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Research Article

Assessment of water quality of river Yamuna in Yamunanagar, India with reference to planktons and macrozoobenthos

*** Bhatnagar Anita, Chopra Girish, Malhotra Priyanka**
Department Of Zoology, Kurukshetra University, Kurukshetra-136119, India

***Corresponding author**
Dr. Anita Bhatnagar
Email: anitabhatnagar@gmail.com

Abstract: This paper presents an assessment of water quality of the river Yamuna, when it meanders along the city Yamunanagar, India and is subjected to sewage and industrial pollution. The analysis of various pollution parameters showed an increase when the sewage and industrial channel joined the river. Changes in the biotic communities: phytoplankton, zooplankton and macrozoobenthos have been explained numerically in terms of abundance and diversity index. Phytoplanktons, zooplanktons, as well as macrozoobenthos showed a decrease in population and diversity values with an increase in pollution, along with a correlation with physico-chemical aspects. *Navicula, Cocconeis*, *Closterium, Micrasterias, Dactylococcus* and *Oscillatoria* were the common phytoplankton taxa, *Keratella* and *Brachionus* were common zooplanktons and *Tubifex* was the common benthic organism with a wide range of tolerance to different physico-chemical conditions. The extent of pollution by certain heavy metals such as Cu, Zn, Ni, Co, Cd and Pb has also been studied.
Keywords: Heavy metals, Macrozoobenthos, Phytoplankton, Species diversity, Water quality, Zooplankton

INTRODUCTION

The biota of an ecosystem when measured quantitatively and qualitatively gives an insight in the conditions existing in aquatic ecosystem. Changes in the structure and function of biological systems are induced by environmental disturbances. [1-2] for the first time described the pollution oriented changes in the composition of aquatic communities of rivers. In natural and unpolluted streams the flora and fauna is represented by a high number of taxa, most of them with relatively small populations. A progressive decrease in the number of individual of each taxa is generally observed with an increase in pollution. Taking account of both the number of taxa present and their abundance relative to one another, the diversity in populations of organisms is a measure of pollution. The diversity is directly correlated with the stability of ecosystem [3]. Higher diversity means longer food chain and more cases of symbiosis increasing stability [4].

Several studies have been undertaken to assess the water quality in terms of phytoplankton, zooplankton and macrozoobenthos. Phytoplankton aids the primary productivity and food chain of aquatic ecosystems. Any disturbance in their community structure directly decreases its productivity [5-6]. Some qualitative and quantitative studies at different places in running waters have indicated a definite correlation with the intensity of pollution [7-13]. Zooplankton is known not only to form an integral part of the lotic community but also contribute significantly to the biological productivity of fresh water ecosystem [14-16]. Several authors have made contributions to the study of zooplanktons in relation to pollution [17-18]. Macrozoobenthic fauna serves as the primary source of food for higher aquatic organisms. The presence of highly tolerant fauna gives a clear picture of the pollution load of streams [19].

The river Yamuna meanders through the district Yamunanagar (Haryana), India, and form the eastern boundary with the neighboring Saharanpur district. Along its path river is getting effluents from the maskara nala from Saharanpur (Uttar Pradesh), India, which is affecting the ecology of the river. Some studies on river Yamuna and its tributary have been undertaken by few workers which dealt with heavy metals pollution [20]-21], physico-chemical characteristics [22-25] and biological assessment [26]. This study is intended to monitor the water quality of river Yamuna using community structure of different communities. It is also intended to study the extent of pollution due to heavy metals.

MATERIALS AND METHODS

Keeping in view the point of influx of discharges into river, three stations have been selected. Station-1 (S1) lies in village Kalanaur at upstream of the river before the influx of discharges, Station-2 (S2) lies 4-5 Kms downstream from station S1 at middle reach of the river where the mill effluents joins the river, Station-3 (S3) at 5 kms downstream from station-S2 after the influx of discharges (Fig.1). Water samples were collected monthly in three replicates from all the sampling stations.

