

HYDROGEOCHEMICAL ASSESSMENT OF SOME SUB-SURFACE WATERS OF KASHMIR VALLEY

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ABSTRACT

Samples from 20 groundwater sources in Pulwama and Islamabad districts of Kashmir valley were collected to identify the major processes influencing the groundwater chemistry. The samples were also assessed for drinking water quality as it is the major source of water in the region used for domestic purposes. Results revealed the dominance pattern of cations in the progression $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ for cations, while the anion concentration was $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$. Similarly, Ca-Mg- HCO_3^- and Ca- HCO_3^- were the major water types in the study area. The hydrochemical facies indicated that alkaline earths (Ca^{2+} and Mg^{2+}) exceed alkalis (Na^+ and K^+) and weak acid (HCO_3^-) exceed strong acids (Cl^- and SO_4^{2-}) which reflects the undisturbed natural condition of these groundwater systems. Most of the samples assessed are suitable for drinking, but alkalinity, total hardness, calcium and magnesium values crossed the desirable limits at most of the sites.

Key words: Ground water, lithology, pollution, precipitation

INTRODUCTION

In India, more than 90% of the rural and nearly 30% of the urban populations depend on groundwater for meeting their drinking and domestic requirements (Reddy *et al.*, 1996). Although, groundwater was

considered to be free from contamination but anthropogenic activities have almost completely changed the scenario and many of the ground waters stand already polluted. Generally groundwater quality is governed by lithology, aquifer properties, groundwater flow, nature of geochemical reactions, residence time, quality of recharge waters, solubility of salts, and human activities such as agriculture, sewage disposal, mining and industrial wastes, etc (Abdel-Lattif, 2003). Chemistry of groundwater provides the basis to investigate the weathering reactions in the basin (Das and Kaur, 2007), which are highly vulnerable to pollution due to absorption and transportation of domestic, industrial and agricultural wastewater. The geochemical processes such as mineral weathering, dissolution/precipitation reactions and ion exchange, are responsible for the temporal and spatial variations in groundwater quality (Reddy *et al.*, 2010). As the groundwater flows through an aquifer it assumes a diagnostic chemical composition as a result of interaction with lithological framework (Fetter, 1994; Reddy and Niranjana, 2010).

In general groundwater is not contaminated but anthropogenic factors may induce some changes in its quality. Once it gets polluted its recovery is almost

irreversible compared to the surface waters (Hem, 1985), and hence ceases to have any potential as a source of water (Selby and Skinner, 1979). In recent years, several researchers evaluated the suitability of groundwater for domestic and irrigation purposes using various physical, chemical, and biological properties (Lumb *et al.*, 2006; Vasanthavigar *et al.*, 2010). Widespread reports of bacteria, nitrate, salinity, and other pollutants in groundwater have increased public concern about the quality of groundwater (Jain *et al.*, 2009). These studies emphasized the significance of groundwater quality monitoring and evaluation in order to protect valuable groundwater sources and to establish future developmental strategy. Presently, there is little information on groundwater portability, aquifer performance and utilization of the groundwater for domestic purposes in the Kashmir valley. The present study was carried out to evaluate the hydrogeochemical characteristics of

groundwater and its suitability for drinking purposes in Pulwama and Islamabad districts of Kashmir Valley, in order to check whether the quality of groundwater sources has deviated from its natural formation.

Geological Setting and Location

The area under study is located towards the south of Kashmir valley in Pulwama (33° 50' - 34° 15' N to 74° 30' - 75° 15' E) and Islamabad (33° 25' - 34° 15' N to 74° 30' - 75° 40' E) districts. The study area comprises rocks ranging from Paleozoic sedimentary to recent alluvium. The main rock containing good groundwater deposits are limestone, Paleo-river channels of alluvial deposits, volcanic rocks, and Fluvio-glacial deposits under lower and middle Karewa. The ground water regime of the area is controlled mainly by river Jhelum and its tributaries, viz., Vishav, Sandran, Bringhi, Liddar, Romshi and Rambiarra. The detail of the sampling sites is given in Fig.1 and Table 1.

