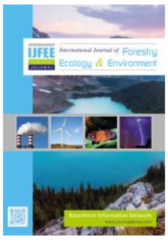
Published with Open Access at Journal BiNET

Vol. 02, Issue 01: 69-78

International Journal of Forestry, Ecology and Environment

Journal Home: www.journalbinet.com/ijfee-journal.html



Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh

Kritika Singh and Manas Katiyar

SHUATS, College of forestry, Rewa Road Old Bridge, near Yamuna, Naini, Prayagraj, Uttar Pradesh 211007.

✉ For any information: Kritika17singh@gmail.com (Singh, K)

Article received: 08.07.2020; Revised: 04.08.2020; Published online: 15 August 2020.

ABSTRACT

Ecology of the rivers has become vulnerable after exploitation for years. The study includes measurements to monitor the relevant physio-chemical and biological indicators of pollution in the aquatic system chosen, assessment of the contaminated states of the system, and estimating the efficiency of the system to assimilate the existing pollution load. The results of the study on the physio-chemical parameters of water from ten different locations in two cities Prayagraj and Varanasi of the River Ganga are concluded as the Temperature, pH, EC, Alkalinity, Total hardness, Ca Hardness were observed under the permissible limit. Parameter such as DO, BOD, Mg Hardness is high and above the permissible limit at Prayagraj. Range of Total Dissolved Solids and Turbidity is beyond the allowed limits for both Cities. The outcomes of this learning on physio-chemical parameters of sediment from ten different spots at two places i.e. Prayagraj and Varanasi of the River Ganga are concluded as the Temperature, pH, EC, and Percentage Organic Carbon were under the fair category except for pH at Varanasi which shows slightly acidic nature and Organic Carbon at Varanasi also shows high range. The overall results of the parameters show that the aquatic system of river Ganges is polluted and continues further degrading at a higher rate at both the cities i.e. Prayagraj and Varanasi. A total of 49 species of microorganisms was identified during the study. In Prayagraj aquatic habitat Amphipod was recorded as a dominating group of microorganism's communities over the others. Whereas in Varanasi, Rotifer and Ostrocoda were recorded as a dominating group of microorganism community over the others. In both the aquatic habitats Protozoa was recorded as the least dominating group of microorganism's communities. The presence of few dominant species were i.e., Volvox, Branchionus & Colpoda along with significantly more BOD & percent Organic Carbon revels greater organic pollution at Varanasi. On the other hand, the dominant species at Prayagraj were, Daphnia, Amoeba, Copipoda & Hartmanella along with high turbidity, DO & Hardness.

Key Words: *Prayagraj, Varanasi, Aquatic ecosystem, Pollution and Microrganism.*

Cite Article: Singh, K. and Katiyar, M. (2020). Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh. International Journal of Forestry, Ecology and Environment, 02(01), 69-78.

Crossref: https://doi.org/10.18801/ijfee.020120.08

I. Introduction

Water is the utmost component for maintaining life on earth (Miller, 1997). Water has considered a limited resource in many parts of the world. In upcoming decades, it can become even more vulnerable because of population boom, urbanization pressure, and climate change calamities (Jackson et al., 2001). Certainly, water is essential for life but 99% of the river in the world has been polluted by man-made activities, such as urbanization, industrialization, and an increasing population (Saha et al., 2012). Prayagraj and Varanasi are one of the important cities in India as a center of cultural, religious, and educational activities (Singh et al. 2005). The Ganga basin is uniquely densely populated river basins in the world and supporting twenty-nine Class-1 cities, twenty-three Class 2 cities, forty-eight towns, and thousands of villages. According to an estimation Over five hundred million individuals were living in the whole Ganga river basin in the year 2000, and the figure is projected to grow to over one billion by the year 2030 (Markandya and Murty, 2000).

Pollution in Ganga has increased day by day and put marine life has a threat, also polluted water has disturbed the ecosystem of the river (Klein, 1957). With the high pollution in the rivers Water, the Ganges River is also interrelated to contracting hepatitis, cholera, dysentery, as well as severe diarrhoea and continues to be the foremost causing factor for the death of children in India (Khanna, 2007). Some studies stated that sewage dilution ratios of 1:11 are in the river Gomati (Tributary of Ganga), large scale fish deaths were reported due to dead zones in the river Kali, severe industrial influences on the river Son, 108 major industrial contaminators included under the deltaic Damodar basin, and foremost silting process in the River Yamuna (Ray, 1998). Studies, conducted by Central Board for the Prevention and Control of Water Pollution from 1979 to 1984, recommended that 70% of the total pollution load in the Ganges comes from twenty-seven Class-1 cities, Fifteen Class-2 cities, and 25 smaller towns; 20% was derived from industries and 10% from other sources (Basu, 1992 and Ray, 1998).

