region. The description of sampling sites is given below in Table 1.

Methods and Methodology

Collection of samples and analysis

Eleven (11) ground water samples were collected from bore wells from the rural areas in January 2018. Each sample was collected in acid-washed Nalgene Wide-Mouth Natural HDPE polypropylene, 1000 ml bottles. Before collection of water in a particular bottle, the bottle was rinsed thoroughly with the respective samples of the groundwater. Sample location was marked on the bottle and suitable preservatives were added for storage till completion of quantitative chemical analysis. The bottle was filled to the brim with water taking care that no air bubble was trapped within the water sample. In order to prevent evaporation, the bottles were sealed with double plastic caps and precaution was also taken to avoid sample agitation during transfer to the laboratory. Immediately after collection, samples were transferred to the laboratory. A total of 10 physico-chemical parameters like Temperature, pH, Electrical conductivity (EC), Total Dissolve Solids (TDS), Dissolve Oxygen (DO), Chloride, Alkalinity, Calcium, magnesium and Total hardness were analyzed out of them Temperature, pH, EC, TDS and DO were observed on the spot with the use of Portable Multi-Parameter Instrument, Model – TMULTI 27 (TOSHCON) and remaining were analyzed as per standard methods of APHA, (2012). These parameters help to evaluate the drinking, irrigational as well as domestic suitability of ground water in the study area.

Statistical analysis

In statistical analysis the Karl Pearson’ correlation matrix between hydro-chemical parameters of groundwater was identified. The water quality index (WQI) by arithmetic mean method was adopted for the classification of water quality into different classes of water for the suitability of drinking and irrigation purposes.

Water Quality Index – WQI (by arithmetic mean method)

The computation of the WQI was done for observed data by the weighted arithmetic index method for different parameters. This method has been implemented by many researchers (Bhutiani et al., 2014; Randey et al., 2016; Gupta et al., 2017).

The equation used for the computation of WQI is:

$$WQI = \sum_{i=0}^{n} \frac{W_i q_i}{W_i}$$

where, $q_i$ = subindex or quality rating for the $i^{th}$ parameter
We calculated the WQI in 4 steps:

1. Selection of parameters, in this study 7 hydro-chemical variables were selected out of 10 due to the lack of proposed permissible limits of drinking water by WHO (2011) and BIS (2012).

2. We calculated the sub-index or quality rating ($q_i$). The equation is expressed as follows (Brown et al. 1972):

$$ q_i = \left( \frac{(V_a - V_i)}{(V_s - V_i)} \right) \times 100 $$

where, $q_i$ = subindex for the $i^{th}$ parameter  
$V_a$ = actual value present of the $i^{th}$ parameter at a given sampling station.  
$V_i$ = ideal value for the $i^{th}$ parameter  
$V_s$ = standard value for the $i^{th}$ parameter  

If quality rating is equal to zero, that means the complete absence of pollutants. While, a quality rating of 0<$q_i$<100 implies that, the pollutants are above the standards (Ahmad 2014).

3. We calculated the unit weight ($W_i$) for the $i^{th}$ parameter, which is inversely proportional to the standard value of that particular variable.

$$ W_i = \frac{k}{V_s} $$

$k$ = proportionality constant, which can be calculated as:

$$ k = \frac{1}{\Sigma \frac{1}{V_s}} $$

4. We categorized the computed WQI values into five classes for water quality, given as: <50 is excellent; 50-100 is good; 100-200 is poor; 200-300 is very poor and above 300 is unsuitable for drinking purposes (Randey et al., 2016).

**Results and Discussion**

During the study average the temperature of ground water samples varied from 20.7-21.5°C at all sites. Kamboj et al., (2015) observed the minimum and maximum values of temperature 19.30-19.64 ℃ in water samples of Solani River during the March-April, 2015. pH is the measure of acidity or basicity of an aqueous solution. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Pure water has a pH very close to 7. The values of pH varied between 6.88 (S-4) to 7.37 (S-2) (Table 1). Kamboj and Aswal, (2015) observed the pH value varied from 7.66-7.76 for suitability of Ganga canal water for drinking purpose at Haridwar city.

