ISSN (Print 0974-2115) (Online 2349-8552)
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Limnological assessment of anthropogenic activities of River Henwal

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ABSTRACT

The River Henwal is ecological important tributary of River Ganga and drain in the western part of Uttarakhand, India. As it flows through the commercial and city areas, the large amount of wastages discharged inform of domestic and commercial wastewater and other activities like clothes washing and bathing using detergent and soaps. Also due to its aesthetic importance large number of tourism activities is also affecting the water body from its originating point itself. In the present study, water quality of the river is assessed at 4 sampling locations including one control site, with the comprehensive pollution index (CPI) by considering the 11 physiochemical parameters like conductivity, turbidity, total solids (TS), dissolved oxygen (DO), free CO_2, total alkalinity (TA), total hardness (TH), Ca hardness, Mg hardness, Cl^-, phosphate and eight heavy metals (Zn, Pb, Mn, Fe, Cu, Al, Cd and Mg). Besides this, Simpson's diversity index (D), Shannon-Weaver index (H) and Taxon Evenness (E) are also calculated to get the diversity of planktons and their impact on water quality of river. The CPI was found to be 1.88-4.37 (CPI > 2), which is indicates that water quality of River Henwal is slightly and severely polluted too on different sites. The high value of Simpson, Shannon-Weiner index and group evenness was 1.60, 4.88 and 0.47 respectively. Therefore, in this study the water quality was found unfit for drinking purposes and requires proper treatment before use.

KEY WORDS: CPI, Simpson's index (D), Shannon-Weaver index (H), River Henwal, River Ganga Tributary, Uttarakhand, Chamba, Freshwater ecosystem.

1. INTRODUCTION

In India, 14 major river systems shares about 83% of the drainage basin. The Himalayas are the source of freshwater rivers so they can be called "the cradle of major rivers" that supports the life of many ecosystems (Matta, 2010; Cherian, 2010; Prachi, 2011; Singh, 2011; Khanna, 2011). The Himalayan Rivers receive about 20-30 % of their water from melted snow during the summer and monsoon seasons and are also important in a geopolitically context which has been realized and attracted the attention of country's planners towards the developmental activities of this mountain region (Matta, 2015, 2016).

Garhwal region in Uttarakhand state lying between the latitude of 29° 26' - 31° 28' N and longitude 77° 99' - 80° 6' E with an area of 30,000 km (approx) has vast source of fresh water bodies are present in the form of rivers, rivulets, tributaries, and springs, fulfilling the freshwater requirement of the population (Khanna, 2009, 2010; Matta, 2011, 2014; Singh, 2010; Tewari, 2010). Along with a large number of snow-fed rivers and streams such as Alaknanda, Bhagirathi, Mandakini Dhauliganga, Pindar and Ganga River, there are so many springs fed rivers such as Bhilangna, Nayar, Gular, Song, Suswa, Henwal and hundreds of rivulets (Matta, 2014, 2015).

River Henwal is spring fed river. It originates from Kaddukhal (Near Surkanda Devi Temple, Chamba, Uttaranchal) and its length is near about 38 kilometers. This river can be divided into three different ecological sections, *viz.*, the upper, the middle and the lower section. River substratum is stony, rocky and pebbly and finally, it is sandy, when it meets the River Ganga (Bhadauriya, 2011; Khanna, 2011, 2012; Arora, 2014; Matta, 2014). Due to the great variation in the velocity and temperature of the water, the biodiversity may also vary.

The present study is to evaluate the influence of anthropogenic activities on water quality in terms of limnological characters of spring fed River Henwal, a tributary of River Ganga. Henwal River is originating from Surkanda hills (2900 msl) in the greater Himalayas and merges into River Ganga at Shivpuri. The present study has been carried out by considering the importance of aquatic ecosystems of Himalayas with special reference to Garhwal region.

2. MATERIALS AND METHOD

Study Area: The present work carried out in Chamba, Distt. Tehri Garhwal to determine pollution status of River Henwal, to be found in newly carved state of Uttarakhand. Chamba is located at a junction of roads between Rishikesh and Mussoorie with the Tehri Dam reservoir, New Tehri. It's nearby to some tourist places like Surkanda Devi Temple, Dhanaulti, Kanatal, Ranichauri, and New Tehri, halfway between Dhanaulti and Chamba. Like other destinations, Chamba (the small hill town of Uttarakhand) is until now unknown to most tourists and just 50km far away from Mussoorie and therefore it is remained as unspoiled and fresh like a daisy for the few lucky people who looking for new places to adventure, explore and enjoy. Chamba is located at an elevation of 1600m above sea level with coordinates 30.21°N 78.23°E. There are good and pleasant views of pine and deodar trees.

Physico-chemical parameters of River Henwal were exmined during the study period. Water samples were taken from three different sites of Henwal River *i.e.* from Nagni, Jajal and Kharee (Fig. 1). This river is the tributary of Holy River Ganga proving water for irrigation, domestic and for other purposes. Due to number of uses, complete monitoring program of river water quality is becoming a essential in order to protect human health and susceptible fresh water resources (Kannel, 2007).

