Limnological Study of River Soan (Punjab), Pakistan

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Summary

River Soan is one of the important aquatic systems of the Punjab province in Pakistan and flows into Indus River near Kalla Bagh (District Mianwali). In order to measure the quality of water and to evaluate planktonic community, an integrated monitoring system was applied from May to December 2001. During the study period total of 202 genera were observed of which 134 were of phytoplankton present in various phylums including *Cyanophyta* (22), *Cyarophyta* (7), *Xanthophyta* (5), *Bacillariophyta* (22), *Euglenophyta* (5), *Chlorophyta* (62), *Chrysophyta* (8), *Pyrrophyta* (1) and *Cphryrotophyta* (2). 53 genera of zooplankton were observed including *Protozoa* (33), *Rotifera* (8), *Cladocera* (7), *Copepoda* (4) and *Aquatic insecta* (1). In addition to phyto and zooplankton 3 genera of *Charophyta* and 11 genera of *Macrophyta* were observed. Diversity index of phytoplankton ranged from 4.6 to 13.5 and of zooplankton from 1.94 to 5.90. Water samples were collected on monthly basis for estimation of various physical and chemical water quality parameters i.e., water temperature (9-31 ^{0}C), light penetration (1.2-22.3 cm), viscosity (0.8570-1.0572 mNS m^{-2}), conductivity (7-19 mv), surface tension (69.28-72.63 dynes cm^{-1}), density (0.980-1.022 mg l^{-1}), specific gravity (0.796-1.025), boiling point (95-98 ^{0}C), turbidity (0.02-0.48 mg l^{-1}), pH (8-9), dissolved oxygen (4.6-9.3 mg l^{-1}), alkalinity (19-36 mg l^{-1}), acidity 1.0-1.8 mg l^{-1}), carbonates (0), bicarbonates (19-36 mg l^{-1}), total solids (0.56-4.24 mg l^{-1}), total dissolved solids (0.53-4.83) and total dissolved volatile solids (0.05-0.29). Among elements, sodium (22.50-168.75 ppm), potassium (3.94-12.31 ppm), calcium (2.75-34.25 ppm), strontium (0.00-0.47 ppm), magnesium (0.00 ppm) and zinc (0.00 ppm) were detected through atomic absorption while seasonal variation in planktonic diversity was analyzed by calculating the frequency of occurrence, relative abundance and diversity index of planktonic life. The overall water quality of the study site remained within safe limits throughout the study period.

Key words

physical and chemical parameters; element concentration; plankton diversity; seasonal variation; Soan river; Pakistan

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Introduction

Rivers are important pathways for the flow of energy, matter and organisms through the landscape. A wide range of human activities at the catchments areas may lead to environmental deterioration of river waters (Kagalou et. al., 2002). However, the assessment of the changes in river communities as the result of the impact of pollution is particularly interesting issue within the frame work of aquatic ecology, since running waters are becoming increasingly affected by anthropogenic discharge (Whitton et. al., 1991)

Water quality deals with the physical, chemical and biological characteristics in relation to all other hydrological properties. Any characteristic of water in production systems that effects survival, reproduction, growth and production of aquaculture species, influences management decisions, causes environmental impact or reduces product quality and safety which can be considered a water quality variable. With other factors being

equal, aquaculture species will be healthier, production more efficient, with less environmental impact and quality better in culture systems with "good" water quality than in those with "poor" water quality (Chhatawal, 1998).

Water quality provides current information on concentration of various parameters at a given place and time. Water quality principles furnish the basis for judging the suitability of water for its designated uses and for improving existing conditions. For optimum development and management of water for the beneficial uses, current information is needed which is provided by water quality programmes (Lloyd, 1992). The unequal distribution of water on the surface of earth and fast declining availability of useable fresh water are the major concerns in terms of water quantity and quality (Boyd, 1998).

Pakistan river systems present interesting features for aquatic organisms including an extended summer period of dryness, land use practices and intense human activities influencing river water quality (Papastergiadou and Babalonas, 1993). Knowledge of specific relationship between particular organisms and environmental factors enables a quick and fairly reliable evaluation of the essential features of a given biotope. Therefore, there is an increasing interest in the utilization of indicative value of various biota in numerous fields of human activities (Fytianos et. al., 2001). In Pakistan, most studies have focused on the abiotic environment and very few have examined the biotic features of the water systems or have attempted to objectively identify those environmental variables influencing species distribution and community structure (Lazaridou et. al., 1999).

Soan is a seasonal river of Punjab. It originates from Murree hills, passes near Rawalpindi, Fateh Jung, Pindi Ghab, Talagang, Mianwali and finally falls in Indus River near Kalla Bagh. Water of Soan is used for drinking and irrigation in Potohar region of Punjab (Iqbal et. al., 2004).

