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# Hydrochemical characteristics and planktonic composition assessment of River Henwal in Himalayan Region of Uttarakhand using CPI, Simpson's and Shannon-Weaver Index

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**ABSTRACT**

In this present study seasonal water quality of River Henwal was conducted in term of the physico-chemical parameters, heavy metals, and plankton composition at four different sites of Chamba, Distt, Tehri Garhwal to observe pollution grade of River Henwal, situated in newly carved state of Uttarakhand. One site was considered as control site out of four and low concentration of physicochemical parameters was observed at it. For this purpose, comprehensive pollution index (CPI) was used, in view of the physiochemical parameters such as conductivity, turbidity, dissolved oxygen, total solids, total hardness (TH), total phosphate, chloride etc. and heavy metals (Fe, Cu, Zn, Cr etc.). Besides this, Simpson index (D) and Shannon-Weaver index (H) and Taxon Evenness (E) are used to depict the planktonic density, diversity and evenness in Henwal river. The CPI value (4.70-10.31) classifies the water quality in severely polluted condition of river water. Highest value was at Khadi. Blue green algae and protozoa were the most abundant group was recorded at all four sites. The highest Simpson (4.74), Shannon-Weiner index (1.58) and taxon evenness (0.46) was at Nagni during monsoon and lowest was at control site (D = 4.37, H = 1.54 and E = 0.43) during winter. Negative correlation was found between turbidity and plankton.

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

## 1. INTRODUCTION

With the quick increment in populace the worldwide requests for nourishment, vitality and material merchandise are expanding and putting exceptional weight on Mother Earth, making the water at the core of this emergency. With conventional arrangements — like working of dams, supplies and different frameworks to address the issues, they are demonstrating too exorbitant and unsustainable all alone. Hippies trusts that coordinating biological arrangements, including the preservation measure, reasonable advancement, actualizing horticulture best administration hones, can help us to comprehend the generous cost reserve funds together with the important return of enhanced water quality and amount. Working in expanded regions we can just recommend or educate or mindful the world the significance of water preservation its administration and ensure this imperative asset for individuals and nature (Matta, 2014, 2015).

The "Freshwater" conditions incorporate waterways, lakes, streams, wetlands, and underground aquifers putting away the perfect water that is essential for living being on earth. Sound freshwater assets supply water for drinking, developing harvests, assembling, vitality and transport. Likewise forestalling disintegration, discard squander and give regular insurance from flooding. Be that as it may, because of indiscreet with the most fundamental asset on earth, freshwater bodies have been bungled, prompting heaps of contamination, drying waterways and harmed biological systems, causing elimination of many water bodies incorporating their living structure in a century ago (Matta, 2010; Matta & Kumar, 2015).

In India, the Himalayas are the real wellspring of crisp water to streams in Northern Region supporting a great many living structures and hectares of land in all giving the life to numerous biological systems. However, waterways are additionally frequently the endpoint for a lot of our mechanical and urban contamination and spillover. When it downpours, concoction compost and creature squander peppering neighborhoods and agrarian terrains is cleared into nearby streams, waterways, and different waterways. The outcome: dirtied drinking water sources and the decrease of amphibian species, notwithstanding beach front no man's lands caused by manure and sewage over-burden (Matta, 2014, 2015, 2016).

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) having large amount of fresh water bodies present in the form of rivers, tributaries, rivulets and springs, fulfilling the freshwater requirement of the population. It comprises of snow fed rivers and streams such as Alaknanda, Bhagirathi, Mandakini Dhauliganga, Pindar and River Ganga and spring fed rivers such as Bhilangna, Nayar, Gular, Song, Suswa, Henwal and hundreds of rivulets (Matta, 2015).

River Henwal is a spring fed river, originates from Kaddukhal (Near Surkanda Devi Temple, Chamba, Uttaranchal) covering a length of about 38 kilometers. River substratum is stony, rocky and pebbly and finally it is sandy, when it meets the River Ganga. Due to the great variation in the velocity and temperature of the water, the biodiversity may also vary.

The present study deals with the assessment of anthropogenic activities on water quality in terms of limnological characters of spring fed River Henwal, a tributary of River Ganga. Henwal River, a major tributary of River Ganga in Himalayan Region is originating from Surkanda hills (2900 msl) in the greater Himalayas and merges into River Ganga at Shivpuri. The study was carried out to understand the importance of aquatic ecosystems of Himalayas with special reference to Garhwal region (Matta & Gjyli 2016; Matta & Uniyal, 2017; Matta, 2017).

## 2. MATERIALS AND METHODS

**Study Area:** The present examination has been completed in Chamba, Distt. Tehri Garhwal to look at contamination status of River Henwal, situated in recently cut territory of Uttarakhand. Chamba is arranged at an intersection of streets associating Mussoorie and Rishikesh with the Tehri Dam repository and New Tehri. Its adjacent visitor places are Dhanaulti, Surkanda Devi Temple, Ranichauri, New Tehri, and Kanatal, somewhere between Chamba and Dhanaulti. Around 50 km from Mussoorie, the little slope town of Chamba, Uttaranchal, is another of those goals yet obscure to most sightseers and thusly untainted and crisp like a daisy for the fortunate couple of who wander out looking for new places to investigate and appreciate. Chamba is arranged at a height of 1600m above ocean level with organizes 30.21°N 78.23°E. There are lovely woodlands of pine and deodar trees, with some great perspectives. Amid course think about period physico-concoction parameters of River Henwal were contemplated. Water tests were taken from three distinct destinations of Henwal River i.e. from Nagni, Jajal and Kharee (Fig.1). This stream is the tributary of Holy River Ganga demonstrating water for water system, household and for different purposes. Because of number of employments, extensive waterway water quality checking program is turning into a need with a specific end goal to shield general wellbeing and to secure the profitable and powerless new water assets (Kannel, 2007; Singh, 2014).

