Idol immersion and its adverse impact on water quality and plankton community in Hooghly (Ganges) River Estuary, India: Implications for conservation management

Dibyendu Rakshit & Santosh Kumar Sarkar *

Department of Marine Science, University of Calcutta, 35, Ballygunge Circular Road, Calcutta 700019, India

*[E-mail: cusarkar@gmail.com]

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Deterioration of water quality due to high turbidity (11.87±1.13 NTU) and biochemical oxygen demand (1.66±0.38 mg l⁻¹) coupled with low chlorophyll (chl a) (0.94±0.15 mgm⁻³) during immersion has been recorded. Decreasing trend of numerical density for loricate ciliate tintinnid (microzooplankton) [post-immersion (224±52 cells l⁻¹) > pre-immersion (144±36 cells l⁻¹) > immersion (85±30 cells l⁻¹)] and phytoplankton [post-immersion (2745±912 cells l⁻¹) > pre-immersion (2337±441 cells l⁻¹) > immersion (1660±334 cells l⁻¹)] was evident.

[Keywords: Idol immersion, water quality, phytoplankton, tintinnid, Hooghly River Estuary]

Introduction

The annual rituals of immersion of idols of Hindu deities during Durga puja which is the biggest annual Hindu festival in south Asia, increases the pollution in the already polluted Ganges River, and also causes the deposition of silt. Moreover, in recent decades, thousands of idols were immersed which relentlessly pollute these water bodies¹,²,³, causing detrimental effects on aquatic biota⁴. Idols are usually made up of wood, bamboo, straw, jute ropes, clay, and plaster of Paris and are painted with bright synthetic colours, which contributing significant pollution in water bodies. Other materials, such as straw, jute ropes, flowers, leaves and germinated grains cause short-term deterioration of water quality on their decay, while heavy metals in the paints pose health hazards in the long-run⁵. The chemical paints used on these idols contain heavy metals as lead, cadmium, copper, iron, manganese, mercury, zinc, chromium, arsenic and various organic and inorganic materials, leading to alteration in water quality. The bioaccumulation of heavy metal transfers toxic element from producer to consumer level and health hazard for consumers⁵,⁶. Spot parts of idols, used plates, rotten flower garlands, plastic bags, coconut shells, papier-mache decoration, crumpled flowers floating down the river water. These materials are resurfaces and floats atop the waves. The toxic chemicals (especially red oxide and red lead) from idol paints during the immersion time contributes high load of nutrients in the water body of the River Ganges. Industrial paints are loaded with metals such as lead, calcium, cadmium and other such chemicals⁷. According to Reddy and Kumar¹, it was evident that thousands of immersed multicolored idols Goddess Durga made up of plaster of Paris and painted with chemical colors worsened the overall quality of the river water. The input of biodegradable and non-biodegradable substances deteriorates the river water quality and enhances silt loaded in the river. The floating materials released through idol in the river and lake after decomposition result in eutrophication of the river, lake⁸. The toxic chemicals used in making the idols tend to cause serious problems of water pollution and also pose a serious threat to the underwater ecological system. When immersed, these colors and chemical dissolve slowly leading to significant alteration in the water quality⁹. The water experiencing a rise in acidity as well as traces of heavy metals depletes the process of metabolism and photosynthesis in the biotas and planktons in the estuary. The present study investigates into the extent of pollution due to immersion of idols in water body and its negative impact on aquatic organisms in different ghats of Hooghly Estuary.

Materials and Methods

Hooghly (Ganges) Estuary (87° 55'01"N to 88° 48'04"N latitude and 21° 29'02"E to 22° 09'00"E longitude), the first deltaic offshoot of the River Ganges,
is a well-mixed estuary due to its shallow depth (mean ~ 6 m) and drains a catchment of $6 \times 10^4$ km$^2$.

