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Suspended Sediment and Solute Characteristics of Two Desert Rivers of India

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Abstract Suspended sediment and solute were studied in two desert rivers for 3 years. Suspended sediment concentration in both the streams was higher in the first seasonal flow and decreased in subsequent flows. The average sediment concentration in Sukri was 4.68 and 2.30 g L^{-1} in Guhiya. Water from both the streams was alkaline. Guhiya, due to its highly mineralised basin carried higher salt concentration than the river Sukri. Except for K, concentration of individual ions tended to decrease with an increase in discharge. Compared with major Indian rivers and world average river water, salt concentrations in desert river waters are high.

Key words Desert rivers, Sediments, Solute concentration

Suspended sediment and solute load for different river basins at different locations have been reported. Gibbs (1970) calculated the deposition of world average river water based on long term observations for the Amazon river. Handa (1972), Raymahasay (1970) and Subramaniam (1979) have reported geochemical characteristics for major Indian river basins. However, such information on Indian desert rivers, which are ephemeral in nature are sparse. The suspended sediment and chemical characteristics of two river basins in arid Rajasthan are discussed here.

Materials and Methods

The study area is located between 25°44′ – 26°13′ N and 77°22′ – 74°16′ E in district Pali, western Rajasthan. Sukri and Guhiya are tributaries of the river Luni and the source of water for the Sardar Samand reservoir constructed at the confluence of the two rivers (Fig.1). The catchment area of river Sukri is 1284.92 km^2 and 349.15 km^2 for Guhiya river. Sukri originates in the Aravalli hill ranges and Guhiya in the isolated hills. The upper catchment of the Sukri river comprising of about 20% of the total area forms part of the Aravalli hill ranges with a relief ratio of 17 m km^{-1}. The drainage density is high indicating favourable runoff characteristics. The isolated hills which are the source of water for Guhiya have short steep slopes with several drainage channels at all sides which terminate on the relatively flat land below the hills. The rest of the area has flat topography with slope ranging from 1-3%. The relief ratio gradually decreases from 3 m km^{-1}. The area below the Aravalli ranges forming the lower catchment consists of sandy to sandy loam soil with compact zone of lime concretion at 0.5-1 m depth. The infiltration rates are therefore high but the storage capacity is low due to shallow depth.

The average annual rainfall in the area is 380 mm with a coefficient of variation of 40-70%. Precipitation is erratic, occurring mostly in the monsoon months of July to September. The annual mean maximum and minimum temperature are

Table 1 *Total monthly bulk precipitation (mm) at Sardar Samand reservoir*

Month	1958-1987 (Mean data)	1988	1989	1990
January	2	–	21	–
February	2	–	–	37
March	4	–	–	4
April	5	5	–	4
May	8	–	–	8
June	39	43	71	69
July	133	227	72	362
August	142	45	140	228
September	70	144	55	106
October	16	–	–	–
November	4	–	–	–
December	2	–	–	–
Total	427	464	359	818

