Weathering Processes and Irrigation Quality Assessment of the Part of River Jhelum, Jammu and Kashmir, India

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Abstract: Eleven water samples were analyzed to assess weathering process and irrigation quality of the River Jhelum. The river water was found to be controlled by chemical weathering of the rock forming minerals. Scatter diagrams suggested the dominance of carbonate and silicate weathering. Two specific types of water were identified with the help of Durov and Piper diagrams that are referred to as Ca–HCO₃, Mg–HCO₃ types. The Langlier-diagram confirms the chemistry of meteoric water, i.e. Ca-Mg-HCO₃. The calculated values of SAR, RSC and sodium percentage indicated that the river water is excellent for irrigation use.

Keywords: river; weathering; scatter; meteoric water; irrigation.

1. Introduction

India has a large river network which has been nurturing its vast fertile lands. The rapid urbanization, industrialization, intensive agriculture and growing demand for energy have adversely
affected the physiochemical parameters of surface water (Jain et al., 2007). The groundwater level is declining continuously and thus increasing the dependency of people on surface water resources. Therefore analysis of river water quality is very essential for sustainable use of river water resources. The river water quality in a region is largely determined by the natural processes, such as precipitation rate, weathering processes, soil erosion etc. as well as anthropogenic processes, such as urban, industrial, agricultural activities and increasing exploitation of water resources (Carpenter et al., 1998). The municipal and industrial wastewater discharge (point as well as non-point sources of pollution) constitutes the constant polluting source of river water quality. The surface run-off during the rainy season also affects river water quality (Kazi et al., 2009). The hydrogeochemistry of river water is controlled by a series of factors, such as climate, vegetation, topography and geology of the catchment area (Alaez et al., 1988). The river water ecosystem is affected by fluctuations in physical and chemical characteristic of river (Guissani et al., 2008).

Major chemical composition of river water (e.g. Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, HCO$_3^-$, SO$_4^{2-}$, Cl$^-$) can reveal the nature of weathering patterns and anthropogenic processes (Gibbs, 1970). Quantifying the major-ion composition of river water also has broad implications, e.g. water quality type, hydrogeology characteristics, weathering processes (Brennan and Lowenstein, 2002; Cruz and Amaral, 2004). Many previous studies have revealed the major-ion chemistry of the world’s rivers, e.g. the Amazon (Gibbs, 1972; Stallard and Edmond, 1983, 1987), the Orinoco (Nemeth et al., 1982), the Yangtze River (Chen et al., 2002), the Yellow River (Zhang et al., 1995; Cheng et al., 2005) and the Ganges–Brahmaputra (Sarin et al., 1989) amongst others.

In the present work, a detailed hydrogeochemical study of River Jhelum has been carried out to determine the major ion chemistry and to understand the weathering and geochemical processes controlling the water composition and suitability of water for irrigation purposes.

2. Material and Methods

2.1. Study Area

After the origin of Jhelum River from Pir Panjal range of mountains it flows through Kashmir valley in north westerly direction till it falls into the Wular Lake in Baramulla District. After its re-emergence from the Wular Lake in Sopore (Fig. 1), it takes a Southwesterly direction and continues its journey through Uri before entering the Pakistan occupied Kashmir.
2.2. Sampling and Analysis

Water samples were collected from River Jhelum during summer 2010. The samples were filtered using 0.45 μm nylon membrane Millipore filters. The standard methods were adapted to analyses (APHA, AWWA and WEF, 2001). Temperature, pH, conductivity (EC) and alkalinity were measured at site. The major ion analysis was carried out at the Geochemistry Lab of Department of Geology and Geophysics, University of Kashmir, Srinagar. Alkalinity was measured by HCl titration; Ca\(^{2+}\) and Mg\(^{2+}\) by EDTA titration; Cl\(^{-}\) by AgNO\(_3\) titration; SO\(_4^{2-}\) by spectrophotometry; Na\(^+\) and K\(^+\) by flame emission photometry. In most of the water samples, the total cation charge (TZ\(^+\) = Ca\(^{2+}\) + Mg\(^{2+}\) + Na\(^+\) + K\(^+\) in meq/L) balances that of the total anions (TZ\(^-\) = HCO\(_3^{-}\) + Cl\(^-\) + SO\(_4^{2-}\) in meq/L) within analytical uncertainties and the normalized inorganic charge balance (NICB = (TZ\(^+\) - TZ\(^-\))/TZ\(^+\) × 100%) is within ±5%.

