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Water quality in upper and middle stretches of river Ganga, India in relation to varying anthropogenic pressures

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Abstract
River Ganga, one of the most important rivers of India, has been facing various types and magnitudes of anthropogenic stress along its course of run through the thickly populated river basin. The present investigation has been conducted for three seasons, for the year 2017-2018 for the upper and middle Ganga basins. The analysis has been performed to examine the variations in the concentrations of diverse water and sediment quality parameters from Devprayag to Haridwar, Bithoor to Kanpur, and Varanasi areas, respectively. The sampling locations have been chosen based on the distinct anthropogenic strains a site encounters. Temperature. pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total coliform (TC), Faecal coliform (FC), Hardness, Total Alkalinity (TA), Nitrate, Phosphate and Total Kjeldahl Nitrogen (TKN) were examined for water using the standard methods of APHA, whereas the parameters evaluated for sediment examination contained Nitrate, Phosphate, TKN and Total Organic Carbon (TOC). The parameter values of DO, BOD, TDS, and TC corresponded with the highest permissible limits specified for the surface water by Central Pollution Control Board (CPCB). Most Upper Ganga basin sites were found in the Water Quality Class A regarding nearly all the parameters, except UG-01 and UG-02, where Class C was found concerning coliforms. UG-05 and UG-06 came under water quality class C and E, respectively, considering DO. In the middle Ganga stretch one, in terms of TDS, all spots were categorized into Class A and, for coliforms, were in Class C, whereas in terms of DO, it delivered an inconsistent trend. Likewise, in the middle Ganga basin two, in terms of TDS, all sites were classified into Class A, whereas DO show a fickle trend. The BOD and TC values transcended all the permissible limits, so they were not indexed into any class. A correlation matrix was established between the various variables. Strong positive correlations were seen between FC-Phosphate, Hardness-TDS, TA-TDS, TA-Temperature, TC-pH, and Phosphate-pH. In contrast, considerable negative correlations were noticed between DO-Temperature, DO-pH, and BOD-DO. The water quality was unacceptable for consuming and cleansing at nearly all locations as the maximum acceptable limitations were surpassed, showcasing the consequences of elevated human actions at all the sites.

Keywords: River Ganga, water quality, pollution, Best use designated class, anthropogenic pressure

Introduction

Water is one of the most indispensable natural resources that serves as the lifeline of humankind and other living beings. While oceans hold around 97 percent of the world's water, the freshwater resources account for just three percent (1386 million cubic kilometers). Around 69 percent of the freshwater is trapped in ice and glaciers, while only 0.3 percent of the freshwater is found in rivers and lakes that is suitable for human use (Postel *et al*. 1996) [11]. Nations have been grouped according to their extent of water shortage employing their per capita annual water resource (AWR) (Gosain *et al*. 2006) [5]. The continuation of all life forms, the provision of food, the growth of the economy, and overall health all rely on water. It is a truly one-of-a-kind gift from nature to human civilization since it can't be exchanged for a majority of its uses, is challenging to clean it up upon contamination, is expensive to transport, and is tough to de-pollute (Kumar *et al*. 2005) [9]. Surface availability of water per person in India was 2309 m^3 in 1991 and 1902 m^3 in 2001, but by the years 2025 and 2050, these figures are anticipated to decline even further to 1401 m and 1191 m^3 (Ramesh and Yadava, 2005) [13]. 4000 km^3 of precipitation, comprising snowfall, fall on India annually.

Rivers are regarded as the lifeblood of humanity and are vital to sustaining the livelihoods of the populace and their traditions by bringing them a variety of advantages. India's extensive cultural legacy places a high value on the river Ganga. The river is regarded as being extremely pious and pure, and bathers are said to be cleansed in body, mind, and spirit by it. It offers water for a wide range of uses, including drinking and non-drinking, energy production, water sports, livelihood generation, fostering ecotourism, and providing habitat for numerous native and migratory birds. The river has regrettably been designated among the top 10 rivers in the world that suffer from the greatest pollution stresses and threats due to the booming population, sizable migrations from rural to urban regions, unorganized urban and industrial enterprises, the building of dams and barrages throughout the river reaches, release of untreated waste from cities and factories, floral and religious offerings, burning of the corpses on the banks of the river, and others (Khwaja *et al*., 2001, WRG, 2009) [8, 18]. The water quality and biodiversity of rivers are both impacted by anthropogenic activities like overgrazing and deforestation (Joshi *et al*. 2009) [7]. River Ganga is noted for having consistently clean, fresh water. Nonetheless, various studies showed that excessive sewage pollution is causing a decrease in the amount of dissolved oxygen in the water and an increase in the number of coliform bacteria, indicating a drop in the water's ability to dilute its contaminants (Agarwal, 2015; Sharma and Kaushik, 2018) [1, 14]. Due to development, the Ganga stream's sediment quality has been negatively impacted (Singh *et al*., 2002) [16]. The characteristics of ground water rejuvenation and the systems and processes that currently exist in rivers are both being drastically altered by the urban clusters that line their banks (Misra, 2011) [10]. Some earlier investigations on the Ganga demonstrate that the river's ecology and water quality have both declined. Sewage contamination and organic solid and liquid wastes have been determined to be the primary causes of river Ganga pollution in Haridwar (Bhutiani *et al*., 2016) [3]. The surge in organic contaminants and wastewater is triggering a rise of pathogenic organisms, which is creating microbiological load in freshwater sources and reservoirs in Uttarakhand (Tyagi *et al*., 2015) [17].

Quality of Kanpur City's treated water from filtration plants, surface water, and ground water have also shown impact on Ganga river (Trivedi *et al*. 2010). The Ganga plain's development has a significant negative impact on the stream's silt quality (Singh *et al*. 2002) [16]. Studies have been conducted to evaluate the Ganga River's water quality by contrasting the pre and post Ganga Action Plan situations. The water quality can change when the anthropogenic activities are minimized, as observed in case of Covid-19 Pandemic lockdown. However, this has been found to result in restoration of water quality only in some areas for a short time. For long term restoration of the river, holistic strategic plans and policy interventions are required. The water quality dynamics of the Ganga River in Varanasi across geographical and temporal variability have been carried out along with the land use changes being analyzed, having closer associations with water quality at Varanasi. Varanasi's cities were reported to more accountable for the Ganga's water pollution owing to the persistence of the pollution there (Rai, 2013) [12].

The present study aims at analyzing and comparing the quality of water in the upper stretch of river Ganga encompassing Devprayag and the Rishikesh-Haridwar region, and the middle stretch covering the regions of Bithoor -Kanpur and Varanasi region covering various ghats. The anthropogenic activities in the two sections of the river show marked variations and hence the river water quality has been assessed and compared in the light of these stressors.

Materials and Methods

Study Area

The study area incorporates 6 sites from Devprayag to Haridwar and 8 locations each from Bithoor to Kanpur and Varanasi region respectively as shown in Figure 1. The study sites have been depicted along with the GPS locations and prevailing anthropogenic activities in Table 1.

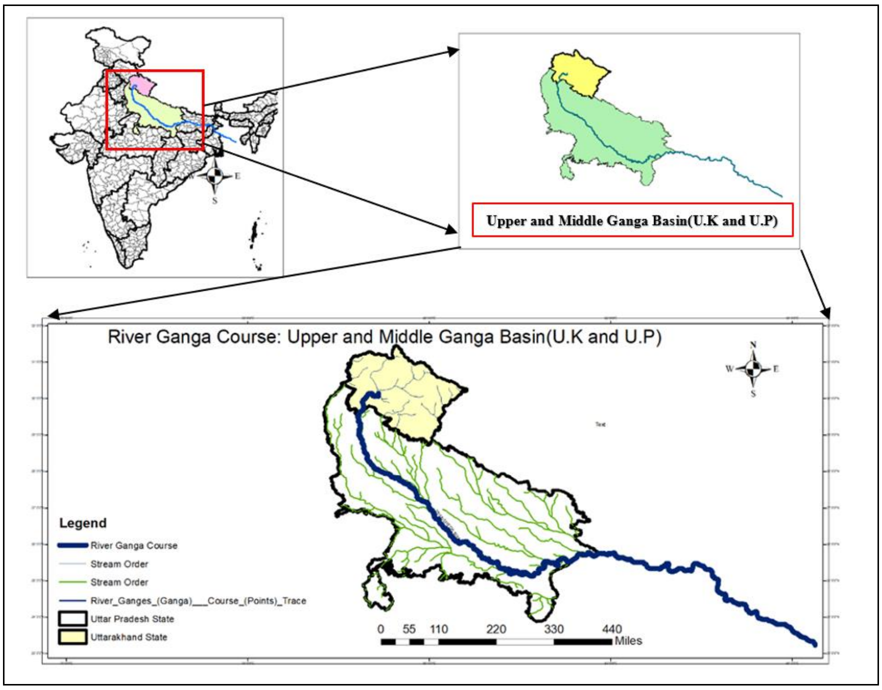

Fig 1: River Ganga Basin (Upper and Middle Ganga) and its course, including states of Uttarakhand and Uttar Pradesh. (Made using ArcGIS 10.7.1 version software)

River Ganga stems at the Gangotri glacier in Gaumukh at an elevation of about 3892 m (12,770 feet) The headwater stream of the Ganga river is Bhagirathi, and multiple diminutive streamlets like Alaknanda, Pindar, Bhilganga, Dhauliganga, and Mandakini comprise the embryones of the Ganga. River Ganga derives its name at the convergence point of Alaknanda and Bhagirathi. It travels a distance of 2525 km before draining its water into the Bay of Bengal. Innumerable branches unite the river in its route.