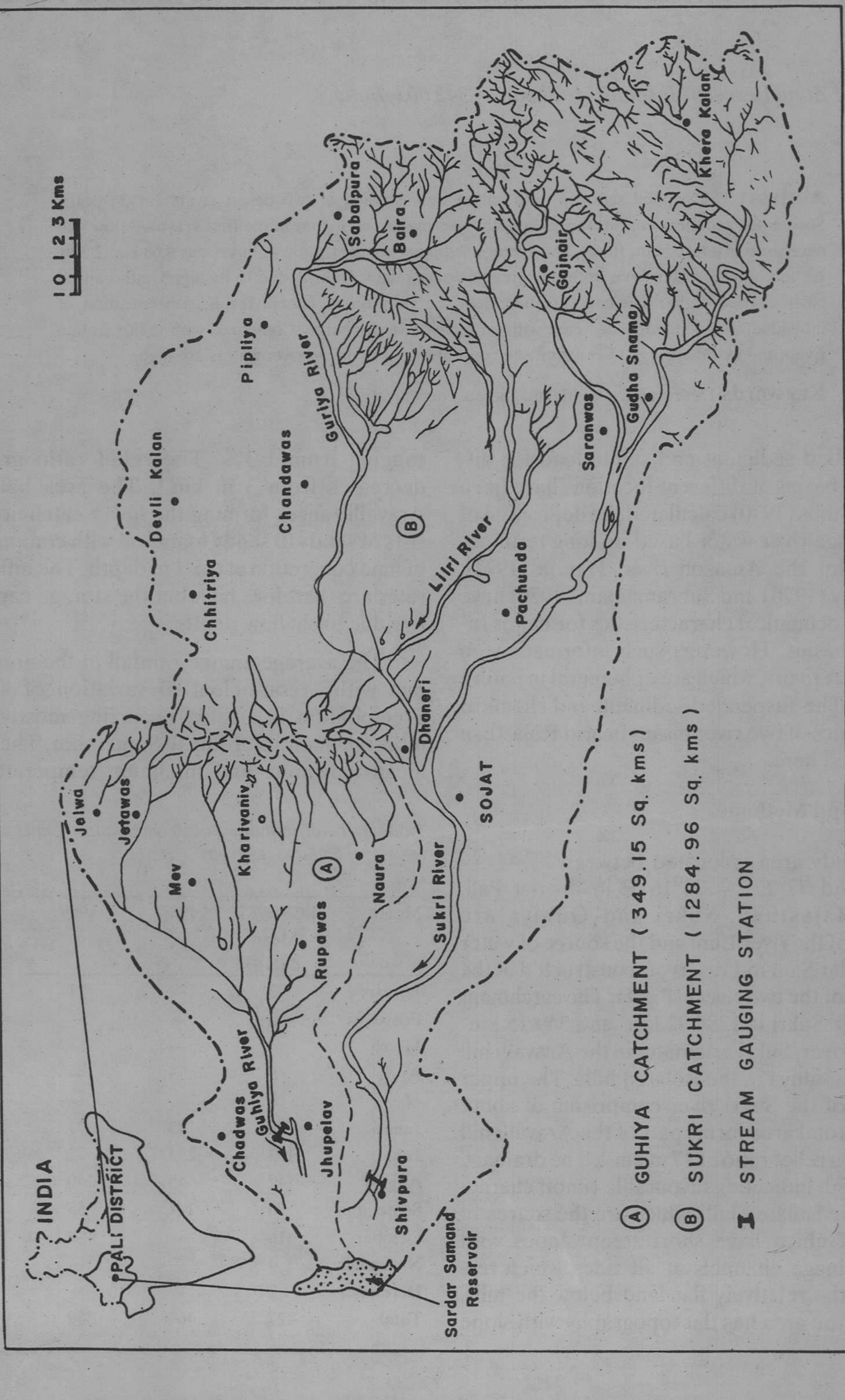

Fig 1 Study area and location of stream gauging stations

44.8°C and 18.7°C, respectively. The average wind speed is 8.9 km h^{-1} and the relative humidity 49%.

At the initiation of the project, rain gauging stations at different locations were established for rainfall data. For the Sardar Samand rain gauging station, mean monthly totals for a 30 year period, the year preceeding the investigation and the period of observation are given in Table 1. Stream gauging stations by installing staff gauge were maintained for stream flow data. For each flow, hourly gauge heights were recorded. For computation of discharge at guaging stations field survey for longitudinal and cross-section before and after the floods were made. The discharge for each flow was worked out by slope-area method.

Water samples for each flow on the rising, peak and falling stages were collected and analysed in the laboratory. Samples were filtered through precombusted Whatman GFC filter pads of normal pore diameter of 0.45 μm in a Millipore filtration unit.

After filtration, the samples were analysed for selected chemical constituents, sodium and potassium were determined by Flame photometer while calcium, magnesium, chloride and bicarbonate were determined titrametrically. Conductivity and pH were measured with Century portable kit model CK 70.

Results and Discussion

Table 2 *Suspended sediment concentration in each flow in the rivers*

River	Station	Flow events	Peak discharge ($m^3 s^{-1}$)	Volume ($10^6 m^3$)	Total suspended matter ($g L^{-1}$)	Sediment rate ($10^3 kg km^{-2}$)	Period
Sukri	Sheopura	1	11.7	0.33	9.90	2.52	June 30–July 1, 1988
		2	91.5	4.72	6.60	24.22	July 11–12, 1988
		3	100.0	6.38	4.00	19.87	July 14–15, 1988
		4	112.0	5.46	2.60	11.05	Aug. 4–6, 1988
		5	115.0	1.21	4.50	4.24	July 2–5, 1989
		6	12.7	0.85	4.40	2.91	July 20–22, 1989
		7	22.5	0.45	3.90	1.32	Aug. 16–17, 1989
		8	20.5	0.46	3.89	1.38	Aug. 26–28, 1989
		9	25.0	0.85	5.10	3.36	July 3–5, 1990
		10	227.0	10.78	1.85	15.51	Aug. 6–8, 1990
Guhiya	Jhupelav	1	16.0	0.19	5.50	2.95	June 28–29, 1988
		2	12.0	0.90	2.32	5.95	July 4–5, 1988
		3	14.0	1.00	1.16	3.32	July 14–15, 1988
		4	35.8	2.45	3.20	15.46	July 13–18, 1989
		5	262.0	25.36	2.50	181.65	Aug. 23–36, 1989
		6	21.0	1.34	1.80	6.92	Aug. 31–Sept. 4, 1989
		7	41.2	7.90	2.29	26.23	July. 3–5, 1990
		8	529.0	51.45	0.54	79.58	Aug. 3–5, 1990
		9	51.5	3.78	1.40	15.48	Sept. 7–8, 1990

