

Environmental pollution supports to constancy and invader potential of *Cyprinus carpio* and *Oreochromis niloticus* from the Ganga river, India

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Abstract

Cyprinus carpio (Common carp) and *Oreochromis niloticus* (Nile tilapia) are commercially and frequently exploited fishes from the Ganga river at Kanpur, India. Study was undertaken during the period 2012 to 2013 from the Ganga river. Rivers are heavily impacted due to their use for carrying off the industrial, municipal, agricultural and domestic effluents. Water samples were collected for the present study from the Ganga river at Kanpur. The minimum temperature was recorded in winter season and maximum in summer season. The pH, TDS, EC, phosphate, chloride, total hardness, nitrate, DO and all heavy metals (e.g. Cu, Cr, Cd, Zn, Pb, Hg) values exhibited their minimum in monsoon season. The sulphate and BOD were recorded minimum in winter season while alkalinity and COD had their lowest values in summer season. The water quality of the Kanpur station was very poor which is not suitable for Indian major carp (IMC). However, the Ganga river waters could host some tolerant fish species such as the exotic *Cyprinus carpio* and *Oreochromis niloticus* and also catfishes. All these species are very hardy, in respect of water quality (poor), thus they have strongly invaded in despoiled ecosystem of the river.

Keywords: Pollution; Environment; invader potential; *Oreochromis niloticus*; *Cyprinus carpio*; Ganga river;

Introduction

The water quality of rivers is an issue of serious concern today. The swiftly raising indiscriminate industrialization and colonization along the rivers have put remarkable stress on water bodies (e.g. lotic ecosystem) and their quality [1-2]. Due to eutrophication, Indian rivers are extremely contaminated with organic, inorganic materials and trace elements [3-5]. The entire life cycle of various aquatic organisms in water are affected due to pollution in water [6, 7]. The Ganga river is a largest river with largest basin in India. The Ganga river has considerable religious, scientific, logical, economical and community values. It is the territories of various organisms adding to gene cache of plants, animals and microbes on the globe [8, 9]. Current time, poor water quality of the Ganga river provides sustainable protection to exotic fish species *Cyprinus carpio* and *Oreochromis niloticus* [10, 11]. Both species stocks are also increased from the Ganga basin (e.g. the Yamuna, Ken, Tons, Gomti and Ghaghara

ivers) especially large ecosystem [12, 15]. These species are generating intricate indigenous fish species (e.g. *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, *L. calbasu*, *L. bata*) for space, food and breeding grounds [16, 19].

A lot of river basins in the world presently host at least one or two non-native fish species as food security and resource utilization [20-24]. Non-native fish species is also responsible for freshwater fish homogenization globally [25-27]. The objective of the present study was to give recent water quality data regarding invader potential of non-native fish species (*C. carpio* and *O. niloticus*) from the Ganga river at Kanpur, India.

Material and methods

Water samples were collected from Kanpur during January 2012 to December 2013 from the Ganga river, India. The Kanpur is an industrial city with various tanneries and other polluting mills. These effluents are responsible for about 20-30% of the total water pollution of the river Ganga. During the entire study period of one year, samples were collected three times in a year: during winter, summer and monsoon seasons. The sampling was done between 9.30 to 11.00 AM.

Water Sampling Procedures

For physico-chemical analysis, surface water samples were collected from each selected site in 500 ml polyethylene bottles fitted with polyethylene caps. For dissolved oxygen analysis, samples were fixed with manganese sulphate and alkaline iodide in 250 ml BOD bottles in the field. For the analysis of heavy metals, 500 ml of water sample was taken from each site and was immediately acidified with 10 ml of 6N HNO₃. All samples were brought to the laboratory. Acidified samples were stored at 4 °C in the refrigerator for further analysis.

Analysis of Physico-Chemical Parameters of Water Sample

The Temperature, pH, total dissolved solids, alkalinity, total hardness, dissolved oxygen and electrical conductivity were estimated on the sampling site by automated water analysis

kit-ITS-701. Sulphate, Nitrate and Phosphates was measured by Perkin Elmer UV/VIS spectrophotometer model Lambda 25. Chlorine was measured by chlorine meter model ITS 1001 directly at the sampling site at the time of sample collection and expressed in mg/l.

Biochemical Oxygen Demand (BOD)

The sample for the determination of DO was collected in BOD bottles and they were fixed at site and brought immediately to laboratory and analyzed by modified winkler's method. It was measured by automated oxygen analyzer. It expressed in mg/l.

Chemical Oxygen Demand (COD)

An automatic analyzer was used to measure the COD level in all sample collected from different rivers at various sites. It is expressed in mg/l.

