Chapter 25
Assessment of Water Quality of Indian Rivers:
Case Study of Ramganga, Dhela, and Kosi During Magh Mela 2021

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ABSTRACT

Magh Mela, held from 14th Jan. to 11th Mar. 2021, is an important yearly ritual held on the bank of river Ganga in Prayagraj, Uttar Pradesh. River Ganga is the longest and most sacred river of India. It originates in the Western Himalayas in the State of Uttarakhand and traverses a distance of approximately 2525 km through the states of Uttar Pradesh, Bihar, Jharkhand before meeting the Bay of Bengal in West Bengal. Magh Mela involves a holy dip (bathing) by pilgrims in the River Ganga at Prayagraj, Uttar Pradesh. To maintain the water quality of River Ganga during Magh Mela, the water quality of its tributaries/sub-tributaries was assessed. Among monitored rivers, Dhela was found to be the most polluted. Rivers Dhela and Bahela impacted the water quality of rivers Ramganga and Kosi, respectively. Moreover, the discharge of wastewater from drains, namely Pachhana drain and Dhandi drain (discharged into river Dhela) and Rampur drain (discharged into river Kosi), impacted the water quality of rivers.

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INTRODUCTION

Magh Mela, an important yearly ritual held on the bank of river Ganga in Prayagraj which involves a holy dip (bathing) into river Ganga, was held from 14th January 2021 to 11th March 2021. River Ramganga is an important tributary of river Ganga which originates in the southern slopes of Dudhatoli Hill in Pauri Garhwal district of the Indian state of Uttarakhand and joins river Ganga at village Katri Chandapur in the Hardoi district of U.P. River Ramganga receives wastewater from cities, towns and villages and tributaries (including rivers Kosi and Dhela).

There has been an unsettling rise in river contamination due to climate change and anthropogenic activities (Tung and Yaseen, 2020). Domestic wastewater and industrial effluents significantly contribute to the contamination of river water quality (Mokarram et al., 2020). Domestic and industrial wastewaters include a wide array of organic/inorganic contaminants such as metals, nitrogenous compounds, dyes, phenolic compounds, petroleum, surfactants, etc. (Madima et al., 2020). Metals are persistent and toxic to the environment and human health. Metals cause gastrointestinal, cardiovascular, hematological, hepatic, renal, neurochemical, neurobehavioral diseases (Maurya et al., 2019).

To maintain the water quality of River Ganga during Magh Mela, 2021 at Prayagraj, the assessment of the water quality of tributaries of river Ganga is necessary. There is a paucity of data on the assessment of water quality of rivers Ramganga, Dhela, and Kosi during Magh Mela. No study on the water quality of these rivers during the mass bathing occasion of Magh Mela has been reported. This study was carried out with the following objectives: (i) assessment of water quality of river Ramganga and its tributaries Kosi and Dhela; and (ii) assessment of pollution in drains discharging wastewater into rivers Kosi and Dhela.

MATERIALS AND METHODS

To maintain the water quality of River Ganga during Magh Mela, 2021 during January 14th to March 11th, 2021 at Prayagraj, sampling of rivers Ramganga, Kosi, and Dhela at 16 locations and three connecting drains (Pachhana drain, Dhandi drain, and Rampur drain) was carried out in Uttarakhand and Uttar Pradesh states of India. The monitoring locations along with geographical coordinates are shown in **Table 1**.

The sampling of rivers and drains was carried out during Magh Mela on fortnightly basis from Jan 04th to Mar 15th, 2021. The sampling schedule is shown in **Table 2**.

Round I: Jan 04th, 2021; Round II: Jan 18th – 19th, 2021; Round III: Feb 01st, 2021; Round IV: Feb 15th – 16th, 2021; Round V: Mar 1st – 3rd, 2021; Round VI: Mar 15th, 2021

Grab samples of river water were collected using polypropylene bottles from 30 cm below the water surface (CPCB 2017). The temperature was measured onsite using a thermometer. The samples for pH, color, conductivity, chemical oxygen demand, total dissolved solids, and total suspended solids were collected in pre-washed polypropylene bottles. Samples for dissolved oxygen, biochemical oxygen demand, total and fecal coliform were collected in glass bottles. Sampling bottles for total and fecal coliform bacteria analysis were pre-sterilized with 70% v/v ethanol before use. Samples for dissolved oxygen were preserved with $MnSO_4$ and NaN_3. After collection, the samples were transported to the laboratory in an ice-box and analyzed using standard protocols (APHA 2017).

