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Comparative assessment of physico-chemical conditions and Plankton diversity of River Tons and Asan in Dehradun District of Uttarakhand

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ABSTRACT

Plankton diversity and physico-chemical parameters are an important criterion for evaluating the suitability of water for drinking and other purposes. In the present paper a comparative study of Physico-chemical parameters and plankton diversity between river Tons and Asan in Dehradun was conducted for a period of one year from April 2011-March 2012. Water samples were taken from three sampling stations of both the rivers every month during the course of study. The samples were analysed for both Physico-chemical attributes and plankton diversity. In the present study the data collected on various physico-chemical parameters of both the rivers showed wide site fluctuations having a direct effect on plankton populations. The physico-chemical attributes of both the rivers were investigated by measuring the degree of correlation with the plankton diversity. Our findings highlighted the deterioration of water quality of both the rivers due to industrial, commercial and anthropogenic activities. The status of plankton diversity of river Asan was so low indicating that the river is highly polluted and the water chemistry have direct effect on plankton diversity. However the water quality of river Tons was good to some extent but needs urgent effective restoration and management strategies for its conservation.

Keywords: Correlation, Plankton, River Asan, River Tons, Restoration, water quality

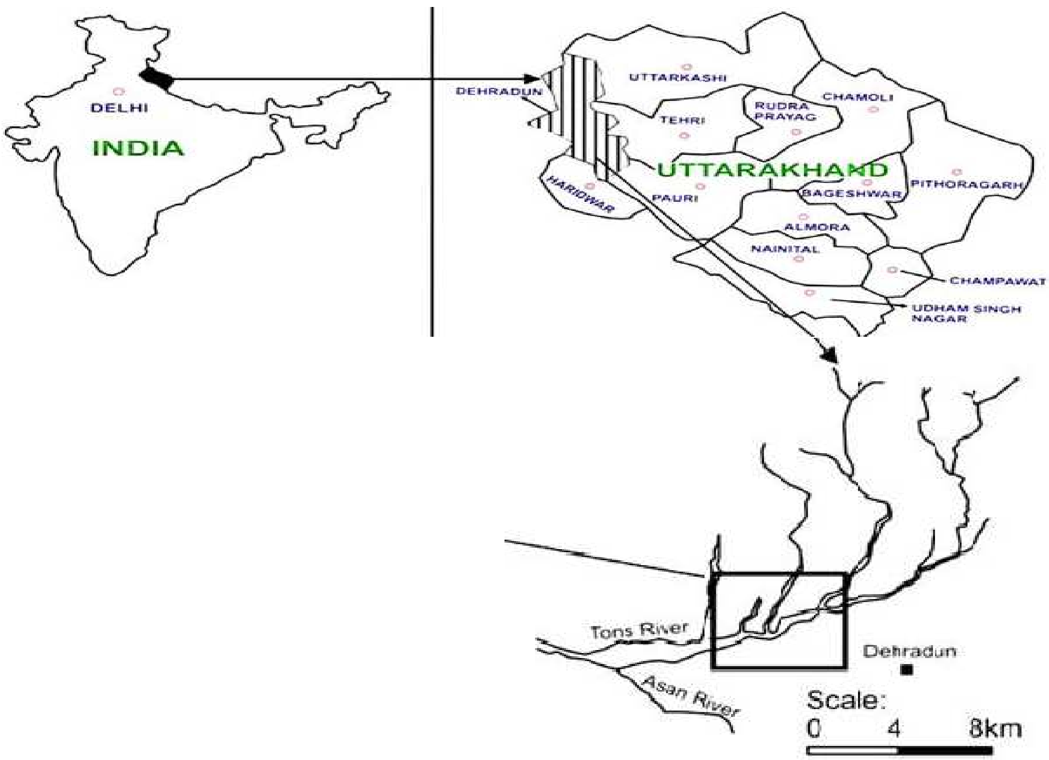
INTRODUCTION

Rivers have always been the most important freshwater resources along the banks of which our ancient civilizations have flourished and most developmental activities are still dependent upon them. River water finds multiple uses in every sector of development like agriculture, industry, transportation, aquaculture, public water supply etc [1]. However, since old times, rivers have also been used for cleaning and disposal purposes. Huge loads of waste from industries, domestic sewage and agricultural practices find their way into rivers, resulting in large scale deterioration of the water quality [2]. The growing problem of degradation of our river ecosystem has necessitated the monitoring of water quality of various rivers all over the country to evaluate their production capacity, utility potential and to plan restorative measures [3]. Anthropogenic processes have physically, chemically and biologically modified our great river ecosystems. Most of the time, the impact of anthropogenic force on river ecosystem is either equivalent or greater than natural force [4]. The importance of human–environment interactions studies are widely recognized to understand the impact of anthropogenic activities on river ecosystem and is, therefore, required for protection of it for further degradation [5]. Phytoplankton are microscopic aquatic plants, occurring as unicellular, colonial or filamentous forms, without any resistance to currents and are free floated or suspended in open/pelagic waters. These are the bottom rung of the food chain in any aquatic ecosystem [6]. Phytoplankton are also the main primary producers in open waters, so they condition the structure and density of consumers as well as physico-chemical properties of water. Moreover, phytoplankton organisms are sensitive indicators, as their structure and metabolism changes quickly in response to environmental changes [7].Phytoplankton are found generally in very large number.

An estimation of their number can be gathered by the statement of Michael [8] that some Phytoplankton may occur in quantities as high as 40,000,000 per liter, but this number can be quickly reduced because they form a regular food of aquatic animals. They represents more comprehensive biological index of the environmental conditions. Zooplankton is microscopic organisms that formulate the base of food chains and food webs in all aquatic ecosystems. All the secondary production in aquatic ecosystems directly or indirectly relies on plankton [9]. They also play a major role in recycling nutrients as well as cycling energy within their respective environments. They are located in the pelagic zone of ponds, lakes, rivers and oceans where light penetrates. Plankton excretes large quantities of organic matter, which dissolves and integrates into the biomass of different bacteria [10]. Zooplankton communities are highly sensitive to environmental variation. As a result, changes in their abundance, species diversity, or community composition can provide important indications of environmental change or disturbance. These are susceptible to variations in a wide number of environmental factors including water temperature, light, chemistry (particularly pH, oxygen, salinity, toxic contaminants), food availability (algae, bacteria), and predation by fish and invertebrates [11 12].

Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In the future, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems [13]. A considerable work on Physico-chemical and plankton populations has been done by many eminent aquatic biologists and limnologists in India and abroad [14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31].

The aim of present study was to made a comparative assessment of river Tons and Asan in Dehradun to know about the pollution status by analyzing the physico-chemical attributes and plankton diversity and recommend suggestive and valuable measures for conservation and sustainability of this riverine ecosystem as both the rivers are important tributaries of River Yamuna.



MATERIALS AND METHODS

Study Area

Dehradun or Doon Valley is the capital city of the State of Uttarakhand in North India. It is surrounded by the Himalayas in the north, Shivalik Hills in the south, the River Ganges in the east and the River Yamuna in the west. It is located between 29 ° 58 'and 31 ° 2' 30 "north latitude and 77 ° 34 '45" and 78° 18' 30 "east longitude [32]. The Tons River is one of the most important and largest tributary of the Yamuna River and flows south-southwest. Its source lies in the 20,720 ft (6,315 meters) high Bandarpunch mountain, and is one of the most major perennial Indian Himalayan rivers. In fact, it carries more water than the Yamuna itself, which meets it below Kalsi near

Dehradun, Uttarakhand. The River Asan is another important tributary of River Yamuna flowing northwest of Doon valley and latter joins the Yamuna River.

METHODOLOGY

The present study was conducted on River Tons and Asan covering a stretch of approximately 30 and 20 km respectively from upstream to downstream. Three sites were selected along both the rivers (three sites S4, S5 and S6 for River Tons and Three sites S7, S8 and S9 for River Asan). The study was carried out for a time period of one year from April 2011-March 2012 on monthly basis. The study sites were Garhi Cant. (S4), Tapkeshwar Temple (S5), Selaqoi (S6), Chanderbani (S7), Asarori (S8) and Confluence point near Selaqoi (S9). Water samples were collected every month early in the morning in sterilized sampling bottles and were analysed for twenty two important physical and chemical Parameters. Few physico-chemical parameters like Temperature (0C), Transparency (cm), Velocity (m/s), pH, Free CO2 (mg/l), and Dissolved Oxygen (mg/l) were performed on spot and other parameters like Turbidity (JTU), Electric conductivity (µmho/cm), Total Solids (mg/l), TDS (mg/l), TSS (mg/l), Total Alkalinity (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), BOD (mg/l), COD (mg/l), Phosphate (mg/l), Nitrate (mg/l), Sodium (mg/l) and Potassium (mg/l) were analysed in laboratory by following the methodology of [33 34 35]. Temperature, Transparency, Velocity was measured by using Celsius thermometer (0–110 0C), Secchi disc, and flow meter. Turbidity, Conductivity and pH were measured by using Jackson Turbidity unit, Conductivity meter and digital pH meter. Total Solids TDS, TSS were measured by gravimetric analysis. Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Free CO2, DO BOD and COD were analysed by titration method. Phosphate and Nitrate were analysed by using UV-VIS Spectrophotometer and Sodium and Potassium by Fame photometer.

