

Assessment the impacts of religious tourism and rituals on the surface water quality using WQI in the upper Godavari River by using GIS techniques

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Abstract:

An attempt has been made to identify religious activities based on rivers and its impact of water quality of Upper Godavari River (UGR). Assessment of surface water quality is becoming importance for drinking purpose especially for rural population for that systematic study has been carried out for the water quality of upper Godavari River. Keeping this view in the account water samples from 10 sampling stations were collected in October 2025. Physico-chemical parameters Like Temperature, pH, Total Solids (TS), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Turbidity, Biological Oxygen Demand (BOD) and Fecal Coliform (F-Coli) were analyzed by standard method. The Karl Pearson correlation matrix has been established for examining relationship between the water quality parameters as well as the study is conducted to analyze the water quality status of Godavari River in terms of water quality Index (WQI). The computed WQI at all 10 sites varied from 16.45 to 74.44. The overall values showed good water quality status at upper stream in the study area, but as religious activities or any other ritual performed in the river it became deteriorated. Comparative WQI analysis used to assess variation in the water quality of Godavari River. For spatial analysis computed results represents through GIS techniques. To analyze the water quality Index (WQI) is the main aim of the research with remedial measures to mitigate the deterioration and related consequences in future. Overall results provide a valuable baseline for environmental management policies aimed at preserving the ecological integrity of sacred rivers under increasing pilgrimage pressure.

Keywords: Water Quality Index, Godavari River, Physico-chemical parameters, Karl Pearson correlation matrix

Introduction:

River water is a precious natural resource for human being. Water plays an important role in various life processes of living organisms (Kharake, A. C., & Raut, V. S., 2021). Hydrosphere is an important segment of environment including 2.5% of the fresh water on Earth, and most of it is easily accessible, which is majorly (68.7%) locked in glaciers and ice caps, groundwater

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(30.1%) and less than 1% fresh water is available from lakes, reservoirs and river systems (UNESCO 1998) which are primary source for human and animal needs. Rivers are crucial support for the biodiversity (Rosca O.M. et.al. 2020). Rivers are biggest reserve of potable and other activities for human populace (Kharake, A., & Raut, V. S.2020). Many human activities like agriculture, industrial, tourism and domestic etc. depend upon the river. Rivers has great potential of economic changes (Patil & Ghorade I.B, 2013) that many villages which are situated along river experienced rapid socio-economic changes that why rivers known as arteries of our planet (Kharake, A, 2021).besides this river water is also considered to have importance in various religions and traditions for attainment of peace through cleansing of mind and soul (Lall A.S. et.al.2022). It has been observed that water resource is under severe environmental stress from past few decades due to population growth, urbanization, industrialization, encroachments and religious activities etc. It all are lead to worsen the water quality and quantity (Khandi & Shrivastava, 2016). According to WHO (2025), in 2021 over 2 billion people live in water-stressed countries, which is expected to be exacerbated in some regions as result of population growth.

Rivers are considers to be sacred in Hindu religion. Many religious festivals and rituals are celebrated on the river banks. Many religious activities adversely affects on river channel like mass bathing, different pujas and discharge of ash of human dead bodies (Kharake, A, 2021). Among various religious activities like immersion of flour, oil, soap, ash, detergents, floral offerings and mass bathing (Varma et.al. 2022) are also one of the important cause that affects water quality of the water body (Bhatnagar A. et.al, 2016), millions of people take holy bath and perform religious activities. To perform religious activities oftenly plastic bags and puja material (*Nirmalya*) has been used and directly discharged in the river channel (Kharake, A, 2021). It cumulatively affects on the water quality and quantity and water become unfit for drinking. Microbiologically contaminated drinking water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid and polio which is estimated to cause approximately 505000 deaths each year (WHO, 2025)

Godavari River is a major source of water for drinking, agriculture, domestic and industrial purposes. Godavari River is also well known for its religious importance for Hindus and is considered a sacred river, with major pilgrimage sites like Trimbakeshwar and the Pushkaram festival celebrated on its banks. After every twelve years millions of devotees are organized at Nashik for major bathing festival called as Pushkaram (Kumbh Mela) is held on the banks of the Godavari River. The fair is celebrated with full passion and keenness in Nashik as one can evidence and about millions of pilgrims come here to wash away their sins in the holy river, Godavari. Apart from Kumbh Mela hindus perform many religious rituals at river Godavari (MPCB, 2015) which resulted contamination of the water and water quality may deteriorated.