Microbes play vital roles in the aquatic ecosystem food chain as it supplies the required amount of protein for the speedy growth of other organisms (Dewan et al., 1977). Microorganism plays a crucial role in freshwater lentic ecologies, due to its essential position in bottom-up and top-down feedback mechanisms that identify zooplankton as a functional indicator of ecosystem wellbeing (Pereira et al., 2002). Rivers are the lifeline of the human settlement but anthropogenic factors are degrading the water quality of the river (Gupta and Chakrapani, 2007). Extreme exploitation of water resources and the generation of a large volume of wastewater emerging challenging problems (Begum and Harikrishna, 2008). The deviations in the river water quality fetched by modern development can be evaluated with chemical and biological analyses. The chemical analysis provides quantitative data of changes in the water as measured by parameters such as dissolved oxygen, biochemical oxygen demand, etc., whereas biological analysis may be useful in monitoring and assessment of pollution (Sinha and Das, 1998).

II. Materials and Methods

Benthic parts of Prayagraj and Varanasi were selected as the study site for sample collection. The study was conducted from February to July 2018.

Sampling Area 1: Prayagraj (Allahabad)

The study site for Prayagraj District is situated with latitudes of 25° 28' 22.9224'' N and 81° 52' 42.0852'' E, (Table 01) the meeting point of the three sacred rivers Saraswati, Yamuna, and the Ganges. Prayagraj is in the south-eastern part of Uttar Pradesh, at the confluence of the Ganga.

Sampling Area 2: Varanasi

The study site for Varanasi is situated at 25° 19' 18.0624'' N and 82° 59' 14.2404'' E. Varanasi is located between the Ganges confluences with two rivers: the Varuna and the Assi stream (Table 02). In the ancient days, the area was known as Kashi and Banaras. Varanasi is situated in the south-eastern part of Uttar Pradesh.

Sampling Frequency: Samples of water and sediment samples were collected once a month (Joshi et al., 2009). All of the stations were located on the river bank. The following chart represents the different sources of pollution for Prayagraj (Table 03) and Varanasi (Table 04) about the level of pollution [1,2,3,4,5,6], explored during this study.

Table 01. Details of sampling sites with GPS location for Prayagraj.

Site Name	Site Notation	Latitude & Longitude	Tentative Distances
Patti Ahmedpur	S1	25◦50.22N, 81◦71.617E	15.5 Km.
Bamraulli	S2	25◦49.317N, 81◦73.793E	13.2 Km.
Rasoolpur	S3	25◦48.422N, 81◦74.652E	11.19 Km.
Dhoomanganj	S4	25◦47.621N, 81◦79.016E	7.38 Km.
Sadar bazaar	S5	25◦48.868N, 81◦81.784E	4.28 Km.
MNNIT	S6	25◦50.309N, 81◦85.702E	0.0 Ref Point
Daraganj	S7	25◦44.561N, 81◦88.573E	9.37 Km.
Sangam	S8	25◦43.463N, 81◦88.369E	10.7 Km.
Delhi Public School	S9	25◦40.094N, 81◦90.432E	14.9 Km.
United College	S10	25◦36.225N, 81◦91.775E	19.4 Km.

Table 02. Details of sampling sites with GPS location for Varanasi.

Site Name	Site Notation	Latitude & Longitude	Tentative Distance
Assi Ghat	S1	25˚28.793N, 83˚00.75E	3.03 Km.
Harishchandra Ghat	S2	25˚29.86N, 83˚00.784E	1.92 Km
Digpitiya Ghat	S3	25˚30.425N,83˚00.889E	1.29 Km.
Dashashwamedh Ghat	S4	25˚30.652N, 83˚01.097E	373 m
Scindia Ghat	S5	25˚31.126N, 83˚01.495E	802m
Manikarnika Ghat	S6	25˚31.201N, 83˚01.599E	0.0 Ref Point
Panchganga Ghat	S7	25˚31.502N, 83˚01.834E	443 m
Gaya Ghat	S8	25˚31.806N, 83˚02.227E	920 m
Prahlad Ghat	S9	25˚32.155N, 83˚02.867E	1.66 Km.
Raj Ghat	S10	25˚32.275N, 83˚02.950E	1.95 Km

Collection of Water and Sediment Samples

Water samples were collected in triplicate glass flasks for physio-chemical analysis. Sediment samples were collected from each site using a sampling container which enclosed an area of 15cm × 15cm square. The sediment samples were kept in clean polythene bags for further analysis.