The plankton collection was made by hauling of water by plankton net (0.1mm mesh size) and preserved in 4% formaline solution. The plankton count was made by Sedgewick rafter cell under the microscope (Model No.CH-20i.) by the formula [33]

$$\text{No. of Species/l} = \frac{C \times 1000\text{mm}3}{L \times D \times W \times S}$$

Here,
C= No of organisms counted
L= Length of each stripe (mm)
D= Depth of each stripe (mm)
W= Width of each stripe (mm)
S= No. of stripes

The qualitative analysis of the plankton samples were made with the help of [36 37 38 39 40 41 42 43 44 45 46].

Statistical Measurement

Statistical analysis like Standard deviation and Karl Pearson's correlation coefficient (r value) were was carried out with the help of the statistical software SPSS to find the relation between the hydrological attributes and their impact on biological variables.

RESULTS AND DISCUSSION

The Physico-Chemical parameters of water of both the rivers have been given in table 1.The most common physical assessment of water quality is the measurement of temperature. Temperature impacts both the chemical and biological characteristics of surface water. The temperature was found to be 18.33±2.42 at S4, 18.25±2.41 at S5 and 19.75±2.37 °Cat S6 where as it was 19.66±2.05 at S7, 19.65±1.77 at S8 and 18.0±3.33°C at S9 respectively showing at little variation at all the sites. Velocity is an important parameter in determining the condition of river. In present study the values of velocity from S4 to S6 ranged from 0.88±0.53 to 1.59±0.87 m/s, however in case of river Asan its values from S7 to S8 ranged from 0.56±0.12 to 1.02±0.54 m/s as shown in table 1. The electrical conductivity value ranged from 0.461±0.06 to 0.409±0.04 µmhos cm-1 among the three sites of river tons whereas the values ranged from 0.516±0.06 to 0.536±0.03 µmhos cm-1 among the three sites of river Asan. EC is found to be good indicators of the water quality [47 48]. According to Gaikwad [48] the dilution of solid substance in turn reduces the EC value, alkalinity and zooplankton production. The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. pH has no direct adverse effects on health, however, higher values of pH hasten the scale formation in water heating apparatus and also reduce germicidal potential of chloride. High pH induces the formation of trihalomethanes which are toxic [49]. pH affects the dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms and the sensitivity of these organisms to pollution, parasites and disease [50]. In the present study the pH recorded at S4 was 8.18±159.68, S5 8.32±0.14 and at S6 was 7.5±0.19 whereas the pH recorded at S7 was 7.4±0.18, S8 7.5±0.14 and at S9 7.4±0.30. Turbidity of all the six sampling stations of both the rivers was listed in table 1. The water of river Tons was more turbid than river Asan. The highest alkalinity value in river Tons was recorded at S4 468.33±68.65 mg/l followed by S5 367.09±179.80 mg/l and S6 133.16±4.93 mg/l whereas the alkalinity recorded in river Asan was highest at S8 267.0±39.06 mg/l followed by S7 253.5±38.09 mg/l and S9 155.75±18.31 mg/l respectively. Alkalinity results from the dissolution of calcium carbonate (CaCO3) from limestone bedrock which is eroded during the natural processes of weathering. The carbon dioxide (CO2) released from the calcium carbonate into the stream water undergoes several equilibrium reactions [51]. Hardness is chiefly a measure of calcium and magnesium, but other ions such as aluminum, iron, manganese, strontium, zinc, and hydrogen ions are also included. When the hardness level is equal to the combined carbonate and bicarbonate alkalinity, it is referred to as carbonate hardness [52]. Hardness values greater than the sum of the carbonate and bicarbonate alkalinity are referred to as non-carbonated hardness. Most aquatic organisms can tolerate a broad range of calcium hardness concentrations, but a desirable range is 75mg/L to 250 mg/L with a minimum concentration of 20 mg/L. In present study Total hardness values ranged from 135.25±21.76 mg/l to 260.66±22.18 mg/l for river Tons whereas in river Asan its value ranged from 153.91±10.30mg/l to 192.33±17.31 mg/l. The mean free CO2 values at S4, S5 and S6 vary from1.91±0.17 mg/l to 2.69±0.32 mg/l whereas their value at S7, S8 and S9 varies from 1.61±0.12 mg/l to 2.87±0.48 mg/l. A major influence on the free carbon dioxide concentration can be attributed to the phytoplankton and macrophyte community, which require light and supply of nutrients in order to convert available dissolved carbon dioxide into plant tissue by photosynthesis [53]. The concentration of free CO_2 recorded in this study falls within recommended value of below 6.0 mg /l [54]. Dissolved oxygen (DO) is an important aquatic parameter whose measurement is vital in the context of culture of any aquatic animal as oxygen plays a crucial role in its life processes. In this study the DO in river Tons was measured highest at S4 9.51±0.82mg/l and lowest at S6 8.59±0.79 mg/l whereas it was found highest at S9 9.37±0.20 mg/l and lowest at S8 8.29±0.66 mg/l. There was a little variation between the values of biochemical oxygen demand (BOD) recorded for all stations. The mean value varied between 3.76±0.50 mg/l at S6 to 2.75±0.40 mg/l at S5 whereas the mean value of BOD recorded in river Asan vary from 2.65±0.15 mg/l at S9 to 4.08±0.57 mg/l at S7. The higher BOD recorded at S7 could probably be due to organic matter degradation which utilized oxygen within the river. According to Umeham [55] and Kolo and Yisa [56] organic matter in the form of increased decomposition of domestic sewage can increase the BOD. A characteristic feature of most of the river waters is a low nutrient status with a high turn over rate which results in rapid utilization of the nutrients as soon as they are released by decomposition, so that very little remains in the water [57].

Table 1 Physico-chemical characteristics (mean value of sampling sites S4, S5, S6, S7, S8 and S9) of River Tons and River Asan for the year April 2011-March 2012.

Parameters	River Tons			River Asan		
Sites	S4	S5	S6	S7	S8	S9
Temperature o C	18.33±2.42	18.25±2.41	19.75±2.37	19.66±2.05	19.65±1.77	18.0±3.33
Transparency Cm	9.95±4.81	10.48±5.60	10.35±3.57	11.84±2.50	10.79±3.78	12.85±4.26
Velocity m/s	1.565±0.88	1.59±0.87	0.88±0.53	0.96±0.42	0.568±0.12	1.02±0.54
Turbidity JTU	328.75±382.84	370.45±418.17	296.66±381.10	203.75±235.88	111.25±150.99	126.66±154.76
Conductivity µmhocm-1	0.472±0.05	0.409±0.04	0.461±0.06	0.536±0.03	0.516±0.06	0.522±0.02
T.S mg/l	725.0±304.88	608.33±274.55	816.66±356.32	666.66±274.13	808.33±314.66	583.3±285.50
TDS mg/l	358.33±99.62	325.0±128.80	466.66±177.52	375.0±135.68	425.0±135.68	291.6±156.42
TSS mg/l	366.66±230.94	283.33±169.66	350.0±206.70	291.66±202.07	383.3±216.74	291.6±150.50
pH	8.18±159.68	8.32±0.14	7.5±0.19	7.4±0.18	7.5±0.14	7.4±0.30
Total alkalinity mg/l	468.33±68.65	367.09±179.80	133.16±4.93	253.5±38.09	267.0±39.06	155.75±18.31
Total Hardness mg/l	252.33±19.52	260.66±22.18	135.25±21.76	192.33±17.31	156.6±8.93	153.91±10.30
Calcium mg/l	53.81±7.18	53.81±5.72	49.92±8.30	61.78±7.60	53.39±7.69	44.19±5.39
Magnesium mg/l	49.85±4.02	49.85±5.86	20.85±3.95	31.84±2.77	25.19±2.78	26.76±2.23
Chloride mg/l	35.60±3.97	33.45±3.08	32.11±4.12	45.46±4.32	47.53±9.26	35.52±5.04
Free CO2 mg/l	1.98±0.42	1.91±0.17	2.69±0.32	2.42±0.13	2.87±0.48	1.61±0.12
D.O mg/l	9.51±0.82	9.26±0.55	8.59±0.79	8.45±0.89	8.29±0.66	9.37±0.20
B.O.D mg/l	2.82±0.50	2.75±0.40	3.76±0.50	4.08±0.57	3.76±0.48	2.65±0.15
C.O.D mg/l	5.45±0.68	6.11±0.54	7.35±0.83	8.23±1.01	6.85±0.49	5.93±0.48
Phosphates mg/l	1.08±0.31	0.969±0.11	1.470±0.25	1.45±0.32	1.33±0.33	0.584±0.19
Nitrates mg/l	0.809±0.26	0.965±0.38	0.691±0.09	0.840±0.32	1.38±0.09	0.537±0.12
Sodium mg/l	0.510±0.12	0.604±0.12	0.590±0.09	0.660±0.13	0.575±0.08	0.564±0.10
Potassium mg/l	0.437±0.07	0.368±0.07	0.476±0.08	0.554±0.12	0.487±0.08	0.523±0.09

The mean values of Phosphate in river Tons varies from 0.969±0.11 mg/l at S5 to 1.470±0.25 mg/l at S6; however the values varied in river Asan from 0.584±0.19 mg/l at S9 to 1.45±0.32 at S7. The nitrate values ranged from 0.691±0.09 mg/l to 0.965±0.38 mg/l for river Tons and 0.537±0.12 mg/l to 1.38±0.09 mg/l for river Asan respectively. There was not a great variation in sodium and potassium concentration between the two rivers. Sodium was found to be in the range of 0.510±0.12 mg/l at S4 and 0.604±0.12 mg/l at S5 followed by S6 0.590±0.09 mg/l in river Tons whereas its value ranged from 0.564±0.10 mg/l at S9 to 0.660±0.13 mg/l at S7 followed by 0.575±0.08 mg/l at S8 in river Asan.