Soan is an important river of Potohar region and Soan water is used for drinking, irrigation and recreation purposes in this region. The ecology of river Soan is threatened because of several factors.

- Sewage waste contaminates water especially near Rawalpindi making it a drainage canal.
- At some places industrial affluent enters the river causing water pollution.
- Lahore-Islamabad Motorway passes over the river at several spots. This motorway is a new source of industry and urbanization in these regions which could possibly pollute the river.
- A new Motorway, from Islamabad to Muzaffarabad, is in the process of construction and some bridges will be constructed over river Soan.
- Construction of small dams is also in process at various spots on this river.

The continuous monitoring of river's water quality is very essential to determine the state of pollution in our rivers. This information is important to communicate to general public and the Government in order to develop the policies for the conservation of the most important natural fresh water resources (Ali et al., 2000).

In the present study, an attempt was made to estimate the water quality of Soan River using physical and chemical parameters, phyto and zooplankton and concentration of elements in river water. The river was chosen because it is a seasonal river in Potohar region in Punjab province and water quality of this river has not been studied so far.

Materials and methods

In the present study, seasonal and temporal variations in physical and chemical parameters, element concentration and planktonic diversity of River Soan were studied at Dhoak Pathan Bridge nearly 25 km from Talagang (Chakwal). The sampling started from May 2001 and continued up to December 2001. The study period consisted of eight months. The samples were taken in one liter plastic bottles from 0.5 m below the water surface on monthly basis.

Physical and chemical parameters

At the time of sampling, water temperature was recorded by using alcohol and digital thermometers. Light penetration was recorded with the Secchi's disk. Dissolved oxygen was determined by using an oxygen meter (Jenway Model 9071). pH and conductivity were determined by using digital pH and conductivity meter (Model WTW-pH 90). While all other water quality parameters i.e., viscosity, conductivity, surface tension, density, specific gravity, boiling point, turbidity, pH, dissolved oxygen, alkalinity, acidity, carbonates, bicarbonates, total solids, total dissolved solids and total dissolved volatile solids, were determined by the methods as described by Boyd (1998). These parameters were compared with standard water quality indicators to indicate probable pollution in the river water.

Element concentrations

Six elements (sodium, potassium, magnesium, calcium, strontium and zinc) were analyzed in Soan water during the study period on monthly basis. Atomic Absorption Spectrophotometer and absorbance measurements and computation were made following Iqbal et al., (2004a), Stalikas et. al., (1994) and Ansari and Iqbal (1993).

Plankton diversity

The plankton (phyto and zoo), charophyta and macrophyta samples were taken in one liter plastic bottles, preserved in 4% formalin and were observed under BH-2 research microscope (Nikon) by using 40 and 100X objectives. The identification of plankton was done following Ward (1959), Prescott (1978) and Battish (1992). Diversity index of plankton was calculated by using following formula:

Diversity index = S – 1/ log n N

where:

S = Total number of phyto/zoo plankton genera observed
N = Total number of phyto/zoo plankton observed
Log n = Natural Log

Results

Physical and chemical parameters

The overall range in air temperature observed was 18-38°C while the water temperature was minimum (12°C) in November and maximum (31°C) in May. The lowest light penetration was observed in May and July (1.2 cm) and the highest value was observed in December (20.9 cm). The maximum boiling point (98°C) was observed in September and December and minimum (95°C) in October. Clouds were 25% in the month of October, 50% in August while the clouds were totally absent in all other months during sampling dates. Rain was not observed through out the study period during the sampling dates. Maximum density (1.022 gm l^{-1}) was observed in the month of June while the minimum value was observed in July (0.992 gm l^{-1}). The maximum specific gravity (1.025) was observed in June and minimum (0.796) in September. The minimum turbidity (0.02 mg l^{-1}) was observed in December while maximum (0.48 mg l^{-1}) in July indicating flooding and raining in this month. The lowest viscosity (0.9126 mNS m^{-2}) was observed in December and maximum viscosity (1.0572 mNS m^{-2}) was observed in June. The minimum value of surface tension (69.36 dynes cm^{-1}) was observed in November while maximum (72.63 dynes cm^{-1}) in May.

The monthly variation in pH ranged from 8.0 to 9.0. The maximum value (9.0) was observed in August and minimum value (8.0) in months of June, July, September, October and November. The maximum electric conductivity (19 mv) was observed in June and minimum (7 mv) in August. The maximum dissolved oxygen (9.3 mg l^{-1}) was observed in December and minimum value (6.1 mg l^{-1}) in June. The maximum alkalinity (32.4 mg l^{-1}) was observed in June while minimum value (19 mg l^{-1}) was observed in August. The maximum acidity (2 mg l^{-1}) was observed in July while the minimum value (1mg l^{-1}) was observed in May and September. The carbonates in Soan River were below detectable limits. The maximum bicarbonates (32.4 mg l^{-1}) were observed in June while minimum value (19 mg l^{-1}) was observed in August. The maximum total solids (4.24 mg l^{-1}) were observed in June while minimum value (0.56 mg l^{-1}) was observed in September. The maximum total dissolved solids (TDS) were observed (4.83 mg l^{-1}) in June and minimum (0.53 mg l^{-1}) in October. The maximum total volatile solids (TVS) (0.29 mg l^{-1}) were observed in June and minimum (0.05 mg l^{-1}) in November (Table 1).

