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Water Chemistry of Chenab River Flowing In Kishtwar - Thatri Area of Jammu and Kashmir

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ABSTRACT

Chemical analysis of water flowing in Chenab river from Kishtwar to Thatri area Jammu and Kashmir (J&K State) was carried out for Si, Ca, Mg, K, Na, Fe, Mn, Cu, Ni, Zn and Pb. The analysis revealed all cations to be present below the permissible limits except Fe and Mn, which are above safer levels and hence toxic for human consumption. As far as agricultural use of this water is concerned, no element is in higher concentration and is non-hazardous for crops. Turbidity values are higher because of higher rate of erosion in the catchment areas. The different parameters, SAR (Sodium Absorption Ratio), SSP (Sodium Soluble Percentage), RSC (Residual Sodium Carbonate), MR (Magnesium Ratio), CR (Corrosivity Ratio), EC (Electrical Conductivity) are < 6, < 20, < 2.5, < 50, < 1, < 1 (in micromohos/cm at 25^0C) respectively and as such water of Chenab river in Kishtwar-Thathri area is safe to be used for agricultural purposes. Total hardness places the waters in soft category. TDS < 500 ppm indicate waters safe both for human consumption and for irrigation. Bicarbonates, sulphates, nitrates and chlorides indicate values lower than permissible limits. pH of waters too is within safer levels. For bringing Fe and Mn down in the waters, the catchment areas need to be properly forested and vetiver grass technology used for the whole belt from Kishtwar to Thatri.

Key words : Water Chemistry of River Chenab, Polluting Elements

The Chenab river is one of the important rivers of Jammu and Kashmir (J & K State). It rises in the Himalayan contour of Laho in two streams, the Chandra and the Bagha. The Chandra issues from a large snow bed on the south-east of the Baralacha (6096 m above sea level) and the Bagha on the north-west slopes of the pass. These flow more or less parallel to each other, but Chandra deviates to the north-west, a distance of about 176 km meeting the Bagha at Tandi. The united stream, Chandra and Bagha or Chenab flows through the Pangi Valley and then enters Padar at an elevation of about 1828 m. The Wadwan river enters the Chenab at Kishtwar. Its perennial source is in the glacier of Nun Kun.

Kishtwar (1100 m) is one of the important plateaus in the south-east of J&K and Chenab river makes a round of this town from three sides after which it takes a southerly course. Six km south of Bandalkut where Chenab meets Maru-Sudar river, river Chenab is receiving water from two mighty nallahs from north-east, namely Raowar nallah and Kalnag nallah. These two nallahs flow as one 2 km south of Kishtwar and then debouch their waters into river Chenab. Through one of important and crowdy places near Kishtwar is Shalamar, from where one more nallah passes and meets Chenab waters opposite Bhandin nallah. Khandru nalla and Khornag nallah rise in the east of Kishtwar in high mountain cliffs and finally debouche its waters into river Chenab near Binak Pachan. Kishtwar from north-east abounds in long assay of springs and nags. These add to the drainages from other seasonal nallahs in this area. All these nallahs become torrential during rainy season and cause a heavy erosion from the cliffs bringing to lower levels sufficient load of sediments downstream.

The Chenab river enters the Kishtwar plateau from north-east and abruptly flows due south upto Thatri. After making a loop at Thatri (Fig. 1), it turns west and flows in that direction upto Pul Doda. In the southerly course of Kishtwar area, in and around Thatri, there are more than 10,000 inhabitants occupying about 88 villages and about 50% of villagers live in far-flunged areas, where facilities of potable water do not exist. The people mostly use Chenab water for human consumption and irrigation. In the present paper, study pertaining to water chemistry of river Chenab of Kishtwar-Thatri area has been undertaken covering nearly about 30 km course of the river.

Thatri (1155 m) is an important town on the National Highway (NHIB) on way from Batote to Kishtwar, Jammu and Kashmir State. Thatri town is surrounded by very high mountains in the north, east and south. Enumerous small nallahs from watersheds existing towards north, north-east and south debouche their waters into the river Chenab. Besides, the seasonal nallahs, the terrains in the north-east, north and south abounds in springs. Number of springs between Kishtwar plateau and Thatri exist and these appear to exist as the feeder pipes to the lakes which are also present in abundance. The lakes are locally called Nags, *e.g.* Bimal Nag, Goras Nag, Kumar Nag, Solo Nag, etc. These Nags and springs add to the drainages passing through ice-fed nallahs which act as tributaries from river Chenab in this rugged terrain flowing in north-east and south-west direction. Besides the Nags (lakes), there are numerous springs in the area: one line of springs exists between Drabshala to Solanag between Kankot and Sherala forest. Second line of springs do occur between Mendar and Shiroti below Bhargad forest. Uppermost line of springs exists below Jinwas forest.

