Dissolved Loads of Rivers and Surface Water Quantity/Quality Relationships
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Trend analysis of water quality in the Sabarmati River at Ahmedabad for a decade (1969-1978)

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ABSTRACT Seasonal variation of the dissolved chemical constituents in the Sabarmati River and trend analysis of its quality at Ahmedabad, Gujarat State, India, is reported. The quality of river water deteriorates from north to south, with considerable deterioration and remarkable seasonal variation downstream of Ahmedabad. Chemograph responses at Ahmedabad show lag or lead effects with respect to rise in discharge. Comparison of annual cumulative distribution curves of dissolved constituents in the river water at Ahmedabad indicates that there is 75% probability of its remaining below 372 mg l^{-1}.

Analyse des tendances des variations de la qualité de l'eau de la rivière Sabarmati à Ahmedabad pendant une décennie (1969-1978)
RESUME On rend compte dans cette communication des variations saisonnières des constituants chimiques dissouts dans l'eau de la rivière Sabarmati et de l'analyse des tendances des variations de sa qualité à Ahmedabad, état de Gujarat, Inde. La qualité de l'eau de cette rivière se détériore du nord au sud, avec une aggravation de la situation, considérable à l'aval d' Ahmedabad et des variations saisonnières remarquables. Le diagramme des réponses chimiques à Ahmedabad montre un effet de décalage par rapport à la montée des débits. La comparaison des courbes annuelles cumulées de distribution des constituants dissouts dans l'eau de la rivière à Ahmedabad indique qu'il y a une probabilité de 75% pour que leur concentration reste en dessous de 372 mg l^{-1}.

INTRODUCTION

Although concern for water quality has many facets, knowledge of two interrelated factors, viz. the trend of water quality and the relationship of dissolved constituents to river discharge, is especially useful for planning, management and development of river water resources. Statistical analysis of water quality data provides a deeper understanding of processes relevant to the protection of river water from pollution. Cummulative distribution curves may illustrate very effectively the most commonly needed information such as water quality variation characteristics at specific locations during specific time periods, percentage probability that a certain range of quality will occur, and variations in relation to water quality objectives and standards. The author reports here an analysis of water quality data for the Sabarmati River at Ahmedabad using cumulative distribution curves and dissolved constituent responses in relation to discharge.

STUDY AREA AND SAMPLING

The Sabarmati River (Fig.1) in its upper reaches flows through outcrops of Precambrian granites and schists and Cretaceous lava flows and a sandstone-shale complex. A little upstream of Derol, the river acts as the boundary between rock exposures on the eastern bank and Quaternary alluvial deposits on the western bank. Downstream of Galteshwar, the river flows through Quaternary alluvial deposits and drains into the Gulf of Cambay in the south. The study area and the locations from where water quality data were collected are shown in

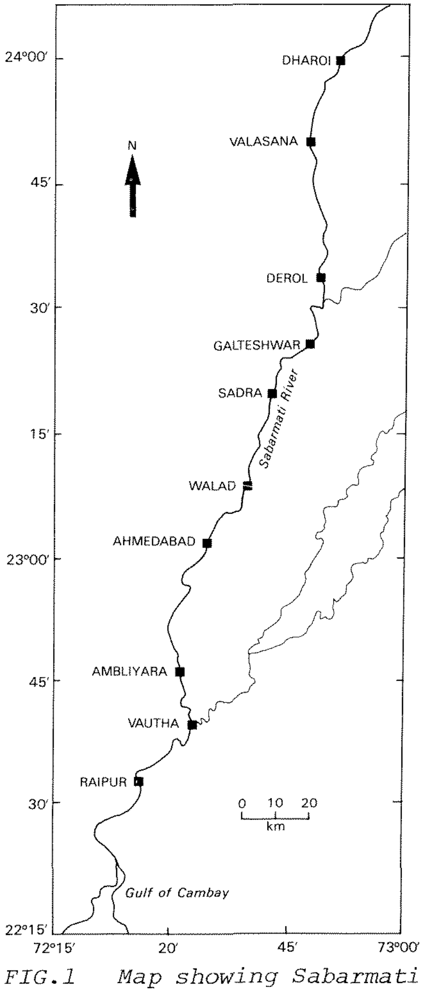

FIG.1 Map showing Sabarmati river water quality stations.