Water quality characteristics

The water quality characteristics *viz*. free CO_2, biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, conductivity, alkalinity, hardness, calcium, magnesium, chloride, orthophosphate, sulphate, ammonia, nitrate and nitrite were analysed in the laboratory in accordance with [27-28] on the following 2-3 days during which samples were kept in cold storage. Dissolved oxygen (DO), pH and conductivity were analysed on the spot using Multiline F-set III (Emark). The concentrations of different heavy metals were estimated by Atomic absorption spectrophotometer (Model No. MPE 60 Zeenit 700 P).

Biological characteristics

Phytoplankton and zooplankton analyses were conducted by filtering water samples through plankton net of mesh 50 µm and preserved in 4% formalin. Each replicate was counted by using Sedgwick rafter cell. For the study of macrozoobenthos, the mud samples were collected with the help of cone sampler and sieved through 0.5 mm mesh size sieve. The organisms were sorted out manually for qualitative and quantitative study and expressed as organisms m^{-2}.

Species diversity

To find the stress on the structure of the phytoplankton, zooplankton and macrozoobenthic community species diversity was determined using "Shannon and weaver diversity index method"[29].

$D = - \sum ni/ N \log_2 ni/N$

D = Species Diversity

ni = Number of individuals of i^{th} species

N = Total number of individuals in the sample

Statistical analysis

Coefficient of correlation was calculated on computer using SPSS package.

RESULTS AND DISCUSSION

Water quality characteristics

Stational variations of different physico-chemical characteristics have been shown in Table 1. Dissolved oxygen contents decreased from station S1(4.9±0.3 mg L^{-1}) to station S2 (DO 2.9±0.2 mg L^{-1}). A slight increase in DO concentration was however observed at station S3 (3.7±0.3 mg L^{-1}). [30-33] have also observed decrease in DO with influx of pollutants. BOD and COD are important index of organic pollution in the river. The values of these two parameters significantly ($P< 0.05$) increased with influx of pollutants at station S2. [34] have reported COD ranging between 6.5 to 29 mg L^{-1} along the stretch of Yamuna. Very high COD in the present studies might be due to influx of effluents of sugar industry. Statistically COD showed a significant positive correlation with BOD ($r = 0.499$ $P<0.05$). pH remained alkaline through out the study period. Conductivity, hardness, free CO_2, calcium, magnesium, chloride, sulphate and nutrients (o-PO_4, NO_2-N, NO_3-N) were also high at station 2. No significant variation in ammonia concentration was observed. Turbidity on the other hand, decreased from station S1 to S3. Increased turbidity at station S1 may be attributed to washing activities taking place there.

The heavy metal contents in water were studied on Atomic absorption spectrometer. The results showed that Pb, Cd, Ni, Cu and Zn were present in recordable concentrations, while Co was in traces at all the stations (Table 2). [35] have also reported the recordable concentrations of these metals in Yamuna near Delhi. The values of present studies when compared with limits according to [36]WHO guidelines were found to be in permissible range, only lead was slightly higher at station S3. Lead is considered hazardous to health as it accumulates in the body and affects the nervous system [37]. However, a comparison of the present results with the results from waters in developed countries [38-39] showed a lower level of pollution due to heavy metals.