The highest point in the map area is 3384 m above mean sea level in the north-east and the lowest is 1038 m in and around Thatri area, near Barnut. The river Chenab passes through deep gorges towards south of Kishtwar area upto Thatri. In the north-east direction, the Chenab river is fed by Goras Nag nallah, Kumar Nag nallah and Gahan nallah, Sarwa nallah and Siber nallah as one stream, debouching its waters into Chenab river 1 km short of Kandar village. This nallah is fed by a long line of springs in the north-east. The gradient of nallahs is very steep flowing from a highest of 3384 m to 960 m at a point where biggest nallah releases its load near Kanda village. There occur some ridges among fairly plain raised areas known as Dhars, namely Kukri Dhar, Makkerpal Dhar, etc. extending to the extreme west upto Panyala forest. One more nallah flowing almost parallel to Gahan nallah as Kutigad nallah having its source between Sherala forest and Nagani forest. It is also highly torrential nallah fed by high mountain areas in the north-east (Chogal Gali, 4310 m). Kutigad nallah debouches its waters into river Chenab 3 km northwest of Dugga village.

Two more nallahs which are important in the map area are: Kaghune Gad nallah and Kal Nal nallah. Kal Nal nallah rises in Bhatnag forest in the southeast and meets Kaghure Gad nallah flowing from Guno in south at Datarsu village. Kaghure Gad nallah has its source in Bhaderwah Formation consisting slates and phyllites (Sharma, 1973; 1975). Kal Nal and Kaghure Gad nallahs flow as a joint stream and debouche its waters very near to Thatri into Chenab river.

In the west of the map area, river Chenab is fed by Macholi nallah rising in the Thalthule forest alongside of the continuous line of Dhars flowing in southeast direction and terminating in a fall of 34 m near Netarbati village. It is one of the biggest streams joining Chenab and flow drainage is through high grade schists and granites. Towards the right bank of river Chenab, there is one more nallah, namely Zatnag nallah rising in the middle mountains in the north and debouching its waters 1 km short of Barnut village. River Chenab forms an interesting study also at number of other places: namely, Akhnoor area (Fotedar *et al.*, 1990), Ranbir Canal (Fotedar and Singh, 1996), full course of Chenab river (Fotedar and Singh, 1994), Chenab through Doda district (Fotedar, 1993).

MATERIAL AND METHODS

Twenty water samples were collected from Chenab river flowing from Kishtwar to Thatri area, J&K State. The river course measures about 30 km distance. The collections of samples in this difficult terrain was made in two years, 2005 and 2006. As the river course flows through deep gorges, help from local labour was necessary to fill up the containers of two litre capacity with water samples. Care was taken to collect water samples before and after the confluence of different nallahs debouching water into river Chenab. This criteria could not be strictly followed because the samples could only be collected from the convenient accessible points. Pre-cleaned acid washed polythene containers were used for collection of water samples. pH, EC and TDS were measured at site using pH, conductivity and TDS testers. Total hardness and calcium were estimated by EDTA titrimetric method, and magnesium estimated by their difference. Na and K were estimated on flame photometer. Bicarbonate was determined by titrimetric method and the chloride estimation by Argentometric method. The sulphate estimation was done by gravimetric method. The nitrate and silicon were determined on UV spectrophotometer. Trace elements were determined on Atomic Absorption Spectrophotometer GBC Australian make, Model No. 902, according to procedures given in GBC Manual (1982).

RESULTS AND DISCUSSION

The upper limit of Ca and Mg for drinking water are 75 ppm and 30 ppm, respectively (BIS, 1991). The Ca concentration of Chenab waters lies between 3 ppm to 7.10 ppm with an average value of 5.14 ppm. The values of Ca are far less than the

Geological succession	
Formation	Age
Alluvium	Pleistocene and recent.
BHADERWAH FORMATION (a) Slates (b) Phyllites	Fine-grained greenish grey slates interlayered with light green coloured phyllites.
SALKHALA FORMATION	Gneissose granites, gneisses, schists, high grade schists, low grade schists, slates, phyllites, carbonaceous shales, shales with unevenly distributed salenite crystals, graphitic phyllites, admixed with graphitic schists and quartzites phyllitic materials occurring in layers. Phyllites containing Cu and Ni encrustrations are frequently met.
INTRUSIVES	
(a) Amphibolitis (b) Tremolite-Activolite (c) Migmaties and (d) Marbles	Due to metamorphism these three rock types represent later variations having occurred in Salkhala group of rocks, which have been metamorphosed into low and high grade of schists and gneisses. The three trans formed rocks represent migmatites and amphibolites in the high grade schists, tremolite and activolite types as a result of low grade metamor phism.

