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Physico-Chemical Studies of the Waterbodies in and Around Shivkhori Area, Jammu Himalaya, in Relation to Geology of the Area

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ABSTRACT

The waters of Shivkhori stream, Raunra Tawi khad and Thanna Tawi khad stream of Kalakot area, Rajouri district, J&K state were subjected to analysis by Atomic Absorption Spectrophotometry for elements Si, Al, Fe, Ca, Mg, Na, K, Mn, Ni, Cu, Pb, Zn and Cr. All the elements except Si and Al were present within permissible limits in all the samples according to Bureau of Indian Standards and WHO. Aluminium is objectionable in four out of the 15 samples analysed, and silicon is present more than the permissible limits in all the samples. A good afforestation programme together with adopting Vetiver technology in the watershed areas of the region will screen out many of the elements including Al and Si not to enter the solution of the waters. Nitrates, sulphates, chlorides, bicarbonates, TDS and total hardness (TH) are all within the prescribed limits, and hence with respect to all these parameters, the waters are safe to be used for human consumption and also for agricultural use. SAR and SSP values of all the samples are within the prescribed limits, and hence the waters cannot be considered to create any harm as far as agricultural use is concerned. The waters of all the three streams are recommended to be subjected to chlorine/bromine disinfection to render the same safe for human consumption. Last, but not the least, attention needs to be paid towards bad sanitation prevailing near the banks of all the streams, which needs to be improved upon.

INTRODUCTION

Shivkhori cave (33° 10'38" : 74° 37'15") is one of the famous pilgrimage centres in the southeast of Kalakot region (Fig. 1). The cave is situated at a height of 1233m above mean sea level and geologically it is the northwestern extension of Vaishnodevi limestone. To the west, this range extends to Chakar coal field area in close contact with the Eocenes in the north and the Murrees in the west. The eastern extension of Vaishnodevi limestone goes as far as Jangal Gali coal field area existing to the southeast of the Shivkhori cave. In the northeast of the Shivkhori, there is Dansal-Sawalkot coal field which is separated by highly folded Murree formation.

The baseline ascend to Shivkhori cave starts from Sunkara village via Ransu (33°09'52" : 75°35'52") situated on the Ranurawali Khad nalla. From Ransu, there is a kutcha mule path which leads to Shivkhori cave. Shivkhori nalla flows all along this mule path, which though is narrow, but is strengthened with pucca cemented tiles from Ransu to the cave area in order to facilitate trekkers to walk enroute without having slips. The terrain involves rugged topography beyond Barakh reaching hill spurs from 1008m to 1810m above mean sea level.

Although, there are a number of dug wells in the whole area, yet the population uses the waters of Shivkhori nalla, Raunra khad and Thanna Tawi khad stream for human consumption. This fact tempted the authors to select these waterbodies for physico-chemical studies.

The watershed for these waterbodies constitutes mainly Vaishnodevi limestone, Subathus and the Murrees. Besides these, Subathus contains coal seams and this is the reason where carbonaceous matter is abundantly dispersed in various types of rocks which has also an impact on the chemical status of different waterbodies in the area.

MATERIALS AND METHODS

For the present study, eight samples from Shivkhori nalla were collected in polythene bottles after measurement of pH on spot in the field. Similarly, five samples were collected from Raura Wali khad stream and two samples from Thanna Tawi stream. Trace element analysis of water was done on Atomic Absorption Spectrophotometer, while other analysis was carried out by standard methods.

GEOLOGY OF THE AREA

The stratigraphic succession already worked out by various workers from time to time and observations in the field presently worked out are as given in Table 1.

Vaishnodevi Limestone: Vaishnodevi limestone is a part of carbonate sediments in the outer Himalaya which exists to the north of the main boundary fault. It is the oldest formation in the area. The formation of Vaishnodevi limestone has been known under various names such as Great Limestone (Meddlicot 1864, Wynne 1872, Lydekker 1876, Simpson 1906), Sirban Limestone (Wright 1906, Middlemiss 1929, Rao et al. 1968), Jammu Limestone (Raha 1980) and Vaishnodevi Limestone (Vankatachala & Kumar 1997, 1998) in the Riasi inlier of Vaishnodevi limestone around Bidda, where previously Raha (1980) had reported stromatolites. The authors have suggested late Riphean to Vendian age for this formation.