The sites have a mean elevation of 13.7–16.7 m, belonging to a lower deltaic plain experiencing intense wave action. The estuary gets semidiurnal tides with maximum range of 5.5 m at spring and minimum 1.8 m at neap\textsuperscript{10}. Because of intense tidal mixing, estuary is vertically homogenized throughout the year except for a short period during southwest monsoon season (June–September) in which the estuary is partially stratified due to high fresh water discharge\textsuperscript{11}. Therefore, the issue of maintaining ecological flows in the river is becoming a serious problem in view of conflicting and competing uses of the water. Moreover, the major cause of environmental problem due to idol immersion activity in Ganges River has been demarcated in Table 1. The study was attempted to establish the impact of religious events in the stretches of Hooghly river estuary. During idol immersion, four sites have been chosen in the upstream stretches in Ganges River where most of the Durga idol immersion takes place (as shown in Fig. 1). In this purpose, Roy ghat (Serampore) [S\textsubscript{1}], Bagbazar ghat [S\textsubscript{2}], Nimtala ghat [S\textsubscript{3}] and Babughat [S\textsubscript{4}] were selected having a distance of 3-5 km in each site. The geographic positions of each site were fixed using GPS (global positioning system).

The surface water samples ($n=24$) were collected during high tide in morning hours from four major Ganges ghats along the Hooghly estuary where immersion of Durga idol takes place mostly. A holistic sampling strategy was designed accordingly to assess the changes in water quality and plankton community in the site of idol immersion at different intervals i.e. pre immersion, during immersion and post immersion. Pre-idol immersion and post-immersion samples were collected ten days before and after the immersion activities and also during idol immersion phases. The samples were subjected to physicochemical analysis adopting standard methodology. The water temperature and salinity were measured on board, using thermometer (mercury, 0-100 °C) and refractometer (Tansui 16E) respectively. Winkler’s titrimetric method\textsuperscript{12} was followed for the estimation of dissolved oxygen (DO) and biochemical oxygen demand (BOD$_5$: difference between DO of 100% saturated water on day 1 and after 5 days incubation). Turbidity, pH and inorganic nutrients (nitrate, phosphate and silicate) were measured by water analyzer 371 (Systronics). To analyze the chlorophyll a concentration (mg m$^{-3}$), 1000ml water was collected and filtered onto glass fiber (Whatman GF/F filter paper). The extract was prepared in 90% acetone and was kept in refrigerator for 24 hours. Later chl-a concentrations were measured spectrophotometrically adopting the procedure of Strickland and Parsons\textsuperscript{12}.

For phytoplankton, the net (20µm) was towed on water surface for about 20 min and collected samples were immediately preserved in 4% buffered formalin and taken to the laboratory for further analyses. An aliquot sample of 1 ml was taken in Sedgwick-Rafter counting cell for quantitative as well as qualitative analyses\textsuperscript{13} with the help of a binocular microscope (Leica, China; Model 13395H2X) at 40X magnification. Identification of phytoplankton was done following standard taxonomic monographs of Desikachary\textsuperscript{14} for diatoms; Subrahmanyan\textsuperscript{15} for dinoflagellates and Fristch\textsuperscript{16} for green and blue-green algae (cyanobacteria).

For tintinnids, 1000 ml of surface water samples were collected by pre-cleaned plastic bottles from each station and immediately preserved with Lugol’s solution (2% final concentration, volume/volume) and stored refrigerated in darkness except during transport
and settling\textsuperscript{17}. In the laboratory the water samples were concentrated to a volume of 25 ml by settling in a measuring cylinder of 1000 ml with 2 special outlets\textsuperscript{18}. From the last 25ml, it was taken drop by drop with a micropipette on a glass slide for quantitative and qualitative analysis by phase contrast microscope at a magnification of 40X (NIKON) Trinocular Microscope (Model E-200). Three aliquots of each sample were counted and the mean value was considered. Tintinnids were identified using lorica morphology described by Kofoid and Campbell\textsuperscript{19,20} and Marshall\textsuperscript{21}.

The community structure in the context of three indices, namely species diversity (H'), evenness (E') and richness (R') of phytoplankton as well as tintinnids were calculated as follows:

\[ H' = - \sum P_i \ln(P_i) \]
\[ E' = H/\ln(S) \]
\[ R' = (s-1)/ \ln(N) \]

Where, \( s \) = total no. of species in the community; \( P_i \) = proportion of \( 's' \) made up of the \( i \)th species and \( N \) = total no. of individuals\textsuperscript{22}.