Element concentration

The synopsis of the element concentration is given in Table 2. Zinc and magnesium concentrations were very low in all the water samples and were below the detection limit.

The maximum sodium concentration (168.75 ppm) was observed in May and minimum (22.50 ppm) in July. The maximum value of potassium concentration (12.31 ppm) was observed in December and minimum (3.94 ppm) in August. The calcium concentration ranged between 2.75 to 34.25 ppm during the study period. The maximum concentration (34.25 ppm) was observed in May and minimum concentration (2.75 ppm) in September.

Strontium was not detected in May and September but it showed seasonal variation in other months of study period. The maximum strontium concentration (0.47 ppm) was observed in November and minimum (0.04 ppm) in June.

Table 1.
Seasonal variation of physical and chemical properties of river Soan at Dhoak Pathan Bridge from May to December 2001

Parameters	May	June	July	Aug	Sep	Oct	Nov	Dec
Water Temperature (^{0}C)	31.0	29.5	26.5	29.9	24.0	20.0	12.0	9.0
Conductivity (mv)	9	19	11	7	9	13	10	18
PH	8.2	8.0	8.0	9.0	8.0	8.0	8.0	8.5
Dissolved O_2 (mg l^{-1})	6.7	6.1	6.8	6.9	7.4	8.1	8.6	9.3
Turbidity (mg l^{-1})	0.05	0.41	0.48	0.03	0.05	0.03	0.03	0.02
Alkalinity (mg l^{-1})	29.6	32.4	22.4	19.0	19.4	20.6	31.6	25.8
Acidity (mg l^{-1})	1.0	1.5	2.0	1.1	1.0	1.8	1.2	1.5
Viscosity (mNS m^{-2})	0.9358	1.0572	0.9774	0.9813	0.9578	0.9823	0.9506	0.9126
Density (mg l^{-1})	0.980	1.022	0.992	0.996	0.994	0.997	0.996	0.988
Specfic gravity	0.983	1.025	0.995	0.999	0.796	0.999	0.999	0.990
Light penetration (cm)	1.2	2.4	1.2	1.4	7.3	11.2	20.2	20.9
Boiling point (^{0}C)	96	97	96	97	98	95	97	98
Surface tension (dynes cm^{-1})	72.63	71.37	71.02	70.78	71.23	70.00	69.35	71.35
Rain	0	0	0	0	0	0	0	0
Clouds %	0	0	0	50	0	25	0	0
Carbonates (mg l^{-1})	0	0	0	0	0	0	0	0
Bicarbonates (mg l^{-1})	29.6	32.4	22.4	19.0	19.4	20.6	31.6	25.8
Total solids (mg l^{-1})	0.83	4.24	2.24	1.11	0.56	0.62	0.67	0.78
TDS (mg l^{-1})	0.81	4.83	0.90	0.55	0.58	0.53	0.63	0.71
TVS (mg l^{-1})	0.14	0.29	0.02	0.14	0.06	0.09	0.05	0.07

Table 2.
Relationship between season and inorganic element concentration of river Soan at Dhoak Pathan Bridge from May to December 2001

Sample #	Months	Zn (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	Sr (ppm)
1	May	0.0	0.0	168.75	4.69	34.25	0.00
2	June	0.0	0.0	44.50	4.71	11.25	0.04
3	July	0.0	0.0	22.50	4.75	4.50	0.34
4	August	0.0	0.0	44.00	3.94	12.50	0.22
5	September	0.0	0.0	38.50	8.56	2.75	0.00
6	October	0.0	0.0	54.50	10.69	4.25	0.37
7	November	0.0	0.0	51.25	10.81	17.00	0.47
8	December	0.0	0.0	72.50	12.31	6.25	0.44
Mean		0.0	0.0	62.06	7.56	11.59	0.23
Std. Dev		0.0	0.0	45.38	3.40	10.38	0.19
Range		0.0	0.0	22.50-168.75	3.94-12.31	2.75-34.25	0.00-0.47

Table 3.
Diversity index of phyto and zooplankton of river Soan at Dhoak Pathan Bridge from May to December 2001

