

Research

Lamellidens marginalis: A super bio-filter of freshwater ecosystems

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Abstract

Freshwater mussels are important bio-filters in aquatic ecosystems, capable of improving the water quality by removing suspended particles through their filter-feeding activity. However, no detailed studies are available on the filtration of polluted water by freshwater mussels under controlled laboratory conditions, hence, this study was conducted. The filtration efficiency of the mussel *Lamellidens marginalis* was evaluated in polluted Subarnarekha River water and aged tap water under controlled laboratory settings. Two sets of aerated aquaria, each containing 20 liters of either polluted river water or aged tap water, were used-one set with mussels and a control set without mussels. Physiochemical parameters including pH, temperature, electrical conductivity, total dissolved solids and turbidity were monitored at 24-hour intervals over a four-day period to assess the impact of mussel filtration on water quality. The turbidity decreased from 191.33 ± 6.9 NTU to 2.4 ± 0.55 NTU in the polluted river water with mussels, and from 1.43 ± 0.11 NTU to 0.76 ± 0.05 NTU in the aged tap water. Similar declines were observed in other parameters. In contrast, no significant changes were observed in the control aquaria without mussels. These findings highlight the exceptional bio-filtration capacity of mussels. Therefore, conserving these species and utilizing them as models for bio-filtration systems is recommended.

Received: 29 December 2025

Accepted: 24 March 2026

Published: 31 March 2026

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Introduction

The human population, expected to surpass 10 billion by 2100 (Ritchie et al., 2023), presents considerable challenges to global resource management and environmental stability. This necessitates the adoption of sustainable ecosystem management strategies to restore degraded ecosystems and maintain ecosystem services. Biomonitoring, bioremediation, bio-conservation, and biotechnological interventions are crucial components of eco-restoration efforts aimed at achieving ecosystem sustainability (Talukdar et al., 2019). Every ecosystem has a self-revival capacity, but this is limited, and when anthropogenic interference exceeds this capacity, ecosystems can no longer provide viable ecosystem services to humans. Freshwater mussels are key contributors to the self-revival of both lentic and lotic aquatic ecosystems, serving as "the Kidney of our rivers" by filtering large volumes of water and removing algae, sediment, nutrients, harmful bacteria, and metals (Jesus et al., 2026; Zieritz et al., 2022).

Lamellidens marginalis (Lamarck), a freshwater bivalve mollusk, is a popular keystone species and an important component of aquatic ecosystems, providing valuable ecosystem services (Bakshi, 2023). Freshwater mussels inhabit various aquatic habitats worldwide, including ponds, streams, lakes, and rivers (Bolotov et al., 2017). These mussels are renowned for their effective bio-filtration efficiency,

Keywords

Aquaculture;
Bivalves;
Ecosystem engineer;
Freshwater mussels;
Water pollution

Citation

Shukla, R. K., Verma, A. K., Prasad, S. S., Singh, N. S., Chandra, S., Shrivastava, R. R., Minj, A., Soreng, P. K., & Rao, N. V. A. (2026). *Lamellidens marginalis*: A super bio-filter of freshwater ecosystems. *T Appl Biol Chem J*, 7(1), e71002. DOI: [10.52679/tabcj.2026.71002](https://doi.org/10.52679/tabcj.2026.71002)

which helps maintain the cleanliness of water systems (Dhuri & Gore, [2024](#)). Their natural ability can be leveraged for bio-purification of wastewater from industrial effluents, municipal sewage, petroleum refineries, micro-plastics waste, pharmaceutical, and biomedical waste. This activity is useful for enabling sustainable use of treated water, particularly in regions facing significant water pollution, thus makes them attractive tools for environmental management (Choi et al., [2018](#)). For instance, freshwater mussels can significantly improve water clarity by removing suspended particles and nutrients, thus reducing water treatment costs and enhancing aquatic ecosystem health (Vaughn et al., [2008](#); Newton et al., [2011](#); Atkinson et al., [2023](#)).

Freshwater mollusks, including mussels, provide a variety of ecosystem services through their feeding habits, such as filter feeding and grazing, which influence nutrient cycling, water purification, and food webs (Zieritz et al., [2022](#); Atkinson et al., [2023](#)). They also serve as excellent bio-indicator species of aquatic habitats, reflecting changes in water quality and ecosystem health (Vaughn et al., [2004](#); Waykar & Deshmukh, [2012](#); Ray et al., [2013](#); Mundhe et al., [2015](#)). Moreover, mussels contribute to provisioning services by acting as a food source for humans and other organisms, and they have cultural significance in jewellery and art (Freshwater Mollusk Conservation Society, [2016](#); Vaughn, [2018](#)).

Beyond their ecological significance, freshwater mussels have economic value, particularly in aquaculture and pearl culture. However, their over-exploitation for these purposes poses a significant threat to their populations and ecosystem roles (Hastie & Young, [2003](#)). The freshwater mussels are well known as multifaceted ecosystem engineers playing the role of bioindicators of environmental health (Verma et al., [2025a](#)). Therefore, it is essential to focus on sustainable practices such as captive or induced breeding to harness their economic value without depleting their natural populations in aquatic habitats (McIvor, [2004](#); Aldridge et al., [2023](#)).

The main objective of this study was to comprehensively evaluate the bio-filtering capacity of freshwater mussels by setting up controlled laboratory experiments using contaminated river water samples. Specifically, the research aimed to determine how effectively *L. marginalis* can remove suspended particles and improve water quality under experimental conditions. In addition, the study sought to analyze the relationship between the morphometric traits of the mussels-such as their shell length, width, and overall biomass-and their filtration efficiency. By establishing these links, the study not only highlights the crucial ecological role of *L. marginalis* in maintaining healthy aquatic environments but also raises awareness about the species' vulnerability to illegal over-capture driven by economic interests. This is particularly important as overexploitation can threaten local populations and undermine the natural water purification services these mussels provide, emphasizing the urgent need for their conservation and sustainable management.