Fig.1. Ahmedabad (23 02'N, 72 36'E) is the centre of industrial, institutional and political activities of the Gujarat State, India. The population of the city, which occupies a metropolitan area of about 310 km^2, has been growing at a very rapid rate during the past few decades. The Sabarmati River, dividing the city in two parts, is used as a source of water supply, bathing, recreation etc. for the community living in the city, and also as a site for waste water disposal following an increase in urbanization and industrialization.

Ten stations were selected on the Sabarmati River in order to obtain general information on the seasonal variation of the water quality along its course. Sampling was undertaken on three occasions (June-July 1975, December 1975, April 1976). Water samples were collected from a point 15-20 cm below the water surface, at mid stream or at some distance from the bank of the river, and were stored in plastic bottles. As far as possible, precautions were taken to collect homogeneous and representative samples. The samples were analysed for electrical conductivity (EC), pH, total dissolved solids (TDS), major anions and major cations, using standard methods of analysis. Electrical conductivity and pH were measured in the field. Precautions were taken to keep the samples in the dark and at low temperatures until they were analysed for major anions and cations. The US Soil Salinity Laboratory system of standards was adopted for interpreting the water quality. For trend analysis of water quality at Ahmedabad, the discharge rate and TDS values were taken from *Hydrology Review* (1975, 1976, 1977, 1978, 1979) and *International Hydrological Decade Newsletter, India* (1972, 1973 and 1974).

RESULTS

It may be seen from Table 1 that there is no remarquable change in the water quality throughout the course of the river during the warmer period of June-July. Between December and April there is a

TABLE 1 Water quality along the course of the Sabarmati River

Station	*Pre-monsoon 1975 June-July*	*Post-monsoon 1975 December*	*Pre-monsoon 1976 April*
Dharoi	C_1S_1	C_2S_1	C_2S_1
Valasna	-	C_2S_1	C_2S_1
Derol	C_1S_1	C_2S_1	C_2S_1
Galteshwar	-	C_2S_1	C_2S_1
Sadara	-	C_2S_1	C_2S_1
Walad	-	C_2S_1	C_2S_1
Ahmedabad	-	C_2S_1	C_3S_1
Ambliyara	C_2S_1	-	C_4S_2
Vautha	C_2S_1	C_3S_1	C_4S_2
Raipur	C_2S_1	C_3S_1	C_4S_2

deterioration in quality from north to south, with a significant increase in EC (>3000 µS cm^{-1}) downstream of Ahmedabad. Although no remarkable seasonal variation in quality is observed in the reach upstream of Ahmedabad to Walad, considerable seasonal variation is apparent downstream. The water becomes highly saline (C_4S_2) in the period from December (post-monsoon) to April (pre-monsoon). It is considered that this trend could be due to effluent discharge from Ahmedabad city.

Since low flow has a capacity to accumulate wastes, TDS concentration tends to rise in baseflow whereas a drop in TDS concentration occurs at times of high flow (Figs 2 and 3). However, there is a lag or lead effect in the drop of TDS concentration after or before a rise in discharge. The work of Glover & Johnson (1974) indicates that due to a difference in the velocities of flood wave and flood water, the trough in solute concentration in water progressively lags behind the peak of water discharge as the flood hydrograph moves downstream. Their results also indicate that the lag effect is greater during smaller events than during higher peak flows due to more favourable conditions for the operation of the kinematic wave effect under the former circumstances. The results of the present study (Table 2) are generally in agreement with the observations of *Glover & Johnson (1974), but there are insufficient data to properly* account for the lead effect during the small events in 1972 and 1974, and the larger event in 1973. Data on water table fluctuations indicate the possibility of groundwater inflow into the river from both banks upstream of Ahmedabad. The gradient in the water level