Data were transformed using the log\textsubscript{10} \((n+1)\) function to allow the less abundant species to exert same influence on the calculation of similarities\textsuperscript{23}. Correlations were calculated by log-transferred data using Pearson’s correlation coefficient\textsuperscript{24} to analyze the relationships among all the variables for each site.

The Index of Dominance of phytoplankton and tintinnids was done by using the formula \( Y_i = (N_i/N) \times f_i \) where \( Y_i \) = Index of dominance; \( N_i \) = No. of individual species; \( N \) = Total no. of all species; \( f_i \) = Frequency of individual species. The analysis of variance (ANOVA) was done by using MINITAB 13 statistical software. To get insight into the spatial coincidences in the distribution of tintinnids in relation to environmental variables involved.

### Results and Discussion

The environmental impact of idol immersion was assessed primarily through the physicochemical analysis of water quality because it is an excellent indicator of human use of the ecosystem. A conspicuous changes and heterogeneity in environmental variables during three phases of the festival was depicted in Table 2. Surface water temperature and salinity showed narrow range of variations from 27°C to 31.5°C and 0.14-0.25 psu respectively throughout the study period. Most importantly, variation in pH concentration of ambient water helps in solubility of nutrients\textsuperscript{25}. During idol immersion, the pH values exhibited small range of variations (7.3 to 8.1) (Table 2). However, the pH was alkaline during pre-immersion phase (8.1) at Bagbazar ghat \([S2]\) and the lowest value (7.3) was recorded during immersion phase at Babughat \([S4]\). The lower pH value was evident at all the 4 stations during this phase. Most interestingly, a huge amount of synthetic organic chemicals were mixed with ambient water during immersion by which the water gets tensed to be acidic in nature. Huge biomass of leaves and flowers, unused materials and different inorganic and organic substances increased the turbidity during the events. An abrupt increase of turbidity value was noticed during idol immersion of idols (19.5 NTU) when huge amount of idol, flowers and other substances were added in the water and makes the water unstable and minimum during post-immersion phase (5.5 NTU). In addition, high turbidity might results from huge erosion\textsuperscript{26} associated with sediment imbalances due to human interference. Dissolved oxygen is an important parameter for influencing the biological processes in any water body and to ascertain the sustainability of aquatic fauna and flora\textsuperscript{25}. Decomposition of organic compounds gradually decreases the DO content within the water
A significant positive linear correlation between pH and DO ($r=0.876$; $p \leq 0.05$) was observed which was also endorsed by Zang et al. 28 in Panjiakou Reservoir, China.

Due to substantial mixing of flowers and leaves during the immersion phase, increase of organic matter could have a direct negative impact on the low DO concentration ($3.77$ to $4.55$ mg l$^{-1}$) comparing to the pre ($4.55$ to $5.12$ mg l$^{-1}$) and post-immersion ($5.3$ to $5.41$ mg l$^{-1}$) phases. This phenomenon was reasonably significant for two consecutive years. There was $2$ to $3$ per cent decrease in the level of dissolved oxygen in compare to pre-and post-immersion. Values of BOD also exhibited similar trend of distribution, higher during-immersion ($1.1-2.86$ mg l$^{-1}$) than pre ($0.69-1.34$ mg l$^{-1}$) and post-immersion ($0.77-1.1$ mg l$^{-1}$) phases. It is revealed that the decomposition of weeds plays a significant role for assimilation of organic load inviting microorganisms, resulting high BOD concentration as referred. High BOD observed during January 2010 was due to utilization of oxygen for the oxidation biodegradation of the organic matter (from idol paints, straws and flowers) 29&30. When the immersion of idol was over, the water gets saturated with oxygen maintaining an overall average concentration of $1.26 \pm 0.21$ mg l$^{-1}$ during the study periods.