Table 1: Description of the sampling stations along river Ganga (Upper and Middle Ganga basins)

Sampling Site Number	*Sampling Site Name*	*Latitude*	*Longitude*	*Elevation*	*Customary Activity*
UG-01.	Alaknanda	30.14557°	78.59788°	455m	Road Construction, Bathing
UG-02.	Bhagirathi	30.14589°	78.59765°	556m	Kayaking, Road Construction, Bathing
UG-03.	Confluence Al+Bh	30.14552°	78.59776°	453m	Religious Bathing
UG-04.	Swargashram	30.11735°	78.31067°	335m	Religious Hotspot
UG-05.	Neem Beach	30.13354°	78.33189°	346m	Water Sports (Rafting)
UG-06.	Vishwakarma Ghat	29.93142°	78.13948°	273m	Ritualistic Spot, Bathing
MG$_1$-01	Dhruv Ghat	26.61759°	80.27345°	103m	Washing, Bathing
MG$_1$-02	Chatrapati Shivaji Ghat	26.61606°	80.27440°	95m	Washing and Cattle Wallowing
MG$_1$-03	Brahmavrat Ghat	26.61391°	80.27483°	98m	Religious Dipping and Washing,Boating
MG$_1$-04	Patthar Ghat	26.61279°	80.27522°	96m	Washing, Cattle Wallowing
MG$_1$-05	Ganga Barrage	26.50622°	80.31801°	84m	Picnic Hotspot, Bathing, Boating
MG$_1$-06	Rani Ghat	26.49666°	80.32472°	92m	Ritualistic Activity, Fishing
MG$_1$-07	Bhairav Ghat	26.49461°	80.32713°	99m	Cremation Site, Religious Hotspot
MG$_1$-08	Permat Ghat	26.48742°	80.34410°	95m	Cremation Site, Religious Hotspot
MG$_2$-01	Badrinarayan Ghat	25.31827°	83.02297°	49m	Washing, Bathing, Boating
MG$_2$-02	Ram Ghat	25.31385°	83.01700°	47m	Washing and religious dips
MG$_2$-03	Manikarnika Ghat	25.31123°	83.01490°	48m	Cremation Hotspot (Electrical, Gas, Wooden pyres)
MG$_2$-04	Tripura Bhairavi Ghat	25.30858°	83.01223°	46m	Religious Bathing
MG$_2$-05	Dashaswamedh Ghat	25.30644°	83.01067°	50m	Religious Hotspot, Ritualistic Bathing, Aarti Spot, Boat dockyard
MG$_2$-06.	Raja Ghat	25.30218°	83.00822°	45m	Washing and Cattle Wallowing
MG$_2$-07	Kedar Ghat	25.29929°	83.00790°	47m	Dhobi ghats, Religious dipping, Cattle bathing
MG$_2$-08	Assi Ghat	25.28924°	83.00717°	44m	Religious Hotspot, Picnic Spot, Aarti Hotspot

Sample Collection

Pre-Sample Preparation

The high-quality Teflon sample bottles were precleaned with dilute nitric acid followed by distilled water. The bottles were rinsed first with sample water and then filled.

Collection of Water Samples

At each sampling spot triplicate samples were collected. Grab sampling technique was brought out for cluster of samples and water quality examination was carried out as per standard procedures (APHA, 2012) [2]. The water samples were collected from 22 sites for the year 2017-2018 for the upper and middle Ganga basins. BOD bottles of 300 ml capacity were employed to collect water samples for DO determination. The parameters of temperature, pH and TDS were evaluated on the site utilizing handheld meter (Eutech multiparameter), while DO was determined using titrimetric techniques on site whereas the rest of the parameters were analyzed in the laboratory.

Collection of Sediment Samples

A sediment core sampler with a tube length of 13 cm and a diameter of 6 cm was used to collect surface sediment samples from 0 to 15 cm in depth. The corer, full of sediments, was enclosed with a steel clamp to minimize any loss of the microscopic sediment particles. From each site, three samples were obtained, which were combined to form a composite sample. Before evaluation, the samples were oven-dried and homogenized in a mortar and pestle.

The estimation of Biochemical Oxygen Demand (BOD), Total coliform (TC), Faecal coliform (FC), hardness, total alkalinity, nitrate, phosphate and Total Kjeldahl Nitrogen (TKN) in water and Total Organic Carbon (TOC), nitrate, Total Kjeldahl Nitrogen (TKN) and phosphate in sediments was done using the methods as shown in Table 2.

Table 2: Methods used for analyzing various physico-chemical parameters of water

Parameters	Methods	Instrumentation/Apparatus used
Temperature	Electrometric	Multiparameter
pH	Electrometric	pH Meter
TDS	Electrometric	Conductivity Meter/TDS Meter
Dissolved Oxygen	Winkler Method	Titrimetric
Biological Oxygen Demand	5-Day BOD Test,	Titrimetric
Total coliform	MPN Technique	Multiple Tube Fermentation Apparatus
Faecal coliform	MPN Technique	Multiple Tube Fermentation Apparatus
Alkalinity	Titration with H_2SO_4	Titrimetric
Hardness	Titration with EDTA	Titrimetric
Nitrate	Ultraviolet Screening	UV-VIS Spectrophotometer
Phosphate	Ultraviolet Screening	UV-VIS Spectrophotometer
Kjeldahl Nitrogen	Analytical Digestion	Kjeldahl Apparatus
Total Organic Carbon	Walkley and Black Method	Chromic Acid Wet Oxidation apparatus

Results and Discussion

Riverine water quality in upper and middle Ganga sampling locations:

The water quality status of 22 sites of upper and middle Ganga has been shown in Figs. 2-5 indicating the mean values for the pre-monsoon, post-monsoon and winters (2017-2018).

