E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2021; 9(1): 288-295

www.fisheriesjournal.com
Received: 09-10-2020
Accepted: 07-12-2020

Akansha Dhondiyal
Doon University, Dehradun, Uttarakhand, India

Anjani Rawat
Wildlife Institute of India, Dehradun, Uttarakhand

VP Uniyal
Wildlife Institute of India, Dehradun, Uttarakhand

Akanksha Rawat
Doon University, Dehradun, Uttarakhand, India

Archana Sharma
Doon University, Dehradun, Uttarakhand, India

S Sathyakumar
Wildlife Institute of India, Dehradun, Uttarakhand

Corresponding Author:
Akansha Dhondiyal
Doon University, Dehradun, Uttarakhand, India

A brief overview of the application of pollution monitoring indices on Amrit Ganga river, Uttarakhand, India

Akansha Dhondiyal, Anjani Rawat, VP Uniyal, Akanksha Rawat, Archana Sharma and S Sathyakumar

DOI: https://doi.org/10.22271/fish.2021.v9.i1d.2413

Abstract
Benthic macroinvertebrates are an indispensable part of aquatic ecosystems. They are used repetitively for evaluation of aquatic health since the emergence of the industrial revolution. Several studies show that their presence and absence are an indicators of aquatic health. In our study at the Amrit Ganga river, four sampling stations (consisting of sampling points each) were selected for the collection of aquatic macroinvertebrates. A total of n= 465 individuals were collected during the sampling period in which Trichoptera and Diptera appeared as dominant orders. According to functional feeding groups, the presence of filters and scrapers was higher than that of detritivore, and the presence of predators was lowest. Based on the presence of sensitive orders,%EPT (Ephemeroptera, Plecoptera, and Trichoptera) was calculated, and the maximum value calculated was 74.5% in (site 2) and the minimum value was 21% in (site 4). We also quantified the Water Quality Index approach which is based on physicochemical properties of water and the minimum and maximum values of WQI (Water Quality Index) varies from 33.94 in Site 2 to 48.61 in Site 4, indicating "excellent" (WQI<50) water quality in all the sites. This study serves as a baseline data for water quality monitoring programs and management and also to quantify the macroinvertebrates assemblage.

Keywords: Amrit Ganga, macroinvertebrates, water quality index (WQI), biotic index (BI)

1. Introduction

Water is an essential abiotic component which is indispensable for humans as well as aquatic ecosystems. All the life on earth has its origin from it, and it holds a significant component in their life cycle. Generally, water health is discussed mainly on two matrices (1) Water Quality Index (WQI), which is an evaluation of its potability based physicochemical characteristics, and (2) Biotic Index (BI) based on evaluating water quality by indicator species. It can be categorized as biotic and abiotic method. Due to the increasing human intervention of aquatic ecosystems, pollution studies mainly focused on the potability of water for human consumption, and the sensitivity of the aquatic ecosystem is ignored repetitively. The definition of clean water varies ecologically and for human society (Boulton, 1999) [8]. Incorporating ecological integrity, along with the societal values of clean drinking water, may not include the ecological health of the river comprising of living organisms (Meyer, 1997) [26]. Generally, humans value rivers and streams as a source of drinking, washing, industrial, agricultural, recreational, and aesthetic use, but the ecological factors are usually missed out. It is evident from the permissible limits and standard set up by the government organizations all over the world, which mainly focuses on the potability of water rather than ecological integrity. A U.S-based national foundation (NSF) 1965 has developed the Index based method comprising of physical, chemical, and biological measures. The concept of the Water Quality Index (WQI) takes into account physicochemical parameters (i.e. water chemistry), whereas the Biotic index deals with the presence and absence of macroinvertebrates. A holistic study of considering BI and WQI has been incorporated in an interesting study by Meridionale River Italy and the study suggests an integrative approach of WQI and BI for measuring river health. (Bonanno *et al.* 2010).

