iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: VI Month of publication: June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72741

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Effect of Mass Bathing on Water Quality of the Ganga River at Haridwar, Uttarakhand

Abhishek Ranjan[1], Abhinav Sahay[2], Umesh Kumar[3], Kundan Kumar[4]
[1]*FRI Deemed University, Dehradun, Uttarakhand, India*
[2,3,4]*Amity University Patna, Bihar, India*

Abstract: The Ganga River, revered as one of the holiest rivers in the world, is facing significant degradation due to urbanization, industrialization, and population growth. Despite its sacred status and origin from the Gangotri glacier in the Himalayas, it accumulates pollutants from various sources including domestic, industrial, and agricultural. Over-abstraction for irrigation has further reduced its dry weather flow. Mass bathing during religious rituals contributes to pollution load. This study analyses the changes in the water quality of the Ganga after Purnima Mass Bathing in 2013. The focus is on assessing how mass bathing impacts water quality specifically during this event at Haridwar, Uttarakhand.
Keywords: Ganga River, Water quality, Mass bathing, Haridwar, Physiochemical characteristics.

I. INTRODUCTION

Water is undeniably essential for life, with the human body containing a significant percentage of it [1,2]. However, the availability of clean water is a growing concern, with water shortages and pollution posing significant challenges [3,4]. The importance of water purification and conscious use is emphasized [5]. The control and ownership of water is also becoming increasingly politicized [6]. In ancient Sanskrit literature, the importance of water is highlighted, with a call for its protection and proper management [7]. Water is the most vital and fundamental requirement for sustaining life. It is impossible to survive without water. Rivers play a crucial role in supporting human settlements, but various natural and human-induced factors can impact the quality of river water.

India possesses 14 major river systems, 55 minor rivers, and numerous small rivers. The Ganges boasts the largest river basin in the country, ranking 15th in Asia and 29th globally. It covers over a quarter (26.2%) of India's geographical area with a drainage capacity of as much as 8,61404 Km2 [8]. The Ganges enters the plains at Haridwar (29°58'N, 78°10'E), renowned for its religious significance. This year witnessed the organization of the world’s largest religious congregation here, during which studies were conducted to assess the water quality of the River Ganges before and after ceremonial baths by examining selected water quality parameters.

A series of studies have consistently shown that mass bathing at Haridwar has a significant negative impact on the water quality of the Ganga River. Several researchers found that mass bathing led to increased levels of pollutants such as biochemical oxygen demand, chemical oxygen demand, total suspended solids, ammonia nitrogen, and coliforms, as well as a decrease in dissolved oxygen. These changes make the water unsuitable for drinking or bathing and can lead to waterborne diseases [9-14]. Srivastava specifically noted that the water was not fit for either purpose [15].

II. STUDY AREA

A. Haridwar

Haridwar is located at a latitude of 29˚ 58ˈN and a longitude of 78˚10ˈE, with an elevation of 285.56 meters above sea level (Fig.1). The study was conducted along a stretch of the river spanning from Bhooma Niketan to Pul Jatwara, which has a width ranging from 15-40 meters and a depth between 2-10 meters. The total surface area for this section was measured at 220000 m^2, with a volume of water recorded at 1760000 m^3.

Haridwar, India, is characterized by a temperate climate with dry winters and warm to hot summers, and an annual precipitation of over 31 centimeters [16, 17]. The region has experienced significant urban development, with a random pattern of urbanization. The spatiotemporal analysis of water resources in the area has revealed an increase in surface runoff from 1995 to 2010, followed by a decrease from 2010 to 2018 [18]. The region's groundwater quality is generally good, but requires continuous monitoring due to the presence of certain ions [19]. The area has also experienced enhanced pre-monsoon warming, which has been attributed to increased atmospheric loading of absorbing aerosols [20]. The study of land surface temperature and NDVI in the region has shown a gradual increase in maximum land surface temperature, likely due to global warming and climatic changes [21].

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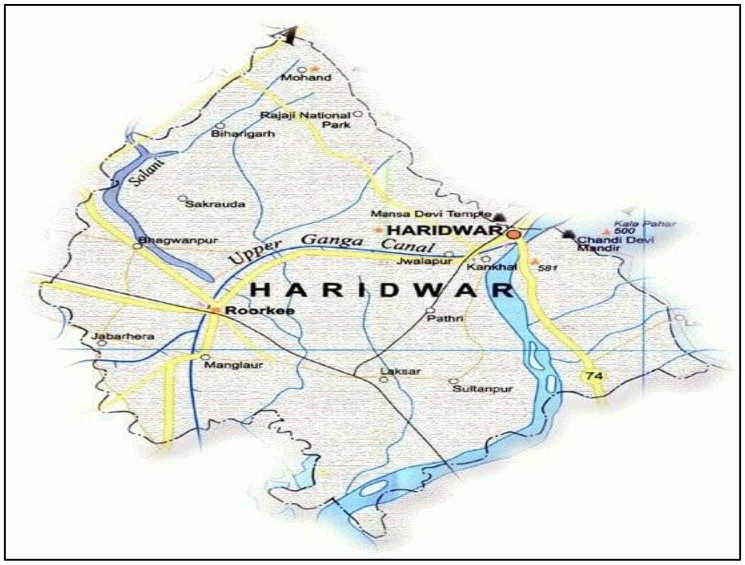

Fig1: Haridwar district

III. METHODOLOGY

The methodology adopted for the present study is described below:

A. *Materials and Methods*

A comprehensive analysis was conducted on 26th March 2013 to evaluate the influence of large-scale bathing on the condition of Ganga River water, focusing specifically on two locations: cable bridge (upstream) and Gau ghat (downstream) along the River Ganga was selected as study and sampling sites. Upstream point selected at Cable Bridge where river Ganga enters Har-ki-pauri and its water is relatively cleaner as compared to the second point (Downstream) where it gets polluted by the practice of mass bathing on different ghats along its journey through Har-ki-pauri.