The Vaishnodevi limestone is an inlier surrounded by Eocene all along from Ransu to one kilometre short of Shivkhori limestone along the Shivkhori nala. It stretches with NW-SE trend, the

Table 1 : Geological succession of the area.

Formation	Lithology	Age
Alluvium	It consists of sandstone, claystone shale fragments, together with limestone associated with brown-grey clays brought down by various nallas from north and northeast.	Recent
Murree formation	Dark grey, purple and green sandstones interbedded with bright reddish-purple clays.	Early Miocene to middle Miocene
Subathus (Eocenes)	Splintery grey shales, limestones with nummlites, pyritous shales, iron stone shales, at place carboncaceous	Middle Eocene to Palaeocene
	Unconformity	
	ChertBreccia	Lower Eocenes (?)
	Unconformity	
Vaishnodevi limestone	Predominantly dolmitic limestones consisting of quartzites and cherty limestone with ooids and peloids, Dense cryptocrystalline and massive flaggy dolomitic limestone occasionally replaced to magnesite with bands of algal stromatolites. Base not exposed	Pre-cambrian

western extension of Eocene terminates at Chakar (33°11'02" : 74°36'10") in the map area all along with Vaishnodevi limestone. The width of Eocene is nearly 1.5 km to 2 km all along but it is concealed in the west by sediments of Murree formation. The area of Chaker is highly folded or faulted and hence Eocenes are not found beyond Balwal, while these make appearance again as inliers near Mahagola in the Kalakot area. As the Vaishnodevi limestone occurs in the tectonic plane, the rocks have become highly plicated and deformed, jointed and faulted. In the southwest these mark the contact with the Murrees at a number of places such as Manju (33°09'30" : 74°37'30"), one kilometre north of Palhar (33°09'32" : 74°36'17") and half kilometre of Krol (33°08'42" : 74°36'48"). One of the contacts also lies to the north of Ambaki Ban (33°07’54” : 74°37’36”).

The limestone in the Shivkhori area (Vaishnodevi limestone) has become very loose on account of water action in the upper reaches of Shivkhori area. The solution galleries are very common. For a great length in the Shivkhori nalla, the limestone boulders are seen all through. The waters of Shivkhori nalla soak well below the stream-bed and as such at a number of places, the beds look, completely dry.

Chert Breccia: The Chert Breccia is overlying the Vaishnodevi limestone. Previously many workers have described this formation in detail and considered it representing a great geological break. The Chert Breccia is overlain by Eocenes in the map area and is also present in the layers of Trikuta limestone in the east of the area.

Eocenes: Eocene bands trend NW-SE from Mara village in the west and Pauni in the southeast (outside the area of study). The Eocenes exhibit dome-shaped lenticular design exactly similar to Vaishnodevi limestone. It is in these bands that different coal seams lie stretched from Kalakot to Chakker area and further southeast in Junglagali. The Eocene beds are well seen when we ascend towards Shivkhori from Ransu on the right of the road alongside Shivkhori nalla. Again, Eocenes with bauxitic deposits are seen at Ransu below the site of the spring. The same lenticular body of Eocenes extends to village Sanarian in the west. Another contact of Eocenes with the Murrees is observed at Palhar and this lenticular body merges with the Vaishnodevi limestone where it meets another Eocene lenticular body half kilometre north of Krol village. In the west, lenticular body can be traced going up to Basantpur village and also beyond Thanna Tawi khad. The lower base of the Eocene lenticular body cuts through Auna village and half kilometre south of Bamliya village. In the east, these merge with the Vaishnodevi limestone formation again. At Manju village, one lenticular body goes almost horizontally and can be traced south of Tala village, where due to high folding character assumed by the Murrees, most of the contact lies concealed.