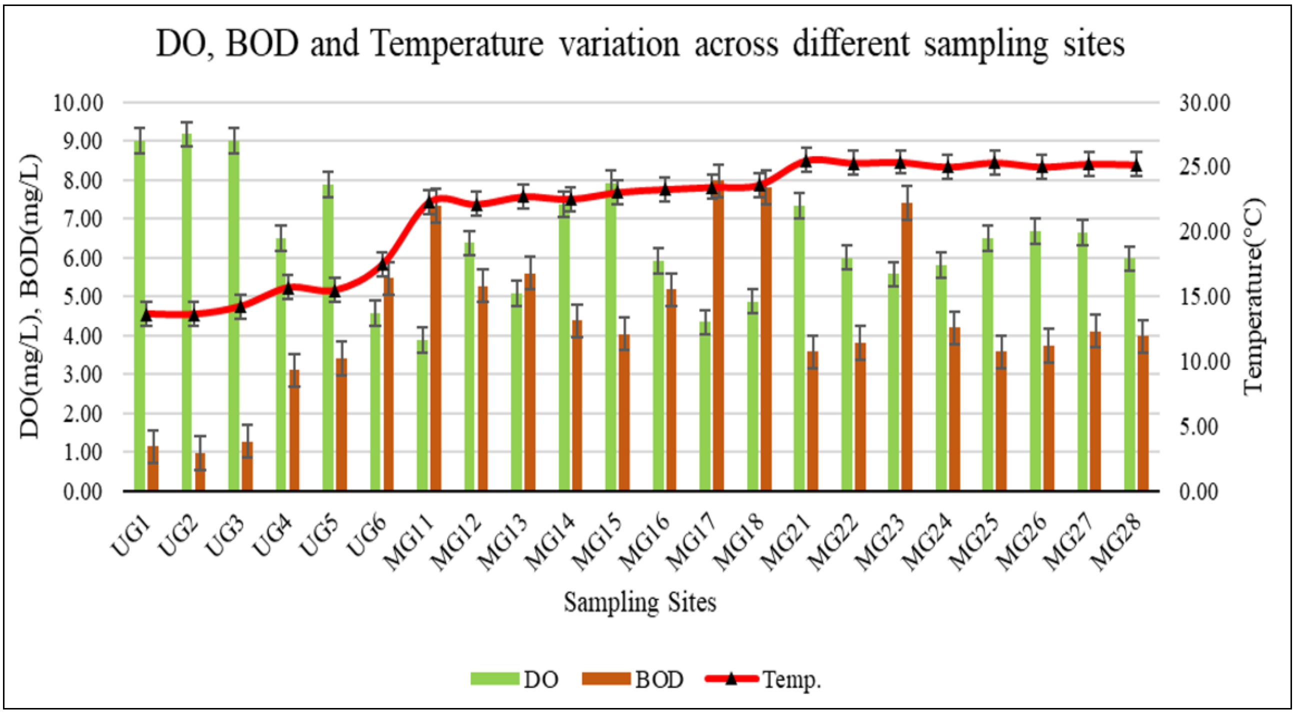

Fig 2: Variation in DO, BOD and temperature across different sites

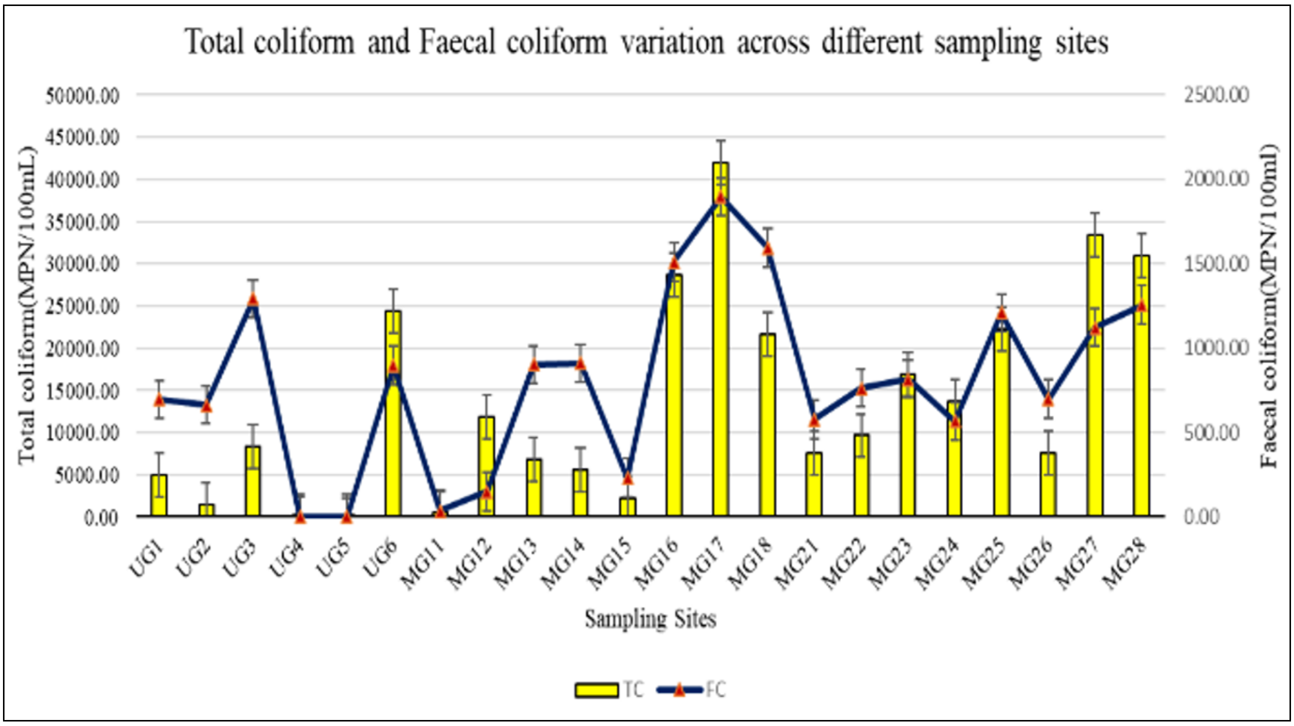

Fig 3: Variation in Total and Faecal coliform across different sites

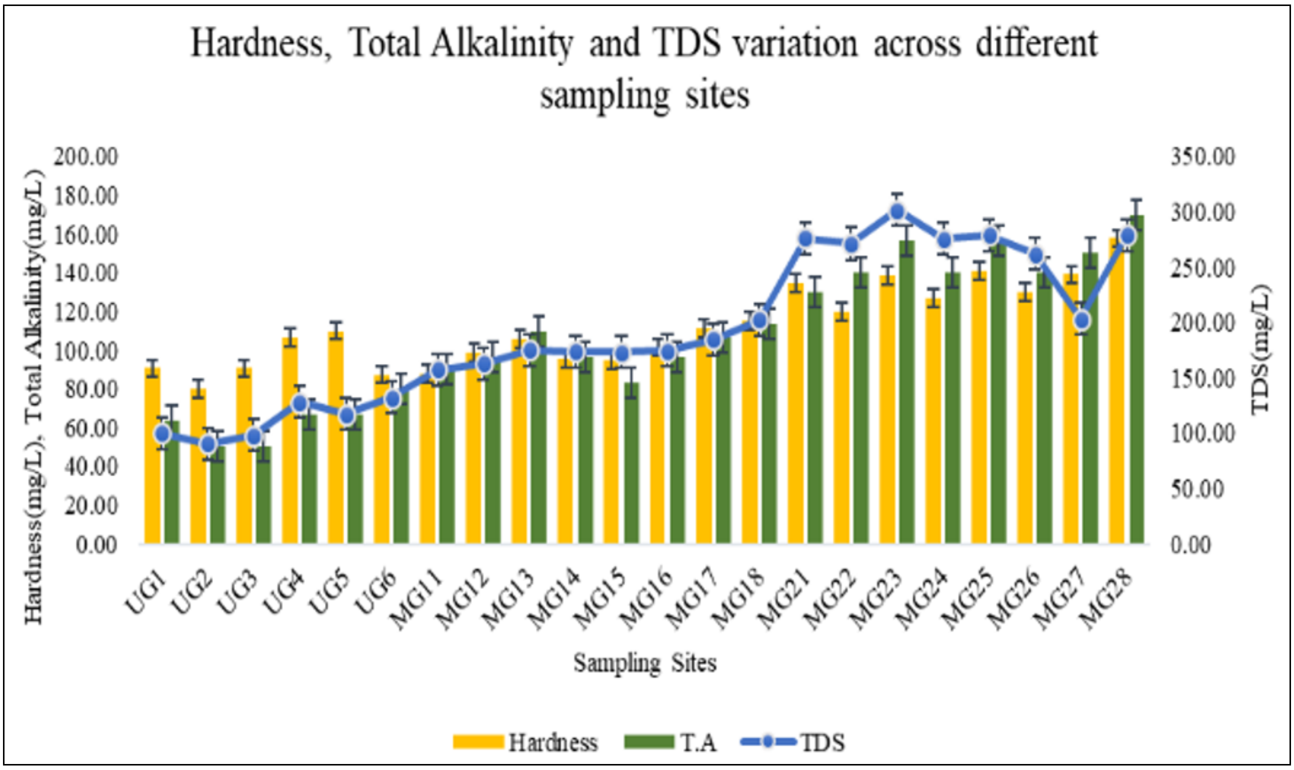

Fig 4: Variation in Hardness, Total Alkalinity and TDS across different sites

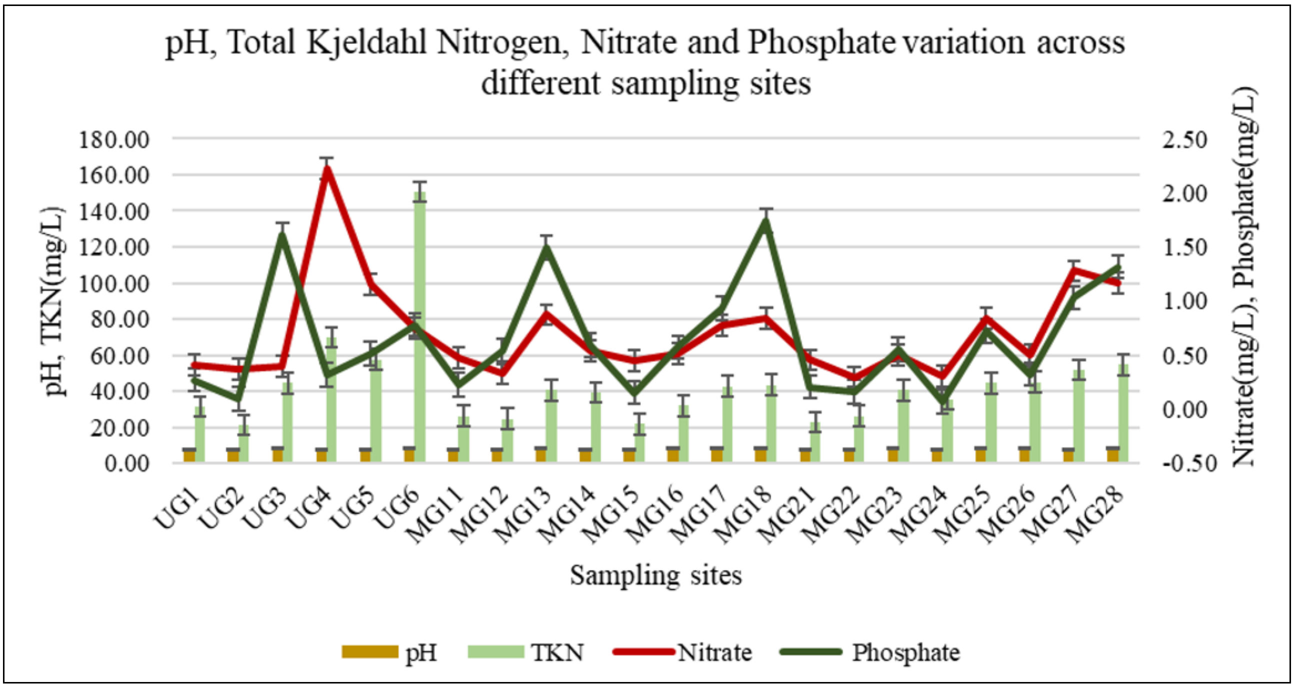

Fig 5: Variation in pH, TKN, Nitrate and Phosphate across different sites

The temperature was found to be varying in the range of (13.60-17.47) °C, (22.10-23.60) °C and (25.00-25.50) °C for the respective basins as above.DO, BOD and Temperature are interrelated as when DO rises, BOD falls. Higher temperature reduces the amount of dissolved oxygen and more the temperature, more is the BOD expected.DO values are seen the highest for UG-02, since it is least affected due to direct drivers of change in the form of human activities in the upper Ganga basin. Likewise in the middle Ganga basin one and two the higher values are seen for MG1-05 and MG2-01 respectively. As MG1-05 is a site after a barrage. Therefore, the water may be warmer and hence less capable of retaining oxygen if discharged from the head of an embankment or reservoir, its enormous surface area and enhanced velocity over a levee and downward may aid oxygenation. As for MG2-01, it is least affected due to sewage and bathing inputs. The BOD values for upper Ganga, middle Ganga basin one and two were found in the range of (0.97-5.47) mg/L, (4.04-7.80) mg/L and (3.57-7.40) mg/L respectively. Higher BOD values were seen for Vishwakarma ghat in upper stretch as it is a religious spot, and receives loads of ritualistic offerings and cremation dismissals. Bhairav ghat and Permat ghat are the cremation sites in middle Ganga basin one along with that surface runoff and animal waste adds more organic matter to the water at these sites. Likewise follows for Manikarnika ghat in middle Ganga basin two, where cremation of dead bodies on wooden pyres is a routine practice. The total coliform values were found to be fluctuating between(20.0-24333.33)MPN/100ml,(590-42000)MPN/100ml and (7533.33-33333.33)MPN/100ml for the upper, middle Ganga one and middle Ganga two stretch.The subset of coliforms believed to reside only in warm-blooded animals' wastes and intestines are termed fecal coliform bacteria. Fecal coliforms are presumed to be a more precise predictor of either human or animal waste rather than the more generic total coliform bacteria category since their sources are more distinctive than the latter. Therefore, the total coliforms are more in number with lesser number of indicator organisms. The higher coliform values are seen for UG-06, MG1-07, MG1-08 and MG2-03, MG2-05, MG2-07 and MG2-08. The Faecal coliforms were found in the range of (2-1292.33) MPN/100ml, (35.33-18960) MPN/100 ml and (577.67-1256.33) MPN/100 ml for the upper, middle Ganga one and middle Ganga two respectively, with higher numbers at UG-03, UG-06, MG1-07, MG1-08, MG2-05, MG2-07 and MG2-08. This can be attributed to all the sites being ritualistic bathing sites and faecal coliform may enter through unregulated human sewage, fertilizer runoff, and direct animal and bird waste disposal. During