Water Quality Index is used to understand a general water quality status of water resource, hence it has been used to determine the water quality of surface and ground water quality. Number of studies are carried out related to Water Quality Index (WQI). (Horton et al. 1965) used WQI for first time as an indicator of water pollution. (Brown et al. 1972) also calculated WQI by basic arithmetic weighting but without multiplicative variables these efforts were supported by National Sanitation Foundation (NSF) in which water quality variables were

calculated using the Delphi method (Dalkey et al. 1968), (Bhargava et al. 1985) also suggested Water Quality Index for river Ganga. (Ichwana et al. 2016), Water Quality Index for Hariyana. (Bhatnagar et al. 2016) (Shah and Joshi 2017), (Bora and Goswami 2017), (Verma et al. 2019), (Dimri D. et al. 2021), (Kharake, A. C., & Raut, V. S. 2020, 2021), Impact of mass bathing on water quality (Lall A et al. 2024) have calculated WQI for different rivers.

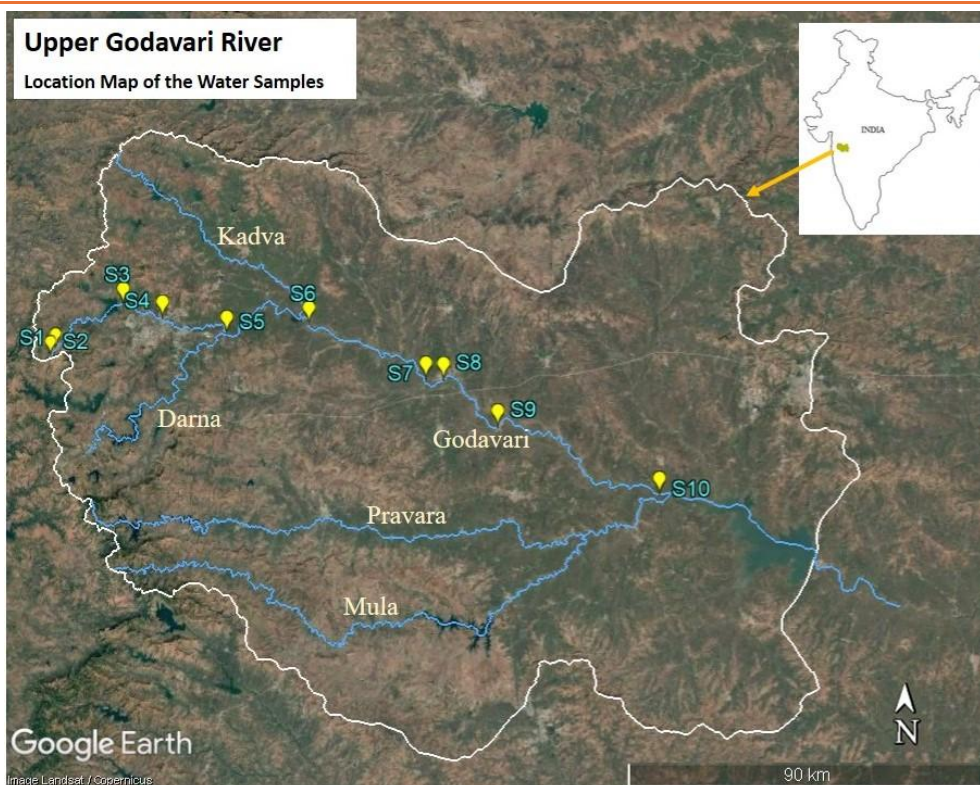
The main objective of the present study is to develop simplified WQI in order to examine the effects of religious activities and rituals on water quality of UGR. To understand inappropriate religious activities and its impact on water quality is the main objective of the paper. Further research will be helpful to minimize religious activities which are responsible for water contamination and for creating awareness among local people, devotees, and saints etc.

Study Area:

For the present study Upper Godavari River has been selected. It is located in the north-west direction of Maharashtra, lies at $19^{\circ}56' \text{ N } 73^{\circ}33' \text{ E}$ to $19^{\circ}48' \text{ N } 75^{\circ}37' \text{ E}$ (Figure 1) Maximum height of the study area is 1298 meters (origin) and minimum is 456 meter (Jayakwadi Dam). The length of study area (From Origin to Jayakwadi Dam) is 248.94 km. The total area is 22419 sq. km.

The area is covered by basaltic lava flow related to Deccan volcanic activity of late Cretaceous to Eocene period. The area is dominated by Black basaltic soil in uplands and deep alluvial soils in lower plains. The distribution of rainfall is mostly uneven. The western part of the study area receives highest rainfall but in eastern part it is more erratic. The average annual rainfall of the area is 812 mm. Natural vegetation in the study area represents the southern tropical dry deciduous type. The average annual temperature of study area is 24°C .