Murree Formation: Murrees are voluminous rocks occupying the map area. Murree outcrop is well seen at Sunarka and onwards along the Kalakot road. The belt extends from Sunarka up to Gontha (33°07'58" : 74°36'), where it is seen lying on both sides on the road. Then after reaching Tangroth (33°09'20" : 74°35'15"), we come across NW-SE trending Eocene belt on the right side of the Kalakot road. At Tangroth, we observe the Murrees and Eocene ridges coming closer to the fault line. At Triyath (33°08'54" : 74°33'48"), we observe big limestone boulders strewn in the Murree beds due to erosion. Towards the market at Triyath, we observe only Murree beds. From Triyath in the eastern side along the Basantpur-Tala-Dheot-Sanarian section, there is a long belt of Murree rocks exposed along the Raunra Tawi khad stream. The rocks here are highly folded and crushed. Some of the beds occur as escarpments in the Raunra Tawi khad. The age of the Murrees is taken as early Miocene to middle Miocene.

Alluvium: Thick alluvium patches lie all along the side of Shivkhori nalla, Runra Tawi khad and in the high slope gradient zone of Shivkhori to Manju area. To the northeast, east and southwest, many nallas flow bringing a lot of alluvium, depositing the same in the lower reaches. Alluvium consists of fragments of shale, bauxite, limestone and other detrital particles.

PARAMETERS OF WATER

The physico-chemical characters of water samples are presented in Tables 2 and 3. The water quality parameters were compared with the water quality standards for drinking and irrigation purposes.

Calcium, Magnesium and Total Hardness: The upper limits for Ca and Mg for drinking water are 75 and 30 mg/L respectively (BIS 1991). In the present case, the concentration of Ca and Mg in all the samples is below the permissible limits. Total hardness value for all the analysed samples lie between 234 to 290 mg/L. The concentration is less than the recommended value of 300 mg/L (BIS 1991) and hence not harmful.

Chlorides: A limit of 250 mg/L for chloride has been recommended for drinking purposes (BIS 1991, WHO 1982). In the present case, the concentration range for all the fifteen samples analysed is between 7.12 to 10.2 mg/L, and thus the waters are safe for human consumption. Such low values of chlorides cannot be considered harmful for agricultural purposes.

Sulphates: Sulphate is naturally occurring anion in all kinds of natural waters. It is an important constituent of hardness with Ca and Mg. In the present case the concentration of sulphates lies in the range of 3.12 to 5.10 mg/L. A limit of 200 mg/L has been suggested for drinking purposes (BIS 1991) and as such the waters cannot be regarded harmful for human consumption as far as this anion is concerned. Such low values cannot be regarded harmful for agriculture also.

Nitrates: The nitrate is present in soils, in most waters and in plants including vegetables in the