Concentration of chl $a$ was ranged from $0.63$ to $2.38$ mg m$^{-3}$ during the idol immersion period with a decreasing trend during pre-immersion to immersion period. Maximum concentration of chl $a$ was recorded at the site Roy ghat [S$_1$] ($2.38$ mgm$^{-3}$) followed by Nimtala ghat (1.63 mgm$^{-3}$), Bagbazar ghat [S$_2$] (1.06 mgm$^{-3}$) and Babughat 0.95 mg m$^{-3}$). It is evident that, highest numbers of idols were immersed in Babughat [S$_3$] and Bagbazar ghat [S$_2$]. Nitrate concentration exhibited wide range of variations with maximum and minimum values of $28.64$ µmol l$^{-1}$ (during immersion at S$_4$) and $14.25$ µmol l$^{-1}$ (during pre-immersion at S$_3$) respectively. The increased nitrate level was due to entry of nitrates through oxidation of ammonia to nitrite$^{31}$. The organic compounds as well as idol paints also favor the input of subsequent nitrogenous compound to the water$^{32}$. The low values recorded pre-immersion phase was mainly due to the utilization by phytoplankton as evidenced by high photosynthetic activity. The observed high concentration of inorganic phosphate at Nimtala (1.2 µmol l$^{-1}$) during-immersion of idols is mainly due to admixing of large amount of oil, soaps and synthetic detergents which contain mineral, phosphorus and nitrogenous compounds acts as binding agents that suspend dirt into water$^{33}$. The site Nimtala [S$_3$] is also used as a burning ghat, thus burial organic and inorganic matter dissolved in the water resulted high concentration of nutrients$^{34}$. The average concentration of inorganic silicate was recorded $89.02 \pm 28.72$µmol l$^{-1}$ with maximum concentration during post-immersion phase ($110.05 \pm 6.27$ µmol l$^{-1}$) mainly due to non-shifting of immersed idol and dissolution of non-degradable substances occurred which might be the main source of this reactive silicate. Higher nutrient loadings can also lead to pollutant dispersal and fecal contamination create short and long term impacts on water quality in estuaries and coastal environment$^{35}$.

**Changes in phytoplankton community structure:**

Adverse impact of idol immersion was evident on the qualitative and quantitative characteristics of phytoplankton (as evident in Table 3) while comparing 3 phases of idol immersion which could well thrive in a widely changing hydrographical condition. In the present study, a total of 12 species of phytoplankters under 7 genera were identified during
Durga idol immersion phase. The numerical density of phytoplankton for three different phases of idol immersion ranged from 1569±225 cells l⁻¹ to 3403±824 cells l⁻¹ (Fig. 2). The community was mainly dominated by the group Bacillariophyceae followed by Cyanophyceae. The changes in species composition of phytoplankton (mainly Coscinodiscus radiatus, C. lineatus, Chaetoceros lorenzianus, Pleurosigma formosum, Biddulphia sinensis, Trichodesmium erythreaeum, T. thebautii, M. granulata and Thalassiothrix longissima) was not very much conspicuous but changes in their numerical abundance were reduced in the following order were reduced in the following order: post-immersion (2745±912 cells l⁻¹) > pre-immersion (2337±441 cells l⁻¹) > immersion (1660±334 cells l⁻¹). The minimum abundance was recorded during immersion period in Babughat [S4] (749 cells l⁻¹) but the count was increase drastically in post-immersion phase in this site (4598 cells l⁻¹). Total numerical abundance of phytoplankton decreased in the year 2012 as compared to 2011. The variation could well thrive in widely changing hydrographical conditions. Due to input of different organic pollutants and chemical paints during immersion time, increase the nutrients load which might enhance the phytoplankton population quiet rapidly. Phytoplanktons were dominated by Trichodesmium erythreaeum, T. thebautii, M. granulata and Thalassiothrix longissima. The water quality characteristics may play a significant role in some species which are not found in some sites and even during idol immersion phase. T. erythreaeum was the most dominant and successful species found during pre-immersion stage in Bagbazar ghat [S4] (439.16±73.82 cells l⁻¹) but its abundance was less in rest of the phases. Both C. radiatus (723.33±59.2 cells l⁻¹) and C. oculus-iridis (465±45.22 cells l⁻¹) are exclusively recorded during immersion at Nintala ghat [S4] and post-immersion in Babughat [S4] respectively. In Nintala ghat [S4], the high concentration of phosphate, turbidity and lowest water transparency were not suitable for phytoplankton growth. In this respect a low phytoplankton density was occurred in this station. Changes in phytoplankton community composition resulted from increased frequency and quantity of inorganic nutrient inputs. For the high nutrient load, maximum and minimum phytoplankton abundance was recorded after and before the immersion respectively.