Figure No.1 Location map of the Study Area



Materials and Methods:

For further study 10 sampling stations within upper Godavari River have been selected. Selection of sampling stations is based on types of human religious activities and their intensity as well as area affected by waste generated through religious practices. For water quality analysis water samples have been collected from the surface water along the river. Temperature and pH of samples have been measured in the field during collection. The water samples were analyzed at Regional Water Testing Laboratory, Nashik under Water Supply and Sanitation department, Government of Maharashtra. The analysis was carried out in the laboratory as per BIS standard methods. Various Physio-chemical parameters like Total dissolved solids (TDS), Dissolved oxygen (DO), Biological Oxygen demand (B.O.D.), Total solids, turbidity and F-Coli were analyzed to evaluate the impact of urban waste on water quality. The Karl Pearson correlation matrix has been established to examine the relationship between the water quality parameters. The data was analyzed for water quality status and water quality index was determined by the formula developed by NSF (National Sanitation Foundation) and modified by CPCB (Central Pollution Control Board) (Table 1) which depicts the water quality in simple and easy way. WQI as it gives a single number (Table 2) that expresses the overall water quality of a certain water sample (location and time specific) for several water quality parameters. It all information classified in color code based on computed WQI according to CPCB (Table 3) It all information summarizes and analyzed with the help of graphs (Figure .17).

$$WQI = \sum_{i=1}^P W_i I_i$$

Table 1. Modified weights for computation of WQI based on DO, FC, pH and BOD

Sr. No.	Parameters	Weight
1	Dissolved Oxygen	0.31
2	pH	0.28
3	BOD	0.22
4	Fecal coli	0.19
	ΣW_i	1.00

Table 2. Sub index equation used to calculate NSF WQI for DO, FC, pH and BOD

Water Quality Parameters (Units)	Range Applicable	Equation
Dissolved Oxygen (DO)(% Saturation)	0-40	$0.18 + 0.66 \times \% \text{ Saturation DO}$
	40-100	$(-13.55) + 1.17 \times \% \text{ Saturation DO}$
	100-140	$163.34 - 0.62 \times \% \text{ Saturation DO}$
Fecal Coliform (FC) (counts/100ml)	$1-10^3$	$97.2-26.6 \times \log FC$
	10^3-10^5	$42.33-7.75 \times \log FC$
	$>10^5$	2
pH	02-05	$16.1+7.35 \times (\text{pH})$
	05-7.3	$(-142.67)+33.5 \times (\text{pH})$
	7.3-10	$316.96-29.85 \times \text{pH}$
	10-12	$96.17-8 \times \text{pH}$
	$<2, >12$	0
BOD (mg/l)	0-10	$96.67-7 \times \text{BOD}$
	10-30	$38.9-1.23 \times \text{BOD}$
	>30	2

Table 3. Water Quality classification and best designated use.

Sr. No.	WQI	Class by CPCB	Remarks	Color Code
1	> 75	A	Excellent	
2	50 – 75	B	Good	
3	25 – 50	C	Poor	

4	< 25	D,E	Very Poor / Unfit	
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Results and Discussions:

• Concentration Values of Parameters in Selected Stations

The analysis report of sample sites has been carried out as per BIS limits, which are given in the Table 4.

Station No.	Location	Temperature (in °C)	PH	TS	DO	TDS	Turbidity	BOD	F-coli (MPN)
S1	Gangadwar (Origin)	21.4	7.5	63	7.8	61	2.9	1.8	1.8
S2	Kushavart/ GodavariKund	27.9	8.7	639	1.6	478	21	61	35
S3	Someshwar	23.2	7.8	81	7.5	72	9.1	21	5.9
S4	Ramkund (Nashik City)	27.0	8.6	628	1.9	483	17.8	60.2	32
S5	Darna Sangavi	24	7.8	164	7.1	187	25.8	31.8	19
S6	Nandur Madhmeshwar	24.9	7.9	171	7.0	156	15.52	32.0	20
S7	Jeur Kumbhari	25.3	7.5	193	6.8	214	15.41	30.9	21
S8	Kopargaon	25.5	8.2	478	3.6	392	24.9	48	24
S9	Puntamba	26.2	8.5	501	2.0	471	25.0	50	28
S10	Toka	25.7	8.1	482	2.3	388	19.7	47	28

Table 4. The Parameters of the Godavari River.