Biological characteristics

Phytoplanktons

In all thirtyfive taxa contributed to the phytoplankton community belonging to Chlorophyceae (twentyone), Bacillariophyceae (ten), Cyanophyceae (three) and Dinophyceae (one). Chlorophyceae was the dominant group at all the stations followed by Bacillariophyceae, Cyanophyceae and Dinophyceae (Fig. 2). [40] have also reported a similar trend of phytoplankton dominance in river Bhadra. A decrease in phytoplankton population was observed from station S1 to station S2 (Fig. 3), which is the area where the channel carrying the effluent joins the river. [41-42] have also observed decline in phytoplankton population with the influx of effluents. The mean total phytoplankton were found to be 10473 L^{-1} at station S1, 7347 L^{-1} at station S2 and 8822 L^{-1} at station S3. Maximum numbers of total phytoplankton were found during July at all the stations and minimum during December at station S1 and S2 and during January at station S3. *Navicula* was the dominant taxa at station S1 and *Micrasterias* at station S2 and S3. [43] have also described dominance of *Navicula* in lotic waters. [44] had reported that species with the highest self-sustaining natural mechanisms of natural increase usually become dominant. *Navicula, Cocconeis, Closterium, Micrasterias, Dactylococcus* and *Oscillatoria* were the taxa common to all sampling stations during the entire period of investigation. [45-46] also found *Navicula*, *Cocconeis* and *Oscillatoria* as dominant and common taxa. [47] has reported presence of *Navicula, Oscillatoria, Pinnularia* and *Gomphonema* in organically polluted water with high BOD, chloride, phosphate and low oxygen. A slight decrease in numerical value of Shannon and Weaver species diversity was also observed from station S1 to S2 and S3 indicating station S2 and S3 as stressed zone of the river. The mean values of species diversity were found maximum (4.08) at station S1 and minimum (3.83) at station S3.

Zooplanktons

Thirteen taxa of zooplankton were recorded from different stations of river Yamuna including four of Cladocera, three of Rotifera, two of each Copepoda and Protozoa while one of Ostracoda and Hymenoptera. The mean zooplankton population at station S1 was 300 L^{-1}, 193 L^{-1} at station S2 and 248 L^{-1} at station S3. Maximum numbers of total zooplankton were found in July at all the stations. Cladocera was the dominant group followed by Rotifera, Copepoda, Protozoa and Ostracoda (Fig. 4). One genera of Hymenoptera, *Polynema* was also observed along with zooplanktons. The maximum density was recorded at station S1 followed by station S3 and station S2 (Fig. 5).

Dominant group Cladocera with 33.5% was represented by *Moina, Sida, Bosmina* and *Ceriodaphnia*. According to [48-50] Cladocera indicates the eutrophic conditions resulted from pollution. [51] also designated Cladocerans as bio-indicators. High number of Cladocera in the present studies supports the view. *Moina* was recorded as tolerant taxa common to all stations. [52-53] have reported that *Moina* is tolerant to heavy pollution. [54] has also designated *Moina* as dominant and tolerant taxa in lake Manzala of Egypt. Rotifera the second dominant group was represented by *Branchionus*, *Keratella* and *Monostyla*. The role of Rotifera as bioindicators has been emphasized [55]. In the present studies *Keratella* and *Branchionus* were common rotifers with a wide range of tolerance to different physico-chemical conditions. Copepoda was represented by *Cyclops* and *Nauplius* larva. [56-57] regarded *Cyclops* and Ostracods as strictly pollution sensitive taxa. In the present studies it was although present at all station but number is low. Similarly *Cypris* the only member of Ostracoda was also low in number. Protozoans were represented by two genera *Trinema* and *Physarum*. No significant variation in their population was observed with respect to stations. However total population of zooplankton decreased from station S1 (300±41L^{-1}) to station S2 (193±28L^{-1}) and further increased at Station S3 (248±30L^{-1}) (Fig. 5).

Macrozoobenthos

Eight taxa of macrozoobenthos were found at different stations of the river during the study period. Oligochaetes were the dominant at all the stations followed by Dipterans, Odonatans, Hymenoptera and Trichoptera (Fig. 6). Maximum numbers of total macrozoobenthos were found in winter at all the stations. The species diversity was found maximum at station S1 (2.60) and minimum at station S2 (2.35). Oligochaeta was represented by *Chaetogaster*, *Dero* and *Tubifex* with percentage distribution of 42.9%. *Tubifex* species have been described as indicator of pollution as they were tolerant to high values of different physico-chemical characteristics [58-59] has stated that when water bodies become organically polluted and dissolved concentration become reduced the *Tubifex* Oligochaete are commonly and dominantly found, thus regarded as pollution indicator. Diptera the second dominant group was represented by *Tanypus* and *Simulium* with percentage distribution of 27.7%. One genera of Odonata, Hymenoptera and Trichoptera were observed with percentage distribution of 12.0%, 9.33% and 7.42% during the study period. Total number of macrozoobenthos showed a decreasing trend from station S1 to S2 and thereafter increased at station S3 indicating station S2 as stressed zone (Fig.7).