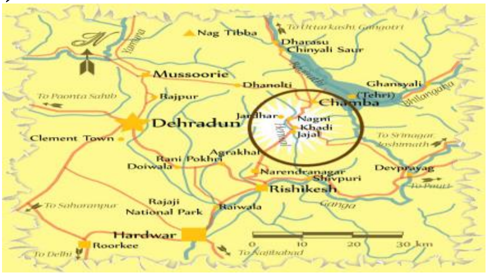

Figure.1. Map showing sampling location on River Henwal

Samples collection and analysis: Seasonally sampling was done during 2011 to 2012. Samples were collected in clean plastic bottles and stored in a deep freezer (-20ºC) till analysis in laboratories. Triplicate sampling was done on every site and mean value for each parameter was observed. The physical parameters like Temperature, pH, Transparency, Velocity, Free CO_2 and DO are recorded on the spot, other parameters are analyzed in the Laboratory using standard methods (Khanna, 2011; APHA, 2012).

Comprehensive pollution index (CPI): The CPI is used to depict the overall water quality through simple numerical number and classify into different categories (Zhao, 2012). It is measured by the following equations as:

$$PI = \frac{Measured\ concentration\ of\ individual\ parameter}{Standard\ permissible\ concentration\ of\ parameter} \quad (1)$$

$$CPI = \frac{1}{n}\sum_{i=0}^{n} PI \quad (2)$$

Where PI represents the pollution index of considered specific water quality parameter (Fig.2), n indicates the number of parameters. The calculation of CPI was done by considering the standard permissible (objectives) limits of different government (CPCB, 2011; BIS, 2012; EPA, 1986; WHO, 2011). The range of CPI is from 0 to 2 and classifies water quality as: Clean (≤0.20 CPI); Sub-clean (0.21–0.40 CPI); slightly polluted (0.41–1.00 CPI); moderately polluted (1.01–2.0 CPI); severely polluted (≥2.01 CPI) (Mishra, 2015).

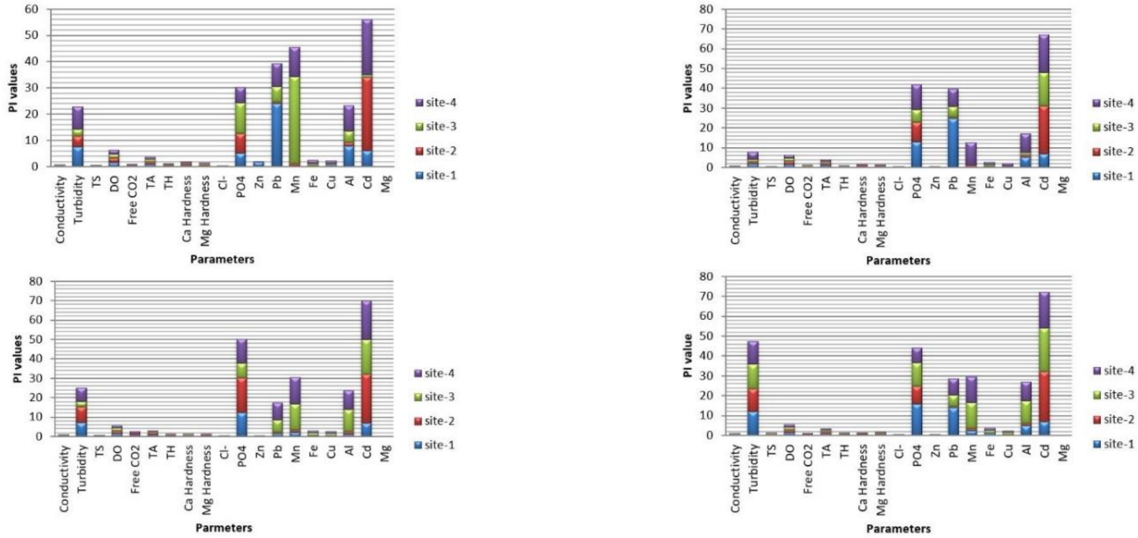

Figure.2. (A) PI of water quality parameters during autumn, (B) for winters, (C) for summer and (D) for monsoon season (2011-2012)

Simpson's diversity index (D): The equation used for the calculation of Simpson's diversity index is:

$$D = 1/\sum (P(i))^2$$

Where p(i) represents the fraction of the total sample made up by the species,

$$p(i) = n(i)/N$$

Where n(i) represents the number of the individuals and N is total number of all species

Shannon-Weaver index (H): This index is commonly used for calculating biotic diversity in aquatic and terrestrial ecosystems and the working equation is:

$$H = -\sum P(i) \log P(i)$$

Where p(i) is the fraction of the total sample made up by the species,

$$p(i) = n(i)/N$$

Where n(i) represents the number of the individuals and N is total number of all species

Taxon Evenness: This is relative distribution of individuals among taxonomic groups within a community and is given by equation:

$$E = H/\ln(R)$$

Where E= Taxon Evenness, R is the Taxon Richness defined as total no. of distinct taxa in a population.