permissible limits and hence waters are safe for human consumption. Such low values cannot be considered harmful for agriculture. The average value of Mg (2.12 ppm) like Ca is far less than permissible limits and hence not harmful for human consumption or agricuture. Ca and Mg are both utilized for calculation of Magnesium Ratio (MR). It is expressed as :

$$MR = \frac{Mg \times 100}{Ca+Mg}$$

where all the ions are expressed in epm

It may be described as the excess amount of magnesium over Ca and Mg amount, where otherwise generally Ca and Mg will be in a condition of equilibrium (Das *et al.*, 1988). Excess of Mg affects the quality of soils which is the cause of poor yield of crops. According to Das *et al.* (*op cit.*), MR should be < 50, which is considered good for crops. In the study area, MR for all the samples is < 50 and hence, the waters of Chenab are not toxic for crops as far as MR values are concerned.

Ca and Mg is also utilized for calculating total hardness. The minimum total hardness in case of Chenab waters is 19 ppm and maximum is 49 ppm with an average value of 27.65 ppm. According to classification based on hardness scale (Rainwater, 1960; McCarty and Sawyer, 1967; Hem, 1991), all the values of Chenab river fall in soft category and so the waters can be used both for human consumption and for agriculture safely.

The calcium concentration in the present case has mainly been contributed by Salkhalas and its metamorphosed equivalents. There are invariably calcic intercalations and marble occurrences observed in phyllites and slates. Subordinately, most of Ca and Mg in the present case is contributed by granitoids which have intruded into the low and high grade schists in Kishtwar-Thatri area. Adsorption processed clay minerals appear to have been most effective in the map area, as due to intensive silicate weathering a lot of clay is available in the Chenab river waters. The adsorption of ions by clay minerals fixes maximum amount of Mg^{2+} ions by adsorption as a measure of ion exchange (Wedepohl, 1978). The various cations are not all equally replaceable. $Na^+ < K^+ < Ca^{2+} < Mg^{2+} < NH_4^+$. This means Mg will more easily replace Ca^{2+} than vice-versa. Indirectly, Mg dissolves more quickly than Ca or Na + K (Goldschemidt, 1954; Engel *et al.*, 1964). Mg inhibits the nucleation of the stable phase calcite since in

Thatri area Mg is invariably present in amphiboles. Because it has undergone dissolution quickly and as such its absence from the system has given rise to formation of marble in the area (Dhar *et al.*, 1996). This is one of the main reasons of abundance of Ca ions in the waters of river Chenab flowing in Kishtwar-Thatri area.

Main contributors of Ca in Chenab waters are amphiboles, marbles, phyllites/slates, pelitic schists, salenites crystals occuring abundantly in Salkhala group of rocks. Moreover, amphibolites incorporate in their lattice sufficient quantities of magnesium and total iron (Fotedar and Raina, 1994). Mg can be withdrawn from the solutions by the formation of chlorite minerals during late diagenesis, a common mechanism having taken place during the burial metamorphism in case of Salkhala group of rocks. So passive build-up of Ca and Mg both keep the concentration in Kishtwar area nearly uniform when especially a large quantities of both Ca and Mg get drained out during run-off. Indirectly, the loss of these two cations is made good by the interconnection of large number of springs and lakes in the area with the surface drainages (Von Engel Hardt, 1960). In case of pelitic sediments, a bulk of Ca and Mg gets trapped in clays during compaction of Ca and Mg of the sediments (Von Engel Hardt and Gaeda, 1963). This holds good in case of Salkhala group of rocks (pre-cambrian in age) in the present case, Ca gets removed from the carbonate system with Ca $(HCO_3)_2$. When sedimentary calcite in limestones undergoes metamorphism, relatively a small amount of overburden is sufficient to prevent its breakdown and escape of CO_2 and in normal course of events the calcite or aragonite merely crystallizes to form a marble. In Kishtwar-Thatri area, the formation of marble appears to have same type of mechanism possible. In metamorphism of pelitic sediments, reworking and frequent recrystallization in the long run makes transport of Ca ions possible with ground water passage through lakes and springs (Deer *et al.,* 1961). In short, passive build-up of calcium in Chenab waters of Kishtwar-Thatri area is possible by burial metamorphism of Salkhala group of rocks, where deep seated hydrothermal waters and reworked sediments have together helped in transport of Ca ions that later entered the solution of Chenab waters.