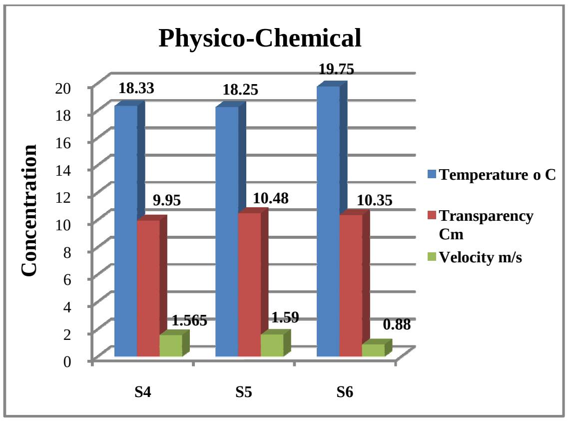


Fig. 1 showing average variation in Temperature, Transparency and Velocity at S4, S5, S6 of River Tons for the year April 2011-March 2012

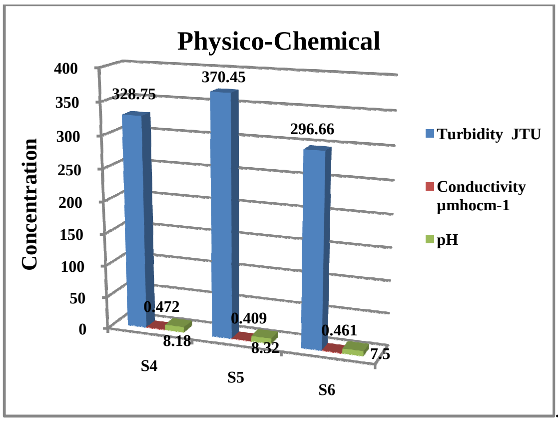


Fig.2 showing average variation in Turbidity, Conductivity and pH at S4, S5, S6 of River Tons for the year April 2011-March 2012

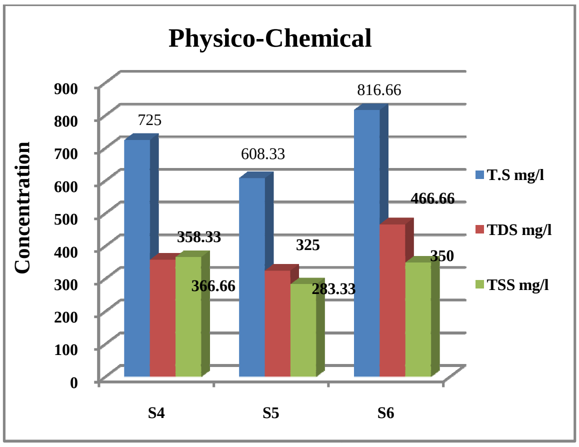


Fig.3 showing average variation in TS, TDS, and TSS at S4, S5, S6 of River Tons for the year April 2011-March 2012

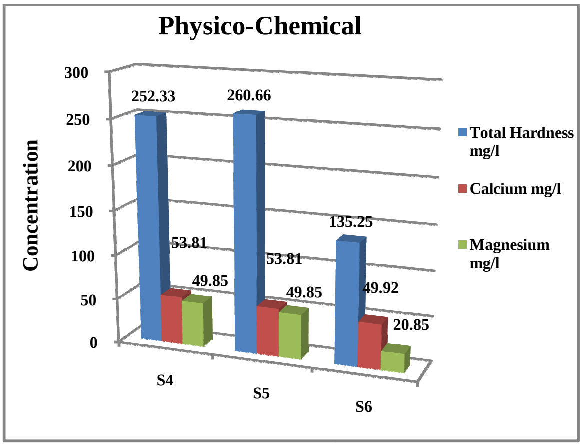


Fig.4 showing average variation in Total Hardness, Calcium, and Magnesium at S4, S5, S6 of River Tons for the year April 2011-March 2012

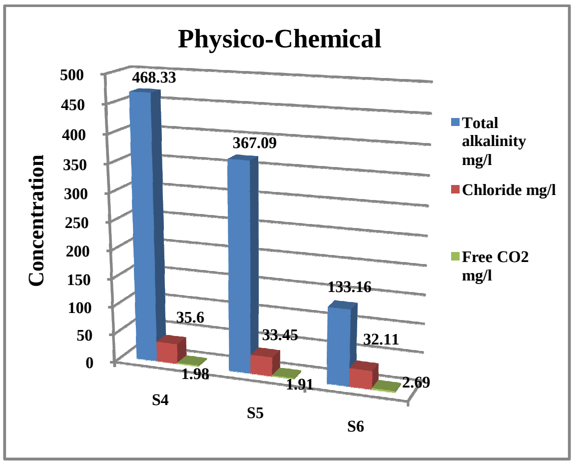


Fig.5 showing average variation in Total Alkalinity, Chloride, and Free CO_2 at S4, S5, S6 of River Tons for the year April 2011-March 2012

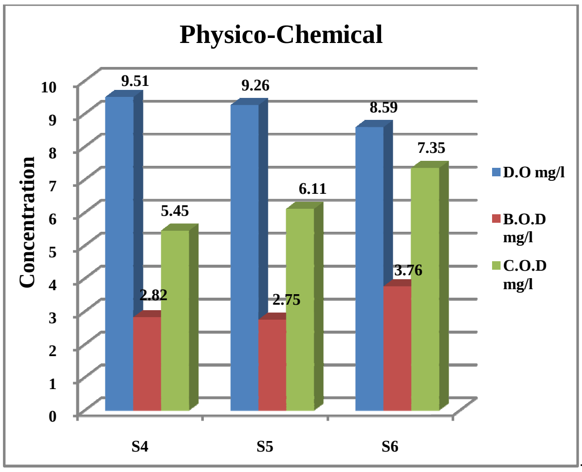


Fig.6 showing average variation in DO, BOD and COD at S4, S5, S6 of River Tons for the year April 2011-March 2012

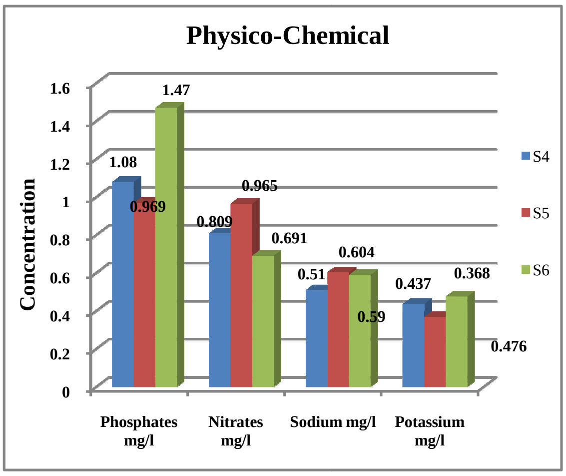


Fig.7 showing average variation in Phosphate, Nitrate, Sodium and Potassium at S4, S5, S6 of River Tons for the year April 2011-March 2012

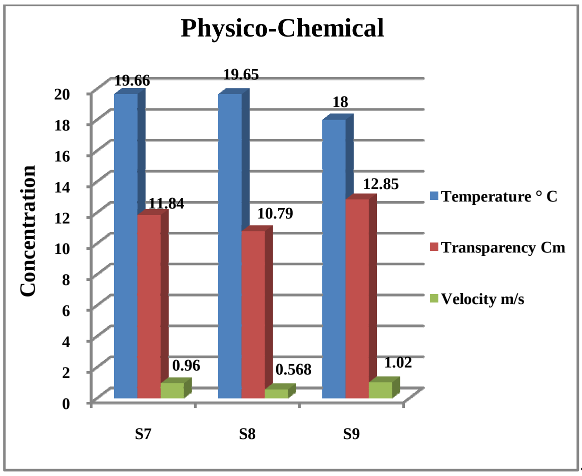


Fig.8 showing average variation in Temperature, Transparency and Velocity at S7, S8, S9 of River Asan for the year April 2011-March 2012

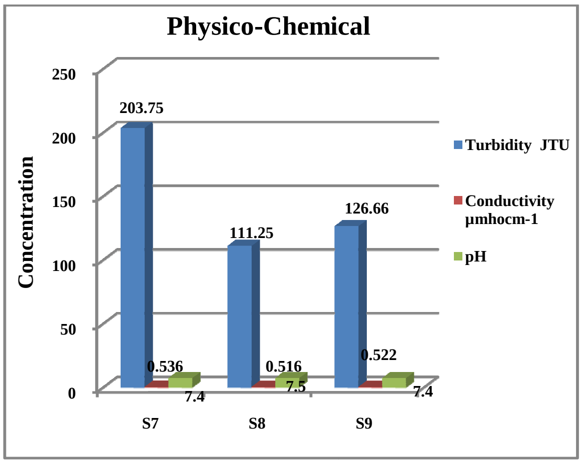


Fig. 9 showing average variation in Turbidity, Conductivity and pH at S7, S8, S9 of River Asan for the year April 2011-March