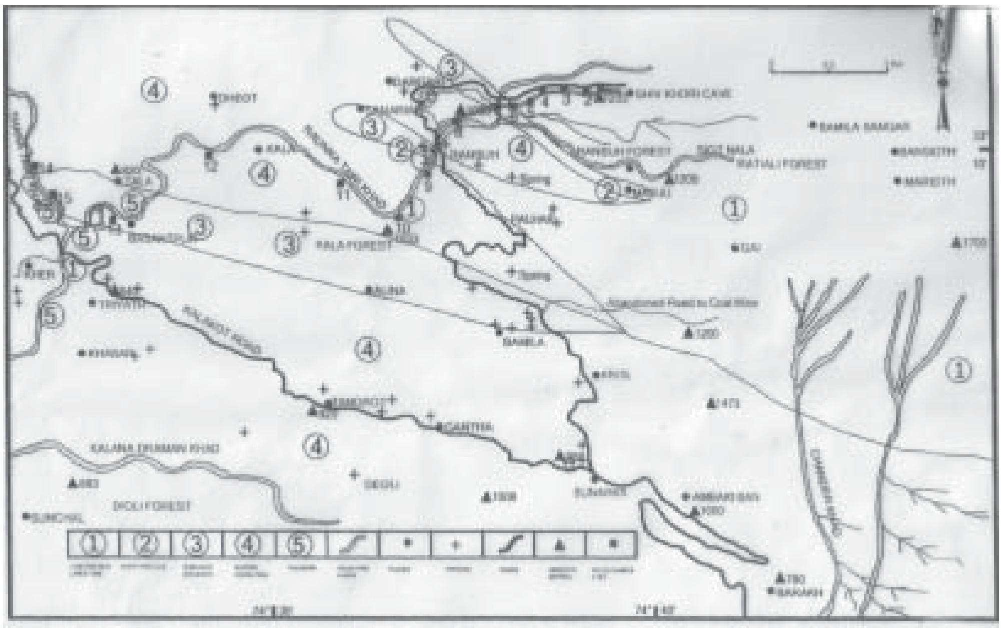

Fig. 1 Geological map of the area in and around Shivkhori cave, Kalakot area, Rajauri district, Jammu Himalaya.

Table 2: Physico-chemical characteristics of Shivkhori nalla, Raunra Tawi khad stream and Thanna Tawi stream, Kalakot area, District Rajouri, Jammu Himalaya.

Parameter	1	2	3	4	5	6	7	8
Si	26.00	24.3	22.8	28.0	30.0	32.0	32.4	32.4
Al^{+3}	0.023	0.12	0.10	0.03	0.021	0.02	0.033	0.036
Fe	0.073	0.051	0.061	0.042	0.046	0.045	0.043	0.039
Ca^{2+}	10.5	11.00	8.00	11.00	12.00	16.00	14.00	13.00
Mg^{2+}	0.20	0.034	0.026	0.014	0.023	0.01	0.025	0.1021
Na^{+}	0.914	0.834	0.773	0.444	0.321	0.15	0.09	1.02
K^{+}	1.8	0.760	0.890	0.660	0.720	0.640	0.710	1.00
Mn	0.041	0.023	0.012	0.009	0.021	0.017	0.021	0.010
Ni	0.0023	0.0021	0.003	0.004	0.0013	0.001	0.00125	0.0014
Cu	0.002	0.0023	0.003	0.002	0.0120	0.004	0.02	0.005
Pb	0.015	0.0020	0.0015	0.002	0.0016	0.0013	0.0011	0.0012
Zn	0.002	0.0020	0.0010	0.010	0.0020	0.0020	0.0010	0.0020
Cr	0.0029	0.0012	0.0023	0.002	0.0020	0.0014	0.0012	0.0020
SAR	0.40	0.35	0.38	0.19	0.13	0.05	0.05	0.03
SSP	20.10	9.58	17.16	9.07	8.00	4.71	5.70	7.73
Parameter	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Average**
Si	32.8	30.5	29.4	28.4	32.6	28.2	27.1	29.12
Al^{+3}	0.042	0.051	0.032	0.020	0.020	0.072	0.03	0.04
Fe	0.050	0.026	0.024	0.070	0.090	0.043	0.02	0.04
Ca^{2+}	4.13	4.6	4.3	3.2	4.7	5.0	4.2	8.37
Mg^{2+}	0.311	0.314	0.200	0.210	0.213	0.119	0.018	0.117
Na^{+}	1.02	1.04	1.26	1.21	0.911	0.811	0.543	0.690
K^{+}	0.812	0.613	0.710	0.412	0.311	0.450	0.112	0.700
Mn	0.013	0.081	0.091	0.043	0.080	0.073	0.034	0.037
Ni	0.014	0.012	0.0026	0.0024	0.002	0.0009	0.001	0.0034
Cu	0.005	0.004	0.0050	0.0060	0.006	0.004	0.002	0.0042
Pb	0.0015	0.0012	0.003	0.0026	0.0014	0.0013	0.0014	0.0025
Zn	0.002	0.004	0.005	0.0040	0.0050	0.0030	0.0030	0.0030
Cr	0.004	0.002	0.001	0.001	0.001	0.002	0.0020	0.0020
SAR	0.700	0.670	0.84	1.11	0.58	1.190	0.370	
SSP	29.00	27.00	30.35	24.35	20.00	19.70	13.40	

Sample Nos. 1-8 are from Shivkhori nalla, Sample Nos. 9-13 are from Raunra Tawi khad stream, Sample Nos. 14-15 are from Thanna Tawi nalla. The values are in mg/L except SAR and SSP

substantial quantities (WHO 1984). The water supplies containing high levels of nitrate have been responsible for cases of infantile methaemoglobinaemia and death. However, this problem does not arise in adults. The limit of general acceptability of nitrate for drinking water is 45 mg/L (BIS 1991). The values of nitrate in the study area range from 1.9 to 3.01 mg/L. It is evident that in all the samples the concentration of nitrates is very small and hence not harmful for domestic consumption.

