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Seasonal variation in physico-chemical and phytoplankton diversity of Alaknanda River at Garhwal region (Uttarakhand)

CK Jain, DS Malik and Garima Tomar

Abstract
Alaknanda River originated from Satopanth and Bhagirathi kharak glacier at an elevation of 3880 m in Garhwal region of Uttarakhand. The seasonal variation of physico-chemical characteristics and phytoplankton diversity of Alaknanda River were studied for a period of one year. In the present study, various physico-chemical parameters i.e. water temperature, velocity, pH, EC, total alkalinity, calcium, magnesium, phosphate, sulfate and nitrate were analyzed during Summer, Monsoon and Winter season on selected four zones from the period of Sep. 2016-Aug. 2017. The present study revealed that the physico-chemical parameters of River water showed a great seasonal variation as DO increases in winter season. pH, EC and total alkalinity were observed highest in rainy season on every zone, which had a strong impact on other physico-chemical characteristics of River. 31 genera of phytoplankton were recorded under family as Bacillariophyceae, Chlorophyceae, Myxophyceae, Euglenophyceae and Xanthophyceae. However, the overall phytoplankton diversity was found maximum in winter and pre-summer season. The present study revealed that the existing water quality and rich phytoplankton diversity of Alaknanda River would be contributed significantly to enhance the ecosystem productivity.

Keywords: Seasonal variation, physico-chemical, phytoplankton, Alaknanda River

Introduction
Phytoplanktons have the most essential biological characteristics for maintain and balancing the aquatic ecosystem [1]. Some of phytoplankton species gives a reliable information about pollution status of aquatic bodies. So, these are called good indicator of water quality. These studies and monitoring are useful for control of the physico-chemical and biological conditions of the water. However, a group of species of phytoplankton as blue green algae, can degrade recreational value of surface water [2]. Past few decades, physico-chemical factors are mainly responsible in the processes of influencing the development of phytoplankton communities [3] [4]. The algae are co-occurring in an aquatic body, although each species has a specific niche i.e. based on the physiological need and restrictions with the environment. Phytoplankton succession is correlated with changes in environmental abiotic parameters as temperature, light and availability of nutrients [5]. Phytoplankton succession is strongly linked to meteorological and physico-chemical factors [2].

Water quality parameters provide the various physico-chemical characteristics of River water. These components vary with space and time [6]. The natural concentration of environmental variables majorly affected by human interference with nature [7]. The scale of socio-economic activities, urbanization, industrialization and hydropower generation have a major impact on water resources [8]. The impact of these activities affected water quality and aquatic biodiversity. Alaknanda is a perinial River which receives water throughout the year from glacier melt runoff and rain runoff. As per the literature review Alaknanda River carries a large biodiversity. Five different Rivers meet with the River at different locations which forms a suitable habitat for aquatic biota. The main objective of the study, determine seasonal variation in physico-chemical and phytoplankton diversity of River Alaknanda.

Study Area
Alaknanda is a Himalayan River, located in Garhwal region of Uttarakhand at an elevation of 3880 m. It originates from the confluence of Satopanth glacier and Bhagirath Kharak glacier at Garhwal Himalayas of Uttarakhand.

The River flows mostly through Chamoli, Rudraprayag and Pauri Garhwal districts of Uttarakhand. The River basin area is 10,882 km^2. After travelling approx. 190 km, River turns into Ganga after one of holy prayag Devprayag. After merging in Devprayag, River is called the Ganga. Four zones have been selected for this study in the study area.

Table 1: Meteorological characteristics of sampling stations at Alaknanda River

Sampling sites	Location	Latitude	Longitude	Elevation
Zone-A	Chamoli (A_1) Nandprayag (A_2)	30°24′08.3″ 30°19′54.8″	79°19′42.4″ 79°18′55.1″	916m 853 m
Zone-B	Karnprayag (A_3) Rudraprayag(A_4)	30°15′49.7″ 30°17′15.6″	79°12′58.2″ 78°58′42.2″	748 m 593 m
Zone-C	Dharidevi (A_5) Chauras (A_6)	30°15′26.1″ 30°13′43.2″	78°52′41″ 78°47′16.1″	608 m 533 m
Zone-D	Kirtinagar (A_7) Devprayag (A_8)	30°12′48.9″ 30°08′21.5″	78°44′50.1″ 78°35′49.2″	539 m 467 m