Result and discussion

Temperature

The average temperature was observed 21.33±5.13 °C, with

minimum 17 °C and maximum 27 °C in winter and summer seasons, respectively (Table 1). The fluctuation in river water temperature usually depends on the season, geographic location and temperature of effluent entering the stream [2]. Reported that temperature at Kanpur ranged from 21-30 °C. In spring and summer seasons of year 2003 and 2004 temperature was found to be 20.6 °C, 20.7 °C, 33.8 °C and 34 °C, respectively at Kanpur site [28,29].

Total Dissolved Solids (TDS)

TDS values were varied from 26-543 mg/l at Kanpur from the Ganga river. The average value was estimated 405.33± 41.66 mg/l. The minimum and maximum values were recorded in monsoon and winter seasons, respectively (Table 1). [30] reported TDS value varied from 178 to 200 mg/l in summer season from the Yamuna river at Agra. [31] TDS mean values were recorded 381.37±70.39 mg/l in summer, 417.25 ±4.33 mg/l in monsoon which was higher than present finding and 371.25 ±14.22 mg/l in winter season at Jajmau, Kanpur which was lower than present finding.

Table 1 Investigation of physico-chemical properties and metal concentration from the Ganga river water at Kanpur

Parameters	Summer	Monsoon	Winter	Mean ± SD
Temperature (°C)	27	20	17	21.33± 5.13
Total Dissolved Solids (mg/l)	413	260	543	405.33±141.66
Electric Conductivity mhos/cm)	631	370	536	512.33±132.10
Sulphate (mg/l)	65	110	52	75.67±30.44
Phosphate (mg/l)	1.61	0.65	0.86	1.04±0.50
Alkalinity (mg/l)	108	144	265	172.33±82.25
Chloride (mg/l)	30	9	26	21.67±11.25
Total Hardness (mg/l)	173	108	242	174.33±67.01
Nitrate(mg/l)	1.7	0.52	0.84	1.02±0.61
Dissolved Oxygen (mg/l)	4.7	3.2	4.7	3.70±0.87
BOD (mg/l)	37	48	32	39.00±8.19
COD (mg/l)	23	39	30	30.67±8.02
Copper (mg/l)	0.32	0.04	0.21	0.19±0.14
Chromium (mg/l)	3.6	0.26	1.9	1.92±1.67
Cadmium (mg/l)	0.41	0.06	0.23	0.23±0.18
Zinc (mg/l)	0.71	0.11	0.23	0.35±0.32
Lead (mg/l)	2.4	0.09	1.7	1.40±1.18
Mercury (mg/l)	0.17	0.05	0.11	0.11± 0.06

Electric Conductivity (EC)

The EC was observed with maximum 631 µmho/cm, minimum 370 µmho/cm and moderate 536 µmho/cm in summer, winter and monsoon seasons, respectively. The average value was recorded 512.33±132.10 µmho/cm. High EC values are indicating the presence of higher amount of dissolved inorganic substances in ionized form [32].

Sulphate (So₄⁻)

The So₄ was observed in the year 2012-2013 at Kanpur from the Ganga river. The values were recorded minimum (52

mg/l), maximum (110 mg/l) and moderate (65 mg/l) in winter, monsoon and summer seasons, respectively. According to [33], the maximum permissible and allowable concentration of Sulphate in drinking water is 200 to 400 mg/l but present study has lower than the permissible limit. Sulphate comes through fertilizers, they contributes to water pollution and increase sulphate concentration in water body. They also come from the runoff water, which contain relatively large quantities of organic minerals and sulphate compound. Sulphate is an abundant ion in the earth crust and its concentration in water can range from a few milligrams to several thousand milligrams per liter.

Phosphate (Po_4^{-})

The average value of phosphate was observed 1.04 ± 0.50 mg/l. The minimum and maximum values were recorded in winter and monsoon seasons, respectively (Table 1). Phosphorus is the most common nutrient; limiting the growth of phytoplankton in lentic fresh water system and concentration are often related to the productivity of aquatic system [34].

Alkalinity

The framework of alkalinity was observed in the year 2012-2013 with the minimum value 108 mg/l, maximum 265 mg/l and moderate 144 mg/l in summer, winter and monsoon seasons, respectively. The variation of alkalinity was very high at Kanpur from the Ganga river. Praveen et al (2013) reported that alkalinity value was ranged from 12.7 to 245 mg/l at Kanpur which is higher than present findings. [30] reported alkalinity values varied from 156 to 210 mg/l in summer season in the Yamuna river at Agra. Alkalinity is an important characteristic of nature and polluted water, in which measure of pH difference between their alkalinity and acidity.