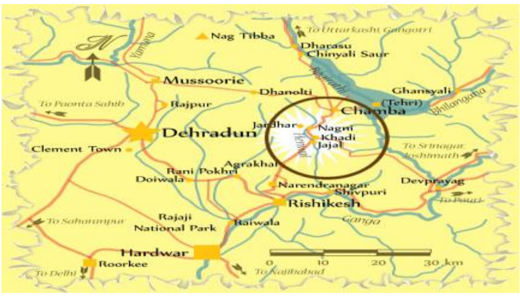



**Figure.1. sampling locations**

**Samples collection and analysis:** Water tests were gathered occasionally amid 2013 to 2014. Tests were gathered utilizing a spotless plastic pail, exchanged to clean plastic jugs and transported to the research center on ice and put away in a profound cooler (- $20^0$C) till examination. Tests were gathered in triplicate from each site and normal incentive for every parameter was accounted for. The physical parameters like pH, Temperature, DO, Transparency, Velocity, and Free $CO_2$ are recorded on the spot and other concoction parameters are recorded in the Laboratory which was resolved utilizing standard strategies (Khanna, 2011; APHA, 2012).

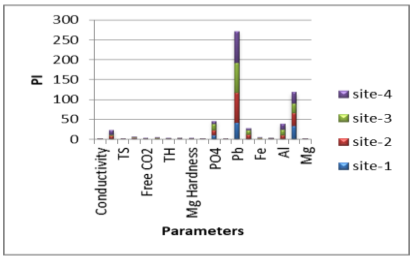
**Statistical Analysis:** Every one of the information acquired subjected to measurable examination. In factual investigation, a relationship created between parameters by utilizing Karl Pearson's coefficient of connection for information examination of Ganga Canal water to quantify the varieties between Site I and Site II parameters. MS Excel, 2000 was utilized to quantify the Mean and Standard deviation (SD) of the information. For other factual investigation like connection Minitab 16 was utilized.

**Comprehensive pollution index (CPI):** This pollution index has been connected to group the water quality status by a considerable lot of the examination discoveries (Zhao, 2012). It is assessed by the accompanying conditions as:

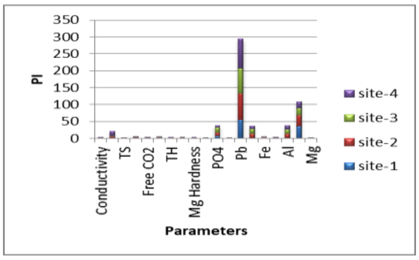
$$PI = \frac{Measured\ concentration\ of\ individual\ parameter}{Standard\ permissible\ concentration\ of\ parameter} \quad (1)$$

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

Where PI is the pollution index of individual water quality parameter considered, as shown in Fig. 2, n is the number of parameters. The standard permissible limit of each parameter considered in this work were used from the proposed norms of the different government for a general discharge of environmental pollutant (EPA, 1986; CPCB, 2011; BIS, 2012; WHO, 2011). CPI classify water quality as: ≤0.20 is Clean; 0.21–0.40 is Sub-clean; 0.41–1.00 is slightly polluted; 1.01–2.0 is moderately polluted; ≥2.01 is severely polluted.



(a)



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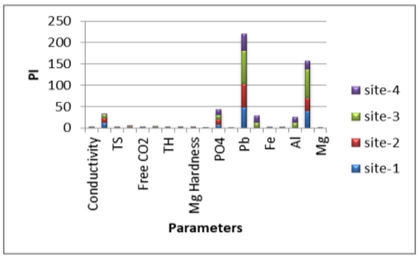

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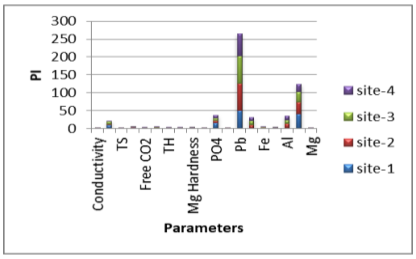
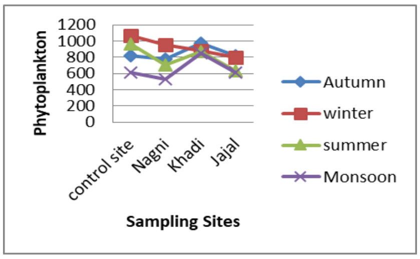
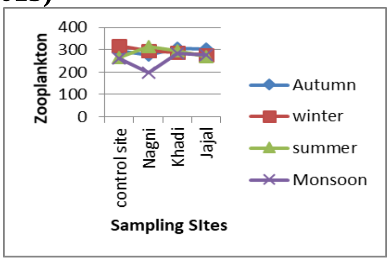


(d)

**Figure.2. (A) PI of water quality parameters during autumn, (B) for winters, (C) for summer and (D) for monsoon season (2014-2015)**



(e)



(f)

**Figure.3. (e) Seasonally density of phytoplankton (f) Seasonally density of zooplankton**

**Simpson's diversity index (D):** The Simpson's diversity index (D) is calculated using the following equation:

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

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

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

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

**Shannon-Weaver index (H):** This is widely used method of calculating biotic diversity in aquatic and terrestrial ecosystems and is expressed as:

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

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

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

Where ***n(i)** is 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 expressed as:

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

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

## 3. RESULTS AND DISCUSSION

River environment are subjected to various change in abiotic and biotic characteristics due to the mixing of different pollutants into river water. During the study period of River Henwal various physic-chemical, heavy metals and planktonic characteristics were studied for four different seasons of 2013-2014 which are appended in Table.1, 2, 3, 4. The site wise average value of all the parameters were observed for comparison between sites for throughout study period and found that control site shows low average values than Site 2 (Nagni), Site 3 (Khadi) and Site 4 (Jajal). The higher concentration of physicochemical and heavy metals was observed for site 3. The total number of planktons was also high (average 893.8 no/l of phytoplankton and 293.31 no/l of zooplankton) on site 3 in comparison to other sites. The sequence of sites on the basis of average values of parameters shows the order as Site 3>Site 4>Site 2>Control site. The concentration of Zn, Fe and Al were not found on control site or might be under the detection limit of AAS. Only the average concentration of Cd was high at control site (0.37 mg/l) in comparison to other sites. Phosphate concentration was high (0.84±0.20mg/l) on khadi site during autumn. Phosphate mainly comes from domestic sewage, effluents and detergents in to these aquatic bodies. The growth of algae flora is dependent on phosphate nutrient (Matta and Uniyal, 2017).

**Table.1. Seasonal physic-chemical and heavy metal observations at Control site**

| Season | Water velocity (m/sec) | Water temperature (°C) | Conductivity (Siemens/cm) | Turbidity (JTU) | Total solids (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 0.61±0.31 | 16.0±0.06 | 100.18±0.16 | 22.17±0.00 | 63.10±25.50 |
| **Winters** | 0.67±2.15 | 21.0±2.15 | 118.17±0.03 | 29.79±2.47 | 92.17±0.03 |
| **Summer** | 0.81±0.02 | 27.40±0.37 | 124.67±0.03 | 215.70±71.51 | 244.41±0.08 |
| **Monsoon** | 1.20±0.04 | 21.00±0.40 | 121.31±0.00 | 302.95±3.00 | 529.17±0.36 |
| **Average** | 0.82 | 21.35 | 116.08 | 142.65 | 232.21 |

| 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** | 9.7±0.08 | 0.3±0.00 | 54.69±0.80 | 209.0±0.12 | 132.0±0.16 | 42.85±0.24 | 15.10±7.25 | 7.92±2.48 | 0.50 ± 0.21 |
| **Winters** | 8.2±0.82 | 1.1±0.21 | 44.21±0.14 | 135.0±4.75 | 123.5±1.72 | 26.45±2.50 | 12.64±6.91 | 8.98±1.68 | 0.33 ± 0.14 |
| **Summer** | 8.5±0.25 | 0.3±0.00 | 54.31±0.24 | 201.0±3.25 | 214.0±0.59 | 22.10±1.68 | 26.40±1.80 | 6.76±0.34 | 0.76±0.21 |
| **Monsoon** | 8.8±0.21 | 0.2±0.00 | 45.78±0.16 | 122.0±5.25 | 152.0±0.23 | 29.00±0.22 | 19.87±3.16 | 7.76±0.20 | 0.40 ± 0.08 |
| **Average** | 8.80 | 0.48 | 49.75 | 166.75 | 155.38 | 30.10 | 18.50 | 7.86 | 0.50 |

| 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 ± 0 | 2.05 ± 2.9 | 0.05 ± 0 | 0 ± 0.01 | 0.03 ± 0.04 | 0 ± 0 | 0.33 ± 0.04 | 0.03 ± 0.01 |
| **Winters** | 0 ± 0 | 2.73 ± 3.86 | 0.05 ± 0.01 | 0 ± 0 | 0.03 ± 0.04 | 0 ± 0 | 0.35 ± 0.08 | 0.03 ± 0.01 |
| **Summer** | 0 ± 0 | 2.51 ± 3.54 | 0.04 ± 0.03 | 0 ± 0 | 0.03 ± 0.04 | 0 ± 0 | 0.4 ± 0.12 | 0.03 ± 0.01 |
| **Monsoon** | 0 ± 0 | 2.45 ± 3.46 | 0.04 ± 0.03 | 0.01 ± 0 | 0.04 ± 0.05 | 0 ± 0 | 0.4 ± 0.1 | 0.03 ± 0.01 |
| **Average** | 0 | 2.44 | 0.05 | 0.00 | 0.03 | 0 | 0.37 | 0.03 |

**Table.2. Seasonal variation in physic-chemical and heavy metal concentration at Nagni**

| Season | Water velocity (m/sec) | Water temperature (°C) | Conductivity (Siemens/cm) | Turbidity (JTU) | Total solids (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 1.02±0.15 | 18.0±1.67 | 129.46±0.00 | 189.93±5.88 | 354.74±11.60 |
| **Winters** | 0.92±1.25 | 17.5±1.51 | 108.76±1.64 | 101.42±0.80 | 188.97±62.50 |
| **Summer** | 0.70±1.68 | 23.0±2.00 | 119.77±0.08 | 84.21±6.32 | 129.79±0.36 |
| **Monsoon** | 0.98±1.62 | 24.0±1.18 | 125.46±0.16 | 279.86±120.00 | 534.71±2.40 |
| **Average** | 0.90 | 20.63 | 120.86 | 163.86 | 302.05 |