Total Dissolved Salts (TDS): Total dissolved salts in all the samples are below the prescribed limits of 300 mg/L (BIS 1991).

Turbidity: The turbidity values in all the samples analysed range between 3.8 to 6.12 NTU, and three samples of Raunra Tawi khad stream have turbidity values more than 5 NTU, which is objectionable.

Table 3: Physico-chemical characteristics of Shivkhori nalla, Raunra Tawi khad stream and Thanna Tawi stream, Kalakot area, district Rajouri, Jammu Himalaya.

Parameter	1	2	3	4	5	6	7	8
NO_3^-	2.1	1.9	1.8	2.0	2.3	0.8	1.04	10.9
SO_4^{2-}	4.2	3.8	3.2	3.4	3.4	3.6	1.2	3.0
HCO_3^-	19.52	24.4	26.8	22.0	20.0	20.2	26.0	27.0
Cl^-	7.12	7.33	7.36	7.23	7.00	7.22	7.22	7.14
TH	256	270	260	290	277	279	283	286
TDS	210	216	226	210	216	233	213	212
Turbidity	4.5	4.3	4.0	4.6	4.6	4.3	4.3	4.2
pH	5.8	6.7	6.6	6.9	6.9	6.9	6.8	6.7
Parameter	9	10	11	12	13	14	15	Range
NO_3^-	3.34	3.01	2.90	2.80	2.90	2.70	2.00	1.9 - 3.01
SO_4^{2-}	3.12	3.22	3.22	3.33	3.12	5.10	3.37	3.12 - 5.10
HCO_3^-	21.00	18.40	17.30	40.30	44.20	35.00	33.30	19.52 - 33.30
Cl^-	7.37	8.20	8.20	8.30	8.17	8.12	10.20	7.12 - 10.20
TH	277	234	254	253	270	267	265	234 - 286
TDS	292	200	227	204	216	227	214	204 - 292
Turbidity	6.12	6.00	5.20	4.30	5.00	4.00	3.80	3.8 - 6.12
pH	6.5	6.3	6.8	6.5	5.8	5.9	6.2	5.8 - 6.8

Sample Nos. 1-8 are from Shivkhori nalla, Sample Nos. 9-13 are from Raunra Tawi khad stream, Sample Nos. 14-15 are from Thanna Tawi nalla. The values are in mg/L except turbidity (NTU) and pH.

pH: pH of all the samples is within the prescribed limits (6.5-8.5), normally acceptable as per guidelines suggested by WHO (1982). In general, the samples reveal slightly acidic nature.

Bicarbonates: There are no carbonate ions present in waters, but bicarbonates are present in the range of 19.52 - 33.3 mg/L. Such low values cannot be considered harmful for domestic consumption and also for agricultural use.

Silica: The range of silica in the water samples lies between 22 to 32.8 mg/L with an average value of 29.12 mg/L. The silica concentration is mainly due to abundant percentage of clay and sand in the Murree formation. This causes turbidity in waters. The turbidity increases manifold during monsoon. The permissible limit for silica in drinking water is 15 mg/L (BIS 1991) and all the samples have silica concentration more than this, which should be taken as objectionable. The waters need sufficient filtration before these are used for human consumption.

Aluminium: The range of aluminium in waters lies between 0.02 and 0.072 mg/L with an average value of 0.04 mg/L. The recommended value of aluminium for drinking water is 0.03 mg/L (BIS 1991). In the present case, five samples are having concentration more than this (sample No. 8 Shivkhori nalla, sample Nos. 9, 10 and 11 of Raunra Tawi khad and sample No. 14 of Thanna Tawi stream). With respect to Al, the waters can be considered slightly toxic for human consumption.

