Evaluation and Efficient Management of Spring Waters in Kashmir Valley: Challenges and Opportunities

[Blank line 11 pt]

Sami Ullah Bhat*

* Assistant Professor, Department of Environmental Science, University of Kashmir, Srinagar-190006 Jand K, India

Email:samiullahbhat11@gmail.com

[Blank Line 9 pt]

Ashok K Pandit°

° Professor, Centre of Research for Development, University of Kashmir, Srinagar-190006 J and K, India

[Blank Line 9 pt]

[Blank line 10 pt]
[Blank line 10 pt]

KEYWORDS

Hydro chemical, Spring, Ground water, Drinking water, Stressor

[Blank line 10 pt]
[Blank line 10 pt]

Abstract

Globally, springs are disappearing at an alarming rate, and most of that loss goes largely unrecognized. Nation efforts are needed to bring attention to the ecological importance of springs and their conservation. The populatio of Jammu and Kashmir like other parts of India is witnessing an enormous growth and supply of drinking wate seems to be a real challenge. Without investment in intensive research and effective public distribution system th per capita demand for potable water is likely to remain a dream. The aim of the study was to evaluate the quality spring waters and to identify options for meeting the demand of ever zooming population apart from identification major anthropogenic stressors and the subsequent remedial response measures.

In this backdrop a field study was conducted to assess variations in physico-chemical characteristics of water of th springs located within the three districts namely Anantnag, Pulwama and Srinagar of the Kashmir valley where th water is being used for many purposes like drinking, swimming, irrigation, washing/bathing, recreation, fishery et The monitoring and evaluation of seven typical freshwater springs depicted that these springs are hard water wit the predominance of bicarbonate and calcium than other ions. Fair to substantial spatial and temporal variations i water temperature, pH, conductivity, dissolved oxygen, hardness, calcium, alkalinity, potassium, nitrate nitroge sulphate and phosphorus were observed among the springs under study. Springs with their location in agricultur and settlement show slightly higher nutrient values than the springs near pine forests. Following the (Theinema 1922) classification of springs, springs like Verinag, Sherebagh, Indraznag and Cheshmashahi fall under th category of limnocrene while Kokernag and Achabal fall under rheocrene and Dobinag under helocrene. Similarl on the basis of magnitude of discharge employing the (Meinzer 1923) classification of springs, the springs viz. (Kokernag and Achabal, (ii) Verinag and Sherebagh, (iii) Dobinag and (iv) Indraznag and Cheshmashahi plunge i the spring order 2, 3, 4 and 5 respectively however according to (Rosenau et al. 1977) these attain the same sprin order excepting Verinag which falls under spring order 2 instead of spring order 3. Based on the hydrauli characteristics and character of opening, the springs under study proved to be artesian and fracture type exceptin Dobinag which is of nonartesian and filtration type. Further, the springs under study happen to fall under cold wate springs as per the classification given by(Meinzer 1923; Waring et al.1965; Reed 1983; Nathenson et al. 200 except Sherebagh spring where annual mean water temperature (16.55±0.47°C) was slightly higher than the annu mean air temperature. Springs under study were also found to have varied impact inflicted by various anthropogeni stressors.

In the light of our observations we recommend that springs managers consider promptly implementing invento and assessment protocols, as well as immediate remedial response measures to cope with immediate threats to th spring ecosystems. Since these springs remain the data deficient systems nationally and as such much addition basic information is needed, and new administrative and technical approaches are crucial to put in place for lon

term protection and restoration of springs. In addition, it would be appropriate to select a group of springs fo intensive research purposes, so that fundamental and outstanding questions on natural spring ecosystem ecolog can be addressed in a better way.

1. Introduction

Karstic terrains cover approximately 12% of the earth's continental surface and 25% of the world's population i supplied partially or entirely by freshwater springs (Williams 1993; Ford and Williams 2007).One of the mos pressing issues the world faces is the management of freshwater resources amongst which springs have become focal points because of their geological, ecological, scientific, cultural and societal importance besides burgeonin demands for drinking, irrigation, industrial, fishery and recreational purposes in different parts of the world (Glazie 2009). However, the concept of sustainable management of freshwater springs in Kashmir valley is poorly reflecte in the policy making despite the fact that these springs contribute in meeting the demands of continuously zoomin population significantly. Our dependence on springs becomes increasingly critical on one side while on the othe hand our knowledge of freshwater spring ecosystems remains spartan. The easy access of freshwaters especiall spring waters, unlike other parts of India, has produced a sense of unlimitedness in the vale of Kashmir which intur gets reflected in the mindset of policy makers.

The intensive agriculture, domestic sewage and other land use patterns have impaired the quality of spring water by contributing large quantities of nutrients to groundwater recharge (Wells and Krothe 1989; Dietrich and Hebe 1997; Pacheco and Cabrera 1997; Focazio et al. 1998; White 1988; Coxon 1999; Katz et al. 2001; Veni et al. 2001 Panno et al. 2001; Bohlke 2002; Katz 2004a).
The number of springs is not exactly known for most geographical regions, and those few regional estimates tha have been made vary by over three orders of magnitude. These numbers are underestimates as they are based o surveys that usually ignore small springs and seeps, which greatly exceed the number of larger springs. Therefore keeping in view the abundance of springs they happen to play key role in part of the hydrologic cycle (Jana 1973 Keshi 1980; Brune 2002; Gray 2005; Sada et al. 2005; Sajna et al. 2007; Sayili et al. 2007). Throughout the worl there is a growing recognition of the value of springs, and several initiatives have been implemented to ensure the protection and sustainable management (Fatchen 2000;Hartnett 2000; Sada et al. 2001; Sada and Sharpe 2004 The goal is to provide water for the environment to sustain and where necessary restore ecological processes an biodiversity of Groundwater Dependent Ecosystems (GDEs) such as springs Springs in the valley are essentiall unexplored with only very few reports on hydrolochemical characteristics while some are important from religiou and cultural context making them significantly known. Information on biodiversity assessment is scant, if it exists a all as being undescribed. There stands no baseline assessment or long-term monitoring in place to scientificall assess threats and concerns to spring ecosystems in the Kashmir Valley. Thus, the potential for a monitoring effo to detect changes in spring ecosystem condition outside the historic range of variability seems must due t pressures on water quality by ever increasing human population growth coupled with modification in land us pattern apart from other contributing factors. The threats and challenges operating at various scales on sprin waters include groundwater withdrawal, pollution from sewage, pesticides and fertilizers, draught, flow reductio etc.These threats can only be addressed for better management of spring waters once the full-fledged long tern monitoring programme is in place to suggest the corrective and remedial measures for using these biotopes in sustainable manner.