Methodology

The study was carried out for a period of one year from Sep. 2016 – Aug. 2017 on monthly basis. Seasonal relation was later found to know the effect of different environmental conditions on River water and aquatic biota. Water samples were collected every month early morning and afternoon in sterilized polyethylene sampling bottles. Few physico-chemical parameters like Temp, Velocity and pH were performed on spot and other parameters like Electric conductivity, Total Alkalinity, Calcium, Magnesium, Sulphate, Phosphate, and Nitrate were analyzed in laboratory by following the methodology of APHA [9], Trivedi and Goel [10], Wetzel and Likens (1991) [11]. Temperature and Velocity was measured by using Celsius thermometer and flow meter. Conductivity and pH were measured by using Conductivity meter and digital pH meter. Total Alkalinity, Calcium, Magnesium, Phosphate, Sulphate and Nitrate were analyzed by Ion Chromatograph. For analysis and enumeration of phytoplankton, samples were collected with the help of plankton net of bolting silk no. 25 with a mesh size of 55µm attached with a collection tube at the base of net. For this a known volume (10 L) of water was filtered through the planktonic net and sample was collected inside the collection tube. The sample was transferred in sterilized bottles of 125 mL capacity and preserved in 4% formaldehyde solution. The phytoplankton were identified following [11-15]. Phytoplankton data was also analyzed by statistical approaches like average and standard deviation (SD).

Results and Discussion

The physico-Chemical parameter (Avg ± SD) values obtained in different seasons of River Alaknanda at Garhwal are given in table-2. The maximum water temperature (19.5±1.0 °C) was recorded during the monsoon period at zone-C whereas the minimum temperature was recorded in winter (10.4±0.8 °C). A temperature higher then 15 °C facilitates the development of microorganisms. In this study results obtained as pH lies between 7.4±0.16 to 7.75±0.10. According to the WHO and BIS standards of potable or natural water the pH varies between 7.2 and 7.6. Electrical conductivity was recorded 144.4±4.3 µS/cm to 200.5±11.2 µS/cm. Higher conductivity values were measured in monsoon at zone-D and minimum in summer at zone-B indicating the significant influence of the River inflow. The concentration of dissolved oxygen (DO) showed a variation of 8.2±0.2 mg/L to 10.5±0.1 mg/L. An increase in DO content was observed in winter at zone-A, B and remained almost same at all sites. It changes in summer season as the temperature starts increasing DO decreases and a further change in monsoon season. The variation of DO seasonally is a function of physico-chemical properties of water, which alter its solubility Aston, 2000. Total alkalinity values observed in the present study, range between 40.2±5.7 mg/L to 66.4±2.9 mg/L. The highest concentration of alkalinity was recorded in monsoon and summer. Low concentration of total alkalinity was recorded at zone-D in summer season. Higher values of total alkalinity at zone-A in monsoon season might be due to the presence of excess of CO_2 produced in summer. Similar observations were recorded by Singh, 2009 [18]. As research scientist findings, If DO increases total alkalinity also increases. Agarwal and Thapliyal, (2010) [19] obtained maximum alkalinity during winter months in Bhilangana River. According to Moyle, (2005) [17], high alkalinity water bodies (>50mg/L) can be considered productive. Primarily, the calcium and magnesium concentration indicates the hardness of water. The desirable limit for calcium in water is 75 mg/L and the maximum permissible limit is 200 mg/L. Magnesium permissible values are 30 and 100 mg/L respectively. In the present investigation, the values for calcium were observed maximum 28.9±1.6 mg/L at zone-D in winter season and minimum in monsoon season at zone-B. Magnesium was recorded highest in winter season at A-6. The observed values of Mg were ranged between 1.9±0.1 mg/L to 5.2±0.5 mg/L. Similar findings are reported by Sedemekar and Angadi, (2003) [20]. In the present observation, phosphate concentration was found NIL on every site of River. Little variations in sulfate content were recorded in all the three seasons. Sulfate is a key nutrient in the productivity of water. Sulfate showed lower values in monsoon season whereas it increases in winter season. Martin *et al.*, (2004) [21] were observed high values of sulfate in winter season.

