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Geochemistry and Irrigation Quality of Groundwater along River Jhelum in South Kashmir, India

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Abstract

A preliminary investigation was made to understand the geochemical characteristics of ground water sources in South Kashmir Jhelum River basin. A total of twenty ground water samples, representing shallow and deep sources were collected and analyzed for different geochemical parameters. The studied ground water sources have generally high alkalinity and hardness owing to the lacustrine deposits in the valley. The dominance pattern of cations in the studied ground water was as follows: Ca>Mg>Na>K and the sequence of anionic dominance was as follows: HCO_3> Cl > SO_4. The study showed that the regional geology as well as rock water interactions has played a dominant role in determining the concentration of various ions in ground water aquifers. In certain aquifers chloride concentration was fairly high and can be attributed to anthropogenic pressure, as there is less predominance of chloride bearing minerals. This study further envisages that these ground water aquifers have low Sodium adsorption ratio and %Na hence are fit for irrigation, while residual sodium carbonate and salinity values indicated that majority of these aquifer have water of marginal to harmful quality for irrigation purposes.

Key Words: Kashmir Himalaya, SAR, RSC, Salinity Hazard

Introduction

Fresh water is one of the earth's vital natural resource, being very critical for the sustainable development [1]. Therefore, the United Nations has proclaimed the period 2005-2015 as the international decade for action on "water for life" [2]. Groundwater is a distinguished component of the hydrological cycle and forms the major source of water supply for drinking purposes in most parts of India. Ground water also plays an important role in agriculture, for both watering of crops and for irrigation during dry season. It is estimated that about 45% of irrigation water requirement in India is met from ground water sources [3].

Ground water which occurs beneath the earth surface, is considered free from contamination, hence usable but anthropogenic as well as natural factors are affecting the quality as well as quantity of this valuable resource [1, 4]. It has been estimated that once pollution enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses [5]. Therefore, understanding the potential influences of human activity on ground water quality is important for protection and sustainable use of ground water resources.

Water chemistry differs depending on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in contact with reactive minerals [6]. There is a wide variation in the chemical quality of ground water in Kashmir Valley, reflecting the diverse geohydrology, hydrometeorology, topographic and drainage conditions and artificially imposed conditions, such as surface water irrigation [7]. In aquifers composed of mostly un-reactive material, like sand and gravel, solute concentrations change only slightly with distance down a flow path. In aquifers composed of reactive rocks and minerals like limestone, dolomite, gypsum, halite, and organic matter, solute concentrations (and isotopic compositions) can change significantly with distance along a ground-water flow path, reflecting extensive chemical reaction [6]. In these reactive aquifers, such as the Jhelum Basin aquifer system, the chemistry of water tends to change as it moves along the ground water flow path.

Kashmir valley has rich deposits of ground water in both confined and unconfined aquifer system, but its occurrence is highly uneven due to diverse geological formations [8]. Although groundwater development in Kashmir valley is at its early stage, but its demand has increased tremendously. Increased demand has led to decline in the supply of water from the aquifers in many parts of the valley, either due to overexploitation, poor management or many other factors. Besides, the drastic environmental changes can affect the groundwater sources as they are important components of the global water cycle [9]. For the last two decades, the valley has witnessed dry weather conditions especially during winters, giving rise to drought like situation. This has decreased not only the level of surface waters but also reduced the discharge from many perennial springs [10] and in some areas springs and wells have even dried completely. Despite its vastness and significance, ground water in Kashmir valley has received very little attention regarding estimation of quality, quantity, conservation and management. It was therefore thought to have a detailed study of the ionic composition of the ground waters of south Kashmir Jhelum Basin and find its suitability for irrigation purposes.

