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Original Article

Mitigating River Pollution During Indian Festivals: The Efficacy of Artificial Idol Immersion Ponds as a Sustainable Solution

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Abstract - *India, with its rich cultural and religious heritage, observes idol immersion in water bodies as a widespread practice. However, this practice frequently results in serious environmental problems, such as heavy metal contamination, water pollution, and ecological imbalance in rivers and other aquatic ecosystems. To address these issues, the current study intends to evaluate the effectiveness of artificial idol immersion ponds as a sustainable remedy to mitigate the adverse environmental impact of idol immersion in rivers during Indian festivals in the Itanagar Capital Complex Region of Arunachal Pradesh, India. Water samples were taken from direct idol immersion in the Dikrong river at Doimukh town during the Vishwakarma Puja and artificial Idol immersion Pond at Jullang town during Durga Puja. The samples were collected in three distinct phases: before, during, and after the immersion. The key factors such as pH, hardness, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), turbidity, temperature, and some heavy metals like lead (Pb), arsenic (As) mercury (Hg), and cadmium (Cd) were analyzed. The findings revealed that Idol immersion in the river significantly impacts the water quality of the Dikrong River, especially through elevated levels of pH, BOD, and heavy metals such as lead and mercury, all of which exceeded permissible limits. The study also revealed that the artificial Idol immersion ponds for the Durga Puja festival celebration had less impact on the Dikrong River than the direct immersion of the idol in the Dikrong River during the Vishwakarma Puja celebration by containing pollutants in controlled environments, allowing for easier waste management and minimizing ecological disruptions.*

Keywords - *Artificial idol immersion ponds, Indian festivals, River pollution, Sustainable solution.*

1. Introduction

Idol immersion is one of the most popular cultural and religious practices observed throughout different regions globally, especially in India, where it is considered an important part of festivals such as Vishwakarma Puja, Ganesh Chaturthi, Durga Puja, and Kali Puja. Vishwakarma Puja and Durga Puja festivals are mainly celebrated in Northeastern India, particularly in Arunachal Pradesh. These days, crafted idols made of plaster of Paris, clay, and other materials are offered and worshipped for days before being finally immersed in water bodies, in the sense of immersing the god in mother nature. This is a culturally and spiritually relevant practice while enhancing environmental problems, primarily on water quality, where these idols are immersed [1]. Such practices degrade the quality of the water, leading to less utility, posing health issues among humans and animals and threatening aquatic survival based on the survivability of such ecosystems [1-3]. The materials that have been used in the preparation of these idols comprise paints and other decorative products. It also includes harmful contaminants like mercury, lead, and cadmium [4, 5]. Studies have also reported that heavy metals dominate water bodies even after idol immersion [6]. When these idols are submerged in water, harmful substances like heavy metals are released into aquatic habitats, thereby deteriorating the water quality [7, 8]. The research was done by Ujjania et al. [9] and Bengani et al. [10], which highlights the immediate effects of idol submersion activities in the water resulting from an increase in turbidity, a change in pH values, and an elevation in the Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) in water. Also, they found that in the long run, these harmful effects may pile up from these pollutants, damaging aquatic life and the whole ecosystem. Tomar and Upadhyay [11] and Reddy and Kumar [12] explored the effects of idol immersion in the Yamuna River in Delhi. They reported that post-immersion lead and mercury levels exceeded the World Health Organization's permissible limit of 0.1 and 0.005mg/l, respectively, which shows a direct linkage between the submersion of religious idols with poor quality water. In the highly populous urban areas, where watersheds are already overwhelmed with water pollutants and overused, urbanization and the expanding sizes of such festivals have added environmental stressors to watersheds [13]. Available literature confirms that these practices of idol immersion negatively impact water quality. It releases heavy metals, organic and inorganic pollutants, and other toxic substances into aquatic ecosystems. So, more research is required to investigate the possible sustainable alternatives and develop policies that balance cultural practices while keeping the environment unharmed. Future studies should focus on long-term supervising and implementing sustainable practices. Some of the recent environmental concerns led other researchers to seek greener alternatives to these traditionally used idols. Bhattacharya et al. [1] and Shukla et al. [14] have examined the use of eco-friendly materials such as clay, natural dyes, and biodegradable paints in idol-making. The results showed that using these materials as immersion practices has reduced the environmental footprint without losing the cultural and religious values of events. These findings have yet to be implemented because of a lack of awareness and regulatory enforcement. Kapoor [15] has asserted strong policy frameworks and community participation in advocating sustainable materials and specified immersion locations. Conducted studies across a couple of Indian cities proved that stringent regulation and public participation played an imperative role in furthering minimum environmental damage at the immersion of idols.

Even though research from other regions of the nation shows that idol submersion activities have negative impacts on water bodies, such as pollution from metallic pollutants, changes in the chemistry of the water, and ecological disturbance, no systematic study has been done to determine the scope and type of these effects in this study area.