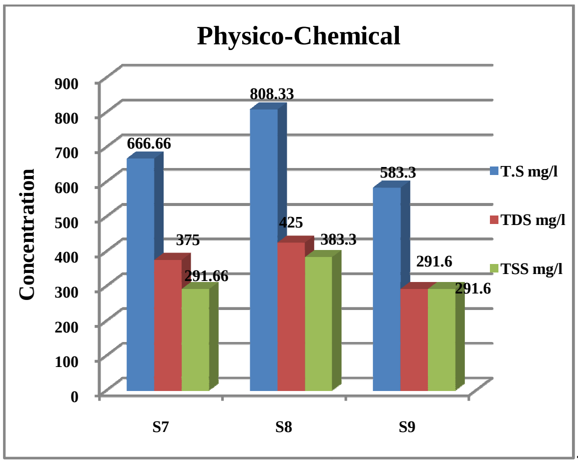


Fig. 10 showing average variation in TS, TDS and TDS at S7, S8, S9 of River Asan for the year April 2011-March 2012

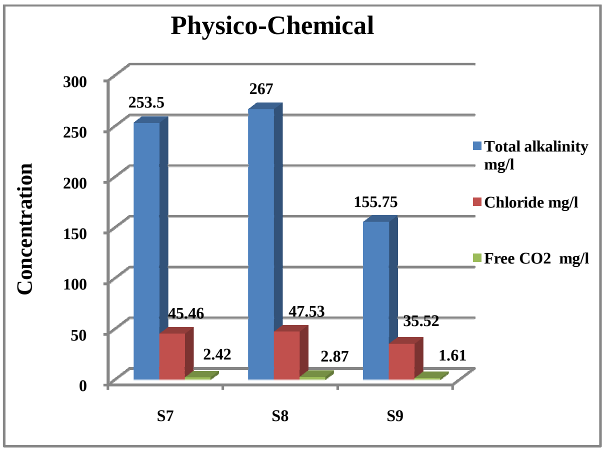


Fig. 11 showing average variation in Total Alkalinity , Chloride and Free CO2 at S7, S8, S9 of River Asan for the year April 2011-March

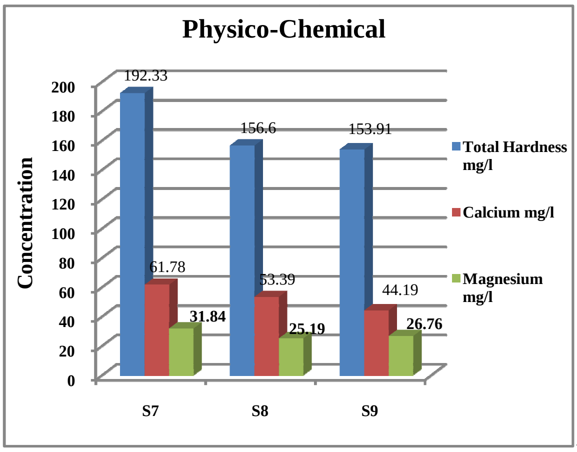


Fig. 12 showing average variation in Total Hardness, Calcium and Magnesium at S7, S8, S9 of River Asan for the year April 2011-March 2012

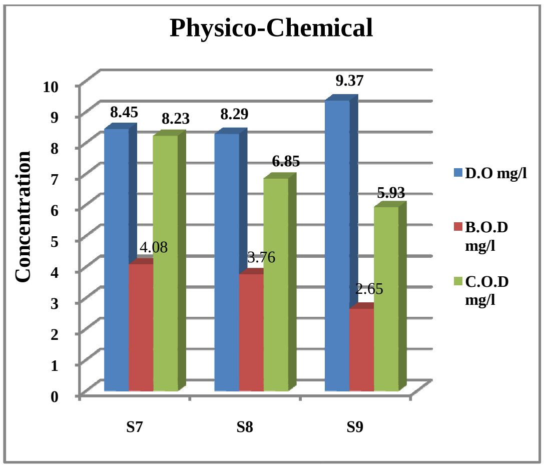


Fig. 13 showing average variation in DO, BOD and COD at S7, S8 , S9 of River Asan for the year April 2011- March 2012

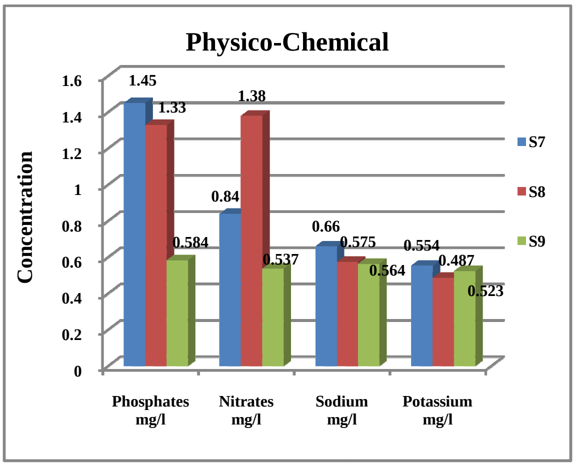


Fig.14 showing average variation in Phosphate, Nitrate, Sodium and Potassium at S7, S8, S9 of River Asan for the year April 2011-March 2012

Relationship between Physico- chemical attributes

Pearson's correlation (r values) calculated to quantify relationships between various hydrological attributes (table 4 and 5) revealed that in river Tons (table 2) transparency was positively correlated with temperature ($r = 0.236$, $p < 0.10$) whereas in river Asan (table 3) transparency was negatively correlated with temperature ($r = -0.857$, $p > 0.001$). In river Tons velocity was found highly negatively correlated with temperature and transparency ($r = -0.999$, $p > 0.001$) whereas in case of river Asan Velocity was found to be negatively correlated with temperature ($r = -0.597$ $p > 0.05$) and positively correlated with transparency ($r = 0.924$, $p > 0.001$). Turbidity was found to be positively correlated with transparency ($r = 0.307$, $p < 0.10$) in river Tons whereas turbidity was found highly positively correlated with temperature, transparency and velocity in river Asan as shown in table 5. Electrical conductivity was found to be positively correlated with temperature ($r = 0.395$, $p < 0.10$) in river Tons whereas electrical conductivity was highly positively correlated with temperature, transparency, velocity and turbidity. In river Tons total solids were negatively correlated with transparency ($r = -0.302$, $p < 0.10$) and turbidity ($r = -0.999$, $p > 0.001$) whereas in case of river Asan total solids were also negatively correlated with transparency ($r = -0.990$, $p > 0.001$) and turbidity ($r = -0.299$, $p < 0.10$). TDS was found to be positively correlated with transparency ($r = 0.059$, $p > 0.05$) and total solids ($r = 0.933$, $p > 0.001$) in river Tons whereas TDS was negatively correlated with transparency ($r = -0.988$, $p > 0.001$) but positively correlated with total solids ($r = 0.957$, $p > 0.001$) in case of river Asan. pH was negatively correlated with temperature ($r = -0.993$, $p > 0.001$) and TSS ($r = -0.473$, $p < 0.10$) in river Tons and in case of river Asan pH was found to be positively correlated with temperature ($r = 0.495$, $p < 0.05$) and TSS ($r = 0.999$, $p > 0.001$). In river Tons total alkalinity was found to be negatively correlated with TDS ($r = -0.865$, $p > 0.001$) and positively correlated with pH ($r = 0.896$, $p > 0.001$) whereas total alkalinity was found to be positively correlated with TDS ($r = 0.964$, $p > 0.001$) and pH ($r = 0.593$, $p > 0.05$) in river Asan. Total hardness was negatively correlated with electrical conductivity ($r = -0.406$, $p < 0.10$) and positively correlated with total alkalinity ($r = 0.936$, $p > 0.001$) in river tons whereas total hardness was positively correlated with electrical conductivity ($r = 0.936$, $p > 0.001$) and total alkalinity ($r = 0.457$, $p < 0.10$) in river Asan. Free CO_2 was positively correlated with temperature ($r = 0.999$, $p > 0.001$) and negatively correlated with pH ($r = -0.997$, $p > 0.001$) in river Tons whereas in river Asan free CO_2 positively correlated with temperature ($r = 0.934$, $p > 0.001$) and pH ($r = 0.773$, $p > 0.01$). DO was negatively correlated with temperature ($r = -0.951$, $p > 0.001$) and free CO_2 ($r = -0.940$, $p > 0.001$) in river tons and in river Asan it was also negatively correlated with temperature ($r = -0.989$, $p > 0.001$) and free CO_2 ($r = -0.975$, $p > 0.001$). In river Tons BOD was positively correlated with temperature ($r = 0.999$, $p > 0.001$) and negatively correlated with DO ($r = -0.947$, $p > 0.001$) and in river Asan BOD was also positively correlated with temperature ($r = 0.978$, $p > 0.001$) and negatively correlated with DO ($r = -0.939$, $p > 0.001$). Potassium, Nitrate, Phosphate and Sodium showed almost no significant correlation with each other and with other parameters during the course of study. In the present study DO was found to be negatively correlated with pH in river Asan. Gupta and Mehrotra [58], Clausen and Biggs [59] recorded negative correlation of pH with dissolved O_2.