(Required desirable limits- As per standards prescribed For Drinking Water by Bureau of Indian Standards, 2002 (BIS) limits, 2012)

The analysis report of sampling stations has been carried out as per BIS Limits (Table 4) we investigated the WQ by measuring 10 parameters shows values of measured values of various parameters. Data shows that water quality deteriorated with increasing religious activities.

pH- pH is an indicator of the amount of hydrogen ion concentration value. It is used to indicate acidity or basicity of the water (Kharke A.& Raut V.,2021). Normal water has pH value between 6.5 to 7.5. If it is <6.5 water became acidic and if it is >7.5 it became alkaline. pH of water is an important factor in drinking and irrigation usages (Şener S. & et.al.2017) determining its quality and suitability for various uses, the present study shows that pH value has been ranging between 7.5 to 8.7 at various sampling sites (Table 4). pH higher than 8.5 may also indicate the dissolved material like calcium, magnesium and bicarbonate (Figure 2). due to religious activities. Figure 9 represents the comparative values of pH.

TS- Total Solids are dissolved solids in the water, representing the combined mass of all solid material including suspended and settleable. Total solids ranged between 63 to 639 mg/l (Figure 3) at various sampling sites. TS has been suddenly increased at S₂, S₄ & S₉ (Figure 15) due to heavy religious offering like flowers, flours and idols. It all responsible to make water unpalatable.

DO- Dissolved Oxygen in the water is an important index in determining the purity of water. It gives nature of organic matter present in water. DO is essential for healthy aquatic life and to maintain the diversity of all forms of life (Maurya P.K. et.al, 2021). High DO indicates a healthy and self-purifying water body. The DO values reveals ranged between 1.6 to 7.8 (Figure 4). It is observed that DO of river at S₂, S₄, S₈, S₉ & S₁₀ is less than 5 mg/l (Figure 10) it may due to contamination of organic matters during rituals.

TDS- Total Dissolved solids (TDS) is combined measure of all organic and inorganic substances including minerals, salts, metals and ions. TDS also shows similar trends it due to contamination of sewage in the river. It has suddenly increased at S₂, S₄ & S₉ (Figure 5) it may due to large amount of solid waste, discharge from rituals. During religious activities like mass bathing, different pujas, cremate and discharge of ash of human dead bodies the river is supposed most suitable place which increases TDS in water and it causes unhygienic atmosphere and creating health problems like malaria, diarrhea etc.

Turbidity- Turbidity is description of the optical properties of water which is calculated by amount of light emitted and absorbed by particles in the water (Ichwana et al. 2016). It is observed that turbidity is maximum at S₅ (25.8 NTU) and high at S₉ and S₈ again due to organic pollutant like cremate and discharge of ash of human dead bodies as well as to perform religious activities flower garlands and other solid waste directly added to the water (Figure 12).

BOD- BOD is the amount of oxygen consumed to break down of organic matter in water. High BOD means high amount of organic pollutants which may stress or kill the organisms and low BOD indicates low pollution. It can be observed (Table 4) there is suddenly increase of BOD value at S₂ and S₄, it may due to heavy religious activities and rituals, this places are famous for Hindu Rituals *Narayan Nagbali*, *Pindshradha* nearby the river bank it involves offering flowers, milk, lamp, floor, coconut, leaves and other organic material in to river. BOD at S₈ and S₉ is found to be highest due to mass ritual activities (Figure 13).

F-Coli- Many people bathing, washing and spending time in water directly increased F-coli because it increased human waste and microbes in the water. It also increased due to immersion and offering in the water and may cause gastrointestinal diseases and body infection. F-coli is highest at S₂ and S₄ (Figure No.8) because both places famous for mass fair based on water. . Figure 14 shows mapping of F-coli.

Figure 2. pH of selected sampling stations	Figure 3. TS of selected sampling stations
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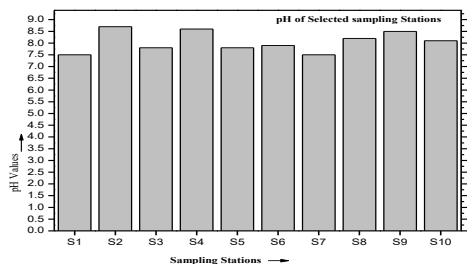