Sample #	Month	Number of genera (S)	Diversity index = S-1/ ln N	Sample #	Month	Number of genera (S)	Diversity index = S-1/ ln N
Phytoplankton				Zooplankton			
1	May	42	7.33	1	May	14	3.79
2	June	22	4.60	2	June	7	1.94
3	July	28	5.35	3	July	7	2.16
4	August	65	12.09	4	August	17	4.21
5	September	76	12.93	5	September	28	5.90
6	October	82	13.5	6	October	16	3.87
7	November	55	9.62	7	November	19	4.73
8	December	51	8.69	8	December	17	3.53

Plankton diversity

During the study period 134 genera of phytoplankton and 54 genera of zooplankton were observed (Table 4-5). Among phytoplankton genera Chlorophyta (62), Cyanophyta (22), Bacillariophyta (22), Chrysophyta (8), Cyarophyta (7), Macrophyta (11), Xanthophyta (5), Euglenophyta (5), Charophyta (3), Pyrrophyta (1) and Cphryrotophyta (2) were more common. 53 genera of zooplankton consist of Protozoa (33), Rotifera (8), Cladocera (7), Copepoda (4) and Aquatic insecta (I). In addition to phytoplankton 11 genera of macrophyta and 3 genera of charophyta were also observed (Table 6).

Among phyto planktonic genus, Cyanophyta, Chlorophyta and Chrysophyta were observed throughout the study period. The members of Euglenophyta were present in all the months except May. In June Bacillariophyta and Xanthophyta genuses were not observed. The members of Charophyta and Macrophyta were not found in May, June and July while Cryptophytans were only observed in September.

Among zooplankton, Protozoa were most common and were present throughout the study period. Copepoda were present only in September and December while Cladocera were present throughout the research period except in June and July while Rotifera were not observed in July and December. Crustacea were only found in May while Aquatic insecta only in November.

Diversity index of phytoplankton ranged from 4.60 to 13.50 during the study period. It was maximum in October (13.50) and minimum (4.60) in June. Diversity index showed a decreasing trend from May to July and then an increase reaching its maximum value in October and then again a decrease till end of study period. Diversity index of zooplankton ranged from 1.94 to 5.90. Its maximum value (5.90) was observed in September while minimum value (1.94) was observed in June. Diversity index showed an increasing trend from June to November and then it decreased in December (Table 3).

Table: 4.
Relative abundance (%) of phytoplankton in all samples

Name of Genera	Name of phylum /division	R.A (%) of genera	R.A (%) of phylum /division
Microcystis sp.	Cyanophyta	2.91	5.13
Dactylococcopsis sp.	Cyanophyta	0.60	5.13
Merismopedia sp.	Cyanophyta	0.80	5.13
Gloeocapsa sp.	Cyanophyta	0.12	5.13
Sorastrum sp.	Cyanophyta	0.16	5.13
Lyngbya sp.	Cyanophyta	0.41	5.13
Phormidium sp.	Cyanophyta	0.94	5.13
Microchaete sp.	Cyanophyta	0.57	5.13
Xenococcus sp.	Cyanophyta	1.23	5.13
Pleurocapsa sp.	Cyanophyta	1.43	5.13
Gloeotrichia sp.	Cyanophyta	0.98	5.13
Raphidiopsis sp.	Cyanophyta	0.6	5.13
Spirulina sp.	Cyanophyta	0.20	5.13
Oscillatoria sp.	Cyanophyta	0.41	5.13
Rivularia sp.	Cyanophyta	0.57	5.13
Anabaena sp.	Cyanophyta	0.20	5.13
Nostoc sp.	Cyanophyta	0.60	5.13
Coelasphaerium sp.	Cyanophyta	0.24	5.13
Ophycitium sp.	Cyanophyta	0.08	5.13
Tetrapedia sp.	Cyanophyta	0.16	5.13
Gomphosphaeria sp.	Cyanophyta	0.04	5.13
Pleurotaenia sp.	Cyanophyta	0.20	5.13
Synechcystis sp.	Cyanophyta	0.41	5.13
Hydroium sp.	Cyanophyta	0.41	5.13
Calothrix sp.	Cyanophyta	0.12	5.13
Tetracus sp.	Cyanophyta	0.24	5.13
Homeothrix sp.	Cyanophyta	0.04	5.13
Aulosira sp.	Cyanophyta	0.12	5.13
Amphanizoeinon sp.	Cyanophyta	0.16	5.13
Tribonema sp.	Xanthophyta	0.74	2.00
Characiopsis sp.	Xanthophyta	0.08	2.00
Botryococaus sp.	Xanthophyta	0.78	2.00
Ophicytium sp.	Xanthophyta	0.32	2.00
Botrydium sp.	Xanthophyta	0.08	2.00
Tabellaria sp.	Bacillariophyta	0.69	8.89
Gyrosigma sp.	Bacillariophyta	0.37	8.89
Pinnularia sp.	Bacillariophyta	0.86	8.89
Nitzschia sp,	Bacillariophyta	1.02	8.89
Meridion sp.	Bacillariophyta	0.94	8.89
Fragilaria sp.	Bacillariophyta	0.49	8.89
Synedra sp.	Bacillariophyta	0.61	8.89
Niedium sp.	Bacillariophyta	0.24	8.89
Amphipleura sp.	Bacillariophyta	1.11	8.89
Navicula sp.	Bacillariophyta	0.65	8.89
Attheya sp.	Bacillariophyta	0.08	8.89
Melosira sp.	Bacillariophyta	0.61	8.89
Diatoma sp.	Bacillariophyta	0.86	8.89
Surirella sp.	Bacillariophyta	0.49	8.89
Cocconies sp.	Bacillariophyta	0.04	8.89
Rhoieosphenia sp.	Bacillariophyta	0.16	8.89
Denticula sp.	Bacillariophyta	0.08	8.89
Rhopalodia sp.	Bacillariophyta	0.08	8.89
Euglena sp.	Euglenophyta	1.35	2.28
Phacus sp.	Euglenophyta	0.49	2.28
Cyclotella sp.	Euglenophyta	0.04	2.28
Gymbella sp.	Euglenophyta	0.28	2.28
Amphora sp.	Euglenophyta	0.12	2.28
Paranema sp.	Euglenophyta	0.24	2.28
Trachelomonas sp.	Euglenophyta	0.16	2.28
Lepocinils sp.	Euglenophyta	0.04	2.28
Hydrodictyon sp.	Chlorophyta	0.12	40.18
Volvox sp.	Chlorophyta	0.45	40.18
Dictylosphaeriam sp.	Chlorophyta	0.28	40.18
Selenastrum sp.	Chlorophyta	0.49	40.18
Ankistrodesmus sp.	Chlorophyta	1.27	40.18
Fmanica sp.	Chlorophyta	0.12	40.18
Scendedesmus sp.	Chlorophyta	0.45	40.18
Closterium sp.	Chlorophyta	1.97	40.18
Arthrodesmus sp.	Chlorophyta	1.23	40.18
Tetrahedron sp.	Chlorophyta	0.41	40.18