Study Area

The Kashmir valley, nested in the north western folds of the Himalaya, lies within the geographical coordinates of $33^{o}30'$- $34^{o}30'$ N latitude and $74^{o}00'$- $75^{o}30'$E longitudes. The valley enjoys a continental climatic condition with marked seasonality resembling sub-Mediterranean type characterized by the rainfall occurring throughout the year but irregular. The valley is mainly drained by river Jhelum and its tributaries and has passed through various geological successions ranging from the oldest Archean to the recent Alluvium [11]. The area under study lies towards the south of the valley comprising of Pulwama and Islamabad districts, within the coordinates of 33^{0} 50´ – 34^{0} 15´ N, 74^{0} 30´ – 75^{0} 40´ E (Fig. 1). The general ground water condition of Kashmir region is considered to be good because of the presence of numerous springs. The main rock containing good ground water deposits are limestone, paleo-river channels of alluvial deposits, volcanic rocks and fluvial- glacial deposits under lower and middle karewa.

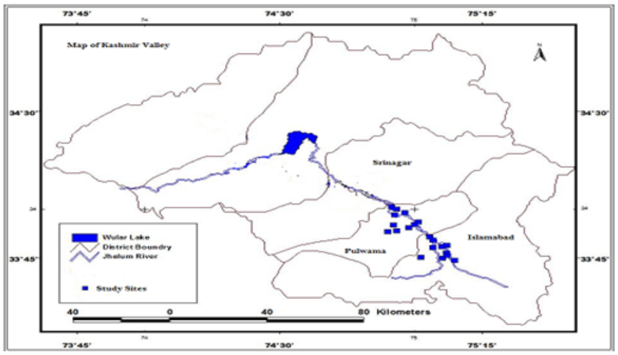

Fig. 1. Georeferenced map showing study sites

Table 1. Details of sampling sites

S no	SAMPLING AREA /	DISTRICT	LATITUDE / LONGITUDE	ALTITUDE	DEPTH
1	Ashajipora	Islamabad	33º 42.835´ N, 75º 09.124´ E	1627 mt	50 ft
2	Wanpooh		33º 43.676´ N, 75º 06.353´ E	1605 mt	131ft
3	Khanibal		33º 44.338´ N, 75º 47.438´ E	1605 mt	80 ft
4	Urnhal		33º 45.535´ N, 75º 07.134´ E	1620 mt	17 ft
5	Bijbehara		33º 47.444´ N, 75º 06.308´ E	1624 mt	52 ft
6	Hasanpora		33º 47.013´ N, 75º 04.395´ E	1613 mt	30 ft
7	Takibal		33º 47.820´ N, 75º 07.305´ E	1620 mt	30 ft
8	Kokergund		33º 44.140´ N, 75º 01.389´ E	1670mt	60 ft
9	Sangamnayun		33º 49.648´ N, 75º 04.334´ E	1602 mt	30 ft
10	Sangam sathar		33º 50.898´ N, 75º 03.300´ E	1660 mt	40 ft
11	Awantipora	Pulwama	33º 54.672´ N, 75º 01.152´ E	1607 mt	50 ft
12	New colony Barsoo		33º 57.357´ N, 74º 58.909´ E	1660 mt	60 ft
13	Galender		33º 59.423´ N, 74º 55.762´ E	1615 mt	50 ft
14	Padgampora		33º 54.325´ N, 75º 00.027´ E	1631 mt	20 ft
15	Malangpora		33º 53.526´ N, 74º 58.967´ E	1602 mt	32 ft
16	Dangherpora		33º 52.260´ N, 74º 54.807´ E	1654 mt	13 ft
17	Pulwama lines		33º 51.349´ N, 74º 53.752´ E	1678 mt	100 ft
18	Pinglen		33º 53.910´ N, 74º 55.188´ E	1653 mt	10 ft
19	Sambura		33º 57.500´ N, 74º 55.610´ E	1627 mt	23 ft
20	Latribal		34º 00.060´ N, 74º 55.031´ E	1602 mt	23 ft