Material & Methods

Collection of Water Sample from Subarnarekha River

The polluted river water was collected from designated sampling sites along the Subarnarekha River using a 25-liter plastic gallon on 28th May 2023. The gallon

was submerged to the brim and securely sealed with its lid while still underwater to prevent contamination from surface exposure. The sampling locations were identified and selected based on satellite imagery, the exact sampling coordinates for site 1 are 85.42677421194882 E; 23.3811083795729 N and for site 2 is 85.44644853464719 E; 23.428115983743208 N, as shown in Figure 1. Immediately after collection, the water samples were transported to the laboratory for experimental setup and further analysis. The pollution source of the water body was the municipal, domestic and industrial wastes from the city area.

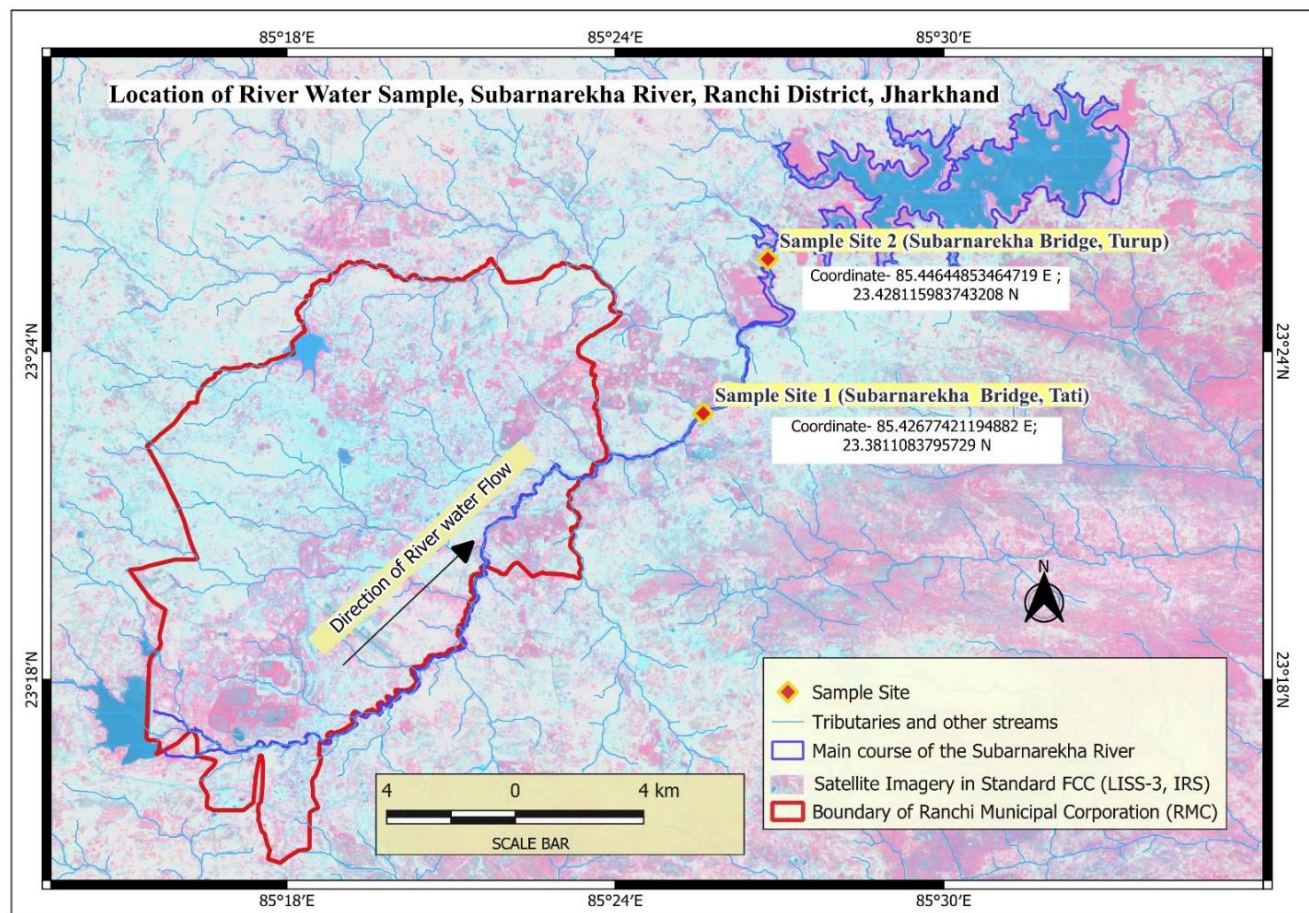


Figure 1. Satellite imagery of river course and sample collection site from the Subarnarekha River in Ranchi District of Jharkhand.

Animal Collection and Maintenance

Thirty live *L. marginalis* mussels, with an average body weight of 39.23 ± 2.47 g, were obtained from a local vendor who collected them from their natural habitat. The mussels were acclimated to laboratory conditions over a period of two weeks. During this time, they were housed in an aquarium measuring 89.7 cm in length, 44.5 cm in width, and 45 cm in height, containing 120 liters of aged tap water, with the exposure to 12-hour daylight and 12-hour darkness. The aquarium was equipped with a 24-hour aeration pump. The mussels were fed ad libitum with plankton feed from the pond water. 2.5 liters of pond water was added to 120 liters of aquarium water on every third day (Verma et al., 2025b). No mortality was observed during the acclimatization period. The physical and chemical parameters

of the water were monitored and maintained according to the guidelines set by APHA (2005) and following the protocols outlined by Trivedy and Goel (1984).

