Major Elemental Chemistry of the Part of River Jhelum, Jammu and Kashmir (India): Weathering Processes and Irrigation Quality Assessment

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ABSTRACT

This paper presents a study on the part of River Jhelum, which is one of the longest rivers in Kashmir Valley, India. Eleven (11) water samples were analyzed, to assess Weathering process and irrigation quality of the river. 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 $CaHCO_3$, $MgHCO_3$ types. The langlier-diagram confirms the chemistry of meteoric water, i.e; $Ca-Mg-HCO_3$. The calculated values of SAR, RSC and sodium percentage indicated that the river water is excellent for irrigation use.

Keywords: Jhelum, River, weathering, scatter, Durov, piper, meteoric water, irrigation

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 viz. precipitation rate, weathering processes, soil erosion etc. as well as anthropogenic processes viz. 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, Mg, Na, K, HCO_3, SO_4, 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; Chen *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.

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.

Fig.1. Map of River Jhelum and sampling locations

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 ($NICB = (TZ^+ - TZ^-)/TZ^+ \times 100\%$) is within ±5%.

RESULTS AND DISCUSSIONS

Physico-chemical characteristics of river Jhelum

Summary of physico-chemical analysis of water samples from river Jhelum is presented in Table.1. The river waters are fresh, colorless, and odorless with lower *temperature* (T range: 17.8C° 19.3C°, mean: 18.5, standard deviation: 0.371). As expected, the river waters are alkaline (pH range: 7.5-7.8, mean: 7.6, standard deviation: 0.1). Medium electrical conductivity (EC range:195.3-279.6μS/cm, mean: 254, standard deviation: 18.3). Medium total dissolved solids (TDS range: 125-179 mg/l, mean: 162.6, standard deviation: 11.7).Calcium concentration ranged from (24-35 mg/l) Mean: 30.7, Standard deviation; 3.2. Magnesium concentration ranged from (4.4-14.5 mg/l) Mean: 8.7, Standard deviation: 2.9; Bicarbonate concentration ranged from (112-178 mg/l), Mean: 140.2, Standard deviation; 15.5); chloride concentration ranged from (3.6-8 mg/l) Mean: 5.4, Standard deviation: 1.2 and sulphate concentration ranged from (5.4-9.8 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. Physio-Chemical analysis of River Jhelum Waters

Location	Site ID	Temp. C°	pH	E.C S/cm	T.D.S mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l	Cl^- mg/l	HCO_3^- mg/l	SO_4^{2-} mg/l
(Kursherpur) Khanabal	A1	17.8	7.5	195.3	125	35	13.1	10.4	0.36	8	178	6.4
(Gur) Khanabal	A2	17.8	7.5	218.7	140	24	14.3	8.6	0.29	6	145	9.8
Sangam	A3	18.4	7.7	223.4	143	32	10	9.4	0.24	7	154	5.6
Kakapora	A4	18.4	7.6	231.2	148	28	4.4	8.4	0.29	4.6	112	7.6
Awantipora	A5	18.8	7.8	240.6	154	24	9.2	8	0.33	5	126	5.4
Srinagar (Amirakadil)	A6	19.3	7.5	248.4	159	34	4.9	6.6	0.25	3.6	127	9.8
Shadipora	A7	18.9	7.7	257.8	165	34	6.8	7.4	0.3	5	140	7
Bunyar	A8	18.4	7.7	264	169	28	14.5	9.4	0.3	4	165	9
Gulamyar	A9	18.4	7.7	265.6	170	31	10.7	9.1	0.44	6	151	9
Sopore (A)	A10	18.1	7.6	275	176	34	9.2	8.6	0.43	7	149	9.4
Sopore (B)	A11	18.1	7.5	279.6	179	31	8.7	8.4	0.46	6.3	138	9.4

