

## Hydrogeochemical Attributes of the Meltwater Emerging from Gangotri Glacier, Uttaranchal

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**Abstract:** The river at its origin known as “Bhagirathi” attains the title “Ganga” after its confluence with Alaknanda, originates from the snout of Gangotri glacier. Water samples were collected from the selected sites from Gaumukh to Haridwar (2000-2001) for two seasons (pre-monsoon and post-monsoon) and analyzed for various physico-chemical characteristics. The pH, nitrate (NO<sub>3</sub>), conductance, chloride, alkalinity, total hardness, fluoride, sulphate and total dissolved solids were found to be in the ranges of 6.0-7.6, 0.225-10.6 mg/l, 73.0-978 µmhos, 5.0-70.0 mg/l, 15-90 mg/l, 10.0-250.0 mg/l, 0.23-1.60 mg/l, 12.0-150.0 mg/l and 37.0-190.6 mg/l respectively.

**Keywords:** Meltwater, Hydrochemistry, Bhagirathi, Gangotri glacier, Uttaranchal.

### INTRODUCTION

The river at its origin known as “Bhagirathi” originates from the snout of Gangotri glacier known as Gaumukh (4120 m.a.s.l.) located at the northern most end of the glacier (Naithani et al. 2001). Another River Alaknanda originates near the holy shrine of Badrinath and the two rivers join at Devprayag, about 200 km downstream of their origin. The combined stream is then named River Ganga. Global warming has become the universal problem and most part of world is experiencing and suffering from the consequences originated by this problem in one or the other form (Singh and Yadav, 2000; Singh and Mishra, 2001; Williamson and Gribbin, 1991). The Gangotri glacier (Gaumukh) is a place of pilgrimage for times immemorial. This glacier has 258.56 sq km area and is about 30.20 km in length with its width varying from 0.5-2.5 km. It is a valley type glacier, situated in the Uttar Kashi district of Garhwal Himalaya, Uttaranchal and the meltwater flows in the northwest direction. The glacier is bound between 30°43' 22"– 30°55' 49" (lat.) and 79°4'41" – 79°16'34" (long.), the elevation varies from 4120 to 7000 m.a.s.l. (Naithani et al. 2001). A significant and alarming fact is the recession of the Gangotri glacier, 25-30 m/year (Naithani et al. 2001; Mukherjee and Sangewar, 2001; Puri and Shukla, 1996). This has compelled people to fear a snow melt that could not only flood the northern plains but ultimately even make the glacier of great religious and scenic value vanish. The

scientific fact is alarming not only River Ganga but the whole ‘Ganga Basin area’ spread over the north India including U.P. and Bihar, depend on melt flows from Gangotri glacier during summer months. It is of great importance to understand the hydrological processes in the Himalayan uplands, particularly in the Ganga River head water, where the river runoff comprises snowmelt, glacial ice melt and the monsoonal rainfall (Hasnain, 1999). The glacial streams in the Himalayan/Karakoram region generate their runoff through monsoonal rainfall, snow/ice and glacier melting, the processes that control the release of sediments and minerals from the glacier basin. Their impact on surface water chemistry of Alpine region in Himalaya/Karakoram is poorly understood. These glacial meltwater data can be used to identify the pattern of chemical species in the atmosphere and regional fluxes of chemical species related to the biogeochemical cycle (Ahmad and Hasnain, 2000). Adequate understanding of the Himalayan proglacial streams is extremely important for the development of a realistic programme for utilizing the potential of water that exists in the form of snow and ice in the area (Singh and Hasnain, 1998).

### MATERIALS AND METHOD

Surface water samples were collected from the various sites from Gaumukh to Haridwar in River Ganga (Fig.1;

