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Chemical And Sediment Load Characteristics of Chandra River, Lahaul, Valley, Himachal Pradesh, India

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SYNOPSIS

An analytical study on major cations and anions in the water of glacial-fed Chandra river of Lahaul valley in Himachal Pradesh in India is attempted in the present work. Water samples for this purpose were collected at regular intervals of time during the summer ablation period (14 th to 18 th August) of 1988 at the upstream and downstream sides of the points of confluence of meltwater from Bara Shigri and Chhota Shigri glaciers. It is observed that the electrical conductivity has gradually decreased from morning and again starts increasing in the late afternoon. It is also observed that the mixing of meltwater causes dilution of river water. Calcium and magnesium among the cations and bicarbonate among anions are found to be dominant. The suspended sediment concentration shows good negative correlation with electrical conductivity.

1.0 INTRODUCTION

1.1 Some studies on the chemical weathering characteristics in alpine environment indicate that it is more intense in these regions than in tropics. Reynolds and Johnson (1972) explained that the silicate minerals are capable of reacting rapidly with water at near freezing temperatures. High dissolution capacity of carbon dioxide in these cold waters enhances the supply of H^+ ions needed for acid hydrolysis of minerals. This gives rise to bicarbonate, cations, dissolved silica and clay minerals (Raiswell, 1984). Partial dissolution of suspended sediment may substantially contribute to the solute concentration (Collins, 1979).

1.2 From the studies of Meybeck (1983) it is clear that the control of local geology on water chemistry is significant. He has reported that the water flowing over sedimentary rocks carries, comparatively, much higher dissolved load than those waters flowing over igneous rocks. The local geological variations may greatly affect the character of rivers, especially near their sources (Gorham, 1961).

1.3 Several authors reported diurnal variations in the chemistry of glacial meltwaters. A two component flow of meltwater was suggested by Rainwater and Guy (1961), and Collins (1979) to explain this phenomenon. According to their observations the subglacial water gets enriched with dissolved solids because of long residence periods and contact with bed sediment. In contrast to this, the supraglacial meltwater is fast flowing, dilute and its flow is directly controlled by heat flux. Variable dilution of concentrated subglacial water by diluted supraglacial water causes diurnal variation in the chemistry of glacial-fed streams.

1.4 The amount of suspended matter in water depends on the hydraulic condition of streams and availability of suitable size fractions of sediment. The physical weathering processes active in the glaciated regions produces very fine sediment which can be carried away in suspension by meltwater. The higher competency and capacity of mountainous streams enables them to carry much higher suspended sediment. Gibbs (1967) found that 82 percent of suspended sediment is derived from 12 percent mountainous area in the Amazon river catchment. With increased melting the volume and velocity of stream water increases which in turn yields higher concentration of suspended matter.

2.0 AREA OF STUDY

2.1 The study was undertaken in the Shigri area of Chandra river catchment, eastern Lahaul valley, Himachal Pradesh, India (fig. 1). Chandra river emerges from a huge ice sheet in the vicinity of Bara Lacha pass (about 50 km to the north of Shigri), and it is fed by meltwater from several valley glaciers. At Shigri, meltwater from two glaciers, namely Bara Shigri and Chhota Shigri, mixes with Chandra river. Bara Shigri is the longest valley glacier in the valley. The valley experiences very low temperatures, much below freezing point, during winter months and it will be completely covered with snow and inaccessible. The valley slopes are devoid of any tall trees, but one can find seasonal grass which grows after the melting of seasonal snow. No human settlements can be found in the catchment area of Chandra river.