Pediastrum sp.	Chlorophyta	3.78	40.18
Westellopsis sp.	Chlorophyta	1.11	40.18
Westella sp.	Chlorophyta	0.37	40.18
Coelastrum sp.	Chlorophyta	0.82	40.18
Ulothrix sp.	Chlorophyta	0.61	40.18
Gonatozygon sp.	Chlorophyta	2.26	40.18
Penium sp.	Chlorophyta	1.06	40.18
Pleurotaenium sp.	Chlorophyta	1.31	40.18
Cosmarium sp.	Chlorophyta	1.43	40.18
Codatella sp.	Chlorophyta	0.04	40.18
Staurastrum sp.	Chlorophyta	0.12	40.18
Closteriopsis sp.	Chlorophyta	10.32	40.18
Crucigenia sp.	Chlorophyta	0.37	40.18
Raphidionema sp.	Chlorophyta	0.32	40.18
Palmella sp.	Chlorophyta	0.94	40.18
Tetraspora sp.	Chlorophyta	0.65	40.18
Gonium sp.	Chlorophyta	0.20	40.18
Chlorococcum sp.	Chlorophyta	0.82	40.18
Characium sp.	Chlorophyta	0.41	40.18
Treubaria sp.	Chlorophyta	0.12	40.18
Tetrallantos sp.	Chlorophyta	0.12	40.18
Dictylosphaerium sp.	Chlorophyta	0.08	40.18
Tetrastrum sp.	Chlorophyta	0.32	40.18
Actinospharium sp.	Chlorophyta	0.12	40.18
Gaminella sp.	Chlorophyta	0.28	40.18
Uronema sp.	Chlorophyta	0.28	40.18
Stigeoclonium sp.	Chlorophyta	1.19	40.18
Cladophora sp.	Chlorophyta	0.24	40.18
Dimorphococcous sp.	Chlorophyta	0.37	40.18
Microspora sp.	Chlorophyta	0.20	40.18
Echinodnium sp.	Chlorophyta	0.04	40.18
Trochiscia sp.	Chlorophyta	0.16	40.18
Gloeotaenium sp.	Chlorophyta	0.08	40.18
Dysmorphododdus sp.	Chlorophyta	0.04	40.18
Gloechocystis sp.	Chlorophyta	0.37	40.18
Chlorella sp.	Chlorophyta	0.32	40.18
Planktosphaeria sp.	Chlorophyta	0.16	40.18
Sorastrum sp.	Chlorophyta	0.08	40.18
Hormidium sp.	Chlorophyta	0.12	40.18
Stichococcus sp.	Chlorophyta	0.24	40.18
Spirogyra sp.	Chlorophyta	0.16	40.18
Spirotania sp.	Chlorophyta	0.12	40.18
Docidium sp.	Chlorophyta	0.20	40.18
Euastrum sp.	Chlorophyta	0.20	40.18
Microthamnion sp.	Chlorophyta	0.08	40.18
Mesotaenium sp.	Chlorophyta	0.20	40.18
Botryococcus sp.	Chlorophyta	0.20	40.18
Kirchenaeria sp.	Chlorophyta	0.20	40.18
Cloniophora sp.	Chlorophyta	0.08	40.18
Pteromonas sp.	Chlorophyta	0.20	40.18
Schroederia sp.	Chlorophyta	0.12	40.18
Zygnema sp.	Chlorophyta	0.04	40.18
Tribonema sp.	Chrysophyta	0.24	2.49
Chrysamoeba sp.	Chrysophyta	0.04	2.49
Phaeothamion sp.	Chrysophyta	0.16	2.49
Botrydopisis sp.	Chrysophyta	0.28	2.49
Mallomonas sp.	Chrysophyta	0.69	2.49
Synura sp.	Chrysophyta	0.16	2.49
Cocconies sp.	Chrysophyta	0.20	2.49
Dinobryon sp.	Chrysophyta	0.08	2.49
Chrysococcus sp.	Chrysophyta	0.20	2.49
Peridinium sp.	Pyrrophyta	0.20	0.20
Chilomonas sp.	Cphryptophyta	0.08	0.08
Scirpus sp.	Cphryptophyta	0.20	0.08