Table 1. Sampling locations on rivers (Ramganga, Kosi and Dhela) and adjoining drains

Locations	Geographical coordinates
River Dhela and adjoining drains	
River Dhela before the confluence with Pachhana drain (upstream Faridnagar)	29.200699, 78.938412
Pachhana drain near Surya Pratap Pipe Industry, Kashipur (U.K.)	29.202066, 78.913602
River Dhela at Faridnagar, Thakurdwara (U. P.)	29.178715, 78.896908
Dhandi drain at Dhandi bridge, Moradabad-Kashipur Road (U.P.)	29.194824, 78.887084
Dhandi drain before the confluence with river Dhela	29.187611, 78.900904
River Dhela after the confluence with Dhandi drain (downstream Faridnagar)	29.176581, 78.896303
River Dhela near Bhojpur Bridge, U. P.	28.971954, 78.824159
River Dhela downstream Bhojpur bridge	28.932467, 78.810696
River Kosi and adjoining drains	
River Kosi before the confluence with river Bahela	28.819632, 78.981674
River Kosi after the confluence with river Bahela and before confluence with Rampur drain	28.786423, 78.986267
Rampur drain before the confluence to river Kosi at Ajeetpur (U.P.)	28.755712, 79.022035
River Kosi after the confluence of Rampur drain and before confluence with river Ramganga	28.647040, 79.021775
River Ramganga and adjoining drains	
River Ramganga before the confluence with river Dhela at Agwanpur (U.P.)	28.894237, 78.744285
River Ramganga after the confluence of river Dhela at Katghar (U.P.)	28.823365, 78.800378
River Ramganga before the confluence with river Kosi	28.634598, 79.027699
River Ramganga after the confluence of river Kosi at Shahbad (U.P.)	28.553985, 79.048635

Table 2. Sampling schedule for assessment of water quality of rivers and drains

Locations	Fortnightly monitoring rounds					
	I	II	III	IV	V	VI
River Dhela before confluence with Pachhana drain (upstream Faridnagar)	✘	✘	✘	✘	✔	✘
Pachhana drain near Surya Pratap Pipe Industry, Kashipur (U.K.)	✘	✔	✘	✘	✔	✘
River Dhela at Faridnagar, Thakurdwara (U. P.)	✘	✔	✘	✘	✔	✘
Dhandi drain at Dhandi bridge, Moradabad-Kashipur Road (U.P.)	✘	✔	✘	✘	✔	✘
Dhandi drain before confluence with river Dhela	✘	✘	✘	✘	✔	✘
River Dhela after confluence with Dhandi drain (downstream Faridnagar)	✘	✘	✘	✘	✔	✘
River Dhela near Bhojpur Bridge, U. P.	✔	✔	✔	✔	✔	✔
River Dhela downstream Bhojpur bridge	✘	✘	✘	✘	✔	✘
River Kosi before confluence of river Bahela	✘	✘	✘	✘	✔	✘
River Kosi after confluence of river Bahela and before confluence with Rampur drain	✔	✔	✔	✔	✔	✔
Rampur drain before confluence to river Kosi at Ajeetpur (U.P.)	✘	✔	✘	✘	✔	✘
River Kosi after confluence of Rampur drain and before confluence with river Ramganga	✘	✔	✘	✘	✔	✘
River Ramganga before confluence with river Dhela at Agwanpur (U.P.)	✔	✔	✔	✔	✔	✔
River Ramganga after confluence of river Dhela at Katghar (U.P.)	✔	✔	✔	✔	✔	✔
River Ramganga before confluence with river Kosi	✘	✘	✘	✘	✔	✘
River Ramganga after confluence of river Kosi at Shahbad (U.P.)	✔	✔	✔	✔	✔	✔

Wastewater samples from drains (using grab sampling technique) were collected before the confluence point of the drains with the rivers. The temperature was analyzed onsite and samples for pH, color, conductivity, total dissolved solids, total suspended solids, and chemical oxygen demand, were collected in pre-washed polypropylene bottles. Samples for biochemical oxygen demand, total and fecal coliform were collected in glass bottles. After collection, samples were transferred to the laboratory in an ice-box and analyzed using standard protocols (APHA 2017).