Morphometric Data

All mussels underwent morphometric measurements to assess their size, shape and weight characteristics (Figure 2). Prior to measurement, each mussel was cleaned to remove surface debris and excess moisture was absorbed using blotting paper. The total body weight of each mussel was recorded using an electronic balance with an accuracy of ± 0.30 g. The total body shell length (measured in the antero-posterior direction) and body shell width were determined using a Vernier caliper. Shell length was defined as the distance from the anterior to the posterior end of the mussel shell, while shell width was measured as the maximum width of the shell. These morphometric data provided insights into the variations and shape characteristics of *L. marginalis*. The mean body length and width were found to be 7.79 ± 0.14 cm and 3.09 ± 0.16 cm, respectively, while the mean hinge length was recorded as 5.31 ± 0.08 cm. The average body weight of the mussels was 39.23 ± 2.47 g.

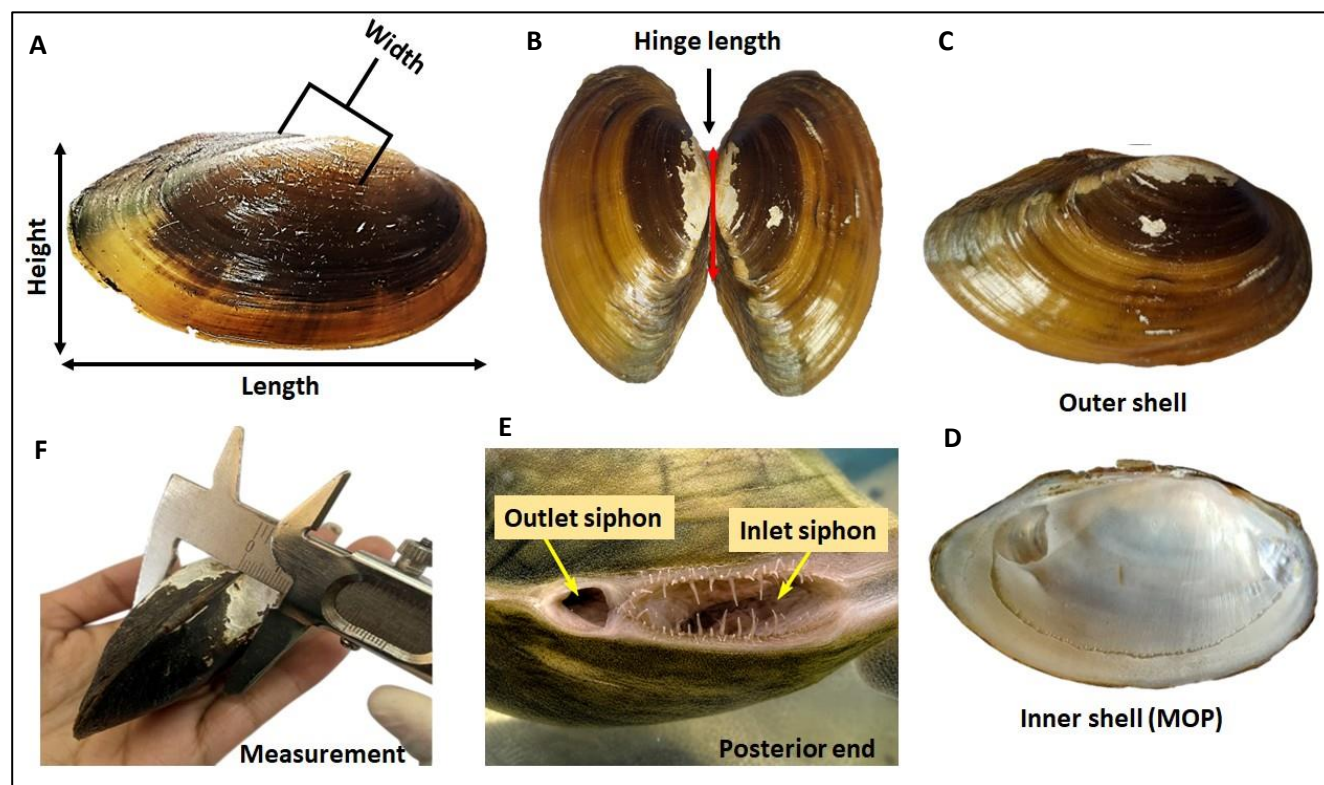


Figure 2. Morphometric characteristics and anatomical features of the freshwater mussel *Lamellidens marginalis* showing (A) shell length, height, and width, (B) hinge length, (C) outer shell morphology, (D) inner shell morphology, (E) posterior end with inlet and outlet siphons and (F) measurement of shell dimensions using a Vernier caliper.