A study was done by Rana *et al.* 2015 in Budhigandaki river Nepal applied the biotic index as well as WQI for assessing the water quality for drinking purposes. Sharifinia *et al.*, 2016 studied Shahrood river employing both WQI as well as BI for evaluating the water quality and suggested using Biotic Index for evaluating stream health. Using the biotic index is vital as the biota is affected by the environmental changes over time, whereas the physicochemical analysis only provides the real-time status of the environment at the moment of sampling. (Wiederholm,1980 and Rosenberg and Resh 1993) [47, 36]. The feasibility of the biotic Index via macroinvertebrates is comparatively cost-efficient than that of the WQI method (Chowdhury *et al.*, 2016) [10]. Macroinvertebrates act as a continuous indicator of water health as they reflect the physical and chemical pollution and physical change is habitat over a long period (Rosenberg and Resh 1993) [36]. The diversity of sensitive taxa or intolerant taxa is higher in undisturbed sections of the river as compared to the disturbed sections, however, to obtain the complete spectrum of water health, the inclusion of WQI is essential (Ghani *et al.* 2018) [11]. River substrate, river discharge, river riparian, and river canopy are also the contributing factor for the river water quality besides WQI (Eh Rak *et al.* 2017) [15]. The WQI method proved to be efficient when done temporally as compared partially because of high mobility and rapid exchange of nutrients (Wu *et al.* 2017) [50]. Studies based on WQI and BI in selected sites of East Java indicated similar results when analysed for drinking purposes. (Wimbaningrum *et al.* 2016) [48]. Although, WQI, which is solely based on physical and chemical parameters is used widely for water quality assessment but its correlation with BI is less studied. (Wu *et al.*, 2019) [51]. Hence, it becomes necessary to highlight their performance. Several studies show the status of water quality of high altitude rivers, glacier-fed lakes, and streams based on WQI and BI in different parts of the Indian Himalayan region. (Mishra *et al.* 2013; Nautiyal *et al.* 2015; Seth *et al.* 2016; Sharma *et al.* 2017; Nautiyal *et al.* 2018 and Ross *et al.* 2019) [27, 29, 38, 39, 30 37]. According to Kumar *et al.* 2019 [32] assessing the water quality of high altitude lake is essential so that trekkers, sages, and wildlife can consume it. Himalayan rivers are a source of clean drinking water for the majority of Indian states, are less studied due to poor connectivity and harsh terrain. Analysing the above factors, we selected Amrit Ganga river, one of the glacier-fed rivers of Uttarakhand Himalayas as our study area with the objective a) To quantify the distribution of benthic macroinvertebrates in Amrit Ganga and b) to analyse water quality index (WQI) and biotic Index (BI) of Amrit Ganga River for its suitability to human consumption as well as ecological integrity.

2. Study Area

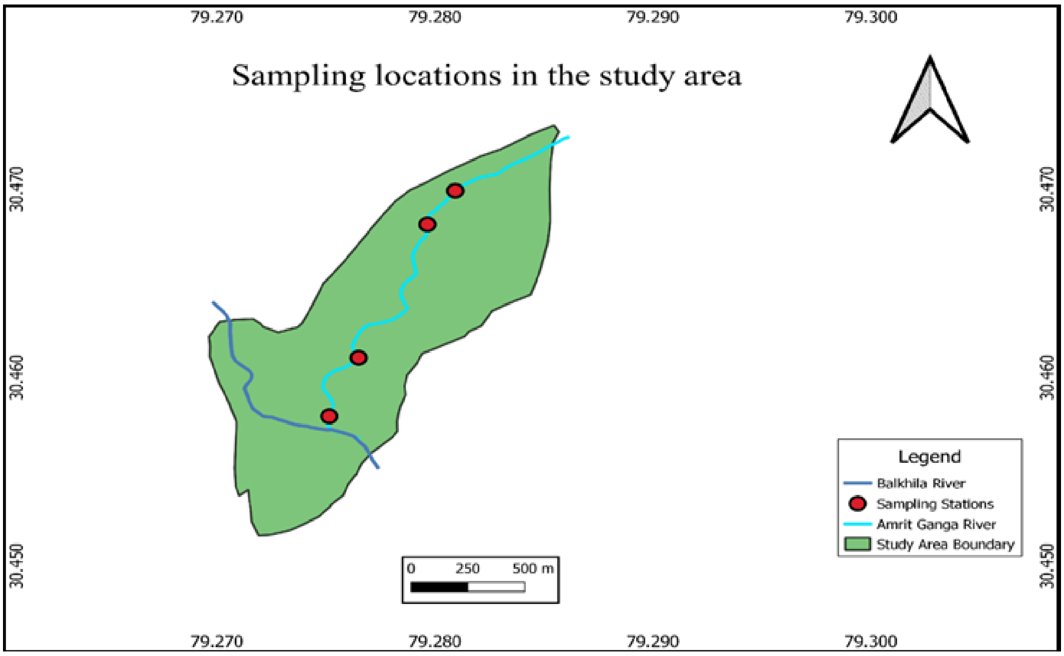

Fig 1: Map of the study area

Amritganga river flows across the Mandal valley of the Chamoli district of Uttarakhand and is one of the glacier-fed rivers of the Alaknanda river. It originates from glaciers above Rudranath, which is a part of Kedarnath Wildlife Sanctuary and is surrounded by mixed forest which is dominated by *Quercus spp.* and *Rhododendron spp.* and furthermore, passes by Atri muni cave (one of the essential Hindu shrine) and drains into Balkhila river in Mandal Valley. The length of the Amrit Ganga River from its origin to the Balkhila confluence is approximately 10 km. Because of its religious and aesthetic importance, several tourists and pilgrims visit here during pilgrimage season (May-September). The substratum of the river is dominated by the cobbled and boulders which imparts the presence of riffles in the stream.

3. Methods

3.1 Calculation of % EPT Index

EPT index is calculated by adding values of Order Ephemeroptera, Plecoptera and Trichoptera and dividing it to the total number of individuals found in the respective site.