Chloride (Cl)

The average value of chloride was estimated 21.67 ± 11.25 mg/l. The pattern flaws observed in the year 2012-2013, where the minimum value was recorded as 9 mg/l in monsoon season, moderate in winter season which was 26 mg/l and maximum in summer season 30 mg/l. [35] reported that Cl value was ranged from 8-30 mg/l in years 2009 at Kanpur from the Ganga river. Reported Cl concentration varied from 180 to 218 mg/l in the Yamuna river at Agra [32].

Total Hardness (TH)

The minimum value of total hardness was recorded as 108 mg/l in monsoon season, moderate in summer season which was 173 mg/l and maximum in winter season 242 mg/l (Table 1). Trivedi, et al. [35] reported that TH was from 108 to 246 mg/l at Kanpur. Gupta et al (2013) reported TH values ranged from 252 to 304 mg/l in the Yamuna River at Agra. The permissible limit of Hardness for water is 300 mg/l (ISI and ICMR). Generally dilution of hardness decreased with the advent of rain and increase with levels of water. Hardness in water is caused by dissolved calcium to lesser extent, magnesium, which is expressed as the equivalent quantity of calcium carbonate [33]. According to WHO guideline (1993) the maximum permissible limit of total hardness is 150-500 mg/l in water.

Nitrate (No_3^{-})

The minimum value of nitrate was recorded 0.52 mg/l, maximum 1.7 mg/l and moderate 0.84 mg/l in monsoon, summer and winter seasons, respectively. The main sources of nitrate and nitrite ions are nitrogen fertilizer in agriculture for the production of agricultural crops [36].

Dissolved oxygen (DO)

The average value of DO was observed 3.70 ± 0.87 mg/l from the Ganga river at Kanpur, India. The pattern of DO was observed

in the year 2012-2013, where the minimum value was recorded as 3.2 mg/l monsoon season, moderate in summer 4.7 mg/l and maximum in winter season 4.7 mg/l. The concentration of DO in the Ganga river at Kanpur is not suitable for Indian major carp (*C. catla*, *L. rohita*, *C. mrigala*) and *L. calbasu*. These fishes demands to higher concentration of DO. Present DO concentration is most suitable for *C. carpio* and *O. niloticus*. [30] Reported DO varied from 5.5 to 8.2 mg/l in summer from Yamuna river at Agra. According to USPH standard DO values vary from 4.0 to 6.0 mg/l. Value of DO increased in winter due to circulation of cold water as well as high solubility of oxygen at low temperature.

Biochemical Oxygen Demand (BOD)

The minimum value was recorded (32 mg/l) and maximum (48 mg/l) in winter and monsoon seasons, respectively (Table 1). The BOD values are also not suitable for Indian major carp from the Ganga river at Kanpur. The higher values of BOD are not suitable for Indian major carp in breeding season (Mayank and Dwivedi 2016). The average value was projected 39.00 ± 8.19 mg/l. [37] reported BOD range was from 97 ± 41 to 265 ± 78 mg/l in the year 2005 at same site, [38] recorded minimum BOD 1.38 mg/l during winter and maximum value 6.51 mg/l in monsoon season. [39] Reported 3.9 mg/l BOD at Ganga Kasi, and 2.1 mg/l at Lucknow in Gomti River. [40] Observed mean BOD value 2.8 ± 0.4 in summer and 3.5 ± 0.4 mg/l in winter at Kanpur from the Ganga river.

Chemical Oxygen Demand (COD)

The pattern of COD were observed in the year 2012-2013, with the minimum value 23 mg/l, maximum 39 mg/l and moderate 30 mg/l in summer, monsoon and winter seasons, respectively (Table 1). The COD values indicated that the industrial effluents concentration is very high at Kanpur. The COD values are also not suitable for Indian major carp from the Ganga river at Kanpur. It is also harmful for indigenous fish species [41]. [42] Estimated mean value of COD was 520 ± 180 mg/l at Varanasi. [39] reported 22 mg/l at Ganga Kasi and 14 mg/l at Lucknow from the Gomti River.

In general, *C. carpio* and *O. niloticus* have not any ecological standard from the lotic ecosystem [5, 43-45]. Both species are commercially exploited from the Ganga basin [46] and highly utilize natural resources, threat biodiversity of fishes and damage indigenous fish stock [47-49]. But reproductive system and recruitment process are damaging by high concentration of metals in fish body [50-53].

Heavy metals analysis from Ganga river water at Kanpur, India

The Cr was the highest accumulated heavy metals from the Ganga river water at Kanpur, India. The lowest accumulations of all metals were recorded in monsoon season while maximum was recorded in summer season (Table 1). Permanent contaminants such as metals may be transferred to higher levels in the food chain through environmental expansion [54, 55].