Table 2 Pearson Correlation (r-values)calculated between physico-Chemical parameters of river Tons in Doon valley for the year April 2011-March 2012

	Temp.	Transparency	Velocity	Turbidity	EC	T.S	TDS	TSS	pH	T Alk	T HD	Ca	Mg	Cl	F CO_2	D.O	B.O.D	C.O.D	Po_4	No_3	Na	K
Temp.	1																					
Transparency	0.236	1																				
Velocity	-0.999	-0.999	1																			
Turbidity	-0.851	0.307	0.843	1																		
EC	0.395	-0.798	-0.380	-0.818	1																	
T.S	0.854	-0.302	-0.846	-0.999	0.814	1																
TDS	0.983	0.059	-0.980	-0.931	0.553	0.933	1															
TSS	0.371	-0.814	-0.356	-0.802	0.999	0.799	0.531	1														
pH	-0.993	-0.125	0.991	0.905	-0.496	-0.907	-0.998	-0.473	1													
T Alk	-0.940	-0.552	0.946	0.623	-0.060	-0.628	-0.865	-0.034	0.896	1												
T HD	-0.999	-0.224	0.999	0.858	-0.406	-0.861	-0.986	-0.382	0.994	0.936	1											
Ca	-0.998	-0.282	0.999	0.826	-0.351	-0.829	-0.974	-0.327	0.987	0.955	0.998	1										
Mg	-0.998	-0.282	0.999	0.826	-0.351	-0.829	-0.974	-0.327	0.987	0.955	0.998	1	1									
Cl	-0.762	-0.809	0.772	0.310	0.293	-0.315	-0.634	0.317	0.684	0.936	0.754	0.791	0.791	1								
F CO_2	0.999	0.203	-0.998	0.426	0.426	0.871	0.989	0.402	-0.997	-0.928	-0.999	-0.996	-0.996	-0.739	1							
D.O	-0.951	-0.524	0.956	0.648	-0.093	-0.653	-0.881	-0.067	0.910	0.999	0.947	0.964	0.964	0.924	-0.940	1						
B.O.D	0.999	0.222	-0.999	-0.859	0.409	0.862	0.986	0.385	-0.995	-0.935	-0.999	-0.998	-0.998	-0.752	0.999	-0.947	1					
C.O.D	0.922	0.593	-0.928	-0.583	0.010	0.588	0.838	-0.015	-0.873	-0.998	-0.917	-0.939	-0.939	-0.953	0.908	-0.997	0.916	1				
Po_4	0.986	0.073	-0.983	-0.926	0.541	0.928	0.999	0.519	-0.999	-0.872	-0.988	-0.977	-0.977	-0.645	0.991	-0.888	0.988	0.846	1			
No_3	-0.849	0.312	0.840	0.999	-0.820	-0.999	-0.93	-0.805	0.903	0.619	0.855	0.823	0.823	0.305	-0.866	0.645	-0.857	-0.58	-0.925	1		
Na	0.331	0.995	-0.346	0.211	-0.735	-0.206	0.157	-0.752	-0.223	-0.631	-0.319	-0.375	-0.375	-0.863	0.299	-0.606	0.317	0.670	0.171	0.216	1	
K	0.804	-0.386	-0.795	-0.996	0.863	0.995	0.898	0.850	-0.867	-0.555	-0.812	-0.775	-0.775	-0.229	0.824	-0.583	0.813	0.513	0.891	-0.996	-0.293	1

Temp. = Temperature, EC = Electric Conductivity, TS = Total Solids, TDS = Total Dissolved Solids, TSS =Total Suspended Solids, T ALK = Total Alkalinity, T HD= Total Hardness, Ca = Calcium, Mg = Magnesium FCO_2 = Free Carbon Dioxide, D.O = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, PO_4= Phosphate, NO_3 = Nitrate, Na = Sodium, K = Potassium

Table 3 Pearson Correlation (r-values)calculated between physico-Chemical parameters of river Asan in Doon valley for the year April 2011-March 2012

	Temp.	Transparency	Velocity	Turbidity	EC	T.S	TDS	TSS	pH	T Alk	T HD	Cl	Mg	Cl	FCO_2	D.O	B.O.D	C.O.D	Po_4	No_3	Na	K
Temp	1																					
Transparency	-0.857	1																				
Velocity	-0.597	0.924	1																			
Turbidity	0.364	0.166	0.528	1																		
EC	0.230	0.303	0.642	0.990	1																	
T.S	0.779	-0.990	-0.968	-0.299	-0.430	1																
TDS	0.926	-0.988	-0.855	-0.012	-0.152	0.957	1															
TSS	0.495	-0.871	-0.992	-0.628	-0.730	0.930	0.785	1														
pH	0.495	-0.871	-0.992	-0.628	-0.731	0.930	0.785	0.999	1													
T Alk	0.993	-0.911	-0.687	0.253	0.115	0.846	0.964	0.593	0.593	1												
T HD	0.557	-0.051	0.331	0.976	0.936	-0.085	0.204	-0.444	-0.445	0.457	1											
Ca	0.881	-0.513	-0.148	0.760	0.662	0.390	0.639	0.027	0.026	0.820	0.883	1										
Mg	0.296	0.236	0.588	0.997	0.997	-0.367	-0.084	-0.682	-0.683	0.183	0.958	0.712	1									
Cl	0.986	-0.931	-0.722	0.204	0.065	0.872	0.976	0.633	0.633	0.998	0.411	0.790	0.133	1								
F CO_2	0.934	-0.984	-0.844	0.007	-0.132	0.951	0.999	0.773	0.773	0.969	0.224	0.654	-0.064	0.980	1							
D.O	-0.989	0.922	0.705	-0.227	-0.089	-0.860	-0.971	-0.614	-0.614	-0.999	-0.433	-0.805	-0.157	-0.999	-0.975	1						
B.O.D	0.978	-0.731	-0.418	0.549	0.427	0.631	0.828	0.304	0.303	0.947	0.718	0.960	0.488	0.929	0.839	-0.939	1					
C.O.D	0.806	-0.387	-0.007	0.844	0.761	0.257	0.524	-0.114	-0.115	0.731	0.940	0.989	0.804	0.696	0.541	-0.714	0.911	1				
Po_4	0.992	-0.788	-0.495	0.475	0.347	0.696	0.873	0.385	0.385	0.971	0.655	0.932	0.411	0.958	0.883	-0.965	0.996	0.872	1			
No_3	0.771	-0.988	-0.971	-0.311	-0.441	0.999	0.954	0.935	0.934	0.840	-0.098	0.379	-0.378	0.866	0.947	-0.854	0.622	0.245	0.687	1		
Na	0.592	-0.093	0.291	0.966	0.920	-0.043	0.245	-0.406	-0.407	0.494	0.999	0.902	0.945	0.449	0.265	-0.471	0.746	0.954	0.686	-0.056	1	
K	-0.037	0.546	0.823	0.916	0.963	-0.655	-0.411	-0.886	-0.887	-0.153	0.808	0.438	0.943	-0.203	-0.392	0.179	0.170	0.560	0.085	-0.665	0.782	1

Temp. = Temperature, EC = Electric Conductivity, TS = Total Solids, TDS = Total Dissolved Solids, TSS =Total Suspended Solids, T ALK = Total Alkalinity, T HD= Total Hardness, Ca = Calcium, Mg = Magnesium, FCO_2 = Free Carbon Dioxide, D.O = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = ChemicalOxygen Demand, PO_4= Phosphate, NO_3 = Nitrate, Na = Sodium, K = Potassium

Phytoplankton diversity and their relationship with hydrological attributes

In the present study the phytoplankton inhabitating the river Tons and Asan comprises of 35 taxa out of which Chlorophyceae constitutes (15 genera), Bacillariophyceae (14 genera) and Myxophyceae (6 genera). Mean variation of all the six sites of both the rivers is shown in table 4. The diversity of phytoplankton in both the rivers was recorded to be maximum for Bacillariophyceae 197.33±78.61 Unit/ l at S4, 153.83±64.19 unit/l at S5, 158.91±62.87 unit/l at S6 and 118.0 ±72.21 Unit/l at S7, 123.08±80.19 Unit/l at S8 and 257.00±169.23 Unit/l at S9. Among the phytoplankton the family Bacillariophyceae was represented by *Ceratoneis, Amphora, Caloneis, Fragilaria, Navicula, Synedra, Diatoms, Gomphonema, Pinnularia, Melosira, Tabellaria, Denticula, Cymbella, and Cyclotella.* The Bacillariophyceae was found to be positively correlated with velocity ($r = 0.376$, $p < 0.10$), pH ($r = 0.253$, $p < 0.10$) and DO ($r = 0.630$, $p< 0.02$) in river Tons whereas in river Asan Bacillariophyceae was positively correlated with velocity ($r = 0.576$, $p > 0.05$) and DO ($r = 0.985$, $p > 0.001$) but negatively correlated with pH ($r= -0.471$, $p <0.10$). The Chlorophyceae was found to be highest in river Tons 154.25±85.05 Unit/l at S4, 116.75±45.47 Unit/l at S5 and 87.50±42.06 Unit/l at S6 whereas in river Asan the diversity of Chlorophyceae was found to be lowest 77.16 ±48.54 Unit/l at S7, 77.33±42.08 Unit /l at S8 and 125.75±59.17 Unit/l at S9. The family Chlorophyceae was represented by *Chlorella, Chlaymydomonas, Spirogyra, Ulothrix, Hydrodictyon, Cladophore, Cosmarium, Chlorococcum, Oedogonium, Microspora, Desmidium, Chara, Zygenema, Syndesmus, and Volvox.* Maximum number of total phytoplankton indicates good physicochemical conditions [60]. Chlorophyceae showed two maxima in both rivers. This bimodal pattern of peak population was also reported [20 61]. Chlorophyceae was found to be positively correlated with turbidity ($r = 0.368$, $p <0.10$), total alkalinity ($r = 0.655$, $p >0.02$), DO ($r =0.946$, $p > 0.001$) and negatively correlated with temperature ($r = -0.800$, $p < 0.001$), free CO_2 ($r = -0.780$, $p > 0.01$) and phosphate ($r = -0.691$, $p> 0.01$) in river Tons whereas in river Asan Chlorophyceae was found to be positively correlated with transparency ($r = 0.858$, $p >0.001$), DO ($r = 0.990$, $P> 0.001$) and potassium ($r = 0.040$, $p < 0.10$) but negatively correlated with all other parameters. In the present study the diversity of Myxophyceae values ranged from 25.91±19.23 Unit/l to 36.16±25.05 unit/l in river Tons and 28.66 ±21.74 Unit/l to 51.33±27.56 Unit/l in river Asan. Dominance of Myxophycean population in polluted habitat has also been reported [62 61 63]. The Myxophyceae was represented by *Nostoc, Anabaena, Oscillatoria, Rivularia, Coccochloris, Phormidium.* Myxophyceae was found to be positively correlated with temperature ($r = 0.071$, $p >0.01$) and DO ($r = 0.239$, $p < 0.10$) in river Tons whereas it was found negatively correlated with temperature ($r = -0.973$, $p >0.001$) and positively correlated with DO ($r = 0.931$, $p >0.001$) in river Asan. Phosphate, nitrate and chloride contents play a vital role in their distributional pattern [64 65].