% EPT = (Total number of EPT / Total number of individuals) *100

3.2 Physico chemical analysis

Total of eight parameters were taken for physicochemical analysis (Dissolved Oxygen, TDS, alkalinity, sodium, potassium, nitrate, total hardness and temperature). Water samples were collected by using the grab sampling technique. Total n=16 samples were collected from each sampling site where each site consists of 4 samples. These samples were analysed using the standard protocol of APHA (2005) [3] (Table 1)

Table 1: Water quality parameter and the Instrument/Method used

Water Quality test	Instrument/Method
Instrument/Method	Titrimetric method (Wrinkler method)
Total hardness	Titrimitric method (complexometric)
Alkalinity	Titrimetric method
Potassium	Flame photometer
Sodium	Flame photometer
Nitrate	Spectophotometer
TDS	TDS meter
Temperature	Thermometer

3.3 Calculation of Water Quality Index

The WQI was calculated using three steps as per Batabyal *et al.* 2015 [4] First, the selected parameters of physicochemical analysis were assigned a weight (wi) according to their relative importance considering the drinking purpose, (TDS, Dissolved oxygen, total hardness, Alkalinity, Nitrate, Sodium, Potassium) according to its relative importance in the overall quality of water for drinking purposes. These weights were assigned between 1 and 5 based on their relative significance in the water quality evaluation. Second, the relative weight (Wi) of the chemical parameter was computed using the following equation:

$$W_i = w_i / \sum_{i=1}^{n} wi$$

Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.

2) In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to guideline (BIS,1991), and the result is multiplied by 100:

$$q_i = (C_i / S_i)100$$

Where, qi is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/L, and S_i is the Indian drinking water standard for each chemical parameter in mg/L.

For computing WQI, the sub index (SI) is first determined for each chemical parameter, as given below003A

$$SIi = W_i \times q_i$$

$$WQI = \sum SI_{i-n}$$

Where SIi is the sub-index of i^{th} parameter, W_i is relative weight of i^{th} parameter; q_i is the rating based on concentration of the i^{th} parameter and n is the number of chemical parameters. The WQI values are classified into five categories:

Table 2: WQI values

Range	Water Quality
<50	Excellent water
50-100	Good Water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

4. Results and Discussion

A total of n=465 individuals were identified during the sampling period consisting of 6 orders from 4 sampling sites of the Amritganga river. Orders were further identified up to the family level. The dominant orders in the river Amritganga were Trichoptera (n=204), Ephemeroptera (n=141) and Diptera (n= 108) whereas other orders comprise of Coleoptera (n=10), Megaloptera(n=1), Plecoptera (n=1) respectively. According to the Functional Feeding Group (FFG) classification, the dominant FFG was filterers & shredders, followed by collectors-gatherers. Collector filterers are the peculiar feature of the Order Trichoptera in which the food particles are captured from the water column by the construction of the net (Ramirez *et al.* 2014). The least common FFG was the predator and its role is to capture the prey to control the population of the benthic fauna (Oberndorfer, Mc Arthur & Barnes, 1984; Cooper, Walde & Peckarsky, 1990) [31, 11]. The abundance of filterers and shredders also indicate high litter content nearby the banks of Amritganga due to riparian vegetation, as shown in Fig 2.

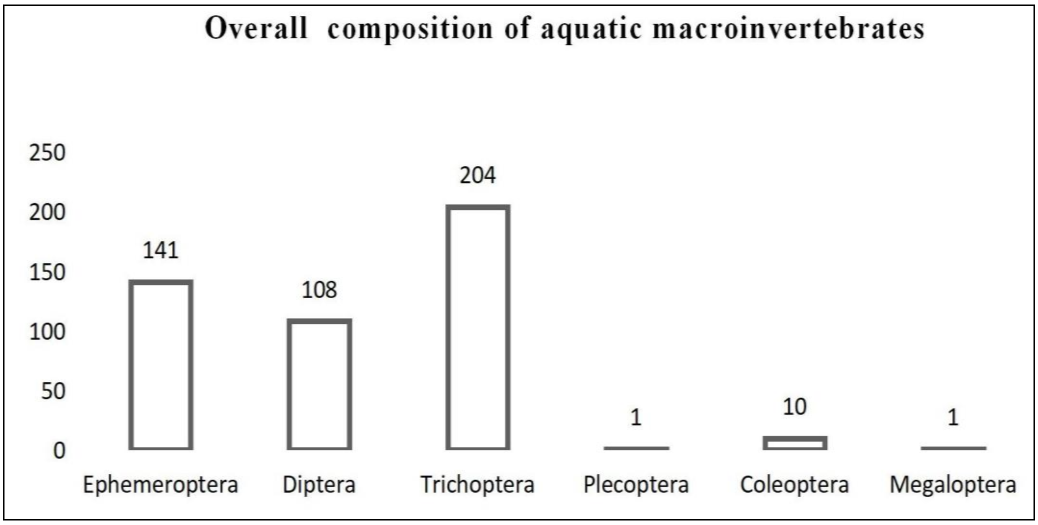

Fig 2: Overall Composition of aquatic macroinvertebrates

Table 3: Presence and absence of common orders and families of Amrit Ganga

Order	Family	Site 1	Site 2	Site 3	Site 4
Ephemeroptera	Baetidae	+	+	+	+
	Ephemerellidae	+	+	+	+
	Heptageniidae	+	+	+	+
Diptera	Athericidae	+	+	+	+
	Chironomidae	+	+	+	+
	Simulidae	-	-	-	+
	Tipulidae	+	+	+	+
Trichoptera	Hydropsychidae	+	+	+	+
	Other caddisflies	+	+	+	-
Plecoptera	Perlidae	+	-	-	-
Coleoptera	Hydrophilidae	-	-	-	+
Megaloptera	Corydiladae	-	-	-	+