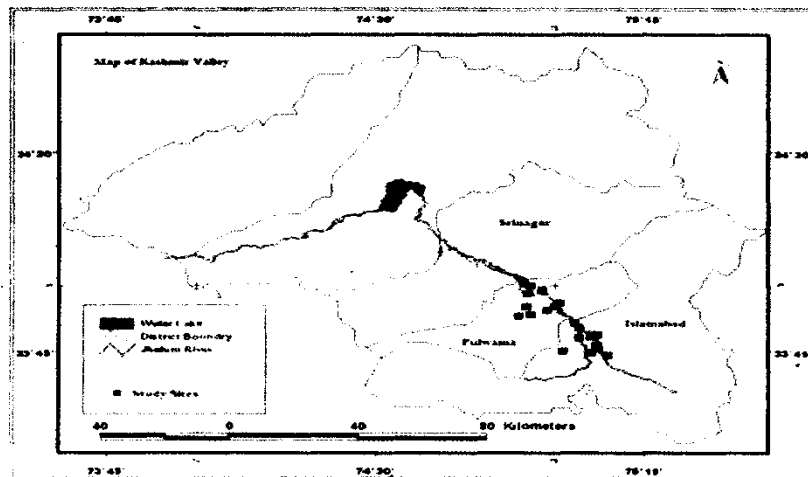


Fig 1. Map of study sites in Islamabad and Pulwama districts

Table 1. Sampling Locations

Site No	Sampling Area	District	Latitude/Longitude	Altitude	Depth
1	Ashajipora		33° 42.835' N, 75° 09.124' E	1627 mt	50 ft
2	Wanpooh		33° 43.676' N, 75° 06.353' E	1605 mt	131 ft
3	Khanibal		33° 44.338' N, 75° 47.438' E	1605 mt	80 ft
4	Urnhal		33° 45.535' N, 75° 07.134' E	1620 mt	17 ft
5	Bijbehara		33° 47.444' N, 75° 06.308' E	1624 mt	52 ft
6	Hasanpora	Islamabad	33° 47.013' N, 75° 04.395' E	1613 mt	30 ft
7	Takibal		33° 44.140' N, 75° 07.305' E	1620 mt	30 ft
8	Kokergund		33° 44.140' N, 75° 01.389' E	1670 mt	60 ft
9	Sangamnayun		33° 49.648' N, 75° 04.334' E	1602 mt	30 ft
10	Sangam Sathar		33° 50.898' N, 75° 03.300' E	1660 mt	40 ft
11	Awantipora		33° 54.672' N, 75° 01.152' E	1607 mt	50 ft
12	New Colony Barsoo		33° 57.357' N, 74° 58.909' E	1660 mt	60 ft
13	Galender		33° 59.423' N, 74° 55.762' E	1615 mt	50 ft
14	Padgampora		33° 54.325' N, 75° 00.027' E	1631 mt	20 ft
15	Malangpora	Pulwama	33° 53.526' N, 74° 58.967' E	1602 mt	32 ft
16	Dangherpora		33° 52.260' N, 74° 54.807' E	1654 mt	13 ft
17	Pulwama lines		33° 51.349' N, 74° 53.752' E	1678 mt	100 ft
18	Pinglen		33° 53.910' N, 74° 55.188' E	1653 mt	10 ft
19	Sambura		33° 57.500' N, 74° 55.610' E	1627 mt	23 ft
20	Latribal		34° 00.060' N, 74° 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, nineteen from bore wells and one from dug well, each provided with hand pump. Prior to the collection of samples, hand pumps were flushed for 5 - 10min, to ensure that the water to be collected represents the actual groundwater aquifer and not the stagnant and polluted one. The water samples were collected in 2 liter plastic bottles (previously cleaned with 10% HNO₃,

followed by distilled water). All the samples were refrigerated at 4°C for detailed chemical analysis. Temperature, pH and conductivity were measured on the spot by Celsius thermometer, digital pH meter MKVI and digital conductivity meter DB 104 respectively.