3. RESULT AND DISCUSSION

During the limnological assessment of River Henwal various characteristics were studied during different season of 2011-2012 which are appended in Table 1-4 and in Table 6-9. The maximum value of water velocity was 1.16±0.82 at Khadi, whether 1.15 ± 0.25, 0.99±0.03, and 1.10±0.00 at control site, Nagni and Jajal respectively during monsoon season. Minimum values was 0.67±0.00 at control sit, whether 0.64±0.03, 0.60±0.34, 0.63±0.22 at Nagni, Khadi and Jajal respectively during study period. Higher temperature was 26^0C at control site and 29^0C, 22.5^0C and 28^0C at Nagni, Khadi and Jajal respectively during study period. Lower was 14^0C at control site whether 16^0C, 15^0C and 13^0C at Nagni, Khadi and Jajal respectively during study period. The high value of conductivity was 126.21 ± 0.21 at control sit whether 125.62 ± 0.26, 118.79 ± 0.01, 134.47 ± 0.05 at Nagni, Khadi and Jajal respectively during study period. Low value was 98.54 ± 0.00, 96.45 ± 0.05, 102.98 ± 0.03, 105.95 ± 0.05 at all sites respectively. The river water was most turbid at Khadi (309.12 ± 18.35 JTU) > Jajal (286.75 ± 158.25) > Nagni (285.71±18.27) during monsoon season.

Table.1. Seasonal physico-chemical and heavy metal observation at Control site

Season	Water velocity (m/sec)	Water temperature (°C)	Conductivity (Siemens/cm)	Turbidity (JTU)	Total solids (mg/l)
Autumn	0.99±0.01	18.5±0.18	125.95±0.00	186.64±13.72	369.71±0.20
Winters	0.72±0.01	14.0±0.01	98.54±0.00	42.98±0.86	71.51±0.32
Summer	0.67±0.00	26.0±0.53	123.16±0.24	176.49±7.81	184.21±0.26
Monsoon	1.15±0.25	22.5±1.62	126.21±0.21	301.76±32.55	498.70±0.32
Objective	-	-	1000	25	1500

Season	DO (mg/l)	Free CO_2 (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Ca Hardness (mg/l)	Mg Hardness (mg/l)	Chlorides (mg/l)	Phosphates (mg/l)
Autumn	9.5±0.19	0.7±0.00	34.52±0.00	176.0±1.00	158.0±6.21	34.50±0.06	19.67±0.03	9.35±0.02	0.26±0.09
Winters	9.7±0.08	0.4±0.00	47.87±1.39	204.6±0.00	173.0±2.46	31.85±0.06	24.96±0.24	7.63±0.14	0.65 ± 0.20
Summer	7.9±0.03	1.4±1.14	44.69±0.02	158.0±2.16	137.0±6.12	24.60±0.00	15.98±0.15	7.79±1.77	0.61 ±0.14
Monsoon	8.1±0.06	0.7±0.02	54.12±0.17	196.0±0.16	219.0±0.26	24.28±0.22	27.30±3.31	7.10±6.25	0.79±0.06
Objective	6	2	-	200	500	75	50	250	0.05

Season	Zn (mg/l)	Pb (mg/l)	Mn (mg/l)	Fe (mg/l)	Cu (mg/l)	Al (mg/l)	Cd (mg/l)	Mg (mg/l)
Autumn	27.9 ± 47.9	1.2 ± 1.59	0 ± 0	0.39 ± 0.02	0.79 ± 1.11	1.58 ± 22.3	0.06 ± 0.02	0.06 ± 0
Winters	0.48 ± 0.83	1.23 ± 1.63	0.01 ± 0	0.36 ± 0.03	0.84 ± 1.18	1.03 ± 1.38	0.07 ± 0.01	0.07 ± 0.01
Summer	1.55 ± 1.4	0.07 ± 0.05	0.67 ± 0.94	0.32 ± 0.02	0.01 ± 0	0.25 ± 0.28	0.07 ± 0.03	0.08 ± 0.05
Monsoon	3.19 ± 3.69	0.7 ± 0.9	0.68 ± 0.89	1.11 ± 0.87	0.01 ± 0	0.98 ± 0.82	0.07 ± 0.02	1.02 ± 1.63
Objectives	15	0.05	0.3	1	1.5	0.2	0.01	100