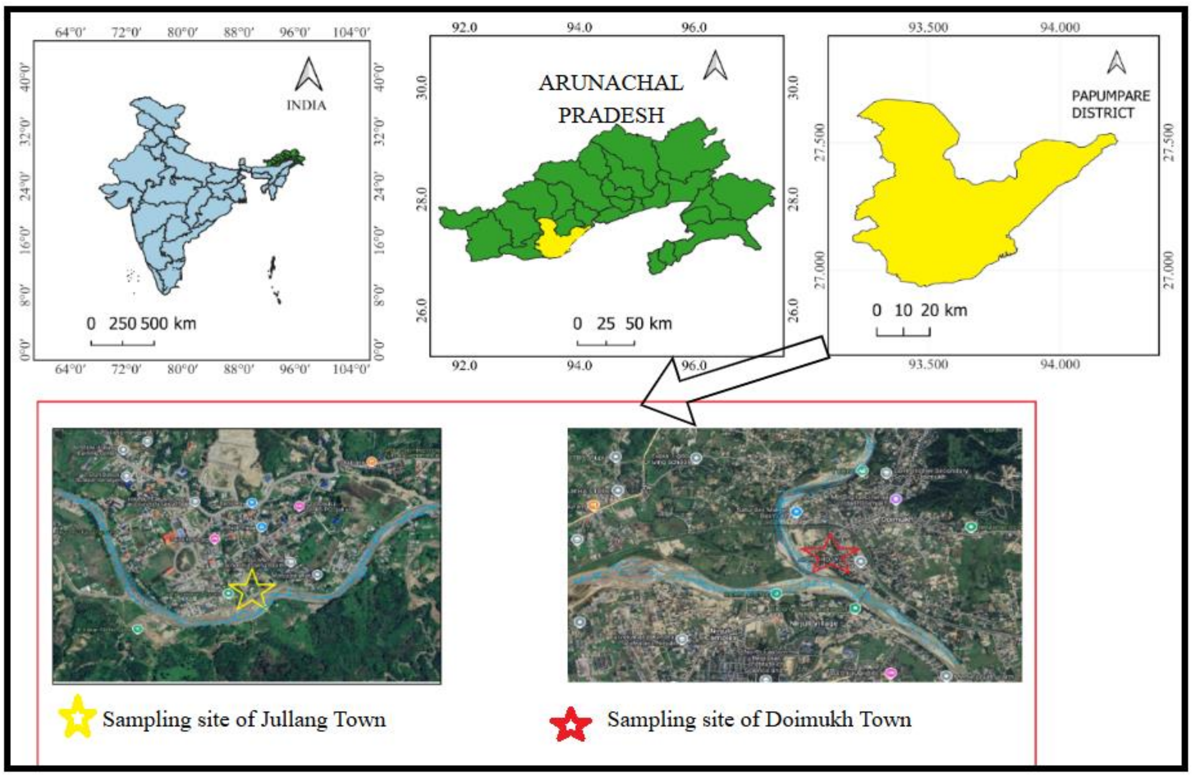

Fig. 1 Study area

The studies that have already been done on river pollution during Indian festivals mostly focus on the negative effects of idol immersion, like heavy metal pollution and deteriorating water quality in India's main rivers. However, no study has thoroughly assessed artificial idol immersion ponds' effectiveness as a long-term way to reduce river pollution.

This study focuses on the Dikrong River in the Itanagar Capital Region, India, and examines the effects of direct river immersion and artificial immersion ponds on water quality in a novel way. The current study closes a significant gap in the literature by addressing both environmental and cultural factors and offering a workable, scalable strategy for lowering river pollution.

Therefore, this study examines the efficacy of artificial idol immersion ponds in reducing the direct contamination of natural water bodies. The current research also focuses on evaluating the consequence of idol submersion on the Dikrong River's water condition under the Itanagar capital region of Arunachal Pradesh, India. With analyses of the most critical parameters related to water quality pre-events, at the time of events, and post-immersion in its phases, this research tries to explain the environmental consequences related to idol immersion. In general, the outcomes shall enrich the debate over sustainable practices at festivals and eventually act as a basis for decision-making for regulations and social mobilization in future endeavors aimed at urban water source sustainability.

2. Materials and Method

2.1. Study Area

Arunachal Pradesh is the largest states of the northeastern states of India, positioned in the middle of latitudes 26.28°N and 29.30°N and longitudes 91.20°E and 97.30°E, the state spans 83,743 square kilometers. Within Arunachal Pradesh, the study was conducted in two study areas under the capital complex region Itanagar, i.e., the Doimukh and Jullang areas (see Figure 1). Doimukh, located in the Papum Pare district of Arunachal Pradesh, covers an area of approximately 24 square kilometers. Jullang is a small town situated at Itanagar, the capital region of Arunachal Pradesh, India. It is a part of the Itanagar Capital Complex, situated in the Papum Pare district, approximately 10-12 km from the heart of Itanagar. It is nestled in the region's hilly terrain, surrounded by lush greenery typical of Arunachal Pradesh. The Dikrong River is among the important rivers of Arunachal Pradesh. It originates in the hills of eastern Himalaya of the Papumpare district of Arunachal Pradesh and plays an important river tributary of The Brahmaputra River.This river passes through these two study areas. This water body is a significant site for idol immersion during festivals such as Viswakarma Puja and Durga Puja, attracting large numbers of devotees.

2.2. Site Selection

The water sample for the study was collected from the Dikrong River at two different idol immersion sites within Itanagar Capital Complex, Arunachal Pradesh, India. The first water sample analysis was done from the immersion site of the Dikrong River, located in Doimukh town during Viswakarma Puja in September 2024, a naturally flowing river shown in Figure 2. The second water sample analysis was done from an artificial immersion pond constructed by IMC (Itanagar Municipal Corporation), Arunachal Pradesh, India, at the bank of the Dikrong River at Jullang town during the Durga Puja festival in October 2024, shown in Figure 3. This artificial immersion pond was specially constructed for the Durga Puja festival. The pond was built on the bank of the Dikrong River with a length of 25m, a breadth of 15m, and a depth of 2m approximately. The bed of the pond was covered with HDPE (High-Density Polyethylene) Liners to prevent seepage of water from the pond to the river.