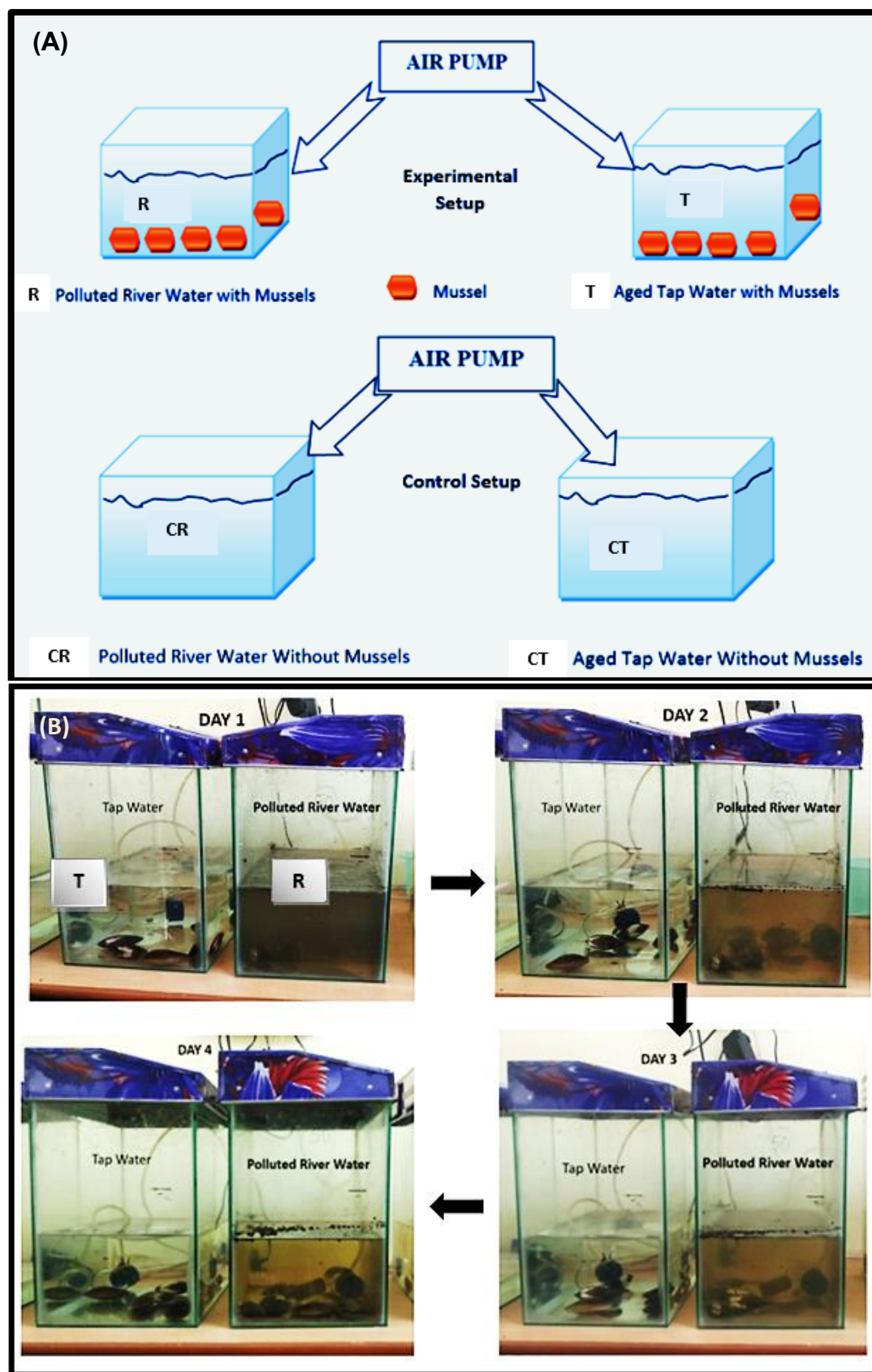


Figure 3. (A) Schematic representation of the experimental design showing Set 1 (experimental setup) and Set 2 (control setup) used for exposure studies in *Lamellidens marginalis*. Set 1 consisted of polluted river water with

mussels (R) and aged tap water with mussels (T), whereas Set 2 included controls containing only polluted river water (CR) and only tap water (CT). Continuous aeration was maintained in all setups using air pumps. (B) Progressive changes in appearance of tap and polluted river water from day 1 to day 4, when kept along with mussels.

Setting the Aquarium Conditions

All the glass aquaria were thoroughly cleaned and washed with KMnO_4 (0.1% w/v), rinsed profusely with aged tap water, and subjected to air dry. The acclimatized mussels were kept in a clear water system and starved for one day before commencement of the experiment.

Set 1 Experiment

Two aquaria (75x45x60 cm each) were taken and labeled 'R' and 'T' respectively containing 20 liters of polluted water from Subarnarekha River and aged tap water (Figure 3). The physio-chemical parameters of both the aquaria water were measured, before adding the mussels and the date and time was also recorded. Thereafter into each aquarium 5 mussels of known morphometric data were placed standardized in every experiment at 200 g total weight of mussels per 20 liters (where $39.23 \pm 2.47\text{g} \times 5$). The parameters of the aquaria water were consecutively measured at 24-hour intervals for four days. The triplicate readings of pH, temperature, TDS, EC and turbidity were recorded from each aquarium by drawing water samples from surface, column and bottom layer of aquarium water.

Set 2 Control Experiment

Two aquaria labeled 'CR' and 'CT' were taken respectively with equal volume (20 liters) of polluted river water and aged tap water (Figure 3). No mussels were added in the aquaria and both were kept under complete aeration. The physio-chemical parameters namely pH, temperature, TDS, EC and turbidity of each aquarium water were recorded with date and time. The filter efficiency (FE) was calculated in % using the formula $\text{FE} = \frac{\text{initial turbidity} - \text{final turbidity}}{\text{initial turbidity}} \times 100$. The triplicate readings of the different parameters were generated after every 24 hours for 4 consecutive days.

Results & Discussion

In Set 1, two aquaria labeled 'R' and 'T' were taken each containing 20 liters of polluted river water and aged tap water respectively and in both of them equal number of mussels were kept (Figure 3). The aquarium 'R1' initially contained polluted river water with a turbidity value of 191.33 ± 6.9 NTU. Following the introduction of mussels, the turbidity significantly decreased to 3.93 ± 1 NTU within 24 hours. This reduction continued over the next few days, reaching 2.4 ± 0.55 NTU by day 4. Concurrently, the mean electrical conductivity (EC) decreased from 1229 ± 49.5 $\mu\text{S}/\text{cm}$ on day 1 to 1124 ± 49.2 $\mu\text{S}/\text{cm}$ on day 2, and further to 1060.66 ± 49.6 $\mu\text{S}/\text{cm}$ by day 4. Similarly, the total dissolved solids (TDS) concentration declined from 608.66 ± 22.12 ppm on day 1 to 516.66 ± 30.51 ppm on day 4. Other parameters, such as pH, showed a slight increase, while temperature remained relatively stable throughout the experiment. These results demonstrated a notable improvement in the water quality of the contaminated river water, with marked reductions in EC, TDS, and salt concentration from day 2 onwards. The clearance

rate of mussels in the present experiment was 26.34 ml of polluted water per mussel per hour. Such a low rate may be due to clogging of siphons and gills in high turbid water.