Table.2. Seasonal physico-chemical and heavy metal observation at Nagni

Season	Water velocity (m/sec)	Water temperature (°C)	Conductivity (Siemens/cm)	Turbidity (JTU)	Total solids (mg/l)
Autumn	0.87±0.12	17.5±1.51	115.75±0.90	101.42±0.80	179.17±0.26
Winters	0.64±0.03	16.00±0.37	96.45±0.05	21.79±0.90	62.79±0.09
Summer	0.89±0.20	29.0±0.50	123.41±0.01	205.48±37.00	236.61±3.52
Monsoon	0.99±0.03	26.00±3.90	125.62±0.26	285.71±18.27	498.95±0.32
Objective	-	-	500	25	1500

Season	DO (mg/l)	Free CO_2 (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Ca Hardness (mg/l)	Mg Hardness (mg/l)	Chlorides (mg/l)	Phosphates (mg/l)
Autumn	9.3±0.11	0.5±0.00	29.10±0.25	167.0±1.68	189.0±0.07	39.84±1.12	17.00±0.19	8.67±0.07	0.37 ± 0.17
Winters	9.5±0.80	0.5±0.01	58.19±1.65	200.0±2.56	147.0±0.25	44.90±1.65	16.36±24.57	7.91±8.07	0.49±0.21
Summer	8.4±0.23	1.9±0.05	47.21±0.31	220.0±0.09	216.0±0.01	24.69±0.02	22.70±0.54	6.56±0.05	0.90 ± 0.18
Monsoon	7.5±0.05	1.0±0.00	44.64±0.42	179.2±2.23	175.0±0.12	28.79±0.53	21.42±1.99	5.01±0.21	0.45 ±0.11
Objective	6	2	-	200	500	75	50	250	0.05

Season	Zn (mg/l)	Pb (mg/l)	Mn (mg/l)	Fe (mg/l)	Cu (mg/l)	Al (mg/l)	Cd (mg/l)	Mg (mg/l)
Autumn	0.5 ± 0.43	0.03 ± 0.01	0.26 ± 0.06	0.02 ± 0.01	0.24 ± 0.37	0.24 ± 0.36	0.28 ± 0.39	0.21 ± 0.3
Winters	0.45 ± 0.31	0.03 ± 0.01	0.28 ± 0.06	0.03 ± 0.01	0.24 ± 0.28	0.2 ± 0.29	0.24 ± 0.3	0.27 ± 0.35
Summer	0.5 ± 0.38	0.03 ± 0.01	0.31 ± 0.07	0.03 ± 0.01	0.25 ± 0.38	0.25 ± 0.33	0.25 ± 0.39	0.21 ± 0.26
Monsoon	0.46 ± 0.23	0.02 ± 0.01	0.32 ± 0.03	0.02 ± 0.01	0.2 ± 0.31	0.22 ± 0.32	0.25 ± 0.34	0.22 ± 0.26
Objectives	15	0.05	0.3	1	1.5	0.2	0.01	100

Table.3. Seasonal physico-chemical and heavy metal observation at Khadi

Season	Water velocity (m/sec)	Water temperature (°C)	Conductivity (Siemens/cm)	Turbidity (JTU)	Total solids (mg/l)
Autumn	0.83±0.20	15.00±0.15	102.98±0.03	65.46±7.35	117.64±0.14
Winters	0.60±0.34	22.5±0.56	116.43±0.26	31.84±0.05	110.23±0.25
Summer	0.70±1.68	21.00±1.05	116.75±0.00	66.79±6.81	129.79±0.36
Monsoon	1.16±0.82	20.00±1.50	118.79±0.01	309.12±18.35	498.21±52.00
Objective	-	-	1000	25	1500

Season	DO (mg/l)	Free CO_2 (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Ca Hardness (mg/l)	Mg Hardness (mg/l)	Chlorides (mg/l)	Phosphates (mg/l)
Autumn	9.5±0.00	0.1±0.01	49.95±0.81	195.0±3.57	143.0±0.05	34.85±2.78	19.50±5.64	8.43±6.13	0.58 ± 0.20
Winters	8.4±1.56	1.1±0.12	41.49±2.54	179.0±0.68	112.5±0.00	19.10±0.30	13.74±2.24	9.06±0.09	0.32±0.25
Summer	8.9±0.26	0.5±0.01	44.11±0.00	114.0±0.19	169.0±0.25	31.78±0.88	20.83±0.12	8.93±0.50	0.37 ±0.07
Monsoon	8.4±0.10	0.2±0.00	35.10±5.60	143.0±0.16	198.0±0.20	36.45±3.10	23.74±0.19	7.92±0.55	0.59 ± 0.21
Objective	6	2	-	200	500	75	50	250	0.05