The two points are taken on at upstream and other at downstream in order to compare the changes that water of Ganga goes through when it passes through the bathing ghats. In order to get the precise result, firstly the speed of flow of river ganga was calculated along with the distance between the two sampling points so that we could calculate the exact time that Ganga water takes to reach the second sampling point from its entrance.

The speed of ganga water was calculated by using a meter tape, a hollow plastic ball and a stopwatch. The time that the hollow plastic ball took to cover 1 meter was calculated and then the time that would be taken by the ball to travel 1000 meters was calculated, which in our case was 9.01 minutes, the distance between the two-sampling point was 1000 meters. After these 12 samples, six samples each from both the points were collected at a regular interval of 1 hour, from 10 am to 3 pm. Since the water took 9.01 minutes to reach Gau Ghat (Down Stream) from Cable Bridge entrance (Upstream) sampling point, two persons had to be present at these two sights and need to communicate to each other through Cell phone to remind each other about the time when the samples have to collected. Some specific physicochemical characteristics such as temperature, pH, dissolved oxygen, total dissolved solids, conductivity, alkalinity, chloride, magnesium, sodium, potassium, nitrate, and calcium were examined. All the collected samples are analyzed in the water quality laboratory of “National Institute of Hydrology” of Roorkee. The physical and chemical parameters of the analytical results of Ganga water were compared with the standard guideline values recommended by WHO and Indian standard specifications for drinking water is: 10500 for drinking and public health purposes.

B. *Laboratory Analysis*

Water Samples were collected from Har ki Pauri ghat on bathing days. Some selected Physio-chemical parameters viz. Temperature, pH, Conductivity, TDS, DO, Turbidity, BOD, Chloride, Hardness, TSS, TS were analyzed. Out of these parameters, Temperature, pH, DO, TDS, Conductivity and Turbidity were analyzed on spot at the time of sampling using Deluxe water and soil analysis kit Model 191 E and Transparency was also measured on the spot by Sacchi disc method. While DO, BOD, Chlorides, Hardness, TSS, TS were determined in the Research laboratory using given method of APHA and Trivedi and Goel [22, 23]

IV. REULTS AND DISCUSSION

The sample denotations U and D means Upstream and Downstream, collected from Cable bridge and Gau ghat on the occasion of mass bathing of Purnima in Haridwar at the interval of 1 hour from 10 am to 3 pm (at the interval of 1hour). (Table 1)

Table: 1 Time interval between samples collected.

SAMPLE	TIME
U-1	10:00am
U-2	11:00am
U-3	12:00pm
U-4	1:00pm
U-5	2:00pm
U-6	3:00pm
D-7	10:09am
D-8	11:09am
D-9	12:09pm
D-10	1:09pm
D-11	2:09pm
D-12	3:09pm

1) *pH:* The pH values was recorded between 6.7-8.1(Table 2, Fig. 2). pH is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity [24]. The minimum pH value was noted 6.7 (sample D6) while maximum pH value was noted 8.1. (sample U2) The pH values of all samples are well within the limits prescribed by BIS and WHO [25,26]. A range of factors contribute to the change in pH of the Ganga River water, including climate change, population growth, land use changes, and pollution control [27]. These changes have led to an increase in nutrient loading, particularly nitrogen and phosphorus, which has altered the N:P:Si stoichiometry and led to a decline in water quality [28]. The presence of heavy metals, such as Zn, Pb, Mn, Fe, Cu, Si, Al, Ni, Cd, Mg, and Co, has also been identified, although these are within acceptable limits [29,30]. The interaction of water quality with alkaline phosphatase has been found to be a useful indicator of river health [31]. However, the overall water quality of the Ganga River has declined, with higher levels of turbidity, total dissolved solids, and suspended solids, particularly in the monsoon season [32-34].

Table: 2 pH values of all the samples collected.

S. No.	***SAMPLES**	**pH Concentration**	**Guidelines**
1	U1	7.2	pH values well within Indian standards and WHO guidelines.
2	U2	8.1	
3	U3	7.3	
4	U4	7.6	
5	U5	7.3	
6	U6	6.7	
7	D1	7.1	
8	D2	7.1	
9	D3	7.1	
10	D4	7.2	
11	D5	7.2	
12	D6	6.7	