Table 3 *Chemincal characteristics of river water*

River	Station	Year	pH	Conductivity dSm^{-1}	Concentration (ppm) Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HC_3^-	TDS
Sukri	Sheopura	1988	8.1	0.636	83.4	34.1	38.2	24.4	113.2	157.0	339
		1989	8.2	0.395	94.0	28.0	43.3	22.3	89.7	133.5	308
		1990	8.0	0.308	63.6	25.8	34.3	19.0	84.3	125.2	280
		Average	8.1	0.446	80.3	29.3	38.6	21.9	95.7	138.6	309
Guhiya	Jhupelav	1988	8.3	0.857	89.4	46.0	50.44	18.5	170.6	202.9	665
		1989	8.4	0.550	105.0	45.8	49.0	16.5	147.5	197.9	495
		1990	8.1	0.443	78.0	44.9	43.0	16.3	130.2	145.1	358
		Average	8.3	0.617	90.8	45.6	47.5	17.1	149.4	182.0	506
Average of the two			8.2	0.539	85.6	37.5	43.1	19.5	122.6	160.3	408
Indian average*			7.7	—	3.7	2.3	23.1	6.3	6.3	90.8	159
World average**			6.1	—	6.3	2.3	15.0	4.1	7.8	58.4	120

* Subramaniam (1977), ** Livingstone (1963)

Sediment concentration

Suspended sediment concentration in both the streams was higher in the first seasonal flow compared with subsequent flows of that season (Table 2). This may be associated with the effect of flushing of fine matrix materials deposited on the rocky surface in the catchment and in the river bed as a result of dust storms during the dry period. In subsequent flows sediment concentration was low due to the exhaustion of the immediate in-channel sediment. Similar observations have beeen reported for moorland areas (Imeson 1974), Negev desert (Yair *et al.* 1980) and Luni basin (Sharma *et al.* 1984). The average sediment concentration was 4.68 L^{-1} in Sukri and 2.30g L^{-1} in Guhiya. The river Sukri which orginates in the Aravalli hill ranges and travels through long alluvial/sandy tract has higher in-channel sediment supply capacity than Guhiya river. Depending upon the total runoff volume for each flow event the sediment rate from the catchment varied from 1.32×10^3 - 24.22×10^3 kg km^{-2} in Sukri and from 2.95×10^3 - 181.65×10^3 kg km^{-2} in Guhiya.

Suspended sediment was also influenced by the discharge in a particular season. Concentration tended to be low with increasing discharge. During the period of observation the lowest concentration value of 1.85 L^{-1} for 227.5 $m^3 s^{-1}$ discharge was recorded in Sukri water, whereas in Guhiya it was 0.54 g L^{-1} for 529.0 $m^3 s^{-1}$. Lower concentration with increasing discharge reflects the dilution affect with water. Gibbs (1967), Pierce *et al.* (1972), Subramaniam and d 'Anglejan(1976) and Bikshamiah (1979) have also reported similar relationships between discharge and sediment concentration for a number of world rivers.

River banks saturated as a result of heavy rainfall and rise in water level, left unsupported by hydrostatic pressure, were observed to collapse as the water level falls. However, the consequent high concentration in the river water short lived and not related to the hydraulic capacity of the flow to entrain sediment. Similar observations have been reported elsewhere (Piest *et al.* 1975, Pickup & Warner 1976).

Chemical characteristics

Water from both the streams was alkaline in nature with pH more than 8 (Table 3). This may be due to the presence of high concentration of chloride and bicarbonate in the river waters. Guhiya contributed higher solute concentration than in Sukri. Average total dissolved solids in Sukri and Guhiya were 309 ppm and 506 ppm, respectively. In general water in two streams were sodium dominated. Concentration of Na, K and Ca were higher in Guhiya than Sukri river water. Magnesium showed a different trend. Higher salt concentration in Guhiya water may be associated with the release of additional salts from its highly