Table 03. Different sources of pollution met with the stations explored during this study at Prayagraj region

Sources of pollution (At Prayagraj)	Stations									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bathing	M	M	M	L	M	L	L	VH	H	H
Washing Clothes / Utensils	L	L	L	-	L	-	-	-	L	L
Defecation on the banks	H	H	H	VH	L	L	M	-	L	L
Waste Dumping	H	H	VH	VH	VH	H	H	L	L	L
See wage outfall	VH	VH	VH	VH	H	VH	H	L	L	L
Open drainage opening	L	M	M	VH	H	VH	VH	M	L	L
Ferry service	VL	VL	L	L	L	VH	VH	VH	L	L
Proximity of industries	L	L	L	L	L	L	L	L	L	L

VL= Very low; H=High; L= Low; VH= Very High; M=Medium; '-'= Nil.

Table 04. Different sources of pollution met with the stations explored during this study at Varanasi region

Sources of pollution (At Varanasi)	Stations									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bathing	VH	M	VH	VH	VH	M	VH	VH	VH	VH
Washing Clothes / Utensils	M	-	M	M	M	-	M	M	M	H
Defecation on the banks	-	-	-	-	-	-	-	-	-	-
Waste Dumping	VL	VL	VL	VL	VL	VL	VL	VL	VL	L
See wage outfall	VL	VL	VL	VL	VL	M	M	VL	VL	L
Open drainage opening	L	L	L	L	L	L	L	L	L	M
Ferry service	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
Proximity of industries	L	L	L	L	L	L	L	L	L	L

Published with open access at journalbinet.com
EISSN: 2312-7945,

Preservation of Collected Samples

The physio-chemical parameters such as the temperature of water and sediment were determined in the field. The other water quality parameters were usually estimated within 24 hrs. except for BOD. Further faunal samples were also preserved with 5% formalin wherever it is necessary.

Analysis of the collected Samples

In case of water, 12 physio-chemical parameters, viz., Temperature (Degree Celsius), pH, Electrical Conductivity (mhos/cm), turbidity (NTU), alkalinity (mg/l), Dissolved Oxygen (mg/l), Biological Oxygen Demand (mg/l), Chloride(mg/l), Calcium Hardness (mg/l), Magnesium Hardness (mg/l), Total Hardness (mg/l), Total Dissolved Solids (mg/l) were determined every month for each site at the two cities for three months. While sampling for sediments, temperature, pH, conductivity, and %Organic Carbon were taken into consideration (Lacy, 2006). All the samples were sampled in the "Environmental Laboratory at the College of Forestry, SHUATS". The standard methods for the examination of water and wastewater (APHA, 1991) were followed for the examination of Physio-chemical parameters. Temperature, pH, EC, DO, BOD, Alkalinity, Turbidity, Chloride, TDS, Total Hardness, Calcium Hardness, Magnesium Hardness were determined as per standard methods Given by (APHA/AWWA).

Analysis of microorganisms

Identification was made consulting taxonomic references (Standard Book of APHA, 1989) and cross verified with taxonomists of Sam Higginbottom University of Agriculture, Technology and Sciences.

Calculation of Biological indices

Biological indices were calculated for each region where species richness (S) is the numerical figure of species existing in an ecosystem (Gangwar, 2007). Shannon diversity index (H) is frequently used to characterize species diversity in a community and accounts for mutually abundance and evenness of the species present,

$H' = \Sigma pi; \ln pi,$

Where,

pi is the proportion of the ith species in a population (Shannon and Weiner, 1949).

Species evenness (J') was calculated by the subsequent formula,

$J' = H'/H' \max$

Where,

$H'\max = \ln S.$

Relative abundance is the total amount of all the species present in an ecosystem.

Statistical Calculation

Differences in species community composition have been described by the environmental variables available that were analyzed with inhibited ordination in CANOCO 5 (Van den Brink et al., 2009). As many of the environmental variables covaried, their relationships were investigated using principal components analysis (PCA). Principal Component Analysis was completed on the correlation matrix to choose the environmental variables associated with each of the first few principal axes most strongly. The redundancy analysis (RDA) was chosen because linear responses are expected along a gradient smaller than 3.0 standard given by (Braak, 2009). Due to a large number of environmental variables, the forwarded selections were used to determine the least number of significant variables ($P<0.05$) to include in the model. The level of significance was tested by Monte Carlo Permutation ($n=499$).