Figure 4. DO of selected sampling stations

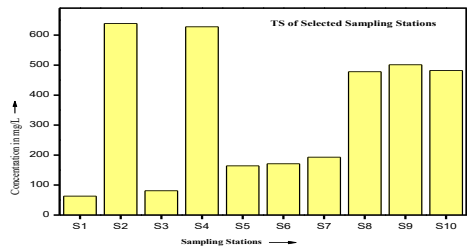


Figure 5. TDS of selected sampling stations

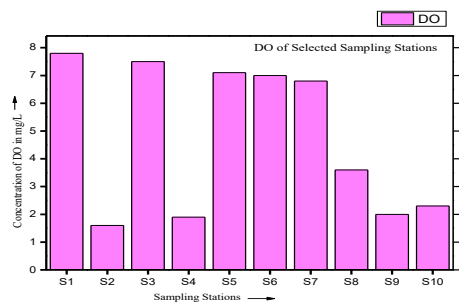


Figure 6. Turbidity of selected sampling stations

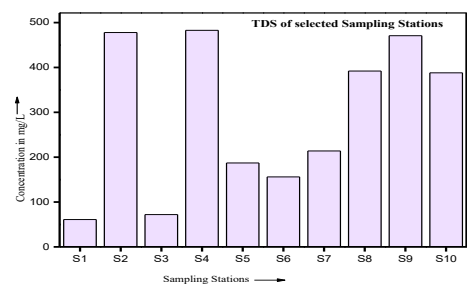


Figure 7. BOD of selected sampling stations

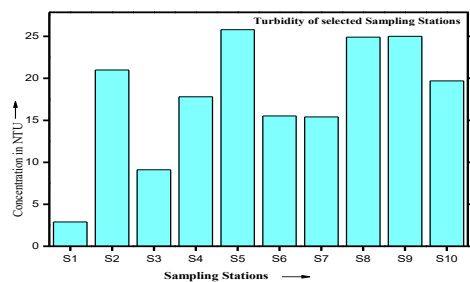


Figure 8. F-Coli of selected sampling stations

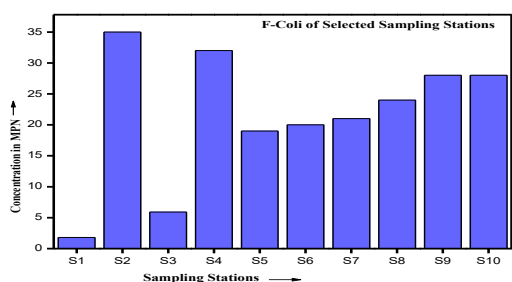
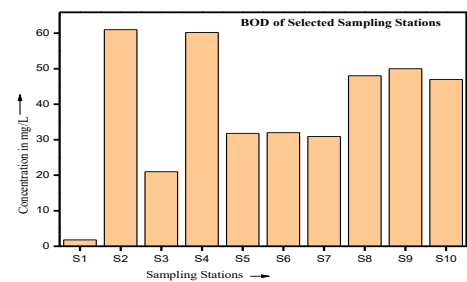