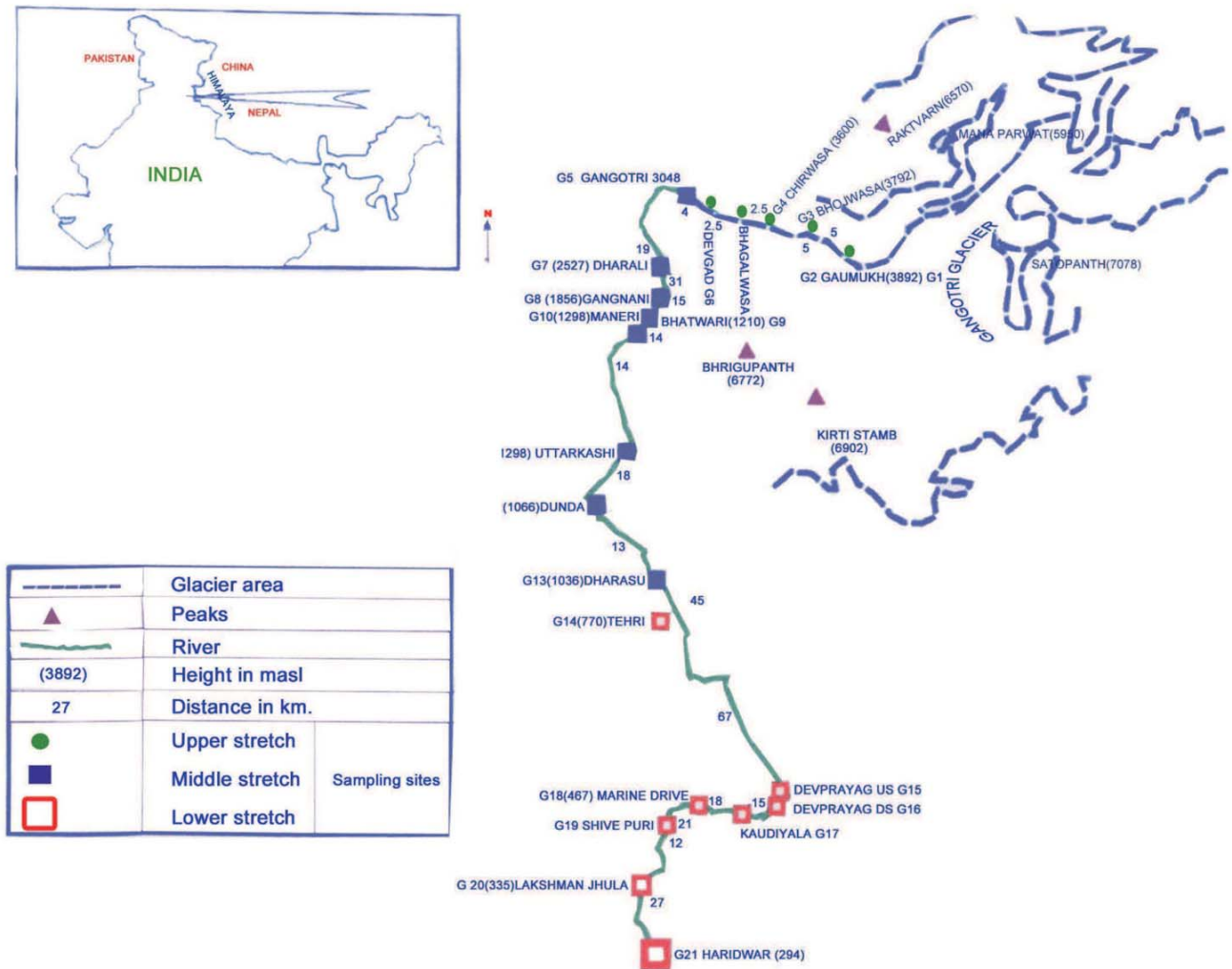


Fig.1. Map exhibiting the study sites from Gaumukh to Haridwar.

G1-S21) in months February, June and September 2000 and June and September 2001 for physico-chemical analysis of water qualities. Sample analysis for the different physico-chemical parameters was carried out as per Standard Methods for the Examination of Water and Wastewater (1998). Sulphate and Chloride were measured by turbidimetric method and argentometric method respectively (APHA, 1998; Pandey et al. 2001). Alkalinity was analysed by titration method and total hardness was calculated by EDTA trimetric method. Nitrate and Fluoride were measured by nitrate electrode method and ion selective electrode method respectively (APHA, 1998).

**SAMPLE COLLECTION**

Samples were collected about 1m away from the bank and at a depth of 0.5 meters in 1L ultra clean high density polyethylene bottles for chemical analysis. Electrical

conductivity (EC), total dissolved solids (TDS) and pH were measured immediately in the field using the portable digital pH meter (Ahmad and Hasnain, 2001; Pandey et al. 2001). In all the cases sampling equipment and plastic containers were cleaned several times first with dilute nitric acid and then soaked in quartz distilled water for 48 hrs. At site the bottles were rinsed with ambient water before transfer and storage of samples.

**TRANSPORTATION AND STORAGE**

All the collected samples were transported to the laboratory and stored at 8-15°C. Samples were handled in a clean room and analytical procedures were carried out under contamination free conditions. The mineral dust grains, if any, were allowed to settle in the bottle and clean supernatant was drawn for chemical analysis (Pandey et al. 2001).