In the aquarium labeled 'T1', which contained aged tap water, the initial turbidity value was 1.43 ± 0.11 NTU. After introducing the mussels, a gradual reduction in turbidity was observed, with values decreasing to 1.26 ± 0.05 NTU, then to 1.03 ± 0.11 NTU, and finally to 0.76 ± 0.05 NTU by the fourth day. The EC, TDS, salt concentration, and oxidation-reduction potential (ORP) also showed significant reductions starting from day 2, with gradual decreases continuing up to day 4.

In control set 2, the control 'CR' (containing 20 liters of polluted river water and without mussels) the initial reading of mean turbidity value of the polluted river water on day 1 was 190.66 ± 10.6 NTU, in day 2 the reading was 191 ± 9 , in Day 3 it was 190.33 ± 10.5 and on the fourth day the reading was 189 ± 10 . The results show no significant reduction in the turbidity value at all. Similarly, the electrical conductivity (EC), total dissolved solids (TDS), salt concentration did not show significant reduction from day 1 to the day 4.

In control 'CT' (containing 20 liters of aged tap water without mussels, (Fig. 3) the initial reading of mean turbidity value of the aged tap was 1.13 ± 0.05 NTU on day one and in day four the value measured was 1.1 ± 0 NTU. Electrical conductivity (EC), total dissolved solids (TDS) and salt concentration did not show any marked reduction in the following days.

The data obtained in the current experiment clearly show the bio-filtering potential of *L. marginalis* mussels, when kept in aquaria containing polluted Subarnarekha River water, collected from respective locations along the river course. These data were statistically analyzed to ascertain the filtering role of freshwater mussels.

Statistical Analysis

Data are presented in mean $\pm$ SEM. The sample size was calculated using resource equation for calculation of sample size on animal experiment in laboratory. $E=N-T$, where N is the number of animals used and T is the number of treatment groups. Our calculation on E value was found to be 16 (N=20 and T=4, 5 number of animals in each 4 groups) which is within the range of 10-20 of the equation. Shapiro-Wilk's test indicated that data were normal in distribution. Taking treatments and days as factors, the data were analyzed by Two-way ANOVA followed by Bonferroni post hoc test if the ANOVA indicated significant. The Effect size (η^2) was also calculated. The relationship between the water parameters and days was determined using regression analysis. All the data were analyzed taking 95% confidence interval. All the data were calculated using GraphPad Prism version 8. The measurements were taken in triplicate for all the time points during the study and the experiment was repeated three times (n=3).

All the morphometric data provide information on the variations and shape characteristics of *L. marginalis*. The mean body length and width ranged from 7.79 ± 1.4 cm to 3.09 ± 0.16 cm, respectively, while the mean hinge length was 5.31 ± 0.08 cm. The average body weight of the mussels was recorded as 39.23 ± 2.47 g.

The study on the quality of water turbidity along the four treated groups' viz., R, T, CR and CT showed significant decreases in the water turbidity (Two-way ANOVA; Table 1; Figure 4A-D). Among these groups, the most substantial decrease in

turbidity was observed in group R ($P < 0.001$) compared to the other groups (T, CR, and CT). A notable reduction in turbidity was recorded in the polluted water containing mussels ($P < 0.001$) on days 2, 3, and 4 compared to day 1 (Figure 4A). In contrast, a significant reduction in turbidity was observed only on day 4 ($P < 0.01$) in the T group, which consisted of tap water with mussels (Figure 4B). While there was no significant change in the turbidity level in the groups of CR (only polluted water without mussels, Figure 4C) and CT (only tap water without mussels, Figure 4D). The analysis on the effect size also indicated a strong effect in days, while it was moderate in interaction and little effect in the treatments (Table 1). The two-way ANOVA analysis (Table 1; Figure 4E-H) showed significant differences in water pH among the treatments. The pH levels steadily increased in groups R and T (Figure 4E and F). A significant increase in water pH ($P < 0.001$) was observed on days 2, 3, and 4 in the polluted water with mussels' group (Figure 4E). In group T, a significant increase was found only on day 3 ($P < 0.05$) and 4 ($P < 0.001$) compared to day 1 (Figure 4F). No significant changes in water pH were observed in groups CR (Figure 4G) and CT (Figure 4H) over the four days of observation. The effect size analysis indicated a strong effect of time (days), a moderate effect on treatment and interaction satisfying the statistical analysis (Table 1).

Table 1. Two-way ANOVA and effect size analysis of water parameters among various treatment groups.

Sl. No.	Parameters	Two-way ANOVA		P value	Effect size (η^2)
1	Turbidity (NTU)	Treatments:	F (3, 8) = 132.1	<0.0001	0.0582
		Days:	F (3, 8) = 3421	<0.0001	0.7829
		Interaction:	F (9, 24) = 236.3	<0.0001	0.1622
2	Water pH	Treatments:	F (3, 8) = 162.2	<0.0001	0.3083
		Days:	F (3, 8) = 110.0	<0.0001	0.5203
		Interaction:	F (9, 24) = 20.38	<0.0001	0.1714
3	Water Temperature ($^{\circ}\text{C}$)	Treatments:	F (3, 8) = 0.5533	=0.6602	0.0614
		Days:	F (3, 8) = 18.88	=0.0011	0.8411
		Interaction:	F (9, 24) = 0.7293	=0.6783	0.0975
4	Electrical Conductivity (S/m)	Treatments	F (3, 8) = 2.088	=0.1801	0.0237
		Days	F (3, 8) = 106.1	<0.0001	0.9136
		Interaction	F (9, 24) = 2.423	=0.0404	0.0626
5	Total Dissolved Solids (ppm)	Treatments	F (3, 8) = 5.389	=0.0344	0.0734
		Days	F (3, 8) = 89.84	<0.0001	0.8359
		Interaction	F (9, 24) = 4.326	=0.0019	0.1207
6	Filter Efficiency (%)	Treatments	F (3, 8) = 610	<0.0001	0.2247
		Days	F (3, 8) = 3135	<0.0001	0.1293
		Interaction	F (9, 24) = 363.6	<0.0001	0.6459

Water temperature showed a significant change over time ($P = 0.0011$) but was not significantly affected by treatment ($P = 0.6602$) or interaction ($P = 0.6783$) (Two-way ANOVA; Table 1; Figure 4I-L). The water temperature gradually increased, becoming significant only on day 3 ($P < 0.05$) of treatment in group R (Figure 4I). Although there was an increase in water temperature in group T, it was found to be insignificant (Figure 4J). No significant changes were observed in groups CR (Figure 4K) and CT (Figure 4L) over the 4-day period. The effect size analysis showed a strong effect of time (days) but little effect of treatment and interaction (Table 1).