1.1 Geological and Hydrogeological charecteristics of the study area

The high altitude valley of Kashmir is an ovoid basin with a nearly flat floor of around 4920 km2 and is existin between the lesser and greater Himalayas. The vale of Kashmir with tectonic origin now lies in Indian occupie Kashmir is 135 km long and 45km broad at its middle, lying as an oval bowl between the Zanaskar range to th North and Pir Panjal range to the South. The valley is surrounded on all sides by high mountais which remain snow-clad for most of the year. The valley abounds in snow-fed, spring-fed streams, rivers with a network of the tributaries and numerous freshwater lakes. Most of the valley lies at an elevation of just over 1500m, though its floo rises steadily from northwest to southwest (Wadia 1966). The vale of Kashmir is drained by the river Jhelum whic leaves it through a deep gorge in its northwest cones. The valley of Kashmir being surrounded by Himalaya ranges resembles the medditraean type being characterised by a rainfall occurring throughout the year except 2- dry periods in summer and autumn. Kashmir valley experienced about 635-680 mm rainfall (2004-05) wit maximum average monthly temperature of about 20.45°C having monthly average extremes ranging from -3.3°C i December 2005 to 30.4°C in August 2005 recorded in capital city Srinagar (Digest of Statistics 2007).
The valley of Kashmir harbours hundreds of springs of different magnitudes which attract the tourists and pla important role in formation of landscape, rearing of fish, irrigation and drinking water (Table 3). Seven freshwate springs falling in three districts of valley namely Srinagar (Cheshmashahi), Anantnag (Verinag, Kokernag, Achaba and Sherebagh) and Pulwama (Indraznag and Dobinag) were selected for the purpose of present study (Table 2

Fig. 1).

2. Material and Methods

In order to measure the detailed hydrochemical variations, seven freshwater springs falling in three districts o Kashmir valley namely Srinagar (Cheshmashahi), Anantnag (Verinag, Kokernag,Achabal and Sherebagh) an Pulwama (Indraznag and Dobinag) were chosen for study during March 2004-February 2005.However, it i important to mention here that the sampling during the month of February 2005 was not possible because of heav snow fall in the valley which claimed many human lives besides property damage. The samples were obtained nea spring bowl and processed on monthly basis however it is extremely difficult to handle large amount of data an taking this thing into consideration the seasonal and annual mean values of different parameters are presented i the paper. The parameters like water temperature, pH and conductivity (APHA 1998) were measured with digita thermometer, pH metre and conductivity metre respectively while dissolved oxygen (APHA 1998 and Wetzel an Likens 2000) was estimated by Winkler's titration method. The parameters like chloride (Argentimeteric), alkalinit (Titrimetric) and hardness (EDTA titrimetrc method) were measured by tittrimetry methods while ammonical nitroge (Phenate method), nitrate (Sodium salicylate), phosphorus (Ascorbic acid), dissolved silica (Molybdate blue sulphate (Turbidimetric method) and sodium and potassium were analysed by spectrophotometric and flam photometric methods respectively (APHA 1998; Wetzel and Likens 2000). Geocordinates and elevations wer determined with GPS and the Tukey HSD was employed through SPSS.

3. Results and discussion

The chemical composition of groundwater results from the geochemical processes occurring as water reacts wit the geologic materials through which it flows. In addition, the land use or human activities within the catchment ca affect the groundwater quality (Back et al. 1965; Appelo and Postma, 1996).Following the (Bornhauser 1912) an (Theineman 1922) classification of springs, springs like Verinag, Sherebagh, Indraznag and Cheshmashahi wer categorised as limnocrene while Kokernag and Achabal fall under rheocrene and Dobinag under helocrene (Tabl 1.) Similarly on the basis of magnitude of discharge employing the (Meinzer 1923) classification of springs, th various types of springs viz. (i) Kokernag and Achabal, (ii) Verinag and Sherebagh, (iii) Dobinag and (iv) Indrazna and Cheshmashahi plunge in the spring order 2, 3, 4 and 5 respectively while as the classification given b (Rosenau et al. 1977) puts these on the same spring order excepting Verinag which falls under spring order instead of spring order 3. Based on the hydraulic characteristics and character of opening, the springs under stud proved to be artesian and fracture type excepting Dobinag which is of nonartesian and filtration type. Further, th springs under study happen to fall under cold water springs as per the classification given by(Meinzer 1923; Warin et al. 1965; Reed 1983; Nathenson et al. 2003) except Sherebagh spring where annual mean water temperatur (16.55±0.47°C) was slightly higher than the annual mean air temperature. The mean annual mean wate temperature oscillated between 10.72±1.0°C (Kokernag) and 16.55±0.47°C (Sherebagh) amongst the springs. Th springs under study are at intermediate elevations (1400-2100m) and probably meet the definition of cold spring except Sherebagh. The slightly constant and higher water temperature of Sherebagh is probably due to longe circulation paths but the slightly anomalous temperature of Sherebagh may also be due to conductive heat transfe rather than any volcanic activity involving a hydrothermal system (Gonfiantini 1978; Rose et al. 1996; Symonds e al. 2001).The variation in annual air temperatures seems behind the sinusoidal pattern in spring water temperature with maxima in summers and minima in winters (Liu et al. 2007).

The pH of the spring waters reflected from seasonal mean values was on the alkaline side excepting Indrazna and Dobinag. The slightly acidic character of these two springs, unlike other springs, is because of their differer catchment and macrophyte dominance. Higher concentration of sulphates in these two springs, related to th presence of pyrite in the catchment, and decomposition of macrophytes releasing organic acids and diurna changes in the dissolved free carbon dioxide are probably the causal factors for lowering the pH values of th springs.The variation in the pH values from one season to another is generally related to dilution, due to influx o rain water in the recharge zone of aquifer. The conductivity of the spring waters exhibited variations within the rang of 147±18.34 µS/cm (Dobinag)-375±48.53 µS/cm (Sherebagh). The lowest seasonal mean values of conductivit were obtained in winter for most of the springs. The possible reason for such a trend is due to the dilution factor a there was a heavy snowfall during the winter as the same has been reported by Kumar et al. (2006) elsewhere. Th springs relatively at higher altitudes depicted lower annual mean values of conductivity as compared to those a lower altitude with the exception of Verinag which may be due to the higher discharge of water, a fact als supported by the studies of Andreo et al. (1999). Data obtained on dissolved oxygen concentrations depicte considerable spatial variations from1.78±0.58 mg/L at Sherebagh to 6.76±1.68 mg/L at Kokernag. The sligh increase in the concentration of dissolved oxygen during the summers is due to photosynthetic activity in th springs. The striking feature connected with dissolved oxygen of springs under study is its nearly constar concentrations exhibited through the study period.