III. Results and Discussion

The contemporary examination includes the study of both water (Table 05) and sediment of the river (Table 06) to know the status aquatic ecosystem in the Ganges. Table 07, Table 08, and Table 09 consist of Physio-Chemical parameters and demonstrate a comparison of both sampling sites (Prayagraj and Varanasi) (Singh and Choudhary, 2013).

Table 05. Physio-Chemical characteristics of Water

Physio-chemical characteristics of water	Permissible limit	Observed values
Temperature	-	21.10- 23.89
pH	5.0 - 8.3	6.92-7.90
Electrical Conductivity	-	0.33-0.47 mS/cm
Turbidity	-	55-70 NTU
Alkalinity	-	9.10-28.99 mg/l
Total Hardness	600 mg/l	267 to 436 mg/l
Calcium Hardness (Ca)	200 mg/l	73-123
Magnesium Hardness	100 mg/l	91-233
Dissolved Oxygen (DO)	6.0 mg/l	2.61-4.24
Biological Oxygen Demand (BOD)	<2.0 mg/l	1.5-4.3
Chloride (Cl^-)	250 mg/l,	50-73 mg/l
Total Dissolved Solids (TDS)	500 mg/l	528mg/l to 698mg/l

Table 06. Physio-Chemical characteristics of Sediment

Physio-chemical characteristics of Sediment	Permissible limit	Observed values
Temperature	-	19°C -- 23°C
pH	5.0 - 8.3	6.3-7.6
Electrical Conductivity	-	0.37-0.64 mS/cm
Percentage Organic Carbon	-	0.67-1.11

Table 07. Table-8, Table-9 shows Physio-Chemical parameters for two sampling cities

Table-7	DO	BOD	Ca Hardness	Mg Hardness	Total Hardness
Prayagraj	3.57889 (0.0799)	1.9133 (0.082)	110.6444 (4.023)	194.522 (11.575)	304.0556 (11.032)
Varanasi	3.20989 (0.08199)	3.36933 (0.10385)	84 (3.8133)	106.556 (3.57566)	189.7222 (3.603274)

Table 08	Alkalinity	Chloride	Turbidity	TDS	%OC
Prayagraj	11.3111 (0.372)	70.5559 (6.533)	66.9 (0.688)	584.467 (6.985)	0.69933 (0.008)
Varanasi	22.53333 (0.99011)	61.1491 (1.391)	57.9111 (0.81257)	619.767 (9.65524)	1.1175 (0.01969)

Table 09	pH (Water)	EC (Water)	Temp. (Sediment)	EC (Sediment)
Prayagraj	7.75256 (0.033)	0.34956 (0.003)	22.36 (0.183)	0.62167 (0.008)
Varanasi	7.354 (0.10769)	0.45111 (0.01016)	19.9 (0.27172)	0.38589 (0.00554)

Species of micro zoobenthos were also identified and the relation between the physio-chemical characteristics and species of micro zoobenthos was studied (Chawla et al., 2011). During the study, a total of 49 species of microorganisms belonging to seven major groups i.e. protozoa, amphipod, rotifer, copepoda, cladocera, ostrocoda, and polychaetes were identified from selected sampling sites (Matta and Bhutani, 2009). To quantify the diversity among the species, four Biological indices were studied i.e. Richness, Shannon Diversity Index, Evenness, and Relative Abundance and explained (Coman et al., 2003).

The Richness of Amphipod was recorded as the maximum in Prayagraj i.e. 52.66, whereas in Varanasi, Rotifer was recorded with maximum richness i.e. 63.66. In both the aquatic habitat Protozoa was recorded with a minimum value of richness i.e. 37.16 and 37.5 respectively. Further results show the trend of species richness at different points

Published with open access at journalbinet.com
EISSN: 2312-7945,

The trend of the richness of species at Prayagraj is,
Aphids > Polychaetes > Ostrocoda > Copepoda > Cladocera > Rotifer > Protozoa

The trend of the richness of species at Varanasi is,
Rotifer > Ostrocoda > Aphids > Cladocera > Polychaetes > Copepoda > Protozoa

The Shannon-Weiner Diversity Index of Amphipod was recorded maximum in Prayagraj i.e. -.25559, whereas, in Varanasi, Ostrocoda was recorded with maximum Shannon-Weiner Diversity Index i.e., -0.25121. In both the aquatic habitat Protozoa was recorded with a minimum value of Shannon-Weiner Diversity Index i.e. -0.18786 and -0.1987 respectively.