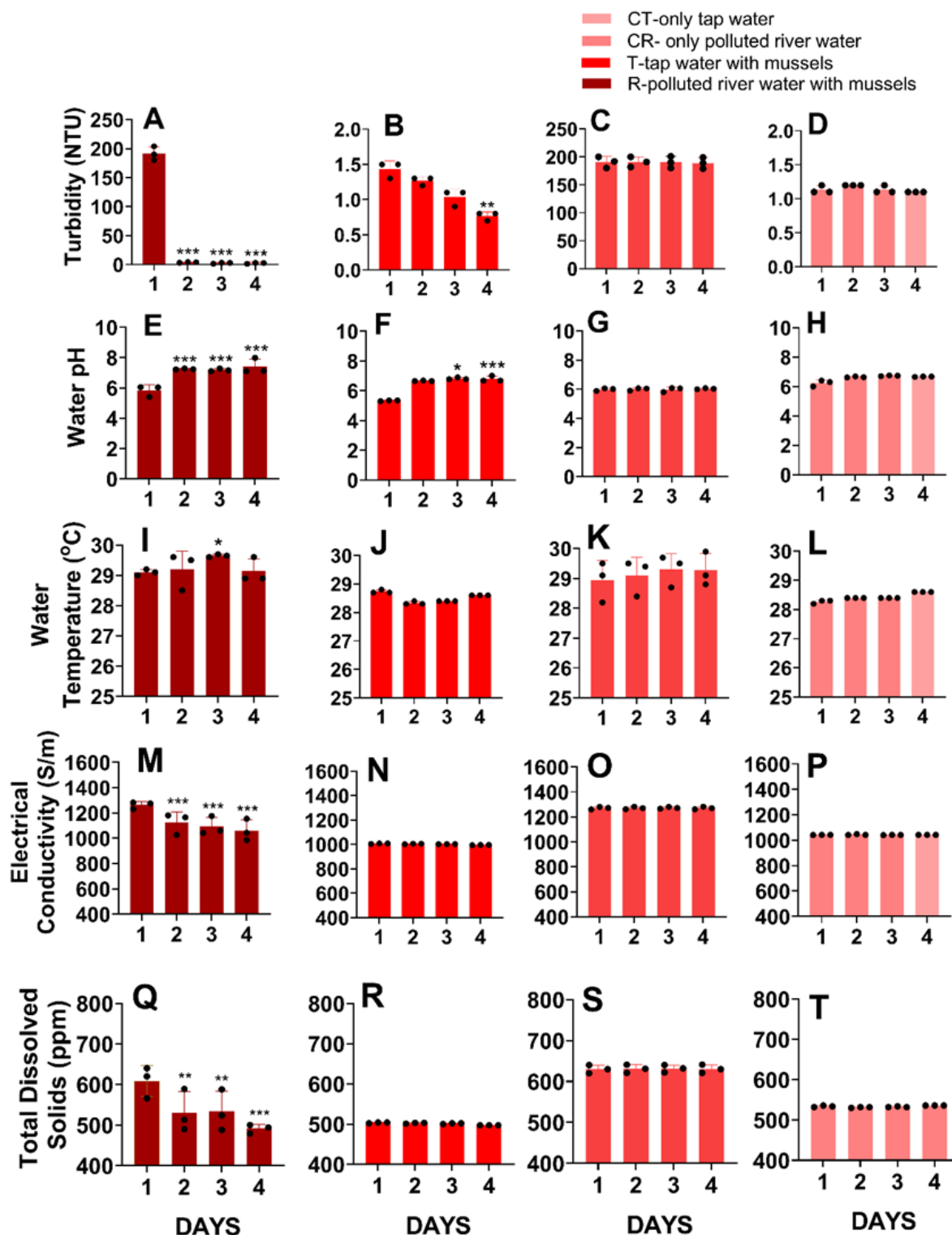


Figure 4. Showing changes in water turbidity (NTU), water pH, water temperature (OC), electrical conductivity (S/m) and total dissolved solids (ppm) in the treatments groups of R-polluted river water with mussels, T-tap water with mussels, CR- only polluted river water and CT-only tap water maintained for 4 days. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$; $n = 3$.

Significant decrease in electrical conductivity was observed over the time ($P < 0.0001$) along with the interaction ($P = 0.0404$) but not among the treatments ($P = 0.1801$) (Two-way ANOVA; Table 1; Figure 4M-P). The conductivity substantially decreases on day 2, 3 and 4 of the treatment in group R ($P < 0.001$) as compared to day 1 (Figure 4M). However, no observable changes in conductivity was observed in all the remaining treatments groups of T, CR and CT (Figure 4N, O and P). The effect size also indicated a strong effect in days, while it shows little effect in the treatments and interaction (Table 1).