## RESULTS AND DISCUSSION

The annual variations in the level of pH, alkalinity and nitrate ( $\text{NO}_3$ ) of the water collected from various study sites are depicted in Fig. 2; Table 1. pH was found between 6.0 and 7.6 and all samples showing a trend towards the acidic nature. In most of the sites pH was found below 7.0, because of weathering processes in the valley, the major ions in the river waters (Sarin and Krishnaswami, 1984) leach into the surface water and thereby alter the composition of the river water. Moreover, carbon dioxide trapped under ice also turns the water acidic through carbonic acid formation. The other reason could be the lack of photosynthetic activity in the surface water streams, because of the continuous free flow of river water. Besides, in early spring, the increased sulphate and nitrate concentrations in the early meltwater fraction input into a stream can drop the pH of stream water, which may be harmful for the aquatic life (Reuss and Johanson, 1986; Ahmad and Hasnain, 2001). Sulphate and nitrate meltwater pulses have been reported in North America and Europe (Bales, 1992). Conductivity was found to be comparable, ranging from 73.0-978 m mhos (Fig.3; Table 2). Chloride was not showing significant fluctuations and has been found ranging from 5.0-70.0 mg/l (Fig. 3; Table-2). Alkalinity values on all the sites were ranging between 15-90 mg/l (Fig.2; table-1). Total hardness was found varying between 10 and 250 mg/l (Fig.3; Table ). Nitrate ( $\text{NO}_3$ ) was observed ranging from 0.225-10.6 mg/l from all the sites indicating palatability of water. Mean concentration of Fluoride was found normally within the range of 0.23-1.4 mg/l (Fig.4; Table 3). Mean Sulphate concentration was varying between 12.0 and 150.0 mg/l (Fig 4; Table 3) and it didn't show significant elevations. The concentration of total dissolved solids was ranging between 37 and 190 mg/l (Fig.4; table-3) reinforcing that the seasonal and spatial variations in TDS are attributed to climatic and lithological control over the ionic concentrations (Singh and Hasnain, 1998).

The geology of Gangotri glacier comprises tourmaline rich granite, mica schist, sericite schist, phyllite, quartzite and traces of sulphide minerals (Bhatt, 1963; Ahmad and Hasnain, 2000), has influenced the hydrogeochemical attributes of river water significantly by the weathering processes in the drainage basin. In addition, atmospheric supply (from marine, terrestrial and anthropogenic sources) of chemical constituents also contributes to the major ion concentration of river waters (Sarin et al. 1992; Pandey et al. 2001). The rapid snow melting processes and rainfall over glaciers may affect the chemistry of surface water in the Himalayan/Karakoram region very significantly (Ahmad

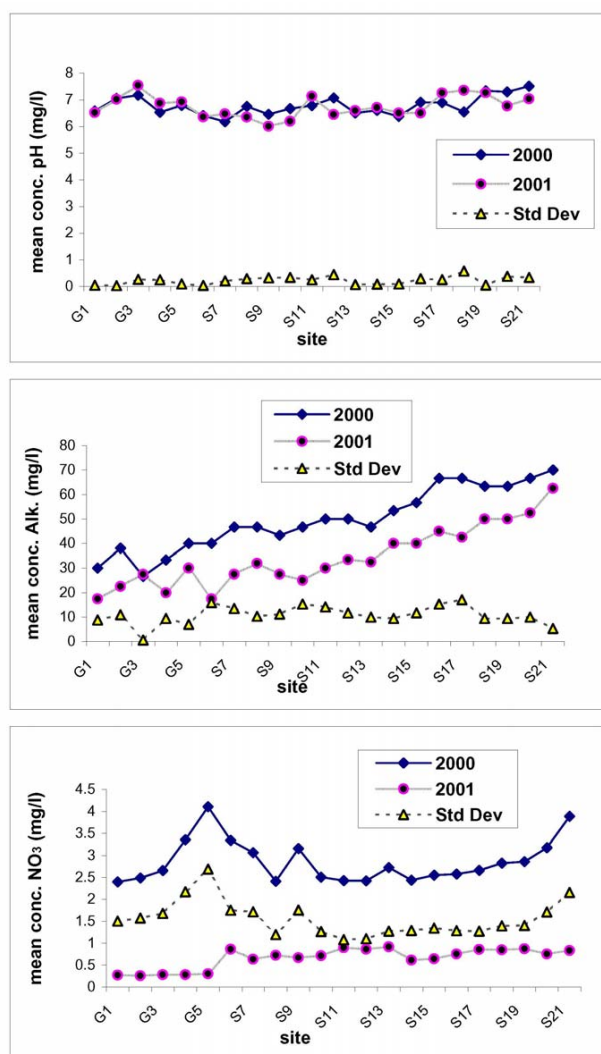


Fig.2. Annual mean concentration of pH, alkalinity and nitrate.