RESULTS AND DISCUSSION

River Water Quality

The color of water regulates the penetration of sunlight into the river depth which, in turn, affects photosynthesis. The pH river water is influenced by various biological, physical, and geochemical processes. The water chemistry encompasses the equilibrium of the components of CO_2-systems such as CO_2, $H_2CO_3^-$, and CO_3^{2-}. The CO_2 content in river water is governed by the pressure equilibrium of CO_2 with the atmosphere along with photosynthesis, respiration of flora and the degradation of organic matter. The pH is directly proportional to the flow of the river where acidic conditions prevail, due to the predominance of water chemistry. However, in alkaline environments, the CO_2 concentration governing the pH is driven by photosynthesis. Photosynthesis is a function of solar radiation, nutrients, temperature, and algal biomass. (Moatar et al., 1999; Tibby et al., 2003; Han and Liu, 2007)). The maintenance of optimum pH in river water is essential for the survival of marine life (Matta et al., 2017).

Dissolved oxygen in rivers regulates important processes in the aquatic environment (Rabee et al., 2011; Haritash et al., 2016; Csábrági et al., 2019). The DO content in the river is driven by the temperature and photosynthesis process. It is directly proportional to the rate of photosynthesis and inversely proportional to the rates of respiration and organic degradation (Kannel et al., 2007; Vidyarthi et al., 2020a). DO content is also affected by some inorganic substances such as H_2S, ammonia, nitrite, ferrous iron, and certain oxidizable substances (Srivastava et al., 2011).

The biochemical oxygen demand and chemical oxygen demand indicate the level of organic pollution in a river. The discharge of sewage and industrial effluents increases the BOD and COD in a river (Vigiak et al., 2019; Vidyarthi et al., 2020b). BOD shows the biodegradable portion however COD depicts both biodegradable and non-biodegradable pollution (Smitha and Shivashankar, 2013; Jouanneau et al., 2014; Khan et al., 2016; Anyanwu and Umeham, 2020).

The epidemiological studies have reported that contact with waters containing high content of fecal coliform may induce gastrointestinal and respiratory illnesses. The coliforms decay with increased water temperature, pH, and nutrient scarcity combined with elevated predation and parasitism (Hong et al., 2010). The presence of fecal coliform in aquatic environments may indicate that the water has been contaminated with the fecal material of humans or other animals. The reason for the presence of fecal coliform in river water could be (i) direct discharge of untreated sewage; (ii) fecal bacteria remaining in the treated wastewater, and (iii) open defecation on the banks of the river (Bravo et al., 2017; Haque et al., 2019).

Water Quality of River Dhela

In river Dhela, color ranged as BDL-68 Hazen, pH 7.3-8.3, conductivity 639-1837 µmho/ cm, dissolved oxygen NIL-8.89 mg/l, BOD 11-168 mg/l, COD 39-364 mg/l, TDS 402-1006 mg/l, TSS 48-91 mg/l, total coliform 79×10^3 - 24×10^7 MPN/100 ml and fecal coliform 68×10^2 - 13×10^7 MPN/100 ml. The various monitoring locations on river Dhela are shown in **Figure 1**.