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 waterrock 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 (TDS:125179 mg/l and weight ratio of Na/(Na+Ca): 0.1620.263) (fig.2)
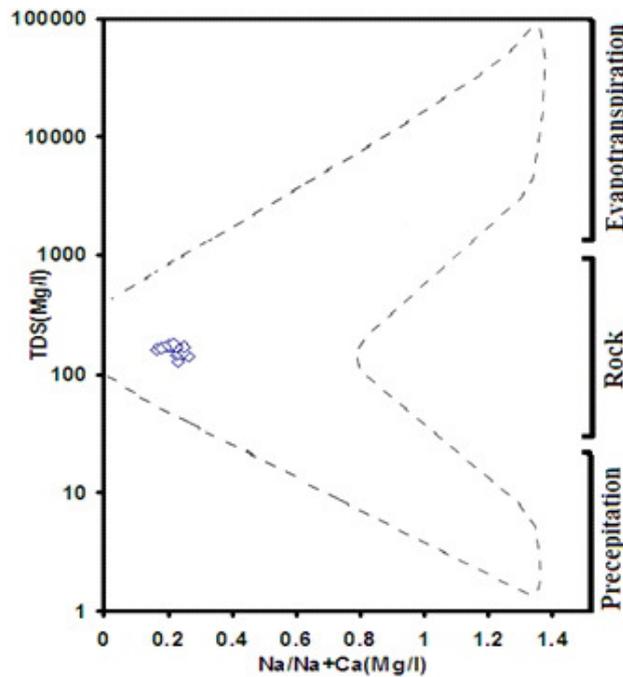
Figure. 2. Gibbs diagram

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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 HCO_3 Type and specific water types were Ca-HCO_3 and Mg-HCO_3.
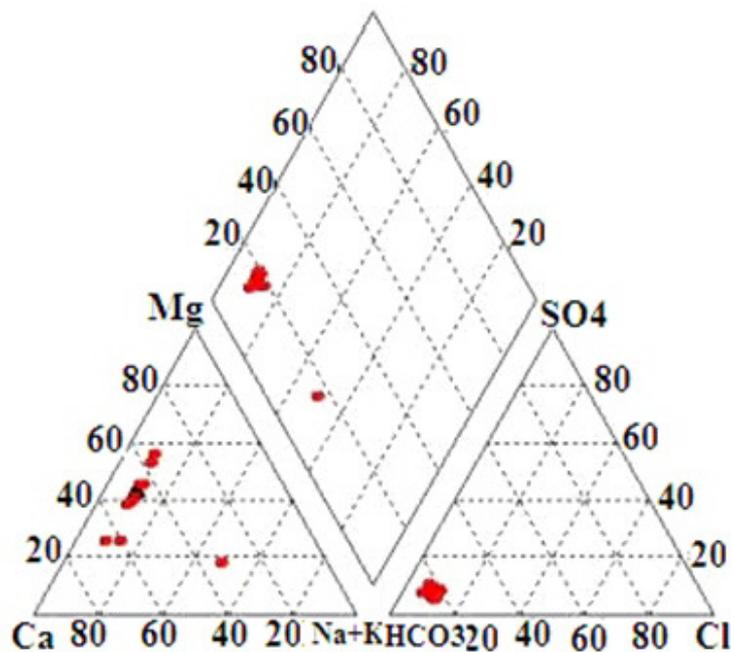
Fig. 3. Piper trilinear diagram showing broad water types

The Durov diagram (Durov 1948) plots the major ions as percentages of milliequivalents in two base triangles. The main purpose of the Durov diagram (Durov 1948) 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^+, $Ca2^+$, 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 chop in Ca-Mg-HCO_3 facie, which can be subdivided into $CaHCO_3$ and Mg-HCO_3 facies. $CaHCO_3$ facie indicates the dominance of alkalies and weak acids. Mg-HCO3 facie again indicate that strong acid i.e Cl and SO_4 does not exceed the weak acids (HCO_3).