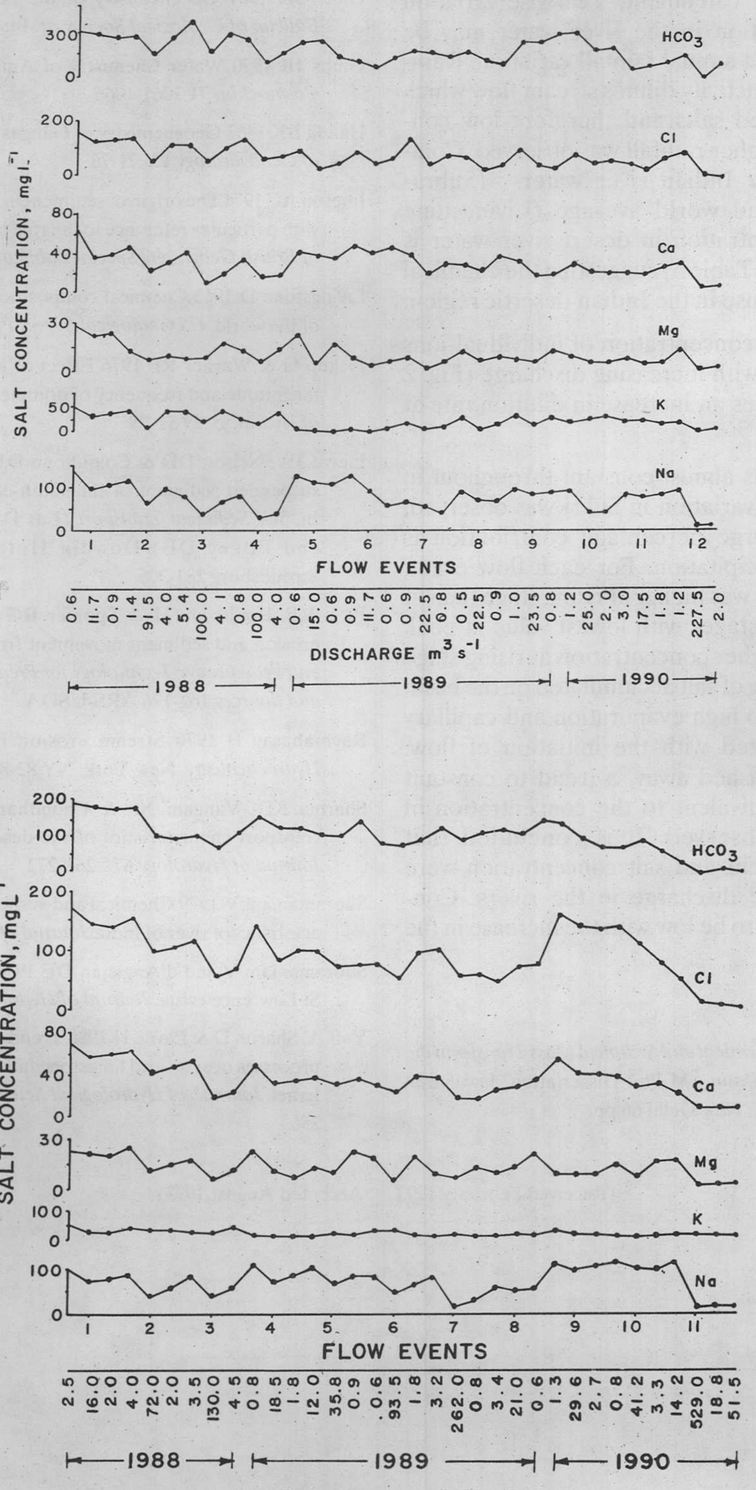

Fig 2 Variation in salt concentration and discharge in (a) river Guhiya at Jhupelav, and (b) river Sukri at Sheopoura

mineralized lower catchment. Yearwise variation in salt concentration in the river water may be associated with the annual rainfall variation. Rainfall with low conductivity dilutes stream flow which is rich in dissolved salts and therefore low concentration with higher rainfall was observed. Compared with major Indian river waters (Subramaniam 1977) and world average (Livingstone 1963), salt concentration in desert river water is significantly high (Table 3) suggesting the chemical weathering is intense in the Indian desertic region.

Except for K concentration of individual-ions tended to be low with increasing discharge (Fig. 2 a & b). This implies an increase in dilution rate at high discharge.

Potassium was almost constant throughout in Guhiya but small variation in Sukri was observed, indicating that large percentage contribution is derived from precipitation. For each flow event, salt concentration was higher at rising stage than at peak and fallling stages with lowest value at peak discharge. The higher concentration at rising stage reflects the flushng of salt accumulated on the basin soil surface due to high evaporation and capillary movement asociated with the initiation of flow. After the salts washed away, a trend to constant concentration equivalent to the concentration in discharge was observed. It is concluded that suspended sediment and salt concentration were influenced by the discharge in the rivers. Concentration tended to be low with the increase in the discharge.

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