2.2 Chandra river catchment is underlain by both sedimentary and highly metamorphosed gneissic complexes. To the upstream side of Shigri, Chandra river flows on the sedimentary formations of paleozoic age, consisting of sandstones, quartzites, shales, siltstone, limestones and dolomites. A major part of the Bara Shigri

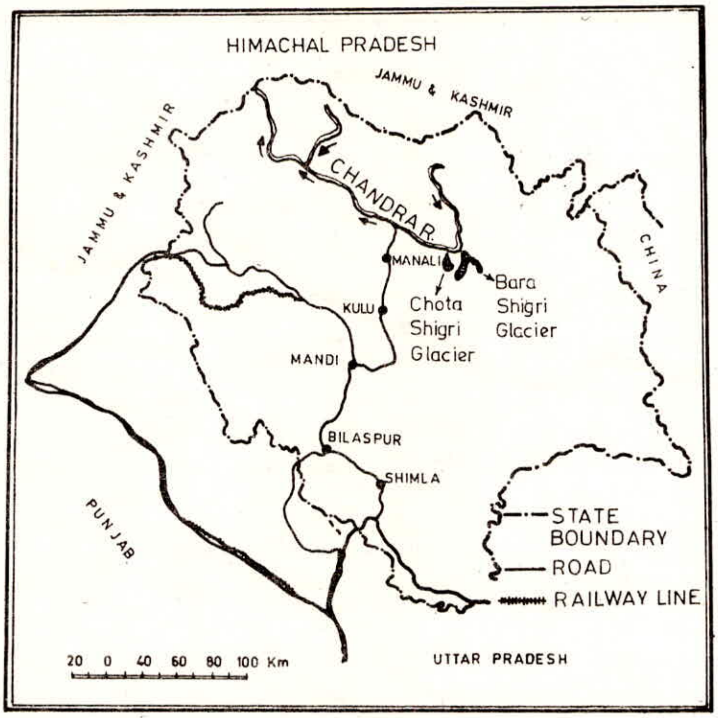

Fig. 1 Location of the study area

glacier flows on highly metamorphosed Rohtang Gneissic Complex of precambrian age. Chhota Shigri glacier is completely underlain by gneisses. The present study is confined to Shigri area because of the lithological variation in the region and the availability of chemical data on the Chhota Shigri glacier.

3.0 SAMPLE COLLECTION AND LABORATORY METHODOLOGY

3.1 Water samples were collected from 14th to 18th of August, 1988. Samples were collected from Chandra river at four places before and after mixing of meltwater from Bara Shigri and Chhota Shigri glaciers (fig.2). To take note of diurnal variations, samples were collected from morning to evening at regular intervals of time. A total of thirty samples were collected, one liter each time in clean polyethylene bottles. pH and electrical conductivity were measured immediately after the collection by using portable pH-conductivity meter. Temperature correction was applied for electrical conductivity. Samples were taken to the laboratory and the suspended sediment was separated by filtering the samples using filters of 0.45 u pore size.

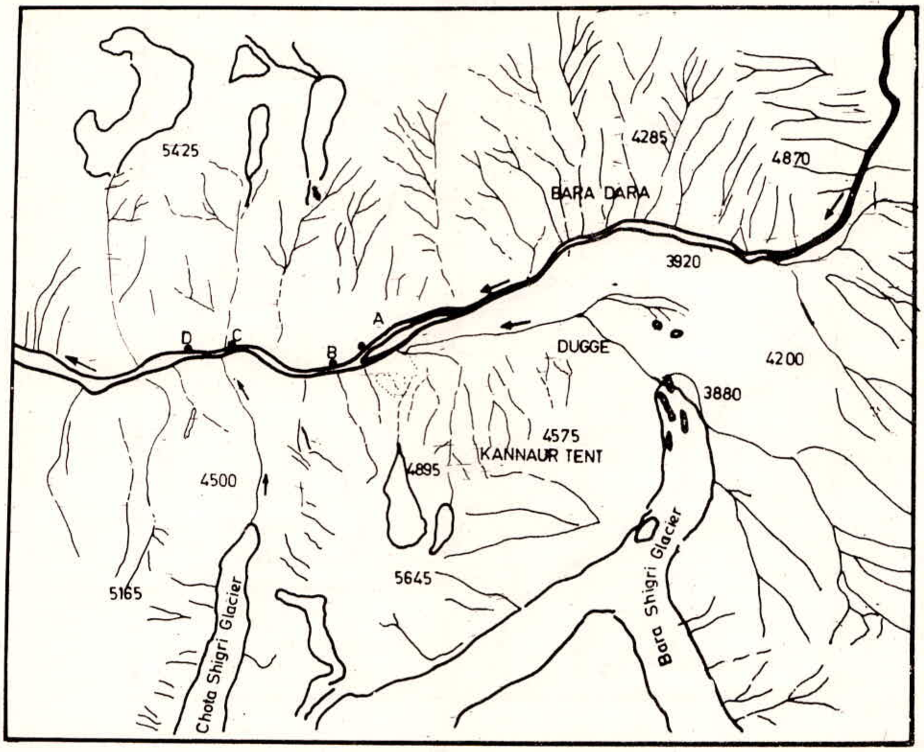

Fig. 2 Sampling points on Chandra river.