the rainy season, individual residential septic tanks may become overburdened, forcing untreated human waste into drainage canals. TDS was found in the range of (90.23-132.40) mg/L, (157.17-202.63) mg/L and (203.33-301.67) mg/L for the stretch in upper, middle Ganga one, middle Ganga basin two respectively. Higher TDS values refer to more amount of organic and inorganic solids entering the river due to various religious and cultural activities including holy dipping, washing activities, flower, leaves and woody debris, partially treated waste and effluent discharge as seen for UG-04, UG-06, MG1 -07, MG1-08, MG2-03, MG2-05 and MG2-08.The hardness values were found to be on the higher side for the same sites showing significant relationships and were seen to be varying between (80-110)mg/L,(88-115.33)mg/L and (120-157.67)mg/L respectively for the three basins(UG, MG1 and MG2) respectively. The reasons could be attributed to high mineral content in water due to natural and anthropogenic sources. The total alkalinity in the upper, middle one and middle two Ganga basins were found in the range of (50.0-80.0) mg/L, (83.33-113.33) mg/L and (130.0-170.0) mg/L respectively. The higher alkalinity values at UG-06, MG1-03, MG1-07, MG1-08, MG2-03, MG2-05, MG2-08 can be ascribed to the fluctuations in the pH due to agricultural runoffs, fossil fuel emissions and acid my drainage. Due to the design and make-up of the stream bed, rivers have some capacity to withstand pH shifts. The pH values were found to be fluctuating between (8.06-8.64), (8.21-8.63) and (8.07-8.55) for UG, MG1 and MG2 respectively. The nitrate content varied between (0.37-2.22) mg/L for UG, (0.33-0.87) mg/L for MG1 and (0.30-1.28) mg/L for MG2 respectively. UG-04, MG1-03, MG1-07, MG1-08, MG2-05, MG2-07 and MG2-08 showed higher nitrate content values as at all the sites human waste introduction, poorly functioning septic systems, waste water input and agricultural runoff are commonly seen. The total kjeldahl nitrogen concentrations were witnessed to be varying between (21.19-150.61) mg/L for upper Ganga, (21.79-43.38) mg/L for middle Ganga one and 22.82-54.70) mg/L for middle Ganga two. Common reasons for the rise in TKN include farming water that contains nutrients, wastewater treatment facility outflow, commercial input from the dairy sector, and many others. Moreover, as nitrogen deteriorates over time, nitrate is released. UG-04, UG-06, MG1-03, MG1 -07, MG1-08, MG2-03, MG2-05, MG2-07 and MG2-08 asserted high TKN content. The phosphate values varied between the range of (0.10-1.61) mg/L for UG, 90.15-1.74) mg/L for MG1 and (0.30-1.28) mg/L for MG2 respectively. The highest phosphate content for UG-03 was discovered in the upper Ganga basin, which may be related to its inherent existence in rocks and mineral resources. Moreover, the MG1-03 and MG1-08 sites receive inputs of organic waste and fertilizer, resulting in higher levels. Because of the site's exposure to organic contamination, MG2-08 showed higher values in the middle Ganga basin 2. The sampling sites were categorized into different water quality classes based on the maximum permissible limits given by CPCB, that have been depicted in Figs. 6-13 respectively.