The trend of Shannon-Weiner diversity index of species at Prayagraj is,
Amphipod > Copepoda > Cladocera > Rotifer > Polychaete > Ostrocoda > Protozoa

The trend of Shannon-Weiner diversity index of species at Varanasi,
Ostrocoda > Rotifer > Amphipod > Cladocera > Polychaete > Copepoda > Protozoa

The Evenness of Amphipod was recorded as maximum in Prayagraj i.e. -0.06882, whereas, in Varanasi, Ostrocoda was recorded with the maximum value of evenness i.e. -0.07446. In both aquatic habitats, Protozoa was recorded with a minimum value of evenness i.e. -0.05059 and -0.05436 respectively.

The trend of evenness of the species at Prayagraj is,
Amphipod > Copepoda > Rotifer > Polychaete > Ostrocoda > Cladocera > Protozoa

The trend of evenness of the species at Varanasi is,
Ostrocoda > Rotifer > Amphipod > Cladocera > Polychaete > Copepoda > Protozoa

The Relative Abundance of Amphipod was recorded as the maximum in Prayagraj i.e. 0.069461, whereas in Varanasi, Rotifer was recorded with the maximum value of relative abundance i.e. 0.076116. In Prayagraj, Protozoa was recorded with the least value of relative abundance i.e. 0.049869, whereas in Varanasi, Polychaete was recorded with the least value of relative abundance i.e. 0.053089.

Speciestrend for relative richness at Prayagraj is,
Amphipod > Copepoda > Polychaete > Rotifer > Ostrocoda > Cladocera > Protozoa

Species trend for relative richness at Varanasi is,
Rotifer > Ostrocoda > Amphipod > Cladocera > Copepoda > Protozoa > Polychaete

An increase in the zooplankton abundance during summer (Singh et al., 2005) probably corresponds of the river water quality, rotting flora, enlarged levels of the carbon-based substance in the deposited sediment, and superior richness of bacteria in the river throughout the summer (Srivastava et al., 1990). Least contribution of protozoa as compared to the rest of the groups of zooplankton possibly because of their short ability to survive in fluctuating limnological circumstances prevailing in changing seasons (Chattopadhyay and Barik, 2009). Most of the species such as rotifers, amphipod, and ostrocoda have the highest contribution because of their wide-spread distribution in waters of all kinds, the great abundance in which they frequently occur, and striking beauty of some of the species (Edmondson, 1959). The high Amphipod, Rotifer, and Ostrocoda in summer indicate the influence of temperature and showing a direct relationship between temperature and population of the species (Rajashekhar et al., 2010).

Multivariate Statistical Analysis

Principal Component Analysis (PCA) of Environmental Variables: Total variability explained by the biplot of environmental factors is 70%. BOD, %OC, Alkalinity is significant in explaining variability in Varanasi (Sravya et al., 2016). Mg hardness, Total hardness, DO, pH (sediment), Temp (sediment), EC (sediment) are significant for explaining variability in Prayagraj (Fan et al., 2010). Principal Component Analysis of Environmental Variables for Varanasi and Prayagraj is demonstrated in Figure 01.

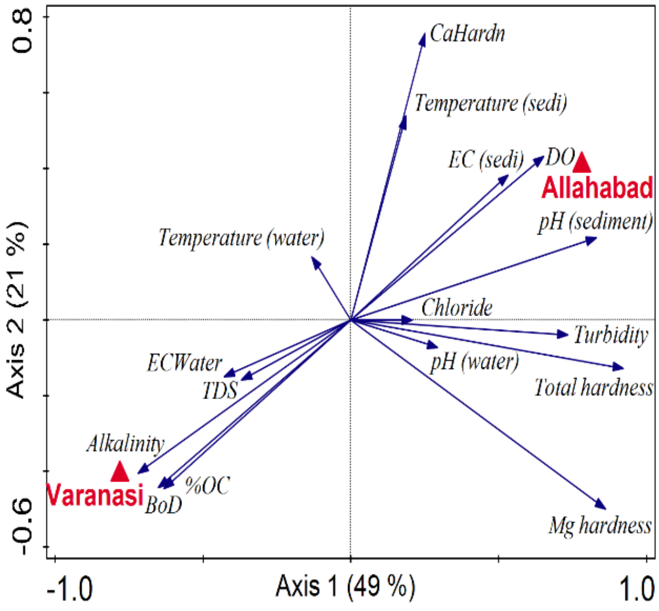


Figure 01. The below figure (Figure 02) demonstrates the Variance partitioning of Environmental Variables for the two regions Prayagraj and Varanasi.