Fig. 2 Idol immersion site at Dikrong River, Doimukh town, during the Viswakarma Puja celebration

Fig. 3 Artificial idol immersion site, Jullang town, during Durga Puja celebration

2.3. Methodology

Water samples were gathered 1 hour before and after the idol immersion activities and during the idol immersion at three distinct time points of two festivals, i.e. Viswakarma Puja in September 2024 and Durga Puja in October 2024 (Table 1). Sampling locations were strategically chosen to cover different zones of the water body, i.e. Upstream or Control Site, Immersion Zone, and Downstream or Dispersal Zone. The important factors such as DO, temperature, pH, hardness, and TDS were measured on the site (Figure 4). The rest of the factors, such as Turbidity, BOD, COD, and metallic pollutants (Pb, Cd, Hg, As), were measured in the Environmental Engineering Laboratory of Civil Engineering department, Northeastern Regional Institute of Science and Technology, Nirjuli, Papumpare District, Arunachal Pradesh, India following the standard methods.

Table 1. The geographic coordinates, festival associations, and immersion methods for selected idol immersion sites

Immersion Site	Festival	Coordinates (Decimal Degree-Lat, long)	Idol Immersion Method
Jullang Town	Durga Puja	27.1442°N, 93.7540°E.	Artificial Idol Immersion Ponds
Doimukh Town	Viswakarma Puja	27.06722°N, 93.63023°E	Direct Idol Immersion into Natural Water Body.

Fig. 4 Analysis of water sample (pH, hardness, DO, TDS) on-site before idol immersion

Contaminants like cadmium, Lead, Arsenic, and mercury have been selected in the present study based on their persistence, toxicity, bioconcentration properties, and anthropogenic contributions related to idol immersion. These metals are released into rivers with immersion and are extensively used in paints, decorative coatings, and synthetic dyes that pose grave dangers to both aquatic environments and humans [16]. The primary contaminant is lead (Pb), principally resulting from idol paints and decorative materials. Pb is a known neurotoxin that bio-accumulates in sediments and bio-magnifies in aquatic organisms and surpasses the safe limit of 0.01 mg/L for WHO post-immersion [17] and often reaches 0.5 mg/L. Likewise, methylmercury (CH_3Hg) is formed in waters by Hg pre-existing in metallic paints and varnishes and bioaccumulates in fish, causing neurological diseases. Hg levels after immersion studies have been as high as 0.02 mg/L, exceeding the WHO limit (0.001 mg/L)[18, 19]. Cadmium (Cd) (commonly in pigments and polymer stabilizers) induces nephrotoxic and ototoxic effects and is a well-known carcinogen that continues to build up in sediments [20]. The WHO has set guideline limits lowest to 0.003 mg/L, but river monitoring shows the value as high as 0.1 mg/L post-wash. Arsenic (As) present in idol dyes and gold leaf decorations impairs aquatic photosynthesis and leads to devastating health issues such as cancer and neurological disorders [21]. The study also reported that arsenic concentrations from rivers subject to multiple immersions were greater than 0.05 mg/L, above the WHO limit of 0.01 mg/L [4].

3. Results and Discussion

The water quality at the two immersion sites, i.e. Doimukh town during the Viswakarma Puja celebration and Jullang town during the Durga Puja celebration, were analyzed before, during, and post-submersion to determine the consequences of idol immersion activities. The concentrations of the various parameters are shown in Table 2. The summary of the changes observed for various parameters is presented below.

Table 2. Concentration of various parameters at both idol immersion sites

	Direct Idol Immersion Site, Doimukh Town			Artificial Idol Immersion Site, Jullang Town		
Parameters	**Pre-Immersion**	**During Immersion**	**Post-Immersion**	**Pre-Immersion**	**During Immersion**	**Post-Immersion**
DO (mg/l)	6.5	5.6	5.8	5.2	4.8	5
pH	6.8	8.8	7.6	8.1	8.8	8.6
Temperature (°C)	27	28.2	28	29.5	31.2	30
TDS (mg/l)	46.4	50.4	38.2	135	223.6	180.02
Hardness (mg/l)	88.47	121.41	112.62	76.52	110.92	80.42
Turbidity (NTU)	5.87	11.4	7.5	7.24	20.64	12.26
BOD (mg/l)	5.8	7.3	4.3	12	16.25	11.32
COD (mg/l)	16.25	35.42	26.65	15.25	28.5	24.25
Pb (mg/l)	0.003	0.005	0.004	0	0.011	0.009
Cd (mg/l)	0	0	0	0	0	0
Hg (mg/l)	0	0	0	0	0.014	0.012
As (mg/l)	0	0	0	0	0	0

3.1. Dissolved Oxygen (DO)

The percentage of oxygen found in water, known as Dissolved Oxygen (DO), is essential to aquatic life's survival and the stability of ecosystems. DO levels are greatly influenced by factors like water flow, temperature, and the breakdown of organic matter. Hypoxia caused by low DO can impact aquatic health and biodiversity. Ecological conservation and water quality management depends on DO monitoring [22, 23]. DO levels declined during immersion at both sites compared to pre-immersion values (see Figure 5). In Doimukh, DO dropped from 6.5 mg/l to 5.6 mg/l during immersion, followed by a slight increase to 5.8 mg/l post-immersion. These levels are marginally acceptable for maintaining aquatic life, but the drop suggests stress during the immersion event. In Jullang, the decline was more pronounced, from 5.2 mg/l before immersion to 4.8 mg/l during immersion, with a small recovery to 5.0 mg/l post-immersion. The drop below 5 mg/l during immersion indicates potential stress on the aquatic ecosystem. The drop in DO is likely due to the organic load introduced into the water during idol immersion, which promotes microbial activity and oxygen consumption.