Material and Methods

A total of twenty ground water samples were collected on seasonal basis during 2005-2006 from the study area of which nineteen were bore wells and one dug well, each provided with hand pump. The details of the sampling sites are presented in Table 1. Standard procedure given in APHA [12] was followed for chemical analysis. The water samples were collected in 2 liter plastic bottles (previously cleaned with 10% HNO_3 followed by distilled water). Prior to the collection of samples, hand pumps were flushed for 5-10 minutes. Collected samples were analysed for major ions (Ca^{2+}, Mg^{2+}, Na^{2+}, K^+, Cl^-, SO_4^{2-} and HCO_3^-), EC, pH and TDS. Sodium Adsorption Ratio (SAR) was calculated by the formula proposed by Richards [13] i.e;

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

All values are expressed in meq/l and represent the index of sodium Hazard (S).While as Salinity hazard was calculated by using conductivity as an index at 25°C. %Na was calculated by using formula proposed by Wilcox [14] i.e;

$$\% Na = \frac{Na^+ + K^+}{Na^+ + K^+ + Ca^{++} + Mg^{++}}$$

All values are expressed in meq/l.

Residual sodium carbonate was calculated using formula proposed by Eaton [15].

$$RSC = (HCO_3^- + CO_3^{--}) - (Ca^{++} + Mg^{++})$$

All values are expressed in meq/l.

Results and Discussion

The statistical range of the water chemistry is represented in Table 2. The mean temperature fluctuated between a narrow range of 15° - 17°C, except at site 18 which recorded the lowest (11.8°C) and site 19 which recorded highest mean temperature (21°C) during the study period (Fig 2). This suggested that most of the sites contain water of shallow type as near surface ground and shallow groundwater temperatures are dominantly affected by air temperature [16, 17]. The mean pH value ranged from a low of 6.51 (site 16) to a high of 7.59 (site 13) Fig. 2. The slightly acidic pH (6.5 to 6.9) at most of the sites may be due to the formation of carbonic acid by the dissolution of carbon dioxide in water [18,19], while slightly alkaline pH (>7) may be due to limestone rich lithology of the valley, liberating Ca, Mg and aluminosilicates into the solution.

Conductivity values ranged from 341µs (site 17) to 1911µs (site 5). The larger variations in electrical conductivity is mainly attributed to lithologic composition and anthropogenic activities prevailing in this region [20]. Higher conductivity may be due to the accumulation of dissolved solids from the upland areas by rain water and leaching of dissolved solids from effluents through the alluvial deposits [21]. In the present study concentration of total dissolved solids (TDS) also showed elevated values at most of the sites and varied from 211mg/l (site 15) to 1137mg/l (site 5). Total dissolved solids followed the same trend as that of conductivity Fig 3.

Alkalinity was mainly contributed by bicarbonate ions and ranged from 113 mg/l at site 17 to 638 mg/l at site 5. Matthess [22] reported that concentration of bicarbonates more than 200 is common to ground waters. However, relatively higher concentration (>300mg/l) at certain sites can be attributed to the dissolution of carbonates due to carbonic acid formed as a result of infiltrating carbon dioxide [18,23]. The total hardness (TH) ranged from 171 mg/l (site 17) to 727 mg/l (site 5). The ground water under study falls between hard (121-180 mg/l) and very hard type (>180 mg/l) as per Durfor and Becker [24] and are not fit for domestic purposes [25, 26]. High hardness values are due to the presence of rich deposits of limestone and evaporates in the valley [11,27]. The variation of hardness with respect to cationic composition is given in Fig.4.