Iron: The range of iron in waters of the study area lies from 0.02 to 0.073 mg/L with an average value of 0.04 mg/L. The upper limit of Fe for drinking water is 0.3 mg/L (BIS 1991). All the water samples with respect to Fe are non-toxic for human consumption.

Sodium: The concentration of sodium lies between 0.09 and 1.26 mg/L with an average value of 0.69 mg/L. Its permissible limit for drinking water is 50 mg/L and in the present case it is far less than this limit. The waters of the study area, therefore, are fit for human consumption as far as Na is concerned.

Sodium is is an important cation for calculation of Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP). The sodium or alkali hazard in the use of water for irrigation is determined with relative concentrations of cations and is expressed in terms of sodium adsorption ratio. If the proportion of sodium is high, the alkali hazard is high and, conversely, if Ca and Mg predominate, the hazard is less. 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 the dispersion of the clay particles. The SAR values should be less than 26 when it can be considered not harmful for agriculture. In the area of study, SAR for all the samples is far below this value. Similarly, value of SSP should be less than 60. Hence, with respect to SAR and SSP, the waters of the study area are fit to be used for agricultural purposes.

Potassium: The concentration of potassium lies between 0.112 and 1.8 mg/L with an average value of 0.70 mg/L. The permissible limit for drinking water with respect to this is not well defined, but such a low concentration of potassium in waters cannot be considered harmful for human consumption, nor can it be harmful for irrigation.

Manganese: Manganese concentration is controlled by Murree formation predominantly. The concentration of this cation in Vaishnodevi limestone is very low. The perusal of Tables 2 and 3 shows that Mn increases downstream. This clearly indicates that Mn is more concentrated in fine grained sediments. Where ion exchange and large negative charge are available it has entered the solution of the waters easily. Fine grained sediments, because of their large surface area, are main sites for the collection and transport of inorganic constituents (Krauskopf 1956, Jenne 1968, Gibbs 1977, Jenne et al. 1980). The range of Mn in water samples lies between 0.01 mg/L and 0.091 mg/L with an average value of 0.037 mg/L. The permissible limit of Mn in drinking water is 0.1 mg/L (BIS 1991). In the present case, the concentration of Mn in all the samples is lower and, hence, the waters are safe to be used for human consumption. The desirable limit of Mn in waters for agriculture is 2.0 mg/L and the waters with respect to Mn are not harmful for agriculture.

Nickel: The concentration of Ni ranges from 0.0009 mg/L to 0.004 mg/L, while the permissible limit of Ni in waters for drinking purposes is 0.03 mg/L. Hence, with respect to Ni, the waters are not toxic. The concentration of Ni more than 5.0 mg/L in waters is unsuitable for agriculture. In the area of study, the concentration of Ni is far below this limit, and as such the waters can safely be used for agriculture.

Copper, Lead, Zinc and Chromium: The permissible limit for Cu is 1.00 mg/L, for Pb 0.05 mg/L, for Zn 5 mg/L, and for Cr 0.05 mg/L (WHO 1982) for drinking purposes. All these four trace elements are present within the prescribed limits and, hence, the waters of the study area are safe for drinking purposes with respect to these. For agricultural purposes, the prescribed limits for Cu, Pb and Zn are 0.2 mg/L, 5.0 mg/L and 5.0 mg/L respectively, and, hence, with respect to these the waters of the study area are safe to be used for agriculture. As far as Cr is concerned, the limit for agricultural use is not defined, but such a low concentration cannot be considered harmful for agricultural use.