Apparently the water, which has just emerged from subterranean cervices and is fairly homogenous with respect t dissolved oxygen concentration, does not remain in contact with the plants of the spring bowl area for a sufficier length of time to allow an increase in dissolved oxygen content due to photosynthetic activity. Apart from Sherebag and Indraznag, the rest of the springs displayed the fair amount of oxygen which is in consonance with the finding of (Bhat and Yousuf 2002; Pandit et al. 2005). Further, the relatively high nutrient level in Sherebagh also interfere with the solubility of oxygen though very passively, thereby decreasing the oxygen concentrations. In general, th spatial characteristics (macrophyte dominance and photosynthetic activity) of individual springs besides wate temperature does have an impact on temporal fluctuations of dissolved oxygen in different springs.
The relatively lesser concentration of dissolved oxygen at Sherebagh and Indraznag is attributable to slightly warr conditions and to some extent the macrophyte dominance at Indraznag which consumes oxygen durin decomposition thereby rendering its concentration to be low. The higher values of dissolved oxygen concentratio were observed in spring season (comparatively at Verinag and Kokernag) possibly because of the low wate temperatures. The decrease in the dissolved oxygen concentration at Indraznag and Sherebagh during the summe is due to slight increase in water temperature because of increase in biochemical reactions which consum dissolved oxygen at a rapid rate, thus rendering its concentration to be lower in summer (Metcalf and Eddy 197! Kumar et al. 1996; Joshi and Kothyari 2003).

The waters, in general, were rich in free CO_2 because of dissolution of carbonates from the catchment. Beside: underground waters usually contain large amounts of carbon dioxide because of decomposition of organic matte and bacterial respiration in the soil (Hynes 1970) as well as its percolation and passage through limestone. Th lower concentration of free CO2 witnessed in spring season is due to heavy rainfall which inturn is responsible fc the dilution effects by rain water via karst conduit and overlying catchment thereby rendering its concentration to th lower levels. On the other hand, relatively low rainfall in autumn followed by winter and summer seasons has direct bearing on the increased CO2 concentration due to dissolving of CO2 into infiltrating rain water which fee the spring catchments (Liu et al. 2004, 2007). The alkalinity of water was mainly due to bicarbonates in all th springs which ranged between 103±20.91 mg/L (Dobinag) and 214±16.14 mg/L (Sherebagh). The season variations in the bicarbonate alkalinity were significant as reflected from higher values during the summer season a most of the sites. The alkalinity increased with a decrease in altitude and also varied in different seasons. Th maximum alkalinity was observed in summer and autumn and minimum during winter except Sherebagh. Additio of the carbon dioxide from rainwater (respiration by plant roots and microbial decomposition of organic matter) is th probable cause of increasing bicarbonate alkalinity during summer and autumn seasons (Joshi and Kothyari 2003 There are differences in the alkalinity values according to the prevailing type of land use/recharge zones. Th higher values of bicarbonate in agriculture than forested land-use have been reported by Giedraitiene et al. (2002 which also stands true though partially in the present study.

The hardness of the spring waters indicated their hard water nature (Moyle 1945) with total hardness >150 mg/ CaCO3 equivalent (Sawyer and McCarty 1978) except Cheshmashahi recording annual mean values < 100 mg/l The maximum total hardness values, in general, were observed during autumn and winter. The springs at highe altitudes were observed to have comparatively lower hardness, while as an in increase in hardness was noted i springs having agriculture land in immediate vicinity. The coefficient of variation (V) of total hardness range between 14.03% (Cheshmashahi) and 37.84% (Kokernag) which is considered indicative that these spring especially (Verinag, Kokernag, Achabal and Dobinag) are fast flowing water (conduit karst type) and therefore sho contact residence time compared to Sherebagh, Indraznag and Cheshmashahi springs with coefficient of variatio less than 20 % (6.75) which is considered partially typical of diffuse flow systems (Schuster and White 1971;Terna 1972). Calcium and magnesium accounted for most of the hardness of water. The ions depicted a variation range c 25.96±6.29 mg/L (Dobinag) to 60.76±12.30 mg/L (Sherebagh) for calcium, and 6.34±3.61 mg/L (Cheshmashahi) t 14.33±8.19 mg/L (Dobinag) for magnesium. In general, the cationic composition of the spring waters revealed th predominance of calcium over the other ions (Jeelani 2004) and, therefore, the usual cation progression obtaine was Ca^{++} >Mg^{++} >Na^{+} >K^{+} except Sherebagh where magnesium gets replaced by sodium (Table 4) which brings close to the well known sequence for global freshwaters (Rhode 1969). The springs proved to be carbonate hoste as is indicated by the higher values of bicarbonate and lower dissolved silica. The spatial variability in wate chemistry indicate the presence of short, localized flow as longer and less discrete paths could have created mor uniform water chemistry spatially. The results suggest that the annual mean of calcium ion increased with decreas in altitude while the maximum values for calcium and magnesium were observed during winter as against th minimum in summer season. The marginal seasonal variations are possibly due to changes in base flow condition through the bed rock. The annual mean concentration of sodium was lower than calcium at all the study sites Among the sites studied, the maximum annual mean concentration was recorded for Sherebagh (41.0±21.86 mg/L and minimum for Cheshmashahi (3.24±1.14 mg/L). Relatively higher concentration of sodium have been attribute to domestic sewage (Sharma et al. 1999 and Panno et al. 2006) as the Sherebagh spring is found in the midst c Anantnag city. Sodium ions in the springs are usually at lower concentrations except Sherebagh and the likel source of the sodium ions is probably the ion exchange when calcium ions from groundwater are replaced b sodium ions absorbed by clay rock particles (Ettazarini 2005). Weathering of silicate rocks is one of the importar processes responsible for higher concentration of sodium in the groundwater (Meybeck 1987). Geochemically wate in the Sherebagh can be classified as having a general Na/Cl composition as against the Ca-Cl composition in res of the springs. Potassium was observed to be present in very low concentrations with a highest annual mea recorded at Sherebagh (4.82±3.66 mg/L) followed by Achabal (3.39±2.65 mg/L) and decreasing to the lowest a Cheshmashahi (0.58±0.41 mg/L) which are well within the range of values reported by (Giedraitiene et al. 200; Madhavan and Subramanian 2003; Motyka 2005; Davraz et al. 2009. Relatively low concentration of potassium i the spring waters may be due to the fixation in the form of clay minerals and greater resistance of potassiur bearing minerals to weathering (Mohan et al. 2000).

