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The Ganga Aarti ritual and its influence on physical and chemical parameters of water quality of river Ganga: A preliminary study

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Abstract
River Ganges has an important influence on the lives of a large portion of India's population, and is in turn influenced by the same population. Various anthropogenic activities have played a role in the development of the river into its present state, and these anthropogenic influences still continue to change the state of the river. The present study investigates the response of some physical and chemical parameters of water quality of the river to the Ganga Aarti Ritual. The parameters of Water Temperature, Dissolved Oxygen, free CO_2, Total Alkalinity, pH and Total Dissolved Solids were studied before, during and after the time of the Aarti and changes in the dissolved gases and alkalinity of the water were observed. It was inferred that organic allochthonous inputs could be driving changes in the dynamics of the dissolved gases by promoting algal growth in the channel, and could also be responsible for causing temporary changes in the Total Alkalinity of the water. Despite these observations, the selected parameters appear to be within acceptable limits, thus indicating the self-purifying capability of the river.

Keywords: ganges, ganga aarti, water quality, anthropogenic influences

1. Introduction
Rivers and streams, in spite of occupying only a small portion of the land surface as compared to the relatively large 1.8% of land area occupied by lakes, have significant importance in human lives [1] and are involved in various anthropogenic activities, including cultural and traditional practices ad rituals. These lotic water bodies are also involved in moving materials from land to the ocean through various estuaries, lakes and other habitats, and thus form a vital link in global biogeochemistry [2]. The Ganga is the largest river system of India, and its basin is shared by India, Nepal, Bangladesh and Bhutan. The river originates from the Gangotri glacier, about 4,000 MSL. The main river originates at Devprayag, where the Alaknanda and Bhagirathi meet to form the Ganga. It is joined by the Ramganga, Sarda, Gomti, Ghagra, Gandak and Kosi on the left bank, and by the Yamuna, Kehtons, Son, Punpun and Kiul [3].

The Ganga Aarti is a ritual practiced every evening at the banks of the river Ganges, mainly at Rishikesh, Haridwar and Varanasi. It involves lighting of lamps or "diyas", which are offered to the river along with flowers [4]. The daily ritual includes the "Sringaar" or adornment of the Goddess of the river with flowers, sindoor and milk. The prayers are offered and 1001 "battis" or lamps are lit for the river. Besides the diya and flowers, people also make other offerings to the river, such as milk, colour, sindoor and ghee or clarified butter. The river itself is revered for its purity and purifying abilities, and its waters are said to be capable of absolving people of their sins [5]. The devotees start offering flowers and diyas to the river some time before the Ganga Aarti actually begins, but the frequency of these offerings decreases substantially after the ritual is over.

Rituals such as idol immersion are known to cause changes in the water quality of sacred water bodies [6], and the present study explores the changes in the water quality of the river at Brahma Kund, Haridwar, during the aarti as compared to the quality before and after the ritual, in the form of a preliminary study, to establish whether the ritual affects the quality of the holy river's water at all. Since most of the offerings made to the river, either during the "Sringaar" or by individual pilgrims, are organic in nature, the study tests the hypothesis that these affect the quality of the river's water in some way.

However, rivers are known to possess an ability of self-purification through physical, chemical and biological processes. The physical and chemical processes are governed to some degree by biological factors and processes [7]. Therefore, by studying the difference in the values of the selected water quality parameters at different times with respect to the ritual, it has also been attempted to understand the self-purification ability of the river.

2. Materials and Methods
The study was conducted at Brahma Kund, Harki Pauri, Haridwar in the state of Uttarakhand (29˚57'25.63"N, 78˚10'15.60"E, 300 m above msl) [8], between July 2019 and March 2020. The samples were collected half an hour before and after the Aarti, and during the Aarti.

The study period can be divided into different periods with respect to the crowds gathered at the banks of the river:

1. July 2019 to October 2019: These months saw the largest crowds during the study
2. November 2019 to early March 2020: The crowds grew smaller from November as the weather grew colder and works on the railway line reduced accessibility of pilgrims to the site by train

3. Late March 2020: This period saw no crowds after the Lockdown was implemented in response to the Covid-19 pandemic.

Six physico-chemical water quality parameters were analysed *viz.* Water temperature, Dissolved Oxygen (D. O.), Free Carbon dioxide, pH, Total Alkalinity and Total Dissolved Solids (T. D. S.), following the guidelines given by APHA[9].

Fig 1: The Ganga Aarti with the usual crowd, before November 2019

Fig 2: The Ganga Aarti in March, after the lockdown was implemented

3. Results

The D.O., Free CO_2, Total Alkalinity, pH, T. D. S. and Temperature of the water from the site of the study were estimated, and the maximum, minimum and mean values along with the standard deviation are given in Table 1.