Among cations, calcium was the most dominant, ranging from 38mg/l (site 17) to 171mg/l (site 18), while, magnesium ion ranged between 4mg/l at site 7 and 85mg/l at site 5. The major source of calcium and magnesium in the valley ground waters might be the lacustrine deposits [11] as sedimentary rocks like limestone, gypsum and dolomite are rich source of magnesium and calcium in ground water [4, 28]. The dominance of calcium ions over magnesium ions is attributable to abundance of these rocks in the study area. Sodium does not occur in many principal rock forming minerals, therefore its normal concentration in most of the ground waters are up to 20mg/l [26]. Concentration of sodium was below 30 mg/l (minimum value of 4 mg/l at site 17). However, at certain sites the concentration was very high, especially at site 5 (130mg/l) and site 11 (96mg/l), which is attributable to evaporitic deposits and anthropogenic sources. Once sodium enters into the solution it behaves like conservative element as it neither gets precipitated (like calcium) nor used in biological processes [25]. Potassium was recorded in traces at majority of the sites, thus contributing very little towards the quality of ground water. The overall cationic composition at the study sites depicted the sequence Ca_2+>Mg_2+ >Na+>K+ (Fig.4).

Chloride ion ranged from 10 mg/l (Site 9) to 250 mg/l (Site 10). The high Cl content in certain water samples might be due to contamination by domestic sewage or due to entrapped relic of seawater in unflushed parts of aquifers composed of karstified limestones [29, 30] or due to the longer residence time of chloride in ground water [31]. Generally the concentration of sulphate in ground water is usually < 100 mg/l [26]. Similarly, in the present study the concentration of sulphate ranged from 4 mg/l (site 12) to 86 mg/l (site 5). Umar et al. [32] reported that low values of sulphate indicated under saturation of the ground water with respect to gypsum or anhydrite. The overall dominance pattern of anions across study sites was HCO_3 > Cl > SO_4^{2-} (Fig.5).

Table 2. Descriptive statistics of the average concentration of the water quality parameters

	Temperature	pH	Conductivity	TDS	Cl^-	HCO_3	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	SO_4^{2-}
Minimum	12	6.51	341	143	10	113	171	38	4	4	0	4
Maximum	21	7.59	1910	1137	250	638	727	171	74	130	33	85
Mean	16	7	726	388	45	302	373	93	28	25	2	18
Standard deviation	1.6	0.3	361.6	236.0	63.6	121.9	139.1	43.4	20.0	32.3	7.4	18.0

All values are in mg/L except temp (°C), pH and conductivity (µS/cm).

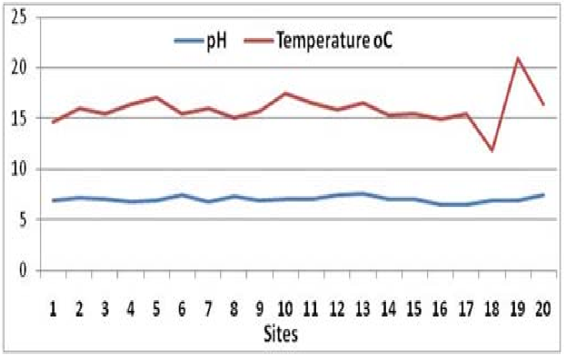

Fig.2.Mean variation in pH and groundwater temperature across study sites

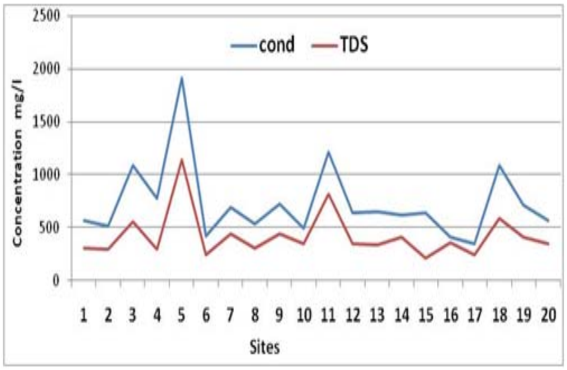

Fig.3. Mean variation of conductivity and TDS across study sites

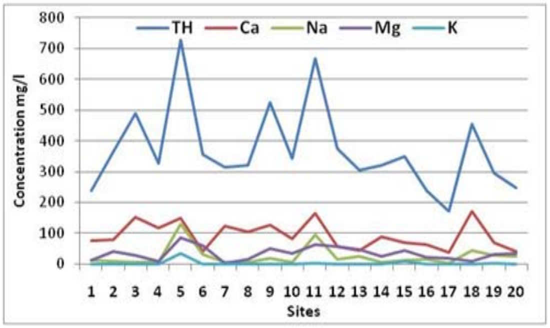

Fig.4. Variation of total hardness values with respect to cationic compositions across study sites