According to [56] and [33] the maximum permissible limit

of Copper in water is 2 mg/l. According to BIS (2005) guidelines permissible limit of copper 1.5 mg/l. [31] mean value of Cr 52.12± 15.52 mg/l in summer, 34.05 ±19.2 mg/l in monsoon and 45.5± 4 mg/l in winter seasons at Jajmau Kanpur which is higher than present work. [39] reported Cr value 0.63 mg/l at Ganga Kasi, and 0.15 mg/l at Lucknow in Gomti River. In present investigation, it was observed that the Cr value was below the permissible limit 0.05 mg/l set by [33] except Lucknow site and 1.0 mg/l as per the USPH standards. [57] stated that the acute toxicity of Cr to invertebrates is highly variable, depending upon species. According to [56] and [33] the maximum permissible limit of Chromium is 0.05 mg/l in water.[57] recorded ranged Cd 0.001 to 0.003 mg/l from the Ganga River at Kolkata. According to [33] the maximum permissible limit of Cd in water is 0.003 mg/l and according to EU (1998) guideline 0.005 mg/l. [58] reported ranged 0.042 to 0.111 mg/l in the Ganga River at Kolkata. [59] Analyzed Zn ranged between 1.05 to 3.31 mg/l from Sangam at Allahabad. According to [33] the maximum permissible limit of Zinc in water is 3 mg/l, and according to USEPA (2003) guideline 5 mg/l. According to BIS (2005) guidelines permissible limit of Zinc 15 mg/l. According to [56] and [33] guideline, the maximum permissible limit of lead in water is 0.01 mg/l. According to BIS (2005) guidelines permissible limit of Lead 0.1 mg/l.[60] estimated Hg ranged 0.16 to 0.95 g/ml in Ganga river at Babugat (Calcutta).The average Hg content in water samples were found to vary in different range at for the different undertaken river from site to site. According to [33] the maximum permissible limit of Hg in water is 0.006 mg/l, and according to [56] guideline

0.001 mg/l and USEPA (2003) MCLG 0.002, MCL/TT 0.002mg/l.

Both fishes living in this environmental condition and well survive with safely. The levels of heavy metals varied significantly among fish species and organs. As expected, muscles always possessed the lowest concentrations of all metals. Accumulation level of heavy metals in river water is higher but muscle (flesh) of *C. carpio* and *O.niloticus* safe for human consumption [61, 62]. Due to pollution in the Ganga river, large size indigenous fish species (e.g. *Catlacatla*, *Labeo rohita*, *Cirrhinus mrigala* and *L. calbasu*) stocks are shrinking. In this situation, large space is available to *C. carpio* and *O.niloticus* for feeding and breeding. Indigenous species, *C. mrigala*, *calbasu*, *sperataaor*, *S. seenghala*, *Clupisoma garua*, *Baragiusbagarius* and *Wallagoattucreate* problem to *C. carpio* and *O.niloticus* for feeding and breeding [63-67]. Hardy fishes are safe in the Ganga basin in natural ecosystem [68-70].

Sperataseenghala (15.76%) was dominated compared to *Clupisoma garua* (14.67%) and *Eutropiichthysvacha* (13.95%). *Cyprinus carpio* and *Oreochromis niloticus* also shared massive proportion from the Ganga river at Kanpur (Figure 1). These two exotic fishes indicated that the near future indigenous species suffering from food and space from the Ganga river at Kanpur, India. These fishes well stable at Allahabad from the Ganga river [71]. It may be concluded that the pollution level from the Ganga river is dangerous point, but survival and invader potential of *C. carpio* and *O. niloticus* dominant. In other words, environmental condition of the Ganga river is very suitable for *C. carpio* and *O. niloticus*.