3. Results and Discussions

3.1. Physicochemical Characteristics of River Jhelum

Summary of physicochemical analysis of water samples from River Jhelum is presented in Table 1. The river water is fresh, colorless, and odorless with low temperature (range: 17.8-19.3 °C, mean: 18.5, standard deviation: 0.371). As expected, the river water is alkaline (pH range: 7.5-7.8, mean: 7.6, standard deviation: 0.1). Electrical conductivity ranged from 195.3 to 279.6 μS/cm (mean: 254, standard deviation: 18.3). Total dissolved solids ranged from 125 to 179 mg/L (mean: 162.6, standard deviation: 11.7). Calcium concentration ranged from 24 to 35 mg/L (mean: 30.7, standard deviation: 3.2). Magnesium concentration ranged from 4.4 to 14.5 mg/L (mean: 8.7, standard deviation: 2.9). Bicarbonate concentration ranged from 112 to 178 mg/L (mean: 140.2, standard deviation: 15.5); chloride concentration ranged from 3.6 to 8 mg/L (mean: 5.4, standard deviation: 1.2) and sulphate...
concentration ranged from 5.4 to 9.8 mg/L (mean: 8.0, standard deviation: 1.6). Among the cations, Mg$^{2+}$ and Ca$^{2+}$ were most abundant and the general order of major cations was Ca$^{2+} >$ Mg$^{2+} >$ Na$^+ >$ K$^+$. Among the anions, HCO$_3^-$ was most abundant and the general order of major anions was HCO$_3^-$ > SO$_4^{2-}$ > Cl$^-$.

### Table 1. Physiochemical analysis of River Jhelum water

<table>
<thead>
<tr>
<th>Location</th>
<th>Site ID</th>
<th>Temp. oC</th>
<th>pH</th>
<th>E.C. $\mu$S/cm</th>
<th>T.D.S. mg/L</th>
<th>Ca$^{2+}$ mg/L</th>
<th>Mg$^{2+}$ mg/L</th>
<th>Na$^+$ mg/L</th>
<th>K$^+$ mg/L</th>
<th>Cl$^-$ mg/L</th>
<th>HCO$_3^-$ mg/L</th>
<th>SO$_4^{2-}$ mg/L</th>
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</thead>
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<tr>
<td>(Kursherpur)</td>
<td>Khanabal</td>
<td>A1</td>
<td>17.8</td>
<td>7.5</td>
<td>195.3</td>
<td>125</td>
<td>35</td>
<td>13.1</td>
<td>10.4</td>
<td>0.36</td>
<td>8</td>
<td>178</td>
</tr>
<tr>
<td>(Gur)</td>
<td>Khanabal</td>
<td>A2</td>
<td>17.8</td>
<td>7.5</td>
<td>218.7</td>
<td>140</td>
<td>24</td>
<td>14.3</td>
<td>8.6</td>
<td>0.29</td>
<td>6</td>
<td>145</td>
</tr>
<tr>
<td>Sangam</td>
<td></td>
<td>A3</td>
<td>18.4</td>
<td>7.7</td>
<td>223.4</td>
<td>143</td>
<td>32</td>
<td>10</td>
<td>9.4</td>
<td>0.24</td>
<td>7</td>
<td>154</td>
</tr>
<tr>
<td>Kakapora</td>
<td></td>
<td>A4</td>
<td>18.4</td>
<td>7.6</td>
<td>231.2</td>
<td>148</td>
<td>28</td>
<td>4.4</td>
<td>8.4</td>
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<td>Awantipora</td>
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<td>240.6</td>
<td>154</td>
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<td>9.2</td>
<td>8</td>
<td>0.33</td>
<td>5</td>
<td>126</td>
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<tr>
<td>Srinagar (Amirakadil)</td>
<td>A6</td>
<td>19.3</td>
<td>7.5</td>
<td>248.4</td>
<td>159</td>
<td>34</td>
<td>4.9</td>
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<td>0.25</td>
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<td>165</td>
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<tr>
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<td>7.7</td>
<td>264</td>
<td>169</td>
<td>28</td>
<td>14.5</td>
<td>9.4</td>
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<tr>
<td>Gulamyar</td>
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<td>265.6</td>
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<td>9.1</td>
<td>0.44</td>
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<td>151</td>
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<td>7.6</td>
<td>275</td>
<td>176</td>
<td>34</td>
<td>9.2</td>
<td>8.6</td>
<td>0.43</td>
<td>7</td>
<td>149</td>
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<td>A11</td>
<td>18.1</td>
<td>7.5</td>
<td>279.6</td>
<td>179</td>
<td>31</td>
<td>8.7</td>
<td>8.4</td>
<td>0.46</td>
<td>6.3</td>
<td>138</td>
</tr>
</tbody>
</table>