3.2 Water samples were analysed for calcium, magnesium, sodium and potassium on GBC 902 double beam atomic absorption spectrophotometer. Calcium and magnesium were found out in absorption mode, and sodium and potassium in emission mode. Molybdosilicate method was used to measure the concentration of dissolved silica on spectrophotometer. The amount of bicarbonate was determined by potentiometric titration of low alkalinity (APHA, 1980). Chloride concentration was found out by by titrating with silver nitrate solution. Sulfate concentration was determined by using barium perchlorate method.

3.3 The mineralogy of suspended sediment was studied by using X-ray diffractogram technique. Caroll (1970), methods were used in identifying the minerals.

4.0 RESULTS AND DISCUSSION

4.1 The pH of Chandra river water at all the four sampling sites is alkaline with a minimum of 7.5 and a maximum of 8.6 during

Table 1. Chemical and suspended load of Chandra river (A, B, C, D are sampling sites, all smples collected during Aug.1988)

S. No.	Da- te	Ti- me	pH	EC	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}	Silica	TSM	TSM/ TDS
Site A														
1	14	15	8.2	154.6	16.67	5.35	1.33	0.92	75.0	2.12	2.00	1.05	966.4	9.2
2	14	17	8.3	150.0	15.49	3.13	0.70	0.70	70.0	2.24	2.55	0.93	1138.3	11.9
3	15	9	7.8	180.8	18.79	5.63	1.01	0.79	91.0	2.63	1.40	1.31	628.8	5.0
4	15	12	8.1	165.1	17.01	5.87	1.36	0.95	78.5	2.56	1.65	1.42	605.2	5.5
5	15	15	7.7	164.2	17.00	3.85	1.02	0.81	68.0	1.48	1.80	1.24	726.0	7.6
6	17	9	7.7	148.1	16.17	6.41	0.94	0.54	59.0	2.56		1.10	324.4	3.7
7	17	12	7.9	135.3	14.69	6.05	0.78	0.35	49.5	0.92		1.33	288.4	3.8
8	17	15	7.6	137.2	15.46	4.94	1.72	0.75	51.0	1.60		1.24	566.8	7.2
9	17	17	8.0	145.8	15.09	5.73	0.93	0.59	53.0	0.80		1.54	843.6	10.6
Site B														
1	14	15	8.2	165.2	16.45	4.67	0.77	0.92	70.0	2.00	2.00	1.91	1101.2	11.2
2	14	17	[illegible]	156.5	16.64	5.09	0.72	0.69	66.0	2.08	1.80	1.54	1164.0	12.3
3	15	9	7.9	175.4	18.91	5.96	0.70	0.76	93.0	1.84	1.50	1.89	622.4	5.0
4	15	12	8.0	155.2	15.72	3.08	0.57	0.60	80.5	1.60	1.75	1.42	556.0	5.4
5	15	15	7.9	162.9	16.63	3.22	0.77	0.79	77.0	1.20	1.50	1.21	707.0	6.9
6	17	9	7.7	142.2	14.08	5.65	0.96	0.54	48.5	1.92		1.24	374.2	4.0
7	17	12	8.1	134.0	14.76	5.97	0.75	0.45	47.0	1.12		0.96	305.6	4.2
8	17	15	7.5	130.0	14.17	5.59	1.09	0.72	50.0	0.76		1.33	643.6	8.5
9	17	17	8.3	131.7	14.33	5.46	0.59	0.54	41.5	1.68		1.73	835.2	12.2
Site C														
1	16	7	7.7	142.6	15.52	5.29	0.83	1.00	57.5	2.20	2.00	1.87	568.0	6.2
2	16	9	8.1	127.8	14.38	5.63	1.19	1.13	56.5	1.12		1.26	585.6	9.0
3	16	12	8.2	115.7	12.99	5.27	0.70	1.03	43.5	1.20	1.90	1.56	503.6	3.8
4	16	15	7.5	119.6	13.24	5.33	1.32	1.32	46.0	1.76		2.52	684.4	9.3
5	16	18	7.7	135.2	15.66	4.87	1.28	1.30	57.5	2.60		1.52	795.6	9.1
6	18	7	7.7	128.7	15.41	3.33	1.40	0.98	50.0	1.04		1.59	464.0	5.4
Site D														
1	16	7	8.1	127.6	13.59	2.88	0.72	0.84	55.5	1.20		1.63	535.2	6.8
2	16	9	7.8	122.2	13.88	3.99	0.97	1.03	54.0	0.80	1.30	1.80	470.4	5.9
3	16	12	7.5	114.3	13.01	0.00	0.75	1.11	43.5	2.64	1.80	2.12	615.2	3.8
4	16	15	8.3	101.0	11.29	4.28	0.73	0.87	35.5	1.36		1.56	753.2	13.1
5	16	18	8.6	116.0	12.52	2.49	0.77	0.84	39.5	1.20		1.42	784.8	12.9
6	18	7	8.1	116.4	13.90	3.30	0.83	0.73	43.5	0.56		1.12	462.4	7.0