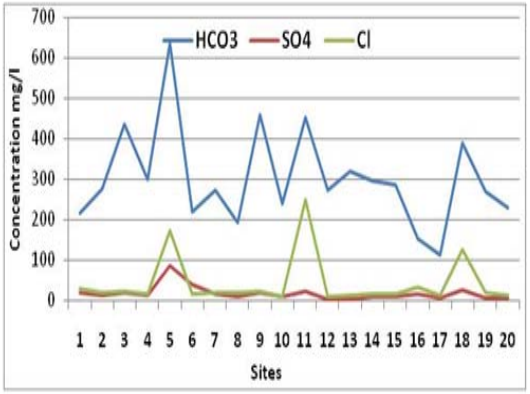

Fig.5. Variation in anionic composition across study sites.

Irrigational quality

Irrigational quality of ground water depends on the ionic composition of Ca, Mg, Na and K, however, lower concentration of Ca and Mg will favor sodium hazard and vice versa for higher concentration [33] . Ca, Mg and Na are among the ionic species that are constantly involved in cation exchange process and interaction with aquifer material [34]. Further, the excessive amounts of dissolved ions in irrigation water affect soil physically and chemically, thus reducing the primary productivity [35].Therefore, salinity, sodicity and toxicity are generally considered for evaluation of the suitability of these groundwater sources for irrigation purpose [20].

Alkali Hazard

Sodium concentration plays an important role in evaluating irrigational quality of ground water because high concentration of sodium is undesirable as sodium is absorbed on the exchange sites causing soil aggregates to disperse, thus reducing its permeability [18,36,37]. From Table 3 all the study sites had very low SAR values, which ranged between 0.1 meq /l to 2.1 meq /l at sites 10 and 5 respectively, indicating that groundwater samples had excellent quality for irrigation with no danger of exchangeable sodium [33].On the other hand, % sodium ranged between 2.67 at site 10 to 31.64 at site 5. According to Todd [38] all sites belong to excellent category (<20%) except sites 5 and 11 which belong to good category where %sodium was > 20%. Low SAR and %sodium seemed to be due to the presence of significant quantities of divalent cations like calcium and magnesium, which are more strongly bonded and tend to replace monovalent ions like sodium and potassium [38].

Salinity Hazard

The combination of electrical conductivity and SAR had also been used to determine the suitability of water for irrigation [25]. According to US salinity hazard diagram [39], sites 3, 8, 13 and 19 fall in the field of C_3S_1 category indicating high salinity and low alkali hazard and rest of the samples fall under C_2S_1 indicating medium salinity and low alkali hazard (Table 3; Fig. 6). These groundwater sources can be used to irrigate all types of soils with little danger of exchangeable sodium. While plotting %Na against electrical conductivity on Wilcox's diagram [14] (Fig.7), it was found that sixteen sites had water quality varying from excellent to good, while four sites (3, 5, 11, 18) had good to permissible. The data suggested that despite good irrigational status of valley ground waters, concentration of dissolved salts showed increasing trend at majority of the sites due to increase in the soluble mineral materials along the flow path [20]. This depicts the evolutionary trend of changing fresh waters into salinized and / or inclination towards more salt concentration.