Geochemical processes controlling water composition

Binary plots 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; 2001 C Own Wlr ppr). 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 (Jeelani and Shah; 2006, Sarin *et. al* 1989) as Ca^{2+} is derived mainly from carbonates with some inputs from silicates.
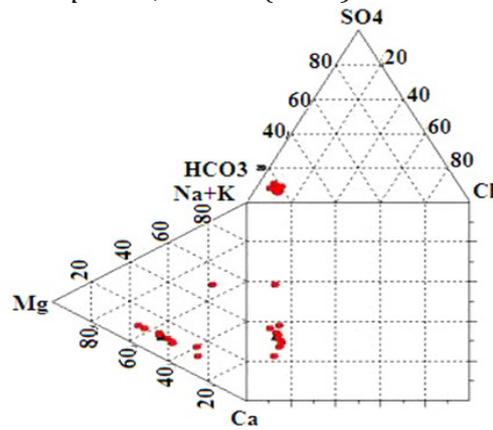
Fig. 4. Durov diagram
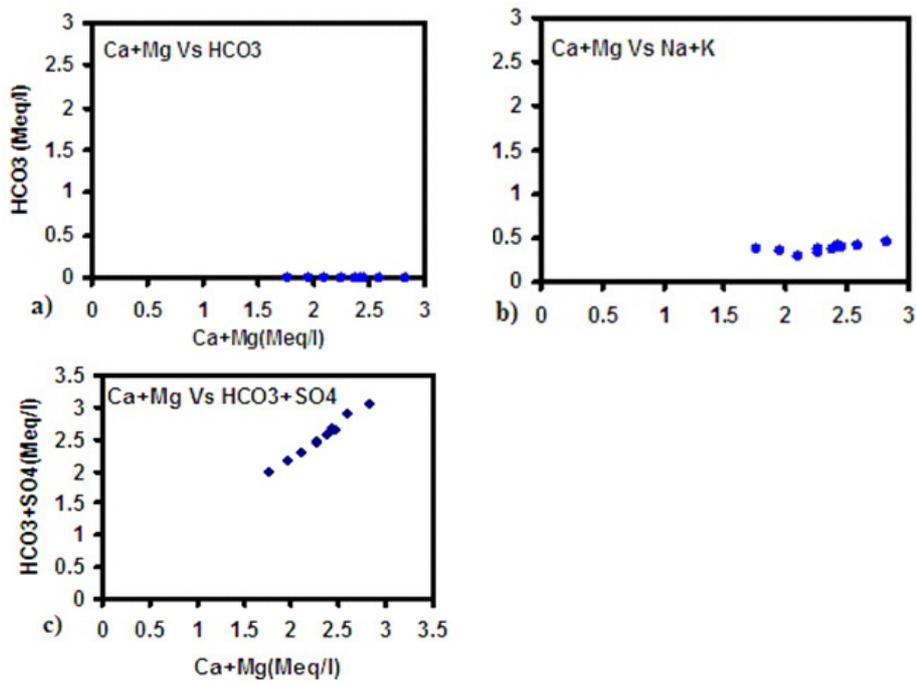
Fig. 5. Scatter diagrams between (a) Ca+Mg vs HCO3; (b) Ca+Mg vs Na+K; (c) Ca+Mg vs HCO$_3$+SO$_4$ showing possible liganding of the major ions.

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-HCO3 type, however a sample showed deviation from core end. The alteration of meteoric water to different chemical composition waters is due to the maximum waterrock interaction (Umar *et al,* 2006).
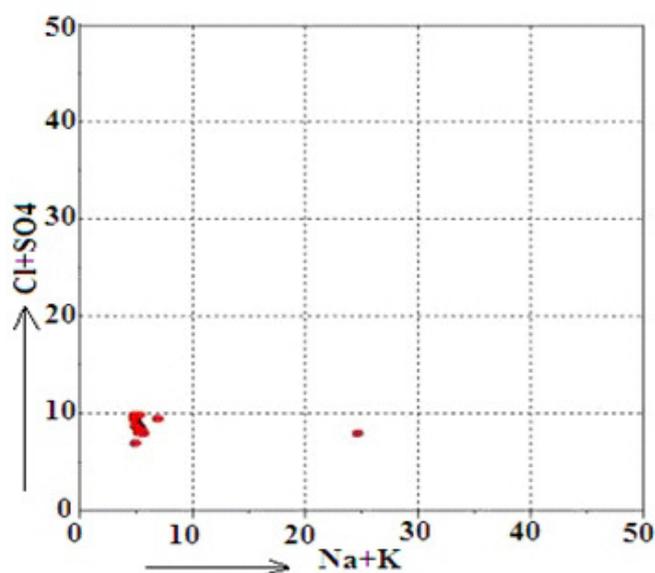
Figure.6. Langlier- Ludwig diagrams

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 lS

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cm)1), medium (250750 lS cm)1), high (7502,250 lS cm)1) and very high (2,2505,000 lS cm)1) salinity zone (Richards 1954). While a high salt concentration (high EC) in water leads to formation of saline soil, 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:

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

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed 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

%Na = (Na+K / Ca+Mg+Na+K) X 100 (after Wilcox, 1955)