Figure 1. (a) River Dhela before the confluence with Pachhana drain (upstream Faridnagar); (b) River Dhela before the confluence of Dhandi drain at Faridnagar, Thakurdwara (U.P.); (c) River Dhela after the confluence with Dhandi drain; (d & e) River Dhela near Bhojpur bridge (U.P.); and (f) River Dhela downstream Bhojpur bridge

Dissolved oxygen in river Dhela before the confluence with Pachhana drain to Faridnagar, Tharkurdwara ranged as 2.01-8.89 mg/l, BOD as 11-53 mg/l, COD as 39-162 mg/l (**Table 3**). The dissolved oxygen in river Dhela after the confluence with Dhandi drain reduced to 1.72 mg/l and BOD & COD increased to 168 mg/l and 364 mg/l, respectively. It has been observed that the Pachhana drain impacted the water quality of river Dhela due to the discharge of untreated or partially treated domestic/industrial wastewater into the river. River Dhela meets river Ramganga near the Moradabad district of Uttar Pradesh. The pollution in river Dhela may impact the water quality of river Ramganga.

Table 3. Water quality of river Dhela during Magh Mela-2021

River location	Sampling round	Temperature	Color	pH	Conductivity	DO	BOD	COD	TDS	TSS	TC	FC
River Dhela before the confluence with Pachhana drain	V	24.2	68	7.8	1142	2.01	53	162	610	89	24×10^7	13×10^7
River Dhela at Faridnagar, Thakurdwara (U.P.)	II	19.6	16	7.7	639	5.56	11	39	402	-	-	-
	V	25.3	33	8.3	1003	8.89	25	108	538	48	49×10^4	22×10^4
River Dhela after the confluence with Dhandi drain	V	25.3	39	7.6	1251	1.72	168	364	822	87	54×10^5	46×10^4
River Dhela near Bhojpur Bridge	I	17.3	BDL	7.4	778	0.85	53	133	518	-	-	-
	II	18.9	37	7.3	910	NIL	37	147	610	-	-	-
	III	16.6	33	7.6	931	0.2	55	147	566	-	-	-
	IV	21	BDL	7.5	857	0.16	47	132	554	-	-	-
	V	20.1	27	7.8	1285	5.16	25	112	706	61	13×10^5	33×10^4
	VI	25.8	67	7.3	1837	0.51	156	343	1006	-	-	-
River Dhela downstream Bhojpur bridge	V	23.5	22	7.9	1172	6.76	26	105	650	91	79×10^3	68×10^2

TDS total dissolved solids, TSS total suspended solids, DO dissolved oxygen, BOD biochemical oxygen demand, COD chemical oxygen demand, TC total coliform, FC fecal coliform; All parameters are expressed in mg/l except pH, Temperature (ºC), color (Hazen), conductivity (µmho/cm) and TC/FC (MPN/100 ml)

Water Quality of River Kosi

In river Dhela, color ranged as BDL-45 Hazen, pH 7.6-8.4, conductivity 587-1061 µmho/ cm, dissolved oxygen 3.69-10.79 mg/l, BOD BDL-28 mg/l, COD 6-99 mg/l, TDS 352-560 mg/l, TSS 22-144 mg/l, total coliform 4300-46000 MPN/100 ml and fecal coliform 200-6800 MPN/100 ml (**Table 4**). DO, BOD and faecal coliform in river Kosi before the confluence with river Bahela were 10.79 mg/l, BDL, 200 MPN/100 ml, respectively. After the confluence with river Bahela, deterioration in the water quality of river Kosi was observed. DO and BOD in river Kosi after the confluence with river Bahela ranged as 3.69-8.23 mg/l and 2-20 mg/l, respectively. The monitoring locations on river Kosi are shown in **Figure 2**. The DO content in river Kosi reduced after the confluence with river Bahela which indicated the impact of river Bahela on the water quality of river Kosi. After the confluence with river Bahela, Rampur drain meets river Kosi which further reduced the DO content in River Kosi.