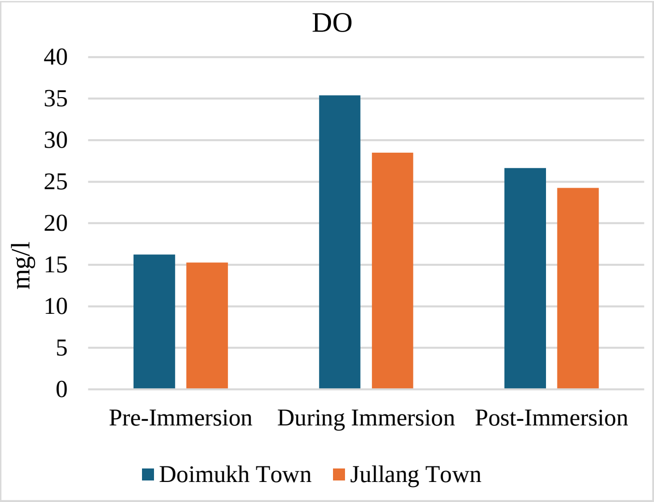

Fig. 5 Graphical representation of dissolved oxygen

3.2. pH

Aquatic ecosystems depend heavily on pH because it affects the solubility and bioavailability of heavy metals and minerals. Water's acidic or basic property is measured, ranging from 0 to 14, where 7 is considered neutral. Excessive acidic or alkaline pH values can damage aquatic life by interfering with physiological functions and leading to stress or death. Maintaining the health of aquatic ecosystems and evaluating the water quality depend on pH monitoring [24, 25]. Both sites showed an increase in pH levels during immersion. Doimukh experienced a significant rise from 6.8 to 8.8, indicating that the water became more alkaline and exceeded the Bureau of Indian Standards (BIS) drinking water safe allowable limits of 8.5, likely due to the materials used in idol construction, which may contain alkaline substances.

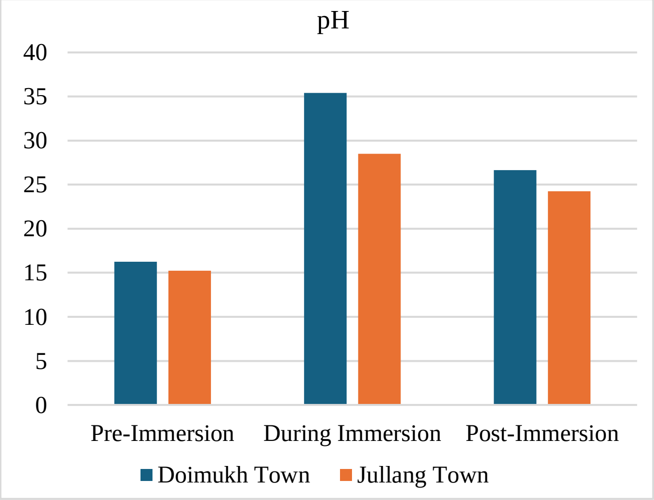

Fig. 6 Graphical representation of pH

Post-immersion, the pH in Doimukh stabilized at 7.6. Similarly, in Jullang, the pH rose from 8.1 pre-immersion to 8.8 during immersion and slightly decreased to 8.6 post-immersion (see Figure 6). Elevated pH levels can disrupt aquatic ecosystems and affect species sensitive to pH fluctuations.

3.3. Temperature

Temperature is a key parameter in river water quality, influencing aquatic ecosystems and human health. The World Health Organization (WHO) reports that temperature affects dissolved oxygen levels, microbial activity, and the toxicity of pollutants, impacting water quality and ecosystem stability [19]. Elevated temperatures can lead to oxygen depletion, increasing the risk of hypoxia and affecting aquatic life [26]. However, there is no standard limit set for the temperature in terms of water quality. The water temperature increased slightly during immersion at both sites. Doimukh showed a rise from 27°C to 28.2°C, while Jullang recorded an increase from 29.5°C to 31.2°C during immersion (see Figure 7). This increase in temperature could be attributed to the influx of large groups of people at the immersion site. During the time of post-immersion, the temperature decreased but remained higher than pre-immersion values, at 28°C in Doimukh and 30°C in Jullang.

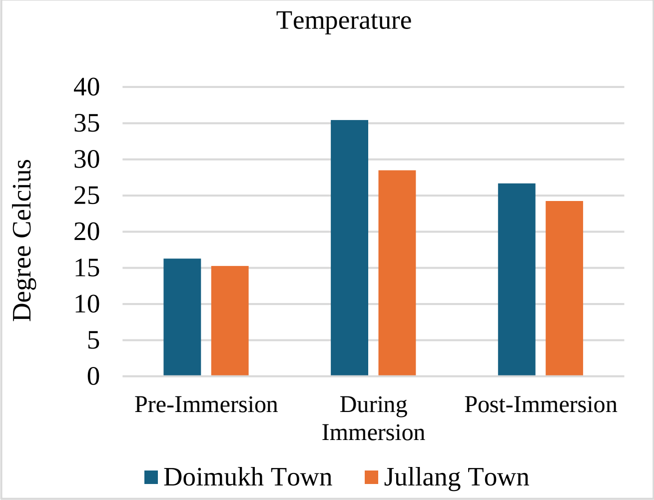

Fig. 7 Graphical representation of temperature

3.4. Total Dissolved Solids (TDS)

TDS quantifies the concentration of biodegradable and non-biodegradable substances dissolved in water, affecting water quality and appropriateness for different applications. Increased TDS levels may impact aquatic ecosystems and human health and can be caused by natural sources, industrial discharges, or agricultural runoff. TDS in drinking water, the United States Environmental Protection Agency (USEPA)suggests a secondary maximum contamination threshold of 500 mg/L to preserve aesthetic quality [27]. Similarly, TDS concentrations under 1,000 mg/L are deemed appropriate for consumers by the World Health Organisation.