* EC is given in uS cm^{-1}.
** All concentration are given in mg l^{-1}.

the observation period (Table 1). This is in contrast to the almost neutral pH of Chhota Shigri glacier meltwater as reported by Hasnain and Dhanpal (1988). The meltwaters from Bara Shigri and Chhota Shigri glaciers dilute the Chandra river water as evident from the electrical conductivities measured at the four sampling sites (fig. 3). The conductivity of meltwater from Chhota Shigri glacier, as reported by Hasnain et al., 1989, shows that they are much dilute when compared with Chandra river water. This can be attributed to the lithology of the area. To the upstream side of Shigri, most part of Chandra river catchment is underlain by sedimentary rocks whereas the Chhota Shigri glacier is flowing over highly metamorphosed Rohtang Gneissic Complex. As indicated by Meybeck (1981), the dissolved load in waters flowing over sedimentary rocks will be more than those waters flowing over igneous and metamorphic rocks. During the acid hydrolysis the H^+ ions in the water will be consumed. So the higher dissolution rates in the sedimentary environment turns the water to alkaline. Figure 3 shows diurnal variations in the

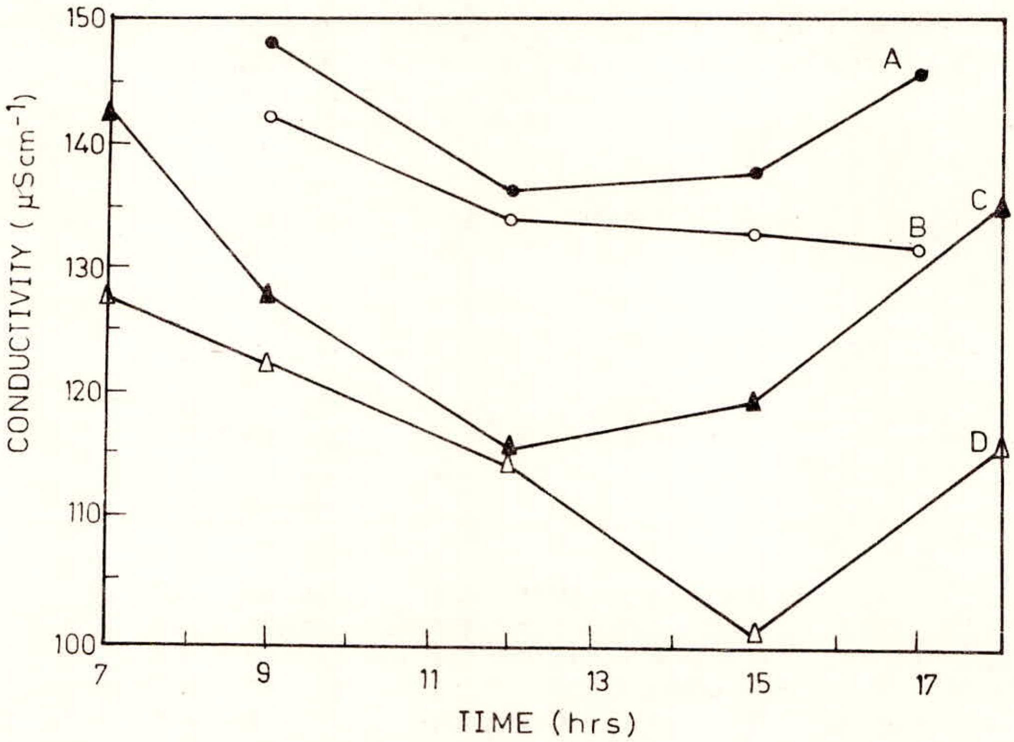

Fig. 3 Diurnal variations in electrical conductivity.

electrical conductivity at all the four sampling sites. It shows a gradual decline in the electrical conductivity in the forenoon and a recovery in the late afternoon. The model of Rainwater and Guy (1961), and Collins (1979) can be used to explain the diurnal variations in the water. In the morning with the supply of solar energy more and more melting takes place which causes dilution of subglacial water. Reduced melting in the late afternoon, as a result of less heat supply, causes less dilution of subglacial flow. So, the electrical conductivity shows an upward trend.