| 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±0.81 | 0.2±0.00 | 52.76±1.24 | 183.0±1.65 | 148.0±1.65 | 33.10±2.14 | 18.40±2.38 | 8.42±1.06 | 0.58±0.18 |
| **Winters** | 9.5±0.80 | 0.2±0.12 | 58.19±1.65 | 203.0±1.68 | 132.0±0.16 | 44.90±1.65 | 15.10±7.25 | 7.92±2.48 | 0.49±0.21 |
| **Summer** | 8.4±1.56 | 0.9±0.05 | 41.49±2.54 | 163.0±0.24 | 123.5±1.72 | 19.10±0.30 | 12.64±6.91 | 8.98±1.68 | 0.32±0.25 |
| **Monsoon** | 7.1±0.16 | 1.4±1.14 | 46.00±1.68 | 172.0±2.16 | 137.0±6.12 | 22.90±0.06 | 14.62±29.48 | 7.79±1.77 | 0.63±0.22 |
| **Average** | 8.60 | 0.68 | 49.61 | 180.25 | 135.13 | 30.00 | 15.19 | 8.28 | 0.51 |

| 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** | 2.56 ± 0.26 | 3.83 ± 0.58 | 3.13 ± 0.01 | 1.74 ± 0.45 | 1.74 ± 0.65 | 2.07 ± 1.17 | 0.33 ± 0.14 | 0.03 ± 0.01 |
| **Winters** | 2.54 ± 0.33 | 3.94 ± 0.88 | 4.04 ± 1.16 | 1.66 ± 0.55 | 1.27 ± 0.1 | 2.54 ± 0.47 | 0.33 ± 0.1 | 0.03 ± 0.01 |
| **Summer** | 2.54 ± 0.34 | 3.79 ± 0.83 | 2.83 ± 0.73 | 1.76 ± 0.61 | 1.16 ± 0.01 | 2.49 ± 0.42 | 0.34 ± 0.04 | 0.03 ± 0.01 |
| **Monsoon** | 0 ± 0 | 2.74 ± 3.87 | 0.06 ± 0.01 | 0 ± 0 | 0.03 ± 0.03 | 0 ± 0 | 0.31 ± 0.04 | 0.03 ± 0 |
| **Average** | 1.91 | 3.58 | 2.52 | 1.29 | 1.05 | 1.78 | 0.33 | 0.03 |

**Table.3. Seasonal variation in physic-chemical and heavy metal concentration at Khadi**

| Season | Water velocity (m/sec) | Water temperature (°C) | Conductivity (Siemens/cm) | Turbidity (JTU) | Total solids (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 0.83±0.00 | 13.0±0.25 | 99.79±0.42 | 64.76±5.62 | 101.24±0.85 |
| **Winters** | 0.71±1.24 | 15.0±1.74 | 97.63±0.86 | 31.93±0.16 | 76.48±0.16 |
| **Summer** | 0.79±0.00 | 26.0±0.06 | 123.16±0.24 | 184.61±8.55 | 187.67±3.25 |
| **Monsoon** | 0.84±1.25 | 27.0±2.14 | 121.43±0.00 | 226.43±32.52 | 225.76±1.97 |
| **Average** | 0.79 | 20.25 | 110.50 | 126.93 | 147.79 |

| Season | DO (mg/l) | Free $CO_2$ (mg/l) | Acidity (mg/l) | Total Alkalinity (mg/l) | Total Hardness (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 7.6±0.02 | 1.1±1.64 | 49.46±0.11 | 208.0±0.14 | 245.0±8.10 |
| **Winters** | 8.4±1.64 | 0.3±0.00 | 55.27±0.25 | 196.0±0.16 | 212.0±1.00 |
| **Summer** | 8.6±0.00 | 0.7±0.00 | 44.91±1.68 | 172.0±0.04 | 164.0±2.80 |
| **Monsoon** | 8.2±0.20 | 0.8±0.00 | 37.48±1.25 | 143.0±1.68 | 189.2±2.15 |
| **Average** | 8.20 | 0.73 | 46.78 | 179.75 | 202.55 |

| Season | Ca Hardness (mg/l) | Mg Hardness (mg/l) | Chlorides (mg/l) | Phosphates (mg/l) |
|---|---|---|---|---|
| **Autumn** | 26.30±2.14 | 24.50±29.00 | 6.45±1.87 | 0.84±0.20 |
| **Winters** | 22.10±1.68 | 27.30±3.31 | 6.98±1.62 | 0.76±0.21 |
| **Summer** | 32.50±1.62 | 19.90±5.74 | 6.12±0.25 | 0.33±0.15 |
| **Monsoon** | 39.40±1.06 | 22.10±5.30 | 7.83±1.54 | 0.48±0.16 |
| **Average** | 30.08 | 23.45 | 6.85 | 0.60 |

| 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** | 2.59 ± 0.08 | 3.76 ± 0.9 | 3.33 ± 0.41 | 1.36 ± 0.08 | 1.32 ± 0.06 | 2.64 ± 0.35 | 0.24 ± 0.38 | 0.22 ± 0.31 |
| **Winters** | 2.71 ± 0.05 | 3.69 ± 0.77 | 4.22 ± 1.65 | 1.28 ± 0.06 | 1.4 ± 0.17 | 2.6 ± 0.26 | 0.21 ± 0.32 | 0.25 ± 0.36 |
| **Summer** | 2.66 ± 0.03 | 3.83 ± 0.66 | 3.49 ± 0.58 | 1.35 ± 0.01 | 1.36 ± 0.02 | 2.04 ± 1.05 | 0.28 ± 0.43 | 0.23 ± 0.29 |
| **Monsoon** | 2.59 ± 0.2 | 3.87 ± 0.55 | 3.89 ± 0.95 | 1.34 ± 0.13 | 1.83 ± 0.57 | 2.56 ± 0.39 | 0.67 ± 0.64 | 0.27 ± 0.4 |
| **Average** | 2.64 | 3.79 | 3.73 | 1.33 | 1.48 | 2.46 | 0.35 | 0.24 |