TDS total dissolved solids, TSS total suspended solids, DO dissolved oxygen, BOD biochemical oxygen demand, COD chemical oxygen demand, TC total coliform, FC fecal coliform; All parameters are expressed in mg/l except pH, Temperature (ºC), color (Hazen), conductivity (μmho/cm) and TC/FC (MPN/100 ml)

Figure 2. (a) River Kosi before the confluence of river Bahela; and (b) River Kosi after the confluence with river Bahela & before the confluence with Rampur drain

Table 4. Water quality of river Kosi during Magh Mela-2021

River location	Sampling round	Temperature	Color	pH	Conductivity	DO	BOD	COD	TDS	TSS	TC	FC
River Kosi before the confluence of river Bahela	V	23.2	BDL	8.4	640	10.79	BDL	06	384	22	49×10^2	200
River Kosi after the confluence with river Bahela & before the confluence of Rampur drain	I	17.6	BDL	7.8	611	6.20	3.6	17	416	-	-	-
	II	18.1	09	7.6	664	3.69	3.8	14	412	-	-	-
	III	17	45	7.6	663	4.5	20	67	388	-	-	-
	IV	21.7	BDL	7.8	587	8.23	4.9	20	358	-	-	-
	V	23.5	BDL	8.1	672	5.83	3.5	13	352	79	43×10^2	1300
	VI	25.5	15	7.8	736	7.96	02	12	402	-	-	-
River Kosi after the confluence of Rampur drain & before the confluence with river Ramganga	II	18.4	09	8.1	644	8.56	1.6	06	372	-	-	-
	V	24.8	36	7.8	1061	4.29	28	99	560	144	46×10^3	68×10^2

Water Quality of River Ramganga

In river Ramganga, color ranged as BDL-49 Hazen, pH 7.2-8.4, conductivity 253-552 µmho/ cm, dissolved oxygen 3.24-9.42 mg/l, BOD 1-12 mg/l, COD 7-71 mg/l, TDS 158-360 mg/l, TSS 13-66 mg/l, total coliform 11×10^2 - 11×10^4 MPN/100 ml and fecal coliform 180 - 79×10^3 MPN/100 ml (**Table 5**).

TDS total dissolved solids, TSS total suspended solids, DO dissolved oxygen, BOD biochemical oxygen demand, COD chemical oxygen demand, TC total coliform, FC fecal coliform; All parameters are expressed in mg/l except pH, Temperature (ºC), color (Hazen), conductivity (µmho/cm) and TC/FC (MPN/100 ml)

DO, BOD and fecal coliform in river Ramganga before the confluence with river Dhela ranged as 7.18-9.42 mg/l, 1-7.4 mg/l, and 180 MPN/100 ml, respectively. After the confluence with river Dhela, the water quality of river Ramganga deteriorated. The DO, BOD, and fecal coliform river Ramganga after the confluence with river Dhela were 4.49-6.21 mg/l, 2.9-18 mg/l, and 79×10^3 MPN/100 ml, respectively. The monitoring locations on river Ramganga are shown in **Figure 3**. The pollution in river Dhela impacted the water quality of river Ramganga. In another study conducted by Khan et al. (2016), pH - 7.3 and biochemical oxygen demand - 15 mg/l has been reported in river Ramganga.

Pollution Load due to Drains

Three drains were monitored during Magh Mela namely Pachhana drain and Dhandi drain which discharges into river Dhela and Rampur drain which discharge into river Kosi. Wastewater characteristics of these three drains are shown in **Table 6**.

TDS total dissolved solids, TSS total suspended solids, DO dissolved oxygen, BOD biochemical oxygen demand, COD chemical oxygen demand, TC total coliform, FC fecal coliform; All parameters are expressed in mg/l except pH, Temperature (ºC), color (Hazen), conductivity (µmho/cm) and TC/FC (MPN/100 ml)