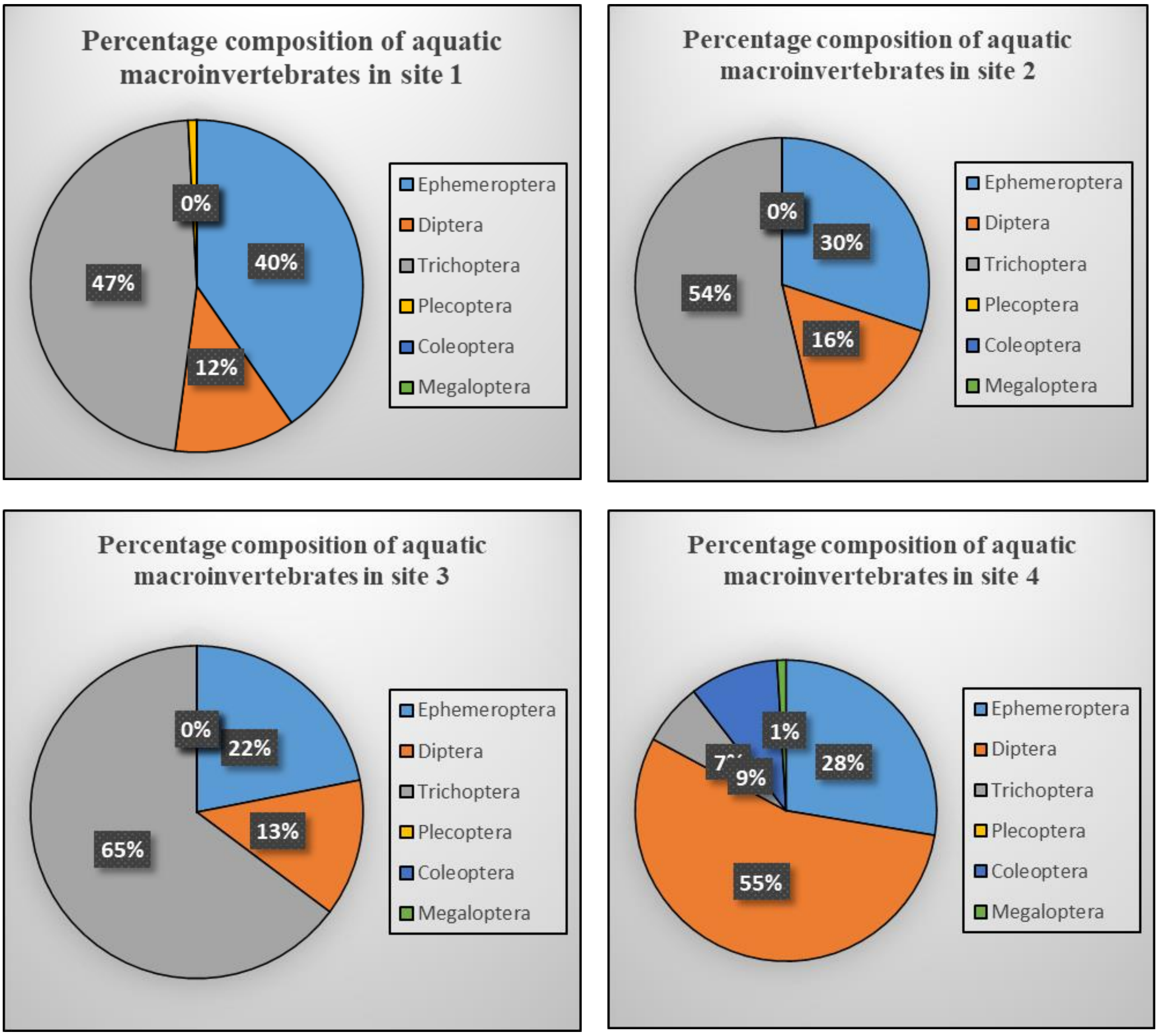

Fig 3: Composition of aquatic macroinvertebrates in selected sites of Amrit Ganga river

The most frequently found aquatic macroinvertebrates were of the Order Ephemeroptera, Trichoptera, and Diptera. Order Trichoptera showed a high percentage composition, 47% (site 1), 54% (site 2) and 65% (site 3) (Fig 3). Similar results with the high annual composition of Trichoptera (38%) followed by Ephemeroptera (32%) was observed by (Sharma *et al.*, 2008) [40] while surveying the aquatic insect diversity in Chandrabhagha river of Garhwal Himalaya. They suggested that the distribution and abundance of aquatic ecosystems are affected by the velocity of water, water temperature, depth, and substrate composition. The bottom substrate may be one of the important reasons affecting the diversity of macroinvertebrates. Boulders, Cobbles, and Pebbles dominate the river Amritganga river. Bottom substrate types such as leaves, wood, gravel, macrophyte support large diversity than the other substrate like bedrock & sand (Angradi 1996, Hawkins 1984) [2]. Temperature variation might be another reason affecting the macroinvertebrate species life cycle