Although phytoplankton produce energy from carbon and water, they still require both inorganic (phosphorous, nitrogen, silicon, iron, etc.) and organic (vitamins) nutrients for growth. Of the three inorganic compounds (silicon, nitrogen, and phosphorous), nitrogenous compounds have the lowest concentrations in riverine waters and are generally thought to limit phytoplankton growth in this estuarine waters. Phosphate is the most biologically available form of phosphorous for most phytoplankton. Finally, silicon, which is used in the cell structure of diatoms and silicoflagellates, usually has concentrations higher than nitrogen and phosphorous. However, the estuarine water with the prevalent ecological stresses still supports aquatic life to maintain the natural food chain. If plankton, a colossal biological force and a critical link in the food chain, were extirpated, most of the aquatic life including fish would also disappear.

Changes in tintinnid community structure:

The changes in environmental variables directly influence the plankton community structure as evident by decreasing trend of tintinnid population during immersion phase. The community showed a decreasing trend of their population dynamics with the changes in water quality characteristics associated with phytoplankton dynamics. Total 5 agglomerated species of tintinnids under 3 genera have been identified during immersion of Durga idol in HRE. The abundance of tintinnids was maximum during post immersion phase in Bagbazar ghat (333±38 ind l⁻¹) and minimum during immersion phase (51±40 ind l⁻¹) (Fig. 3). The community was comprised of T. beroidea, T. tubulosa, Tintinnidium primitivum. It was found that Tintinnopsis minuta was only species recorded from Roy ghat [S1] during all the three
phases with a maximum abundance of 75±20 ind l$^{-1}$) during immersion phase. Another tintinnid species *Leprotintinnus simplex* is only found in Bagbazar ghat (250±28 ind l$^{-1}$) during post immersion phase. The high turbid condition at the time of immersion results in less concentration of chl $a$ in some station compare to post-immersion phase could be attributed to low population density of phytoplankton and further it might affect the tintinnids abundance.

Most tintinnid species occurred for a limited period of time and the period of occurrence was species specific. The observed dominance of agglutinated species appears to be related to the availability of particles to construct the lorica in addition to the presence of its preferred food$^{44}$. Dolan et al.$^{17}$ postulated that the tintinnid diversity reflected the resource diversity more closely than the competitive interactions or predation. Interestingly, it was evident that the numerical density of tintinnid was high in 2012 in comparing to 2011. The tintinnid abundance was positively correlated with chl $a$ concentration ($r=0.87; p\leq0.05$) and this could be explained by their feeding on phytoplankton (pico- and nano phytoplankton), hence this is evident that the phytoplankton biomass regulated the ciliates abundance in this estuarine system$^{45}$. The excystment of tintinnids on the bottom probably plays an important role in forming tintinnid populations in the water column$^{46}$. Previous studies have indicated that temperature, light and extracellular products of phytoplankton have synergistic effects on the excystment of tintinnids$^{47}$, the exact mechanism of nature is unknown and further study is needed to explore this process in detail. The surface water characteristics could play a crucial role in determining the natural patterns of occurrence in tintinnid assemblages$^{48}$. In addition, the existence of a site-specific tintinnid fingerprint based on recurrent pattern of the most abundant species has been proposed$^{49}$. This, in turn, highlights the importance of possible shifts in tintinnid communities as related to environmental changes due to their numbers and form an important link in the food chain$^{50}$.

**Linkage between biotic and abiotic factors**

As evidenced from the correlation matrix, a significant relationship was found between different species of phytoplanktons and tintinnids with the water quality characteristics during Durga idol immersion. A significant negative correlation was found between dissolved oxygen and *Trichodesmium thebautii* ($r= -0.706; p<0.01$) in contrast, this species exhibited a strong significant correlation with BOD ($r= 0.69; p<0.01$). The other phytoplankton species *M. granulata* exhibited significant positive correlation with the silicate ($r= 0.811; P<0.01$) but negatively correlated with the turbidity ($r= -0.785; p<0.01$). Tintinnids species like *T. beroidea* was positively correlated with the nitrate concentration ($r= 0.765; p\leq0.05$) and negatively correlated with richness ($r= -0.801; p\leq0.05$) indicating that existence of a particular species can lower the diversity as well as the population density in all the sites. A
significant positive correlation between phytoplankton and tintinnid abundance \((r = 0.856; p \leq 0.05)\), reveals their association in fluctuating environmental conditions in two consecutive years.