Table 4 Qualitative and quantitative distribution (mean values of six sampling sites) of phytoplankton (Unit/l) in River Tons and River Asan for the period of April 2011- March 2012

Phytoplankton	River Tons			River Asan		
	S4	S5	S6	S7	S8	S9
Chlorophyceae						
Chlorella	18.58±9.68	13.16±10.11	10.50±6.77	7.50 ±8.85	6.83±6.76	10.5±8.41
Chlaymydomonas	13.83±11.09	9.41±4.90	6.50±4.90	5.25 ±3.22	3.25±2.26	9.08±5.51
Spirogyra	16.58±13.93	6.91±4.25	6.00±5.22	4.08 ±3.89	3.58±3.05	9.41±6.15
Ulothrix	8.50±5.91	8.41±6.03	4.50±3.89	3.41 ±2.84	2.75±2.83	8.08±5.55
Hydrodictyon	5.91±4.37	6.91±3.94	4.00±3.43	4.50 ±3.17	3.75±2.76	8.33±4.81
Cladophore	8.83±5.96	4.16±3.51	6.33±4.75	7.25 ±5.47	4.00±3.43	7.83±5.71
Cosmarium	5.91±5.46	9.41±6.69	6.50±5.35	2.66 ±2.93	2.50±2.31	8.33±7.30
Chlorococcum	9.83±6.04	6.33±4.11	3.16±2.85	2.66 ±2.96	4.58±4.12	5.25±4.61
Oedogonium	12.91±6.63	10.66±6.87	6.91±5.61	5.66 ±4.31	7.58±4.54	6.75±4.53
Microspora	9.33±8.92	9.16±5.40	6.25±4.47	5.58 ±5.33	4.16±3.37	12.25±5.75
Desmidium	15.41±8.33	14.83±5.78	9.41±5.82	7.41 ±5.38	10.58±5.36	12.33±3.86
Chara	9.08±3.91	3.83±2.85	3.16±2.28	5.75 ±5.65	6.83±4.74	9.50±6.15
Zygenema	7.75±4.04	2.50±2.57	3.41±3.67	7.00 ±5.51	7.58±4.98	6.08±5.64
Syndesmus	5.58±4.56	4.75±3.74	7.33±4.37	4.58 ±3.87	4.83±3.83	6.50±4.75
Volvox	6.16±4.30	6.25±3.81	3.50±2.57	3.83 ±3.09	4.50±3.11	3.50±2.50
Total	154.25±85.05	116.75±45.47	87.50±42.06	77.16 ±48.54	77.33±42.08	125.75±59.17
Bacillariophyceae						
Ceratoneis	9.00±3.61	7.41±3.87	6.00±3.74	5.91 ±4.81	8.66±7.16	9.16±3.71
Amphora	9.66±8.55	4.91±4.05	3.83±3.71	8.08 ±6.05	6.66±5.28	8.25±5.95
Caloneis	4.00±3.83	3.91±3.67	5.58±5.08	5.16 ±5.63	7.41±6.69	2.00±2.37
Fragilaria	31.50±18.03	19.91±11.04	19.16±8.38	14.33 ±7.95	12.16±9.08	31.83±22.92
Navicula	25.33±10.81	31.41±22.65	25.00±10.85	16.83 ±8.21	14.75±9.81	39.16±24.74
Synedra	8.91±3.98	11.66±6.25	12.91±9.37	8.16 ±4.10	9.75±6.18	14.16±9.57
Diatoms	20.16±6.33	12.00±5.73	21.91±8.09	9.41 ±5.10	12.25±5.29	30.91±17.58
Gomphonema	11.25±9.20	10.33±6.85	12.33±5.28	6.75 ±4.11	10.58±8.77	19.08±11.72
Pinnularia	6.25±4.47	7.58±5.43	5.75±4.43	7.66 ±5.19	7.83±4.83	12.00±7.80
Melosira	13.41±4.62	6.41±4.33	5.75±4.47	5.41 ±5.14	5.50±4.68	8.50±5.17
Tabellaria	18.25±5.62	13.50±10.63	9.16±7.27	9.16 ±7.40	8.08±6.85	18.25±14.30
Denticula	12.75±7.84	4.75±2.73	13.16±6.80	9.91 ±7.26	8.66±6.18	28.58±23.59
Cymbella	13.25±4.95	17.50±11.95	6.16±5.98	5.25 ±3.69	5.00±5.25	32.08±28.72
Cyclotella	13.58±5.19	2.50±2.90	12.16±7.89	5.91 ±4.50	5.75±4.04	3.00±3.19
Total	197.33±78.61	153.83±64.19	158.91±62.87	118.0 ±72.21	123.08±80.19	257.00±169.23
Myxophyceae						
Nostoc	6.75±5.17	3.33±2.57	6.25±5.59	4.91 ±4.07	5.83±5.40	9.66±4.84
Anabaena	6.25±4.61	4.58±4.20	6.91±5.63	2.66 ±2.01	7.00±4.26	7.41±4.52
Oscillatoria	1.91±2.39	3.00±3.01	5.33±5.12	5.41 ±4.20	6.41±3.91	8.66±4.82
Rivularia	5.58±3.91	4.91±3.75	4.41±3.44	3.50 ±3.42	6.41±5.05	8.16±5.98
Coccochloris	7.41±6.33	4.83±4.32	4.33±3.11	5.50 ±4.96	2.50±2.46	4.00±3.74
Phormidium	8.25±6.92	5.25±4.13	4.00±2.66	6.66 ±4.90	6.00±3.74	13.41±10.25
Total	36.16±25.05	25.91±19.23	31.25±17.88	28.66 ±21.74	34.16±21.77	51.33±27.56

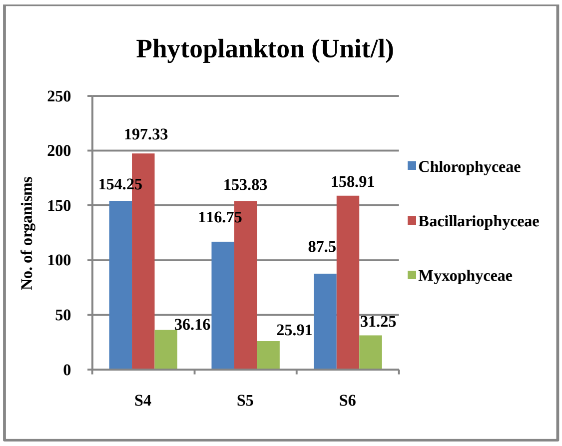


Fig.15 showing Phytoplankton (Unit/l) at S4, S5, S6 of River Tons for the April 2011-March 2012

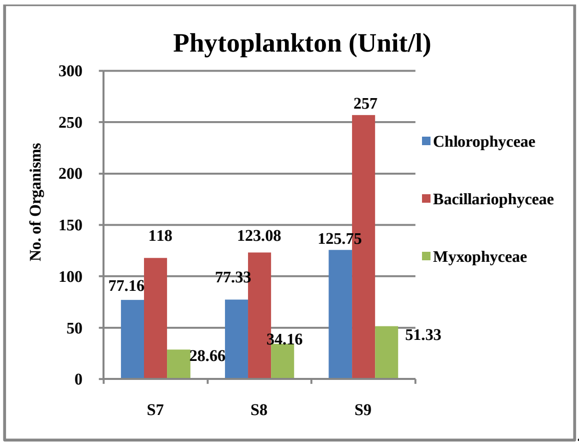


Fig. 16 showing Phytoplankton (Unit/l) at S7, S8, S9 of River Asan for the year April 2011-March 2012