Fe concentration in Chenab waters lies between 0.32 ppm to 0.71 ppm with an average value of 0.55 ppm. The permissible limit of Fe in waters is 0.3 ppm, but in the present case, all the samples of Chenab waters have high concentration of Fe present in them. The high concentration of Fe appears to have been contributed by haematitic phyllites and slates of Salkhala group of rocks. Iron concentration is also contributed by amphibolites which are commonly occurring in Salkhala in both low and high grade schists. Amphibolites are concentrated both in the north-east and in the south fo the Thatri area. The drainages from south entering into Chenab waters transport considerable Fe-ions from amphibolites and migmatites in and around Thatri area. There has been enormous clay present in Chenab waters due to intensive erosion along with organic matter. These two parameters have helped in arresting iron as coatings on the large surfaces available in clays. Mn has also been arrested by the clays and organic matter through the same mechanism (Krauskopf, 1956; Jenne, 1968; Horowitz, 1974; Gibbs, 1977; Jenne *et al.*, 1980). The presence of heavies mainly Fe and Mn have been reported to be present in Sewa waters of Kathua district and river Chenab of Doda district through the same mechanism (Fotedar and Singh, 1994; Tiku, 2004; Fotedar, 2006). Coincidently the Sewa catchment and that of river Chenab for the most part have Salkhala group of rocks common in both.

Mn concentration in Chenab river lies in between 0.12 ppm to 0.56 ppm with an average value of 0.27 ppm. Mn concentration is increasing downwards because of smaller grain size (Horowitz, 1974). The permissible limit of Mn in potable waters is 0.1 ppm but in the present case the values of all samples are high.

Ni concentration in Chenab waters lies between 0.001 to 0.009 ppm, with an average value of 0.004 ppm. The low values of Ni in the present case are due to low values of Mg in waters indicating that both elements have sufficiently got diluted due to enormous nallahas joining the Chenab waters from high levels to low levels. Cu, Zn and Pb are present less than the permissible limits in Chenab waters (Table 3) and hence, with respect to these the waters are safe to be used for domestic consumption and agriculture.

The values of Si lie within the permissible limit of 15 ppm (BIS, 1991), except in three samples it is slightly more than 15 ppm (Table 3). It cannot be considered harmful for human consumption, but along with organic matter it has caused turbidity in Chenab waters, hence usual hygienic filtration is necessary before supplies are being made. pH values of all the samples are within the permissible limits.

The conductivity values for Chenab waters lie in between 0.038 - 0.094 micromohos/cm at 25^{0}C with an average value of 0.052. According to Richards (1954) and US Laboratory Salinity Staff (1984), the values fall in low salinity zone and hence the waters can safely be used for irrigation on all types of soils.

Potassium is one of the important elements occurring in the earth's crust. Some of the main minerals in the area of study containing K are K-feldspars, alkali feldspars, two micas, orthoclase and microcline. The bulk of the K in the earth's crust is contained in alkali feldspars. Salkhala group of rocks in Kishtwar-Thatri area contain feldspars and micas is abundance and besides all these, gneisses, schists, phyllites and slates all abound in K-element. The average K concentration in Chenab waters is 3.29 ppm. The amphibolites, marbles and other carbonate rocks present as intrusives do not contain appreciable K in them.

Precipitations is the result of solution of sea salts, taken up by wind and dust particles. Reasonable amount of K^+ enters the atmosphere from industries, but in the present area of study there are no industries and so the maximum contribution of K comes from rocks over which the river flows for a considerable distance. The K content of the rivers is derived primarily from weathering solutions such as ground water and soil water. In the map area, the ground water interaction with surface drainages appears to be an important factor for high influx of K resulting in near equal uniform high values in Chenab waters.

A smaller proportions of the K content from the atmospheric precipitation in the study area is possible as compared to that of Na. Livingstone (1963) suggests an average K concentration of world rivers as 2.3 ppm. But in the present case, the value is 3.29 ppm. It indirectly certifies the ground water source for the K concentration in Chenab waters. The K content, as with other dissolved components, usually decreases with increased discharge which implies that major source of K in such cases should be ground water.