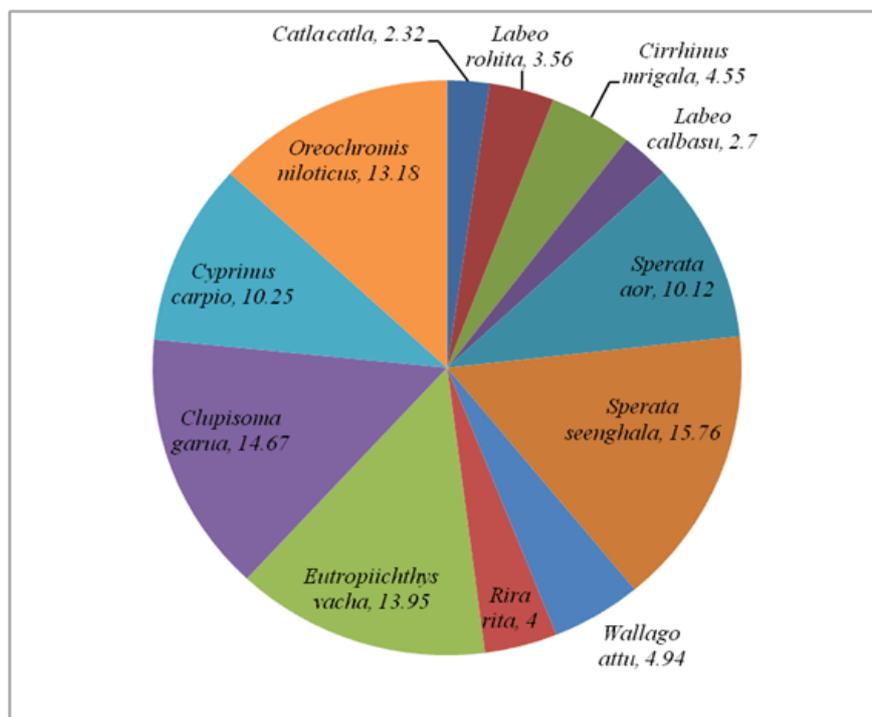


Figure 1: Relative abundance (%) of some commercially important fishes from the Ganga river at Kanpur (source: Dwivedi et al 2016)