Zooplankton diversity and their relationship with hydrological attributes

In the present study the zooplankton inhabitating the river Tons and Asan comprises of 28 taxa out of which Protozoa consist of (10 genera), Rotifera (11 genera), Copepoda (6 genera) and Ostracoda (2 genera). Mean variation of all the six sites of both the rivers is shown in table 5. The diversity of zooplankton was recorded to be maximum for Rotifera 152.16±96.98 Unit/l at S4, 117.83±68.79 Unit/l at S5, and 95.75±58.11 Unit/l at S6 in river Tons and 64.08±47.40 Unit/l at S7, 66.00±50.59 Unit/l at S8 and 137.25±89.62 Unit/l in river Asan. The dominance of Rotifera was not unexpected as it has been reported by Jeje and Fernando [66] Egborge and Tawari [67] Akin-Oriola [68] and Mustapha and Omotosho [69] as the most dominant zooplankton group in most aquatic ecosystems. Among the zooplankton the Rotifera was represented by *Keratella, Nolthoca, Rotatoria, Testudinella, Ascomorpha, Trichocera, Philodina, Asplanchna, Pompholix, Brachionus, Polyarthra.* About 1700 species of rotifers have been described from the different parts of the world and 500 species (only 330 species belonging to 63 genera and 25 families have so far been authenticated) was described from Indian water bodies [15 70]. Rotifera was found to be positively correlated with pH ($r = 0.690$, $p < 0.02$), total alkalinity ($r = 0.939$, $p > 0.001$) and DO ($r = 0.927$, $p > 0.001$) and negatively correlated with temperature ($r = -0.767$, $p > 0.01$), and BOD ($r = -0.758$, $p > 0.01$) in river Tons whereas Rotifera was negatively correlated with pH ($r = -0.479$, $p > 0.10$) and total alkalinity ($r = -0.990$, $p > 0.001$) but positively correlated with DO ($r = 0.987$, $p > 0.001$) in river Asan. In the present study Protozoans was found to be highest in river Tons 121.25±82.45 Unit/l at 101.66±65.43 Unit/l and 74.50±43.97 S6 and lowest in river Asan 60.25±45.53 Unit/l at S7, 59.16±43.35 Unit/l at S8 and108.75±70.30 Unit/l at S9. The Protozoa was represented by *Actinophrys, Actinosphaerium, Euglena, Paramecium, Peridinium, Campenella, Epistylis, Vorticella, Arcella and Diffugia*. The population density and biomass of zooplankton during the study was traced to high population of phytoplankton food source which were highly abundant within the river. According to Rocha [24] increase in primary production (phytoplankton), tends to be followed by increase in zooplankton number and biomass. Muylaert [71] also corroborated the finding that zooplankton biomass usually reaches their peak when phytoplankton population of river ecosystem is high. The protozoa was found to be positively correlated with TSS ($r = 0.096$, $p < 0.10$) and chloride ($r = 0.974$, $p > 0.001$) and negatively correlated with temperature ($r = -888$, $p > 0.001$) and phosphates ($r = -0.800$, $p < 0.001$) in river Tons whereas in case of river Asan protozoa was negatively correlated with TSS ($r = -0.571$, $p > 0.05$) and chloride ($r = -0.989$, $p > 0.001$) but positively correlated with transparency ($r = 0.870$, $p > 0.001$) and DO ($r = 0.993$, $p > 0.001$). In river Tons Copepoda were in the range of 51.5±37.77 Unit/l to 68.50±37.81 Unit/l and 26.91±0.63 Unit/l to 59.08±38.01 Unit/l in river Asan. The Copepoda was represented by *Cyclops, Diaptomus, Daphnia, Bosmina, Helobdella and Nauplius Stages.* Copepoda were positively correlated with velocity ($r = 0.216$, $p < 0.10$) and total alkalinity ($r = 0.521$, $p < 0.05$) and negatively correlated with temperature ($r = -0.200$, $p > 0.10$) and free CO_2 ($r = -0.167$, $p < 0.10$) in river Tons whereas in river Asan Copepoda were positively correlated with DO ($r = 0.995$, $p > 0.001$) and negatively correlated total solids ($r = -0.904$, $p > 0.001$). In river Tons Ostracoda were recorded maximum and minimum in river Asan and represented by Cypris and Stenocypris. Ostracoda were positively correlated with pH, total alkalinity, Chloride and DO in river Tons but negatively correlated with pH, total alkalinity, Chloride in river Asan. The species composition of zooplankton with dominance of rotifers was also observed in present study. Arora and Mehra [15] also observed richness and dominance of rotifers among zooplankton in Yamuna river. Kaushik and Saksena [72] observed that the polluted zone of river Kali had a decreased population of zooplanktonic forms. This is in agreement with present study [73] studied the zooplankton of lower river meuse, Belgium. They studied the impact of industrial and municipal discharges on zooplanktonic population where rotifers were dominant while Ostracoda and copepods were less abundant. However the total number of Zooplankton in river Tons were considerably higher than river Asan indicating that river Asan is polluted as also concluded after the investigation of physico-chemical parameters. Pearson’s correlation coefficient indicated that several environmental variables exert a considerable influence on the zooplankton abundance especially dissolved oxygen, temperature, total alkalinity, total hardness, phosphate and pH. Consistent with our findings, Sarkar and chaudhary [74] Ward [75] reported significant multiple correlations between plankton abundance and several physical and chemical variables in their study. Our study confirms the influence of these abiotic factors on zooplankton population.

Table 5 Qualitative and quantitative distribution (mean values of six sampling sites) of Zooplankton (Unit/l) in River Tons and River Asan for the period of April 2011- March 2012

Zooplankton	River Tons			River Asan		
	S4	S5	S6	S7	S8	S9
Protozoans						
Actinophrys	11.00±8.07	9.25±6.49	5.91±5.21	4.66±3.79	4.91±3.60	13.00±8.31
Actinosphaerium	9.25±7.25	8.00±6.03	6.50±4.25	6.08±5.12	5.50±4.85	12.75±9.80
Euglena	13.66±10.67	11.25±7.91	9.50±6.25	7.83±7.14	6.75±5.49	11.00±6.01
Paramecium	15.66±11.26	13.58±8.15	8.83±4.56	7.58±4.27	6.00±3.71	10.75±7.28
Peridinium	10.41±8.60	9.66±7.04	4.41±3.65	4.75±4.53	6.75±5.15	9.91±7.34
Campenella	9.41±7.42	9.83±8.38	5.83±3.88	4.25±3.62	5.75±4.24	6.91±5.07
Epistylis	11.66±6.84	9.16±6.60	6.83±5.58	3.41±3.34	3.83±3.29	9.75±6.83
Vorticella	13.25±8.93	9.00±5.70	9.91±5.12	6.33±5.03	6.25±4.99	9.83±6.23
Arcella	13.66±8.42	11.50±5.12	8.25±3.76	5.83±3.80	7.16±5.18	13.00±8.54
Diffugia	13.25±6.86	10.41±7.06	8.50±5.03	9.50±6.30	6.25±4.28	11.83±7.28
Total	121.25±82.45	101.66±65.43	74.50±43.97	60.25±45.53	59.16±43.35	108.75±70.30
Rotifera						
Keratella	13.00±9.04	12.16±7.79	10.25±5.86	6.16±4.70	6.50±4.64	13.58±9.22
Nolthoca	15.75±9.76	10.75±8.51	7.58±5.45	4.58±4.29	5.41±4.94	11.41±7.08
Rotatoria	13.58±8.38	7.08±3.98	4.41±3.84	3.58±2.53	5.33±5.80	8.75±5.02
Testudinella	14.91±10.89	8.25±5.47	8.91±5.77	5.58±4.60	5.58±3.75	12.91±7.69
Ascomorpha	13.16±8.28	11.41±5.77	10.33±6.31	6.83±5.70	7.16±5.82	15.41±10.15
Trichocera	15.66±10.62	8.66±4.79	11.08±8.83	5.66±3.65	5.83±4.62	12.25±7.86
Philodina	14.83±11.86	13.33±8.02	11.41±6.00	7.16±4.91	6.00±3.07	11.08±7.47
Asplanchna	12.58±6.61	10.00±5.98	6.75±4.37	7.00±4.70	7.58±5.74	13.08±7.12
Pompholix	13.41±6.22	13.41±8.07	7.33±4.75	7.16±4.56	6.16±4.52	15.16±12.45
Brachionus	12.91±6.21	12.83±6.97	10.50±5.43	5.25±4.30	4.50±4.37	13.41±10.25
Polyarthra	12.33±9.07	9.91±7.42	7.16±4.50	5.08±5.48	5.91±5.03	10.16±8.38
Total	152.16±96.98	117.83±68.79	95.75±58.11	64.08±47.40	66.00±50.59	137.25±89.62
Copepoda						
Cyclops	12.50±5.64	7.33±4.88	12.08±8.45	5.16±3.12	7.25±4.53	10.91±5.61
Diaptomus	13.58±7.95	7.08±6.81	7.00±5.73	4.41±3.96	4.00±3.35	7.33±4.63
Daphnia	12.66±8.03	9.58±6.34	9.16±7.15	7.66±4.45	4.75±3.86	11.16±6.33
Bosmina	10.08±6.37	5.66±5.15	9.16±7.43	5.16±4.32	2.50±3.14	10.25±8.80
Helobdella	7.33±4.49	7.75±5.24	8.33±6.99	4.75±4.22	3.08±3.23	6.91±5.48
Nauplius Stages	12.33±5.86	14.08±9.98	10.50±7.96	7.41±4.87	5.33±4.51	12.50±8.55
Total	68.50±37.81	51.5±37.77	56.25±42.38	34.58±23.47	26.91±0.63	59.08±38.01
Ostracoda						
Cypris	11.75±7.25	5.91±3.84	4.5±3.52	4.41±4.83	2.33±2.46	8.33±4.27
Stenocypris	8.66±7.35	6.25±5.27	7.5±5.10	2.83±3.56	3.00±3.07	7.58±5.74
Total	20.41±14.55	12.16±9.03	12.00±8.50	7.25±8.35	5.33±5.41	15.91±9.91