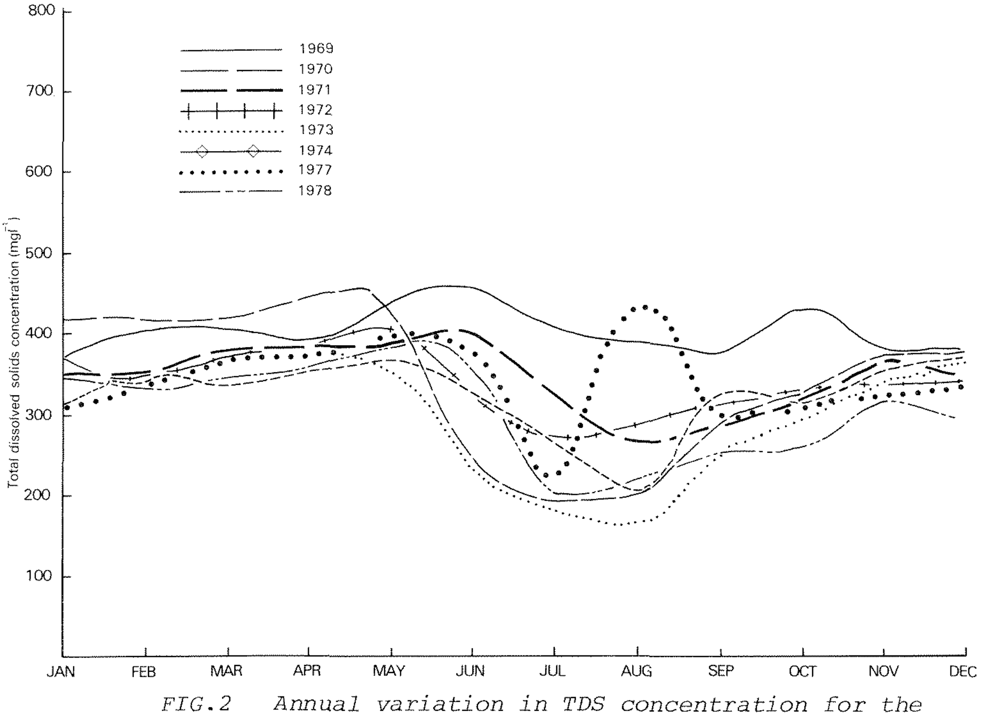

FIG.2 Annual variation in TDS concentration for the Sabarmati River at Ahmedabad.

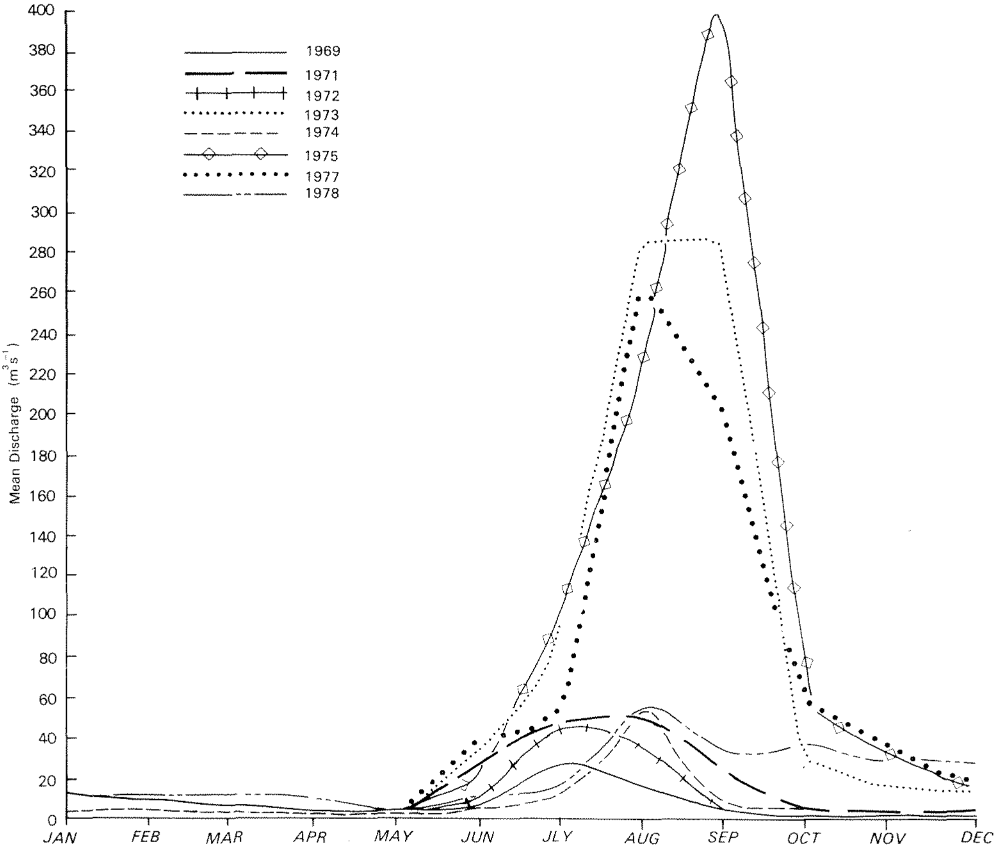

FIG.3 Discharge of the Sabarmati River at Ahmedabad.