Table 1: Values for physico-chemical water quality parameters observed between July 2019 and March 2020

Parameters	Minimum	Maximum	Mean (July 2019 to March 2020)	Mean (July 2019 to October 2019)	Mean (November 2019 to March 2020)	Mean (After March 2020 Lockdown)
Dissolved Oxygen (ppm)	5.20	11.00	8.780 ± 1.329	8.027 ± 1.693	8.307 ± 0.433	10.007 ± 0.194
Free Carbon dioxide (ppm)	.60	1.60	0.956 ± 0.255	1.120 ± 0.281	0.840 ± 0.229	0.907 ± 0.167
Total Alkalinity (ppm)	64.00	110.00	74.622 ± 7.720	78.933 ± 11.853	72.533 ± 3.815	72.400 ± 1.549
pH	6.50	8.00	7.167 ± 0.320	7.233 ± 0.458	7.133 ± 0.229	7.133 ± 0.229
Total Dissolved Solids (ppm)	80.00	108.00	88.333 ± 7.903	98.333 ± 5.327	83.200 ± 1.821	83.467 ± 1.959
Water Temperature (˚C)	15.40	21.70	17.640 ± 1.750	16.767 ± 1.232	16.127 ± 0.528	17.027 ± 0.360

The average D.O. content of the water was estimated at 8.780±1.329 ppm over the period of the study. The values for Free CO_2, Total Alkalinity, pH and TDS averaged at 0.956±0.255 ppm, 74.622 ± 7.720 ppm, 7.167 ± 0.320 and 88.333 ± 7.903 ppm, respectively. The average water temperature was recorded at 17.640 ± 1.750 ˚C.

When the results of the study were split into three distinct periods according to the size of the crowds gathered at the aarti, some differences were observed in the mean values of the parameters. For the period of July to October, the average water temperature was 16.767 ± 1.232 ˚C. The mean values for DO, Free CO_2, Total Alkalinity, pH and TDS were found to be 8.027 ± 1.693 ppm, 1.120 ± 0.281 ppm, 78.933 ± 11.853 ppm, 7.233 ± 0.458 and 98.333 ± 5.327 ppm, respectively.

For the period from November to early March, when the site was less crowded due to lack of accessibility to pilgrims by trains, the average water temperature was recorded at 16.127 ± 0.528 ˚C. The mean values for DO, Free CO_2, Total Alkalinity, pH and TDS were 8.307 ± 0.433 ppm, 0.840 ± 0.229 ppm, 72.533 ± 3.815 ppm, 7.133 ± 0.229 and 83.200 ± 1.821 ppm, respectively.

The average water temperature during the lockdown was 17.027 ± 0.360˚C; the average values for DO, Free CO_2, Total Alkalinity, pH and TDS were 10.007 ± 0.194 ppm, 0.907 ± 0.167 ppm, 72.400 ± 1.549 ppm, 7.133 ± 0.229 and 83.467 ± 1.959 ppm, respectively.

An Analysis of Variance for the parameters during the period of the study was carried out, and is given in Table 2. It revealed significant variance in the concentration of Free CO_2 for the period between July and March, and November to March, before the lockdown. Significant differences were also observed in the water temperature and dissolved oxygen levels during the lockdown.

Table 2: ANOVA for the selected water quality parameters by the time of collection of water sample

Parameter	F (July 2019 to March 2020)	F (July 2019 to October 2019)	F (November 2019 to March 2020)	F (After March Lockdown)
Dissolved Oxygen	0.388	0.706	1.043	4.730*
Free Carbon di Oxide	5.789**	2.280	4.222*	1.300
Total Alkalinity	0.818	0.431	1.490	0.000
pH	0.157	0.286	0.286	0.286
Total Dissolved Solids	0.013	0.032	0.757	0.106
Water Temperature	0.433	0.412	1.518	5.215*

An anlaysis of the pH of the various constiuents of the individual offerings was also done to observe their effect on the pH and alkalinity of the water, and the values are given in Table 3.