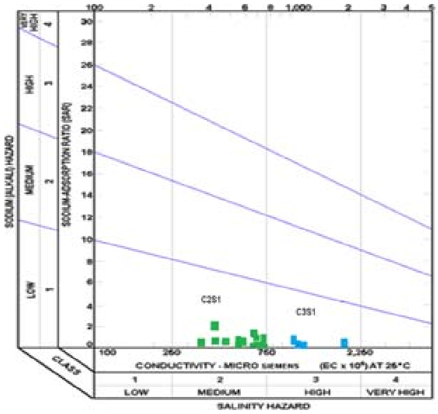

Fig.6. Plotting SAR against EC (USSL, 1954)

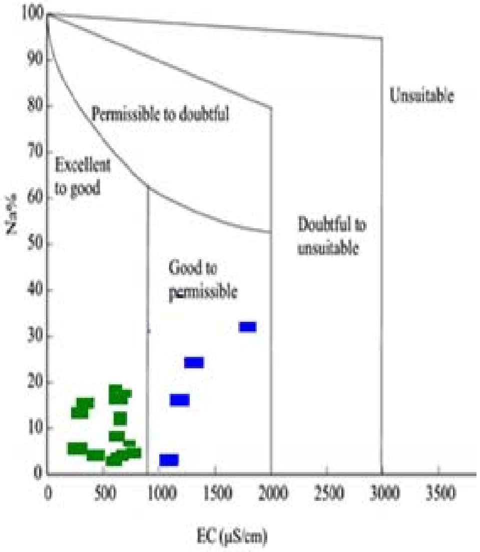

Fig.7. Plotting %sodium against electrical conductivity

Bicarbonate Hazard

Residual sodium carbonate is an index used to determine the bicarbonate hazard [40] as well as to distinguish between the different water classes for irrigation purposes. The average concentration of RSC varied from 1.28 to 6.12meq/l at sites 20 and 11 respectively. The classification of water quality for irrigation on the basis of RSC as proposed by Eaton [15], indicated that eleven sites viz., 1, 3, 4, 7, 13, 14, 15, 16, 17, 19 and 20 have marginal quality with RSC ranging between 1.25 meq/l and 2.5 meq/l, these were suitable for irrigation purpose, eight sites (2, 5, 6, 8, 9, 10, 12 and 18) belong to unsuitable category (RSC 2.5 - 5 meq/l), while site 11 had RSC > 5 meq/l, is harmful for irrigation purpose as it leads to an increase in adsorption of sodium on soil which eventually lead to the clogging of the soil [15] Table 3.

Table.3.Mean values of SAR, %Na & RSC

Sites	SAR (meq/l)	%Na	RSC (meq/l)	SALINITY HAZARD
1	0.3	8.64	1.42	C2 S1
2	0.18	4.34	2.91	C2 S1
3	0.14	3.10	2.42	C3 S1
4	0.18	4.75	1.67	C2 S1
5	2.1	31.64	4.38	C2 S1
6	0.71	16.06	3.56	C2 S1
7	0.13	3.68	2.06	C2 S1
8	0.13	3.48	3.21	C3 S1
9	0.35	7.15	3.03	C2 S1
10	0.1	2.67	2.91	C2 S1
11	1.61	24.38	6.12	C2 S1
12	0.18	4.12	3.15	C2 S1

13	0.62	14.70	1.66	C3 S1
14	0.16	4.27	1.72	C2 S1
15	0.35	10.81	2.42	C2 S1
16	0.5	13.84	2.31	C2 S1
17	0.14	5.15	1.61	C2 S1
18	0.94	17.19	3.01	C2 S1
19	0.92	17.23	1.63	C3 S1
20	0.69	17.83	1.28	C2 S1

Conclusions

It can be concluded that lithology has played an important role in influencing the chemistry of the studied groundwater sources. The chemistry showed that these waters are hard and highly mineralized. Although these groundwater sources were fit for irrigation purposes as far as SAR and %Na values are concerned, but the value of RSC and concentration of dissolved solids showed increasing trend at majority of the sites which may render them unfit for irrigation purposes in future.

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