The physico-chemical analysis was performed by standard methods given in APHA (1998). The total alkalinity, chloride and hardness were analyzed by titrimetric method, using 0.02N H₂SO₄, AgNO₃ and 0.1N EDTA respectively as titrants. Sodium

and potassium content was determined by Systronics 130 flame photometer, while sulphate was analyzed by turbidimetric method and dissolved silica by molybdosilicate method, using Systronics 105 spectrophotometer. The TDS was assessed by gravimetric method.

RESULTS AND DISCUSSION

The data collected on various parameters are presented 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. 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 (Lee, 2006; Lee and Hahn, 2006). The mean pH value ranged from a low of 6.51 (site 16) to a high of 7.59 (site 13). The slightly acid 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 (Tijani, 1994; Yangjun *et al.*, 2006), 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 large variation in electrical conductivity is mainly attributed to lithologic composition and anthropogenic activities prevailing in this region (Khodapanah *et al.*, 2009). 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 (Sanchez-perez and Tremolieres, 2003) In the present study concentration of total dissolved solids varied from 211mg/l (site 15) to 1137mg/l (site 5). Total dissolved solids followed the same trend as conductivity at most of the study sites (Fig 2).

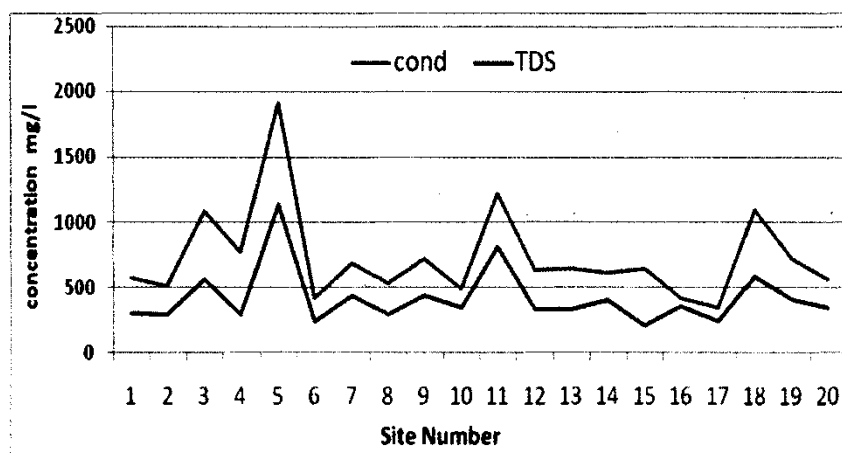


Fig. 2. Variation of mean conductivity values with respect to TDS across study sites

Table 2. Mean±SD of different parameters at different sites (n=4)