and Hasnain, 2001). During collection significant amount of discharge was observed, that resulted from snow/glacier melting in the Himalaya especially during the month of May-June, facilitating the pre-monsoonal analysis. The study of major ions and trace metals in snow and old ice from the Himalaya also has a special significance, as the snow/ice melt water streams feed the north Indian rivers and surface water reservoirs during the lean period (Nijampurkar et al. 1993).

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**Table 1.** pH, alkalinity and nitrate

Sites	pH					Alkalinity					Nitrate				
	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01
G1	6.52	6.5	6.71	6.5	6.54	30	40	20	15	20	0.682	0.412	6.1	0.268	0.275
G2	7.04	7	7.12	6.73	7.31	40	54	20	20	25	0.721	0.524	6.22	0.252	0.265
G3	7.02	7.51	7	7.59	7.5	30	20	30	25	30	0.638	0.617	6.72	0.274	0.29
G4	6.51	6.05	7.04	6.63	7.12	40	20	40	20	20	0.683	0.651	8.74	0.256	0.309
G5	6.67	6.5	7.21	6.85	7	50	40	30	30	30	0.872	0.858	10.6	0.312	0.298
S6	6.5	6.54	6.18	6.54	6.18	50	30	40	20	15	0.644	0.479	8.91	1.32	0.411
S7	6.53	6	6	6.71	6.23	50	40	50	25	30	0.701	0.418	8.08	0.939	0.329
S8	7.14	6.73	6.39	6.51	6.19	50	40	50	30	34	0.665	0.458	6.12	1.18	0.27
S9	6.74	6.5	6.13	6.02	6	50	40	40	25	30	0.676	0.432	8.37	0.917	0.422
S10	7.32	6.59	6.1	6.34	6.06	60	30	50	25	25	0.676	0.443	6.4	1.11	0.319
S11	7.13	6.51	6.71	7.23	7.04	60	40	50	30	30	0.626	0.475	6.18	1.43	0.365
S12	6.57	7.12	7.53	6.19	6.71	70	40	40	32	35	0.679	0.531	6.06	1.44	0.29
S13	6.5	6.61	6.41	6.52	6.68	60	40	40	25	40	0.631	0.624	6.92	1.41	0.425
S14	7.02	6.5	6.28	6.78	6.64	70	40	50	25	55	0.548	0.533	6.23	0.921	0.307
S15	6.63	6.5	6	6.51	6.5	80	40	50	30	50	0.551	0.587	6.52	1.07	0.225
S16	7	6.71	7	6.5	6.51	70	70	60	40	50	0.557	0.57	6.6	1.09	0.421
S17	6.53	7	7.16	7.51	7	60	80	60	40	45	0.611	0.651	6.73	1.29	0.43
S18	6.5	6.62	6.51	7.5	7.21	70	60	60	50	50	0.571	0.485	7.42	1.26	0.442
S19	7.12	7.24	7.66	7	7.53	70	50	70	50	50	0.569	0.54	7.48	1.26	0.49
S20	7	7.37	7.52	6.53	7	80	60	60	50	55	0.763	0.661	8.11	1.06	0.451
S21	7.67	7.36	7.5	6.5	7.57	90	50	70	50	75	0.751	0.614	10.3	1.16	0.505