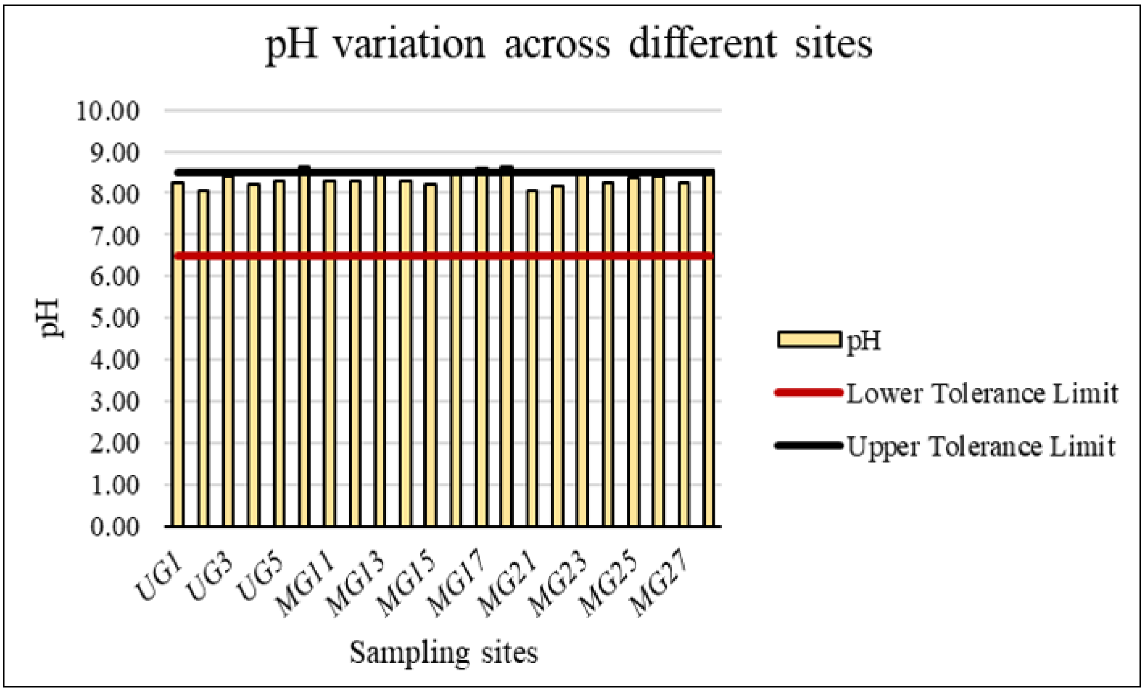

Fig 6: Water Quality class with respect to pH

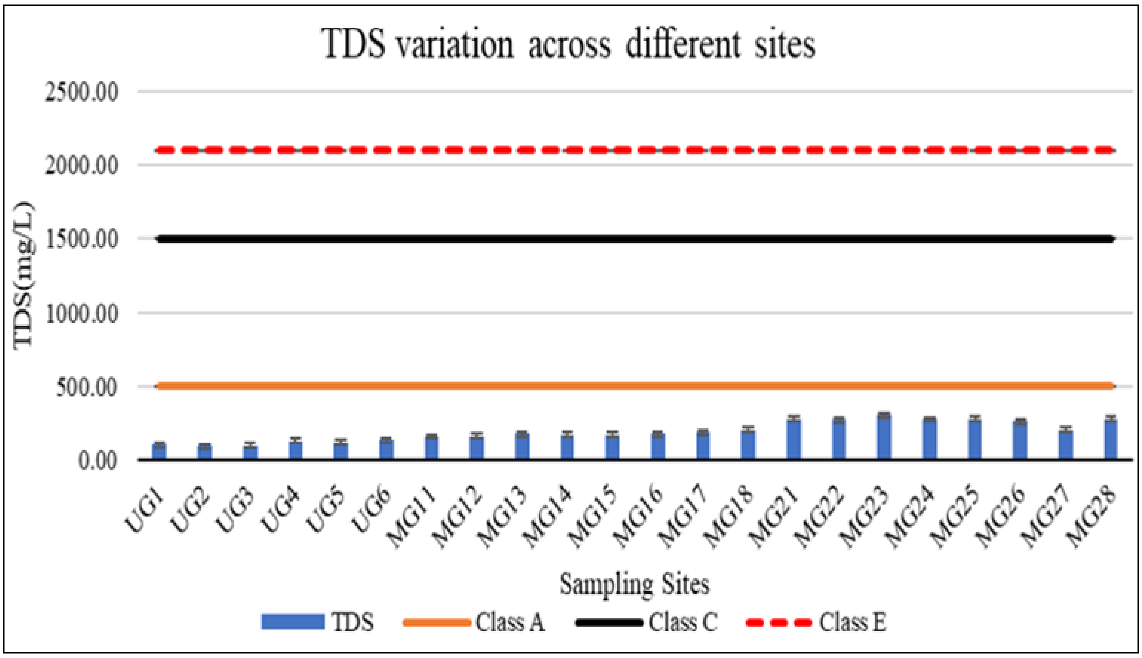

Fig 7: Water Quality class with respect to TDS

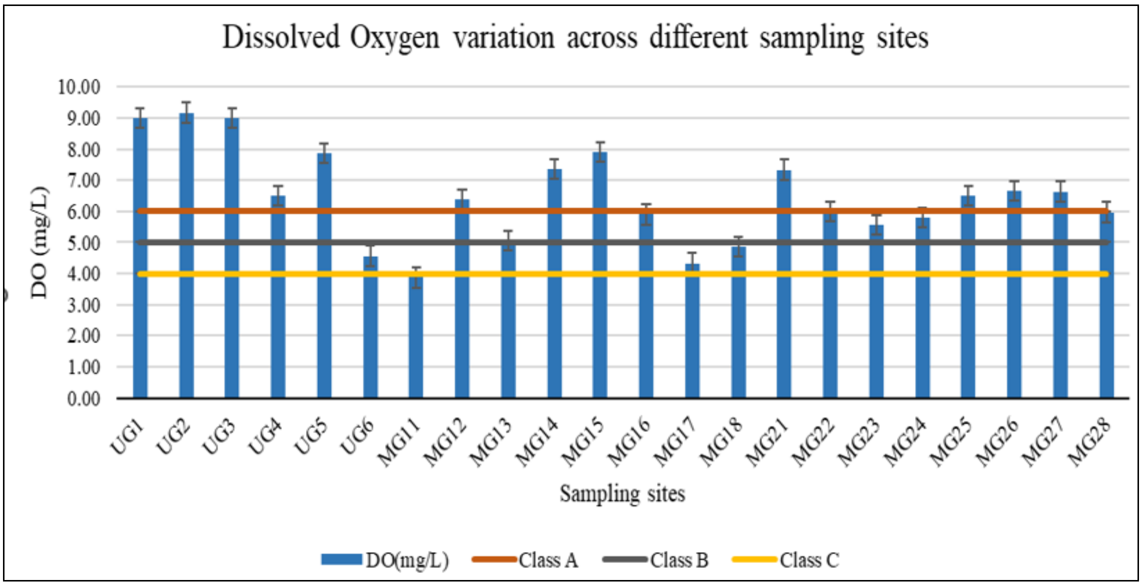

Fig 8: Water Quality class with respect to DO

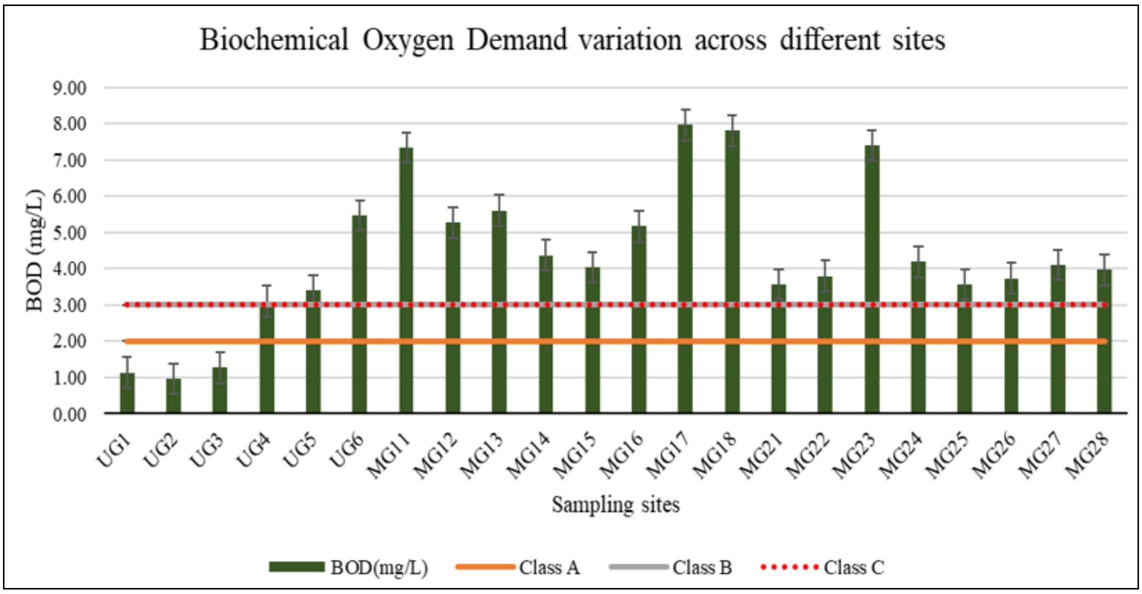

Fig 9: Water Quality class with respect to BOD

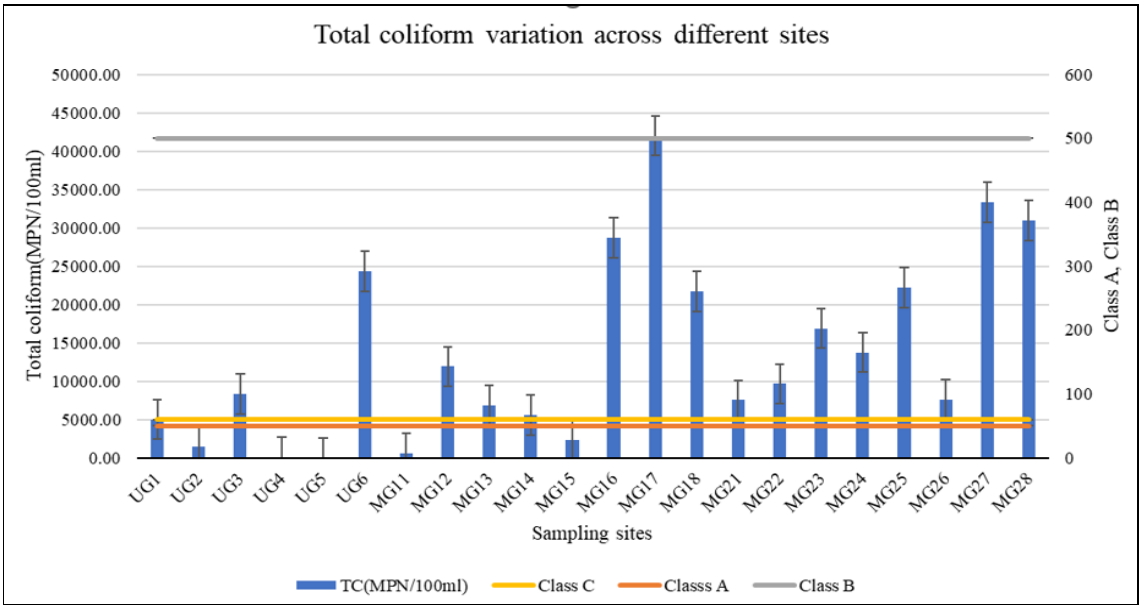

Fig 10: Water Quality class with respect to TC

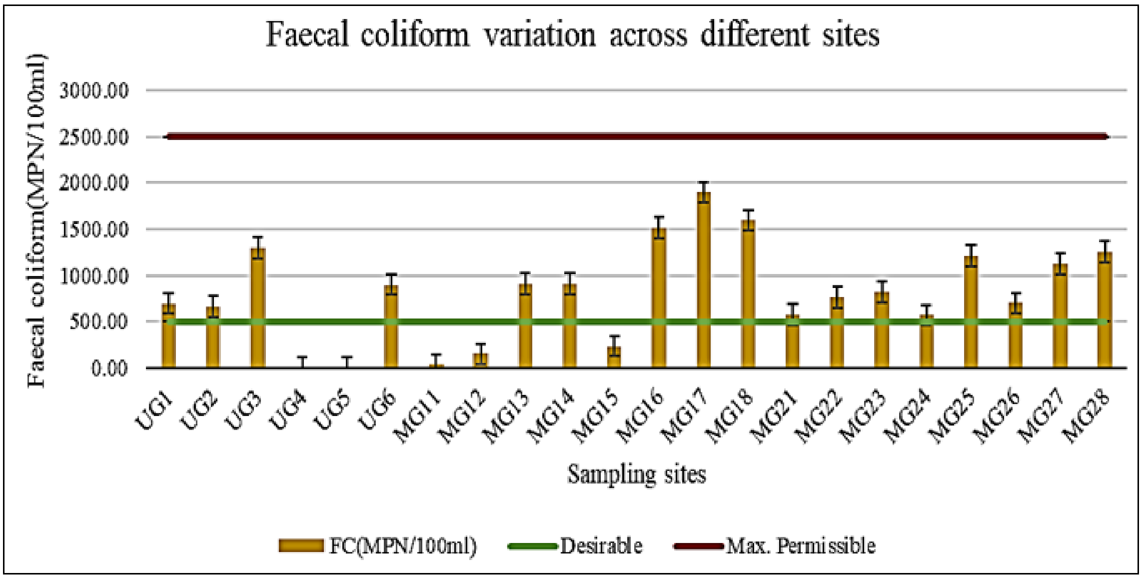

Fig 11: Water Quality class with respect to FC

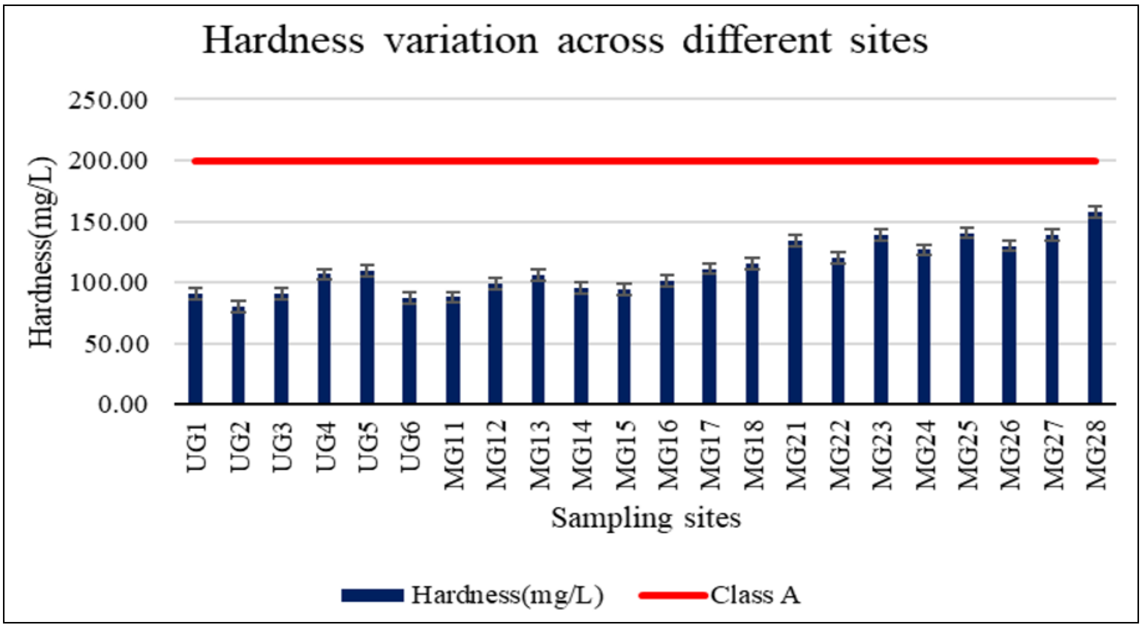

Fig 12: Water Quality class with respect to Hardness

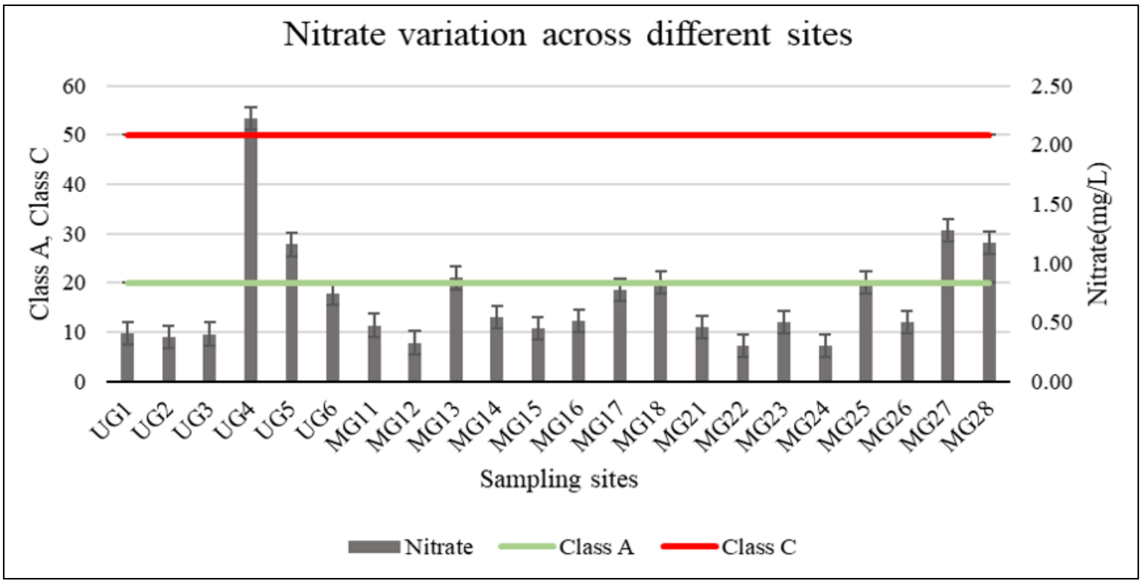

Fig 13: Water Quality with respect to Nitrate concentration

	Temp.	pH	TDS	DO	BOD	TC	FC	Hardness	T.A	TKN	Nitrate	Phosphate
Temp.	1.000**											
pH	0.180	1.000**										
TDS	0.881**	0.104	1.000**									
DO	-0.546**	-0.592**	-0.374	1.000**								
BOD	0.558**	0.601**	0.327	-0.882**	1.000**							
TC	0.449*	0.647**	0.344	-0.477*	0.445*	1.000**						
FC	0.273	0.633**	0.206	-0.226	0.254	0.792**	1.000**					
Hardness	0.695**	0.148	0.858**	-0.220	0.154	0.451*	0.252	1.000**				
T.A	0.887**	0.210	0.947**	-0.433*	0.357	0.502*	0.301	0.905**	1.000**			
TKN	-0.245	0.510*	-0.175	-0.297	0.102	0.271	0.086	-0.051	-0.092	1.000**		
Nitrate	-0.156	0.120	-0.125	-0.137	0.006	0.115	-0.079	0.246	-0.003	0.419	1.000**	
Phosphate	0.044	0.694**	-0.056	-0.227	0.263	0.462*	0.636**	0.159	0.102	0.250	0.252	1.000**

Fig 14: Correlation matrix between Water Quality parameters, *p< 0.05, **p< 0.01