### 3.2. Major Ion Composition

The major ion chemistry of groundwater is a powerful tool for determining solute sources and for describing water evolution as a result of water–rock interaction leading to the dissolution of carbonate minerals, and silicate weathering and ion exchange processes (Herczeg et al., 1991; Hiscock, 1993; Kimblin, 1995; Elliot et al., 1999; Edmunds and Smedley, 2000; Jeelani and Shah, 2006). Gibbs (1970) gave a relation for determining the major mechanism controlling water chemistry, which suggested that the major mechanism controlling the water chemistry of River Jhelum is the chemical weathering of the rock forming minerals (Fig. 2).
Evolution of water and relationship between rock types and water composition can be evaluated by the Piper trilinear diagram (Piper, 1944), which is very useful in determining chemical relationships in water in more definite terms than possible with other plotting methods (Walton, 1970). The Piper diagram is an ingenious construction, which consists of two triangular diagrams at the lower left and lower right, describing the relative composition of cations and anions and an intervening diamond-shaped diagram that combines the composition of cations and anions. River water samples were plotted on Piper trilinear diagram (Fig. 3.), which reveals that general chemical water type identified was Ca-Mg-HCO₃ type and specific water types were Ca-HCO₃ and Mg-HCO₃.
The Durov diagram (Durov, 1948) plots the major ions as percentages of milliequivalents in two base triangles. The main purpose of the Durov diagram is to show clustering of data points to indicate samples that have similar compositions. Chemical facies that determine the water type are calculated by first converting the concentration (meq/L) of the major cations (Na\(^+\), K\(^+\), Ca\(^{2+}\), Mg\(^{2+}\)) and anions (Cl\(^-\), SO\(_4^{2-}\), HCO\(_3^-\)) to percentages (Guler et al., 2002). The Durov plot (Fig. 4) indicates dominance of the major ions Ca\(^{2+}\), Mg\(^{2+}\), HCO\(_3^-\) while other ions, such as SO\(_4^{2-}\), Na\(^+\), K\(^+\) and Cl\(^-\), are comparatively less represented, indicating weathering inputs in the water system (Cetindag and Okan, 2003). All the samples belong to Ca-Mg-HCO\(_3^-\) facie, which can be subdivided into Ca-HCO\(_3^-\) and Mg-HCO\(_3^-\) facies. Ca-HCO\(_3^-\) facie indicates the dominance of alkalines and weak acids. Mg-HCO\(_3^-\) facie again indicate that strong acid i.e. Cl\(^-\) and SO\(_4^{2-}\) does not exceed the weak acids (HCO\(_3^-\)).