Table 5. Relative abundance (%) of zooplankton in all samples

Name of Genera	Name of phylum /division	R.A (%) of genera	R.A (%) of phylum /division
Paramecium sp.	Protozoa	0.58	13.97
Amoeba sp.	Protozoa	1.68	13.97
Aecella sp.	Protozoa	1.24	13.97
Difflugia sp.	Protozoa	1.85	13.97
Tinema sp.	Protozoa	1.64	13.97
Linotus sp.	Protozoa	1.57	13.97
Pseudodifflugia sp.	Protozoa	1.20	13.97
Tintinnidium sp.	Protozoa	1.30	13.97
Tintinnopsis sp.	Protozoa	1.31	13.97
Acanthocytis sp.	Protozoa	0.41	13.97
Cyproderia sp.	Protozoa	0.45	13.97
Actinosphaeiroum sp.	Protozoa	0.16	13.97
Sphenoderia sp.	Protozoa	0.04	13.97
Uronema sp.	Protozoa	0.28	13.97
Dileptus sp.	Protozoa	0.28	13.97
Didinium sp.	Protozoa	0.04	13.97
Vorticella sp.	Protozoa	0.12	13.97
Spirostrum sp.	Protozoa	0.57	13.97
Pelomyxa sp.	Protozoa	0.28	13.97
Trinema sp.	Protozoa	0.24	13.97
Raphidiophyrs sp.	Protozoa	0.12	13.97
Lacrymaria sp.	Protozoa	0.08	13.97
Trochilia sp.	Protozoa	0.16	13.97
Quadrullea sp.	Protozoa	0.24	13.97
Nabella sp.	Protozoa	0.20	13.97
Bursella sp.	Protozoa	0.20	13.97
Bursellopsis sp.	Protozoa	0.20	13.97
Frontonia sp.	Protozoa	0.08	13.97
Scapholeberis sp.	Protozoa	0.04	13.97
Askenesia sp.	Protozoa	0.08	13.97
Enchlys sp.	Protozoa	0.04	13.97
Eoleps sp.	Protozoa	0.08	13.97
Trachelophyllum sp.	Protozoa	0.04	13.97
Pseudoprodon sp.	Rotifera	0.20	1.16
Cephallodela sp.	Rotifera	0.32	1.16
Testudinella sp.	Rotifera	0.16	1.16
Synchaela sp.	Rotifera	0.16	1.16
Schizocera sp.	Rotifera	0.24	1.16
Lepadella sp.	Rotifera	0.04	1.16
Notholca sp.	Rotifera	0.04	1.16
Proales sp.	Rotifera	0.04	1.16
Diapsonema sp.	Cladocera	0.32	0.88
Daphnia sp.	Cladocera	0.24	0.88
Alonella sp.	Cladocera	0.08	0.88
Paracyclopina sp.	Cladocera	0.04	0.88
Oxyurella sp.	Cladocera	0.12	0.88
Ceriodephnia sp.	Cladocera	0.04	0.88
Alona sp.	Cladocera	0.04	0.88
Acartiella sp.	Copepoda	0.08	0.24
Nitocra sp.	Copepoda	0.04	0.24
Cyclops sp.	Copepoda	0.04	0.24
Brachiodopsis sp.	Copepoda	0.08	0.24
Ptychoptera sp.	Aquatic insecta	0.08	0.08