A correlation matrix was created between the diverse water parameters that has been depicted in Fig. 14. CPCB carried out the analysis for whole stretch of Ganga taking into account the major hotspot locations of anthropogenic inputs for the year 2002-2011, which was compiled in 2013.

If the concentration values of the parameters are found to be exceeding the maximum permissible limits with respect to the standards, the status of the water quality is believed to be poor and the condition is said to be degraded.

When compared to the earlier report of CPCB (2013) [4], the water quality parameter values in the study area were seen to be transcending the maximum admissible limits at multiple sites as per established best use categories of surface water by CPCB.

The water quality attributes revealed favorable improvement in terms of parameters of electrical conductivity, dissolved oxygen, biochemical oxygen demand and total coliform when analogized to prior reports of Central Pollution Control board but yet the water was not found appropriate for drinking and bathing purposes.

FC-Phosphate, Hardness-TDS, TA-TDS, TA-Temperature, TC-pH, and Phosphate-pH showed significant positive correlations. In contrast, notable negative correlations were witnessed between DO-Temperature, DO-pH, and BOD-DO.

Phosphate crystals are an important constituent of faeces, thus faecal contamination causes a greater number of faecal coliform bacteria. More the amount of total dissolved solids, more would be the electrical conductivity. Total Hardness is due to salts of Ca, Mg and HCO3.All these are included in