Table.1: Water Quality characteristics (Mean±S.E) of river Yamuna at various stations

Parameters	**S1**	**S2**	**S3**	**I.C.M.R Standards**
DO mg L^{-1}	4.9±0.3	2.9±0.2	3.7±0.3	>5 mg L^{-1}
BOD mg L^{-1}	4.2±0.2	8.2±0.3	5.6±0.1	<5 mg L^{-1}
COD mg L^{-1}	192±17.7	282±15.8	262±25.6	
pH	7.6±0	7.4±0.1	7.6±0.1	<7.0-8.5>
Conductivity µm cm $^{-1}$	320±21.1	363±17	328±22.5	-
Turbidity NTU	6±1.7	5.6±1.5	4.6±1.5	-
Free CO_2 mg L^{-1}	9.6±1.9	17.8±3.0	16.3±4.0	-
Alkalinity mg L^{-1}	100±8.6	131±10.5	104±11.4	<120 mg L^{-1}
Hardness mg L^{-1}	148±11.2	179±18.3	144±7.9	-
Calcium mg L^{-1}	37.1±3.8	46.1±4.8	38.5±4.1	<75 mg L^{-1}
Magnesium mg L^{-1}	13.6±1.8	15.8±4.5	11.7±2.1	<50 mg L^{-1}
Chloride mg L^{-1}	11.3±1.0	12.8±1.0	11.5±0.6	<250 mg L^{-1}
Orthophosphate mg L^{-1}	0.1±0	0.2±0	0.2±0	-
Sulphate mg L^{-1}	0.3±0	0.3±0	0.3±0	<200 mg L^{-1}
Ammonia mg L^{-1}	0.2±0	0.2±0	0.1±0	-
Nitrite mg L^{-1}	0.2±0.1	0.4±0.1	0.3±0.1	-
Nitrate mg L^{-1}	0.3±0.1	0.4±0.1	0.5±0.1	-
WQI	67.4±2.8	39.9±4.3	47.5±3.0	-

Table. 2: Concentration of different heavy metals (ppm) at different stations of the river Yamuna

Metals	S1				S2				S3				PPM
	S	M	PM	W	S	M	PM	W	S	M	PM	W	
Pb	.0038	.0024	.0051	.0031	.0041	.0032	.0059	.0042	.0054	.0025	.0029	.0051	0.05
Cd	.0035	.0050	.0040	.0090	.0040	.0020	.0070	.0050	.0050	.0060	.0040	.0050	-
Ni	.0022	.0008	.0010	.0007	.0014	.0006	.0011	.0016	.0011	.0007	.0008	.0009	0.07
Co	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	-
Cu	.0015	.0013	.0021	.0016	.0016	.0014	.0011	.0009	.0020	.0021	.0014	.0021	0.05
Zn	.0227	.0364	.0290	.0336	.0342	.0404	.0406	.0365	.0292	.00341	.0364	.0341	5.00

S = Summer, M = Monsoon, PM = Post Monsoon and W = Winter, PPM (As per WHO Guidline values 1991), tr= traces

Fig.1: Map of river Yamuna showing stations.