![Durov diagram](image)

**Figure 4.** Durov diagram

### 3.3. Geochemical Processes Controlling Water Composition

Binary plots that were plotted to study the weathering regimes and dominance of major ions Ca\(^{2+}\) + Mg\(^{2+}\) is plotted against HCO\(_3^-\) (Fig. 5a). All the points fall below 1:1 equaline suggesting some contribution from silicates or/and sulphates. In the plot of Ca\(^{2+}\) + Mg\(^{2+}\) vs Na\(^+\) + K\(^+\) (Fig. 5b), all the points fall below 1:1 equaline indicating carbonate lithology as the dominant source of major ions (Das and Kaur, 2001). In the plots of Ca\(^{2+}\) + Mg\(^{2+}\) vs HCO\(_3^-\) + SO\(_4^{2-}\) (Fig. 5c), all the points fall near/or above 1:1 trend line indicating carbonate lithology as the main contributor of major ions with some contribution from silicate lithology (Sarin et al., 1989; Jeelani and Shah, 2006) as Ca\(^{2+}\) is derived mainly from carbonates with some inputs from silicates.
Figure 5. Scatter diagrams between (a) Ca$^{2+}$ + Mg$^{2+}$ vs HCO$_3^-$; (b) Ca$^{2+}$ + Mg$^{2+}$ vs Na + K; (c) Ca$^{2+}$ + Mg$^{2+}$ vs HCO$_3^-$ + SO$_4^{2-}$ showing possible liganding of the major ions.

The Langlier-diagram helps arrive at closer classification of waters. Analyzed water samples from river Jhelum (Fig. 6) confirm the chemistry of meteoric water, i.e. Ca-Mg-HCO$_3$ type, however a sample showed deviation from core end. The alteration of meteoric water to different chemical composition water is due to the maximum water–rock interaction (Umar et al., 2006).

Figure 6. Langlier - Ludwig diagrams
3.4. Irrigation Quality Assessment

The parameters such as sodium adsorption ratio (SAR), percent sodium (%Na) and residual sodium carbonate (RSC) were estimated to assess the suitability of water from the River for irrigation purpose. EC and sodium concentration are very important in classifying irrigation water. The total concentration of soluble salts in irrigation water can be expressed for the purpose of classification of irrigation water as low (EC ≤ 250 µS/cm), medium (250–750 µS/cm), high (750–2,250 µS/cm) and very high (2,250-5,000 µS/cm) salinity zone (Richards, 1954). High salt concentration (high EC) in water leads to formation of saline soil, and a high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of SAR and it can be estimated by the formula:

$$\text{SAR} = \frac{\text{Na}^+}{(\text{Ca}^{2+} + \text{Mg}^{2+})} \quad \text{(expressed in milli-equivalent per liter)}$$

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is adsorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that the surface water samples fall in the category C1S1 and C2S1, indicating low to medium salinity and low sodium water which can be used for irrigation in most soil and crops with little danger of development of exchangeable sodium and salinity (Fig. 7). Sodium percent is another parameter used to assess the suitability of water for irrigation and is calculated by formula:

$$\%\text{Na} = \frac{(\text{Na}^+ + \text{K}^+)}/(\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+) \times 100\%$$

The sodium percentage (%Na) in the study area ranges between 17% and 21%. As per the BIS (Bureau of Indian Standard), maximum sodium of 60% is recommended for irrigation water. To quantify the effects of carbonate and bicarbonate, RSC has been computed. A high value of RSC (residual sodium carbonate) in water values leads to an increase in the adsorption of sodium on soil (Eaton, 1954). Irrigation water having RSC values greater than 5 meq/L has been considered harmful to the growth of plants, while water with RSC values above 2.5 meq/L is not considered suitable for
irrigation purpose. The RSC values of the study area varied between 0.9-1.5 meq/L, again indicating that the water is safe for irrigation purposes.

![Salinity hazard diagram](image)

**Figure 7.** Salinity hazard diagram

### 4. Conclusions

From the forth going discussion, following conclusions were drawn: (a) the water from Jhelum River is alkaline, medium electrical conductivity and total dissolved solids; (b) the river water was found to be controlled by chemical weathering of the rock forming minerals; dominated by carbonates and silicates; (c) water of River Jhelum is meteoric, i.e. Ca-Mg-HCO₃; (d) analytical data from the study area confirm that river water present in the area is suitable for irrigation purposes.

### References