The chloride concentrations, in general, was found maximum during summer and spring while as winter and autum depicted minimal concentrations of the ion for almost all the springs under study (Fig. 1). The springs like Kokerna and Cheshmashahi at higher elevations depicted lower concentrations while as Indraznag and Sherebag (comparatively at low altitudes) depicted highest chloride concentration. Considerable spatial variations in th chloride between different springs suggest a difference in the input level of impurities that contaminate th groundwater. No discernible seasonal trend was recorded in chloride concentration which suggests the cumulativ effect of various factors operating at different springs however higher rainfall has been related elsewhere to th increased chloride concentrations in the spring-autumn seasons responsible for dissolution of more salts from wate rock interaction (Ramesam 1982; Ballukraya and Ravi 1999). Further, the high chloride content in springs may b related to the presence of large amounts of organic matter of both allochthonous and autochthonous origin an contamination by sewage waste carrying detergents and sewage from human settlements especially Sherebagl Both sulphate and sulphide occur in springs with sulphate being the dominant form. Concentrations of sulphat proved highly variable from 3.64±0.70 mg/L (Cheshmashahi) to 15.55±6.87 mg/L (Indraznag). Sulphate i carbonate rocks may be derived from dissolution of sulphate minerals (primarily gypsum and anhydrite) or oxidatio of pyrite (Drever 1982). Concentration of sulphate in the spring waters may be controlled by a study stat dissolution process which perhaps gets influenced by biological sulphate reduction (McCready and Krouse 1980 The springs at higher elevations usually registered relatively a bit higher concentrations than springs at lowe elevations except Indraznag. The reason for low sulphate values in the studied springs may be attributed to roc formation being impregnated with low concentration of $CaSO_4$ which is also reflected in the water chemistr especially when the water is issuing from under ground sources (Cole 1983).

Presence of ammonia in the water indicates pollution of recent origin where as the nitrates in water suggests tha some time has already elapsed during which nitrification has taken place and the water has got purified itself t some extent (Metcalf and Eddy 1979). Relatively higher concentrations of ammonia may be attributed to the releas of ammonia from decomposition of algal mats, zooplankton and fishes which occurr in higher densities a Sherebagh, Verinag and Dobinag . However, it is difficult to say precisely whether the main source of ammoni dissolved in the spring waters comes from bacterial mineralization of dead plants and animals or whether it i excreted by living animals. The NO_3^- N concentration varied between 560±235.55 µg/L (Cheshmashahi) 1533±1224.91 µg/L (Dobinag) throughout the study period. Relatively the higher concentration of nitroge compounds may be due to domestic sewage (Voznaya 1981; Katz et al. 2009)) which enters into groundwate through leaching from soil. In the present study, the domestic sewage near the springs seems a remote possibilit except Sherebagh while as the agriculture activities and decomposition of organic matter remains the only source of nitrogen in the recharge area. Storage of nitrate in the soil zone can delay and prolong the release of nitrate tha is why less seasonal variations of nitrate concentrations in karst basins than nonkarst basins due to storage ha been reported (Panno and Kelly 2004). However, the isotopic studies have revealed that it is difficult to predict th nitrate concentration because of variability in source term and type of recharge. The variation in nitrat concentrations among the springs lying in the forests and agriculture catchements suggested a difference in inpu levels of nitrogen based fertilizers which lead to the contamination of the spring waters. Relatively higher levels c nitrate observed at Verinag, Indraznag and Dobinag indicate the influence of agriculture activities an decomposition of organic matter in terms of increased pollution and due to the application of urea as a majc inorganic fertilizer. Lower nitrate concentrations have less possibility of contamination from agriculture wastes whic in turn indicates the decomposition of living matter as a source of nitrate.

The springs usually contain only a minimal phosphorus levels because of the low solubility of native phosphat minerals and the well known ability of the soils to retain phosphate. The relatively lower concentrations c phosphorus in spring waters is attributed to the strong bond formation of phosphate with clay minerals and meta hydroxide as well as its involvement in biological cycle (Mathess 1982). The annual mean values o orthophosphorus and total phosphorus for the studied springs were in the range of 13.95±9.52 (Kokernag) t 45.73±12.31 µg/L(Sherebagh) and 129.63±58.99 (Verinag) to 497.09±225.13 µg/L (Sherebagh) respectively, whic are higher than the values recorded in Irish Karst springs by Kilroy and Coxon (2005). However, our results are we in consonance with Imbach (1993) who reported concentration of phosphate ranging from 190-880 µg/L for karsti springs in the Çekirge-Bursa area of Turkey while (Elhatip 1997) reported concentration of phosphate ranging fror 70-90 µg/L for the Pamukkale thermal karst springs in Turkey. The spatial variations of phosphate concentration indicate that springs having forested recharge zones usually recorded low concentrations as compared to Indrazna surrounded by agriculture fields while as the same is not true for Dobinag which is also surrounded by agricultur but having helocrene nature. Another probable reason is that springs like Verinag, Kokernag, Achabal an Sherebagh lie in the region covered by hard rock formation and thick weathered zone, where as sedimentar formation mostly alluvium and sand occur near Indraznag and Dobinag.

The dissolved silica fluctuated but with a little constancy, exhibiting mean values between 4.40±0.89 mg/ Kokernag) and 14.72±3.18 mg/L (Indraznag). The springs which recorded comparatively higher annual mea temperatures were found to contain higher concentration of dissolved silica. Dissolved silica has been reported wit higher concentration in warm as compared to cold springs (Kadiri 2000).The cold (non-thermal springs) show reasonably linear relation of increasing silica concentrations with increasing specific conductance that most likel reflects the degree of reaction with carbon dioxide, the major ion being bicarbonate (Nathenson et al. 2003) whic stands true for Sherebagh. Dissolved silica was the only parameter which was relatively at higher concentrations i Cheshmashahi thereby indicating the probable origin of silicate from dissolution of rocks within the catchment.

Conclusions and recommendations

The springs under study are at intermediate elevations (1400-2100m) and probably meet the definition of col springs except Sherebagh. The geochemical signatures in the spring waters reflected the dominance of carbonat weathering while as the cationic composition of the spring waters revealed the predominance of calcium over th other ions and, therefore, the usual cation progression obtained was Ca^{++}>Mg^{++}>Na^{+} >K^{+} except Sherebagh wher magnesium gets replaced by sodium. The results obtained suggest that these springs are dynamic and variable a reflected from their nutrient chemistry which showed marginal spatio-temporal variations. The variations at tempor scale are largely as the result of temperature and rainfall pattern besides other factors. In general, the spring wate chemistry at Sherebagh shows trends indicating the possibility of percolation of polluted surface water which intur influences the base flow through rocks. Results suggested that the anthropogenic influences (agriculture activitie including application of fertilizers) are manifested in slightly acidic character, conductivity, free CO_2 ,alkalinit sodium, ammonia, nitrate and phosphate at Sherebagh, Indraznag and Dobinag. The springs at higher altitude were observed to have comparatively lower hardness, while as an in increase in hardness was noted in spring having agriculture land in immediate vicinity. The coefficient of variation (V) of total hardness in general exceeds 5 for most of the springs which reflects that these springs are fast flowing water (conduit karst typre) though wit variable residence time periods. Throughout the vale of Kashmir, springs are not being properly monitore managed and conserved, and as such are disappearing rapidly without being investigated/catalogued scientificall especially in arid regions. Major threats to springs and their inhabitants include human draining and diversion o groundwater sources, pollution, habitat alteration etc. This study has the some potential to act as a case study fo making any spring glossary and long term monitoring programme to be put in place in the future for th management of spring ecosystems in the Kashmir valley. Public awareness, sensitization of policy makers and th importance of these spring ecosystems by the scientists and water resource managers is much needed, to avoi any catastrophe in the form water crises.