Figure 9. Distribution of pH selected sampling stations

Figure 10 Distribution of DO selected sampling stations

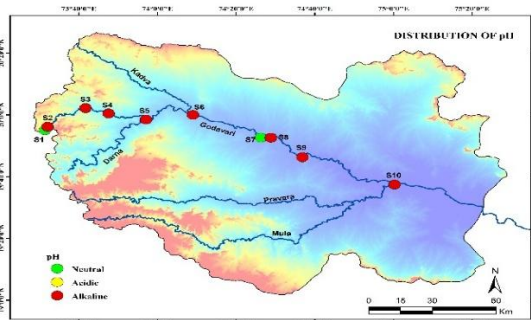


Figure 11. Distribution of TDS of selected sampling stations

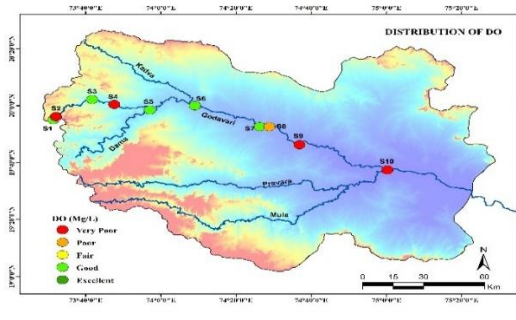


Figure 12. Distribution of Turbidity of selected sampling stations

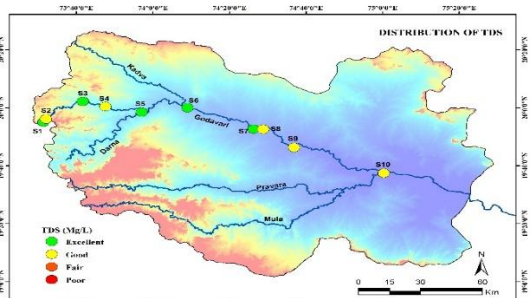


Figure 13. Distribution of BOD of selected sampling stations

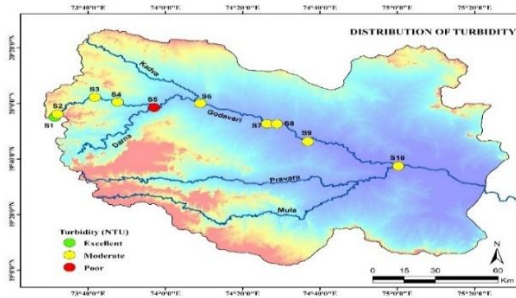


Figure 14. Distribution of F-Coli of selected sampling stations

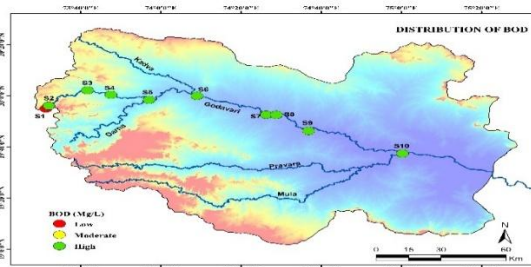
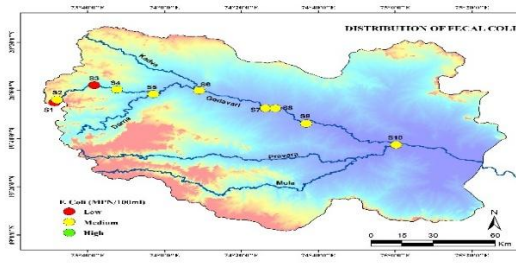


Figure 15. Distribution of TS of selected sampling stations



• **Karl Pearson Correlation Matrix -**

Table No.4 Statistical Summary of Physico-Chemical Parameters

Parameters	Max.	Min.	Mean	Sum
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pH	8.7	7.5	8.06	80.6
TS	639	63	340	3400
DO	7.8	1.6	4.76	47.6
TDS	483	61	290.2	2902
Turbidity	25.8	2.9	17.713	177.13
BOD	61	1.8	38.37	383.7
F-coli (MPN)	35	1.8	21.47	214.7

(Max.-Maximum, Min.-Minimum)

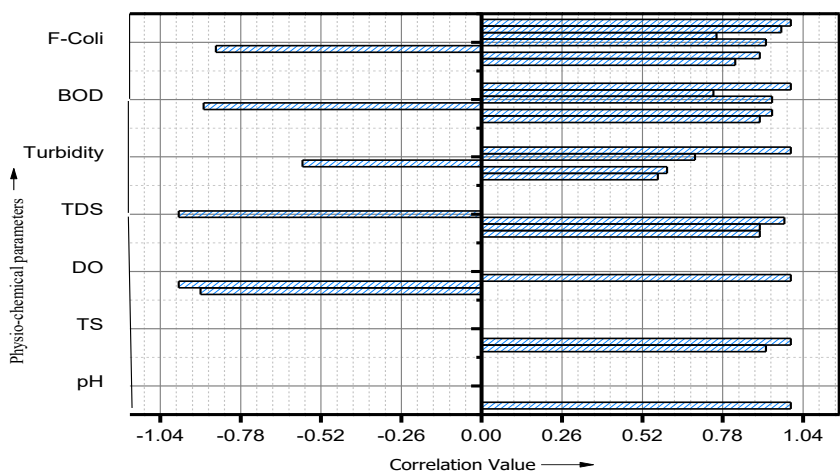
Table No.5 Karl Pearson Correlation Matrix for Water Samples of Upper Godavari Basin

Parameters	pH	TS	DO	TDS	Turbidity	BOD	F-Coli
pH	1.0						
TS	0.92	1.0					
DO	-0.91	-0.98	1.0				
TDS	0.90	0.90	0.98	1.0			
Turbidity	0.57	0.60	-0.58	0.69	1.0		
BOD	0.90	0.94	-0.90	0.94	0.75	1.00	
F-Coli	0.82	0.90	-0.86	0.92	0.76	0.97	1.00

(Computed by Researchers)

Statistical summary represents (Table 5) range between computed value which could helpful for comparative study. The Karl Pearson correlation matrix has been established for examination of the relationship between two parameters of the samples. The value of correlation coefficient around 0.7 and above is considered to be a strong positive correlation. It has been found from analysis that there is positive correlation is found between total dissolved solids and DO. Positive correlation also found between turbidity and TDS (Table No.6). This is due to fact as the number of particles in water (TDS) increases, TS and turbidity also has been increased. It can be seen that there is a positive correlation between BOD and TS, higher the BOD values which arise TS presents in the water. There is positive correlation between BOD and Turbidity as amount of suspended matter increases turbidity also increases which in turn increases BOD value. There is positive correlation between TDS, F-Coli & BOD it may due to mass bathing and mass rituals increased the value of TDS as well F-coli and BOD. It depicted with the help of Figure 16

Figure 15. Karl Pearson Correlation graph for Water Samples of Upper Godavari River.