**Table.4. Seasonal variation in physic-chemical and heavy metal concentration at Jajal**

| Season | Water velocity (m/sec) | Water temperature (°C) | Conductivity (Siemens/cm) | Turbidity (JTU) | Total solids (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 1.07±1.66 | 22.5±1.62 | 125.13±0.60 | 301.76±32.55 | 486.79±2015 |
| **Winters** | 1.16±0.82 | 19.0±1.92 | 121.31±0.00 | 331.76±13.72 | 498.21±52.00 |
| **Summer** | 0.63±0.18 | 17.0±1.16 | 96.54±1.24 | 21.49±7.16 | 51.76±0.78 |
| **Monsoon** | 0.67±2.15 | 21.0±2.15 | 116.43±0.26 | 29.79±2.47 | 97.18±1.86 |
| **Average** | 0.88 | 19.88 | 114.85 | 171.20 | 283.49 |

| Season | DO (mg/l) | Free $CO_2$ (mg/l) | Acidity (mg/l) | Total Alkalinity (mg/l) | Total Hardness (mg/l) |
|---|---|---|---|---|---|
| **Autumn** | 8.9±1.16 | 0.1±0.10 | 44.91±0.11 | 121.0±0.14 | 132.4±1.64 |
| **Winters** | 9.5±0.15 | 0.6±0.00 | 32.35±1.60 | 179.0±5.64 | 157.0±0.01 |
| **Summer** | 9.3±2.14 | 0.2±0.10 | 27.54±0.06 | 167.0±1.68 | 198.0±0.16 |
| **Monsoon** | 10.4±0.17 | 0.4±0.00 | 39.79±0.13 | 208.0±1.40 | 173.0±2.46 |
| **Average** | 9.53 | 0.33 | 36.15 | 168.75 | 165.10 |

| Season | Ca Hardness (mg/l) | Mg Hardness (mg/l) | Chlorides (mg/l) | Phosphates (mg/l) |
|---|---|---|---|---|
| **Autumn** | 31.50±1.60 | 19.00±0.19 | 8.23±1.62 | 0.35±0.09 |
| **Winters** | 35.60±1.25 | 19.90±6.03 | 13.21±3.51 | 0.28±0.10 |
| **Summer** | 40.50±0.12 | 17.00±0.19 | 9.13±1.62 | 0.43±0.12 |
| **Monsoon** | 27.50±2.46 | 24.50±0.00 | 7.63±0.14 | 0.63±0.19 |
| **Average** | 33.78 | 20.10 | 9.55 | 0.42 |

| 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** | 1.9 ± 0.61 | 3.92 ± 0.79 | 1.5 ± 0.26 | 1.13 ± 1.17 | 1.63 ± 0.6 | 3 ± 0.16 | 0.28 ± 0.24 | 0.25 ± 0.34 |
| **Winters** | 2.3 ± 0.06 | 4.31 ± 0.62 | 2.7 ± 1.08 | 1.6 ± 1.26 | 1.65 ± 0.6 | 2.4 ± 0.41 | 0.19 ± 0.32 | 0.2 ± 0.27 |
| **Summer** | 2.3 ± 0.1 | 3.14 ± 0.65 | 2.7 ± 1.81 | 1.62 ± 0.6 | 1.57 ± 0.6 | 2.4 ± 0.47 | 0.22 ± 0.34 | 0.21 ± 0.28 |
| **Monsoon** | 2.3 ± 0.04 | 1.97 ± 1.39 | 4.6 ± 2.78 | 1.38 ± 0.69 | 1.55 ± 0.6 | 2.4 ± 0.41 | 0.19 ± 0.32 | 0.25 ± 0.33 |
| **Average** | 2.20 | 3.34 | 2.88 | 1.43 | 1.60 | 2.55 | 0.22 | 0.23 |

The CPI values were observed and represented in Table.5. The calculated CPI for each sampling site falls beyond the range, *i.e.* ≥2.01 which indicates that the river Henwal was severely polluted i.e. CPI: 4.70-10.31 during all four season. The highest CPI value *i.e.* 10.31 was observed during monsoon at site-3 and lowest was observed at control site (4.70) in comparison to other sites. A considerable lot of the analysts detailed the comparable condition for Hindon stream which starts from upper Shivalik Himalayan area close to the Saharanpur locale of U.P., India (Suthar, 2010; Sharma, 2014; Mishra, 2015). The seasonal variation in pollution level at all four sites reveals that there has been dilution or reduction in pollution load during monsoon season as compared to other season, except at site-3. This could be due to the influx of sewage and domestic wastes into river water which is beyond its assimilative capacity or tolerance capacity.

**Table.5. Water pollution at each sampling location**

| Sampling sites | CPI (Autumn) | CPI (Winters) | CPI (Summer) | CPI (Monsoon) | Polluted |
|---|---|---|---|---|---|
| **Control** | 4.70 | 5.33 | 6.23 | 5.96 | Severely |
| **Nagni** | 8.26 | 8.35 | 7.79 | 6.00 | Severely |
| **Khadi** | 7.88 | 7.62 | 7.74 | 10.31 | Severely |
| **Jajal** | 7.98 | 8.03 | 6.43 | 5.61 | Severely |

Karl Pearson's correlation matrix was developed between the seasonally average values of analysed abiotic and biotic characteristics of river water. In this matrix highly positive relationship between parameters is represented by green colour and highly negative correlation is through red colour. So, it can be clearly found that water velocity is negatively related to hardness, phosphate and plankton diversity, which indicates natural dispersion of these parameters. Turbidity also shows the negative correlation with planktons which could the reason of less light availability for plankton growth and food production (Table.10).