References

1. Dwivedi AC, Khan S, Mayank P. Stressors altering the size and age of *Cirrhinus mrigala* (Hamilton, 1822) from the Ghaghara river, India. 2017 Oceanogr Fish Open Access J. 2017;4(4). DOI: 10.19080/OFOAJ.2017.04.555642
2. Tiwari A, Dwivedi AC, Mayank P. Time scale changes in the water quality of the Ganga River, India and estimation of suitability for exotic and hardy fishes. Hydrology Current Research. 2016;7(3). doi:10.4172/2157-7587.1000254
3. Tiwari A, Dwivedi AC, Shukla DN, Mayank P. Assessment of heavy metals in different organ of *Oreochromis niloticus* from the Gomti river at Sultanpur, India. Journal of the Kalash Science. 2014;2(1):47-52.
4. Pathak RK, Gopesh A, Dwivedi AC. Invasion potential and biology of *Cyprinus carpio* (Common carp). LAP LAMBERT Academic Publishing GmbH & Co. KG, DudweilerLandstr. 99, 66123 Saarbrücken, Germany, 2015.
5. Mayank P, Dwivedi AC. Biology of *Cirrhinus mrigala* and *Oreochromis niloticus*. LAP LAMBERT Academic Publishing GmbH & Co. KG, DudweilerLandstr. 99, 66123 Saarbrücken, Germany. 2015;188.
6. Tiwari A, Dwivedi AC, Shukla DN. Accumulation of heavy metals in Liver, Muscle and Gill of *Cyprinus carpio* from the Gomti river at Jaunpur, Uttar Pradesh. Journal of the Kalash Science. 2013;1(2):127-132.
7. Imran S, Thakur S, Jha DN, Dwivedi AC. Size composition and exploitation pattern of *Labeo calbasu* (Hamilton 1822) from the lower stretch of the Yamuna river. Asian Journal of Bio Sciences. 2015;10(2):171-173. DOI: 10.15740/HAS/AJBS/10.2/171-173
8. Dwivedi AC, Mishra AS, Mayank P, Tiwari A. Persistence and structure of the fish assemblage from the Ganga river (Kanpur to Varanasi section), India. Journal of Geography and Natural Disasters. 2016;6:Doi: 10.4172/2167-0587.1000159
9. Tripathi S, Gopesh A, Dwivedi AC. Framework and sustainable audit for the assessing of the Ganga river ecosystem health at Allahabad, India. Asian Journal of Environmental Science. 2017;12(1):37-42. DOI: 10.15740/HAS/AJES/12.1/37-42
10. Pathak RK, Gopesh A, Dwivedi AC. Age composition, growth rate and age pyramid of an exotic fish species, *Cyprinus carpio* var. *communis* from the Ganga river at Allahabad, India. National Academy of Science Letter. 2011;34(5 & 6):223-228.
11. Dwivedi AC, Mayank P, Imran S. Reproductive structure of invading freshwater fish, *Oreochromis niloticus* (Linnaeus, 1757) in respect of climate from the tributary of the Ganga river, India. Climatology and Weather Forecasting. 2016;4:2. doi.org/10.4172/2332-2594.1000164
12. Dwivedi AC, Nautiyal P. Alien fish species, *Cyprinus carpio* (common carp) as a invader in the Vindhyan region (Ken, Paisuni, Tons rivers), India. Journal of the Kalash Science. 2013;1(2): 133-139.
13. Dwivedi AC, Nautiyal P, Rizvi AF, Mayank P. Landing scenario, size, age and population dynamic of *Labeo rohita*, *Tor torand* L. *calbasu* response to need their restoration in the Vindhyan region, India. Journal of the Kalash Science. 2016;4(1):27-40.
14. Mayank P, Dwivedi AC. Stock assessment and population structure of alien fish species, *Oreochromis niloticus* (Linnaeus) from the lower stretch of the Yamuna river, India. Journal of the Experimental Zoology, India. 2016;19(1):163-167.
15. Tripathi S, Gopesh A, Dwivedi AC. Fish and fisheries in the Ganga river: current assessment of the fish community, threats and restoration. Journal of Experimental Zoology, India. 2017;20(2):907-912.
16. Pathak RK, Gopesh A, Dwivedi AC. Alien fish species, *Cyprinus carpio* var. *communis* (common carp) as a powerful invader in the Yamuna river at Allahabad, India. National Academy of Science Letter. 2011;34(9):367-373.
17. Mayank P, Dwivedi AC. Role of exotic carp, *Cyprinus carpio* and *Oreochromis niloticus* from the lower stretch of the Yamuna river. In: Advances in biosciences and Technology edited by Pandeya KB, Mishra AS, Ojha RP and Singh AK, published by NGBU, Allahabad. 2015;93-97. DOI: 10.13140/RG.2.1.3674.0241
18. Imran S, Thakur S, Jha DN, Dwivedi AC. Age structure of *Labeo calbasu* (Hamilton 1822) from the river Yamuna. Journal of the Inland Fisheries Society of India. 2015;47(2):81-85.
19. Tahseen S, Shahin, Agrwal S, Dwivedi AC, Mishra AS. Studies on age and growth of *Labeo bata* (Hamilton, 1822) from the middle stretch of the Ganga river, India. Journal of the Kalash Science. 2015;3(1):61-66.
20. Villéger S, Blanchet S, Beauchard O, Oberdorff T, Brosse S. Homogenization patterns of the world's freshwater fish faunas. Proc Natl Acad Sci USA. 2011;108(44):18003-18008.
21. Kumar J, Pandey AK, Dwivedi AC, Naik ASK, Mahesh V, Benakappa S. Ichthyofaunal diversity of Faizabad district (Uttar Pradesh), India. Journal of Experimental Zoology, India. 2013;16(1): 149-154.
22. Dwivedi AC, Jha DN. Population structure of alien fish species, *Oreochromis niloticus* (Linnaeus, 1757) from the middle stretch of the Ganga river, India. Journal of the Kalash Science. 2013;1(1): 157-161.
23. Dwivedi AC, Jha DN, Mayank P. Food security, livelihood and non-native fish species: status, trends and future Perspectives. Journal of the Kalash Science. 2014;2(3)(Special Volume):41-46.
24. Dwivedi AC, Mayank P, Tiwari A. The River as transformed by human activities: the rise of the invader potential of *Cyprinus carpio* and *Oreochromis niloticus* from the Yamuna River, India. Journal of Earth Science & Climatic Change. 2016;7(7):361. doi: 10.4172/2157-7617.1000361
25. Olden JD, Kennard M, Pusey B. Species invasions and the changing biogeography of Australia freshwater fishes. Glob EcolBiogeogr. 2008;17:25-37.
26. Villéger S, Blanchet S, Beauchard O, Oberdorff T, Brosse S. From current distinctiveness to future homogenization of the world's freshwater fish faunas. Diversity and Distributions. 2014;1-13. Doi: 10.1111/ddi.12242
27. Toussaint A, Beauchard O, Oberdorff T, Brosse S, Villéger S. Worldwide freshwater fish homogenization is driven by a few widespread non-native species. Biological Invasions. 2016. doi: 10.1007/s10530-016-1067-8
28. Praveen A, Kumar R, Pratima, Kumar R. Physico-chemical properties of the water of river Ganga at Kanpur. International Journal Computational Engineering Research. 2013;3(4):134-137.
29. Zafer A, Sultana N. Seasonal analysis in the water quality of river Ganga disaster ecology and environment. Arvind K (eds.), Daya publishing house, India. 2007;57-62.
30. Maheshwari A, Sharma M, Sharma D. Hydro Chemical Analysis of Surface and Ground Water Quality of Yamuna River at Agra, India. J. mater. Environ. 2011;2(4):373-378.