**Table 2.** Hardness, chloride and conductance

Sites	Total Hardness					Chloride					Conductance				
	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01
G1	60	40	10	30	40	15	35	15	10	45	196	181	106	92	73
G2	80	60	80	50	100	15	45	30	10	35	212	146	172	98	311
G3	60	30	50	60	150	15	35	45	10	30	192.3	216	212	102	281
G4	50	20	40	60	50	12.5	45	35	25	25	126	122	121	107	103
G5	70	60	60	50	50	10	45	15	30	25	168.1	112	106	92	84
S6	90	10	250	40	100	5	30	12.5	20	25	166.1	84	124	96	111
S7	80	20	150	70	50	10	40	15	15	30	161.5	106	132	103	113
S8	60	20	10	100	30	5	25	30	75	35	122.7	104	307	146	312
S9	60	22	10	50	40	10	25	15	15	25	152.3	105	152	107	212
S10	70	32	18	50	50	10	20	15	15	25	155.2	100	118	79	108
S11	80	30	25	60	80	15	25	15	20	40	156.3	96	115	133	164
S12	100	20	20	60	80	5	30	12.5	30	30	186.8	108	115	381	147
S13	80	30	20	100	100	5	25	10	20	35	155.2	101	115	111	241
S14	70	30	20	70	40	5	20	12.5	10	35	153.3	102	113	104	155
S15	90	40	25	70	80	5	20	12.5	15	30	169.5	103	113	144	174
S16	80	70	20	60	50	5	20	12.5	15	30	162.1	153	129	136	142
S17	90	80	21	80	80	5	25	15	10	45	165.7	195	128	232	182
S18	80	60	31	70	40	5	25	15	15	40	166.4	161	131	134	168
S19	70	60	47	60	50	5	20	12.5	20	35	175.9	143	155	150	175
S20	130	60	40	90	100	5	25	10	30	40	228	159	154	136	162
S21	120	60	60	100	40	5	25	15	40	30	230	150	178	152	191

**Table 3.** TDS, sulphate and fluoride

Sites	Total Dissolved Solid					Sulphate					Fluoride				
	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01	Feb-00	Jun-00	Sep-00	Jun-01	Oct-01
G1	58	46	98	46.8	37	45.5	41	49	55	45	1.12	1.31	1.18	1.29	1.36
G2	92	49	102	140	160	32	30.5	51.5	52	48.4	0.89	1.21	1.1	0.79	0.37
G3	112	62	72	155	145	37.5	43	38	49.5	39	1.16	1.44	0.82	0.62	0.38
G4	52	111	68	48.2	52	22.5	24.8	21	47	37.5	0.82	0.751	1.45	0.82	0.41
G5	58	42	65	42.4	43	120	47	22.5	48	50	0.46	0.597	1.29	0.71	0.75
S6	65	79	72	69	71	65	25	52.5	50.5	60	1.09	0.576	1.19	1.17	0.48
S7	72	52	64	51.9	73	54.5	30.5	50.5	49	65	1.02	0.56	0.933	0.74	0.38
S8	67	53	67	73	83	21	24.5	43	69	56.5	0.616	0.579	0.901	0.8	0.36
S9	83	91	78	103.5	91	45	25	37	48	65	0.59	0.54	1.09	0.84	0.46
S10	72	85	60	99.3	85.2	48.5	24.5	28	53	48	0.611	0.516	0.843	0.72	0.48
S11	49	49	58	66.7	68.4	45.5	18.5	22.5	63.5	72.5	0.52	0.482	0.821	0.78	0.38
S12	53	55	58	190.6	73	35.5	19.5	21.5	29	37	0.535	0.444	0.814	1.6	0.33
S13	45	52	58	55.5	98	32	19.4	28	150	135.5	0.52	0.431	0.768	0.93	0.36
S14	48	52	57	52.4	83.2	31	17	17	26	32	0.467	0.415	0.756	0.88	0.43
S15	89	52	57	72	90	25.5	16.5	15.5	32	40.5	0.478	0.423	0.745	0.78	0.39
S16	63	78	66	68.1	73.4	31.5	13	12	34	37	0.355	0.381	0.719	0.6	0.31
S17	72	100	65	116.3	65	27	15	12.5	40.5	38.5	0.45	0.373	0.67	0.4	0.28
S18	37	83	67	67.4	52	31.2	18	16.5	48	27	0.363	0.377	0.658	0.32	0.26
S19	48	76	80	75.1	94	38	20	15	52	22	0.371	0.389	0.628	0.31	0.24
S20	53	81	78	68.4	83	55.2	20.5	25.5	63.5	21.5	0.334	0.37	0.628	0.4	0.27
S21	86	77	91	76.1	98	68	18.5	23	69	23.5	0.341	0.359	0.59	0.31	0.23