Season	Zn (mg/l)	Pb (mg/l)	Mn (mg/l)	Fe (mg/l)	Cu (mg/l)	Al (mg/l)	Cd (mg/l)	Mg (mg/l)
Autumn	0.22 ± 0.29	0.29 ± 0.38	10 ± 15.3	0.69 ± 0.88	0.68 ± 0.88	0.9 ± 0.65	0.01 ± 0	2 ± 1.73
Winters	0.29 ± 0.4	0.28 ± 0.36	0.05 ± 0	0.96 ± 1.52	0.25 ± 0.33	0.26 ± 0.32	0.17 ± 0.87	0.5 ± 0.24
Summer	0.24 ± 0.32	0.33 ± 0.45	4.021 ± 0.56	1.347 ± 0.104	1.967 ± 0.54	2.27 ± 0.08	0.18 ± 0.91	0.58 ± 0.3
Monsoon	0.22 ± 0.29	0.29 ± 0.38	3.898 ± 0.87	1.293 ± 0.075	1.935 ± 0.61	2.26 ± 0.08	0.22 ± 0.59	0.63 ± 0.3
Objectives	15	0.05	0.3	1	1.5	0.2	0.01	100

Table.4. Seasonal physico-chemical and heavy metal observation at Jajal.

Season	Water velocity (m/sec)	Water temperature (°C)	Conductivity (Siemens/cm)	Turbidity (JTU)	Total solids (mg/l)
Autumn	0.97±0.30	18.00±1.06	134.47±0.05	215.46±27.00	398.72±1.35
Winters	0.81±0.06	13.0±0.35	105.95±0.05	98.45±4.86	105.15±0.15
Summer	0.63±0.22	28.0±0.07	122.18±0.01	180.17±7.86	187.67±3.25
Monsoon	1.10±0.00	24.0±0.15	127.78±0.35	286.75±158.25	505.14±0.34
Objective:	-	-	1000	25	1500

Season	DO (mg/l)	Free CO_2 (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Ca Hardness (mg/l)	Mg Hardness (mg/l)	Chlorides (mg/l)	Phosphates (mg/l)
Autumn	9.4±0.22	0.8±0.02	35.91±0.13	189.0±4.75	149.0±0.05	37.84±1.43	19.58±29.97	9.21±1.06	0.30 ± 0.10
Winters	10.2±0.03	0.4±0.00	41.00±0.19	225.0±3.02	172.0±0.10	27.50±2.46	24.50±0.00	7.86±0.11	0.63±0.19
Summer	8.1±0.02	1.7±0.03	46.10±3.02	147.0±0.09	139.0±8.61	22.90±0.06	14.62±29.48	7.35±6.10	0.63±0.22
Monsoon	8.8±0.07	0.4±0.01	43.21±0.10	178.5±3.71	183.0±0.09	31.54±0.34	19.10±1.07	5.65±0.21	0.37±0.05
Objective:	6	2	-	200	500	75	50	250	0.05

Season	Zn (mg/l)	Pb (mg/l)	Mn (mg/l)	Fe (mg/l)	Cu (mg/l)	Al (mg/l)	Cd (mg/l)	Mg (mg/l)
Autumn	2.33 ± 0.03	0.45 ± 0.604	3.339 ± 0.2	1.346± 0.028	1.682 ± 0.7	1.92 ± 0.65	0.21± 0.57	0.62± 0.02
Winters	2.3 ± 0.16	0.44 ± 0.029	3.422 ± 0.28	1.355± 0.074	1.671± 0.59	1.93 ± 0.63	0.19± 0.54	0.709± 0.1
Summer	2.29 ± 0.12	0.44 ± 0.596	4.099 ± 0.56	1.343± 0.065	1.669± 0.51	1.95 ± 0.63	0.20± 0.79	0.67± 0.14
Monsoon	2.27 ± 0.06	0.41 ± 0.646	3.897 ± 0.28	1.335 ± 0.05	1.303± 0.11	1.92 ± 0.6	0.18± 0.75	0.66± 0.21
Objectives:	15	0.05	0.3	1	1.5	0.2	0.01	100

Table.5. Water pollution at each sampling location

Sampling sites	CPI (Autumn)	CPI (Winters)	CPI (Summer)	CPI (Monsoon)	Polluted
Control	3.05	2.99	1.88	3.25	Slightly (in summer), Severely in other season
Nagni	2.45	2.20	3.13	2.77	Severely
Khadi	3.37	1.94	3.47	4.37	Slightly (in winter), Severely in other season
Jajal	3.82	3.82	4.15	3.91	Severely

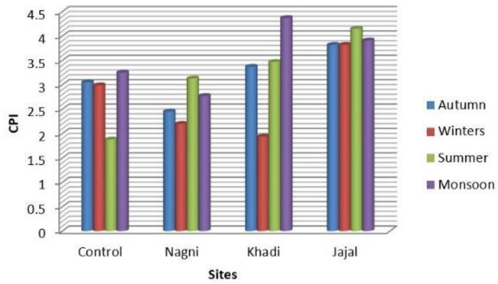

Figure.3. Variation of CPI during autumn, winter, summer and monsoon season

The CPI clearly indicates that the river Henwal was slightly to severely polluted i.e. CPI: 1.88-4.37. The CPI calculated for each sampling location falls beyond the range, i.e. ≥2.01 which represents that water quality of the river is severely polluted in all the four seasons except control site during summer and Khadi during winter which represents these sites as slightly polluted, i.e. (Table 5). To know the variation in water quality due to different season, a CPI plot has been shown in Fig. 3, which shows the variation in pollution level of water quality during study period. Calculation of CPI indicates that there is high influx of sewage and domestic waste which is beyond its tolerance capacity.