4.2 The chemical composition of Chandra river water is given in table 1. Calcium is the major constituent (70%) among the cations followed by magnesium (22%). Sodium and potassium are comparatively smaller in amount. Bicarbonate constitutes about 95% of the total anions. Bicarbonate in river water may be derived from carbonates or silicates as a result of reaction with carbonic acid [H_2CO_3] (Raymahashay, 1986). Along with bicarbonate calcium and magnesium will be released to the water if carbonates are the source. If silicates are involved in the reaction, then, cations, bicarbonate, clay minerals and dissolved silica will be produced. Carbonic acid mainly comes from the dissolution of carbon dioxide in the atmosphere. No significant contribution of carbon dioxide from organic matter can be expected as the region is cold desert and the vegetation is scarce. Though the waters are getting diluted, dissolved silica in Chandra river water is increasing after the mixing of Bara Shigri meltwater (fig. 4). This is because of the dominance of silicate mineral weathering in the Bara Shigri area whereas the carbonate weathering dominates in the upstream side (very high concentrations of calcium, magnesium and bicarbonate compared to the amount of dissolved silica). Slight reduction in the dissolved silica content, after the mixing of Chhota Shigri meltwater stream may be because of comparatively lower rates of chemical weathering in the Chhota Shigri glacier. Sodium is getting diluted in Chandra river water after the mixing of meltwaters. When sodium is derived from atmosphere, its concentration will not be affected by mixing of tributaries (Meybeck, 1983). So, atleast a part of sodium might have been derived from lithogenic source. Lithogenic source suggests the origin of these alkalies to the evolution of clay minerals and ion exchange. But the low silica content in water when compared with the total of sodium and potassium indicates that, atleast a part of these alkalies might have been derived by ion exchange or a part of sodium is from atmosphere.

4.3 Chloride in the water is mainly derived from oceanic source. The atmospheric fallout contributes most of the chloride in fresh waters. Walling and Web (1986) discussed about the influence of certain factors, such as altitude and proximity to the sea, on chloride concentration. The present study area is at a very high