TDS must be regularly monitored to guarantee water quality and stop environmental deterioration[28, 29]. The TDS levels increased during immersion in both locations (see Figure 8). In Doimukh, TDS rose from 46.4 mg/l before immersion to 50.4 mg/l throughout the immersion but dropped to 38.2 mg/l post-immersion. Jullang also increased from 135 mg/l before immersion to 223.6 mg/l while immersing, followed by a decrease to 180.02 mg/l post-immersion. Higher TDS during immersion can be attributed to the introduction of solids and materials from idols and offerings.

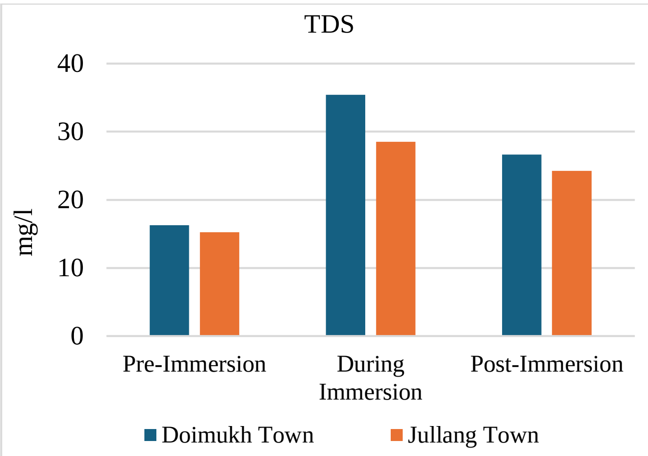

Fig. 8 Graphical representation of TDS

3.5. Hardness

Water quality and its suitability for different uses are greatly influenced by water hardness, which is mainly determined by the proportion of calcium and magnesium ions. High hardness levels can cause scale to build in industrial equipment and pipes, which lowers productivity and raises maintenance expenses. On the other hand, low-hardness water could be more corrosive and might potentially leach metals from plumbing systems. To maintain ideal water quality for residential and commercial use and stop infrastructure deterioration, water hardness must be effectively managed [30].

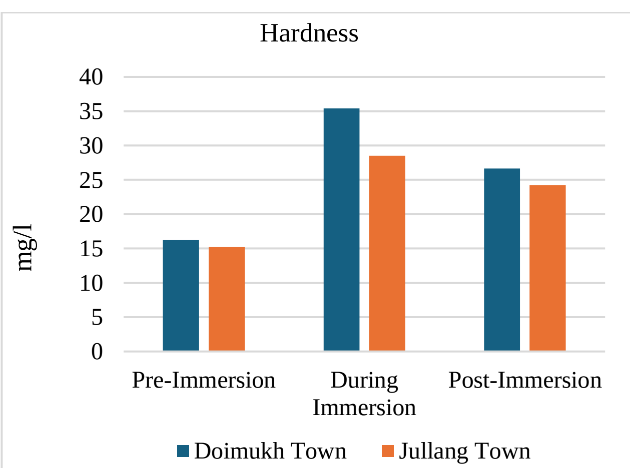

Fig. 9 Graphical representation of hardness

Hardness levels increased significantly during immersion at both sites. Doimukh's hardness increased from 88.47 mg/l before immersion to 121.41 mg/l throughout the immersion, while Jullang saw a rise from 76.52 mg/l to 110.92 mg/l respectively. The hardness remained elevated post-immersion, though it decreased to 112.62 mg/l in Doimukh and 80.42 mg/l in Jullang (see Figure 9). Increased hardness could be a result of the dissolution of materials from idols containing calcium and magnesium.

3.6. Turbidity

Turbidity, which indicates the concentration of suspended particles, including clay, silt, biodegradable materials, and microbes, is a crucial metric in the evaluation of water quality. High turbidity levels may indicate pollution or pathogen infection and can hinder photosynthesis in aquatic environments by reducing light penetration. Turbidity monitoring is crucial for maintaining ecological health and water safety [31]. Turbidity levels exceeded the BIS permissible limit of 5 NTU during and after immersion at both sites. At Doimukh town during the Viswakarma puja festival, Turbidity rose from 5.87 NTU pre-immersion to 11.4 NTU during immersion, then decreased to 7.5 NTU post-immersion (See Figure 10).