Table.6. Quantitative Analysis of the Plankton of the Henwal River at Control site

Season	Phytoplankton	Zooplankton	Plankton
Autumn	765.74±2.26	326.85±4.78	1092.59±6.77
Winters	940.86±1.00	333.04±2.79	1273.90±3.79
Summer	922.37±1.83	285.52±4.55	1207.89±6.38
Monsoon	644.35±1.40	256.40±6.37	900.75±7.77

Number of different Group among the Phytoplankton of the Henwal River

Season	Total Phytoplankton/ Liter of water	Total Diatoms / Litre of water	Total green algae/ Litre of water	Total Blue green algae/ Litre of water
Autumn	765.74±2.26	267.40±0.23	259.77±0.92	238.57±1.11
Winters	940.86±1.00	245.12±0.13	287.46±0.55	408.28±0.32
Summer	922.37±1.83	208.13±0.43	288.11±0.38	426.13±1.02
Monsoon	644.35±1.40	191.27±0.52	179.80±0.31	273.28±0.57

Number of Different Genera among Zooplankton in the Henwal River

Season	*Protozoa*	*Rotifera*	*Cladocera*	*Copepod*	*Ostracods*	D	H	E
Autumn	92.89±0.68	69.88±1.58	83.05±0.81	38.28±0.28	42.75±1.43	4.50	1.55	0.44
Winters	107.30±0.17	59.25±0.57	88.29±0.69	48.83±0.38	29.37±1.29	4.24	1.52	0.42
Summer	85.55±1.04	59.85±0.59	60.92±0.27	51.02±0.76	28.18±1.89	4.53	1.55	0.44
Monsoon	73.25±1.65	58.59±1.57	49.98±1.09	38.85±0.58	35.73±1.48	4.65	1.57	0.45

Table.7. Quantitative Analysis of the Plankton of the Henwal River at Nagni

Season	Phytoplankton	Zooplankton	Plankton
Autumn	1007.61±3.36	270.31±5.37	1277.92±8.73

Winters	932.95±2.1	294.18±3.04	1227.13±5.14
Summer	973.74±3.05	261.00±4.18	1234.74±7.23
Monsoon	504.96±1.97	228.05±6.81	733.01±8.78

Number of different Group among the Phytoplankton of the Henwal River

Season	Total Phytoplankton/ Liter of water	Total Diatoms / Litre of water	Total green algae/ Litre of water	Total Blue green algae/ Litre of water
Autumn	1007.61±3.36	248.46±0.19	391.23±1.36	367.92±1.81
Winters	932.95±2.1	225.28±0.23	289.16±0.95	418.51±0.92
Summer	973.74±3.05	208.85±0.55	298.46±1.38	466.43±1.12
Monsoon	504.96±1.97	151.73±0.19	149.35±0.71	203.88±1.07

Number of Different Genera among Zooplankton in the Henwal River

Season	*Protozoa*	*Rotifera*	*Cladocera*	*Copepod*	*Ostracods*	D	H	E
Autumn	46.58±0.82	65.08±1.51	88.01±0.91	39.23±0.68	31.41±1.43	4.37	1.54	0.43
Winters	103.19±0.57	50.26±0.52	64.57±0.36	46.83±0.39	29.33±1.20	4.23	1.53	0.43
Summer	59.97±0.58	60.85±0.57	59.95±0.57	59.07±0.66	21.16±1.80	4.60	1.56	0.44
Monsoon	43.84±1.80	56.59±1.52	49.99±1.49	37.87±1.58	39.76±1.42	4.88	1.60	0.47

Table.8. Quantitative Analysis of the Plankton of the Henwal River at Khadi

Season	Phytoplankton	Zooplankton	Plankton
Autumn	827.16±3.36	279.15±5.54	1106.31±8.90
Winters	923.82±2.1	306.18±3.85	1230.00±5.95
Summer	909.20±3.05	263.00±5.09	1172.20±8.14
Monsoon	555.09±1.97	217.06±8.38	772.15±10.35

Number of different Group among the Phytoplankton of the Henwal River

Season	Total Phytoplankton/ Liter of water	Total Diatoms / Litre of water	Total green algae/ Litre of water	Total Blue green algae/ Litre of water
Autumn	827.16±3.36	223.89±0.19	276.45±1.36	326.82±1.81
Winters	923.82±2.1	221.30±0.23	290.26±0.95	412.26±0.92
Summer	909.20±3.05	204.73±0.55	291.69±1.38	412.78±1.12
Monsoon	555.09±1.97	149.24±0.19	161.53±0.71	244.32±1.07