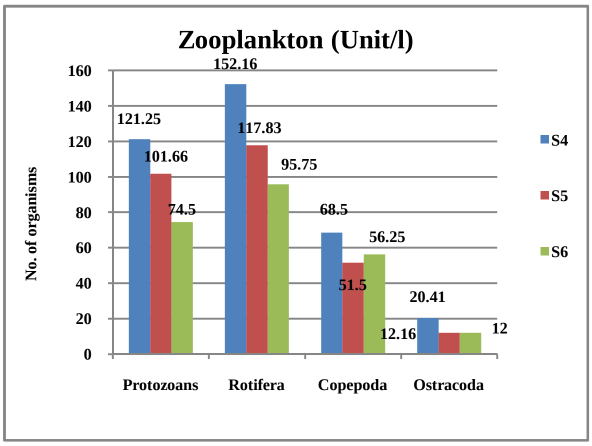


Fig. 17 showing Zooplankton (Unit/l) at S4, S5, S6 of River Tons for the year April 2011-March 2012

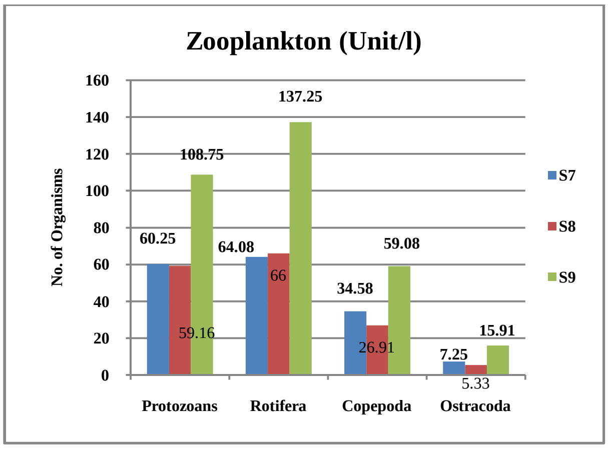


Fig. 18 showing Zooplankton (Unit/l) at S7, S8, S9 of River Asan for the year April 2011-March 2012

Table 6 Pearson Correlation (r-values)calculated between Phytoplankton and Zooplankton diversity and physico-Chemical environmental variables of river Tons in Doon valley for the year April 2011-March 2012

	Temp.	Transparency	Velocity	Turbidity	EC	T.S	TDS	TSS	pH	T Alk	T HD	Ca	Mg	Cl	FCO_2	D.O	B.O.D	C.O.D	Po_4	No_3	Na	K
Chlorophyceae	-0.800	-0.771	0.810	0.368	0.233	-0.374	-0.680	0.258	0.728	0.956	0.793	0.828	0.828	0.998	-0.780	0.946	-0.791	-0.969	-0.691	0.363	-0.830	-0.289
Bacillariophyceae	-0.360	-0.991	0.376	-0.181	0.713	0.175	-0.188	0.731	0.253	0.655	0.3496	0.404	0.404	0.878	-0.329	0.630	-0.347	-0.693	-0.202	-0.185	-0.999	0.262
Myxophyceae	0.071	-0.952	-0.055	-0.583	0.944	0.578	0.248	0.952	-0.183	0.271	-0.083	-0.024	-0.024	0.591	0.105	0.239	0.086	-0.319	0.234	-0.587	-0.917	0.649
Protozoans	-0.888	-0.656	0.895	0.515	0.070	-0.521	-0.791	0.096	0.830	0.991	0.882	0.908	0.908	0.974	-0.872	0.986	-0.881	-0.996	-0.800	0.511	-0.728	-0.441
Rotifera	-0.767	-0.804	0.778	0.318	0.284	-0.324	-0.640	0.309	0.690	0.939	0.759	0.797	0.797	0.999	-0.745	0.927	-0.758	-0.955	-0.651	0.313	-0.859	-0.237
Copepoda	-0.200	-0.999	0.216	-0.342	0.820	0.336	-0.022	0.834	0.089	0.521	0.188	0.246	0.246	0.787	-0.167	0.492	-0.186	-0.563	-0.036	-0.346	-0.990	0.419
Ostracoda	-0.473	-0.967	0.487	-0.058	0.621	0.052	-0.308	0.641	0.370	0.744	0.462	0.514	0.514	0.930	-0.443	0.721	-0.460	-0.776	-0.321	-0.063	-0.987	0.141

Temp. = Temperature, EC = Electric Conductivity, TS = Total Solids, TDS = Total Dissolved Solids, TSS =Total Suspended Solids, T ALK = Total Alkalinity, T HD= Total Hardness, Ca = Calcium, Mg = Magnesium, FCO_2 = Free Carbon Dioxide, D.O = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, PO_4= Phosphate, NO_3 = Nitrate, Na = Sodium, K = Potassium

Table 7 Pearson Correlation (r-values)calculated between Phytoplankton and Zooplankton diversity and physico-Chemical environmental variables of river Asan in Doon valley for the year April 2011-March 2012

	Temp	Transparency	Velocity	Turbidity	ECC	T.S	TDS	TSS	pH	T Alk	T HD	Ca	Mg	Cl	FCO_2	D.O	B.O.D	C.O.D	Po_4	No_3	Na	K
Chlorophyceae	-0.999	0.858	-0.362	-0.362	-0.228	-0.781	-0.927	-0.497	-0.497	-0.993	-0.555	-0.880	-0.294	-0.986	-0.934	0.990	-0.977	-0.804	-0.992	-0.772	-0.590	0.040
Bacillariophyceae	-0.999	0.843	0.576	-0.389	-0.256	-0.762	-0.916	-0.472	-0.471	-0.989	-0.579	-0.893	-0.322	-0.981	-0.924	0.985	-0.983	-0.821	-0.995	-0.753	-0.613	0.010
Myxophyceae	-0.973	0.718	0.399	-0.566	-0.445	-0.616	-0.816	-0.285	-0.284	-0.940	-0.731	-0.965	-0.505	-0.922	-0.828	0.931	-0.999	-0.919	-0.994	-0.606	-0.759	-0.190
Protozoans	-0.999	0.870	0.617	-0.341	-0.206	-0.794	-0.935	-0.517	-0.516	-0.995	-0.537	-0.869	-0.273	-0.989	-0.942	0.993	-0.972	-0.791	-0.989	-0.786	-0.572	0.062
Rotifera	-0.999	0.848	0.583	-0.380	-0.247	-0.768	-0.919	-0.480	-0.479	-0.990	-0.572	-0.889	-0.313	-0.982	-0.927	0.987	-0.981	-0.816	-0.994	-0.759	-0.606	0.020
Copepoda	-0.972	0.953	0.768	-0.136	0.003	-0.904	-0.988	-0.684	-0.684	-0.992	-0.348	-0.747	-0.065	-0.997	-0.991	0.995	-0.902	-0.645	-0.936	-0.898	-0.387	0.269
Ostracoda	-0.984	0.934	0.729	-0.195	-0.056	-0.877	-0.978	-0.640	-0.640	-0.998	-0.403	-0.785	-0.124	-0.999	-0.982	0.999	-0.689	-0.689	-0.955	-0.871	-0.441	0.212

Temp. = Temperature, EC = Electric Conductivity, TS = Total Solids, TDS = Total Dissolved Solids, SS =Total Suspended Solids, T ALK = Total Alkalinity, T HD= Total Hardness, Ca = Calcium, Mg = Magnesium, FCO_2 = Free Carbon Dioxide, D.O = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, PO_4=Phosphate, NO_3 = Nitrate, Na = Sodium, K = Potassium

CONCLUSION

The river water is a natural medium for the growth of aquatic flora and fauna and the fluxing of the wastes by natural or anthropogenic factors cause a disturbance in its composition. This causes the change in the optimum conditions favorable for the growth of the aquatic life. Very contrasted hydro and biological conditions were experienced between the two rivers during the course of present study. The overall plankton diversity was higher in river Tons than river Asan. It might be due to the conditions that are more feasible and adaptable for the planktonic diversity present in river Tons, however the river was no more free from pollution but the abiotic factors which were in good condition made the plankton to survive in water of river Tons. It may be concluded that pollution of the river Asan has attained alarming dimensions, adversely its algal community which serves as natural oxygenator of the river. It has become unsuitable for human consumption. The physico-chemical parameters play an important role in growth and sustainability of planktonic diversity in river ecosystem. The hydrological parameters of river Tons and Asan have been greatly deteriorated due to anthropogenic and industrial activities. The abiotic factors of both rivers have direct effect on the diversity of plankton and result in decreased planktonic diversity. If all the necessary measures were taken by Government and non-Government simultaneously and seriously can go a long way in alleviating and abating further deterioration of both the rivers with a view to restore its natural unpolluted and healthy ecosystem.

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