Electrical Conductivity (EC) is the measure of its ability to conduct electrical current through ionic charge carriers. The ease with which the current moves through water is related to the amount of dissolved salt (Na$^+$, Ca$^{2+}$, Mg$^{2+}$, K$^+$, Cl$^-$, SO$_4^{2-}$, HCO$_3^-$ and CO$_{3}^{2-}$) predominant. During the study period electrical conductivity varies from 356 μS/cm to 734 μS/cm with an average of 541.92 μS/cm. Total Dissolved Solids (TDS) is the sum of all inorganic salts and small amounts of organic matter present in solution in water. The presence of excess dissolved solids in water affects its palatability. A high level of TDS is objectionable because it imparts bad taste and causes excessive scaling in water pipes, boilers and household appliances. The values of TDS range from 189.00 mg/L to 396 mg/L with an average of 292.5 mg/L, Considering
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temp (°C)</th>
<th>pH</th>
<th>EC (μS/Cm)</th>
<th>TDS (mg/L)</th>
<th>DO (mg/L)</th>
<th>Chloride (mg/L)</th>
<th>Alkalinity (mg/L)</th>
<th>Ca (mg/L)</th>
<th>Mg (mg/L)</th>
<th>TH (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1</td>
<td>21.00</td>
<td>7.26</td>
<td>533.00</td>
<td>283.00</td>
<td>6.87</td>
<td>73.84</td>
<td>195.00</td>
<td>160.00</td>
<td>29.20</td>
<td>189.20</td>
</tr>
<tr>
<td>S-2</td>
<td>21.10</td>
<td>7.37</td>
<td>559.10</td>
<td>293.10</td>
<td>5.89</td>
<td>68.16</td>
<td>172.00</td>
<td>175.00</td>
<td>34.30</td>
<td>209.30</td>
</tr>
<tr>
<td>S-3</td>
<td>20.90</td>
<td>7.35</td>
<td>716.00</td>
<td>383.00</td>
<td>9.65</td>
<td>71.00</td>
<td>190.00</td>
<td>190.00</td>
<td>22.50</td>
<td>212.50</td>
</tr>
<tr>
<td>S-4</td>
<td>20.70</td>
<td>6.88</td>
<td>356.00</td>
<td>189.00</td>
<td>8.72</td>
<td>59.64</td>
<td>100.00</td>
<td>126.00</td>
<td>26.60</td>
<td>152.60</td>
</tr>
<tr>
<td>S-5</td>
<td>21.50</td>
<td>7.24</td>
<td>723.00</td>
<td>385.00</td>
<td>8.70</td>
<td>76.68</td>
<td>143.00</td>
<td>160.00</td>
<td>31.30</td>
<td>191.30</td>
</tr>
<tr>
<td>S-6</td>
<td>21.30</td>
<td>7.06</td>
<td>734.00</td>
<td>396.00</td>
<td>9.65</td>
<td>79.52</td>
<td>195.00</td>
<td>210.00</td>
<td>34.30</td>
<td>242.20</td>
</tr>
</tbody>
</table>

**Table 1:** Water Quality Measurement in the campus of Gurukula Kangari Vishwavidyalaya, Haridwar

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$V_a$</th>
<th>$V_i$</th>
<th>$w_i$</th>
<th>$q_i$</th>
<th>$w_i^*q_i$</th>
<th>$\sum w_i q_i/w_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS</td>
<td>283.00</td>
<td>500.00</td>
<td>0.0252</td>
<td>14.47</td>
<td>0.3647</td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>73.84</td>
<td>250.00</td>
<td>0.0504</td>
<td>23.49</td>
<td>1.1843</td>
<td></td>
</tr>
<tr>
<td>Alkalinity</td>
<td>195.00</td>
<td>200.00</td>
<td>0.0840</td>
<td>1.25</td>
<td>0.1050</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>160.00</td>
<td>75.00</td>
<td>0.2521</td>
<td>68.00</td>
<td>17.1429</td>
<td>11.81</td>
</tr>
<tr>
<td>Mg</td>
<td>29.20</td>
<td>30.00</td>
<td>0.5042</td>
<td>1.14</td>
<td>0.5762</td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>189.20</td>
<td>300.00</td>
<td>0.0840</td>
<td>36.93</td>
<td>3.1036</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2:** Calculation of WQI for sampling site-1

<table>
<thead>
<tr>
<th>Sites</th>
<th>Site-1</th>
<th>Site-2</th>
<th>Site-3</th>
<th>Site-4</th>
<th>Site-5</th>
<th>Site-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQI</td>
<td>11.81</td>
<td>18.57</td>
<td>13.73</td>
<td>20.00</td>
<td>12.48</td>
<td>23.85</td>
</tr>
</tbody>
</table>