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

| Season | Phytoplankton | Zooplankton | Plankton |
|---|---|---|---|
| **Autumn** | 822.14±163.54 | 294.09±27.16 | 1116.23±179.25 |
| **Winters** | 1067.12±1.99 | 318.60±4.04 | 1385.72±6.30 |
| **Summer** | 968.40±0.82 | 266.01±4.88 | 1234.41±5.70 |
| **Monsoon** | 616.93±1.86 | 259.71±5.80 | 876.64±7.21 |
| **Average** | 883.65 | 284.47 | 1153.25 |

**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** | 822.14±163.54 | 231.39±44.00 | 257.05±72.79 | 333.70±76.99 |
| **Winters** | 1067.12±1.99 | 298.34±0.22 | 381.49±0.36 | 387.29±1.41 |
| **Summer** | 968.40±0.82 | 266.67±0.38 | 368.51±0.09 | 333.22±0.35 |
| **Monsoon** | 616.93±1.86 | 183.20±0.21 | 178.57±0.57 | 255.16±1.08 |

**Number of Different Genera among Zooplankton in the Henwal River**

| Season | ***Protozoa*** | ***Rotifera*** | ***Cladocera*** | *Copepod* | ***Ostracods*** | **D** | **H** | **E** |
|---|---|---|---|---|---|---|---|---|
| **Autumn** | 87.13±14.62 | 61.67±8.65 | 68.45±10.83 | 44.39±7.94 | 32.45±4.90 | 4.53 | 1.56 | 0.44 |
| **Winters** | 105.01±0.21 | 59.68±0.57 | 68.19±1.08 | 55.25±0.76 | 30.47±1.42 | 4.37 | 1.54 | 0.43 |
| **Summer** | 76.54±0.15 | 51.29±1.58 | 62.82±0.82 | 40.14±1.12 | 35.22±1.21 | 4.63 | 1.57 | 0.45 |
| **Monsoon** | 68.57±1.25 | 49.14±2.57 | 61.23±0.85 | 55.28±1.59 | 25.49±0.31 | 4.63 | 1.56 | 0.44 |

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

| Season | Phytoplankton | Zooplankton | Plankton |
|---|---|---|---|
| **Autumn** | 777.61±204.67 | 275.91±35.56 | 1053.52±225.84 |
| **Winters** | 957.83±1.11 | 294.27±3.36 | 1252.10±4.47 |
| **Summer** | 705.95±3.37 | 313.14±4.23 | 1019.09±7.60 |
| **Monsoon** | 525.11±3.57 | 199.06±6.85 | 724.17±10.42 |
| **Average** | 741.63 | 270.60 | 1012.22 |

**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** | 777.61±204.67 | 201.65±53.73 | 252.76±79.84 | 320.69±97.35 |
| **Winters** | 957.83±1.11 | 238.27±0.33 | 268.37±0.29 | 451.19±0.49 |
| **Summer** | 705.95±3.37 | 217.82±0.27 | 229.94±1.92 | 258.19±1.18 |
| **Monsoon** | 525.11±3.57 | 119.22±0.65 | 128.36±1.70 | 277.53±1.22 |

**Number of Different Genera among Zooplankton in the Henwal River**

| Season | *Protozoa* | *Rotifera* | *Cladocera* | *Copepod* | *Ostracods* | D | H | E |
|---|---|---|---|---|---|---|---|---|
| Autumn | 88.67±0.37 | 53.22±1.76 | 67.81±0.32 | 44.16±1.12 | 30.22±1.27 | 4.44 | 1.55 | 0.44 |
| Winters | 91.27±0.39 | 56.67±0.27 | 64.17±1.18 | 52.26±0.96 | 48.77±1.45 | 4.72 | 1.58 | 0.46 |
| Summer | 71.95±22.58 | 59.54±9.57 | 68.36±11.30 | 44.56±8.24 | 31.51±7.35 | 4.65 | 1.57 | 0.45 |
| Monsoon | 39.81±1.03 | 44.14±2.42 | 54.83±1.39 | 30.20±1.59 | 30.08±1.02 | 4.74 | 1.58 | 0.46 |

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

| Season | Phytoplankton | Zooplankton | Plankton |
|---|---|---|---|
| Autumn | 968.97±1.17 | 306.58±6.03 | 1275.45±7.2 |
| Winters | 882.58±1.95 | 286.85±6.83 | 1169.43±8.78 |
| Summer | 875.02±1.95 | 295.74±6.03 | 1170.76±7.98 |
| Monsoon | 848.61±1.01 | 284.08±4.84 | 1132.69±5.85 |
| Average | 893.795 | 293.3125 | 1187.5 |

**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 | 968.97±1.17 | 227.68±0.23 | 302.41±0.69 | 438.78±0.25 |
| Winters | 882.58±1.95 | 239.06±0.37 | 285.71±0.69 | 357.81±0.89 |
| Summer | 875.02±1.95 | 248.51±0.37 | 288.27±0.69 | 338.24±0.25 |
| Monsoon | 848.61±1.01 | 206.62±0.27 | 338.38±0.29 | 303.61±0.45 |

**Number of Different Genera among Zooplankton in the Henwal River**

| Season | *Protozoa* | *Rotifera* | *Cladocera* | *Copepod* | *Ostracods* | D | H | E |
|---|---|---|---|---|---|---|---|---|
| Autumn | 91.28±1.21 | 65.26±1.04 | 78.26±0.95 | 37.26±1.32 | 34.52±1.51 | 4.41 | 1.54 | 0.43 |
| Winters | 76.25±1.08 | 51.65±1.23 | 86.22±1.75 | 33.20±1.40 | 39.53±1.37 | 4.43 | 1.54 | 0.43 |
| Summer | 79.25±0.98 | 58.65±1.27 | 84.22±1.65 | 40.09±1.41 | 33.53±0.72 | 4.47 | 1.55 | 0.44 |
| Monsoon | 56.12±1.83 | 48.14±1.82 | 69.27±1.75 | 54.20±1.51 | 27.47±1.79 | 4.67 | 1.57 | 0.45 |