Sites	Temp	SD	pH	SD	TDS	SD	Chloride	SD	Alkalinity	SD	Hardness	SD	Ca ²⁺	SD	Mg ²⁺	SD	Na ⁺	SD	Na ⁺	SD	K ⁺	SD	SO ₄	SD	SiO ₂	SD	
1	14.6	1.6	6.85	0.03	570	11	304	21	30	2	216	21	238	31	76	12	12	3	11	1	0	0	20	3	15	1	
2	16	0.8	7.19	0.13	513	8	290	11	19	3	276	19	367	12	60	6	41	6	8	2	0	0	13	3	19	3	
3	15.4	0.8	7.02	0.08	1084	139	560	18	25	5	437	59	491	50	152	8	27	10	7	1	0	0	20	5	24	2	
4	16.4	0.8	6.77	0.17	772	32	292	14	17	1	300	9	328	18	118	7	8	4	7	1	0	0	13	6	16	6	
5	17	0.9	6.87	0.11	1911	240	1137	42	173	20	638	28	727	14	151	3	85	4	130	1	33	2	86	12	25	5	
6	15.4	0.8	7.38	0.18	414	6	243	21	18	3	221	32	357	13	42	7	61	7	32	3	0	0	41	2	16	4	
7	16	0.8	6.76	0.16	686	4	445	30	19	9	273	14	316	12	125	4	4	1	6	1	0	0	18	4	17	3	
8	15.1	0.5	7.28	0.06	531	10	299	47	19	4	195	26	320	12	103	6	15	2	5	1	0	0	11	5	14	2	
9	15.7	0.8	6.85	0.21	720	18	440	46	25	5	462	15	525	15	127	5	50	4	18	2	0	0	19	4	16	5	
10	17.4	1	7.08	0.14	490	15	351	36	11	3	239	15	342	49	82	9	33	8	5	1	0	0	9	2	12	1	
11	16.5	0.6	7.01	0.17	1215	86	213	5	250	30	453	14	669	14	166	3	62	4	96	9	4	0	24	6	18	1	
12	15.8	1.9	7.37	0.12	639	68	341	35	10	0	273	10	375	38	56	4	57	10	14	2	0	0	4	1	15	2	
13	16.5	0.7	7.59	0.20	647	29	331	23	14	4	321	47	306	11	44	2	48	2	25	3	0	0	5	3	18	1	
14	15.3	1	7.08	0.20	615	28	407	20	16	2	295	5	322	20	88	0	25	5	6	1	0	0	11	5	10	2	
15	15.4	1.4	7	0.44	643	26	211	10	16	2	287	22	351	9	68	0	44	2	13	1	8	1	12	3	17	2	
16	14.9	2	6.51	0.04	413	19	364	17	35	9	155	19	239	11	62	1	20	2	15	3	0	0	16	5	9	2	
17	15.5	1	6.55	0.16	341	12	242	46	14	3	113	11	171	6	38	3	19	2	4	1	0	0	6	1	9	2	
18	11.8	1.3	6.87	0.17	1052	210	588	27	128	19	389	33	455	26	171	1	8	4	45	4	0	0	25	6	14	0	
19	21	2.2	6.92	0.22	714	17	413	15	20	3	271	29	297	25	69	4	30	4	29	7	4	1	6	2	12	2	
20	16.4	0.5	7.48	0.12	565	19	351	24	14	2	229	18	247	29	42	20	35	7	25	3	0	0	8	3	17	3	
WHO standards (2006)			6.5-8.5		1400		500-1500		250						>=200		30-150		200				200				
BIS Standards (1993)									1000		200-600		300-600														

All values are in mg/l except conductivity (µs/cm) & pH. SD=standard deviation

Alkalinity was mainly contributed by bicarbonate ions and ranged from 113 mg/l at site 17 to 638 mg/l at site 5. Matthes (1982) 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 (Tijani, 1994; Kumar *et al.*, 2006). The hardness ranged from 171 mg/l (site 17) to 727 mg/l (site 5). The ground waters under study fall between hard (121-180 mg/l) and very hard type (>180 mg/l) as per Durfor and Becker (1964) and are not fit for domestic purpose (Hem, 1985; Bell, 1998). High hardness values might be supported by the presence of rich deposits of limestone and evaporates in the valley (Raza *et al.*, 1978; Hussain, 2000).

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 (Table 2). The major source of calcium and magnesium in the valley ground waters might be the lacustrine deposits (Hussain, 2000) as sedimentary rocks like lime stone, gypsum and dolomite are rich source of magnesium and calcium in ground water (Davis and DeWeist, 1996). The dominance of calcium ions over magnesium ions is attributable to abundance of these rocks in the study area. Higher magnesium content at site 6, 12 and 13 seems to be related to decomposition of pyroxene in the volcanics (Bhat *et al.*, 1981). Since 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 (Bell, 1998). Concentration of sodium was below 30 mg/l (minimum value of 4 mg/l 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 (Hem, 1985). 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 $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$.

Chloride ion ranged from 10 mg/l (Site 9) to 250 mg/l (Site 10). All the samples fall within permissible category. 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 (Patalas *et al.*, 2006; Arumugam and Elangovan, 2009) or due to the longer residence time of chloride in groundwater (Driscoll, 1986). Generally the concentration of sulphate in ground waters is usually <100 mg/l (Bell, 1998). In case of the present sites its concentration ranged from 4mg/l (site 12) to 86mg/l (site 5). Umar *et al.* (2008) reported that low values of sulfate indicated under saturation of the groundwater with respect to gypsum or anhydrite. The overall dominance pattern of anions in the samples was $HCO_3^{-} > Cl^{-} > SO_4^{-}$.