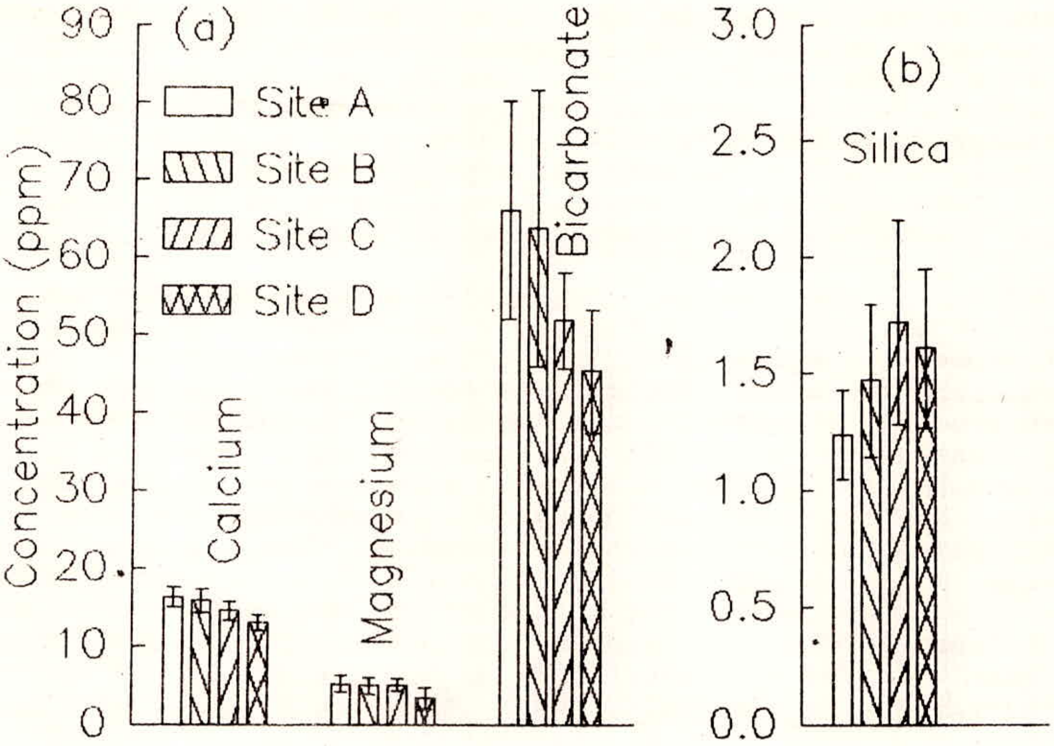

Fig. 4 Average concentration of (a) calcium, magnesium, bicarbonate and (b) silica at the four sampling sites.

altitude and far away from the sea. Because of the obstruction provided by Pir Panjal ranges, monsoon can not reach the area Very low concentrations of chloride in Chandra river water is also due to the less efficiency of ice in collecting materials from atmosphere. The observed sulfate concentration ranges from 1.30 to 2.56 mg l^{-1}. The sulfate ions in water may come from the breakdown of sulfate minerals in the bedrock or atmospheric fallout. Due to lack of complete analytical data for sulphate it is difficult to attribute any source in the present study.

4.4 The mineral content of suspended sediment is given in table 2. Kaolinite and illite are found to be dominant among clay minerals with little chlorite. Quartz and feldspars dominate the detritals. Relief plays an important role in the type of clay mineral formation. The study area is having high relief, and it is well drained, favouring the formation of kaolinite Under conditions of limited weathering and decomposition, muscovite, k-feldspar and plagioclase may provide the alumina and silica necessary for forming kaolinite (Berner, 1971). Negative correlation coefficients for

Table 2. Mineralogy of suspended sediment (in percent)

S. No.	Quartz	Feldspar	Muscovite	Dolomite	Kaolinite	Illite	Chlorite
1	42.07	16.39	2.59	1.26	26.12	8.34	3.23
2	43.08	11.59	1.53	0.37	31.20	8.97	3.93
3	42.36	19.30	3.24	1.21	19.05	12.74	2.00
4	34.73	21.86	3.63	2.25	24.79	11.01	1.73
5	33.17	22.08	5.00	3.79	19.63	14.14	2.29

Kaolinite with feldspar, muscovite and illite (-0.81, -0.82, -0.87 respectively) indicates that the weathering of these minerals leads to the formation of kaolinite in suspended sediment.