K appears to be mobile under conditions of medium to high grade regional metamorphism. This movement of K is indicated by increasing K content of porphysoblastic growth of K feldspars giving rise to gneisses, pegmatites and amphibolites (Dhar *et al.*, 1996). The K content of argillaceous sediments and shales usually is highly correlated with the clay fraction (Havard, 1967). According to Hirst (1962) and Williams (1967), K_2O content always increases with decreasing grain size. Cressman (1962) stated that most of alkali metals of non-detrital silicons sediments and rocks reside in detrital phases. In riverine transport, decreased grain size contains a reasonable concentration of K^+ in the sediments (Jones and Bowser, 1978). Fine grained sediments, because of their large surface area are the main sites for the collection and transport of inorganic constituents. K and Na are more affected by ion exchange processes. The exchange capacities greatly vary according to pH, saturation of solutions and temperatures (Deer *et al.*, 1961). In sediment solutions, K, Mg and K are more firmly adsorbed and as against these, Na is weakly adsorbed and hence Na gets more effectively drained from the soil sediments than K (Wedepohl, 1978). Na has more replacing power than K but in hydrous environment this doe not hold good.

The classification with Herman Bouwer (1978) with respect to SAR (sodium adsorption ratio) has been followed. All the values are less than 6 and hence, the Chenab waters fall in "No Problem Category". The values lie in between 0.18 to 0.25, which indicates that no hazard of alkalinity (Richards, 1954) is anticipated as far as irrigation with Chenab waters of Kishtwar and Thatri areas are concerned. The water is of excellent quality according to SAR classification of Raghunath (1987) also. Similarly, SSP (soluble sodium percentage) values < 20 for all the 20 samples of Chenab waters in the present case indicate that the waters are safe/or marginally safe to be used for agricultural purposes (Kudesia, 1983). RSC (residual sodium carbonate) values are also favourable for considering Chenab waters to be used for irrigation purposes (Table 3).

Concentration of sulphates, bicarbonates, chlorides and nitrates have been observed to be all less than permissible limits (Table 3). TDS (total dissolved salts) too are present in safer levels and hence, waters suitable for both human consumption and agricultural use.

The corrosivity ratio (CR) in case of Chenab waters have been calculated for all 20 water samples. The corrosive ratio is defined by the formula :

$$CR = \left(\frac{Cl}{35.5} + \frac{SO_4}{48}\right) \div \left(\frac{HCO_3 + CO_3}{50}\right)$$

where all the ions are expressed as ratios of alkaline earths to saline salts in waters. It denotes susceptibility of water to corrosion and is expressed as ratio of alkaline earths to saline salts in water. The effects of corrosion or losses do hydraulic capacity of pipes used for irrigation purposes in the agricultural fields. Aravindan *et al.* (2004) have used