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

| Season | Phytoplankton | Zooplankton | Plankton |
|---|---|---|---|
| Autumn | 816.42±3.37 | 302.06±5.99 | 1118.48±9.36 |
| Winters | 793.36±148.06 | 277.26±33.11 | 1070.62±175.40 |
| Summer | 631.44±3.20 | 268.46±6.81 | 899.90±10.01 |
| Monsoon | 616.18±3.57 | 274.64±7.95 | 890.82±11.52 |
| Average | 714.35 | 280.61 | 994.955 |

**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 | 816.42±3.37 | 279.30±0.27 | 254.63±1.92 | 282.49±1.18 |
| Winters | 793.36±148.06 | 207.08±44.58 | 255.51±55.03 | 330.77±67.79 |
| Summer | 631.44±3.20 | 165.52±0.37 | 211.21±1.61 | 254.71±1.22 |
| Monsoon | 616.18±3.57 | 132.12±0.65 | 187.25±1.70 | 296.81±1.22 |

**Number of Different Genera among Zooplankton in the Henwal River**

| Season | *Protozoa* | *Rotifera* | *Cladocera* | *Copepod* | *Ostracods* | D | H | E |
|---|---|---|---|---|---|---|---|---|
| Autumn | 90.25±1.33 | 54.97±1.57 | 67.17±1.08 | 50.26±0.98 | 39.41±1.03 | 4.62 | 1.57 | 0.45 |
| Winters | 87.68±0.54 | 87.35±1.35 | 72.05±1.11 | 47.72±1.25 | 32.69±1.83 | 4.50 | 1.55 | 0.44 |
| Summer | 70.56±23.73 | 62.02±10.00 | 67.44±13.18 | 43.31±7.49 | 33.93±6.64 | 4.69 | 1.57 | 0.45 |
| Monsoon | 32.41±1.23 | 67.58±1.07 | 57.83±1.33 | 46.09±0.76 | 36.08±1.92 | 4.65 | 1.57 | 0.45 |