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, 1950). Irrigation waters having RSC values greater than 5 meq/l have been considered harmful to the growth of plants,

while waters with RSC values above 2.5 meq/l is not considered suitable for irrigation purpose. The RSC values of the study area varied between 0.91.5 meq/l, again indicating that the water is safe for irrigation purposes.
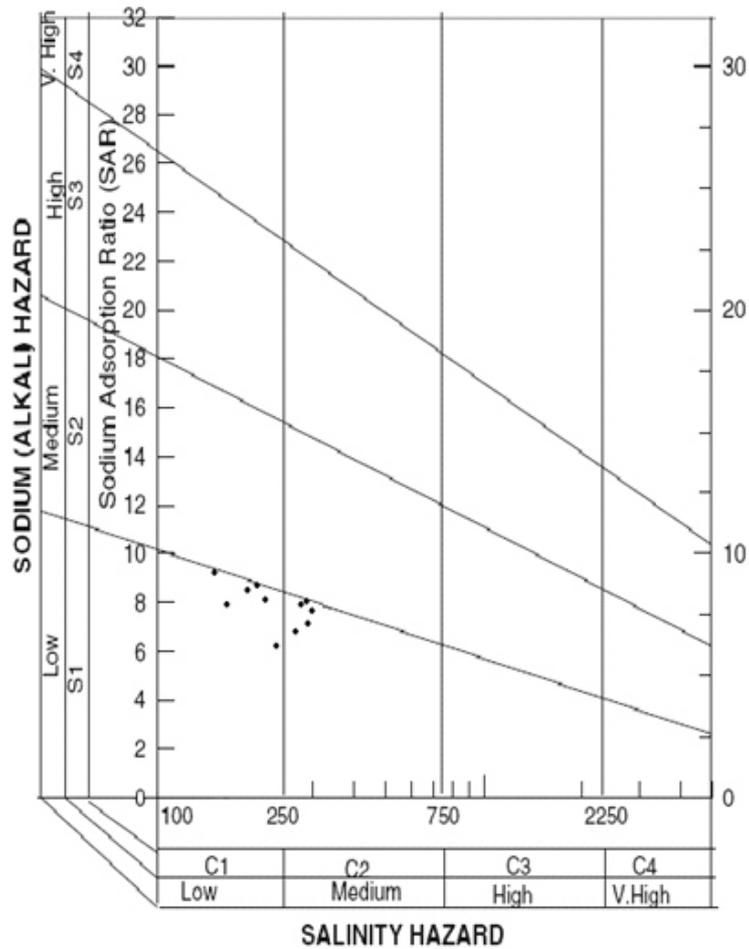
Fig.7. Salinity Hazard Diagram

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-HCO$_3$.

d)   Analytical data from the study area confirm; river water present in the area is suitable for irrigation purposes.

REFERENCES

Alaez, M.C.F., Alaez, M.F and Calabuig E.L 1988. Variation in time and space of some physical and chemical variables in the Bernesga River, León, Spain. *Ann Limnol* **24**: 285-291

Brennan, S.K., and Lowenstein, T.K., 2002. The major ion composition of Silurian seawater. Geochim. *Cosmochim. Acta.* **66**: 2683-2700.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N and Smith, V.H. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecol Appl* **8:** 559-568

Cetindag, B and Okan, O.O 2003. Hydrochemical characteristics and pollution potential of Uluova aquifers, Elazig, Turkey. *Environ Geol* **45**:796-807

Chen, J., Wang, F., Xia, X., and Zhang, L., 2002. Major element chemistry of the Changjiang (Yangtze River). *Chem. Geol.* **187**, 231-255.

Cheng, X.S., Jia, L., and Cheng, X.F., 2005. Analysis of natural water chemistry characteristics in the Huai River basin and Shandong Peninsula. *Water Resour. Protect.* **21**, 15-18

Cruz, J.V., and Amaral, C.S., 2004. Major ion chemistry of groundwater from perchedwater bodies of Azores (Portugal) volcanic archipelago. *Appl. Geochem.* **19,** 445-459.

Das, K.B and Kaur, P. 2001. Major ion chemistry of Renuka Lake and weathering processes, sirmaur District, Himachal Pradesh, India. *Environmental Geology*. **40:** 908-917.