4.5 Wide variations are observed in the total suspended matter of Chandra river water. Repeated diurnal variation are observed in

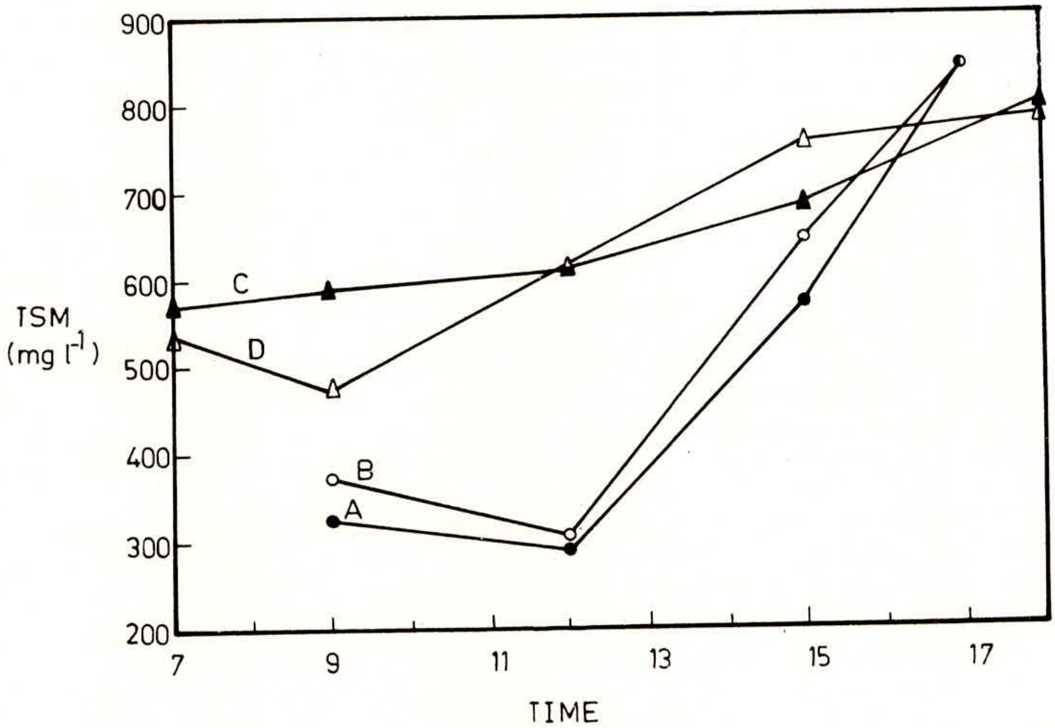

Fig. 5 Diurnal variations in the concentration of suspended sediment at the four sampling sites.

the concentration during sampling period (fig. 5). Chandra river gets enriched with suspended sediment after the meeting of Bara Shigri stream. After the confluence of Chhota Shigri stream, the concentration of suspended sediment gets slightly reduced. This shows that the erosion rate of Bara Shigri is higher when compared with Chandra river and Chhota Shigri stream. The suspended sediment load is increasing from morning to evening with the addition of more and more meltwater.

4.6 The ratio of sediment load to chemical load gives an idea about the dominance of physical weathering over chemical weathering in the area (Table 1). It also shows increasing trend from morning to evening signifying the importance of physical load over chemical load with increase in discharge.

5.0 CONCLUSION

5.1 Based on the above discussion, the present work can be summarised as follows- The Chandra river water is alkaline because of the higher dissolved load it carries. The higher dissolved load in the river water and dilution after mixing of meltwater from the two glaciers is caused by change in the lithology of the area from sedimentary to gneissic formations. Diurnal variations in the chemical load are caused by change in the volume of supraglacial water added to the subglacial flow from time to time. At Shigri, silicate mineral weathering contributes cations and bicarbonate to water. To the north of Shigri, carbonates in sedimentary rocks are the major source of calcium, magnesium and bicarbonate in water. Sodium and potassium concentration is related to clay mineral formation and ion exchange. Also, a small part of sodium might have been derived from atmosphere. Kaolinite in suspended sediment is derived from the weathering of feldspars, muscovite and illite. Increase in the suspended matter concentration from morning to evening can be attributed to higher rates of melting of glaciers. Higher suspended sediment concentration after the mixing of glacier meltwater streams, indicate greater velocity of these streams. The prominence of physical weathering over chemical weathering with increasing discharge is evident from higher TSM/TDS ratio.

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