Table 6. Relative abundance (%) of Macrophyta and Charophyta in all samples

Name of Genera	Name of phylum /division	R.A (%) of genera	R.A (%) of phylum /division
Zizania sp.	Macrophytes	0.08	3.08
Potamogeton sp.	Macrophytes	0.32	3.08
Najas sp.	Macrophytes	0.98	3.08
Vallisnaria sp.	Macrophytes	0.41	3.08
Ceratophylum sp.	Macrophytes	0.28	3.08
Hydrilla sp.	Macrophytes	0.20	3.08
Wallffia sp.	Macrophytes	0.32	3.08
Spirodella sp.	Macrophytes	0.12	3.08
Lemna sp.	Macrophytes	0.12	3.08
Myriophyllum sp.	Macrophytes	0.37	3.08
Sagitalaria sp.	Macrophytes	0.08	3.08
Nitella sp.	Charophyta	0.08	0.28
Chara sp.	Charophyta	0.16	0.28
Laychnothamus sp.	Charophyta	0.04	0.28

Discussion

Fresh water environments, unlike the marine ones, are subjected to variations in the environmental factors such as temperature, dissolved gases, light penetration, turbidity, density etc. These factors are responsible for distribution of organisms in different fresh water habitats according to their adaptations, which allow them to survive in that specific habitat (Jaffries and Mills, 1990).

Temperature fluctuations, both diurnal and seasonal, are more evident in fresh water habitats. Flowing waters, however, lack wide fluctuations in temperature (Leonard, 1971). Air temperature was at its maximum in June while water temperature was at its maximum in May and then both had a decreasing trend till December in present study indicating seasonal variation. Photoperiod was shorter in winter than summer. Photoperiod is directly related to temperature (Odum, 1971). Photoperiod and temperature, both were at maximum in June. The minimum value of turbidity (0.02 mg l^{-1}) was observed in December and highest value (0.48 mg l^{-1}) in July showing floods and rains in this month which brings clay, sand and organic matter from adjoining areas of the river. After July, there was a rapid decrease in water turbidity. Turbidity showed an inverse relationship with light penetration. When turbidity was low, light penetration was high and when turbidity was high light penetration was low. Salam and Rizvi (1999) and Ali et al., (2000) observed the similar results while working on River Chenab and Rachna Doaab respectively.

Boiling point of river Soan was maximum (98 ^{o}C) in September and December while minimum (95 ^{o}C) in October. The boiling point of water rises due to presence of total solids, total dissolved solids and total volatile solids (Lloyd, 1992).

Density of river varies at different sites and different times. These differences may be due to variations in temperature and salt concentration of water. There are fluctuations in water density with increase or decrease in total dissolved solids. The change in density due to temperature fluctuations is more important. Specific gravity and density are related with one another (Schwoerbel, 1987).

Surface tension of water varies with temperature and with the contents of dissolved solids (Odum, 1971). Therefore in the present study, it showed relationships with dissolve solids and water temperature. Higher values of surface tension were observed in months with higher values of temperature and dissolved solids.

Viscosity was increasing with relation to solids present in water. With increase of solids the increase of viscosity was observed. In the present study, the maximum value of viscosity was observed in the month of June when the dissolved solids were also at maximum level.

The pH of water is important because many biological activities can occur only within a narrow pH range. Thus, any variation beyond acceptable range could be fatal to a particular organism. The favorable range of pH is 6.5-9.0 at daybreak, is suitable for fish production (Chhatawal, 1998). pH range in the present study was 8.0-9.0 touching the upper limit of favorable range, which indicates that water is suitable for fish production.

Dissolved oxygen showed maximum values in winter season. It may be due to temperature variations. Dissolved oxygen showed inverse relationship with water temperature (Ali, 1999). Similar type of results was observed in present study as dissolved oxygen decreased with increase in temperature. Dissolved oxygen also had an inverse relationship with photoperiod. When the photoperiod was long, the dissolve oxygen value was low and when photoperiod was short, dissolved oxygen value was high. Ali et al., (2000) and Chaudhry and Inayat (1990) also came to the same conclusion.

Several factors influence the conductivity including temperature, ionic mobility and ionic valences. In turn, conductivity provides a rapid mean of obtaining approximate knowledge of total dissolved solids concentration and salinity of water sample (Odum, 1971).

Brown (1993) reported that total hardness acts as limiting factor for alkalinity. Calcareous water with alkalinity more than 50 ppm is most productive, 0-20ppm for low production, 20-40 ppm for medium production and 40-90 ppm for higher production. Carbonates and bicarbonates in hydroxides of Ca, Mg, Na, K, NH_4 and Fe generally cause alkalinity of natural fresh water. Carbonates and bicarbonates are the major components of alkalinity; they have positive correlation with alkalinity.

In natural unpolluted waters dissolved CO_2 is main contributor to the acidity. In polluted waters weak acids like CH_3COOH may contribute significantly to the total acidity. In some organic waters organic acids also contribute to acidity (Brown, 1993). In present study, both alkalinity and acidity were with in safe limits.