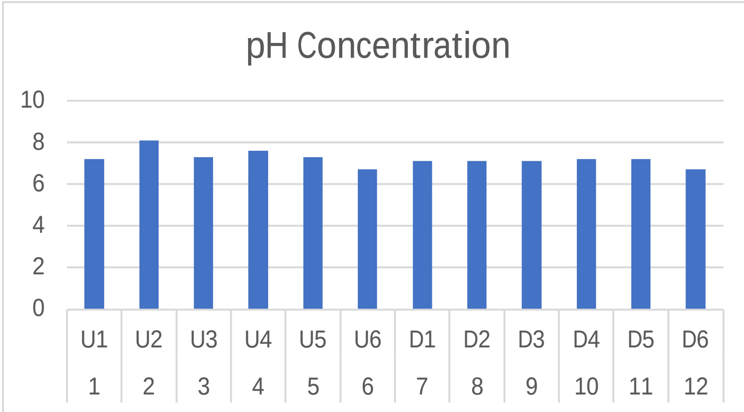

Figure: 2 Bar diagram of different values of pH

2) *Electrical Conductivity (EC):* Electrical Conductivity of the 12 samples ranges from 164-193 (µs/cm) (Table 3, Fig. 3). EC shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, and chloride and iron concentration of water. Most of the salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess river water quality. The minimum EC value noted was 164 µs/cm (sample U3) and the maximum value noted was 193 µs/cm (sample U2).
The electrical conductivity of river water is influenced by various factors, including physicochemical parameters such as color, total dissolved solids, chloride, fluoride, total phosphorus, total alkalinity, calcium, magnesium, sodium, and dissolved oxygen [35]. Diurnal fluctuations in electrical conductivity can be attributed to evapotranspiration and earth tide effects [36]. Urbanization, particularly the expansion of impervious surfaces, can lead to increased specific conductance in streams [37]. The intrusion of river water into aquifers can also affect electrical conductivity [38]. Electrical conductivity has been proposed as a single indicator of water quality deterioration in tropical rivers [39]. The effect of pressure on the electrical conductivity of sea water has also been studied [40]. Lastly, fluctuations in electrical conductivity have been used as a natural tracer for bank filtration in a losing stream [41].

Table: 3 EC of the samples collected.

S. No.	*SAMPLES	Electrical Conductivity (µs/cm)	Guidelines
1	U1	169	No limits mentioned in Indian standards and WHO guidelines.
2	U2	193	
3	U3	164	
4	U4	166	
5	U5	168	
6	U6	165	
7	D1	168	
8	D2	166	
9	D3	166	
10	D4	165	
11	D5	165	
12	D6	168	

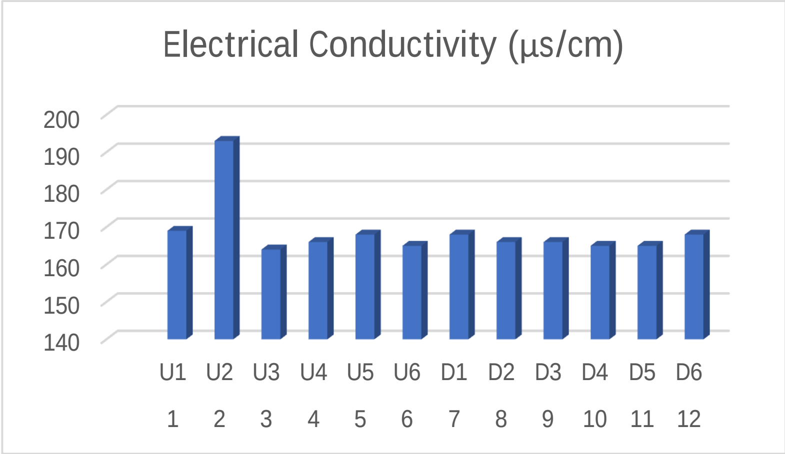

Figure: 3 showing bar diagram of EC for all the samples collected.

3) *Total Hardness:* The total hardness of river water can be influenced by a variety of factors, including seasonal changes, the construction of diversion hydropower dams [42], and the application of a magnetic field [43]. The use of silver nanoparticles and partial least squares modeling has also been proposed as a method for predicting total hardness [44]. Other factors such as pH, temperature, and buffer solution preparation can also impact the determination of total hardness [45]. Hardness of the Ganga River water at Haridwar during mass bathing ranged between 2 -92 mg/L. The minimum value noted was 62 mg/L (sample U4) and the maximum value noted was 92 mg/L (sample D1) (Table 4, Fig. 4). The Total Hardness values of all samples are well within the limits prescribed by BIS and WHO [25,26] .

Table: 4 Total Hardness of all the samples collected.

S. No.	*SAMPLES	Total Hardness (mg/L)	Guidelines
1	U1	72	Limits within the range of Indian standards and WHO guidelines.
2	U2	86	
3	U3	64	
4	U4	62	
5	U5	70	
6	U6	70	
7	D1	92	
8	D2	70	
9	D3	82	
10	D4	86	
11	D5	72	
12	D6	86	

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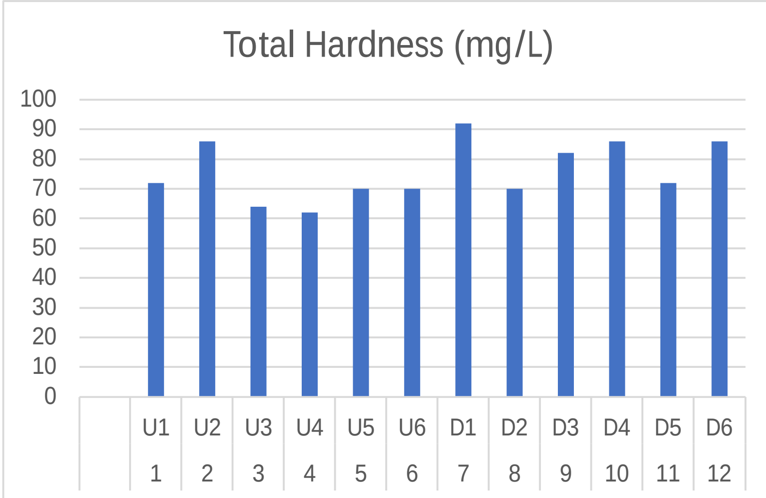

