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Evaluating the Effects of Urbanization on Surface Water Quality in Mangalore, Dakshina Kannada District, Karnataka, India

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Abstract

The transfer of residents from rural areas to cities, the resulting decline in rural populations, and the ways in which communities adapt to these changes are taken into consideration of urbanization. Surface water quality and quantity are also impacted by increasing urbanization. The biological, physical, and chemical characteristics of water are commonly used to assess its quality. The major objective of this study is to ascertain how urbanization impacted the surface water's physicochemical properties in Mangalore—the Gurupura and Netravati rivers—which are used for drinking. To determine whether the surface water characteristics of the Netravati and Gurupura rivers in the Dakshina Kannada District, Karnataka, are suitable for household and drinking use in the city of Mangalore, a thorough monitoring program was conducted. The monitoring took place in before-monsoon, after the-monsoon, monsoon seasons of 2018 and 2019. Eighty-four surface water samples from the Gurupura and Netravati rivers were analyzed for a number of physico-chemical factors. Majority of the metrics are within the WHO and BIS allowed ranges after the monsoon season, because of the increase in fresh rainwater during and after the monsoon. The Weighted Arithmetic Index (WAI) method was applied to categorize the quality of surface water. According to this method, Five categories are utilized to classify surface water quality, Such as: Excellent (0 to 25), Good (26 to 50), Bad (51 to 75), Very Poor (76 to 100), and Unfit for Consumption (more than 100). Considering the outcomes of the Weighted Arithmetic Index (WAI) method, samples of surface water collected during the monsoon season are of good quality.

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Introduction

Urbanization and population increase have resulted in variations in land cover and land use on a local to global scale. This process has the potential to significantly alter the structure and function of ecosystems[1]. Although they make up only 2% of the planet's land area, cities create 78% of greenhouse gases, which has a substantial impact on global climate change. Because of the benefits that the oceans provide, including a food source, a means of transportation, a position that can be defended, and a healthy environment, humans have historically dwelt along the coast. Most main cities are situated along the coast, and halved of the global populations lives inside the hundred kilometres of sea.[2,3] Urban areas are a major source of the pollution that is putting strain on the seas and oceans. Waste water and sewage discharge from cities is one of the significant harmful approaches that cities contaminate coastal areas. Numerous cities around the coast release waste water, including sewage and industrial effluent, straight into the nearby rivers and seas. Improper disposal of plastics and other waste, contamination from household activities like using detergents and medications, untreated sewage and industrial wastewater containing chemicals and heavy metals, and urban storm water runoff that transports oil, grease, pesticides, and litter from streets and roofs. Because of pollution, habitat destruction, and overexploitation, the concentration of human populations close to the coast seriously damages freshwater supplies and aquatic ecosystems. These effects harm human health and marine biodiversity, disturb delicate coastal ecosystems, and deteriorate water quality.

The aquatic ecosystems that surround coastal communities, including estuaries, rivers, oceans, seashores, and coastal wetlands, have been heavily contaminated by pollution as a result of urbanization, industrialization, population increase,and differing farming practices. This leads to the deterioration of the environment. The sustainability of coastal environments is significantly hampered by pollution.[4] Substantial industrial areas in the study region are found along the banks of the Gurupur and Nethravati rivers, which combine to form a single estuary before entering the Arabian Sea. Untreated home and industrial waste discharge and disposal into estuaries, rivers, nearshore waterways, and harbor operations are the main causes of coastal pollution in the study area.[5] Two of the rivers that run westward in the Mangaluru coastline region are Gurupura and Nethravthi. The adjacent industries discharge a significant quantity of pollutants into them, which degrades the water's quality. For this research, seven surface water samples, including river water, were collected, for this investigation throughout the monsoon, pre-monsoon, and post-monsoon and subjected to established procedures for the analysis of multiple water quality indicators. Unplanned urbanization has significant continuing effects on both the human health and environment. Two particularly persistent and rapidly-evolving issues are air pollution from traffic smoke and water contamination from urban debris.[6] In unplanned cities, access to safe drinking water is becoming increasingly difficult for residents, and municipal supplies are not always reliable. Groundwater supplies are also being impacted by sewage pipe leaks. Water shortages are something that most people deal with on a regular basis. Human waste and an inadequate sewage system, which are major causes of water pollution and seep into subsurface water sources, are significant factors that contribute to the impureness of the water in metropolitan areas.[7] The release of domestic trash into water supplies is a practical aspect of urbanization, and this activity causes changes that impact the stability of the environment and the quality of the water for a variety of reasons. Urbanization, however, is one of the biggest issues groundwater planners face and one of the most detrimental elements affecting the quality of streams. Industrial waste give rise to a serious hazard to human health and water supplies. Aquatic creatures are negatively impacted by waste released from manufacturing processes, including untreated effluents, heavy metals, poisons, alkaline compounds, and contaminants.[8] South Kanara, also known as Dakshina Kannada, is the 4866 square kilometer southern coastal district of the state of Karnataka. The district is situated between latitudes 120 57' and 130 50' north and longitudes 740' and 750' east. At its thinnest, it is around 177 kilometer length, 40 kilometer width, 80 kilometer width,[9] and 20, 83,625 people are living there, according to the 2011 census. The Udupi district forms the district's northern boundary, to the east by the Shimoga, Chickmagalur, and Hassan districts, to the south by the Coorg district and the Kerala state's Kasaragod district, and to the west by the Arabian Sea. In addition to having the maximum literateness rate in Karnataka