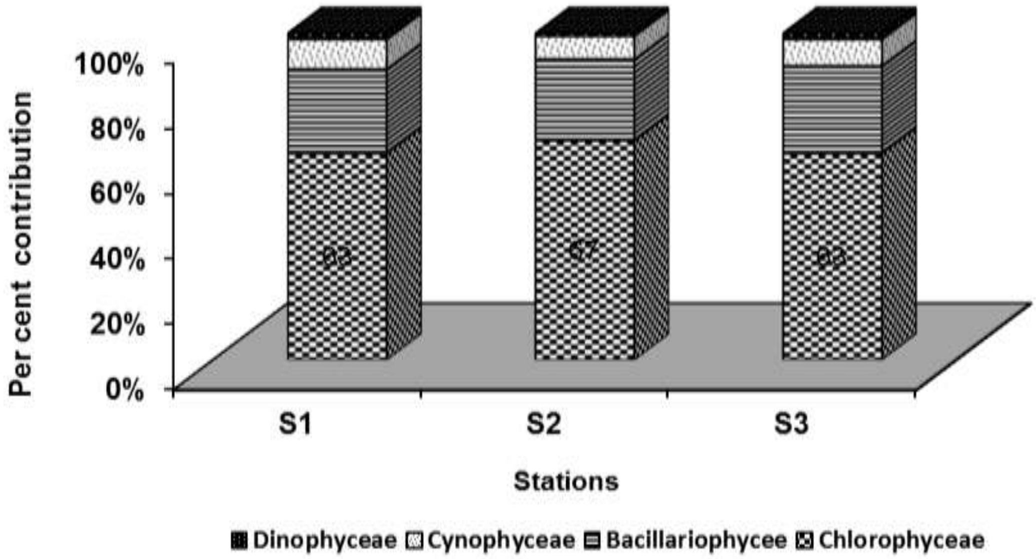

Fig.2: Percentage distribution of different groups of phytoplanktons.

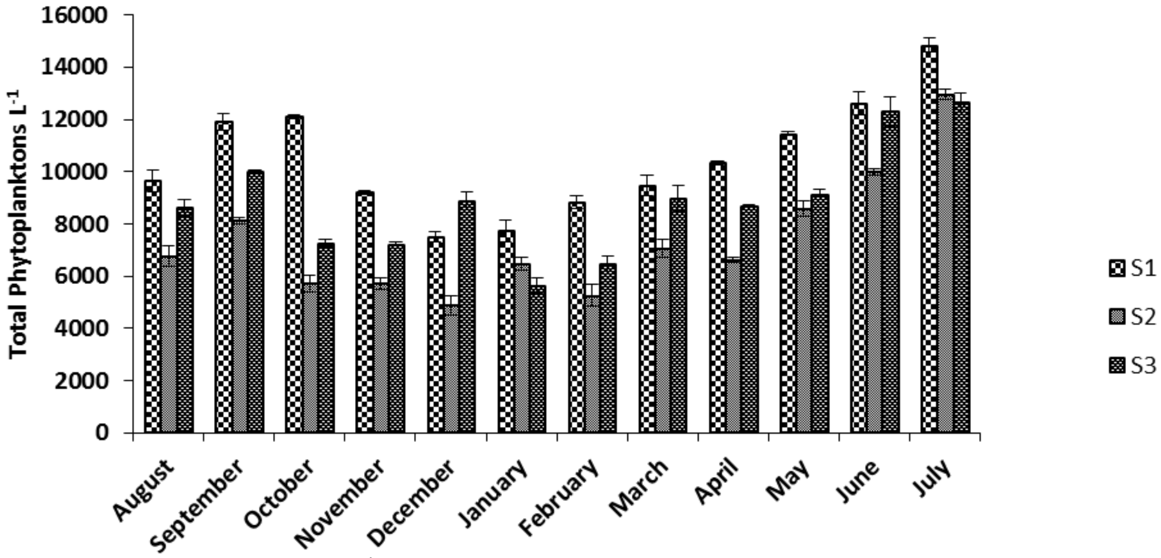

Fig.3: Density (Nos. L^{-1}) of phytoplanktons of river Yamuna at different stations.