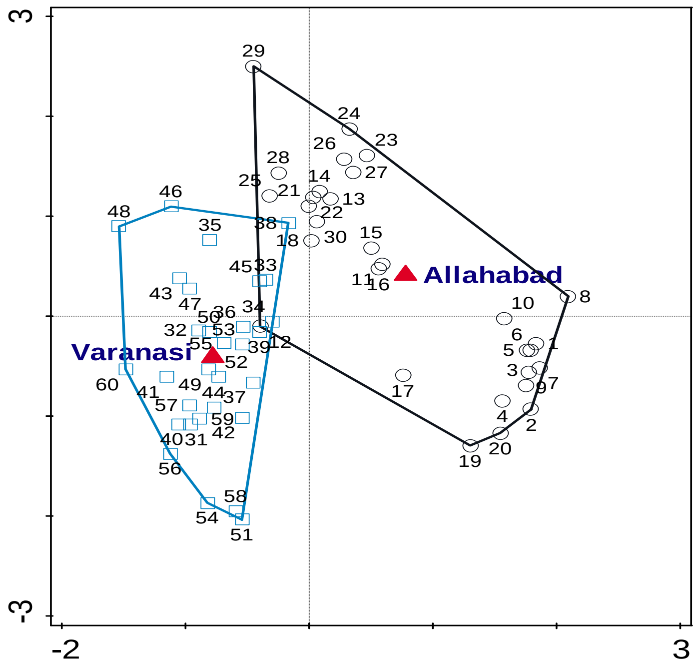


Figure 02. Redundancy Analysis (RDA) of Species (Dependent factor) with Environmental Variables (Independent Variables):

Total variability in species explained 48% (by abiotic variables) Volvox, Colpoda & Branchionus dominant species at Varanasi (Akpan, 2013). Daphnia, Amoeba, Copepodids & Hartmanella was dominant at Prayagraj. Presence of few dominant species i.e., *Volvox, Branchionus & Colpoda* along with significantly more BOD & percent Organic Carbon revels greater organic pollution at Varanasi (Sladecek, 1983). On the other hand, the dominant species at Prayagraj were *Daphnia, Amoeba, Copepoda & Hartmanella* along with high turbidity, DO & Hardness. This signifies industrial pollution at Prayagraj (Madoni, 2011).

Published with open access at journalbinet.com
EISSN: 2312-7945, ©2020 The Authors, Research paper

IV. Conclusion

The Richness of Amphipod was recorded as the maximum in Prayagraj i.e. 52.66, whereas in Varanasi, Rotifer was recorded with maximum richness i.e. 63.66. In both the aquatic habitat Protozoa was recorded with a minimum value of richness. The Shannon-Weiner Diversity Index of Amphipod was recorded maximum in Prayagraj i.e. -0.25559, whereas, in Varanasi, Ostrocoda was recorded with maximum Shannon-Weiner Diversity Index i.e. -0.25121. In both the aquatic habitat Protozoa was recorded with a minimum value of Shannon-Weiner Diversity Index. The Evenness of Amphipod was recorded as maximum in Prayagraj i.e. -0.06882, whereas, in Varanasi, Ostrocoda was recorded with the maximum value of evenness i.e. -0.07446. In both aquatic habitats, Protozoa was recorded with a minimum value of evenness. The Relative Abundance of Amphipod was recorded as the maximum in Prayagraj i.e. 0.069461, whereas in Varanasi, Rotifer was recorded with the maximum value of relative abundance i.e. 0.076116. In Prayagraj, Protozoa was recorded with the least value of relative abundance, whereas in Varanasi, Polychaetes was recorded with the least value of relative abundance. Total variability explained by the biplot of Principal Component Analysis of environmental factors is 70%. BOD, %OC, Alkalinity is significant in explaining variability in Varanasi. Mg hardness, Total hardness, DO, pH (sediment), Temp (sediment), EC (sediment) are significant for explaining variability in Prayagraj. Total variability in Redundancy Analysis of species explained 48 % (by abiotic variables) Volvox, Colpoda & Branchionus are dominant in Varanasi. Daphnia, Amoeba, Copepodids & Hartmanella was dominant at Prayagraj.