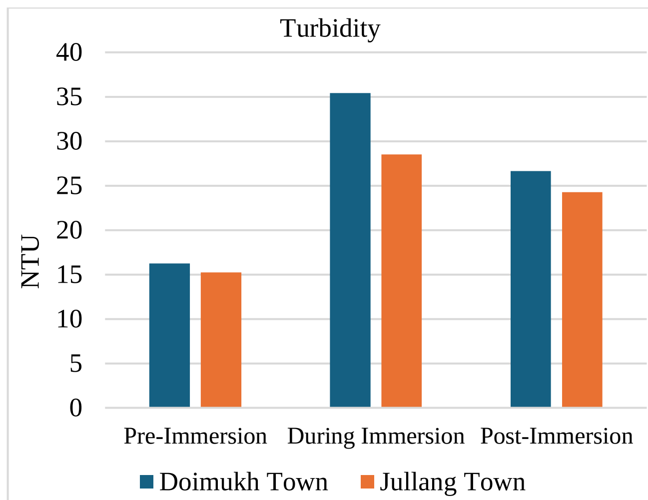

Fig. 10 Graphical representation of turbidity

Both during and post-immersion turbidity levels exceeded the permissible limit, which can affect aquatic biodiversity by reducing light penetration and promoting sedimentation. At Jullang town during the Durga Puja festival celebration, Turbidity increased sharply from 7.24 NTU pre-immersion to 20.64 NTU during immersion, reducing to 12.26 NTU post-immersion. These high turbidity levels indicate substantial input of suspended particles, which could lead to long-term sedimentation issues.

3.7. Biochemical Oxygen Demand (BOD)

Monitoring BOD is crucial for evaluating water quality and controlling pollution in freshwater systems. BOD measures the quantity of dissolved oxygen microorganisms need to break down bio-degradable substances in water. Elevated BOD levels indicate significant organic pollution, which can deplete oxygen and harm aquatic life. Elevated BOD concentrations are frequently linked to anthropogenic sources, such as industrial emissions, combined sewer overflows, and domestic and livestock waste [32]. BOD levels rose significantly during immersion in both immersion sites, indicating an increased organic load in the water (see Figure 11).

Doimukh showed an increase from 5.8 mg/l in the event of pre-immersion to 7.3 mg/l throughout the immersion, then dropped to 4.3 mg/l post-immersion. Jullang exhibited a more drastic change, with BOD increasing from 12 mg/l to 16.25 mg/l during immersion, followed by a decrease to 11.32 mg/l post-immersion. Elevated BOD levels suggest that idol immersion introduces biodegradable organic matter, which can deplete oxygen as it decomposes.

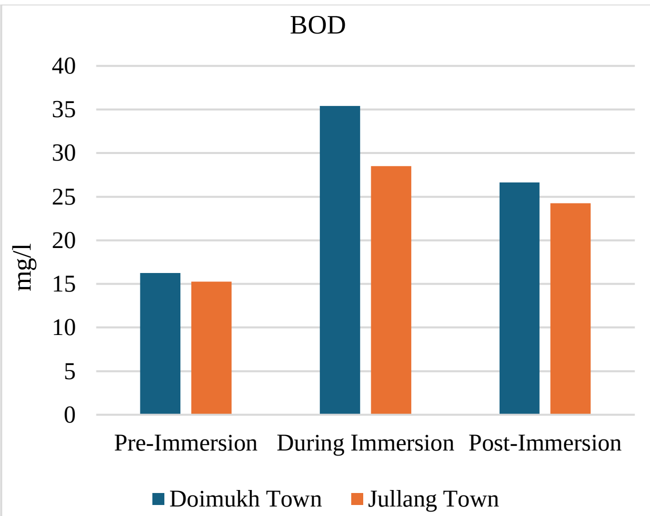

Fig. 11 Graphical representation of BOD

3.8. Chemical Oxygen Demand (COD)

The concentration of oxygen needed to oxidize chemically, both bio-degradable and non-biodegradable in water, is measured by the Chemical Oxygen Demand (COD). Higher concentrations of oxidizable elements, which can reduce dissolved oxygen and negatively impact aquatic life, are indicated by elevated COD levels. COD monitoring is crucial to evaluate water quality and the possible environmental effects of wastewater discharges[33].

The COD levels also increased during immersion, reflecting the introduction of chemical pollutants. Doimukh showed an increase from 16.25 mg/l in the event of pre-immersion to 35.42 mg/l throughout the immersion, followed by a decrease to 26.65 mg/l post-immersion. Jullang recorded an increase from 15.25 mg/l before immersion to 28.5 mg/l throughout the immersion, dropping to 24.25 mg/l post-immersion (see Figure 12). This indicates the contamination of non-organic and organic compounds in the water during immersion activities.

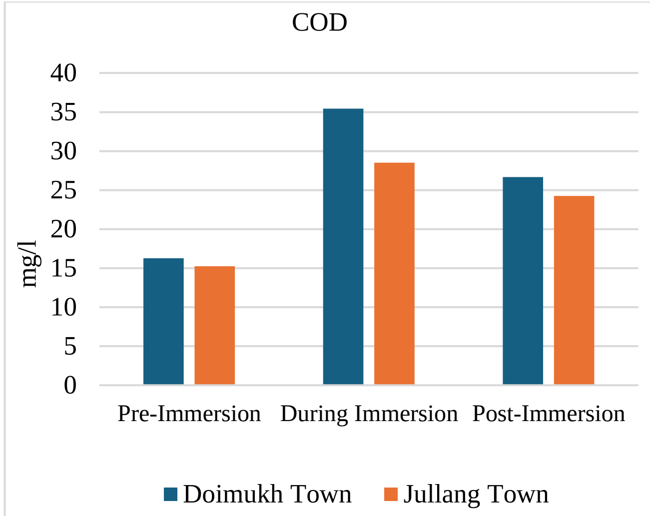

Fig. 12 Graphical representation of COD

3.9. Heavy Metals

Heavy metals are elements characterized by high atomic weights and densities, such as cadmium, lead, mercury, and arsenic, that can be harmful to living beings, even in small amounts. These metals can build up in water bodies because of both man-made activities like mining operations, industrial discharges, and agricultural runoff, as well as natural processes like rock weathering and volcanic activity.