Acknowledgements
This work was conducted in Aquatic Ecology Laboratory, Centre of Research for Development, University of Kashmir, Srinag and supported by University of Kashmir through the University Scholarship scheme. The authors are grateful to th HOD/Director Environmental Science/CORD for providing lab facilities and rendering full cooperation during the period of th research programme. Dr Arshid Jehangir is highly acknowledged for statistical treatment of data.

REFERENCES

APHA (1998). *Standard Methods for Examination of Water and Waste Water* (20 th ed.) Washington DC, USA: American Publ Health Association 1220 pp.

Andreo, B., Martin, M.M., and Algarra, A.M. (1999). Hydrochemistry of spring water associated with travertines. Example of th Sierra de la Alfaguara (Granada, Southern Spain). *Surface Geosciences/ Geosciences de surface,* 328, 745-750.

Appelo, C. A. J., and Postma, D. (1996). *Geochemistry of Groundwater and Pollution*, Balkema, 536 p.

Back, W., Baumann, P., Hanshow, B. B., Kramer, M. O., Li, Shu-T'ien and Van Dorn, W. G(1965). In: Ven Te Chow (ed.), *Avances in Hydrosciences*, Academic Press, New York and London, Vol. 2, pp. 49–109.

Ballukraya, P.N., and Ravi, R. (1999). Characterization of groundwater in the unconfined aquifer of Chennai city, India. *Journal o Geological Society of India*, 54, 1-11.

Bhat, F.A., and Yousuf, A.R. (2002). Ecology of periphytic community of seven springs of Kashmir. *Journal of Research an Development,* 2, 47-59.

Böhlke, J.K. (2002) Groundwater recharge and agriculture contamination. *Hydrogeol Journal*, 10, 153-179.

Bornhauser, K. (1912). Die tierwelt der quellen in der umgebung Basels. Internationalen Revue der Gesamten. Hydrobiologi und Hydrographie Biologische Supplemente, 5, 1–90.

Brune, G. (2002). Springs of Texas, vol. I. College Station: Texas A & M University Press. 590 pp.

Chhathawal, G.R., Mehara, M.C., Satake, M., Kathyal, T., Kathyal, M., Nagahiro, T. (1989). Environmental Analysis (Air, Wate and Soil). New Delhi: Anmole Publication. 204 pp.

Cole, G.A. (1983). Text Book of Limnology 3rd (Ed.) St. Louis, C.V. Mosby,401pp.

Coxon, C. (1999). Agriculturally induced impacts. In: Drew D, Hotzl H (eds). Karst Hydrogeology and Human Activities Rotterdam, Balkema, pp. 37–80.

Davraz, A., Karaguzel, R., Soyaslan, I., Sener, E., Seyman, F., Sener, S. (2009).Hydrogeology of Karst aquifer systems in SW Turkey and an assessment of water quality and contamination problems. *Environmental Geology,* 58(5), 973-988.

Dietrich, P.G., and Hebert, D. (1997). Regional discharge of a Triassic artesian karst aquifer: mixing and age of spring waters i the Thuringian basin, Germany, estimated by isotope methods. In: Gunay, G., Johnson, A.I., and Balkema, A.A. editors Karst Waters and Environmental Impacts, Rotterdam, pp. 221-229.

Digest of Statistics 2006-07 Digest of Statistics. Directorate of Economics and Statistics, Planning and Development Departmen Govt. of Jammu and Kashmir.

Drever, J.I. (1982). The Geochemistry of Natural Waters. Prentice Hall, London, pp. 138-162.

Elhatip, H.(1997). The influence of karst features on environmental studies in Turkey. *Environmental Geology,* 31, 27-33.

Ettazarini, S. (2005). Processes of water-rock intereaction in the Turonian aquifer of Oum Er-Rabia Basin, Morocco *Environmental Geology,* 49(2), 293-299.

Fatchen, T.J. (2000). Mound springs management planning: management issues, strategies, and prescriptions for mound springs in far north South Australia. South Australian Department for Environment and Heritage, Adelaide. 115 p.

Focazio, M.J., Plummer, L.N., Böhlke, J.K., Busenberg, E., Bachman, L.J., and Powars, D.S. (1998). Preliminary estimates o residences times and apparent ages of groundwater in the Chesapeake Bay Watershed, water quality data from survey of springs.U.S. Geological Survey Water-Resources Investigations Report. pp. 97-4225.

Ford, D., and Williams, P. (2007). Karst Hydrogeology and Geomorphology. John Wiley & Son Ltd, England, 562 pp.

Giedraitiene, J., Satkunas, J., Graniczny, M., Doktor, S. (2002). The chemistry of groundwater: A geoindicator of environmenta change across the Polish-Lithuanian border. *Environmental Geology*, 42, 743-749.

Glazier, D.S. (2009). Springs. In: Liken, G.E. (ed). Encyclopedia of Inland Waters.1,734-755.

Golterman, H.L., and Clymo, R.S. (1969). Methods for Chemical Analysis for Freshwaters. IBP. Handbook no. 8. Blackwe Scientific Publications Oxford, 172pp.

Gonfiantini, R. (1978). Standards for stable isotope measurements in natural compounds. Nature, 271, 534-536.

Gray, D.P. (2005). Braided River Springs: Distribution, Benthic Ecology and Role in the Landscape. Dissertation, New Zealand University of Canterbury.

Hartnett, F.M. (2000). Florida's springs: strategies for protection and restoration. Florida Department of Environmental Protection, Tallahassee, FL. 59 p.

Hynes, H.B.N. (1970). The Ecology of Running Waters. University of Toronto Press, 555 pp.

Imbach, T.(1993). Environmental hydrogeology of a karst system with thermal and normal ground waters: examples from th Bursa region (Turkey). Proc. Hydrogeological Processes in Karst Tarranes, IAHS Pub. No. 207, 7-13.

Jana, B.B.(1973). The thermal springs in Bakreswar, India: Physico-chemical conditions, flora and fauna. *Hydrobiol*, 41, 291 307.

Jeelani, G. (2004). Effect of subsurface lithology on hydrochemistry of springs of a part of a Kashmir Himalaya. *Himalaya Geology*, 25(2), 145-151.