Total dissolved solids (TDS) showed significant changes over the 4-day treatment period (Two-way ANOVA: treatments ($P = 0.0344$), days ($P < 0.0001$) and interaction ($P = 0.0019$); Table 1; Figure 4Q-T). A significant decrease in TDS was observed in group R ($P = 0.0344$) compared to the other treatment groups (T, CR, and CT; Figure 4Q). The TDS levels decreased significantly on day 2 ($P < 0.01$), 3 ($P < 0.001$), and 4 ($P < 0.001$) compared to day 1 (Figure 4Q). Additionally, a significant decrease in TDS ($P < 0.001$) was observed in group T compared to groups CR (polluted water without mussels, Figure 4S) and CT (tap water without mussels, Figure 4T). Effect size analysis indicated a strong effect of time (days), while the effect of treatment and interaction was minimal (Table 1). The study on filter efficiency (%) by Two-way ANOVA showed significant ($P < 0.0001$) in treatments, days and interactions (Figure 5A). The filter efficiency increases significantly ($P < 0.001$) in 2, 3 and 4 days in R groups. A gradual increase in filter efficiency was also observed in T group with in day 2 ($P < 0.05$), 3 and 4 ($P < 0.001$). However, no significant changes was observed in the group of CR and CT group. Further, the η^2 values of treatments, days and interaction were found to be of large effect size.

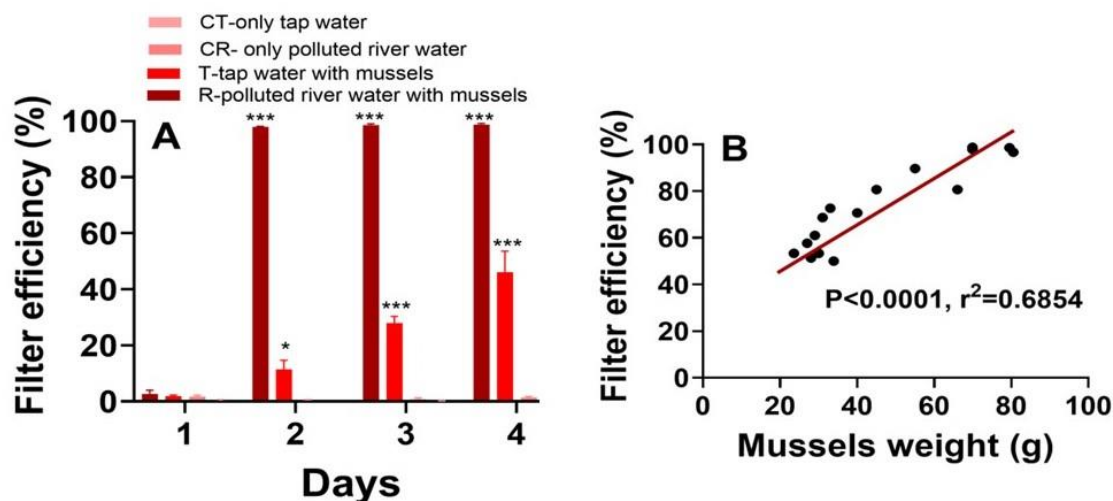


Figure 5. Showing changes in (A) filter efficiency that are kept for 4 days under various treatments of R-polluted river water with mussels, T-tap water with mussels, CR- only polluted river water and CT-only tap water, (B) regression analysis showing positive correlation with the mussel's weight; *** $P < 0.01$, * $P < 0.05$; $n = 3$.

Regression analysis of the correlation between water parameters and treatments is shown in Table 2. The relationship between treatment duration and turbidity showed a negative correlation, indicating that water turbidity decreased as exposure days increased. This decrease in turbidity over days was observed in group R ($r^2 = 0.6043$) and group T ($r^2 = 0.9096$), while no significant changes were observed in group CR ($r^2 = 0.0060$) and group CT ($r^2 = 0.1429$; Table 2). The increase in pH and water temperature showed a positive correlation with treatment duration, indicating that both pH and temperature increased over the 4 days' treatment period in group R (pH $r^2 = 0.5967$; temperature $r^2 = 0.1554$) and group T (pH $r^2 = 0.6065$; temperature $r^2 = 0.0526$) (Table 2). However, a significant correlation was found only for pH, while

water temperature changes over time were minimal (Table 2). A significant negative correlation was observed for electrical conductivity and total dissolved solids, which decreased with increasing treatment duration in groups R (EC $r^2 = 0.4207$; TDS $r^2 = 0.7946$) and T (EC $r^2 = 0.2201$; TDS $r^2 = 0.7692$). However, no correlation was found in groups CR and CT (Table 2). Further analysis on the filter efficiency of the mussels showed a positive correlation with the mussels' weight indicating that an increase in mussel weight increased the filter efficiencies in the present study ($P < 0.0001$; $r^2 = 0.6854$; Figure 5B).

Table 2. Regression analysis of the correlation between water parameters and treatment groups that are kept for 4 days.

Sl. No.		Days	P value	Regression (r^2)
1	Turbidity (NTU)	R-polluted river water with mussels	=0.0029	0.6043
		T-tap water with mussels	<0.0001	0.9096
		CR- only polluted river water	=0.809	0.006
		CT-only tap water	=0.2258	0.1429
2	Water pH	R-polluted river water with mussels	=0.0032	0.5967
		T-tap water with mussels	=0.0028	0.6065
		CR- only polluted river water	=0.6173	0.0259
		CT-only tap water	=0.0027	0.6095
3	Water Temperature ($^{\circ}\text{C}$)	R-polluted river water with mussels	=0.2048	0.1554
		T-tap water with mussels	=0.4732	0.0526
		CR- only polluted river water	=0.4063	0.0699
		CT-only tap water	<0.0001	0.8491
4	Electrical Conductivity (S/m)	R-polluted river water with mussels	=0.0225	0.4207
		T-tap water with mussels	<0.0001	0.7946
		CR- only polluted river water	=0.9310	0.0007
		CT-only tap water	=0.7606	0.0097
5	Total Dissolved Solids (ppm)	R-polluted river water with mussels	=0.0081	0.2201
		T-tap water with mussels	=0.0002	0.7692
		CR- only polluted river water	=0.9198	0.0010
		CT-only tap water	=0.1907	0.1646