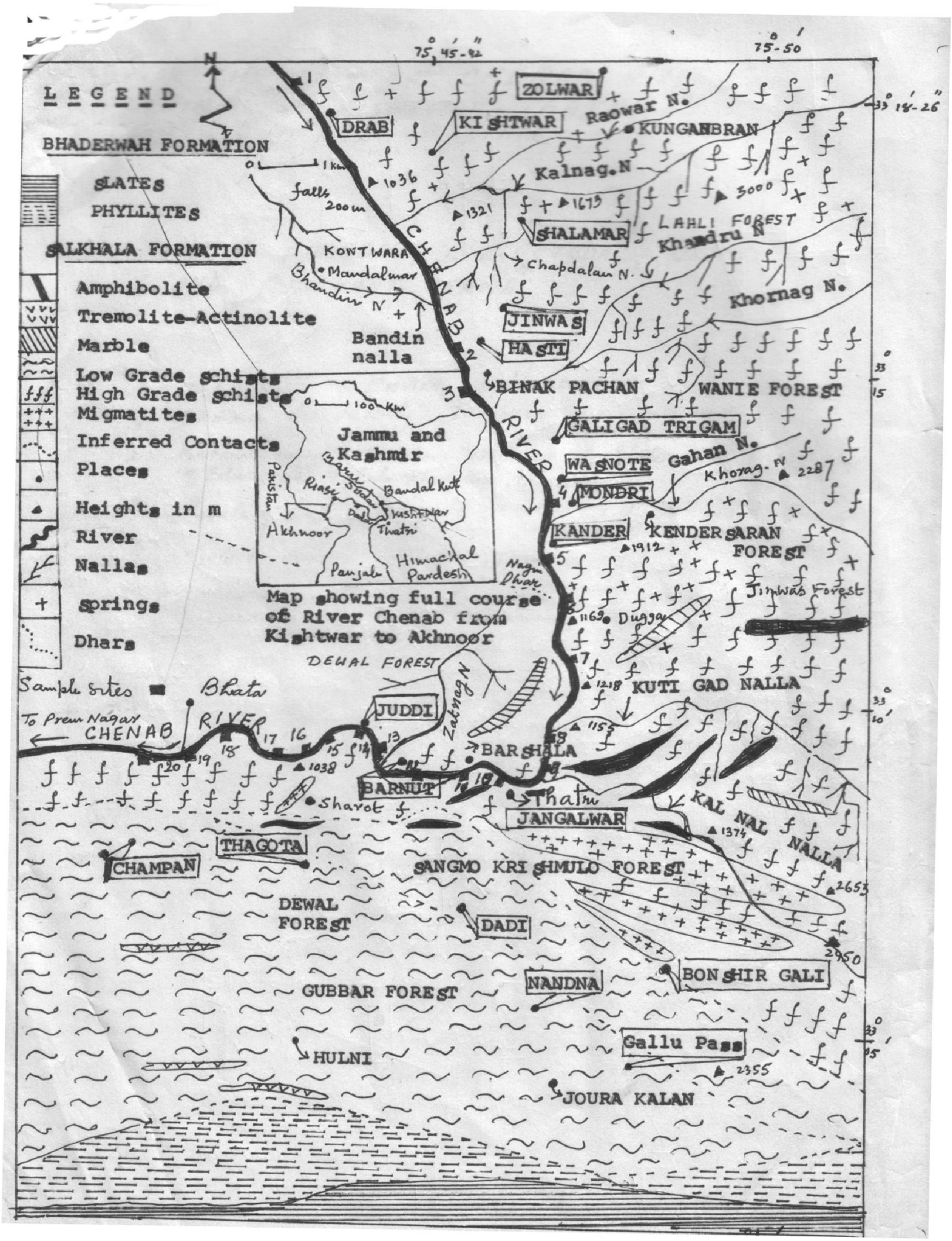

Fig 1. Course of Chenab river from Kishtwar to Thatri area.

Table 1. Chemical analysis of Chenab waters flowing from Kishtwar to Thatri (J&K State), alongwith other quality measurement parameters

S. No.	EC	TDS	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	Si	Fe	Mn	Cu	Ni	Zn	Pb
1.	0.046	67	4.25	2.00	2.30	3.25	22.00	4.06	3.76	0.72	15.43	0.31	0.12	0.101	0.001	0.001	0.004
2.	0.038	65	4.10	2.17	2.65	3.25	20.88	3.00	4.42	0.71	16.10	0.63	0.22	0.101	0.001	0.001	0.004
3.	0.041	60	3.00	2.10	2.70	3.20	21.10	3.00	4.20	0.61	14.10	0.32	0.22	0.102	0.001	0.001	0.005
4.	0.038	66	4.04	2.18	2.31	3.25	18.14	5.00	5.41	0.97	16.10	0.62	0.21	0.02	0.004	0.001	0.003
5.	0.062	63	4.14	2.11	2.20	3.28	18.26	5.03	5.31	0.80	15.25	0.51	0.19	0.02	0.009	0.008	0.007
6.	0.040	64	4.15	2.22	2.19	3.27	19.00	4.00	4.74	0.95	14.12	0.60	0.24	0.03	0.008	0.002	0.009
7.	0.094	135	4.13	2.33	2.23	3.28	21.10	4.23	4.98	0.78	12.12	0.62	0.28	0.03	0.007	0.012	0.010
8.	0.048	69	4.22	1.98	2.30	3.14	20.00	4.10	4.72	0.61	22.10	0.58	0.27	0.02	0.004	0.010	0.010
9.	0.084	119	4.22	2.16	2.16	3.12	19.12	4.06	4.60	0.72	14.22	0.56	0.28	0.02	0.005	0.014	0.008
10.	0.036	52	5.44	2.38	3.02	3.82	18.92	4.13	4.12	0.61	15.32	0.66	0.38	0.01	0.004	0.009	0.007
11.	0.045	54	6.12	2.40	3.09	3.92	17.62	3.93	4.04	0.70	14.42	0.63	0.32	0.02	0.004	0.004	0.002
12.	0.046	66	7.10	2.60	2.70	3.10	16.00	4.00	3.98	0.40	13.12	0.64	0.30	0.04	0.004	0.004	0.004
13.	0.039	57	6.10	2.10	2.72	3.14	20.00	4.64	3.72	0.63	12.12	0.69	0.32	0.03	0.006	0.001	0.007
14.	0.085	122	6.70	1.96	2.10	3.22	22.14	3.78	3.77	0.64	14.22	0.66	0.41	0.04	0.007	0.003	0.009
15.	0.067	97	5.00	1.48	2.10	3.23	20.18	5.12	4.76	0.77	13.13	0.71	0.56	0.05	0.008	0.006	0.005
16.	0.094	111	5.10	2.01	2.50	3.20	19.78	4.80	4.70	0.61	12.10	0.53	0.26	0.04	0.007	0.002	0.006
17.	0.034	48	6.10	2.02	3.01	3.70	18.02	3.90	3.99	0.52	11.18	0.36	0.29	0.02	0.004	0.001	0.004
18.	0.043	64	6.30	2.12	3.00	3.60	18.25	3.92	3.60	0.59	12.16	0.47	0.18	0.04	0.003	0.003	0.009
19.	0.041	63	6.34	1.99	2.88	3.40	17.32	4.06	3.60	0.0	13.10	0.48	0.21	0.04	0.002	0.002	0.008
20.	0.042	64	6.28	2.10	2.70	3.20	18.00	4.12	3.72	0.64	12.90	0.51	0.17	0.03	0.001	0.002	0.010
Mean	0.052	75.3	5.14	2.12	2.55	3.29	19.29	4.29	4.30	0.81	14.16	0.55	0.27	0.03	0.004	0.004	0.006