Dissolved silica was present in low concentrations in the study area, ranging from 9mg/l to 25 mg/l which seems to be

related to its low solubility (Bell, 1998).

Drinking Water Quality of Ground Waters

Qualitative analysis of the present ground water sources vis-à-vis their use for drinking purpose showed that all the ground water sources had pH, chloride, sodium and sulphate within the desirable limits specified by WHO. Electrical conductivity values exceeded the prescribed upper limit of 1400µS only at Bijbehara (site 5). The study revealed that TDS values were within the desirable limit of 500 mg/l at majority of the sites, except at Khanibal, Bijbehara, Awantipora and Pinglen. At these sites also the values were below the maximum permissible limit of 1500mg/l. A total of sixteen sites crossed the BIS desirable limit of 200mg/l for alkalinity, while Bijbehara crossed the maximum permissible value of 600mg/l. In case of total hardness, thirteen sites crossed the desirable limit of 300mg/l and two sites (Bijbehara and Awantipora) crossed the maximum permissible limit of 600mg/l. Similarly, sixteen sites in case of calcium and ten sites in case of magnesium crossed the desirable limits of 75mg/l and 30mg/l respectively.

Hydrochemical Facies

Hydro chemical facies are a function of lithology, solution kinetics and flow patterns of the aquifer (Back, 1960) and help to characterize the ground water. From the piper diagram (Fig 3) it becomes evident that Ca-Mg-HCO₃ was the dominant facies and was represented by 60% sites followed by Ca-HCO₃ type, which was represented by 30% sites. Freeze and Cherry (1979) and

Ophori and Toth (1989) reported that the dominance of alkaline earth metals and weak acids signify that water corresponds to upper zone and occur in recharge area. The occurrence of young waters as a major group in the area represented the presence of limestone and dolomite rocks. Moreover, the dominance of alkaline earth bicarbonates reflects the undisturbed natural condition of these groundwater systems. However, site 18 and site 11 showed Ca-Cl-HCO₃ and Na-Cl-HCO₃ facies respectively (Table 3). The occurrence of such type of facies can be attributed to the external factors affecting the water quality (Drever, 1997), as quality of these ground water sources seems to have deviated from its natural formation (carbonate bed rock).

Table 3. Chemical type of water at different study sites

Site No.	Chemical of Water
1	Ca - Mg - HCO ₃
2	Ca - HCO ₃
3	Ca - Mg - HCO ₃
4	Ca - HCO ₃
5	Ca - Mg - HCO ₃
6	Ca - Mg - HCO ₃
7	Ca - HCO ₃
8	Ca - HCO ₃
9	Ca - Mg - HCO ₃
10	Ca - Mg - HCO ₃
11	Ca - Cl - HCO ₃
12	Ca - Mg - HCO ₃
13	Ca - Mg - HCO ₃
14	Ca - Mg - HCO ₃
15	Ca - Mg - HCO ₃
16	Ca - HCO ₃
17	Ca - Mg - HCO ₃
18	Na - Cl - HCO ₃
19	Ca - Mg - HCO ₃
20	Ca - Mg - HCO ₃

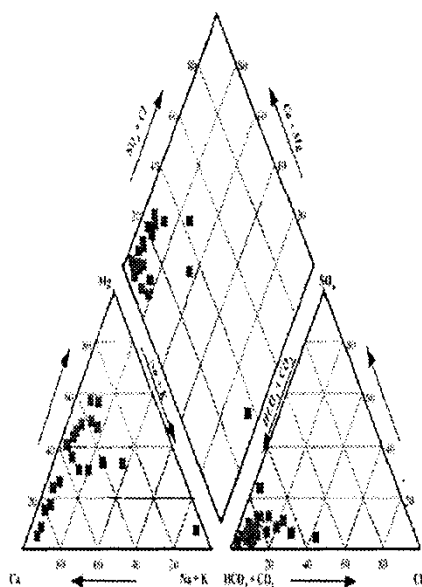


Fig.3. Hydrochemical facies of different ground water sources
 ■ Ca-HCO₃ ■ Ca-Mg-HCO₃ ■ Na-Cl-HCO₃ ■ Ca-Cl-HCO₃

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