Table 2: Seasonal variation in physicochemical characteristics of River Alaknanda for a year (Sep. 2016- Aug. 2017)

S.No	Param.	Monsoon (Avg±SD)				Winter (Avg±SD)				Summer (Avg±SD)			
		A	B	C	D	A	B	C	D	A	B	C	D
1	Water temp	13.2±0.7	13.0±1.4	15.4±1.6	14.0±0.5	11.0±0.2	10.4±0.8	12.2±0.1	10.5±1.8	17.8±1.4	17.2±0.3	19.5±1.0	16.7±0.8
2	pH	7.7±0.2	7.7±0.1	7.8±0.02	7.6±0.04	7.7±0.04	7.7±0.1	**7.7**±0.1	7.7±0.2	7.4±0.1	7.6±0.1	7.6±0.1	7.9±0.02
3	EC	190.8±1.4	180.6±15.9	176.1±6.1	200.5±11.2	169.2±7.4	140.1±3.0	153.9±1.5	156.3±15	169.2±7.4	140.1±3.0	153.9±1.5	156.3±15
4	DO	9.1±0.1	9.7±0.5	10.3±0.5	9.9±0.1	10.3±0.2	10.5±0.1	9.4±0.2	9.1±0.1	8.2±0.2	9.9±0.1	9.0±0.1	9.3±0.04

5	T.Al.	66.4±2.9	52.6±8.2	53.5±2.2	50.6±1.7	52.0±1.7	50.4±0.7	52.6±2.4	44.1±8.0	61.0±1.7	50.4±0.7	52.6±2.4	40.2±5.7
6	SO_4	9.0±2.3	8.4±0.7	8.4±0.3	11.7±0.6	22.5±3.0	17.1±2.7	15.4±1.6	24.1±1.9	19.2±3.0	14.4t±0.3	16.4±1.0	21.4±0.6
7	NO_3	0.6±0.05	0.7±0.03	0.7±0.1	1.1±0.1	0.7±0.4	0.3±0.2	0.2±0.1	0.5±0.02	1.4±0.3	1.6±0.2	1.7±0.1	1.2±0.2
8	Ca	17.1±2.7	14.6±2.9	19.3±1.5	18.5±3.5	20.8±2.2	18.0±2.7	19.0±0.5	28.9±1.6	23.4±0.5	19.5±2.8	20.8±1.7	17.6±5.5
9	Mg	2.4±0.1	1.9±0.1	2.4±0.1	2.6±0.2	5.0±1.7	5.2±0.5	3.9±0.03	5.1±1.8	4.8±0.6	3.6±0.8	3.9±0.3	4.6±0.5

Average nitrate values of River Alaknanda are given in the table-2. Nitrate concentration in water indicates the water quality, generally nitrate entering in aquatic system, contribute to aquatic pollution. Domestic runoff, decomposition of organic matter and domestic sewage are the main sources of nitrate in any water body. Nitrate values were recorded highest in summer and lowest in winter season which are under prescribed value of potable water. During the present study, observed concentration of nitrate indicated low pollution. According to Ganapathi, (2009) discharge of sewage, runoff, and nitrogen fixation increases nitrate concentration in water bodies.

Phytoplankton diversity

Phytoplankton plays a key role in solving some environmental problems, studying photosynthesis, understanding aquatic ecosystems and the production of useful substances. In the present study, monthly analysis of phytoplankton communities (Tables 3) as well as diversity and density of different species were carried out to assess the phytoplankton structure of River Alaknanda.