DISCUSSION

Silica concentration has predominantly been affected by Murree sediments as limestones contain lesser quantities of silica in them. This has caused turbidity in majority of the samples. Turbidity is more pronounced in the waters of Raunra Tawi khad and Thanna streams. More turbidity in the waters is due to the fast erosion from the watershed areas because of inadequate forest cover. So in order to lessen the turbidity vast afforestation programme is needed to be launched in the whole northern belt. A good forest cover will also help in screening out many of the undesirous cations from entering into the solution of the waters. Freshwater in the form of rains dilutes SiO_2 in streams to a large extent. If the waters of the study area are recharged from checkdams storing rainwater in them, the acidity in most of the samples will come down and also Si concentration will appreciably come down in waters to the desired prescribed limits.

Ca, Mg and hardness values in all the samples are well within the prescribed limits. Mg dissolves more rapidly than Ca in the waters. Also the runoff in the Shivkhori nalla waters is very high making the river bed of the nalla dry at number of places. Ca and Mg in large quantities is thus washed downstream and, hence, do not reach the undesirable levels in waters.

Na and K are expected to be contained in feldspars, but model feldspar in Murrees is present in meagre amount as most of the them have denuded away due to intense weathering and washed along with the run off. The lesser amounts of alkalis present in waters is on account of less Na and K being present in the rocks of the watershed area and, moreover, potassium does not easily leach from the soil profiles as compared to sodium.

The inputs of aluminium in the Shivkhori nalla is mainly from the bauxite present in the Subathus in the watershed areas. The average range of aluminium in the world rivers is 0.001 mg/L. In the present case, its range lies between 0.023 and 0.1 mg/L with the average value of 0.04 mg/L. Murrees are mainly shales and sandstones and these are not expected to contribute such a high aluminium to waters. Aluminium toxicity is mainly connected with breakdown of nervous system. More recently, the researchers have connected aluminium with Alzheimer’s disease (Majumdar 1999). In the area of study, six samples are having concentration of aluminium more than the permissible limits, and as such the waters with respect to this element can be harmful for domestic consumption. A good forest cover in the watershed area can be screen out aluminium to a great extent from entering into the solution of the waters. Further, Vetiver technology in the whole watershed area is recommended. This technology (Lavania 2000, 2004) has proved helpful in checking the erosion from the soil profiles and also has been able to screen out many of the cations from entering the solution of water. Moreover, this technology is also useful in conserving water and reducing runoff.

As documented by Garrels et al. (1967), the weathering of primary or igneous rocks can be described by the attack of CO_2 rich soil solution on silicate minerals to form new aluminium silicate minerals (clays) plus dissolved cations, silica and bicarbonate in solution. During the process, aluminium is assumed to be insoluble. In case of silicate containing iron, the additional reaction, the oxidation of oxygen or iron to ferric oxide must be considered. Magnetites are much more resistant than iron silicates during chemical weathering, but it can undergo oxidation to haematite especially under tropical or sub-tropical conditions. Iron does not reach appreciable concentrations in waters for the pH exceeding the range of 6-7 corresponding to near neutrality at the recorded temperatures, but in more acid waters, iron is usually present in concentrations of several mg/L. The pyrites which could contain appreciable iron in them are absent in the area of study, except that shales of Murrees are expected to contain a good quantity of iron in them. The pH of many samples corroborates the fact that under high or slightly acid conditions, iron oxides may have become unstable. Ferric oxides formed by weathering are invariably fine-grained and as a result are carried by rivers either as stabilized colloids or as adsorbed coatings on detrital particles. Suspensions of ferric chloride may be stabilized by and intimately associated with organic matter (Shapiro 1964). Caroll (1958) has demonstrated the importance of clay minerals, which have a large specific surface area due to small particle size, as agents for the transport of adsorbed iron oxide. Much of the iron must have remained as coatings on suspended load of the streams in the area of study, and did not consequently enter the solution of nallas in the area of study (Gibbs 1977). The total iron of sedimentary rocks is 3.27% (on average basis) (Pettijohn 1963), while as in Murree sediments it is 1.88%. This accounts for less quantity of iron present in waters. Shales are expected to contain good quantity of iron in them. The average concentration of iron in river waters of the world is 0.67 mg/L, while in the present study it is only 0.04 mg/L.