**Table 3:** WQI for various sampling locations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temp</th>
<th>pH</th>
<th>EC</th>
<th>TDS</th>
<th>DO</th>
<th>Chloride</th>
<th>Alkalinity</th>
<th>Ca</th>
<th>Mg</th>
<th>TH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.2940</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>0.7357</td>
<td>0.5007</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>0.7287</td>
<td>0.4756</td>
<td>0.9994</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>-0.0357</td>
<td>-0.3596</td>
<td>0.3396</td>
<td>0.3615</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>0.8220</td>
<td>0.3568</td>
<td>0.8573</td>
<td>0.8061</td>
<td>0.0896</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkalinity</td>
<td>-0.0741</td>
<td>0.8755</td>
<td>0.1877</td>
<td>0.1673</td>
<td>-0.3580</td>
<td>0.1352</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>0.4517</td>
<td>0.4162</td>
<td>0.8169</td>
<td>0.8208</td>
<td>0.1170</td>
<td>0.7282</td>
<td>0.1472</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.6294</td>
<td>0.0904</td>
<td>0.0957</td>
<td>0.0831</td>
<td>-0.6703</td>
<td>0.3465</td>
<td>-0.2005</td>
<td>0.1703</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>TH</td>
<td>0.5260</td>
<td>0.4148</td>
<td>0.8026</td>
<td>0.8045</td>
<td>0.0173</td>
<td>0.7527</td>
<td>0.1135</td>
<td>0.9901</td>
<td>0.3072</td>
<td>1.0000</td>
</tr>
</tbody>
</table>
the classification of water on the basis of TDS (Freeze and Cherry 1979), the waters can be classified into fresh water (TDS <1000 mg/L). Dissolved oxygen is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water, the DO value indicates the degree of pollution in water bodies. In the present study the average DO was 5.89-9.65 mg/l observed. The sources of calcium and magnesium in groundwater are weathering of primary minerals such as hornblende, mica, feldspar, calcite and dolomite. In humans and animals, they are essential nutrients for strength of teeth and bones. They help in strengthening of cell wall structure, metabolic processes and nutrient uptake in plants. But excess calcium and magnesium leads to hardness of water. Hard water leads to formation of scums and corrodes pipes. It interferes with the cleansing action of detergents. In general Calcium and Magnesium maintains a state of equilibrium in most groundwater (Hem, 1985; Giggenbach, 1988). The concentration of calcium in the water samples collected vary from 126 to 210 mg/L with an average of 168 mg/L. The concentration of magnesium in the water samples collected vary from 22.50 to 34 mg/L with an average of 28.25 mg/L.

Chloride is found naturally in groundwater through the weathering and leaching of sedimentary rocks and soils and the dissolution of salt deposits. Chloride is often attached to sodium, in the form of sodium chloride (NaCl). Sodium chloride imparts saline taste to water. Deficiency of chloride in plants leads to leaf mottling and chlorosis. Chloride toxicity symptoms in plants are: leaf margins are scorched and abscission is excessive, leaf size is reduced and may appear to be thickened and plant growth is stunted. The concentration of chloride in the water samples collected vary from 59.56 to 79.52 mg/L with an average of 69.54 mg/L. Total Alkalinity value of water gives us an idea of natural salts present in water. Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonates, carbonates and hydroxide compounds of calcium, sodium and potassium. According to BIS the permissible range of TA in groundwater is 200 - 600 mg/l. All water samples fall within the prescribed range. The observed values of alkalinity ranged within 100-195 mg/l. Kamboj et al., (2015) observed the value of Alkalinity 229.6 (mg/l) was found in Hardness of groundwater primarily results due to excessive concentration of divalent cations like calcium and magnesium in water. These ions enter a water supply by leaching from minerals within an aquifer. High levels of hard-water ions such as Ca\(^{2+}\) and Mg\(^{2+}\) can cause scaly deposits in plumbing, appliances, and boilers. These two ions also combine chemically with soap molecules, resulting in decreased cleansing action. The TH values vary between 152.60 mg/L and 242.2 mg/L with an average of 197.4 mg/l. Kamboj et al., (2016) observed the value of Total Hardness 221.8- 224.1 mg/l in ground water samples of Roorkee.

The calculation of WQI for the ground water samples of different locations were done by selecting six parameters out of ten on the basis of their proposed standard limits and presented in Table 2. The estimated values of WQI for all selected sites were given in Table 3. The index values for site-1, 2, 3, 4, 5 and 6 were 11.81, 18.57, 13.75, 20.00, 12.48 and
23.85 respectively. The observed index value for all different site was found within the range of 11.81-23.85 which indicates that the ground water quality of all concerned locations are in excellent condition (as estimated WQI ranged <50) and suitable for drinking purposes.

The Karl Pearson’s correlation matrix was developed between analyzed physico-chemical parameters and presented in Table 4. The highly positive correlation (0.99) was noticed between Ca\(^{2+}\) concentration and hardness of water samples which also supports the fact of hardness due to this ion and a negative correlation was reported between DO and Mn\(^{2+}\).

**Conclusion**

In the present study the ground water samples were analyzed to assess the water quality of different location of Haridwar district. To achieve this goal water quality index method was used to categorize the water quality into different pollution potential conditions based. The comparison of physico-chemical parameters with WHO and BIS describes that all the parameters of water samples were below the permissible limits except the concentration of Ca\(^{2+}\) and Mn\(^{2+}\). The calculated index value also represents that the water quality is in excellent condition (i.e. WQI<50) and suitable for drinking purposes. The correlation analysis of analyzed parameters revealed the relationship between Ca\(^{2+}\) level and hardness of water samples. The results contribute essential baseline information that should aid in detailed evaluation of the state of these water bodies in future and also in the better conservation and management of the precious water bodies.

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