Figure: 4 Total Hardness of all the samples collected

4) *Alkalinity:* Alkalinity is the measure of the capacity of the water to neutralize a strong acid. The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free State. The bicarbonate alkalinity of the Ganga river water at Haridwar during mass bathing ranged between 60 to 92 mg/L(Table 5,Fig. 5). Most of the natural waters contain substantial amounts of dissolved carbon dioxide, which is the principal source of alkalinity. The minimum value of alkalinity noted was 56 mg/L (sample D3) and the maximum value noted was 92 mg/L (sample U2). The values of Alkalinity of all the samples are well within the limits prescribed by BIS and WHO [25,26]. The alkalinity of river water can be influenced by a variety of factors, including human activities, watershed geology, and seasonal variations. For example, the presence of high concentrations of nitrogen and phosphorus can lead to algae bloom, which in turn can increase the pH value of the water [46]. Similarly, human-accelerated chemical weathering, acid deposition, and topography can contribute to increased river alkalinization [47]. In urban areas, the discharge from industries, including untreated wastewater, can also lead to high alkalinity levels in river water [48]. The reduction of nutrient loads in rivers can result in changes in carbon and alkalinity dynamics [49]. Other factors, such as the addition of oxidizing bactericide and the equilibria of carbonic acid, can also affect the pH and alkalinity of river water [50,51].

Table: 5 showing alkalinity of all the samples collected

S. No.	SAMPLES	*Alkalinity (mg/L)	Guidelines
1	U1	60	Values well within Indian standards, there are no guidelines mentioned in WHO.
2	U2	92	
3	U3	60	
4	U4	64	
5	U5	66	
6	U6	60	
7	D1	64	
8	D2	64	
9	D3	56	
10	D4	72	
11	D5	62	
12	D6	66	

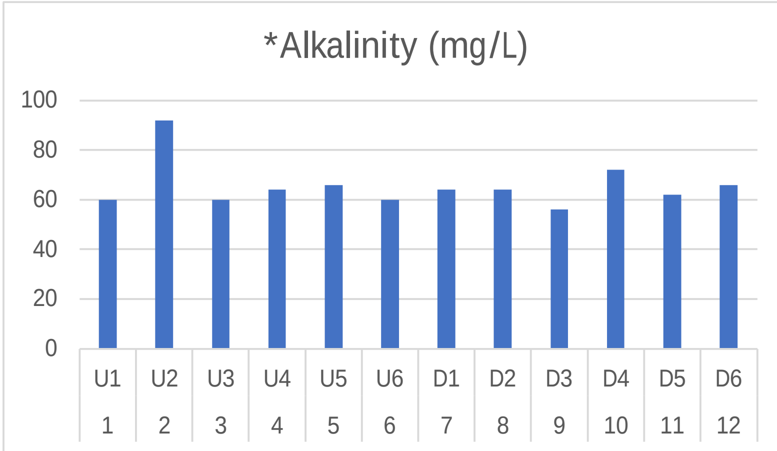

Figure: 5 Bar diagram for Alkalinity of all the samples collected.

5) *Chlorides:* Chlorides of the Ganga River water at Haridwar during mass bathing ranged between 1-2 mg/L (Table 6, Fig. 6). In majority of the sample's chlorides are not determined. The minimum value of chloride noted was 1mg/L (samples U4, U6 and D1) and the maximum value noted was 2 mg/L (sample D3). The values of Chlorides in all the samples are well within the limits prescribed by BIS and WHO [25,26]. The Ganga River's chloride levels are influenced by a variety of factors, including heavy metal contamination [52], climate change and socio-economic changes [27], and urban influences [28]. These factors have led to an increase in chloride levels, as seen in the case of Japan's rivers [53]. The presence of heavy metals in the river's sediments [54] and the seasonal variation in hydro-chemical parameters [29] further contribute to the changes in chloride levels. The decline in water quality due to untreated sewage and industrial effluents [32] and the presence of heavy metals in the river's surface water also play a role in these changes [55].

Table: 6 values of Chlorides of all the samples collected

S. No.	*SAMPLES	Chlorides (mg/L)	Guidelines
1	U1	0	Limits are within The Indian standards and WHO guidelines.
2	U2	0	
3	U3	0	
4	U4	1	
5	U5	0	
6	U6	1	
7	D1	1	
8	D2	0	
9	D3	2	
10	D4	0	
11	D5	0	
12	D6	0	

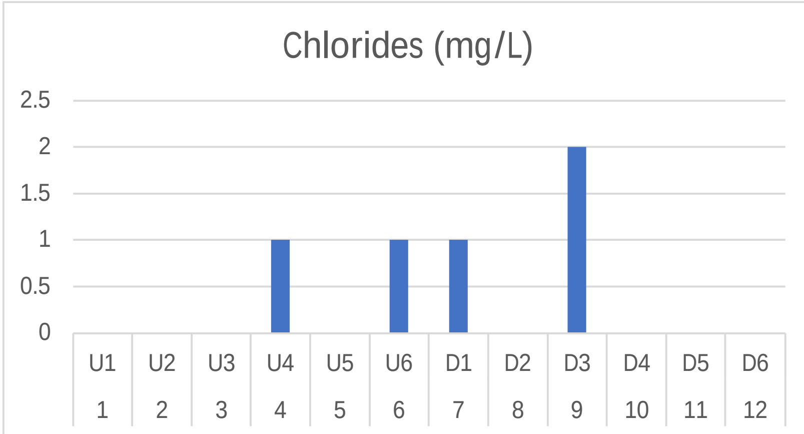

Figure: 6 Bar diagram for Chloride of all the samples collected.