(Soulsby *et al.*, 2001) [44]. It is a well-established fact that many insect species have seasonal life cycles and it results in fluctuations in the numbers of certain groups of macroinvertebrates occurring in samples taken from the streambed at different times of the year (Hynes, 1972) [22]. showed that autumn is a period of egg hatching, and for many species, it is a period of multiplication or often of maximum numbers, including many small individuals. Similarly, in lowland headwater streams of the Alafia River, Cowell *et al.* (2004) [12] also found the highest abundance in autumn. We also observed that the riparian vegetation during the first sampling (March 1, 2019) was less as compared to another sampling period, which might result in less saprobic during the winters. Several studies have shown that seasonal abundance of food may strongly influence the life cycles of the stream community (Ross, 1963; Cummins, 1977; Moore 1977; Townsend & Hildrew, 1979) [37, 13, 38, 46]. However, more sampling effort is required for a robust explanation of it.

4.1 Analysis of results%EPT

We analyzed the presence of pollution sensitive taxa namely Mayfly (Order Ephemeroptera), Stonefly (Plecoptera), and Caddisfly (Trichoptera) and upstream and downstream of the Amrit Ganga river by% EPT indices. During the 1st sampling period (1 March) the highest value of EPT was 72% (Site 1) and the lowest value observed was 30.8% (site 2). In the 2nd sampling period (March 15) the highest value of EPT was 56.5% (Site 1) whereas the lowest value was 21.6% (Site 4). On April 1(3rd sampling period) the highest and the lowest value of EPT obtained was 74.5% (Site 2) and 38.5% (Site 3) respectively. On the last sampling, the (April 15) the highest value of EPT was 60.9% (Site 3) whereas the lowest value observed was 21% (site 4) as represented in the graph.

Aquatic macroinvertebrates are influenced by the land use and their composition varies according. Our results are consistent with several studies all around the world. According to Bouchelouche and Saal 2020, the values of% EPT changed in the lower stream of the river Kebir-Rhumel catchment area (northeast Algeria) where the anthropogenic stress was higher. However, the physicochemical attributes and WQI remained intact. Song *et al.* indicated that the decrease in EPT taxon is due to the changes in the quality of water due to human intervention in the basin of the Garonne River in southern France. Suhaila and Che Shalmah (2017) [45] in their study in rivers of Gunung Jerai Forest Reserve (GJFR) in the north of peninsular Malaysia also showed that EPT taxa get affected by the changes in water parameters.

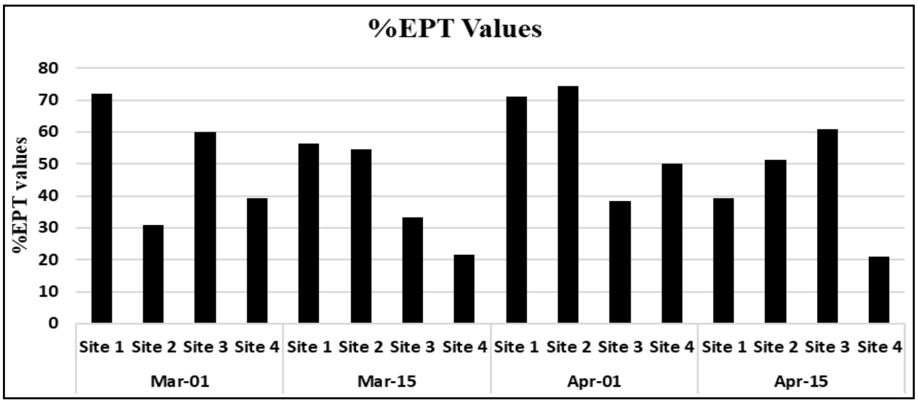

Fig 4: Values of%EPT during the sampling season

4.2 Analysis of physicochemical parameters of water

All 8 physicochemical parameters were analyzed in the laboratory by standard protocol. Dissolved oxygen is related to the concentration of oxygen in the water, and it is essential to support aquatic life thriving on it. (Hussain *et al.* 2011) [21]. Dissolved oxygen varies from 7.655 (site 1) – 7.7 mg/l (site 4) in Amrit Ganga River, which was under the permissible limits (5 mg/L) as recommended by Central Pollution Control Board (CPCB). The hardness of water is mainly due to the calcium and magnesium ions, which is expressed in terms of equivalent CaCo3 (Das *et al.* 1996) [14]. Total hardness ranges from 160.095 (site 4) to 206.59 (site 1). The values of sodium vary from 1.17 ppm (site 2) to 1.5975 (site 4). According to the World Health Organization, potassium is an essential element present in animal and plant tissue, and a low level of potassium does not cause any health concerns. In the Amrit Ganga river, values of potassium ranged from 1.02 (site 2) to 1.11 (site 1) ppm, which is in the permissible limit of WHO (8 mg/L). Nitrate occurs in the anionic form in water bodies and is an essential indicator of organic pollution (Seth *et al.* 2016) [38]. However, in the Amrit Ganga river, nitrate concentration ranged from 0.105 (site 4) to 0.12 (site 1) ppm. Alkalinity in water depicts the number of carbonates, bicarbonates, and hydroxyl ions, and it can neutralize the acid (Bora *et al.* 2017) [5]. Alkalinity varies from 33.75 (site 1 and site 4) to 41.25 (site 2) and the permissible limits as prescribed by BIS (120 mg/L). The concentration of TDS is the total dissolved solids varies from 20 (site 3) - 20.5 (site 1). According to BIS, the prescribed values of TDS is 500 mg/L (Bora *et al.* 2017) [5]. The sampling duration of our study was during the winter season, and due to the elevation gradient of the sampling locations, water temperature ranges from 11.5 (site 1) to 12.5 (site 4). Air temperature affects the temperature of water bodies, and fluctuation in temperature is associated with the chemical and biological reactions necessary for the survival of aquatic ecosystems. (Hefni *et al.* 2015) [20] All the parameters analyzed were within the permissible limit of BIS, WHO and CPCB).