Abbreviations:

BOD- Biological Oxygen demand; COD- Chemical Oxygen Demand; pH-Potential of hydrogen; EC-Electrical Conductivity; DO- Dissolved Oxygen; PCA- Principal Component analysis; POC- Percentage Orgain carbon; RDA- Redundancy analysis

V. References

[1]. Akpan. I. (2013). Assessment of water quality in Imo river estuary using Multivariate Statistical Method. IOSR Journal of Applied Chemistry (IOSR-JAC), 4, 35-40. https://doi.org/10.9790/5736-0453540

[2]. APHA (1989). Standard methods for the examination of water and wastewater, 17th Edn. APHA, AWWA, WPCF, Washington DC.

[3]. APHA (1991). Standard methods for the examination of water and wastewater 14th edition., American Public Health Association, pp. 1189-1193.

[4]. Basu, A. K. (1992). Ecological and resource study of the Ganga delta. K. P. Bagchi & Company, Calcutta.

[5]. Begum, A. and Harikrishna, (2008). Study on the quality of water in some stram of Cauvery River. E-Journal of Chemistry, 5, 377-384. https://doi.org/10.1155/2008/234563

[6]. Braak, C. J. F and Verdonschot, P. F. M. (1995). Canonical correspondence analysis and related multivariate methods in aquatic ecology, Aquatic sciences, 57, 255-289. https://doi.org/10.1007/BF00877430

[7]. Chattopadhyay, C. and Barik, A. (2009). The composition and diversity of Net zooplankton species in a tropical freshwater lake. International Journal of lakes and rivers, 2 (1), 2-30.

[8]. Chawla, K., Barah, P., Kuiper, M. and Bones, A. (2011). Systems Biology: A Promising Tool to Study Abiotic Stress Responses. https://doi.org/10.2174/978160805092511101010163

[9]. Coman, F. E., Connolly, R. M. and Preston, N. P. (2003), Zooplankton and epibenthic fauna in shrimp ponds: factors influencing assemblage dynamics. Aquaculture Research, 34, 359-371. https://doi.org/10.1046/j.1365-2109.2003.00898.x

[10]. Dewan, S. Ali, M. and Islam, A. (1977). Study of the size and pattern of feeding of fries and fingelings of three major carpos eg. Labeo rohita, Catla catla and Cirrhina mrigala. Bangladesh Journal of Agriculture, 2, 223-228.

[11]. Edmondson, W. T. (1959) Freshwater Biology, 2nd Edition. Ward and Whipple, John Wiley Sons, Inc New York.

[12]. Fan, X., Cui, B., Zhao, H., Zhang, Z. and Zhang, H. (2010). Assessment of river water quality in Pearl River Delta using multivariate statistical analysis techniques, International Society for