**Table.10. Correlation matrix between the hydrochemical characteristics and planktonic composition**

| | Velocity | Temperature | Conductivity | Turbidity | Total solids | DO | Free CO2 | Acidity | T.Alkalinity | T.Hardness | Ca Hardness | Mg Hardness | Chlorides | Phosphates | Phytoplankton | Zooplankton | Zn | Pb | Mn | Fe | Cu | Al | Cd | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Velocity | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| Temperature | -0.2287 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Conductivity | 0.81845 | 0.34946318 | 1 | | | | | | | | | | | | | | | | | | | | | |
| Turbidity | 0.943601 | -0.31778775 | 0.66364524 | 1 | | | | | | | | | | | | | | | | | | | | |
| Total solids | 0.958251 | -0.02397989 | 0.86176355 | 0.947231 | 1 | | | | | | | | | | | | | | | | | | | |
| DO | 0.543062 | -0.3112561 | 0.20608532 | 0.78929 | 0.6485062 | 1 | | | | | | | | | | | | | | | | | | |
| Free CO2 | -0.29207 | 0.13965852 | -0.0432746 | -0.58289 | -0.459243 | -0.95237 | 1 | | | | | | | | | | | | | | | | | |
| Acidity | -0.26718 | 0.79412494 | 0.29385319 | -0.51987 | -0.227665 | -0.78134 | 0.707773 | 1 | | | | | | | | | | | | | | | | |
| TA | 0.037899 | -0.26207426 | 0.04386547 | -0.23998 | -0.212554 | -0.71803 | 0.889334 | 0.374056 | 1 | | | | | | | | | | | | | | | |
| TH | -0.80021 | -0.39961219 | -0.9785867 | -0.7045 | -0.894656 | -0.35112 | 0.225731 | -0.21362 | 0.1627101 | 1 | | | | | | | | | | | | | | |
| Ca Hardness | 0.389503 | -0.68138955 | -0.128661 | 0.648439 | 0.392218 | 0.893629 | -0.81857 | -0.97802 | -0.493951 | 0.0257595 | 1 | | | | | | | | | | | | | |
| Mg Hardness | -0.7764 | -0.42092622 | -0.996826 | -0.62463 | -0.838958 | -0.1901 | 0.048468 | -0.3389 | -0.00324 | 0.9838587 | 0.16757245 | 1 | | | | | | | | | | | | |
| Chlorides | 0.77509 | -0.36952224 | 0.4282436 | 0.94057 | 0.8254935 | 0.949475 | -0.81342 | -0.71673 | -0.498272 | -0.525209 | 0.83706084 | -0.39709728 | 1 | | | | | | | | | | | |
| Phosphates | -0.70071 | 0.14792023 | -0.4648854 | -0.8839 | -0.819419 | -0.96118 | 0.883844 | 0.606654 | 0.6649527 | 0.5958352 | -0.7584501 | 0.45285624 | -0.96875 | 1 | | | | | | | | | | |
| Phytoplankton | -0.93753 | 0.52666736 | -0.5686783 | -0.96057 | -0.861549 | -0.68089 | 0.426272 | 0.573025 | 0.0109415 | 0.5634559 | -0.6534751 | 0.51201745 | -0.87087 | 0.74897047 | 1 | | | | | | | | | |
| Zooplankton | -0.94584 | -0.07363483 | -0.9592363 | -0.82073 | -0.939736 | -0.35085 | 0.130818 | -0.04922 | -0.082914 | 0.9301327 | -0.0978911 | 0.93537353 | -0.59678 | 0.57440782 | 0.773824336 | 1 | | | | | | | | |
| Zn | 0.11369 | -0.89387831 | -0.3273351 | 0.062949 | -0.159187 | -0.1254 | 0.318175 | -0.43795 | 0.6594417 | 0.4595042 | 0.28349932 | 0.39897699 | 0.000994 | 0.2444358 | -0.333469259 | 0.10136329 | 1 | | | | | | | |
| Pb | 0.129727 | -0.75036273 | -0.1950339 | -0.0072 | -0.158584 | -0.32648 | 0.53563 | -0.19543 | 0.834019 | 0.3647228 | 0.04486979 | 0.26290042 | -0.14914 | 0.38900939 | -0.270223946 | 0.01260733 | 0.963997 | 1 | | | | | | |
| Mn | 0.041144 | -0.87216148 | -0.3800997 | -0.01324 | -0.232314 | -0.18452 | 0.361576 | -0.40084 | 0.6773988 | 0.5152882 | 0.23621677 | 0.44888996 | -0.07001 | 0.31152591 | -0.260683696 | 0.1654565 | 0.997093 | 0.965782 | 1 | | | | | |
| Fe | 0.361694 | -0.91211012 | -0.1122743 | 0.311648 | 0.0986068 | 0.050672 | 0.191558 | -0.51049 | 0.600729 | 0.2350752 | 0.39748237 | 0.19043605 | 0.221382 | 0.02740486 | -0.561374096 | -0.1372439 | 0.96667 | 0.92737 | 0.944608 | 1 | | | | |
| Cu | 0.191454 | -0.97784567 | -0.3387304 | 0.216256 | -0.051042 | 0.119378 | 0.06935 | -0.64932 | 0.4564376 | 0.4290143 | 0.51543765 | 0.41255664 | 0.213826 | 0.02544772 | -0.45940977 | 0.0779973 | 0.967797 | 0.871506 | 0.953586 | 0.964958 | 1 | | | |
| Al | 0.188332 | -0.9656141 | -0.3264782 | 0.196014 | -0.062084 | 0.073618 | 0.119894 | -0.60884 | 0.502565 | 0.4264052 | 0.47167254 | 0.40061356 | 0.178385 | 0.06395494 | -0.44580117 | 0.07082303 | 0.979314 | 0.896066 | 0.966562 | 0.973104 | 0.998618 | 1 | | |
| Cd | -0.56732 | 0.78191779 | -0.0174223 | -0.75592 | -0.506957 | -0.82828 | 0.67245 | 0.944011 | 0.2661463 | 0.0715269 | -0.9597117 | -0.03782877 | -0.85946 | 0.73065665 | 0.811279108 | 0.27521591 | -0.45174 | -0.25366 | -0.3961 | -0.59465 | -0.65241 | -0.61823 | 1 | |
| Mg | -0.32696 | -0.83469206 | -0.8056944 | -0.16589 | -0.471558 | 0.118449 | -0.11032 | -0.7018 | 0.0932928 | 0.8152537 | 0.53960958 | 0.84797364 | 0.016617 | 0.13927731 | -0.012317636 | 0.60591319 | 0.7332 | 0.555197 | 0.74874 | 0.623719 | 0.804325 | 0.787006 | -0.50862 | 1 |

**Plankton community:** The total number of phytoplankton and zooplankton with their different groups are presented in Table 6-9. The total number of most common phytoplanktonic group i.e. diatoms, green algae and blue green algae and zooplanktonic taxa i.e. protozoa, rotifer, cladocera, copepod and ostracods are also represented. Taxon richness was high during the autumn and winter season and low in monsoon season at all four sites. High plankton taxa value (R) 1067.12±1.99 and 318.60±4.04 unit/l was recorded for control site in winter season and least number 525.11±3.57 and 199.06±6.85 unit/l were recorded on Nagni during monsoon. In present study the density of phytoplankton and zooplankton was plotted in Fig. 3 which clearly indicates the seasonal variation in planktonic density. The dominant taxa in phytoplankton were blue green algae (451.19±0.49 unit/l at Nagni) and in zooplankton, protozoa (105.01±0.21unit/l at control sit) during winter.

The seasonally zooplankton group diversity indices and group evenness is calculated for River Henwal. The highest Simpson (D), Shannon- Weiner (H) index and evenness (E) value was 4.74, 1.58 and 0.46 respectively recorded for Nagni site in Monsoon. The lowest value of D, H and E was 4.37, 1.54 and 0.43 for control site during winter. 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 (Lv, 2013). According to this classification the water quality of Henwal river is moderately polluted. 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 (Hu, 2000; Li and Yu, 2002; Gilbert, 1988).

## 4. CONCLUSION

For the assessment of biotic and abiotic characteristics of River Henwal CPI, Simpson, Shannon-Wiener index and taxon evenness are calculated for four sites, out of which one site is considered as control site to compare the water quality of River Henwal with other considered sites. The higher concentration of physic-chemical and heavy metal was found on Site-3 (Khadi), due to which density of blue green algae in phytoplankton and protozoa in zooplankton was dominance group on this site. CPI value clearly indicates that river water was severely polluted (CPI >2 i.e. 4. 70-10.31). Even though CPI value was lower at control site in comparison to other sites. So, it could be said that control site is less polluted then other sites in terms of physic-chemical characteristics. The Simpson, Shannon-Weiner index and evenness was useful to understand the trophic state of River Henwal in terms of zooplankton abundance. The higher value of D, H and E was in monsoon season and lower during the winters.

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