Table 4: Summary statistics of water quality parameters at Amrit ganga river

Parameters	Min	Max	Mean
DO(Mg/L)	5.2	7.8	6.5±0.77
Total hardness	44.66	297.79	182.85±59.43
Sodium(ppm)	0.73	2.22	1.43±0.42
Potassium(ppm)	1	1.33	1.096±0.109
Nitrate(ppm)	0.049	0.193	0.11±0.0518
Alkalinity(ppm)	20	50	36.56±8,891
TDS(ppm)	18	25	20.31±2.386
Temperature	10	14.7	11.98±1.606

4.3 Evaluating Water Quality
The overall analysis of water quality shows that all the values of WQI were in the "excellent" category (WQI<50) and suitable for drinking purposes. The highest value of WQI is 48.61 in site 4 during the first sampling, and the lowest value was 33.94 in site 2 in the same sampling period. However, in the other sampling period and sites, the values of WQI are almost identical. These results are similar to the study held in river Ravi, located in Madhopur district of Punjab (Kumar *et al.* 2009) [23]. As it is the preliminary analysis and earlier studies are not available, further research is recommended. The integration of different parameters into a single unit makes the interpretation easier. (Bordalo *et al.*) [7].

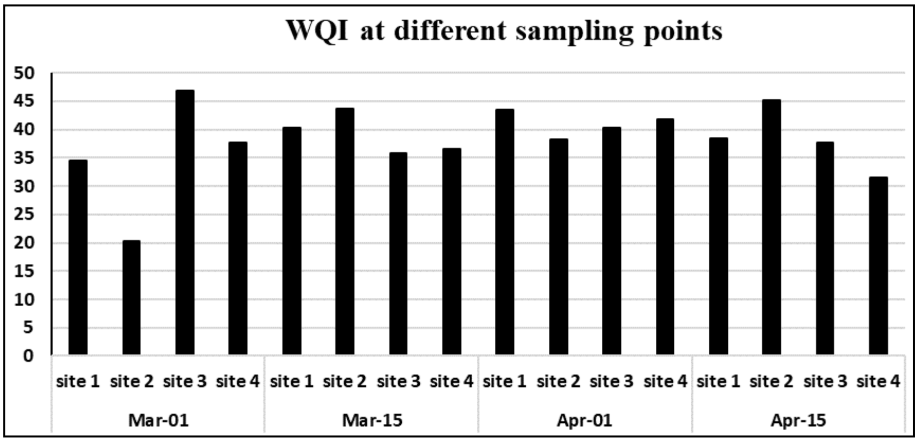

Fig 5. Values of Water Quality Index during the sampling season

5. Conclusion
The present study indicates the composition of macroinvertebrates orders of the Amritganga river and is helpful for future research as no study has been conducted earlier in it. Results of the%EPT index show that the water quality has slightly deteriorated in the lower stream of the river. Downstream of the river consists of the village population which influences the composition of benthic fauna; as a result, affecting the water quality of this pristine river. However, the WQI of the river shows "excellent" water quality upstream as well as downstream. So, it can be concluded that the water quality of the river is excellent for human consumption, but from the ecological point of view, the downstream sites are being affected by human activities. Thus, it still needs management to prevent future impairment. Further scientific study is recommended in this river for a more precise explanation

6. Conflict of interest: We have no conflict of interest.

7. Funding information: National Mission on Himalayan Studies (NMHS)

8. Acknowledgement: We are thankful to the Wildlife Institute of India for providing guidance and technical support to conduct the research activity. We also thank Mr. Pankaj for assisting us in field sampling collection.