• **Water Quality Index-**

Table No.6 WQI rating of various sampling sites of Upper Godavari Basin

Station	Location	WQI Score	Water Quality	Color Code
S1	Gangadwar (Origin)	74.44	Excellent	
S2	Godavari Kund/ Kushavart	16.45	Very Poor	
S3	Someshwar	53.56	Good	
S4	Ramkund (Nashik City)	17.66	Very Poor	
S5	Darna Sangavi	45.80	Poor	
S6	Nandur Madhmeshwar	47.50	Poor	
S7	Jeur Kumbhari	47.25	Poor	
S8	Kopargaon	25.08	Poor	
S9	Puntamba	22.60	Very Poor	
S10	Toka	25.71	Poor	

Figure 16. WQI of collected water samples.

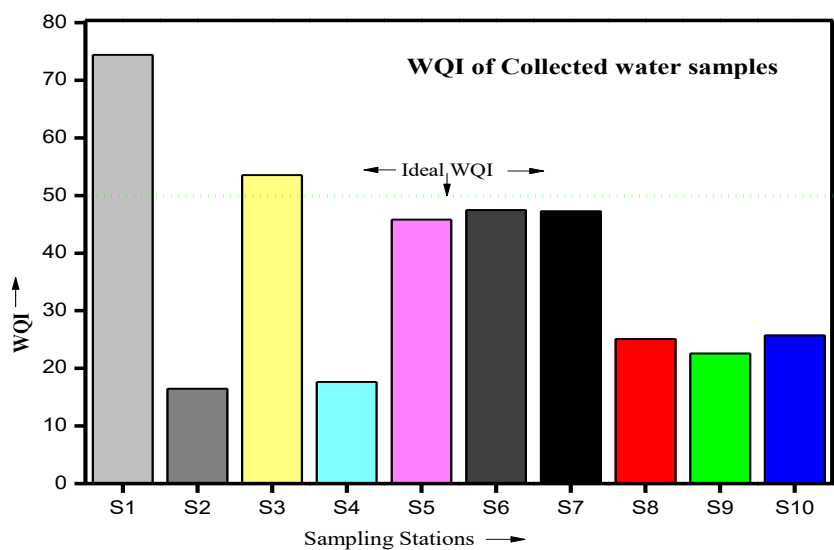
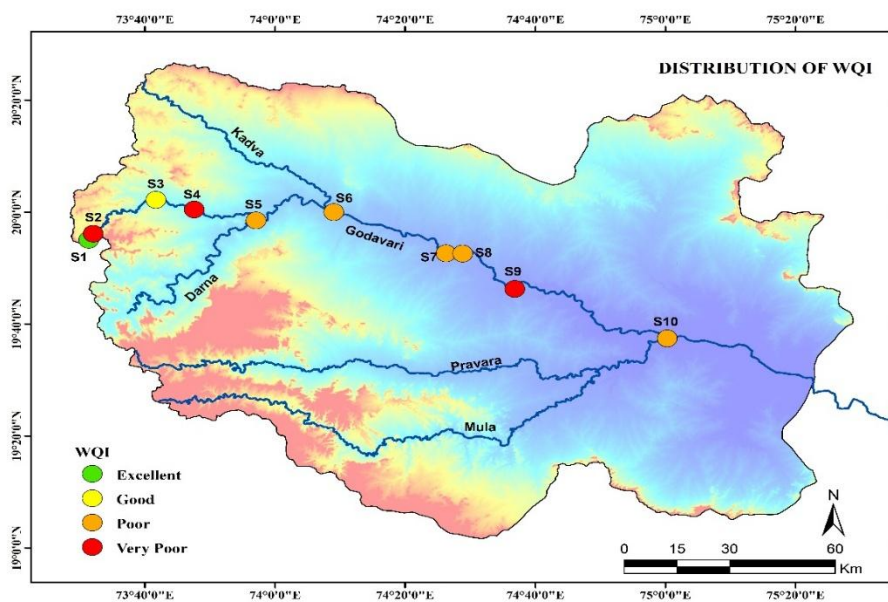


Figure 17. Distribution of WQI of collected water samples



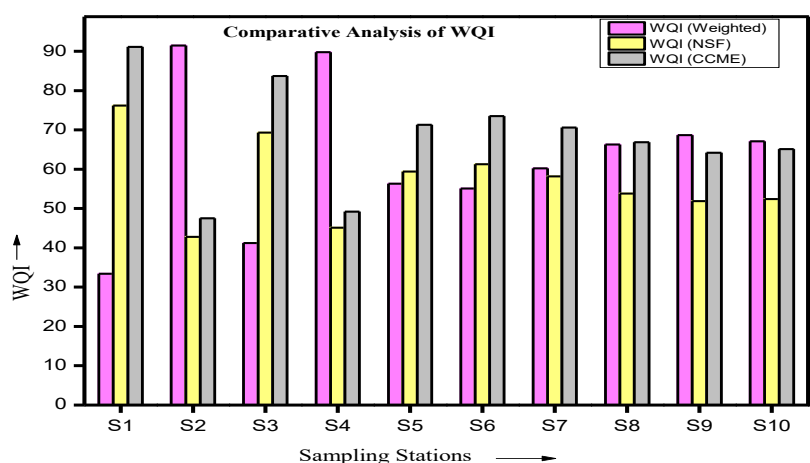
• Comparative Water Quality Index-

Table No.7 Comparative Water Quality Index (WQI)