Environmental information Sciences 2010 Annual Conference (ISEIS), Vol. 2, pp. 1220-1224. https://doi.org/10.1016/j.proenv.2010.10.133
[13]. Gangwar, K. K. and joshi, B. D. (2007). Impact of mass bathing on water quality of river Ganga during Magh Purnima at Haridwar. National Symposium on Limnology, 61, 358-363.
[14]. Gupta, H., Chakrapani, G. J., Selvaraj, K. and Kao, S.-J. (2011). The fluvial geochemistry, contributions of silicate, carbonate and saline-alkaline components to chemical weathering flux and controlling parameters: Narmada River (Deccan Traps), India. Geochimica et Cosmochimica Acta, 75, 800-824. https://doi.org/10.1016/j.gca.2010.11.010
[15]. Joshi, M. D. Kumar, A. and Aggarwal, N. (2009). Assessment of the irrigation water quality of river Ganga in Haridwar District. RSAYAN Journal of Chemistry, 2 (2), 285-292.
[16]. Khanna, D., Sarkar, P., Gautam, A. and Bhutiani, R. (2007). Fish scales as bio-indicator of water quality of River Ganga. Environmental monitoring and assessment, 134. 153-60. https://doi.org/10.1007/s10661-007-9606-5
[17]. Klein, L. (1957). Aspects of River Pollution. Butterworth, London, pp. 821.
[18]. Lacy, S. (2006). Modeling the Efficacy of the Ganga Action Plan's Restoration of the Ganga river, India. M. Sc. Thesis, University of Michigan.
[19]. Madoni, P. (2011) Protozoa in wastewater treatment process- A mini review. Italian Journal of Zoology, 78 (1), 3-11. https://doi.org/10.1080/11250000903373797
[20]. Markandya, A. and Murthy, M. N. (2000). Bioaccumulation of metals in different food fishes in wastewater fed wetlands, A. P. H. publishing Corporation, New Delhi.
[21]. Matta, G. Bhutiani, R. Khanna, D. R. Kumar, D. Singh, V. and Ashraf, J. (2009). A study of zooplankton diversity with special reference to their concentration in river Ganga at Haridwar, india. Environment Conservation Journal., 10(3), 15-20.
[22]. Miller, G. T. Jr. (1997). Environmental Science: Working with the Earth. (6th Ed.) California: Wadsworth Publishing Company, 50(3), 271-273.
[23]. Pereira, R.. Soares, A. M. V. M.. Rebeiro, R. and Gonzaives, F. (2002). Assessing the trophic state of Linbos lake; a first step towards ecological rehabilitation. Journal of Environment Management, 64, 285-297. https://doi.org/10.1006/jema.2001.0521
[24]. Rajashekhar, M. Vijaykumar, K. and Paerveen, Z. (2010). Seasonal variations of zooplankton community in freshwater reservoir Gulbarga District, Karnataka, South India, International Journal of Systems Biology, 2(1), 6-11.
[25]. Ray, P. (1998). Ecological imbalance of the Ganga river system: Its impact on aquaculture, Daya Publishing House, Delhi.
[26]. Saha, D. P. Sengupta, R. Saha, J. and Banerjee, P. K. (2012). Assessment on the water quality characteristics of river Ganga at Kolkata Region, India, using water quality index and ANN simulation method. Archeological Environmental Science, 6, 34-41.
[27]. Shannon, C. E. and Weiner, W. (1949). Mathematical Theory of Communication, Urbans III. University of Illinois Press.
[28]. Singh, K., Malik, A. and Sinha, S. (2005). Water Quality Assessment and Apportionment of Pollution Sources of Gomti River (India) Using Multivariate Statistical Techniques – A Case Study. Analytica Chimica Acta - ANAL CHIM ACTA. 538. 355-374. https://doi.org/10.1016/j.aca.2005.02.006
[29]. Singh, L. and Choudhary, S. K. (2013). Physio-chemical characteristics of river water of Ganga in Middle Ganga Plains. International Journal of Innovative research in Science, 2(9), 4349-4357.
[30]. Sinha, R. K. and Das, N. K. (1998). Polychaetes from River Ganga Near patna, Bihar, India, Recent Advances in Ecobiological research, 2, 299-308.
[31]. Sladecek, V. (1983). Microorganism as indicator of water quality. Hydrobiologia, 100, 169-201. https://doi.org/10.1007/BF00027429
[32]. Sravya, P. V. R. and Sreejani, T. P. (2016). Water quality moeling- Statistical approach. International Advanced research journal in Science, Engineering and Technology, 3(2), 6-10.
[33]. Srivastava, K. N. Srivastava, P. and Sinha, A. K. (1990). Zooplankton studies of Ganga river between Kalkankar (Pratapgarh) and Phaphamau (Allahabad), Uttar Pradesh. Recent trends in Limnology, 1(4), 129-133.
[34]. Tare, V. Bose, P. and Gupta, S. K. (2003). Suggestion for a modified approach towards implementation and assessment of Ganga Action Plan and other similar River Action Plans in India, Water Quality Research Journal of Canada, 38, 607-626. https://doi.org/10.2166/wqrj.2003.039

Published with open access at journalbinet.com
EISSN: 2312-7945,

[35]. Van den Brink, P. J., den Besten, P. J., bij de Vaate, A., and ter Braak, C. J. F. (2009). Principal response curves technique for the analysis of multivariate biomonitoring time series. Environmental Monitoring and Assessment 152, 271. https://doi.org/10.1007/s10661-008-0314-6

HOW TO CITE THIS ARTICLE?

MLA

Singh, K. and Katiyar, M. “Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh”. International Journal of Forestry, Ecology and Environment, 02(01) (2020): 69-78.

APA

Singh, K. and Katiyar, M (2020). Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh. *International Journal of Forestry, Ecology and Environment*, 02(01), 69-78.

Chicago

Singh, K. and Katiyar, M. “Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh”. International Journal of Forestry, Ecology and Environment, 02(01) (2020): 69-78.

Harvard

Singh, K. and Katiyar, M. 2020. Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh. International Journal of Forestry, Ecology and Environment, 02(01) pp. 69-78.

Vancouver

Singh, K and Katiyar, M. Microbial components and physio-chemical parameters of river Ganga, Prayagraj and Varanasi, Uttar Pradesh. International Journal of Forestry, Ecology and Environment, 2020 August 02(01): 69-78.