Table 3: Average (Avg±S.D values) seasonal spatial qualitative and quantitative distribution of phytoplankton (unit/L) in River Alaknanda from Sep. 2016-Aug. 2017

Phytoplankton	Monsoon (Avg±SD)				Winter (Avg±SD)				Summer (Avg±SD)			
	A	B	C	D	A	B	C	D	A	B	C	D
Bacillariophyceae												
Achananthes sp.	5.25±3.1	5.0±2.9	4.2±3.0	3.5±2.1	14.75±4.0	12.5±5.1	12.0±7.0	9.35±3.6	10.5±6.7	12.5±7.1	10.3±5.5	8.5±6.2
Amphora ovalis	4.25±2.2	4.1±1.0	3.75±2.9	1.5±1.0	9.5±5.0	9.7±4.1	10.0±5.4	9.5±4.5	9.5±6.7	8.0±4.7	9.1±6.3	7.3±9.0
Cytotella sp.	5±2.5	5±1.5	3.5±2.0	2.2±1.7	16.5±7.7	15.5±6.7	13.9±6.2	10.9±7.0	11±4.1	9±4.3	10.3±6.1	8.0±3.9
Cymbella sp.	3.5±2.8	3.1±2.2	2.5±1.8	1.0±0.8	21.25±6.7	21.25±6.7	21.25±6.7	21.25±6.7	7.5±2.4	7.5±2.4	7.5±2.4	7.5±2.4
Denticula sp.	3±3.5	3±3.5	3.7±1.9	1.5±1.3	19.5±8.7	17.8±6.7	18.0±7.2	15.5±5.0	10.25±9.6	10.0±8.7	10.0±9.1	8.5±7.6
Diatoma vulgaris	5±0.8	4±1.8	5.2±1.6	2.9±3.8	19±12.9	18.2±11.5	17.3±10.3	11.9±9.2	12.25±11.9	10.5±9.4	11.21±10.1	9.3±8.0
Fragilaris inflate	2.25±2.5	2.5±1.3	2.10±1.8	1.3±0.5	22.25±5.3	15.2±5.0	18.0±7.3	11.51±8.6	10.25±9.7	10.25±9.0	9.5±8.7	8.3±6.1
Tabellaria fenestris	2.5±1.7	2.5±0.9	1.5±0.9	1.0±1.5	24.5±9.3	15.1±8.2	20.7±8.2	11.5±7.0	7.5±7.6	7.0±4.9	7.0±6.2	5.0±5.3
Hantzchia sp.	3.25±1.9	2.0±1.2	1.5±1.1	1.0±0.9	12.75±4.3	10.8±6.3	12.0±8.1	9.0±5.8	3.75±2.9	2.75±1.9	2.0±0.9	1.5±1.9
Syendra ulna	2.75±2.6	1.5±1.0	2.0±2.1	2.2±1.7	20.2±8.9	20.5±9.5	16.2±9.1	11.4±6.3	8.0±5.0	8.6±6.3	7.3±4.8	6.0±4.1
Navicular radiosa	3±2.3	1.9±1.1	3.0±2.7	1.8±0.9	16.5±7.7	14.2±8.2	10.3±5.1	14.5±4.9	10.4±9.5	9.0±8.2	9.4±8.5	7.9±8.5
Nitzchia	7±1.0	9±7.0	7.5±1.6	4.3±1.2	14.5±9.6	14.5±9.6	14.5±9.6	14.5±9.6	16.7±13.0	14.2±12.5	17.5±15.2	11.3±9.5
Opephora sp.	1.2±1.0	1.0±2.1	1.5±0.6	1.0±0.8	10.5±6.4	12.5±5.8	9.3±7.8	9.2±6.1	10.0±8.1	9.4±7.2	12±9.3	8.5±7.2
Pinnularia	2.5±1.5	1.7±1.4	1.8±1.2	1.0±0.7	9.7±6.3	8.5±4.2	5.7±6.3	9.0±5.3	11±12.2	10.5±11.0	9.0±8.4	8.0±7.1
Tetracylus rupestris	3.75±2.0	2.75±2.0	3.0±2.0	2.5±2.1	10.2±9.8	13.25±8.8	12.2±8.1	10.2±8.8	12.5±8.4	10.7±8.9	10.54±7.4	8.5±7.1
Total	48±10.23	44.0±9.2	38±9.3	32.6±8.5	246.75±86.9	231.5±72.9	210.0±67.2	186.3±76.2	79.1±89.2	82.1±101.7	72.3±91.2	69.0±56.3
Chlorophyceae												
Chlamydomonas sp.	2.5±1.3	2.1±1.4	2.0±1.7	1.5±1.1	19.7±10.7	16.5±11.0	15.5±10.1	12.1±10.3	10.6±9.5	12±6.5	9.7±7.0	8.0±6.5