9. References
1. Adriaenssens V, Goethals PLM, DePauw N. Assessment of land-use impact on macroinvertebrate communities in the Zwalm River basin (Flanders, Belgium) using multivariate analysis and geographic information systems. In Proceedings of the 2nd Symposium on European Freshwater Systems. The Scientific World Journal 2002;2:546ñ557.
2. Angradi TR. Inter-habitat variation in benthic community structure function and organic matter storage in 3 appalachian headwater streams. Journal of the North American Benthological Society (USA) 1996;15:42-63.
3. APHA. Standard methods for examination of water and wastewater, 21st edn. American Public Health Association, Washington 2005.
4. Batabyal AK, Chakraborty S. Hydrogeochemistry and Water Quality Index in the Assessment of Groundwater Quality for Drinking Uses. Water Environment Research 2015;87(7),607–617. doi:10.2175/106143015x1421265861395
5. Bora M, Goswami DC. Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. Appiedl Water Science 2015;7:3125-3135 (2017). https://doi.org/10.1007/s13201-016-0451-y
6. Bonanno G, Giudice RL. Application of Two Quality Indices as Monitoring and Management Tools of Rivers. Case Study: The Imera Meridionale River, Italy. Environmental Management 2010;45(4):856-867. doi:10.1007/s00267-010-9450-1
7. Bordalo AA, Nilsumranchit W, Chalermwat K. Water quality and uses of the Bangpakong River (Eastern Thailand). Wat. Res 2001;35(15):3635-3642.
8. Boulton AJ. An overview of river health assessment: philosophies, practice, problems and prognosis. Freshwater Biology 1999;41(2):469-479. doi:10.1046/j.1365-2427.1999.00443.x
9. Bureau of Indian Standards. Retrieved 9 March 2020, from https://bis.gov.in/
10. Chowdhury GW, Gallardo B, Aldridge DC. Development and testing of a biotic index to assess the ecological quality of lakes in Bangladesh. Hydrobiologia, 2016;765(1), 55-69.
11. Cooper SD, Walde SJ, Peckarsky BL. Prey exchange rates and the impact of predators on prey population in streams. Ecology 1990;71:1503-1514
12. Cowell BC, Remley AH, Lynch DM. Seasonal changes in the distribution and abundance of benthic invertebrates "in six headwater streams in central Florida. Hydrobiologia 2004;522(1-3):99-115.
13. Cummins KW. From headwater streams to river. American Biology Teacher (May) 1977, 305-312