6) *Calcium (Ca):* Magnesium of the Ganga River water at Haridwar during mass bathing ranged between 16-26 mg/L (Table 7, Fig. 7). The minimum value noted was 16 mg/L (samples D1) and the maximum value noted was 26 mg/L (sample D3). The values of Calcium for all the samples are well within the limits prescribed by BIS and WHO [25,26]. A range of factors contribute to changes in calcium levels in the Ganga River, with potential impacts on water quality and ecosystem health. These include water-rock interaction, vegetation, atmospheric deposition, and urban influences.
[55- 61]. For example, Pandey highlight the role of changing atmospheric deposition chemistry and urban influences in increasing nutrient and heavy metal concentrations in the river. These changes can lead to imbalances in nutrient ratios, potentially affecting river ecology [62]. The presence of Cryptomeria japonica in headwater streams can also alter calcium dynamics [59].

Table: 7 Values for Calcium of all the samples collected

S. No.	SAMPLES	*Calcium (mg/L)	Guidelines
1	U1	23	Values within Indian standards, there are no WHO guidelines mentioned.
2	U2	24	
3	U3	22	
4	U4	23	
5	U5	20	
6	U6	20	
7	D1	16	
8	D2	22	
9	D3	26	
10	D4	22	
11	D5	17	
12	D6	21	

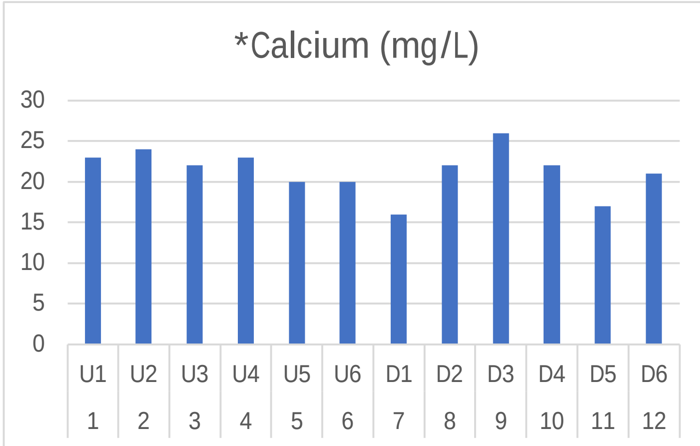

Figure: 7 Bar diagram for Calcium of all the samples collected.

7) Magnesium: Magnesium of the Ganga river water at Haridwar during mass bathing ranged between 1-13 mg/L (Table 8,Fig. 8). The minimum value noted for Magnesium was 1mg/L (sample U4) and the maximum value noted was 13mg/L (sample D1). The values of Magnesium for all the samples are well within the limits prescribed by BIS and WHO [25,26]. A range of studies have identified various factors contributing to changes in the magnesium levels of the Ganga River. Pandey [57,63]and Khan [64] allude to the impact of changing atmospheric deposition chemistry, with increased levels of nitrogen, phosphorus, and heavy metals being significant contributors. This is further exacerbated by urban influences, as evidenced by Pandey and Pandey, which have led to imbalances in nutrient limitation and shifts in the N:P: Si stoichiometry [28,58]. The presence of heavy metals in the river, particularly downstream of urban areas, has been highlighted by Matta (2018) and Pandey (2010), with the latter also noting a correlation between heavy metal concentration and atmospheric deposition. These changes have led to a slight to high level of pollution in the river, as indicated by Matta and Matta [29,30].

Table: 8 Values for Magnesium of all the samples collected.

S. No.	*SAMPLES	Magnesium (mg/L)	Guidelines
1	U1	3	Value are within Indian standards and WHO guide lines.
2	U2	6	
3	U3	2	
4	U4	1	
5	U5	5	
6	U6	5	
7	D1	13	
8	D2	3	
9	D3	4	
10	D4	8	
11	D5	7	
12	D6	8	

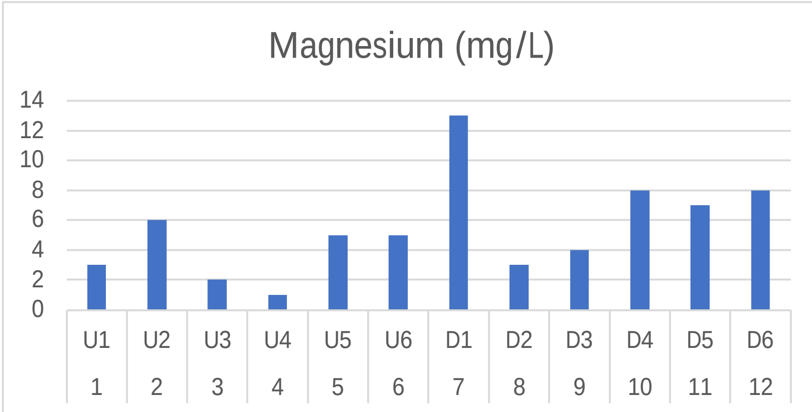

Figure: 8 Bar diagram for Magnesium of all the samples collected**.**

8) *Sodium (Na):* Magnesium of the Ganga river water at Haridwar during mass bathing ranged between 3.14-3.41 mg/L (Table 9,Fig. 9). The minimum value noted for sodium was 3.12 mg/L (sample D3) and the maximum value noted was 3.43 mg/L (sample D1). The values of Sodium for all samples are well within the limits prescribed by BIS and WHO [25,26].