Table 3: pH of the constituents of the individual offerings

Constituent	pH
Leaf	6.40 ± 0.36
Flowers	6.33 ± 0.25
Ash	9.90 0.26

4. Discussion

Dissolved Oxygen is an indicator of the level of organic pollution in aquatic systems [10]. Since the dissolved gases did not show significant variation in the months with the larger crowds in the present study, it can be assumed that these are influenced by factors other than the crowds and their activities along the banks. Guasch *et al.* (1998) [11] observed that in the presence of low biological activity and high aeration, the dissolved oxygen and CO_2 do not show a clear diurnal pattern of variation. They recognized metabolism and reaeration as the main processes affecting the dynamics of dissolved gases in streams. This implies that the differences observed in the values of both D.O. and free CO_2 would exist due to high biological activity in the river's water. Rajwa-Kuligiewicz *et al.* (2015) [12] observed that anastomosing rivers experience a less stable oxygen regime than sandy bed rivers. The oxygen regime in such modified channels was observed to be primarily dependent upon seasonal temperature variation, discharge and trophic status. The variance of daily frequencies in DO concentration was also observed to be driven by mixing and depth, which influence the daily cycle of photosynthesis/respiration. This is of importance to the site of the present study, as the river channel has been modified and diverted from the main channel at Bhimgora Barrage. Matta *et al.* (2015) [13] observed that the canal system of the Ganga in Haridwar had a higher nutrient load and consequently higher plankton density as a result of anthropogenic influences. Since the river flows through a canal at Harki Pauri and is influenced by various anthropogenic activities including the introduction of organic substances in the form of offerings to the river, it can be assumed that the water would be rich in terms of nutrients and plankton density at the site of the study. Khanna *et al.* (2012) [14] observed higher phytoplankton and zooplankton density in the winter and spring months in the Ganga as compared to the other months and since the free CO_2 showed a significant variation in the winter months in the present study, it can be inferred that it was the community respiration that was responsible for this observation. The significant difference in the D. O. levels observed during the lockdown in March may also be attributed to the difference between community photosynthesis and community respiration in the spring.

Another parameter of interest, despite no significant difference indicated in the ANOVA, is Total Alkalinity. The value of Total Alkalinity was observed to be the lowest during the aarti in the periods between July and October, and from November to March before the implementation of the lockdown, but there was little variation in the value after the lockdown was implemented. The variations in the parameters of the study before, during and after the aarti have been shown in Fig. 3 – 6.

Since there was little variation in the value of total alkalinity during the period when the ritual saw no crowds, it can be assumed that the parameter was influenced by some factor associated with the number of individuals interacting with the river during the ritual. Shashi and Dwivedi (2009) [15] observed significant positive correlation between alkalinity and pH of water, and following this correlation, the influence of the individual offerings of flowers in leaf-boats with lamps on the pH of water was observed. These were identified as the principal factor causing a change in alkalinity and pH of the water. Both the flowers and leaves were found to have an acidic pH and these form the bulk of these offerings. The ash from the *batti* of the oil lamp had an alkaline pH, but its proportion in the offering is very low. It may also be noted that the average value for TDS was higher before November 2019, when the crowds were larger. This also implies that allochthonous inputs by people contributed to a higher TDS of the river's water in these months.

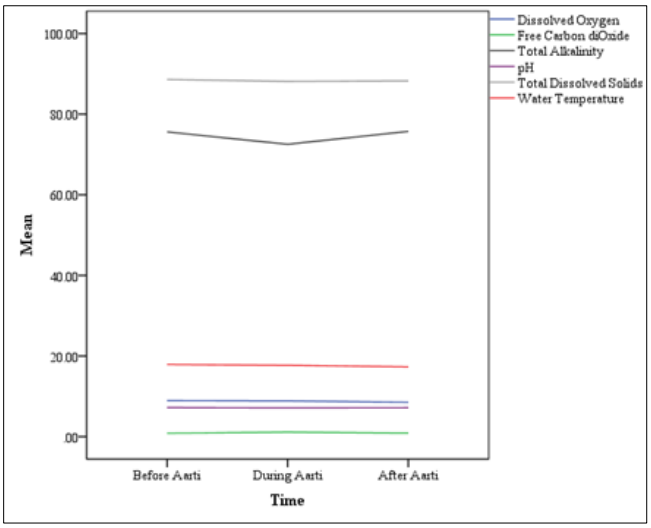

Fig 3: Trends observed in the water quality parameters from July 2019-March 2020

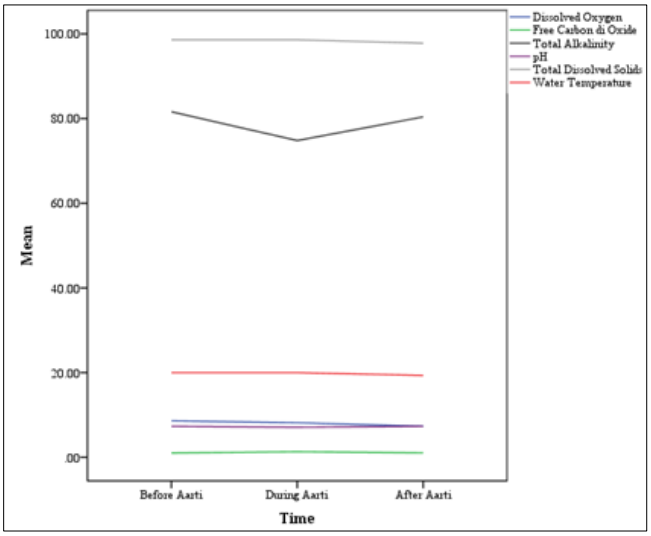

Fig 4: Trends observed in the water quality parameters from July 2019-October 2019