The ability of heavy metals to build up in organisms and biomagnify down the food chain makes elevated concentrations of these metals in water a serious threat to aquatic ecosystems and human health [34]. The lead concentration increased from 0.003 mg/l pre-immersion to 0.005 mg/l when immersed and slightly reduced to 0.004 mg/l post-immersion at the Doimukh town immersion site (see Figure 13). All values are below the Bureau of Indian Standards (BIS) permissible limit of 0.01 mg/l, suggesting that while lead contamination increased due to idol immersion, it did not exceed the regulatory threshold [35].

But at the artificial immersion site of Jullang, Lead was not detected pre-immersion (0 mg/l), but it spiked to 0.011 mg/l during immersion and decreased to 0.009 mg/l post-immersion (see Figure 14). During immersion, the lead concentration slightly exceeded the BIS permissible limit (0.01 mg/l), but post-immersion values fell below the permissible limit.

While the increase in lead concentration during immersion at both sites suggests contamination from idol materials, only Jullang's water exceeded the BIS limit during immersion. Though the post-immersion concentrations dropped below the limits, even these low levels can accumulate in the environment and pose long-term health risks. Lead is harmful even at low concentrations, particularly for aquatic life and human health, as it can cause neurological and developmental issues [16, 36]. Both arsenic and cadmium could not be detected in all water samples from Doimukh and Jullang during the entire immersion stages.

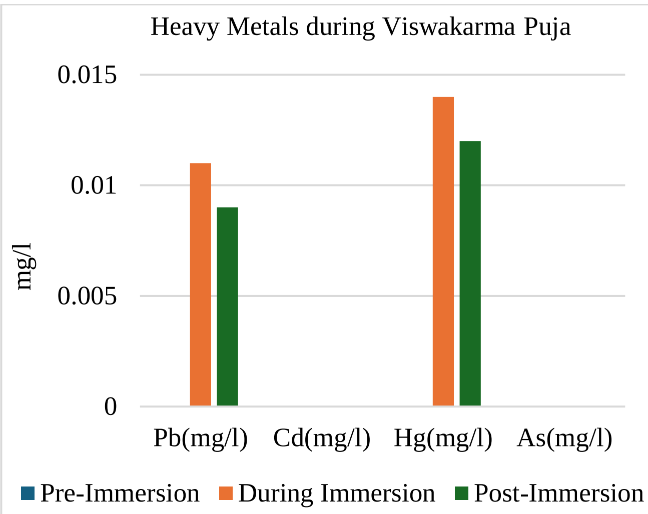

Fig. 13 Heavy metals concentration at doimukh town sampling site

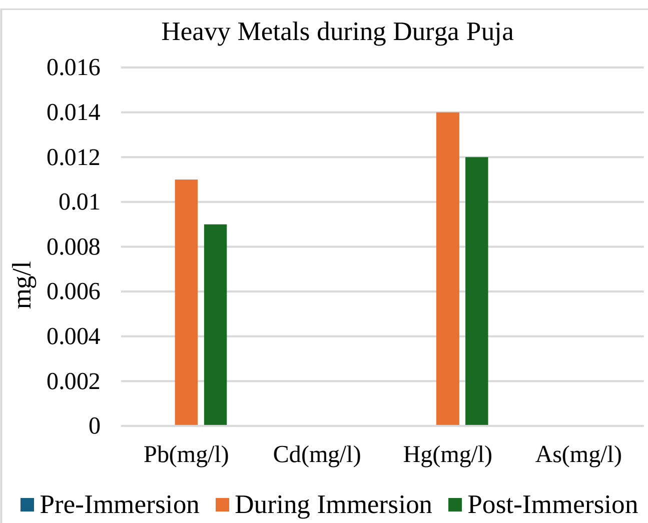

Fig. 14 Heavy metals concentration at jullang town sampling site

The absence of cadmium and arsenic contamination is a positive outcome. Both metals are highly toxic, and their lack of detection suggests that the materials used in these idols do not contain these hazardous substances. However, the focus on lead and mercury remains crucial, as they still present significant risks despite the absence of these two metals. The analysis of water quality parameters at the idol immersion sites in Doimukh Town (Viswakarma Puja) and Jullang Town (Durga Puja) (see Table 3) shows notable differences in physicochemical characteristics, raising potential environmental issues. The temperature, an important factor for aquatic ecosystems, was significantly higher in the artificial immersion pond at Jullang (mean: 30.23°C) compared to Doimukh (mean: 27.73°C), which could result in lower Dissolved Oxygen (DO) levels. In line with this, DO levels at Jullang (5.0 mg/l) were lower than those at Doimukh (5.97 mg/l), indicating increased organic pollution and microbial activity in the artificial pond. The pH levels at Jullang (8.5) were slightly more alkaline than at Doimukh (7.73), likely due to the dissolution of idol materials after immersion.

The concentration of Total Dissolved Solids (TDS) was significantly higher at Jullang (179.54 mg/l) compared to Doimukh (45 mg/l), suggesting a greater presence of dissolved ions and pollutants. Additionally, hardness levels were lower at Jullang (89.28 mg/l) than at Doimukh (107.5 mg/l), which may be linked to variations in local water sources and geological conditions. The turbidity levels at Jullang (13.38 NTU) were also higher than at Doimukh (8.25 NTU), indicating increased suspended solids and decreased water clarity, likely due to the dissolution of idol materials. Assessing pollution caused by organic materials through chemical and biochemical oxygen demand highlights the greater pollution load at Jullang.