The diversity index value \((H')\) indicates the degree of complexity of a community structure. For phytoplankton, the minimum (1.18) and maximum (2.11) mean values for species diversity were found during and post-immersion phase respectively (Table 3). For tintinnids, similar trend has been followed where, species diversity \((H')\) was recorded maximum (1.21) during post-immersion in 2012 and minimum (0.48) during-immersion in 2011 (Table 3). Species diversity decreases when a community becomes uneven, dominated by a single or a few species and this has been observed that their functioning is less resistant to environmental stress\(^5\). The Richness indices \((R')\) showed its maximum value during Post-immersion phase in Nimtala ghat (5.69) and species evenness i.e., species equitability \((E')\) was found to be maximum during post-immersion in Babughat (0.75). In case of tintinnids the diversity index and species evenness both were highest during Post-immersion in Bagbazar \([S_2]\) with a value of 1.38 and 0.86 respectively, whereas species richness \((R')\) was found to be highest during Pre-immersion phase in Nimtala ghat \([S_3]\) (2.51).

Increased level of BOD during immersion phase also indicates the pollution through non-biodegradable materials. The excess rate of solid particles in aquatic environment caused various stresses on planktonic community through increasing oxygen demand, low nitrification rate and reduces light penetration\(^5\). The results of the index of dominance \((Y_i)\), (as shown in Fig. 4) revealed almost a similar trend of distribution for phytoplankton (0.0248 to 2.3086) and tintinnid (0.0734 to 2.3745). During pre-immersion, the community was dominated by 9 phytoplankton species while, the highest index of dominance was of *N. sigma* \((Y_i = 0.58)\) and lowest was of *C. sublineatus* \((Y_i = 0.04)\) whereas tintinnid was dominated by *T. tubulosa* \((Y_i = 0.55)\). In contrast, during the immersion only 5 species of the phytoplankton and 2 species of tintinnid was found to be dominated among which *T. primitivum* \((Y_i = 0.39)\) was the new intrusion to the coastal waters. During post-immersion, phytoplankton (8 species) and tintinnid (5 species) regain their numerical abundance with maximum dominance by *M. granulata* \((Y_i = 0.91)\) and *T. beroidea* \((Y_i = 0.93)\) respectively.

Result of Analysis of Variance (ANOVA) was highly significant between phytoplankton species and its numerical abundance \((F\text{ value}=6.03; P\text{ value}=0.00)\) during Durga idol immersion but different stations and phases were found to be insignificant relationship. Due to difference in water quality during different phases as well as in different stations, the abundance and diversity of phytoplankton were varied remarkably. The results of Box-and-whisker plots provided statistical evidence of environmental variables which were not homogeneously distributed in all the immersion phases as shown in Fig. 5. The value of turbidity, BOD and nitrate showed the following increasing sequential order: immersion > post-immersion > pre-immersion phase, in contrast, chl \(a\), DO, phosphate and silicate showed the following decreasing order: immersion > post-immersion > pre-immersion.

The detailed case study first highlights the conspicuous changes in water quality characteristics and plankton community structure due to idol immersion activities along the Hooghly estuary. This has wide implications and could be applicable to other such festival activities and also for adopting sound management strategies. Recently Khezri et al.\(^5\) and Rakshit et al.\(^5\) recorded similar kind of negative impact on environment during traditional Hungry ghost festival in Singapore and annual Gangasagar festival in Sagar Island respectively. According to the guidelines prepared by Central Pollution Control Board (CPCB), flowers, cloth and other decorative items should be removed before immersion. Bioaccumulation of heavy metal in biological system transfers the toxic element from producer to consumer level, which would post several health hazards.
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