Chlorella vulgaris	4.2±4.4	3.7±4.0	2.3±4.1	2.5±3.2	17.5±7.8	15.0±10.8	12.5±9.8	9.5±8.8	14.7±11.5	13.0±10.1	14.0±12.5	11.5±10.0
Cledophora sp.	1.5±1.3	1.1±1.0	1.5±1.3	1.0±0.9	18.5±8.6	14.5±9.1	12.5±8.6	11.5±9.6	20.7±14.2	18.5±15.0	15.3±14.2	13.75±14.2
Desmidium sp.	4.0±2.6	3.5±1.7	4.0±1.6	2.7±1.6	20.5±2.1	18.1±4.0	21.5±4.2	13.5±2.2	12.2±9.1	12.7±8.0	10.3±2.5	9.2±6.3
Gonatozygon sp.	1.5±1.2	0.5±0.6	0.5±0.6	0.5±0.6	17.2±3.6	17.5±2.5	14.2±6.9	11.0±6.1	9.5±5.8	7.5±4.8	9.5±6.2	5.9±5.0
Hydrodictyon	3.5±2.9	1.5±2.4	2.5±2.4	1.0±1.4	10.5±7.0	12.5±7.0	11.5±9.1	12.5±6.5	16.7±10.0	13.5±9.1	16.5±13.0	14.0±9.1
Microspora	4.5±3.1	3.7±2.4	4.5±2.9	2.7±2.8	13.5±7.8	11.5±7.2	10.3±6.3	10.5±7.1	21.2±12.3	21.5±13.0	18.2±12.5	15.0±11.3
Ulothrix zonata	5.7±3.2	4.7±3.9	3.5±3.4	2.7±2.1	16.5±12.4	13.7±10.1	11.2±10.1	10.1±9.4	26.2±10.2	26.5±15.2	20.2±14.1	15.0±12.2
Zygnema	3.2±1.0	3.0±1.5	2.2±1.0	1.5±1.3	12.7±10.3	12.7±9.3	10.2±9.3	11.5±10.1	25.5±7.3	22.5±12.1	20.5±9.2	17.1±8.9
Closterium leibleinii	2.5±1.7	2.0±1.2	1.5±1.0	1.0±1.6	16.7±10.1	16.5±12.0	14.3±12.7	14.0±10.3	26.7±9.4	26.2±10.1	20.2±10.2	20.5±17.4
Spirogyra	3.5±3.0	2.5±2.0	1.5±1.7	1.5±2.1	15.5±12.7	10.5±9.7	11.2±10.1	9.5±7.7	20.5±4.5	23.7±4.5	18.2±5.5	14.2±8.5
Total	30.2±9.1	34.7±8.2	32.1±8.7	25.1±9.0	181±82.8	151±52.2	170±62.9	101±52.6	209.5±71.4	230.3±69.2	247.5±73.2	139.5±79.4
Myxophyceae												
Anabena Anabena	0.7±1.0	0.7±1.0	0.5±0.4	0.7±0.4	11.2±8.7	9.2±7.7	11.0±9.1	9.2±5.7	13.7±6.4	12.7±5.4	11.5±9.1	10.7±6.3
Anabena	2.2±1.9	2.5±1.0	1.5±1.2	1.2±1.0	16.2±12.3	12.0±10.3	10.0±11.2	10.2±11.3	19.5±5.4	21.5±5.4	17.0±5.9	11.2±8.4
Coccochloris sp.	4.5±3.7	3.5±3.0	4.0±2.7	1.5±2.7	18.7±7.5	14.7±4.5	13.0±6.0	12.7±3.5	23.7±4.9	20.5±7.9	23.1±9.4	17.2±7.2
Phorimidium sp.	5.7±2.2	3.2±1.2	2.0±2.2	1.5±2.5	11±5.9	13.2±6.0	10.0±4.3	9.5±2.1	19±10.5	18.1±13.2	16.2±4.3	13.0±8.9
Total	10.2±3.8	13.5±5.2	10.1±7.8	9.2±4.0	52.6±13.8	67.0±30.4	57.5±23.2	40.25±33.2	69±14.4	78±17.1	60±12.3	53.2±19.4
Eugleniaceae												
Euglena sp.	4.7±2.8	5.2±2.1	7.3±1.3	5.8±1.9	12±7.3	16.2±3.9	11.0±2.7	5.4±3.9	17.25±6.9	14.0±3.1	11.8±2.8	8.1±2.7
Xanthophyceae												
Vaucheria sp.	2.5±1.3	1.9±2.4	2.6±1.9	1.0±0.8	10.25±6.6	8.3±3.2	6.1±3.2	6.0±2.1	12.75±8.3	10.0±3.7	9.9±2.0	7.1±2.9