Durov, S.A 1948. Natural waters sand graphic representation of their composition. *Dok.Akad Nauk*. **59**: 87-90

Edmunds, W. M and Smedley, P. L 2000 Residence time indicators in groundwater: The East Midlands Triassic sandstone aquifer; *Appl. Geochem.* **15**: 737-752.

Elliot, T., Andrews, J. N and Edmunds, W. M 1999. Hydrochemical trends, paleorecharge and groundwater ages in the fissured Chalk aquifer of the London and Berkshire basins, UK; *Appl. Geochem.* **14**: 333-363.

Eton, F.M. 1954 Formulae for estimating leaching and gypsum requirement of irrigation waters. Texas Agricultural Experiment Station Misc. Pub No. 3. University of Texas, College Station

Guissani B, Monticelli D, Gambillara R, Pozzi A, Dossi C 2008. Three way principal component analysis of chemical data from lake Como watershed. Microchem J **88**:160166

Guler, C., Thyne, G.D., McCray, J.E. and Turner, A.K. 2002. Evaluation of graphical and multivariate statistical methods for classification of water chemistry data. J *Hydrogeol.* **10:** 455-474

Gibbs, R.J., 1970. Mechanisms controlling world water chemistry. *Science* **170:** 1088-1090.

Gibbs, R.J., 1972. Water chemistry of the Amazon River. Geochim. *Cosmochim. Acta* **36:** 1061-1066.

Herczeg, A L., Torgersen, T., Chivas, A. R and Habermehl, M. A. 1991 Geochemistry of groundwaters from the Great Artesian Basin, Australia; *J. Hydrol.* **126** :225-245.

Hiscock, K. M. 1993. The influence of pre-Devensian deposits on the hydrogeochemistry ofthe Chalk aquifer system of north Norfolk, UK; *J. Hydrol.* **144:** 335-369.

Jain, S.K., Agarwal, P.K and Singh, V.P. 2007. Hydrology and water resources of India. Springer, Dordrecht

Jeelani, G and Shah, A. Q . 2006 Geochemical characteristics of water and sediment from the Dal Lake, Kashmir Himalaya, India: Constraints on weathering and anthropogenic activity; *Env. Geol.* **50:** 12-23.

Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I, Sarfraz, R.A, Baig, J.A and Shah, A.Q. 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. *Ecotoxicol Environ Saf.* **72**: 301-309

Kimblin R T 1995 The chemistry and origin of groundwater in Triassic sandstone and Quaternary deposits, northwest England and some UK comparisons; *J. Hydrol.* **172**: 293-311.

Nemeth, A., Paolini, J.and Herrera, R., 1982. Carbon transport in the Orinoco River: the preliminary results. In: Degens, E.T. (eds.), Transport of Carbon and Minerals in Major World Rivers, vol. 52. SCOPE/UNEP Sonderband Heft, p357-364.

Piper, A.M. 1944. A graphic procedure in the geochemical, interpretation of water analysis. *Am Geophys Union Trans* **25**: 914-923

Richard, L.A 1954. Diagnosis and improvement of saline and alkali soils. Agriculture handbook 60. US Department of Agriculture,Washington DC

Sarin, M. M., Krishnaswami, S., Dilli, K., Somayajulu, B. L. K and Moore, W.S 1989 Major ion chemistry of the GangaBrahmaputra river system: Weathering processes and fluxes to the Bay of Bengal; *Geochim. Cosmochim. Acta* **53**: 997-1009.

Stallard, R.F. and Edmond, J.M., 1983. Geochemistry of the Amazon: 2. The influence of geology and weathering environment on the dissolved load. *J. Geophys. Res*. **88**: 9671-9688.

Stallard, R.F. and Edmond, J.M. 1987. Geochemistry of the Amazon: 3. Weathering chemistry and limits to dissolved inputs. *J. Geophys. Res*. **92**, 8293-8302.

Umar, R., Muqtada, M. and Absar, A. 2006. Groundwater hydrochemistry of a sugarcane cultivation belt in parts of Muzaffarnagar district, Uttar Pradesh, India; *Environ Geol.* **49**: 999-1008

Walton ,W.C. 1970. Groundwater resource evaluation. McGraw- Hill, New York

Zhang, J., Huang, W., Letolle, R. and Jusserand, C. 1995. Major element chemistry of the Huanghe, China weathering processes and chemical fluxes. *J. Hydrol*. **168**: 173-203.