31. Katiyar S. Impact of tannery effluent with special reference to seasonal variation on physico-chemical characteristics of river water at Kanpur (U.P.). *India. J Envi. Anal. Toxicol.* 2011;1(3). doi:10.4172/2161-0525.1000115
32. Gupta N, Yadav KK, kumar V, Singh D. Assessment of physicochemical properties of Yamuna river in Agra city. *Intern. J.Chem. Tech. Res.* 2013;5(1):528-531.
33. WHO. Evaluation of Certain Food Additives and the Contaminants Mercury, Lead and Cadmium. WHO Technical Report, Series No. 505. Geneva: WHO Press. 2006.
34. Wetzel RG. *Limnology*, Second Edition, edited by Wetzel L.G., Michigan State University, CRS College Publishing Philadelphia, New York, Chicago. 1983;784.
35. Trivedi P, Bajpai A, Thareja S. Comparative study of seasonal variation in physico-chemical characteristics in drinking water quality of Kanpur, India with reference to 200 MLD filtration plant and ground water. *Nature and Science.* 2010;8(4):11-17.
36. Mohammadi S, Ziarati P. Nitrate and nitrite content in commercially-available fruit juice packed products. *J. Chem. Pharmaceutical Res.* 2016;8(6):335-341.
37. Rai PK, Mishra A, Tripathi BD. Heavy metal and microbial pollution of the river Ganga: a case study of water quality at Varanasi. *Aquatic Ecosystem and Health Management.* 2010;13(4):352-361.
38. Chavan AW, Dhamani AA, Murkute VB. Seasonal variation in the physicochemical parameter of river Wainanga near Bramhapuri, distChandrapur. *Vidh. Inter. Interd. Res. J.* 2005-2006;1(1):28-35.
39. Chandra S, Singh A, Tomar PK, Kumar A. Evaluation of Physicochemical Characteristics of Various river water in India. *E Journal of Chem.* 2011;8(4):1546-1555.
40. Khwaja AR, Singh R, Tandon SN. Monitoring of Ganga water and Sediment tannery pollution at Kanpur (India): A Case Study. *Environmental Monitoring and Assessment.* 2001;68:19-35.
41. Mayank P, Dwivedi AC. Linking *Cirrhinus mrigala* (Hamilton, 1822) size composition and exploitation structure to their restoration in the Yamuna river, India. *Asian Journal of Bio Science.* 2016;11(2):292-297. doi: 10.15740/HAS/AJBS/11.2/292-297
42. Tripathi BD, Sikandar M, Shukla SC. Physico-chemical characterization of city sewage discharged into river Ganga at Varanasi, India. *Environ. Int.* 1991;17(5):469-478.
43. Dwivedi AC, Singh KR, Khan S, Mayank P. Dynamics of exploited fish populations and sex ratio of *Cyprinus carpio* var. *communis* (Linnaeus) in the Yamuna river at Allahabad. *The Asian Journal of Animal Sciences.* 2008;3(2):198-202.
44. Dwivedi AC, Mayank P, Masud S, Khan S. An investigation of the population status and age pyramid of *Cyprinus carpio* var. *communis* from the Yamuna river at Allahabad. *The Asian Journal of Animal Science.* 2009;4(1):98-101.
45. Pathak RK, Gopesh A, Joshi KD, Dwivedi AC. *Cyprinus carpio* var. *Communis*, in middle stretch of river Ganga at Allahabad. *Journal of the Inland Fisheries Society of India,* 2013;45(2):60-62.
46. Dwivedi AC, Mayank P, Tripathi S, Tiwari A. Biodiversity: the non-natives species versus the natives species and ecosystem functioning. *Journal of Biodiversity, Bioprospecting and Development.* 2017;4(1):164. DOI: 10.4172/2376-0214.1000164
47. Mayank P, Dwivedi AC, Tiwari A. Reproductive profile of *Cirrhinus mrigala* and suggestion for restoration (Hamilton, 1822) from the Yamuna river, India. *Bioved.* 2016;27(1):115-120.
48. Mayank P, Dwivedi AC. Resource use efficiency and invasive potential of non-native fish species, *Oreochromis niloticus* from the Paisuni River, India. *Poultry Fisheries & Wildlife Sciences.* 2017;5(1):177. DOI: 10.4172/2375-446X.1000177
49. Dwivedi AC, Mayank P, Tiwari A. Size selectivity of active fishing gear: changes in size, age and growth of *Cirrhinus mrigala* from the Ganga River, India. *Fisheries and Aquaculture Journal.* 2017;8(2):205. DOI: 10.4172/2150-3508.1000205
50. Tiwari A, Dwivedi AC, Shukla DN. Level of heavy metals Cu, Cr, Pb and Zn in alien fish species, *Cyprinus carpio* from the Gomtiriver at Sultanpur, India. *Asian Journal of Bio Science.* 2013;8(2):255-258.
51. Tiwari A, Dwivedi AC. Assessment of heavy metals bioaccumulation in alien fish species *Cyprinus carpio* from the Gomti river, India. *European Journal of Experimental Biology.* 2014;4(6):112-117.
52. Dwivedi AC. Reproductive profile of Indian Major Carp, *Cirrhinus mrigala* (Hamilton, 1822) with Restoration from the Ganga River, India. *Journal of Fisheries & Livestock Production.* 2017;5(1):212. DOI: 10.4172/2332-2608.1000212
53. Dwivedi AC, Jha DN, Das SCS, Mayank P. Population structure of Nile tilapia, *Oreochromis niloticus* (Linnaeus 1758) from the Ken River, India. *Journal of Scientific Achievements.* 2017;2(5):23-27.
54. Ziarati, P, Kermanshah A, Moslehishad M. Adsorption heavy metals from contaminated water by modified shell of wild endemic Almonds: *Amygdaluslycioides* and *Amygdaluswendelboi*. *Biosciences Biotechnology Res. Asia.* 2005;12(3):2451-2457.
55. Dwivedi AC, Tiwari A, Mayank P. Seasonal determination of heavy metals in muscle, gill and liver tissues of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) from the tributary of the Ganga River, India. *Zoology and Ecology.* 2015;25(2):166-171. DOI: 10.1080/21658005.2015.1020012
56. EU. The commission of the European communities, commission regulation, EU No 221/2002 amending regulation EU No.466/2001 setting maximum levels for certain contamination in food stuff in order to protect public health official journal of the European Communities. 2002.
57. Jain CK. A Hydro-chemical study of mountainous watershed: The Ganga India, *Water Res.* 2002;36(5):1262-1272.
58. Kar D, Surr P, Mandal SK, Saha T, Kole RK. Assessment of heavy metal pollution in surface water. *Int. J. Environ. Sci. Tech.* 2008;5(1): 119-124.
59. Pandey J, Shubhashish K, Pandey R. Heavy metal contamination of Ganga river at Varanasi in relation to atmospheric deposition. *Tropical Ecology.* 2010;51:365-373.
60. Saha PD, Sengupta R, Saha J, Banerjee PK. Assessment on the water quality characteristics of River Ganga at Kolkata Region, India using water quality index and ANN simulation method, *Arch. EnvironSci.* 2012;(6):34-41.
61. Tiwari A, Kushwaha AS, Dwivedi AC. Accumulation of heavy metals in liver, muscle and gill of *Cyprinus carpio* from the Ganga river at Varanasi, Uttar Pradesh. *Journal of the Kalash Science.* 2015;3(1):47-51.