Table 5. Water quality of river Ramganga during Magh Mela-2021

River location	Sampling round	Temperature	Color	pH	Conductivity	DO	BOD	COD	TDS	TSS	TC	FC
Ramganga, before the confluence of river Dhela at Agwanpur	I	16.7	BDL	7.4	253	9.42	1.2	09	164	-	-	-
	II	17.9	BDL	7.4	304	7.18	01	10	198	-	-	-
	III	15.8	BDL	7.5	312	9	7.4	48	160	-	-	-
	IV	19.6	BDL	7.5	280	9.34	3.6	28	172	-	-	-
	V	20.8	27	8.4	276	9.16	1.3	09	158	50	11×10^2	180
	VI	22.4	37	7.8	295	8.38	02	08	168	-	-	-
Ramganga, after the confluence of river Dhela at Katghar	I	19.3	BDL	7.6	352	6.21	9.6	23	220	-	-	-
	II	17.9	15	7.2	530	5.13	18	71	296	-	-	-
	III	17.3	49	7.7	417	6.1	11	63	236	-	-	-
	IV	20.6	BDL	7.6	382	5.54	2.9	07	238	-	-	-
	V	21.3	BDL	7.7	394	4.56	7.6	33	206	66	11×10^4	79×10^3
	VI	25.6	15	7.3	434	4.49	12	49	238	-	-	-
River Ramganga before the confluence of river Kosi	V	20.5	BDL	7.9	410	7.6	4.2	16	212	21	79×10^2	2300
Ramganga, after the confluence of river Kosi at Shahbad	I	18.1	BDL	7.7	427	3.24	6.3	30	272	-	-	-
	II	17.5	11	7.8	536	3.55	5.5	13	360	-	-	-
	III	16.8	49	7.7	529	4.6	11	51	290	-	-	-
	IV	20.6	BDL	7.7	476	5.26	5.1	15	274	-	-	-
	V	21	BDL	7.8	450	4.7	5.5	17	230	13	27×10^3	2000
	VI	24.5	BDL	7.7	552	7.17	05	13	306	-	-	-

Wastewater samples collected from the Pachhana drain showed BOD as 104-154 mg/l and COD as 249-258 mg/l. In Dhandi drain, BOD varied as 101-386 mg/l, COD as 255-740 mg/l, and TDS as 632-956 mg/l. High BOD and COD indicated the possibility of untreated/partially treated industrial discharge from industries in the catchment of the drain. Sludge flakes were found floating on the surface of the Pachhana and Dhandi drain. Rampur drain carried pungent-smelling dark-colored wastewater and solid waste dumping along the drain was observed (**Figure 4**). In Rampur drain, BOD and COD varied as 130-139 mg/l and 339-416 mg/l, respectively.

Figure 3. (a) River Ramganga before the confluence with river Dhela at Agwanpur (U.P.); (b) River Ramganga after the confluence with river Dhela at Katghar (U.P.); and (c) River Ramganga after the confluence with river Kosi at Shahbad (U.P.)