Zn, Cu, Ni and Pb are well below the permissible limits. The average Mn concentration in the area of study is 0.037 mg/L. Fine grained sediments because of their large surface area are main sites for the collection and transport of inorganic constituents (Krauskopf 1956, Jenne 1968, Gibbs 1977, Jenne et al. 1980). In the area of study, because of steep gradients, fine sediments are removed to a faster rate, which could otherwise contain sufficient concentration of inorganic constituents and are, therefore, present in low concentrations. Mn ions in many rivers of the world get greatly diminished because of the decreasing grain size. This sort of decrease in Mn ion, has been observed by Bukhari et al. (1999) in Banganga river of Vaishnodevi area. Banganga river also, like Shivkhori stream, flows over limestone terrain. Grain size gets diminished downstream and due to discharges, it gets washed off. Mn is the first element to get transported among Mn, Fe, Cr, Ni, Cu and Co in many streams of the world (Horowitz 1974). In case of Shivkhori and other streams of the present area of study, Mn shows considerable decline downstream. Fotedar et al. (1993, 1994, 2003) observed the same type of decline in Jajjar nalla and other nallas of Udhampur district downstream due to riverine transport.

Sulphates, bicarbonates and chlorides are all less than the permissible limits. Hardness values too are less than the permissible limits (BIS 1991). Turbidity values show a marked increase downstream due to fast rates of weathering and erosion. Dissolved salts are less than 300 mg/L and hence the waters with respect to these parameters are safe to be used for human consumption. Also, the waters with less than agricultural norms present can safely be utilized for irrigation purposes.

Nitrate values in all the samples are lower than the permissible limits, but the banks of Shivkhori nalla, Raunra khad and Thanna stream are full of garbage and human excreta. Build-up of nitrates in the rivers of the study area is not significant and heavy monsoon rains usually wash away good quantity of nitrates present in the waters. In dry periods, when the runoff is minimum, there is apprehension of these values to go higher. In this connection, check over the prevailing bad sanitation needs immediate attention. Reduction in the level of bad sanitation in the whole area is very much needed. This is necessary to keep the prestinity of waters of Shivkhori nalla, Thanna stream and Raunra Tawi stream intact.

According to US Sanitary Laboratory, Department of Agriculture, USA, SAR lesser than 26 and SSP lesser than 60 for waters is recommended for agricultural purposes. In the present case, the values are within the prescribed limits.

MANAGEMENT AND CONTROL

In the area, in and around Shivkhori, a number of adequate measures need to be taken, to save the aquatic ecology of the famous pilgrimage centre:

1. Proper filtration methods and disinfection with chlorine/bromine is necessary to render the

waters of Shivkhori nalla, Raunra Tawi khad and Thanna Tawi khad streams safe for human consumption.

2. The areas from Ransu-Triyath to Shivkhori and the banks of both Raunra Tawi and Thanna Tawi streams are full of filth and human excreta. More so, the pilgrims and local people unabatingly defecate near the banks of all the streams, making the waters highly contaminated. Separate privacy corners in the whole belt should be constructed, so that with a proper sewerage system, the drainage can be diverted off from the site of pilgrimage. By such steps, aesthetic and recreational values of the waters can be maintained and everybody including the pilgrims would observe a healthy atmosphere while going for darshan to Shivkhori.
3. The area in the north and west of Shivkhori should be properly forested so that the erosion from the slopes gets checked and siltation reduced. Adequate forestation will screen many of the cations including Al and Si from entering the solution of waters. Proper forest cover also will check the turbidity in all the three streams of the area.
4. To check high rate of weathering, Vetiver Grass Technology (Lavania 2000, 2004) should be adopted to bind the soil together, reduce erosion and screen many of the cations from entering the solution of the waters. This technology has proved very helpful in controlling erosion and landslides in many parts of Himalaya. It is one of the cheapest methods for reducing erosion, mass wastage and contamination in waters.
5. The area between Ambika Ban and Triyath is water scarce area. There should be a provision for harvesting rain by constructing checkdams. This water can also be used to dilute the acid character of the waters in the study area, so that the same could be safely used for human consumption.
6. Mass awareness programmes about maintaining good sanitation in the whole area should be initiated at the earliest.

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