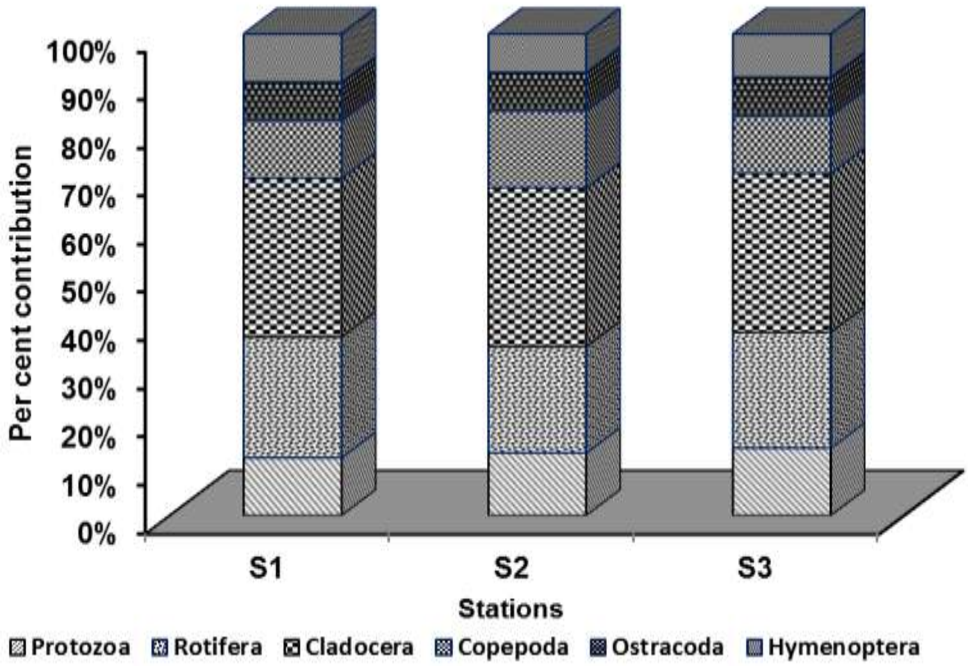

Fig.4: Percentage distribution of different groups of zooplanktons.

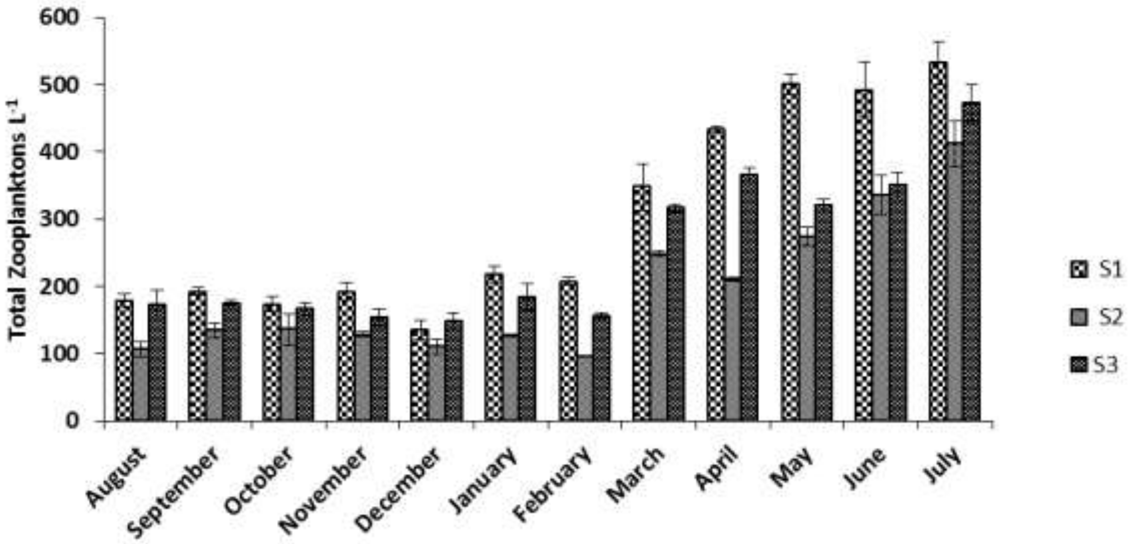

Fig.5: Density (Nos. L^{-1}) of zooplanktons of river Yamuna at different stations.