Station	WQI (Weighted)	WQI (NSF)	WQI (CCME)
Gangadwar	33.4	74.44	91.1
Kushavart	91.5	16.45	47.5
Someshwar	41.2	53.56	83.7

Ramkund	89.8	17.66	49.2
Darna Sangavi	56.3	45.80	71.3
Nandur Madhmeshwar	55.1	47.50	73.5
Jeur Kumbhari	60.2	47.25	70.6
Kopargaon	66.3	25.08	66.9
Puntamba	68.7	22.60	64.2
Toka	67.1	25.71	65.1

Figure No.18 Comparative Water Quality Index (WQI)



Station No.	Location	Distance from 1 st sampling station	Coordinates	Observed Religious Activities
S1	Gangadwar (Origin)	00 km.	19°55'49.03"N 73°31'12.05"E	Religious tourism
S2	Kushavart/ GodavariKund	1.1 km.	19°55'57.78"N 73°31'39.42"E	Rituals, Mass Bathing, Festivals etc.
S3	Someshwar	31.1 km.	20°0' N 73° 67'E	Religious tourism
S4	Ramkund (Nashik City)	38.5 km.	20° 0' N to 73° 68' E	Rituals, Festivals, Mass Bathing, Immersion
S5	Darna Sangavi	53.9 km.	20° 0' N to 73° 68' E	Rituals

S6	Nandur Madhmeshwar	77.3km.	20° 0' N to 73° 69' E	Religious tourism
S7	Jeur Kumbhari	111.9 km.	20° 0' N to 73° 70' E	Religious tourism
S8	Kopargaon	120 km.	20° 0' N to 73° 78' E	Religious tourism
S9	Puntamba	136.2 km.	20° 0' N to 73° 78' E	Rituals, Festivals, Bathing
S10	Toka	233.5 km.	20° 0' N to 73° 78' E	Rituals, Bathing etc

Table No.8 Sampling stations of UGR and observed Religious activities

(Personal Investigation)

Conclusion:

It has been observed that Godavari River is also well known for its religious importance and is considered a sacred river, with major pilgrimage sites like Trimbakeshwar, Ramkund and the Pushkaram (Table 9) festival celebrated on its banks. It is also well known for purifier of sins and source of Spritual merit. After every twelve years millions of devotees are organized at Nashik for mass bathing festival called as Pushkaram (Kumbh Mela). In this study water quality of UGR was evaluated, for it 10 sampling stations were determined and 8 parameters were selected for physico-chemical analysis. It has been clearly observed that heavily ritual sites are more affected than others (table 7). As pollutants have been added by devotees in the river water at various stations it has decreased dissolved Oxygen value, due to addition of pollutant at these stations BOD and Turbidity values has increased. F-coli also increased due to immersion and offering in the water. The physico-chemical analysis of water samples indicate that the river water sample have alkaline properties.

Water quality parameters pH, DO, BOD and F-coli were used to calculate Water Quality Index (WQI) for evaluation of water Quality. The water quality Index values of Godavari River of about 248.94 km *the stench* from Gangadwar (Origin) to Jayakwadi Dam (Figure 18) shows that due to mass festivals, mass bathing and religious tourism s lots of waste has been generated. It may in liquid or solid forms responsible for water pollution. The computed WQI (Table 8, Figure 19) values are between 16.45 and 74.44 in the study area. The WQI classification shows that S₁ has good water quality status, but as religious activities enhansed considerable changes in WQI were observed at S₂, S₄ and S₉ sites due to mass bathing, burial activities, encroachment and contamination. In spite of all efforts made by government authorities, local people and devotees not aware about river pollution. From the above analysis, it has been concluded that the acceleration of mass religious activities increases the human interventions along the river which deteriorate the water quality. Hence the suggested measures would help to minimize human interventions such as rituals like *puja*, bathing and offering in and along the River Godavari. It's also helpful to minimize negative consequences of such impacts in the future and conserve the water resource.

Declarations

Conflict of interest: The authors declare no competing interests

Funding: No funding was received to assist with the preparation of this manuscript.

Availability of data and materials: The data sets supporting the results of this article are included within the article.

Research involving Human Participants and/or Animals- This article does not contain studies with human or animal subjects.

Informed consent- We fully agree with the information provided in this article.

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