A range of factors have been identified as causes of change in the sodium levels of the Ganga River. Pandey [58,63,] and Chatterjee [65] all point to the impact of changing atmospheric deposition chemistry, with increased levels of nitrogen, phosphorus, and sodium from this source. This is further exacerbated by the dissolution of saline-alkaline soils, which contributes to the river's sodium levels [65]. The changing stoichiometry of nitrogen, phosphorus, and silicon in the river, as well as the impact of carbon and nutrient loading, also play a role in altering the river's sodium levels [28,57]. These changes have significant implications for the river's ecology and water quality, as highlighted by Tiwari [66].

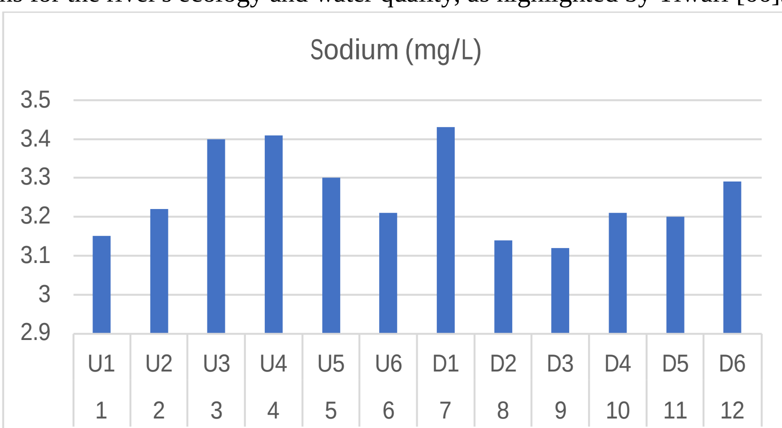

Figure: 9 Bar diagram for Sodium of all the samples collected.

Table: 9 values for Sodium of all the samples collected.

S. No.	*SAMPLES	Sodium (mg/L)	Guidelines
1	U1	3.15	Values are well within Indian standards and WHO guidelines.
2	U2	3.22	
3	U3	3.4	
4	U4	3.41	
5	U5	3.3	
6	U6	3.21	
7	D1	3.43	
8	D2	3.14	

9	D3	3.12	
10	D4	3.21	
11	D5	3.2	
12	D6	3.29	

9) *Potassium (K+):* Potassium of the Ganga river water at Haridwar during mass bathing ranged between 2.12-2.29 mg/L(Table 10,Fig. 10). The minimum value noted was 2.12 mg/L (sample D2) and maximum value noted was 2.29 mg/L (sample U4). A range of factors have been identified as causes of change in potassium (K+) levels in the Ganga River, including atmospheric deposition of nitrogen and phosphorus [63], climate change and socio-economic factors [27,67], and anthropogenic activities such as urban-industrial development [58]. These changes have significant impacts on the river's water quality, with increased nutrient and carbon loads from both point and non-point sources [31] and a decline in water quality due to untreated sewage and industrial effluents [52,68]. The specific impact of these changes on K+ levels in the river, however, is not explicitly addressed in the literature.

Table: 10 Values for Potassium of all the samples collected.

S. No.	*SAMPLES	Potassium (mg/L)	Guidelines
1	U1	2.17	No limits mentioned in Indian standards as well as in WHO guidelines.
2	U2	2.2	
3	U3	2.2	
4	U4	2.29	
5	U5	2.19	
6	U6	2.18	
7	D1	2.21	
8	D2	2.12	
9	D3	2.13	
10	D4	2.17	
11	D5	2.14	
12	D6	2.15	

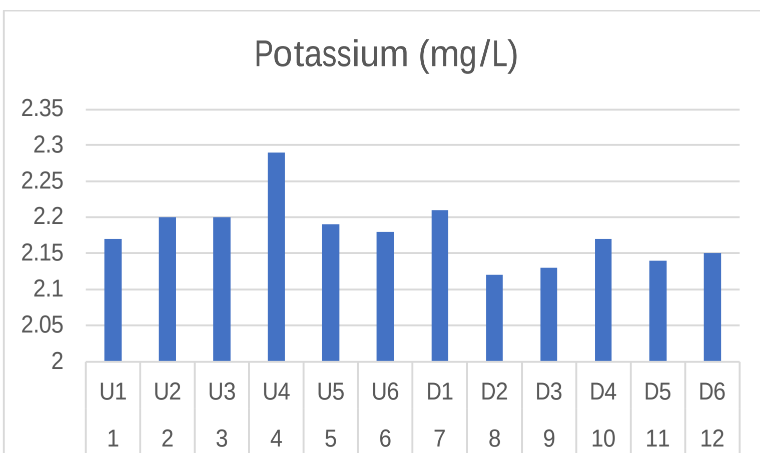

Figure: 10 Bar diagram for Potassium of all the samples collected

10) *Nitrate:* Sample analysis of Ganga river during mass bathing the level of nitrate ranged between 1.76-6.6 mg/L(Table 11,Fig. 11). The minimum value noted for nitrate was 1.76 mg/L (sample U2) and the maximum value noted was 6.6 mg/L (sample U3 and U5). All the 12 samples of upstream and downstream are well within the prescribed by the BIS [25] but the sample U3 and U5 values are marginally higher than WHO [26] prescribed value. A range of factors contribute to the changes in nitrate levels in the Ganga River, including atmospheric deposition of nitrogen and phosphorus [63], future climate and socio-economic changes [67], and non-point source-driven carbon and nutrient loading [69]. These changes have significant impacts on the river's water quality, with implications for aquatic life and human health [66,70]. The use of multivariate statistical techniques can help in evaluating and managing these changes [71].