Number of Different Genera among Zooplankton in the Henwal River

Season	*Protozoa*	*Rotifera*	*Cladocera*	*Copepod*	*Ostracods*	D	H	E
Autumn	47.56±1.07	64.58±1.91	83.01±0.51	38.23±0.64	45.77±1.41	4.60	1.57	0.45
Winters	114.19±0.55	59.26±0.42	61.57±0.76	42.83±0.37	28.33±1.75	4.06	1.50	0.41
Summer	52.97±0.54	66.85±0.51	51.95±1.57	55.07±0.66	36.16±1.81	4.83	1.59	0.46
Monsoon	47.84±1.60	59.60±1.92	40.99±1.47	32.87±1.53	35.76±1.86	4.76	1.59	0.46

Table.9. Quantitative Analysis of the Plankton of the Henwal River at Jajal

Season	Phytoplankton	Zooplankton	Plankton
Autumn	764.75±1.37	299.26±5.46	1064.01±6.70
Winters	930.81±0.93	328.66±3.19	1259.47±4.12
Summer	905.89±3.79	289.84±5.34	1195.73±9.13
Monsoon	621.91±5.20	263.98±5.45	885.89±10.65

Number of different Group among the Phytoplankton of the Henwal River

Season	Total Phytoplankton/ Liter of water	Total Diatoms / Litre of water	Total green algae/ Litre of water	Total Blue green algae/ Litre of water
Autumn	764.75±1.37	231.22±0.32	289.55±0.03	243.98±1.02
Winters	930.81±0.93	256.67±0.52	259.82±0.29	414.32±0.12
Summer	905.89±3.79	204.88±2.11	298.90±1.31	402.11±0.37
Monsoon	621.91±5.20	178.52±2.23	189.60±1.22	253.79±1.75

Number of Different Genera among Zooplankton in the Henwal River

Season	*Protozoa*	*Rotifera*	*Cladocera*	*Copepod*	*Ostracods*	D	H	E
Autumn	96.28±0.88	58.97±1.25	77.85±1.09	36.59±0.67	29.57±1.87	4.24	1.52	0.42
Winters	102.50±0.24	59.38±0.58	69.28±0.28	58.91±1.27	38.59±1.28	4.53	1.56	0.44
Summer	89.85±1.05	61.45±0.38	58.76±1.08	50.19±1.12	29.59±1.71	4.49	1.55	0.44
Monsoon	79.25±1.55	53.48±1.04	55.28±0.90	39.19±0.43	36.78±1.53	4.61	1.57	0.45

Maximum total solids were recorded around 500mg/l at all four sites during monsoon and minimum solids were observed in winter. DO level was good at all four sites during winter season. Jajal area was rich in DO level (10.2 ± 0.03mg/l). Maximum Free CO_2 concentration was 1.4±1.14, 1.9±0.05, 1.1±0.12 and 1.7±0.03 (mg/l) observed at all four sites respectively during summer season. At Khadi, concentration was high in winters. Minimum level was 0.4±0.00, 0.5 ± 0.00, 0.1 ± 0.01 and 0.4 ± 0.00 (mg/l) respectively. The higher value of acidity was 54.12 ± 0.17mg/l at control site during monsoon, 58.19 ± 1.65, 49.95 ± 0.81 and 46.10 ± 3.02mg/l at remaining sites during study period. Lower value was 34.52 ± 0.00, 29.10±0.25, 35.10 ± 5.60 and 35.91 ± 0.13mg/l respectively.

The highest total alkalinity was 204.6 ± 0.00, 220.0 ± 0.09, 195.0 ± 3.57 and 225.0 ± 3.02mg/l recorded at control, Nagni, Khadi and Jajal site respectively. Lowest alkalinity was 158.0±2.16, 167.0±1.68, 114.0±0.19 and 147.0±0.09 respectively. Higher level of Total hardness was 219.0±0.26, 216.0±0.01, 198.0±0.20, 183.0±0.09mg/l respectively. Lowest value was 137.0±6.12, 147.0±0.25, 112.5±0.00, 139.0±8.61mg/l recorded. Maximum calcium hardness was 34.50±0.06, 44.90±1.65, 36.45±3.10 and 37.84±1.43mg/l at all sites respectively. Minimum value was 24.28±0.22, 24.69±0.02, 19.10±0.30 and 22.90±0.06mg/l recorded. Magnesium Hardness 27.30±3.31, 22.70±0.54, 23.74±0.19, 24.50±0.00mg/l. 15.98±0.15, 16.36±24.57, 13.74±2.24 and 14.62±29.48 Chloride 9.35±0.02, 8.67±0.07, 9.06±0.09 and 9.21±1.06mg/l. Minimum was 9.35±0.02, 8.67±0.07, 9.06±0.09 and 9.21±1.06mg/l during monsoon season. Phosphate were 0.79±0.06, 0.90±0.18, 0.59±0.21 and 0.63±0.22mg/l. Lower value was 0.26±0.09, 0.37±0.17, 0.32±0.25 and 0.30±0.10 recorded during study period. In the present investigation density and diversity of Phytoplankton, zooplankton and plankton are evaluated. The density and diversity of Phytoplankton, zooplankton and plankton are interrelated and completely dependent on many factors like sediment exchange, zooplankton grazing and water quality of any aquatic system. The highest diversity and density of Phytoplankton, zooplankton and plankton were observed during winter season.