In this study, great fluctuation was observed in phytoplankton diversity and density in three different seasons. The phytoplankton density and diversity were recorded maximum in winter, moderate in summer and minimum in monsoon period at all four zones. Malik and Panwar, (2014) [22] recorded maximum values of phytoplankton in winter and minimum during rainy season. Phytoplankton diversity was recorded lowest at zone-D in all three season. There is observed a great effect in biodiversity due to SHP dam. The Phytoplankton diversity in River Alaknanda comprised of 31 genera out of which Bacillariophyceae (15 genera), Chlorophyceae constitute (11 genera), Myxophyceae (4 genera), Euglenophyceae (1genera) and Xanthophyceae (1genera). The diversity of Bacillariophyceae biomass was observed dominating in River. Bacillariophyceae was recorded highest in wnter season at zone-A. The qualitative study of phytoplankton revealed that the family Chlorophyceae was represented by *Chlorella vulgaris, Chlaymydomonas, Spirogyra, Ulothrix, Hydrodictyon, Cladophora, Microspora, Desmidium, Zygenema and gonatozygon*. The family Bacillariophyceae was represented by *Achananthes, Tabellaria fenestris, Hantzchia, Nitzchia, Opephora, Tetracylus rupestris, Amphora, Fragilaria, Navicula, Synedra, Diatoms, Pinnularia, Denticula, Cymbella and Cyclotella.* The family Myxophyceae was represented by *Anabaena, Oscillatoria, Coccochloris* and *Phormidium*. The family Eugleniaceae and Xanthophyceae were represented by *Euglena* and *Vaucheria* respectively. In this investigation, the Bacillariophyceae was reported maximum of 247 unit/L in winter season and minimum 48 unit/L at zone- D in the summer season. Chlorophyceae was reported maximum 209 unit/L in the month of November to January and minimum of 34 unit/L in June to October. Nautiyal and Bhatt (2007) [23] observed the similar trend in River Bhagirathi. The results also revealed that *Chlamydomonas* mostly dominate in the family Chlorophyceae whereas *Cymbela, Navicula* and *Diatoms* were dominating the family Bacillariophyceae. The family Myxophyceae was mostly dominated by *Anabena* and *Phormidium*. However, Bacillariophyceae was found with higher diversity in the River and showed much greater abundance among the five families. Hydrological factors such as discharge or water residence time are thought to be of greater importance to planktonic development in Rivers [24]. It is well known that a combination of physical, chemical and biological factors determined the distribution of the Bacillariophyceae in Rivers [25]. Diversity of phytoplankton is an indication of purity and the use of community structure to assess pollution is conditioned by four assumptions: the natural community will evolve towards greater species complexity which eventually stabilizes; this process increases the functional complexity of the system; complex communities are more stable than simple communities, and pollution stress simplifies a complex community by eliminating the more sensitive species. The present study revealed that Alaknanda River ecosystem carried high biological productivity in terms of better density of different phytoplankton communities.

Conclusion
This study revealed that seasonally variation in physico-chemical and biological parameters recorded in Alaknanda River. Phytoplankton diversity was also recorded in Alaknanda River. Phytoplankton species was recorded highest in winter and pre-summer season. 31 genera of five different families were recorded in River water. Phytoplankton diversity was recorded highest at Zone-A, B and C whereas minimum at Zone-D. Physico-chemical parameters concentration of water showed that River water was under good quality condition i.e. good for phytoplankton growth and survival.

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