Table: 11 Values for Nitrate of all the samples collected.

S. No.	*SAMPLES	Nitrate (mg/L)	Guidelines
1	U1	3.08	Values within Indian standards But maximum value above WHO guidelines.
2	U2	1.76	
3	U3	6.6	
4	U4	2.64	
5	U5	6.6	
6	U6	5.72	
7	D1	2.64	
8	D2	3.08	
9	D3	3.08	
10	D4	0	
11	D5	0	
12	D6	4.84	

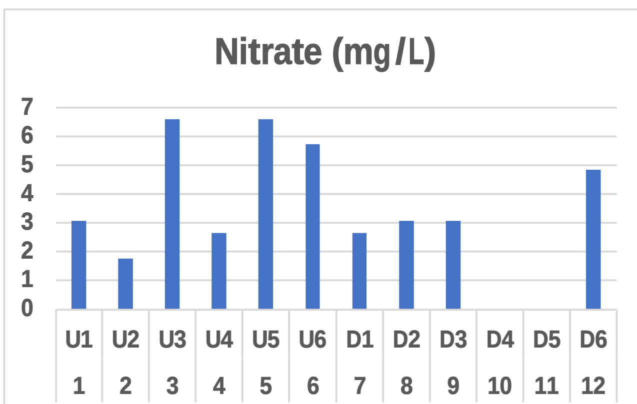

Figure: 11 Bar diagram for Nitrate of all the samples collected.

11) *BOD:* Bio-Chemical Oxygen Demand (BOD) of the Ganga river water at Haridwar during mass bathing ranged between 0.80-9.20 mg/L (Table 12, Fig. 12). The minimum value noted for BOD was 0.8 mg/L (sample D3 and D5) and the maximum value noted was 9.2 mg/L (sample U2). The values of BOD for all samples are well within the limits prescribed by BIS [25] but the value of BOD of sample U1 is well above prescribed WHO [26] values A range of factors have been identified as causes of change in the BOD of the Ganga River. These include increased atmospheric deposition of nitrogen and phosphorus [63], future climate and socio-economic changes [67], and the impact of sewage treatment plants' effluent discharge [72]. The COVID-19 lockdown also had a significant impact, leading to a decrease in dissolved oxygen and an increase in BOD [73]. The river's water quality has been further affected by non-point source-driven carbon and nutrient loading [69]. These changes have implications for the river's suitability for aquatic life [66] and the effectiveness of management strategies [27].

Table: 12 showing values for BOD of all the samples collected.

S. No.	*SAMPLES	BOD (mg/L)	Guidelines
1	U1	9.2	Values within Indian standards but maximum value above WHO guidelines.
2	U2	8.4	
3	U3	0	
4	U4	0	
5	U5	5.6	
6	U6	2.8	
7	D1	0	
8	D2	6.4	
9	D3	0.8	
10	D4	2.8	
11	D5	0.8	
12	D6	2	

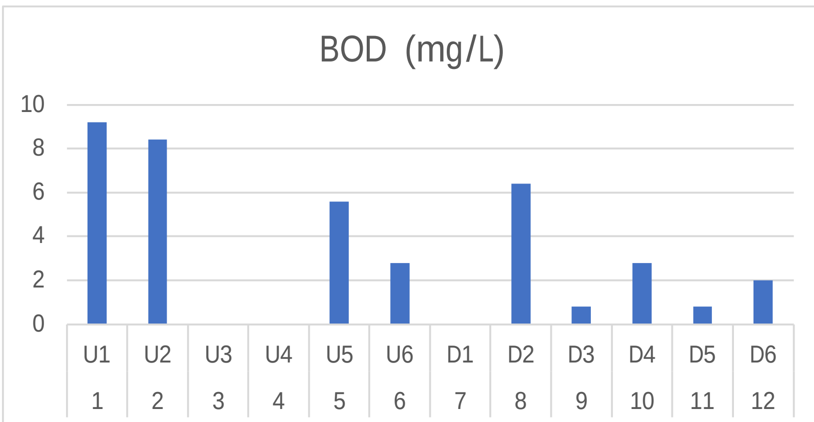

Figure: 12 Bar diagram for BOD of all the samples collected

Table: 13 Maximum and minimum values of all the parameters along with Standards.

S. No	Parameter	Unit	Maximum	Minimum	Average	Indian standards	WHO standards
1	pH		8.1	6.7	7.4	6.5-9.5	6.5-9.5
2	EC	µs/cm	193	164	178.5	-	-
3	TH	mg/L	92	62	77	300	200
4	Alkalinity	mg/L	92	56	74	200	-
5	Cl^-	mg/L	1	2	1.5	250	250
6	Ca^{++}	mg/L	26	16	21	75	-
7	Mg^{++}	mg/L	13	1	7	30	150
8	Na^+	mg/L	3.43	3.12	3.27	180	200
9	K^+	mg/L	2.29	2.12	2.20	-	-
10	NO_3^-	mg/L	6.6	1.76	4.18	45	3
11	BOD	mg/L	9.2	0.8	5	30	6

V. CONCLUSION

The systematic study conducted on the Ganga River during the Purnima Mass Bathing in Haridwar on 26th March 2013 provides valuable insights into the impact of mass bathing on water quality. Two key sampling points, Cable Bridge (Upstream) and Gau Ghat (Downstream), were chosen to assess changes in water quality as the river passes through bathing ghats in Har-ki-pauri.