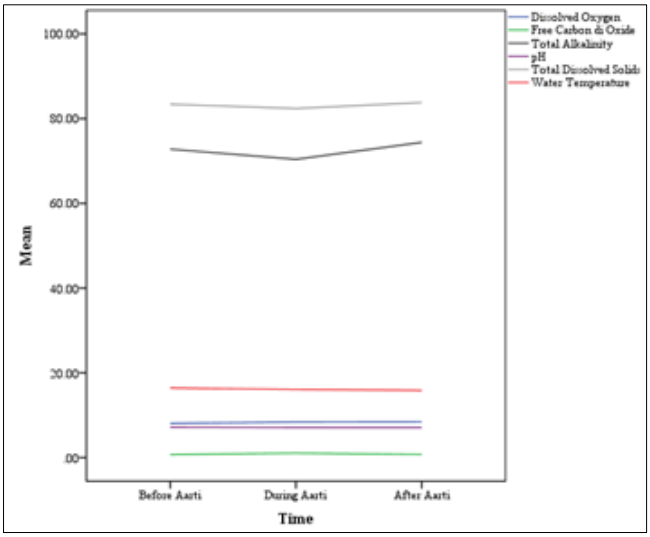

Fig 5: Trends observed in the water quality parameters from November 2019-early March 2020

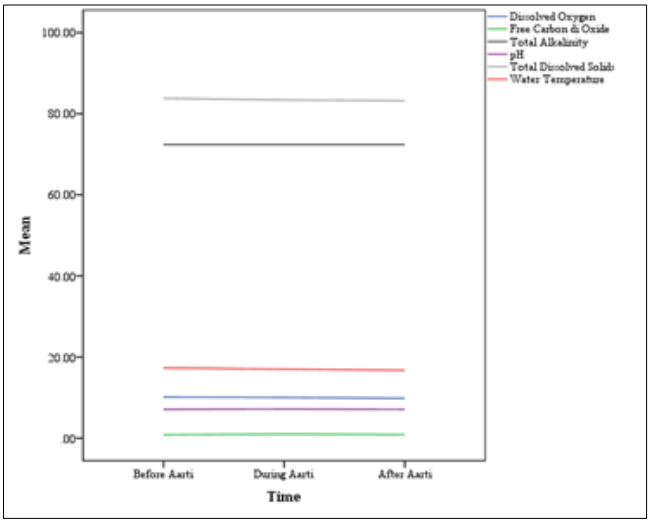

Fig 6: Trends observed in the water quality parameters after the implementation of the lockdown

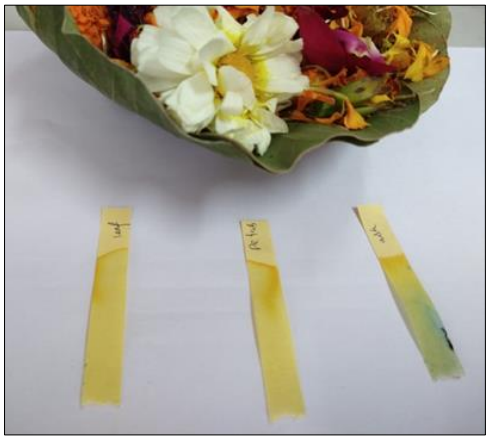

Fig 7: Difference in pH of different constituents of an aarti offering demonstrated with the help of pH strips: The two strips on the left show the pH of the leaf and flowers at a value of 6, and the one on the right shows the pH of the ash at 10

5. Conclusion

The quality of the water of the Ganges at the site of the ritual of Ganga Aarti appears to be affected most by the allochthonous input of nutrients and pH-altering substances in the form of offerings to the river. The nutrients influence the algal and planktonic biomass in the canal, which in turn influences the dynamics of dissolved gases in the water.

The alteration in the Total Alkalinity of the water does not last for long after the crowds disperse, indicating a certain degree of resilience of the river to such changes driven by anthropogenic activity. The results indicate that the river possesses a self-purification ability which is most likely facilitated by the process of dilution as a result of the volume of water it carries and the flow velocity, but the addition of organic inputs to the river might hamper the biological processes involved in the self-purification. Therefore, on the one hand, the river can still tolerate allochthonous inputs and ameliorate its water quality on its own, but if the addition of certain materials such as organic pollutants is not checked, the processes that facilitate the maintenance and amelioration of water quality of the river may be affected negatively.

6. Acknowledgements

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