Note : All cations, anions and TDS are in ppm. EC is in Micromhos/cm @ 25^0C

Table 2. Quality measurement parameters of Chenab water flowing from Kishtwar to Thatri area, J&K State

S. No.	SAR	SSP	RSC	TH	MR	CR	pH	Turbidity
1.	0.22	31.40	–0.07	24	35.04	0.69	7.4	6.5
2.	0.21	31.70	–0.06	23	33.22	0.69	7.5	6.2
3.	0.19	31.40	–0.05	22	34.80	0.52	7.6	6.7
4.	0.18	29.50	–0.03	49	36.07	0.50	7.3	6.4
5.	0.002	29.30	–0.01	25	32.00	0.47	7.6	6.3
6.	0.19	31.40	–0.02	43	40.14	0.52	7.8	6.0
7.	0.26	32.80	–0.01	19	30.43	0.51	7.8	6.4
8.	0.25	36.00	–0.19	19	28.16	0.54	7.4	6.6
9.	0.22	23.60	–0.28	24	26.80	0.59	7.6	7.7
10.	0.18	28.80	–0.13	21	25.61	0.50	7.6	7.8
11.	0.20	26.56	–0.10	44	22.63	0.41	7.4	7.6
12.	0.21	27.60	–0.08	35	22.84	0.42	7.6	6.0
13.	0.22	30.50	–0.08	35	22.84	0.42	7.6	6.0
14.	0.25	30.80	–0.13	17	24.87	0.38	7.7	6.0
15.	0.25	27.70	–0.16	23	25.17	0.40	7.8	6.5
16.	0.17	32.00	–0.19	23	23.90	0.41	8.0	6.7
17.	0.20	30.00	–0.15	23	25.05	0.50	7.9	6.5
18.	0.21	32.00	–0.02	25	32.00	0.49	8.0	6.2
19.	0.23	32.70	–0.02	26	34.60	0.37	7.7	6.4
20.	0.24	32.70	–0.01	28	41.70	0.37	7.5	6.0
Mean/Range	0.18 - 0.25	26.56 - 32.70	–0.01to –0.28	27.65	30.16	0.48	7.4 - 8.0	6.0 - 7.8

Note : Total hardness is in ppm

the ratio to evaluate corrosive tendency of waters on metallic pipes of various regions in Tamil Nadu. The values < 1 are considered safe and in the present case, the values of all samples are < 1 revealing that the waters of Chenab can safely be used for transportation of irrigation water in pipes without causing corrosion.

WATER CHEMISTRY IN GENERAL

The general chemistry of ions in Chenab waters of Kishtwar-Thatri area correspond to Ca > K > Na > Mg and HCO_3^- > SO_4^{2-} > Cl > NO_3^-. Which shows the alkaline earths exceed alkalies and weak acids exceed strong acids. Total chemistry is dominated by alkaline earths and weak acids. Ca^{2+}, Mg^{2+} and HCO_3^- indicate temporary hardness. Cations like Fe and Mn indicate higher values due to more of mafic constituents available in the rocks over which Chenab river flows. Due to stronger index of weathering and steep gradients in the area of study in the upper course of Chenab river feldspars have been diluted quickly. Sulphates slightly more than chlorides indicate chalcophile phase of rocks having contaminated waters greatly. There has been dominance of ground water meeting surface drainages through enumerous springs and lakes in the area of study.

MANAGEMENT AND CONTROL

1. The area from north, northeast and eastern belt of Chenab flowing through Kishtwar-Thatri area should have an adequate forest cover. This will arrest many of the unwanted inorganic and organic materials to pass on into the solution of waters.