In case of heavy metal, the concentration of Pb, Mn, Fe, Al and Cd was high at Jajal site throughout the study period and cross the standard permissible limit.

Phytoplankton: The composition of phytoplankton varies with the season and this is due to the change in nutrient availability, temperature and light (Jouenne, 2007). Phytoplanktons are very well known as primary producers in food web and to balance the ecological conditions of any aquatic body but the can also be very useful to represent the water quality (Rey, 2004). The high density of phytoplankton was 940.86±1.00, 1007.61±3.36, 923.82±2.1 and 930.81±0.93 observed during winter season at control site, Nagni, Khadi and Jajal respectively. Lower density was present during Monsoon season 644.35±1.40, 504.96±1.97, 555.09±1.97 and 621.91±5.20 respectively (Table.6).

The diatoms to be prominent during the pre-monsoon and post-monsoon where there was a dominance of marine water in the estuarine region and the results were found to be corroborated with our studies (Thessen, 2005). The dominance of diatoms found near coastal waters in west coast of India and diatoms were found to flourish at mouth of both the estuaries due to hydro-chemical conditions (WHO, 2011; Mishra, 2015).

Zooplankton: In this study five major groups of zooplanktons in Henwal river are evaluated and their composition including Protozoa, Rotifer, Cladocera, Copepod and Ostracods shown in (Table.8) The protozoa, rotifer, copepod, decapoda, cladocera, ostracoda and branchiopoda mainly formed the net zooplankton (NZP) groups of the fresh water. The main cause of increased abundance of NZP species probably water quality, decomposing flora, higher levels of organic substance in the sediment and increased bacteria loads in the water during summer time (Rey, 2004). The NZP species decreased their abundance during winter probably corresponding to high alkalinity and low temperature of water (Chattopadhyay and Banerjee, 2008). The sequence of zooplankton groups at control site found in order of protozoan>rotifers >cladocera>copepod>ostracoda. Zooplankton Group Diversity indices for control site during study period also demonstrated values of Group Richness, Evenness, Shannon-Weiner Index and Simpson Index and respectively (Table.8).

Nagni had the highest diversity index (D = 4.88, H = 1.60) of the four sites in the monsoon season and the Khadi had the lowest diversity index (D = 4.06, H = 1.50) in the winter season. Group richness (R) was 5 and high evenness was 0.47. The Shannon-Wiener (H) and Simpson (D) indices can be used to indicate water quality as follows: $H > 3$ (or $D > 6$) indicates clean water, $3 > H > 2$ (or $6 \geq D \geq 3$) indicates slight contamination, $2 > H > 1$ (or $3 \geq D \geq 2$) indicates moderate contamination and $1 > H > 0$ (or $D < 2$) indicates heavy contamination. According to these indicators, the water quality of the Henwal river slightly to moderately contaminated. These results are consistent with phytoplankton and comprehensive trophic state indices (TSIc). The species diversities of copepods and rotifers responded differently to water nutrient levels; when the levels changed from nutrient-moderate to nutrient-rich, the species diversity decreased (*i.e.*, nutrient enrichment decreased zooplankton diversity). Because contamination-resistant species in nutrient-rich water can become dominant, the growth of other species can be inhibited, which can decrease diversity. However, many researchers warn against using the zooplankton diversity index as a measure of water quality and have indicated the drawbacks of using the Shannon-Wiener (H) and Simpson (d) indices to calculate zooplankton diversity (Thessen, 2005; Tiwariand Nair, 1998; Senthil, 2002; Coman, 2003).

4. CONCLUSION

In conclusion the present study summarizes the great seasonality in various physico-chemical characters and planktonic composition in River Henwal as output of statistical data analysis. Beside the variation, there was less pollution load observed at control site in comparison to other sites. The sequence of polluted sites is control site < Khadi < Nagni < Jajal. In case of heavy metal pollution Jajal site is also highly contaminated. CPI clearly indicates that the river Henwal was slightly-severely polluted (CPI: 1.88-4.37). Different biodiversity indices showed that Nagni had the highest diversity index (D = 4.88, H = 1.60) of the four sites in the monsoon season and the Khadi had the lowest diversity index (D = 4.06, H = 1.50) in the winter season. According to these biotic indices, the water quality of the Henwal River was slightly-moderately contaminated. Therefore, River Henwal requires the better treatment before any utilization.

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