Joshi, B.K., Kothyari, B.P. (2003). Chemistry of perennial springs of Bhetagad watershed: a case study from central Himalaya *Environmental Geology, 44*, 572-578.

Kadiri, M.O. (2000). Limnological studies of two contrasting but closely linked springs in Nigeria, West Africa. *Plant Biosystem* 134(2), 123-131.

Katz, B.G. (2004a). Nitrate contamination in karst ground water. In: Culver D, White W(editors). Encyclopedia of Cave Amsterdam, Netherlands: Elsevier Science.

Katz, B.G.(2004b). Sources of nitrate contamination and age of water in large karstic springs of Florida. *Environmental Geolog* 46,689–706.

Katz, B.G., Böhlke, J.K., Hornsby, H.D. (2001). Timescales for nitrate contamination of spring waters, northern Florida. *Chemic Geology*, 179(1–4),167–86.

Katz, B.G., Griffin, D.W., Davis, J.H. (2009). Groundwater quality impacts from the land application of treated municip wastewater in a large karstic spring basin: Chemical and microbiological indicators. *Science of the Total Environmen* 407, 2872–2886

Keshi, A.(1980). Thermal springs in China. *Geology Journal*, 46, 507–513.

Kilroy, G., and Coxon, C. (2005). Temporal variability of phosphorus fractions in Irish Karst springs. *Environmental Geology*, 4 421-430.

Kumar, K., Rawat, D.S., Joshi, R.(1996). Chemistry of springwater in Almora Central Himalaya, India. *Environmental Geolog* 28(2), 1-7.

Kumar, M., Ramanathan, A., Rao, M.S., Kumar, B. (2006). Identification and evaluation of hydrogeochemical processes in th groundwater environment of Delhi, India. *Environmental Geology*, 50,1025-1039.

Liu, Z., Groves, C., Yuan, D., Meiman, J., Jiang, G., and He, S.(2004). Hydrochemichal variations during flood pulses in th Southwest China peak cluster karst: impacts of $CaCO_3$-H_2O-CO_2 interactions. *Hydrological Processes*, 18, 2423-2437.

Liu, Z., Li, Q., Sun, H., Wang, J.(2007). Seasonal, diurnal and storm-scale hydrochemical variations of typical epikarst springs i subtropical karst areas of SW China: Soil CO2 and dilution effects. *Journal of Hydrology,* 337, 207-223.

Madhavan, N., and Subramanian, V.(2003). Water quality of Indus river in the Ladakh Himalaya. AWRA Spring Special Conference.

Mathess, G. (1982). The Properties of Groundwater. Wiley, New York, 498pp.

McCready, R.G.L., and Krouse, H.R.(1980). Sulphur isotope fractionation by Dsulfovibrio vulgaris during metabolism of BaSO *Journal of Geomicrobiology*, 2, 55-62.

Meinzer, O.E.(1923). Outline of ground-water hydrology, with definitions. U.S.Geol Surv Water- Supply Paper 494, 1-69.

Metcalf and Eddy (1979). Wastewater Engineering: Treatment, Disposal, Reuse. Tata McGraw-Hill, New Delhi, pp.920.

Meybeck, M.(1987). Global chemical weathering of surficial rocks estimated from river dissolved loads. *American Journal Science*, 287, 401- 428.

Mohan, R., Singh, A.K., Tripathi, J.K., Chowdhary, G.C. (2000). Hydrochemistry and quality assessment of groundwater in Nai industrial area, Allahabad district,U.P. *Journal of Geological Society of India*, 55, 77-89.

Motyka, J., Gradziński, M., Bella, P., Holŭbek, P.(2005). Chemistry of waters from selected caves in Slovakia-a reconnaissanc study. *Environmental Geology*, *48*, 682-692.

Moyle, J.B. (1945). Some chemical factors influencing the distribution of aquatic plants in Minnesota. *American Midlar*

Naturalist. 34, 402-480.

Nathenson, M., Thompson, J.M., White, L.D.(2003). Slightly thermal springs and non-thermal springs at Mount Shasta California: Chemistry and recharge elevations. *Journal of Volcanology and Geothermal Research*, 121, 137-153.

Pacheco, A.J., Cabrera, S.A.(1997).Groundwater contamination by nitrates in the Yucatan Peninsula, Mexico. *Hydrogeolog Journal*, 5,47–53.

Pandit, A.K., Rather, G.H., and Rashid, H.U.(2005). Comparative limnology of two religiously important springs of Kashmi *Journal of Research and Development,* 5, 57-62.

Panno, S.V., Kelly, W.R.(2004). Nitrate and herbicide loading in two groundwater basins of Illinois sinkhole plain. *Journal Hydrology*, 290, 229-242.

Panno, S.V., Hacjley, K.C., Hwang, H., Greenberg, S.E., Krapac, I.G., Landsberger, S.O., and Kelly, D.J. (2006 Charecterisation and identification of Na-Cl sources in ground water. *Ground Water*, 44, 176-187.

Panno, S.V., Hackley, K.C., Hwang, H.H., Kelly, W.R.(2001). Determination of the sources of nitrate contamination in kar springs using isotopic and chemical indicators. *Chemical Geology*, 179,113–28.

Ramesam, V. (1982). Geochemistry of groundwater from a typical hard rock terrain. *Journal of Geological Society of India*, 2 201-204.

Reed, M.J.(1983). Assessment of low temperature geothermal resources of the United States. *U.S.Geol Surv Circ*., 892, 1-8.

Rhode, W.(1969). Crystallization of eutrophic concepts in Northern Europe. Eutrophication, Causes, Consequences, Corrective National Academy of Science, Washington, D.C, pp.50-64.

Rose, T.P., Davisson, M.L., and Criss, R.E. (1996). Isotope hydrology of voluminous cold springs in fractured rock from an activ volcanic region, Notheastern California. *Journal of Hydrology*., 179, 207-236.

Rosenau, J.C., Faulkner, G.L., Hendry, C.W., Hull, R.W.(1977). Springs of Florida: Florida Geological Survey Bullet 31(Revised), 461pp.

Sˇajna, N., Haler, M., Sˇkornik, S., and Kaligaricˇ, M.(2007). Survival and expansion of Pistia stratiotes L. in a thermal stream i Slovenia. *Aquatic Botany*, 87,75–79.

Sada, D.W.; Williams, J.E.; Silvey, J.C.; Halford, A.; Ramakka, J.; Summers, P.; Lewis, L. (2001). A guide to managing, restoring, and conserving springs in the Western United States. Desert Research Institute, Reno, Nevada. 70 p.

Sada, D.W.; Sharpe, S.E. (Eds) 2004: Conference Proceedings, Spring-fed Wetlands: Important Scientific and Cultural Resources of the Intermountain Region, May 7–9, 2002, Las Vegas, Nevada. DHS Publication No. 41210.