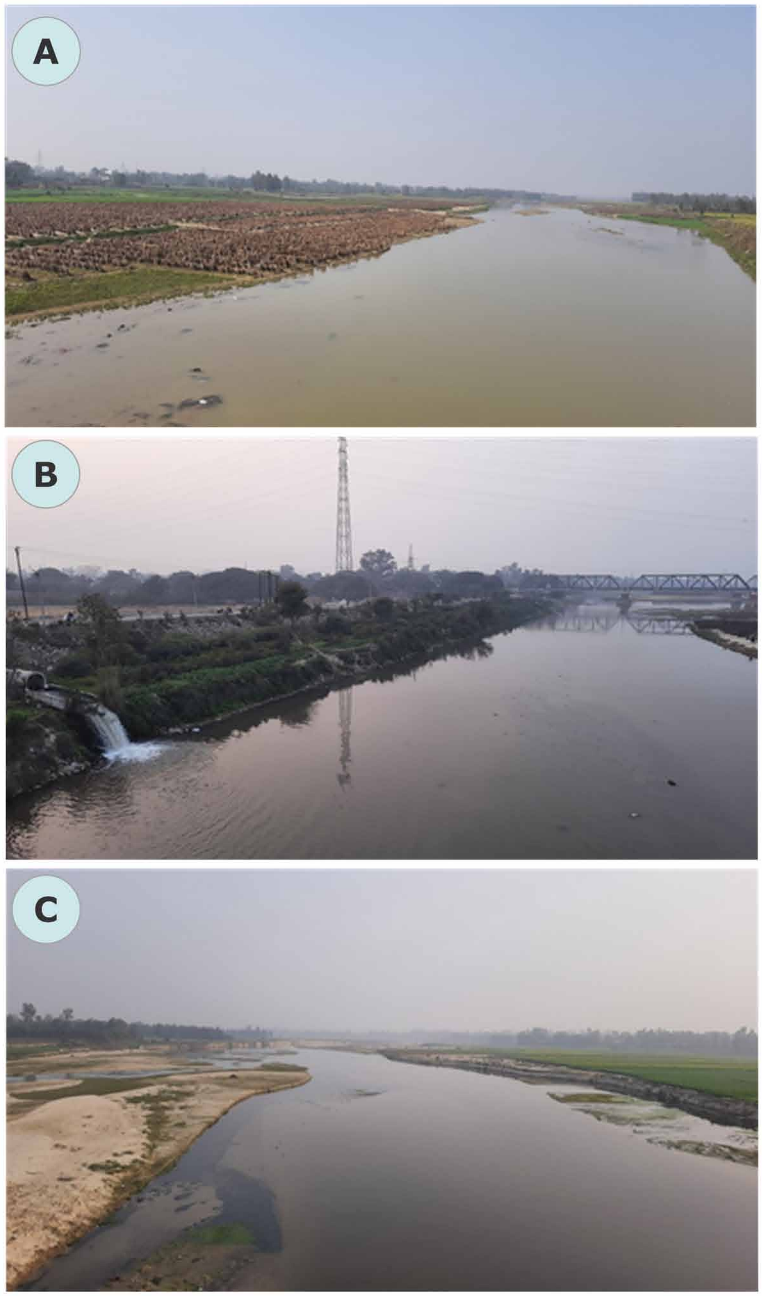

Table 6. Characteristics of wastewater in drains discharging into rivers Dhela and Kosi

Monitoring location	Sampling round	Temperature	pH	Color	TDS	TSS	BOD	COD	Conductivity	TC	FC
Pachhana drain near Surya Pratap Pipe Industry, Kashipur (U.K.)	II	21.1	6.7	65	952	105	104	249	-	-	-
	V	20.5	6.9	26	628	67	154	258	1210	16×10^6	54×10^5
Dhandi drain at Dhandi bridge, Moradabad-Kashipur Road (U.P.)	II	19.8	6.8	102	708	152	101	255	-	-	-
	V	24.2	6.7	59	956	84	386	740	1490	14×10^5	27×10^4
Dhandi drain before confluence with river Dhela	V	23.5	6.8	40	632	184	299	507	1502	13×10^6	61×10^4
Rampur drain	II	21.1	6.8	139	1004	153	130	339	-	-	-
	V	21.5	7.1	43	684	252	139	416	1495	70×10^5	17×10^5

CONCLUSION

Magh Mela is a yearly event that takes place at Prayagraj wherein pilgrims take a holy dip in the river Ganga. To maintain the water quality of river Ganga during Magh Mela, fortnightly monitoring of rivers Ramganga, Dhela, and Kosi was carried out at various locations in the states of Uttarakhand and Uttar Pradesh. Among monitored rivers, Dhela was found to be the most polluted. *Rivers Dhela and Bahela impacted the water quality of rivers Ramganga and Kosi, respectively.* Moreover, the discharge of wastewater from drains namely Pachhana drain and Dhandi drain (discharged into river Dhela), and Rampur drain (discharged into river Kosi) impacted the water quality of rivers. The present study suggests that it should be ensured that there is no discharge of untreated/partially treated domestic as well as industrial wastewater into drains discharging into rivers. Proper functioning of sewage pumping stations shall be ensured so that no untreated sewage should be discharged through tapped drains. Sewage treatment plants shall be operated properly and treated sewage shall meet the prescribed sewage discharge norms. Industrial effluents not meeting the treated effluent quality standards shall not be discharged into the rivers. The feasibility of applying alternate decentralized wastewater treatment technologies such as constructed wetlands shall be explored to reduce the load on conventional treatment systems and restore the water quality of rivers.

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Figure 4. (a) Pachhana drain; (b) Dhandi drain; and (c) Rampur drain

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