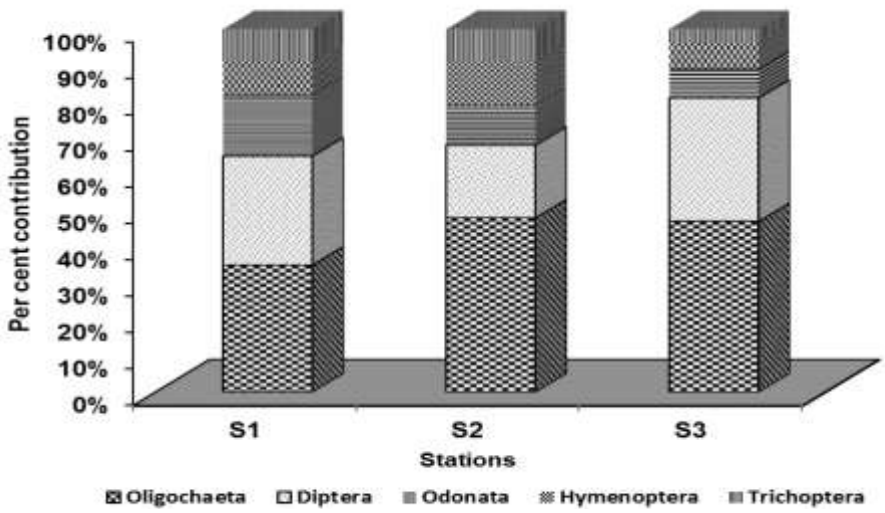

Fig. 6: Percentage distribution of different groups of macrozoobenthos.

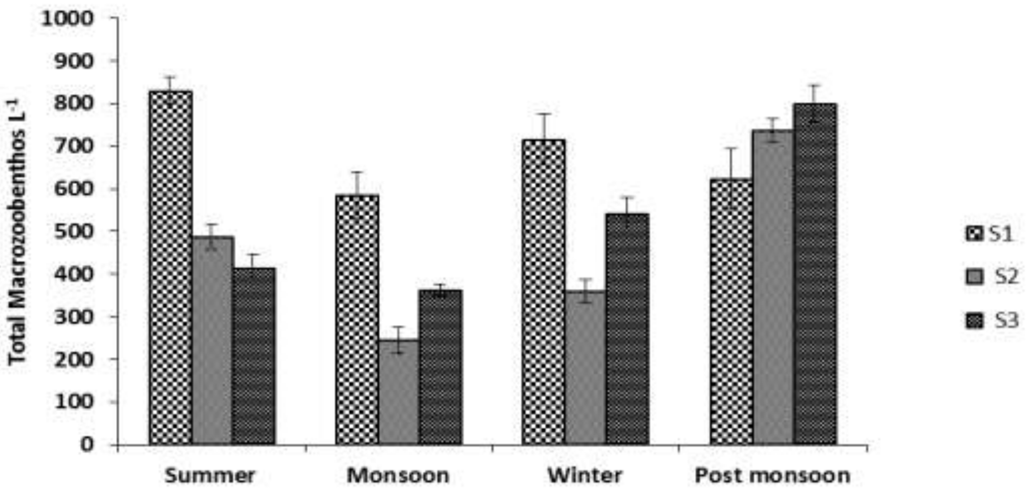

Fig. 7: Population of macrozoobenthos of river Yamuna at different stations.

Conclusion

Thus study of different biotic and abiotic features reveled that the intensity of pollution increases as the river is subjected to sewage and industrial wastes. In the growing awareness of relationships between human health and water pollution and for the sustainability of the system it is essential to undertake regular monitoring and surveillance of important aquatic ecosystems.

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