Sada, D.W., Fleishman, E., Murphy, D.D.(2005). Associations among spring-dependent aquatic assemblages and environment and land use gradients in a Mojave Desert mountain range. *Diversity and distributions,*11, 91–99.

Sawyer, C.N., and McCarty, P.L. (1978). Basic concepts from biochemistry In: Chemistry for Environmental Engineerin McGraw-Hill, New York, 262-277.

Sayili, M., Akca, H., Duman, T., and Esengun, K.(2007). Psoriasis treatment via doctor fishes as part of health tourism: A cas study of Kangal Fish Spring,Turkey. *Tourism Management*, 28, 625–629.

Sharma, S., Mathur, R., and Mathur, A.(1999). Pollution studies of Swarna Rekha River in Gwalior, India. In: Durgaprasad M.K Pitchaich P.S. editors. Inland Water Resources- India. Discovery Publishing House, New Delhi, pp.431-452.

Shuster, E.T., and White, W.B. (1971). Seasonal fluctuations in the chemistry of limestone spring. A possible means f characterizing carbonate aquifers. *Journal of Hydrology*., 14, 93-128.

Suzukie, T.T., Katsuno, T., Yamaura, G. (1992). Land application of wastewater using three types of trances in lysimeters an mass balance of nitrighen, *Water Research*, 26(11), 1433-1444.

Symonds, R.B., Gerlach, T.M., and Reed, M.H.(2001). Magmatic gas scrubbing: implications for volcano monitoring. *Journal Volcanology and Geothermal Research*, 108, 303-341.

Ternan, J.L. (1972). Comments on the use of a calcium hardness variability index in the study of carbonate aquifers: wi reference to the central Pennines, England. *Journal of Hydrology*, 16, 317- 321.

Theineman, A.(1922). Hydrobiologissch Untersuchungen an Quellen. *Archiv Für Hydrobiologie*, 14,151-190.

Veni, G., DuChene, H., Crawford, N.C., Groves, C.G., Huppert, G.N., Kastning, E.H., et al.(2001) Living with karst. America Geological Institute Environmental Awareness Series, vol. 4. 65 pp

Voznaya, N.F.(1981). Chemistry of Water and Microbiology. Mir Publishers, Moscow, 347pp.

Wadia, D.N. (1966). Geology of India. 3rd edition (Revised). MacMillan & Co, New Delhi, 536pp.

Waring, G.A., Blankenship, R.R., and Bentall, R.(1965). Thermal springs of the United States and other countries of the world-summary. U.S.Geol Surv Prof Pap.492. pp. 383.

Wells, E.R., and Krothe, N.C.(1989). Seasonal fluctuation in δ15N of groundwater nitrate in a mantled karst aquifer due t macropore transport of fertilizer-derived nitrate. *Journal of Hydrology*, 112,191–201.

Wetzel, R.G., and Likens, G.E. (2000). Limnological Analysis, 3rd edition. Springer Verlag New York Publications, 429 pp.

White, W.B. (1988). Geomorphology and hydrology of karst terrains. Oxford University Press, 464 pp.

Williams, P.W. (1993). (ed.). Karst Terrains; Environmental Changes and Human Impacts, Catena Supplement, 25,pp. 1–268.

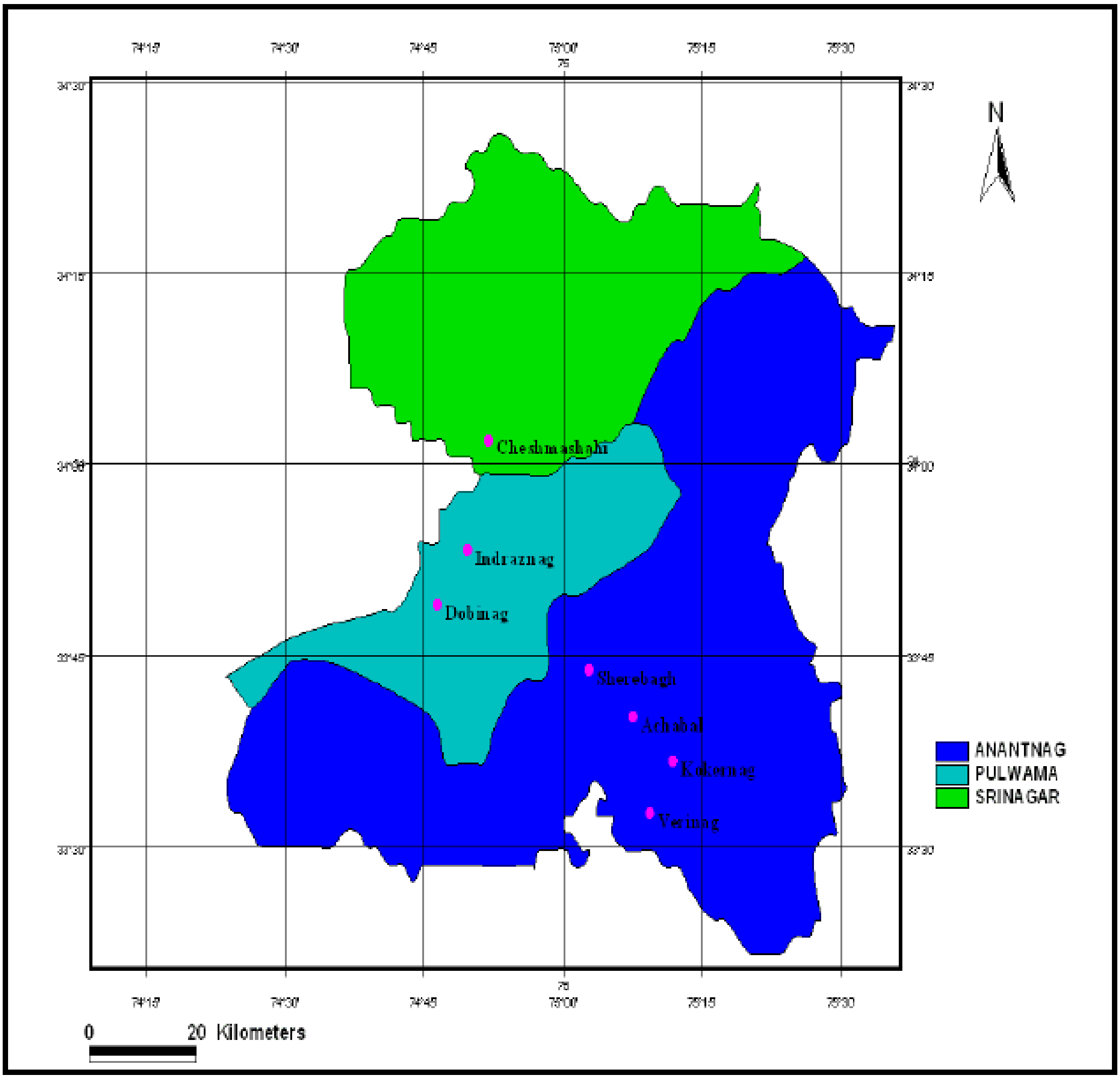

Figure 1 Location map of the study area showing various selected freshwater springs

Table 4. Summary statistics for concentration of chemical constituents (Mean+SD) in seven freshwater springs of Kashmir Himalaya during March 2004 to February 2005.