The analysis of physico-chemical parameters, including pH, Electrical Conductivity (EC), Total Hardness (TH), Alkalinity, Chlorides, Calcium (Ca), Magnesium, Sodium (Na), Potassium (K+), Nitrate, and Bio-Chemical Oxygen Demand (BOD), revealed several noteworthy findings. The results indicate that the water quality of the Ganga River during mass bathing remains within acceptable limits set by Indian standards and World Health Organization (WHO) [25,26] guidelines for most parameters.

pH values ranged from 6.7 to 8.1, demonstrating the water's neutral to slightly alkaline nature. EC, indicative of water salinity, fluctuated between 164 and 193 µs/cm. The TH values, an important aspect of water hardness, fell within the range of 62 to 92 mg/L. Alkalinity ranged from 60 to 92 mg/L, while chloride levels remained minimal, between 1 and 2 mg/L.

The concentrations of calcium, magnesium, sodium, and potassium were within acceptable limits, indicating the absence of excessive mineral content. Nitrate levels, though generally within Indian standards, slightly exceeded WHO guidelines in a few samples. BOD values, representing organic pollution, ranged from 0.8 to 9.2 mg/L. While most values were within Indian standards, one sample exceeded the WHO guideline.

In conclusion, despite the practice of mass bathing, the water quality of the Ganga River at Haridwar during the Purnima Mass Bathing event remains relatively stable and within acceptable limits for the majority of parameters. Continuous monitoring and proactive measures are essential to ensure the preservation of this sacred river's ecological integrity and safeguard the health of those participating in religious rituals.

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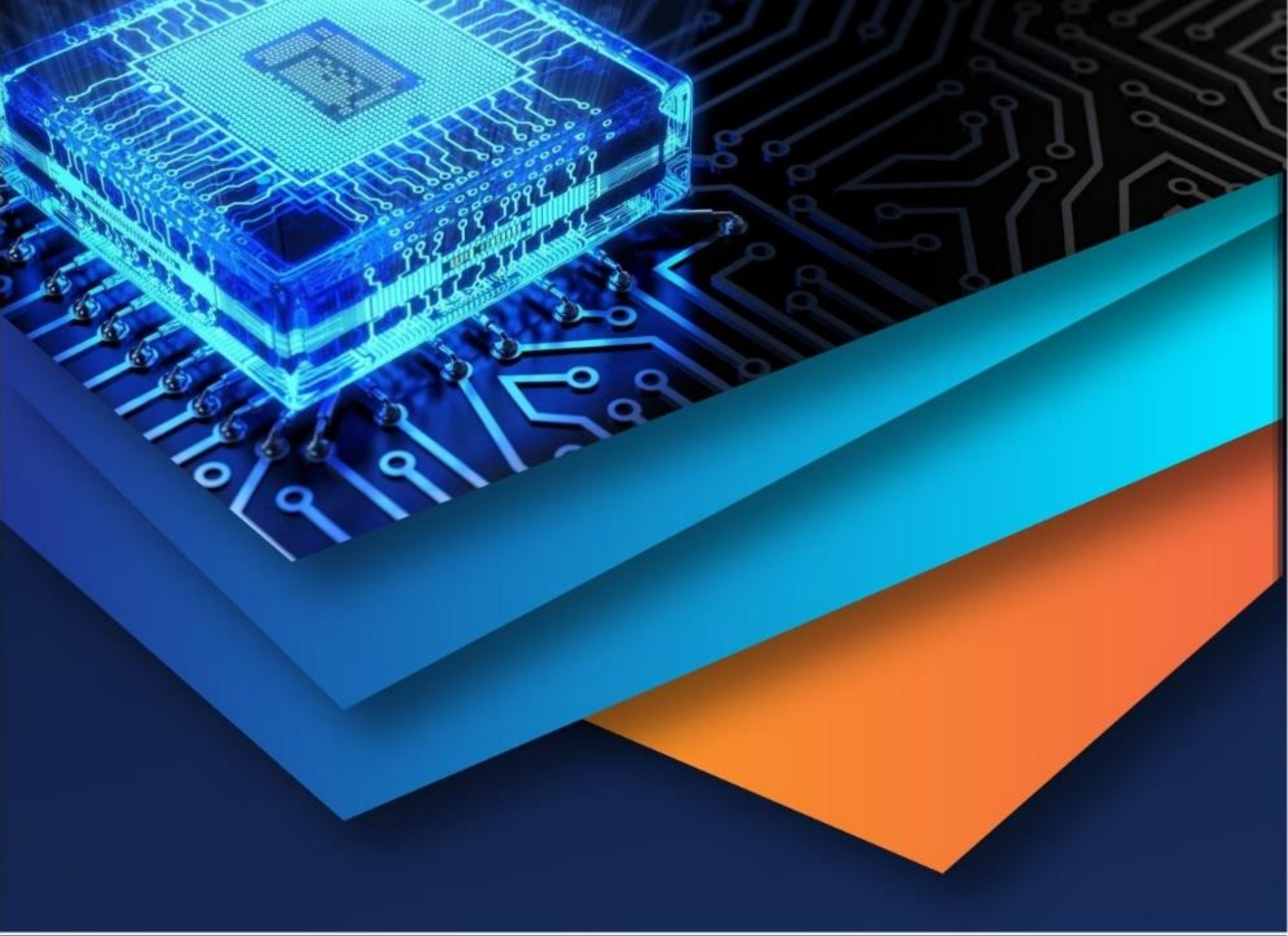

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