The mussel's bio-filtering capacity depends upon filter feeding habit for the procurement of their nourishment. Due to this activity various physio-chemical parameters of the water body undergo remarkable changes. The water quality rather improves, which is beneficial for the other aquatic organisms and can be assessed by several approaches, biochemical methods and digital sensors. Turbidity is one of the physical parameters used for assessing water quality (Davies-Colley & Smith, 2007). It is the cloudiness or the clarity of water due to the presence of clay, silt, organic material, plankton, and other suspended particulates. The present experimental data reveals that there is significant and notable reduction in the turbidity value of all the water samples after adding the mussels. While there was no significant change recorded in the control groups in the tap water without mussels. Similar results were reported by Kirsch and Dzialowski (2012) who experimentally

studied the effects of Zebra mussels on phytoplankton and turbidity value in the reservoir water. When this occurs in the natural water body, it improves the penetration of sunlight to a greater depth, thereby improving the photosynthetic activity of phytoplankton resulting in the increase in the DO levels. Smith et al. (2012), have conducted laboratory experiment to evaluate the filtering activity of mussels by the use of Secchi's disc to measure the transparency of yeast water containing mussels. Nath et al. (2023), have also reported the turbidity clearance rate of *L. marginalis* similar to this current experiment.

The filtration/ clearance rate of *L. marginalis* in the present experiment is 4.38 liters per mussels per day as per the calculation using Coughlan formula for determination of the filtration rate, using the turbidity data. (Zhang et al., 2024).

$$\text{Filtration rate, } F = \frac{V}{n.t} \ln \frac{C_o}{C_t}$$

where, F = filtration rate, V = total volume of water (20 liters), n = number of mussels (n = 5), t = time period in days (4 days), C_o = initial turbidity of the polluted water (191 NTU), C_t = final turbidity of the polluted water (2.4 NTU)

Other water quality indicators include pH, TDS, and EC (Omer, 2020). The pH of the water samples also showed reducing trends due to the activity of mussels. Although there was a slight decrease. TDS is the measure of combined content of all inorganic as well as organic substances dissolved in water. The TDS of all the water samples showed reduction in the value after being treated by the mussels. The electrical conductivity (EC) of water is a measure of the ability of a solution to carry or conduct an electrical current and indirect indicator of pollution, since it is directly related to the presence of dissolved salts of the water (de Sousa et al., 2014). In the present experiment mussels have been able to reduce the EC value of water through their filtering activity. They filter ions present in the water and even absorb calcium and carbonate ions to build their shells thereby the EC is reduced (Machado & Lopes-Lima, 2010). Our findings were similar to the experimental work carried out by Saha et al. (2023), which demonstrated that the mussel treated water showed improvement in various water quality parameters.

Our results on the filter efficiency showed that mussels are good candidates for serving as a super bio-filter and this unique bioactivity of mussels can be used as simple and low-cost efficient technique for easy removal of contaminants from the polluted water, without the use of any chemical treatment method. Mamun and Khan (2011) have advocated in their review article about the conservation of freshwater mussels *Margaritifera margaritifera* due to their bio-filter activity and their importance in controlling water pollution. Nuraisyah and Riyanto (2025) have experimentally demonstrated the effectiveness of freshwater mussel (*Pilsbryconcha exilis*) as a bio-filter in improving the water quality parameters. The bio-filtering activity is accounted by the pumping action of the inhalant and exhalant siphons present in the posterior end of the mussels (Figure 2), (Foster-Smith, 1976). The authors also want to emphasize the captive breeding of these mussels to ensure ex-situ conservation of these vital species and then later releasing them in the natural habitats as suggested by Thomas et al., (2010) and Geist et al., (2023).

Conclusion

In conclusion, the experimental findings underscore the exceptional bio-filtering capacity of freshwater mussels, highlighting their role as ecological engineers. The significant reduction in turbidity within the first 24 hours, followed by a gradual decrease, demonstrates their ability to effectively improve water quality. Similarly, the decreases in electrical conductivity (EC), total dissolved solids (TDS), and salt concentration further emphasize their ecological importance. These results illustrate how freshwater mussels play a crucial role in self-cleansing their natural habitats, making them vital components of aquatic ecosystems.

However, the conservation of these mussels is currently threatened by several factors. The overwhelming presence of contaminants in water bodies often exceeds the mussels' bio-filtering capacity, leading to their mortality. Additionally, the excessive and illegal harvesting of riverine mussels for pearl production poses a significant threat to their populations. To address these challenges, it is imperative to implement conservation strategies such as culturing, induced breeding, and captive breeding programs. By utilizing freshwater mussels as models for bio-filtration, we can develop innovative solutions for treating contaminated water, which can then be repurposed for various uses. This approach not only supports the conservation of these ecologically vital species but also contributes to sustainable water management practices.

Declarations

Acknowledgments: The authors thank the Society for Earth Observation and Conservation (SEOC), a multidisciplinary research center under Research & Development Cell of St. Xavier's College, Ranchi for providing the laboratory infrastructure to carry out the study. The authors also express their sincere gratitude to the Anusandhan National Research Foundation (ANRF), Government of India, under "JNU-PAIR network on Science for Sustainable Future" project (FILE NO. ANRF/PAIR/2025/000029/PAIR) for using the resources for the present work. The AI system (ChatGPT-5.5) and Claude AI were used strictly as supportive tools to improve clarity, readability, organization and presentation of the manuscript.

Author Contribution: RKS has designed and conducted the entire protocol to generate the data and has drafted the entire manuscript; AKV, NSS and AM have contributed in the statistical analysis of the primary data; SC and RRS have contributed in remote sensing and making the satellite imagery of the collection site of water sample; SSP, NVAR and PKS have contributed in critical review of overall manuscript and suggested the necessary changes.

Conflict of Interest: No potential conflict of interest was reported by the authors.

Funding: The entire expenditure in conducting the experiment was funded by the management of St. Xavier's College, Ranchi and Society for Earth Observation and Conservation, Research & Development Cell of the St. Xavier's College, Ranchi.

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