Total solids showed a positive increasing trend with season showing peak in June. Total solids also showed a positive correlation with turbidity as observed by other authors (Chaudhary and Inayat, 1990; Salam and Rizvi, 1999 and Iqbal et al., 2004). Total dissolved solids indicate the total amount of inorganic chemicals in solution. The portion of dissolved solids has carbonates, bicarbonates, sulphates and chlorides of sodium and calcium. A maximum value of 400 mg l^{-1} of total dissolved solids is permissible for diverse fish population (Chhatwal, 1998). Total dissolved and total volatile solids showed seasonal fluctuations through out the study period.

Dissolved metallic ions create turbidity and discoloration, can precipitate and form bottom sludge. Limits on individual metals are usually based on toxicity levels. Various metals including those, which are essential micronutrient, are toxic to organisms at their higher concentrations. Normally free form of the element is potentially toxic to aquatic biota; complexation with organic ligands significantly reduces this concentration and adverse effects. There are other factors such as pH and hardness that effect the concentration of free metal ions and thus regulate toxicity. However, several regulatory agencies have specified limits on total metals to provide a sufficient safeguard against possible synergistic effects. These limiting stream concentrations are generally set at 1.0 g ml^{-1} of total heavy metals (Iqbal et al., 2004).

It has been observed that sodium concentration increases in winter season when the river is at lowest flow and decreases in summer season when the river is at its highest flow. Our study showed interesting and opposite results and maximum value was observed in May. The concentration of sodium ions becomes remarkably high in saline and brakish water. The higher concentration of 'Na' limits the biological diversity due to osmotic stress. If 'Na' content in the form of chloride and sulphates is very high, it makes the water salty and unfit for human consumption. A high 'Na' content in irrigation water brings about puddling of soil. As a result the water intake of soils gets reduced and it becomes hard, so the germination of seeds becomes difficult (Trivedi, 1992).

Potassium acts in water in the same way as sodium. Although it occurs in small amounts it plays an important role in the metabolism of freshwater environment and regarded to be an important macronutrient (Mourkidis et. al., 1990).

Calcium is essential for metabolic processes in all living organisms and as a structural or skeletal material in many. All the vertebrates, mollusks, coral reefs and certain other invertebrates require large quantities of $CaCO_3$ as a major skeletal strengthening material. 'Ca' is present in ionic form and as suspended particulates mainly $CaCO_3$. Calcium salts are the main source of hard water (Mearns, 1977). As it is an important contributor to hardness in water, it is able to reduce the utility of water for domestic use (Trivedi, 1992).

Strontium shows actions in body similar to Calcium. The deficiency of "Sr" can cause decreased growth, osteoporosis, dental caries and bone pain in animals and human beings (Mourkidis et. al., 1990).

Soan is a seasonal river, so great variation in types and distribution of phyto and zooplankton was observed which was mainly due to the variation in water quality parameters throughout the study period. Change in water quality parameters directly affects the aquatic life (Goldman, 1983). Diversity indices are good indicators of pollution in aquatic ecosystems. Diversity index greater than 3 indicates clean water. Value in the range of 1 to 3 is characteristic of moderately polluted conditions and values less than 1 characterize heaviely polluted condition (Mason, 1998). Diversity index of phytoplankton was greater (4.6-13.5) than 3 throughout the study period which indicate that water is suitable for phytoplanktonic growth. Diversity index of zooplankton was also higher than 3 in all months of study period except June (1.94) and July (2.16) indicating that during these two months Soan water was not suitable for zooplankton growth. During summer season, in June and July, the concentration of dissolved metallic ions was increased and as result river water became too much turbid, light penetration was decreased which seriously affected the photosynthesis and result was decrease in planktonic number during these months (Tables 1, 4 and 5). Acidity is another factor that affects the diversity of plankton. During summer, the acidity of river water was increased due to some known and unknown reasons and as a result less plankton was observed. On the other hand, increased number of plankton was observed in winter because low winter temperatures, turbidity and acidity favor the planktonic growth.

Regarding data from the present study we conclude that overall physical and chemical parameters, levels of the inorganic element concentrations and planktonic diversity were within the safe limit at the sampling site throughout the study period and water of river is suitable for farming as well as for aquaculture. Following suggestions are made in order to conserve the ecology of river Soan in the future;

- Limnological study of river Soan must be done at various spots, both up and downstream, in order to observe complete picture of its water quality.
- Necessary steps must be taken in order to prevent entry of sewage in river water.
- Sewage treatment plants should be constructed in big cites to prevent sewage entry in river water.
- Construction of Motorways and dams on or near river Soan must be planned in such a way that water quality of river should not be affected.
- Government must take necessary steps to make the public aware of the importance of water quality and biodiversity.

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