TDS. Thus, stronger correlation values. As alkalinity includes, bicarbonate, hydroxide and carbonate of salts, thus it can be positively correlated to TDS. Although Temperature does not affect the alkalinity to a much extent but it is a property of water that is dependent on the presence of certain chemicals in water. So, Hardness and TDS presence can be the coincidental cause of high alkalinity along with high temperature. Total coliform concentrations are known to be affected by pH as more sewage dismissals would move the pH to alkaline, causing rise in concentrations of coliforms and if the pH decreases due to industrial pollution load or septic tanks input, would reduce the number of the bacteria. The moderate positive correlation between phosphate and pH indicates that manure and fertilizer input would be the cause of pH in water.

Negative correlations between DO and temperature exists because of the fact that the greatest solubility of the oxygen depends on temperature. Similarly DO and BOD have a significant negative correlation

as the aerobic microorganisms use dissolved oxygen to disintegrate the organic matter in river water. Th**e** pH levels are not directly influenced due to dissolved oxygen because the two have no physical-chemical connection. Nevertheless, in some circumstances, there are indirect associations from outer elements, such as added nutrients advancing algal bloom.

The results of the sedimental component analysis for nitrate, phosphate, total kjeldahl nitrogen and total organic carbon have been illustrated in Figs15-18 respectively.