14. Das BK, Singh M. Water chemistry and control of weathering of Pichola Lake, Udaipur district, Rajasthan, India. Environment Geology 1990;27:184-190
15. Eh Rak A, Syed Omar SA, Abas Kutty A. Influence of habitat characteristics on the assemblage and distribution of ephemeroptera, plecoptera and trichoptera (EPT) at selected recreational rivers in Kelantan, Malaysia. *J. Fundam.* Appl. Sci 2017;9(7S):38-48.
16. Flotemersch JE, Saavedra JM, Laffitte L, Laurenzano B, Bonardi MA, Blocksom KA, *et al.* Benthic macroinvertebrate field sampling effort required to produce a sample adequate for the assessment of rivers and streams of Neuquén Province, Argentina. Limnologica-Ecology and Management of Inland Waters 2017;65:55–60. doi:10.1016/j.limno.2017.05.004
17. Ghani WMHW A, Kutty AA, Mahazar MA, Al-Shami SA, Ab Hamid S. Performance of biotic indices in comparison to chemical-based Water Quality Index (WQI) in evaluating the water quality of urban river. Environmental monitoring and assessment 2018;190(5),297.
18. Hall MJ, Closs GP, Riley RH. Relationships between land use and stream invertebrate community structure in a South Island, New Zealand, coastal stream catchment. New Zealand Journal of Marine and Freshwater Research 2001;35(3):591-603.
19. Hawkins CP. Substrate association and longitudinal distribution in species of Ephemerellidae (Ephemeroptera: Insect) from Western Oregon. Freshwater Invertebrate Biology 1984;3(94):18-88.
20. Hefni E Romanto, Wardiatno Y. Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. Procedia Environmental Sciences 2015;24:228-237
21. Hussain QA, Pandit AK. Hydrology, Geomorphology and Rosgen classification of Doodhganga stream in Kashmir Himalaya, India. International Journal of Water resource and Environmental Engineering 2011;3(3):57-65
22. Hynes HBN. The Ecology of Running Waters. University of Toronto Press, Toronto 1972, 555pp
23. Kumar A, Dua A. Water Quality Index for assessment of water quality of river Ravi at Madhopur (India). Global Journal of Environmental Science 2009;8(1):49-57.
24. Lenat DR, Crawford JK. Effects of land use on water quality and aquatic biota of three North Carolin Piedmont streams. Hydrobiologia 1994;294(3):185-199. doi:10.1007/bf00021291.
25. Merritt RW, Cummins KW, Berg M. (Eds.). An introduction to the aquatic insects of North America. Iowa: Kendall/Hunt Publishing Company 2008.
26. Meyer JL. Stream health: incorporating the human dimension to advance stream Ecology. Journal of the North American Benthological Society 1997;16:439±447
27. Mishra AS, Nautiyal P. Functional composition of benthic macroinvertebrate fauna in the plateau rivers, Bundelkhand, central India. Journal of Threatened Taxa 2013;5(13):475-4758. https://doi.org/10.11609/JoTT.o3226.4752-8
28. Moore JW. Seasonal succession of algae in rivers II. Examples from Highland water, a small woodland stream. Archiv fu¨ r Hydrobiologie 1977;80:160-171
29. Nautiyal P, Mishra AS, Semwal VP. Spatial distribution of benthic macroinvertebrate fauna in mountain streams of Uttarakhand, India. In Aquatic Ecosystem: Biodiversity, Ecology and Conservation (pp. 31-51). Springer, New Delhi 2015.
30. Nautiyal P, Mansi Sharma N, Kumar P, Singh D. Biological Monitoring of Water Quality Before and After Completion of the Hydroelectric Project on the River Alaknanda at Srinagar. In: Siddiqui N., Tauseef S., Bansal K. (eds) Advances in Health and Environment Safety. Springer Transactions in Civil and Environmental Engineering. Springer, Singapore 2018.
31. Oberndorfer RY, McArthur JV, Barnes JR. The effects of invertebrate predators on leaf litter processing in an alpine stream. Ecology 1984;65:1325-1331.
32. Rahul Kumar, Ramesh C Sharma. Assessment of the water quality of Glacier-fed lake Neel Tal of Garhwal Himalaya, India, Water Science 2019;33:1,22-28, DOI:10.1080/11104929.2019.1631554
33. Ramirez A, Fonseca PEG. Functional Feeding Groups of Aquatic Insect families in Latin America: a critical analysis and review of existing literature. International Journal of Tropical Biology 2014;62:155-16.
34. Rana A, Chhetri J. Assessment of river water quality using macro-invertebrates as indicators: a case study of Bhalu Khola tributary, Budhigandaki river, Gorkha, Nepal. International Journal of Environment 2015;4(3):55-68.
35. Rawat A, Gulati G, Maithani R, Sathyakumar S, Uniyal VP. Bioassessment of Mandakini River with the help of aquatic macroinvertebrates in the vicinity of Kedarnath Wildlife Sanctuary. Applied Water Science 2020;10(1):36.
36. Resh VH, Rosenberg DM. (Eds.) Freshwater biomonitoring and benthic macroinvertebrates (No. 504.4 FRE). New York, NY, USA:: Chapman & Hall 1993.
37. Ross HH. Stream communities and terestrial biomes. Archiv fu¨ r Hydrobiologie 1963;59:235-242.
38. Seth R, Mohan M, Singh P, *et al.* Appl Water Sci 2016;6:137. https://doi.org/10.1007/s13201-014-0213-7
39. Sharma RC, Kumar R. Water quality assessment of sacred glacial Lake Satopanth of Garhwal Himalaya, India. Applied Water Science 2017;7:4757-4764. doi:10.1007/s13201-017-0638-x
40. Sharma A, Sharma RC, Anthwal A. Environmentalist 2008;28:395. https://doi.org/10.1007/s10669-007-9155-z
41. Sharifinia M, Mahmoudifard A, Namin JI, Ramezanpour Z, Yap CK. Pollution evaluation in the Shahrood River: Do physico-chemical and macroinvertebrate-based indices indicate same responses to anthropogenic activities?. Chemosphere 2016;159:584-594.
42. Sivaramakrishnan K, Subramanian K, Ramamoorthy K, Sharma V, Chandra K. Checklist of Ephemeroptera of India 2014. https://www.researchgate.net/publication/267560499_CHECKLIST_OF_EPHEMEROPTERA_ OF_INDIA.
43. Song MY, Leprieur F, Thomas A, Lek-Ang S, Chon TS, Lek S, *et al.* Impact of agricultural land use on aquatic insect assemblages in the Garonne river catchment (SW France). Aquatic Ecology 2009;43:999-1009. https://doi.org/10.1007/s10452-008-9218-3
44. Soulsby C, Malcolm R, Gibbins C, Dilks C. Seasonality water quality trends and biologicalresponses in four streams in the CairngormMountains, Scotland. Hydrology and Earth System Sciences 2001;5(3):433-

450.
45. Suhaila AH, Che Salmah MR. Application of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) in water quality assessment of Malaysian headwater. Trop Life Sci Res 2017;28:143-162
46. Townsend CR, Hildrew AG. Foraging strategies and coexistence in a seasonal environment. Oecologia 1979;38:231-234.
47. Wiederholm T. Use of benthos in lake monitoring. Journal (Water Pollution Control Federation) 1980, 537-547.
48. Wimbaningrum R, Indriyani S, Retnaningdyah C, Arisoesilaningsih E. Monitoring water quality using biotic indices of benthic macroinvertebrates along surfaces water ecosystems in some tourism areas in East Java, Indonesia. Journal of Indonesian Tourism and Development Studies 2016;4(2):81.
49. World Health Organisation. Retrieved 9 March 2020, from https://www.who.int/
50. Wu Z, Zhang D, Cai Y, Wang X, Zhang L, Chen Y, *et al.* Water quality assessment based on the water quality index method in Lake Poyang: The largest freshwater lake in China. Scientific reports 2017;7(1):1-10.
51. Wu Z, Kong M, Cai Y, Wang X, Li K. Index of biotic integrity based on phytoplankton and water quality index: Do they have a similar pattern on water quality assessment? A study of rivers in Lake Taihu Basin, China. Science of The Total Environment 2019;658:395-404. doi:10.1016/j.scitotenv.2018.12.216.