62. Tiwari A, Dwivedi AC. Distribution of heavy metals in tissues of the Common carp, *Cyprinus carpio* Linnaeus, 1758 from the Ganga river, India. International Journal of Environmental Science. 2015;6(1):881-891. DOI: 10.6088/ijes.xxxxxxxx.
63. Mayank P, Tyagi RK, Dwivedi AC. Studies on age, growth and age composition of commercially important fish species, *Cirrhinus mrigala* (Hamilton, 1822) from the tributary of the Ganga river, India. European Journal of Experimental Biology. 2015;5(2):16-21.
64. Rizvi, AF, Dwivedi AC, Singh KP. Study on population dynamics of *Labeo calbasu* (Ham.), suggesting conservational methods for optimum yield. National Academy of Science Letter. 2010;33(7& 8):247-253.
65. Dwivedi AC. Ecological assessment of fishes and population dynamics of *Labeo rohita*(Hamilton), *Tor tor* (Hamilton) and *Labeo calbasu* (Hamilton) in the Paisuni river. Aquacult. 2009;10(2):249-259.
66. Khan S, Dwivedi AC, Mishra P. Sex ratio and exploitation structure of *Labeo calbasu* (Hamilton) in the tributary of the Ganga river system (Ghaghara river). Bioved. 2007;18(1, 2):7-12.
67. Tripathi S, Gopesh A, Joshi KD, Dwivedi AC. Size composition, exploitation pattern, sex ratio and sex structure of *Eutropiichthys vacha* (Hamilton, 1822) from the middle stretch of the river Ganga at Allahabad, India. In: Advances in biosciences and Technology edited by KB. Pandeya, AS. Mishra RP. Ojha and A.K. Singh published by NGBU, Allahabad. 2005;116-120.
68. Tiwari A, Mayank P, Dwivedi AC. Assessment of human health risk via the consumption of the freshwater fish, *Cyprinus carpio* and *Oreochromis niloticus* from the Ganga River, India. Bioved. 2017;28(2): 341-349
69. Jha DN, Joshi KD, Dwivedi AC, Mayank P, Kumar P, Tiwari A. Assessment of fish production potential of Chitrakoot district, Uttar Pradesh. Journal of the Kalash Science. 2015;3(3):7-10.
70. Mayank P, Dwivedi AC. River health and commercially important catfishes from the Yamuna river, India. Journal of the Kalash Science. 2015;3(3):23-26.
71. Mayank P, Dwivedi AC, Pathak RK. Age, growth and age pyramid of exotic fish species *Oreochromis niloticus* (Linnaeus 1758) from the lower stretch of the Yamuna river, India. National Academy Science Letter. 2011;34(5):223-228. doi.org/10.1007/s-40009-018-0673-7