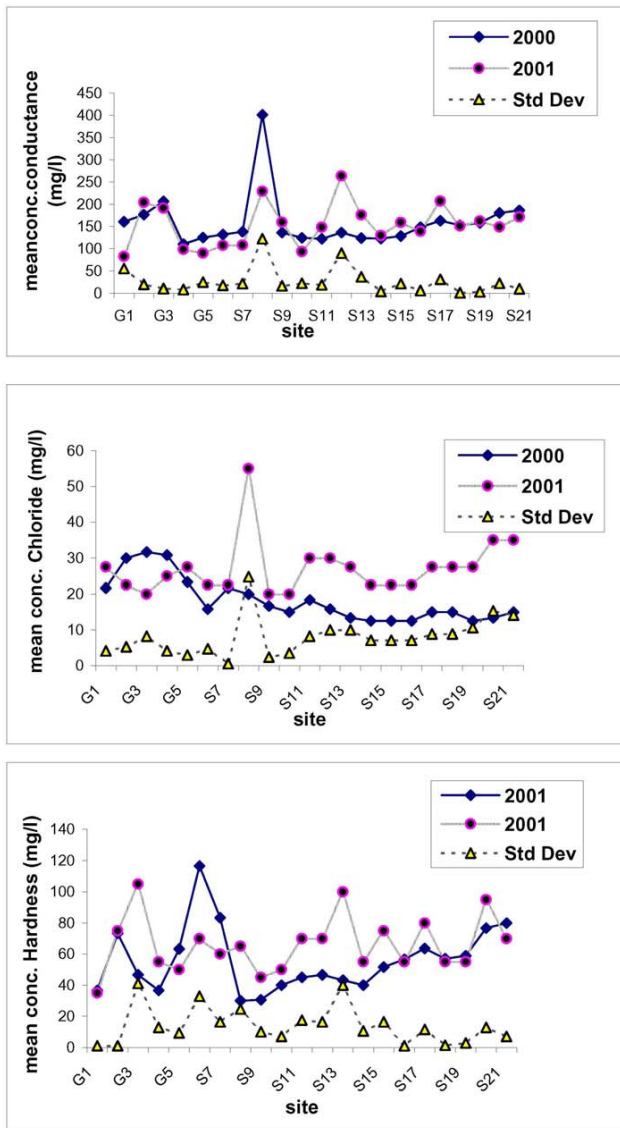


Fig.3. Annual mean concentration of hardness, chloride and conductance

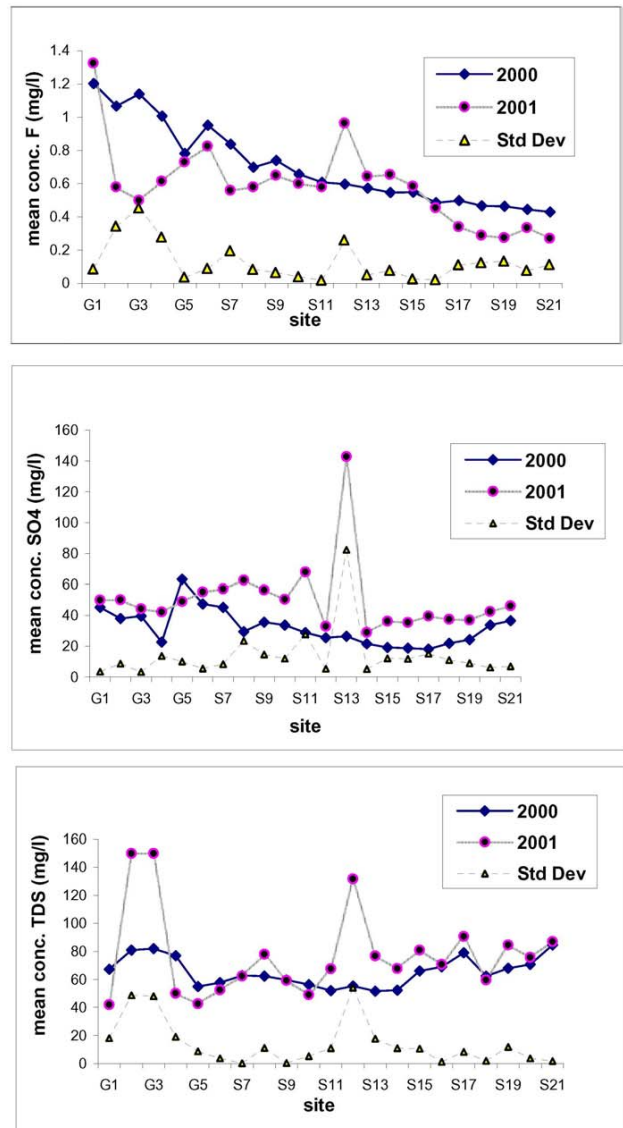


Fig.4. Annual mean concentration of TDS, sulphate and fluoride.

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