The BOD and COD levels at Jullang (13.19 mg/l and 22.67 mg/l, respectively) were notably higher than those at Doimukh (5.8 mg/l and 26.11 mg/l, respectively), indicating increased organic matter decomposition and microbial activity in the artificial pond. Heavy metal analysis also showed concerning results, with lead (Pb) levels slightly elevated at Jullang (0.0066 mg/l) compared to Doimukh (0.004 mg/l), likely due to idol paints and coatings. Mercury (Hg) was found only at Jullang (0.0045 mg/l), suggesting possible contamination from idol decorations, while Cadmium (Cd) and Arsenic (As) could not be detected at either site.

In summary, the artificial immersion pond at Jullang demonstrates significantly higher pollution levels than the direct immersion site at Doimukh, with increased turbidity, organic matter, and heavy metal contamination. However, through the concentration and containment of pollutants in a controlled environment, artificial idol immersion ponds successfully prevent direct contamination of the Dikrong River.

The greater levels of organic matter, turbidity, Total Dissolved Solids (TDS), and heavy metal deposition in these ponds require routine treatment and waste management techniques to stop long-term environmental deterioration. Although the dilution effect of the running river resulted in relatively reduced contamination levels at the direct immersion site at Doimukh, town during the Viswakarma Puja celebration, the pollutants were immediately released into the Dikrong River, posing a serious ecological hazard to aquatic life and water quality.

Table 3. Descriptive statistics of both the idol immersion site

Direct Idol Immersion Site at Doimukh Town During Viswakrma Puja Celebration				Artificial Idol Immersion Pond at Jullang Town During Durga Puja Celebration		
Parameters	**Descriptive statistics**			**Descriptive statistics**		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**
DO (mg/l)	5.6	6.5	5.966667	4.8	5.2	5
pH	6.8	8.8	7.733333	8.1	8.8	8.5
Temperature (°C)	27	28.2	27.73333	29.5	31.2	30.23333
TDS (mg/l)	38.2	50.4	45	135	223.6	179.54
Hardness (mg/l)	88.47	121.41	107.5	76.52	110.92	89.28667
Turbidity (NTU)	5.87	11.4	8.256667	7.24	20.64	13.38
BOD (mg/l)	4.3	7.3	5.8	11.32	16.25	13.19
COD (mg/l)	16.25	35.42	26.10667	15.25	28.5	22.66667
Pb (mg/l)	0.003	0.005	0.004	0	0.011	0.006667
Cd (mg/l)	0	0	0	0	0	0
Hg (mg/l)	0	0	0	0	0.014	0.00867
As (mg/l)	0	0	0	0	0	0

4. Conclusion

Artificial immersion ponds are an ideal and nature-friendly option to alleviate the problems associated with idol immersion into natural water bodies. Such controlled systems can result in pollution prevention, water quality management and respect for cultural traditions. However, in addition to their environmental benefits, artificial ponds have far-reaching impacts, making them scalable models for sustainable religious and community practices in other regions facing similar ecological pressures.

To maximize their effectiveness, a well-defined policy framework is essential. Governments and local authorities should create clear guidelines for ponds' construction, maintenance, and waste disposal after immersion. Incorporating artificial ponds into urban planning can further enhance their long-term sustainability. Moreover, engaging in the community is vital for successful implementation. Public awareness campaigns, educational programs, and participatory initiatives can foster wider acceptance, while partnerships with local artisans to promote biodegradable idols can help strengthen eco-friendly traditions.

These outcomes draw attention to the need for strict controls on idol materials and the promotion of sustainable alternatives to minimize the environmental issues due to religious practices. Additionally, the study found that using artificial ponds for idol immersion can help mitigate the contamination of natural water bodies like rivers. A detailed analysis of the graph representation shows that concentrations of contamination were higher in the artificial immersion site at Jullang town during the Durga Puja festival than in the immersion site at the natural river immersion site during the Viswakarma Puja festival at Doimukh town.

The higher Contamination at Jullang town is the basic technique of pollution abatement in the artificial pool constructed by IMC, i.e., to concentrate and contain. After the idol immersion period is over, the authority has segregated the waste generated from the immersion activity, and these wastes are carried to the municipal solid waste management plant for further processing. Whereas in the case of Doimukh town, the direct contamination value was less than the contamination value of the Jullang immersion site. But the contamination was directly disposed of into the river.

So, from the overall analysis, it was found that the artificial idol immersion site during the Durga Puja festival celebration had no impact on the Dikrong river compared to the direct idol immersion in the river at Doimukh town during the Viswakarma Puja festival. Thus, the artificial immersion pond constructed by IMC is working effectively. Therefore, it is recommended that artificial idol immersion be used as a sustainable solution to decrease the direct contamination of river water during the Indian festivals associated with idol immersion in rivers.

In conclusion, though idol immersion is integral to cultural and religious festivities, its environmental cost is highly dangerous. By adopting sustainable practices like artificial immersion ponds, encouraging the use of available biodegradable materials to construct idols, and strengthening regulatory frameworks, cultural traditions and water ecosystems' health can be preserved.

Future research should aim at Conducting longitudinal studies of artificial ponds vis-à-vis traditional water body immersions so that the differential impacts on the pollution of waters, health of ecosystems, and biodiversity can be quantified. Exploring the innovative designs for ponds that not only enhance containment of pollutants but also improve treatment efficiency and the ease of idols' eco-friendly disposal. Studies on social acceptability, behavioral barriers, and cultural factors driving the adoption of artificial immersion ponds.

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