Parameters/sites	Verinag	Kokernag	Achabal	Sherebagh	Indraznag	Dobinag	Cheshmashahi
W.Temp (□ C)	10.86±0.86 a	10.72±1 a	11.73±1.82 ab	16.55±0.47 e	14.55±1.01 c	15.50±1.60 cd	12.82±1.45 b
pH	7.42±0.06 b	7.68±0.16 c	7.54±0.20 bc	7.41±0.10 b	7.03±0.18 a	7.06±0.16 a	7.41±0.25 b
Cond. µScm-1	318±36.80 c	190±51.65 ab	217±48.34 b	375±48.53 d	295±42.34 c	147±18.34 a	148±27.25 a
DO (mg/L)	6.18±1.20 c	6.76±1.68 c	6.22±1.24 c	1.78±0.58 a	4.25±1.22 b	5.65±1.79 bc	5.53±0.71 bc
Free CO_2	8.54±4.82 a	10.18±9.61 a	9.27±5.39 a	14.18±7.77 a	28.91±10.48 b	11. 82±4.33 a	9.27±10.36 a
Alk.(mg/L)	159±18.91 cd	113±22.64 ab	140±30.27 bc	214±16.14 e	180±29.63 d	103±20.91 a	114± 28.51 ab
TH (mg/L)	188±38.21 cd	146±55.32 bc	148±37.24 bc	198±34.19 d	168±30.81 bcd	124±29.38 ab	92±12.85 a
TH% (V)	20.29	37.84	25.22	17.30	18.30	23.71	14.03
Ca(mg/L)	57.70±14.21c	41.28±18.65 ab	41.19±10.82 ab	60.76±12.30 c	48.15±12.71 bc	25.96±6.29 a	25.89±6.32 a
Mg(mg/L)	12.78±3.55 ab	10.42±4.17 ab	10.86±4.08 ab	10.87±4.24 ab	11.66±6.16 ab	14.33±8.19 b	6.34±3.61 a
Na(mg/L)	7.0±5.84 a	6.36±3.64 a	10.55±6.98 a	41.0±21.86 b	12.64±5.75 a	5.01±1.67 a	3.24±1.14 a
K(mg/L)	2.51±2.07 abc	2.17±1.42 b	3.39±2.65 bc	4.82±3.66 c	1.87±1.34 ab	0.96±0.42 ab	0.58±0.41 a
Cl(mg/L)	12.18±3.49 a	13.36±2.98 a	14.0±2.37 ab	19.82±4.79 b	19.36±5.78 b	14.0±7.07 ab	10.91±4.01 a
$SO_{4\,(mg/L)}$	12.69±8.25 bc	6.71±6.67 ab	7.24±2.54 ab	6.32±3.97 ab	15.55±6.87 c	8.55±3.75 ab	3.64±0.70 a
$NH_{3\,(\mu g/L)}$	129±126.74 a	87±97.62 a	119±133.15 a	543±407.80 b	90±80.87 a	202±180.68 a	77±72.80 a
$NO_{3(\mu g/L)}$	1424±1042.06a	991±1086.44 a	960±1094.90 a	1058±1235.73 a	1141±1129.92 a	1534±1224.91a	560±235.55 a
$PO_{4(\mu g/L)}$	24.18±11.68 ab	13.95±9.52 a	26.95±14.44 ab	45.73±12.31 c	34.91±14.10 bc	24.45±8.05 ab	33.91±6.50 ab
TP(µg/L)	129.63±58.99 a	172±132.71 a	138.18±57.76 a	497.09±225.13 b	235.36±81.39 a	268.09±98.18 d	215.09±95.54 a
D. Si(mg/L)	5.69±1.60 a	4.40±0.89 a	6.12±1.09 a	14±1.88 b	14.72±3.18 b	11.56±2.52 b	14.35±5.38 b

N= 11;V= Coefficent of variation(V= S.D/Mean× 100); Different letters in rows indicate that means are significantly different($P<0.05$) among springs (Tukey HSD).

Table 1. General attributes of studied springs

Sites	Discharge(mean) (L/sec)	Spring Order		Spring Type		Substrate composition
		Meinzer, 1923	Rosenau et al., 1977	Hydraulic	Topography	
Verinag	842	3	2	Artesian	Limnocrene	Cobble, Gravel, Sand, Mud etc.
Kokernag	1371	2	2	Artesian	Rheocrene	Cobble, Pebble, Sand, Leaf litter etc.
Achabal	1012	2	2	Artesian	Rheocrene	Cobble, Pebble, Mud, Sand, etc.
Sherbagh	199	3	3	Artesian	Limnocrene	Gravel, Sand, Mud, Organic Detritus, etc
Indraznag	4.5	5	5	Artesian	Limnocrene	Mud, Sand, Organic detritus, etc
Dobinag	3.5	5	5	Gravity/non artesian	Helocrene	Mud, Organic detritus, etc
Chesmashahi	2	5	5	Artesian	Limnocrenee	Cement Bed

Table 2. General Characteristics of studied springs

Sites	Latitude	Longitude	Altitude	Average Depth (m)	Catchment	Uses
Verinag	33°.32.128`N	75°.15.036`E	1839	15	Forest	Domestic
Kokernag	33°.35.202`N	75°.17.926`E	1922	0.5	Forest	Domestic
Achabal	33°.40.954`N	75.°13.395`E	1663	0.5	Forest	Domestic
Sherbagh	33°.43.916`N	75°.09.325`E	1617	1.2	Forest/residential	Domestic
Indraznag	33°.54.341´N	74°.54.199´ E	1604	0.4	Agricultural	Irrigation
Dobinag	33°48.574`N	74°51.367´E	1804	0.5	Agricultural	Irrigation /Fisheries
Chesmashahi	32°.35.870´N	75°.21´120 E´	1686	0.5	Forest	Drinking

Table 3. Water usage category of different studied springs

+++ = High water use; **++** = Moderate water use; **+** = Low water use; **—** = Negligible water use

Spring	Drinking	Irrigation	Washing/Bathin	Fishery
Verinag	++	+++	+++	++
Kokernag	+++	+++	+++	+++
Achabal	+++	+++	++	++
Sherebagh	++	+++	+++	++
Indraznag	–	+++	–	–
Dobinag	–	+++	–	++
Cheshmashahi	+++	–	+	–