2. On both the banks of river Chenab in Kishtwar-Thatri area, vetiver grass should be grown. It will arrest many of unwanted elements including Fe and Mn to move into the solution of waters. The vetiver grass has the property of binding soil together and hence, many of the contaminants will get arrested at the site of slopes and waters will undergo natural filtration in a cost-effective manner. Vetiver growth is a tested technology having been used in many Himalayan terrains for checking contaminants moving into water besides getting rid of mass wastage and landslides (Lavania, 2004).

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Table 3. Average concentration values of different cations, anions and values pertaining to other parameters for Chenab waters flowing from Kishtwar to Thatri area, J&K State

Element / Parameter	Average conc. sample	Conc. recommended for human consumption	Reference	Toxic / Non-toxic	Conc. recommended for agriculture (Reference and Remarks)
1	2	3	4	5	6
Ca	5.14 ppm	75 ppm	BIS,1991	Non-toxic	Such a low conc. cannot be taken as toxic for agricultural use
Mg	2.12 ppm	30 ppm	– do –	– do –	– do –
Na	2.55 ppm	Not defined	—	– do –	– do –
K	3.29 ppm	50 ppm	BIS,1991	– do –	– do –
Fe	0.55 ppm	0.3 ppm	– do –	Toxic	5000 ppm (Kudesia, 1983)
Mn	0.27 ppm	0.1 ppm	WHO, 1984	Toxic	200 ppm (Kudesia, 1983)
Ni	0.004 ppm	0.05 ppm	Rodier,1975	Non-toxic	200 ppm (Kudesia, 1983)
Cu	0.03 ppm	1 ppm	BIS, 1991	Non-toxic	200 ppm (Kudesia, 1983)
Zn	0.004 ppm	5 ppm	WHO,1984	– do –	2000 ppm (Kudesia, 1983)
Pb	0.006 ppm	0.05 ppm	Rodier,1975	– do –	5000 ppm (Kudesia, 1983)
HCO_3^-	19.29 ppm	—	—	—	Such a low conc. cannot be considered toxic for crops
SO_4^{2-}	4.30 ppm	50 ppm	BIS, 1991	Non-toxic	– do –
NO_3^-	0.81 ppm	45 ppm	WHO, 1984	– do –	– do –
TH	27.5 ppm	300 ppm	Kudesia,1983	– do –	Such low values of hardness cannot be considered harmful for agriculture
Cl^{1-}	4.29 ppm	250 ppm	BIS, 1991	– do –	Such low values of chlorides cannot be considered harmful for agriculture
TDS	75.3 ppm	500 ppm	BIS, 1991	Non-toxic	2000 ppm (Kudesia, 1983)
Conductivity micromohos /cm at 25^0C	0.052	—	—	—	The value of EC < 1 do not fall in high salinity zone and hence with respect to conductivity the waters are safe to be used for irriga tion for all types of crops (Richards, 1954 and US Laboratory Salinity Staff, 1984)
SAR	0.18 - 0.25	—	—	—	< 6 (Herman Bouwer,1978) considered of excellent category in respect of irrigation fro all types of crops
SSP	26.56 - 32.70	—	—	—	Kudesia (1983) considers values < 20 satisfactory for agriculture and values 20 to 40 fairly satisfactory as such overall w.r.t. SSP the waters can safely be used for agriculture

RSC	–0.01 to –0.28	—	—	—	Kudesia (1983), the values < 2.5 are considered satisfactory for agricultural use
MR (magnesium ratio)	30.16	—	—	—	The values of < 50 ppm (Das *et al.*, 1988), are not harmful for crops
Corrosivity Ratio (CR)	0.48	—	—	—	The values > 1 are unsafe to be used for transport in pipes (Aravindhan *et al.*, 2004). In the present case, the values for all the samples are < 1 and as such the water for irrigation can be transported through pipes without corrosion.
pH	7.4 - 8.0	6.5 - 8.5	Kudesia, 1983	Non-Toxic	Safe for agriculture
Turbidity	6 - 7.8	5 units	Kudesia, 1983	Toxic	More than 5 units are harmful for human consumption, therefore hygienic filtration needed
Total Hardness (TH) as $CaCO_3$	27.5 ppm	300 ppm	Kudesia, 1983	Non-Toxic	Such a low value of hardness cannot be considered harmful for agriculture (McCarty and Sawyer, 1967)
Si	14.16 ppm	15 ppm	BIS, 1991	Non-toxic (only in 3 samples it is slightly higher than permissible limit)	—

doing water analysis for trace elements on Atomic Absorption Spectrophotometer, Model-902, GBC make. The authors are also thankful to the Head of the Department of Environmental Sciences, Jammu University, Jammu for giving the laboratory facilities for other analytical work used in this paper.

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