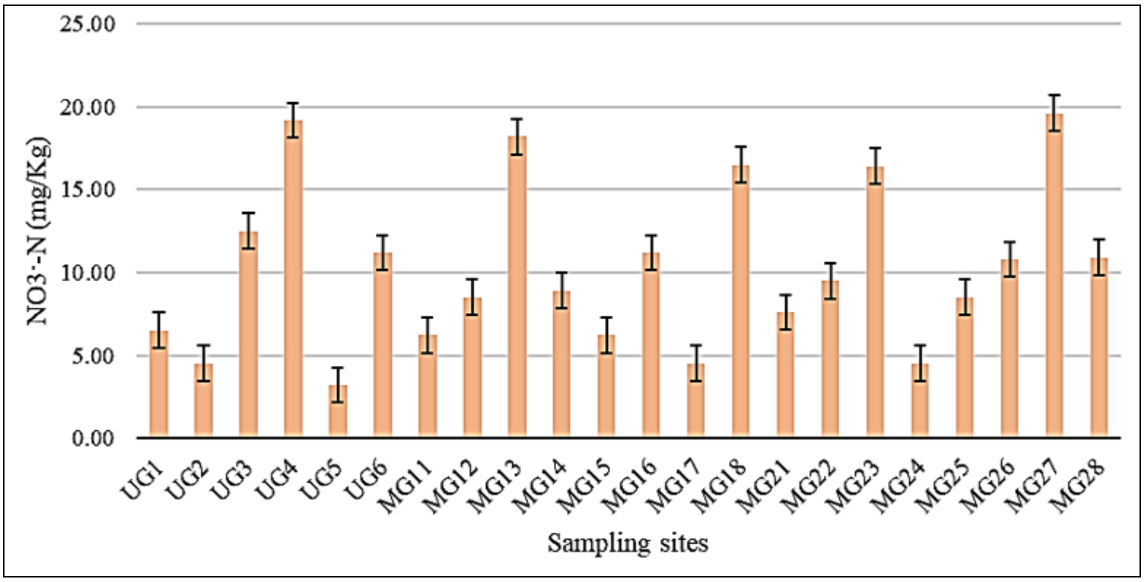

Fig 15: Variation in NO3⁻-N across different sites

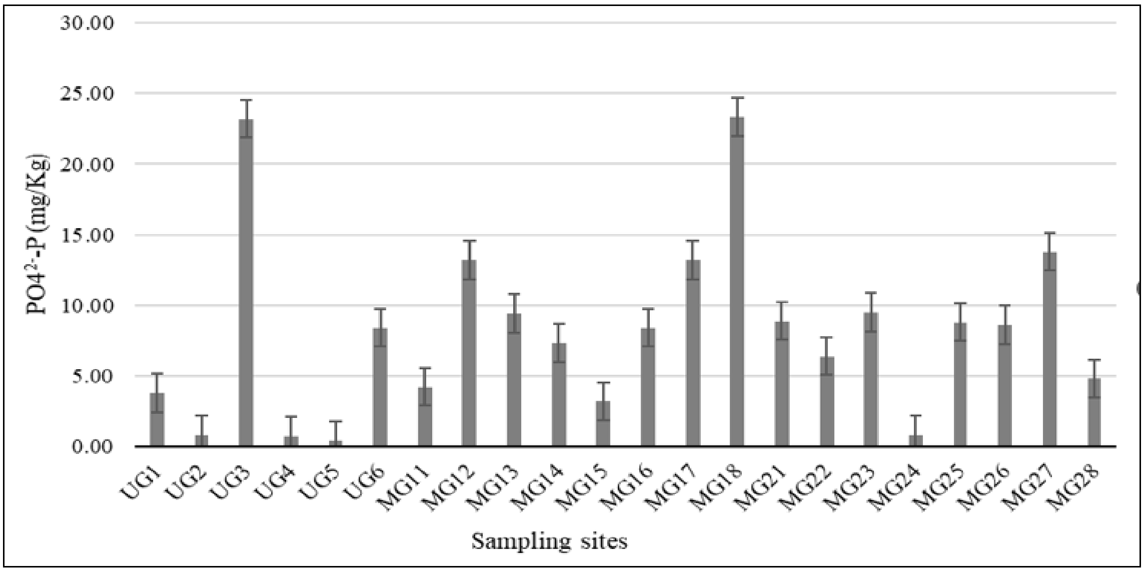

Fig 16: Variation in $PO4^{2-}$-P across different sites

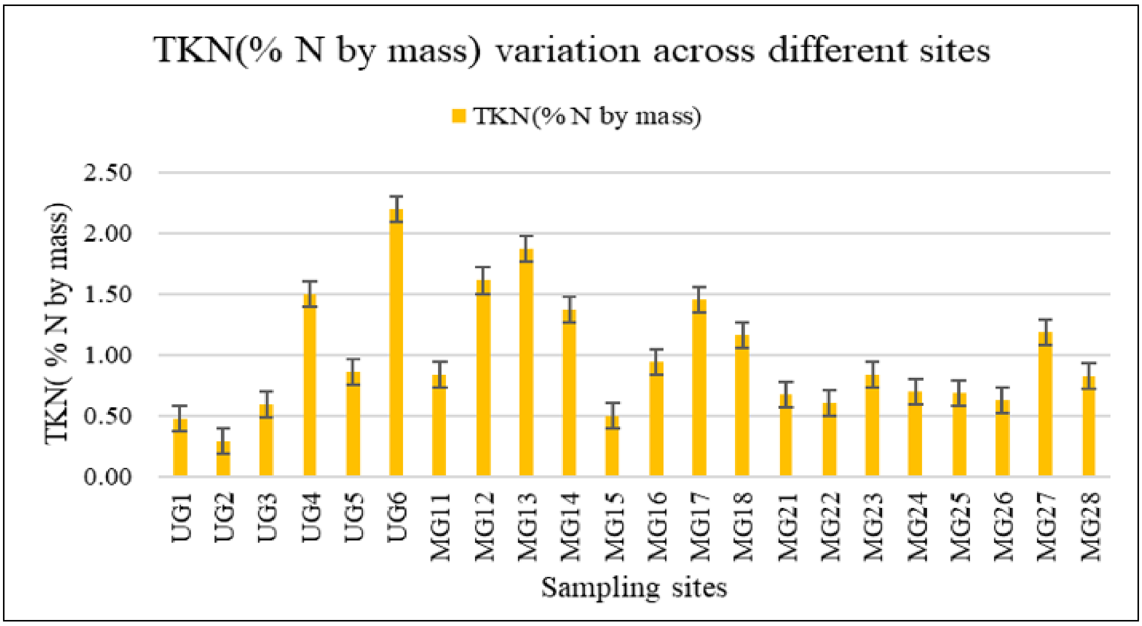

Fig 17: Variation in TKN across different sites

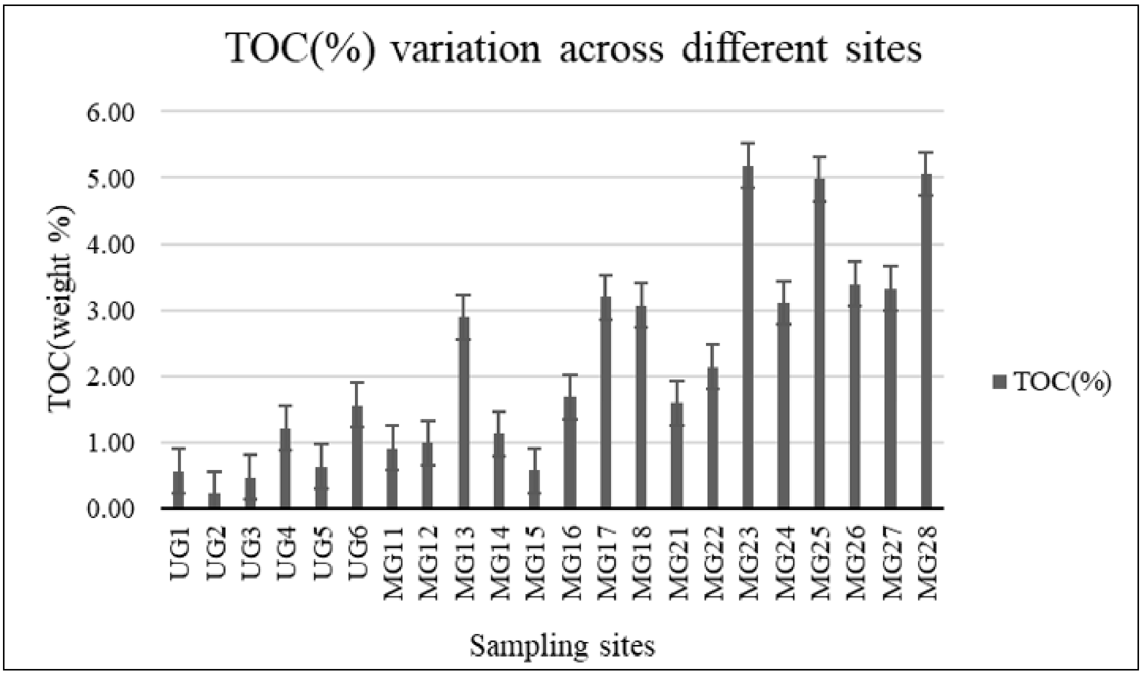

Fig 18: Variation in TOC across different sites

Higher sedimental enrichment of nitrates, phosphates and total kjeldahl nitrogen are seen at the sites of Swargashram and Vishwakarma ghat in upper Ganga basin, whereas the middle Ganga basin1 and 2, witness this for the sites of Brahmavrat Ghat, Bhairav ghat, Permat ghat, Manikarnika ghat, Dashashwamedh ghat and Assi ghat, respectively. The reasons could be attributed to the high anthropogenic inputs at these sites in the form of industrial and domestic waste besides religious waste.

The TOC values in sediments are seen highly enriched during winters, followed by post monsoon season, as during summer, rise in temperature causes the degradation of organic matter.

pH values for all the sites were found within the appropriate limits of 6.5-8.5. All the sampling sites were found under water quality class A in terms of TDS.In the upper Ganga basin, all the sites were categorized into Class A in terms of DO, except for UG-06 which was found under Class C. MG1-01, MG1-03, MG1-07, MG1-08 all were found under Class C, where the rest in middle Ganga basin one were found in Class A.Whereas MG2-01, MG2-05, MG2-06 and MG2-07 were found to be falling in water quality class A and the rest of the locations under Class B. Throughout the basin, the three sites of UG-01,UG-02 and UG-03 were found to be falling under class A in terms of BOD, whereas the rest of the sites were found to be in class C.In terms of the total coliforms, UG-01, UG-04, UG-05,MG1-01and MG1-05 were found to be in class A, remaining sites were categorized into class C.All the sites showcased faecal coliform concentrations within permissible limits, whereas UG-04, UG-05,MG1-01,MG1-02, MG1-05 sites showcased concentrations within desirable limits. The hardness values for all the sites were found within the limits of category A. Most of the sites qualified for class A in terms of nitrate concentrations except UG-05, MG1-03, MG2-07 and MG2-08, that were falling in class C and UG-04 exceeded the class C concentration too.

Conclusion

It is inferred that the water quality parameter values surpass the permissible values at all the locations as per designated best-use categories of surface water by CPCB. The water quality attributes have indicated little progress when approximated to earlier Central Pollution Control board reports. However, still, the water needs to be seen as eligible for domestic use. All the water quality parameters for one of the sites in the upper Ganga basin (UG-03) were found to be falling under permissible limits, except for the total and faecal coliform values for which it qualified for class C and exceeded the desirable limits respectively, which could be due to the open defecation activities prevalent at the site. Besides that, UG-04 and UG-05 showcased the faecal coliform values within desirable limits and in terms of total coliforms qualified for Class A, which is attributed to the full functionality of STPs at the sites. River Ganga, the scared river of the country, is impaired by the endless gush of municipal sewage, domestic discharges, non-biodegradable industrial effluents, and runoffs from the fields that are swirled out of the anthropogenic stirs along the river banks and have prolonged consequences on human and marine healthiness due to their tainted disposition. Unparalleled population augmentation in the river basin and mechanization have altered land use, behaving as drivers of river ecosystem modification. These drivers can imperil diverse ecosystem benefits being supplied by the river Ganga. If the population detonation and pollution problems and retention capability of the river are given prompt watch, it will be easier for us to switch the natural condition of river Ganga. Though the environmental administration and lawful policy framework are now acknowledged as prime subjects, proper execution of environmental criteria must be practiced to address the pollution pressure and preserve the ecosystem health of the river. Stringent measures are required to restore the river quality.

Declaration of conflict of interests

The authors declare no conflict of interests or personal relationships that could have appeared to influence the research reported in this paper.

Credit Authorship Contribution Statement

Prerna Sharma: Writing-original draft, Data curation, Methodology, Software, Formal Analysis, Investigation, Resources.

Anubha Kaushik: Conceptualization, validation, review and editing, Visualisation, Supervision.

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