TABLE 2 Rainfall and solute response at Ahmedabad

Year	*Rainfall (mm)*	*Solute response*
1969	*465*	*22.5 days lag*
1971	*478*	*30 days lag*
1972	*491*	*3 days lead*
1973	*1046*	*8.5 days lead*
1974	*411*	*13.5 days lead*
1977	*1264*	*15 days lag*
1978	*716*	*15 days lag*

on both sides of the river ranges between 0.4 and 0.6 m km^{-1} towards the river. The effect of aggregation and channel routing may also provide an alternative explanation of these responses and need to be considered when interpreting solute behaviour.

Table 3 and Fig.4 reveal a trend of declining TDS levels in the river in the period from 1969 to 1973, which was followed by a gradual increase in TDS concentrations and deterioration in quality

TABLE 3 A summary of TDS concentration data (mg l^{-1}) for the Sabarmati River at Ahmedabad

Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Number of samples	11	12	12	9	6	11	8	12	12	11
Minimum	365	192	256	258	154	185	141	192	179	185
Maximum	467	461	410	416	368	384	1168	1152	499	384
Average	404.9	344.5	348.8	341.6	252.3	323.7	413.6	424.7	367.9	305.1
Standard deviation	36.1	100.2	45.4	49.4	84.46	55.5	330.4	281.4	76.9	61.4
Percentiles:										
10	365	192	256	258	154	185	141	192	179	185
25	371	205	320	288	192	304	160	211	307	256
50	384	384	352	339	208	336	256	339	333	336
75	416	416	384	371	336	352	336	384	371	352
95	448	448	384	416	368	371	1168	800	403	384

until 1976. A further decline in TDS levels occurred in 1977 and 1978. Comparison of annual cumulative distribution curves (Fig.4) for the Sabarmati River at Ahmedabad during the past decade (1969-1978) indicates that there is a 50% probability of the TDS concentra-

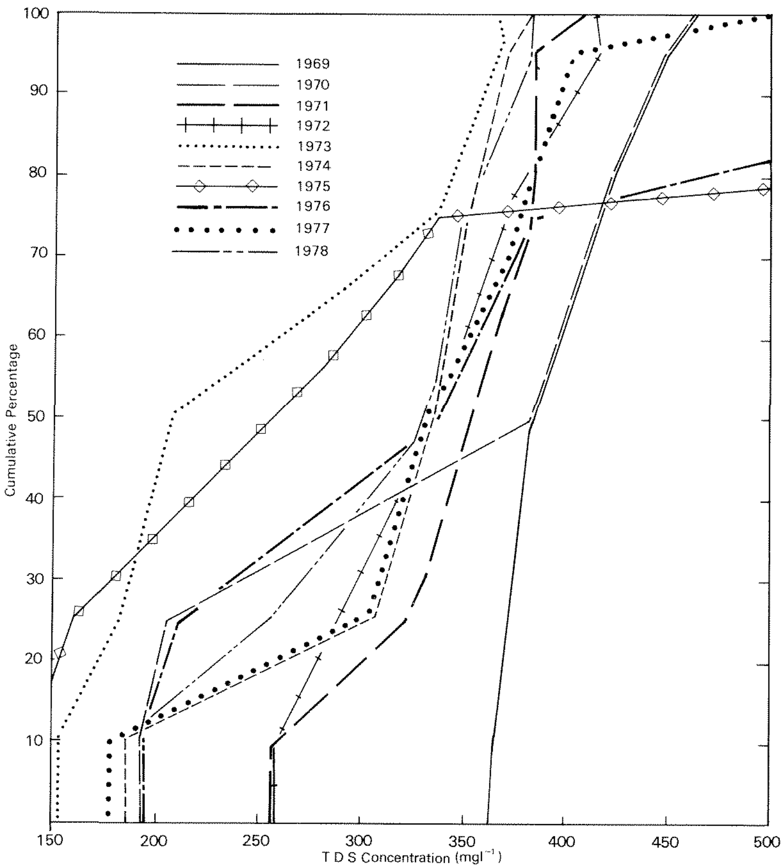

FIG.4 Annual cumulative distribution curves for TDS levels in the Sabarmati River at Ahmedabad.

tion remaining below 327 mg l^{-1} and a 75% probability of its remaining less than 372 mg l^{-1}.

The results of this study, although empirical and site specific, indicate that in trend analysis there is a need to consider the effects of intermixing between river and groundwater, the relationship of dissolved constituents to discharge and the influence of channel routing.

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REFERENCE

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