(88.62%).[9] Dakshina Kannada district is well-known for its professional and higher education institutions as well as its banking industry. In Karnataka, it is second evenly more compactly district with a population,of 457 people per square kilometer. Over the past few decades, the seaside region of the Dakshina Kannada (DK) district has experienced incredible growth. This area expanded due to increased commercial activity with the establishment of a significant seaport in Panambur, as well as industry expansion as fertilizers, iron ore pelletization, and petrochemicals. Furthermore, it is anticipated that the planned establishment and growth of Mangalore's Special Economic Zones (SEZs) will accelerate the trend of development. Dakshina Kannada district has the second-highest number of registered vehicles in the state of Karnataka. The number of registered automobiles is increasing annually by over 10%.[10] The Regional Transport Office in Mangalore reports that approximately thirty thousand automobiles were registered in 2010 and 2011, while thirty-five thousand vehicles were registered in 2012 up until the month of March. 22,659 two-wheelers and 6,574 vehicles had been registered between June 2019 and May 2020, according to data from the regional transport office in Mangalore. There was a slight increase up until May 2021, when 7,957 cars and 25,702 two-wheelers were registered. The principal objective of this investigation is to know the influence of urbanization on water resources in Mangalore, along with specific objective, to collect water samples in different locations of Netravati and Gurupur River and to conduct standard laboratory tests for important water quality parameters and, to Analyze Water quality using WHO and BIS guidelines, weighed arithmetic Index method is employed to assess the urbanization impact on water quality.

Materials and Methods

Demography

According to the Census of India 2001, the urban area of Mangalore had citizens of 601 thousand in 2001, up from 44 thousand in 1901. The urban population growth of Mangalore from 1901 to 2001 is depicted in Figure 1. Between 1991 and 2001, there was a 4% annual increase in population growth, up from 1% between 1901 and 1911.

In 2011, 488,968 people called Mangalore home. Mangalore city has 488,968 residents, however there are 623,841 people living in its urban and metropolitan areas. The city of Mangalore had 724,159 residents in 2021.[10] A study conducted in 2011 on literacy rates in India found that 96.49% of men and 91.63% of women were literate.[10]

Six years old and younger made up about 8.5% of the population.[10] In Mangalore city, 7726 people, or 1.55% of the total population, lived in slums.[11] Urban population growth in Mangalore shown in Fig 1.

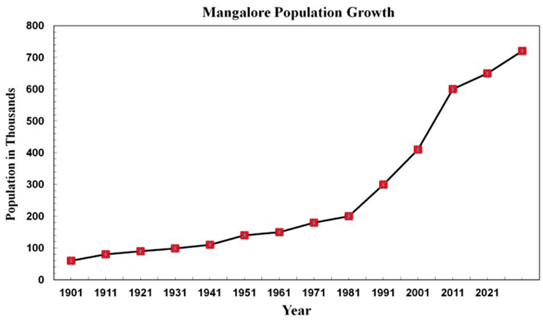

Fig. 1: Urban Population Growth in Mangalore, 1901–2021

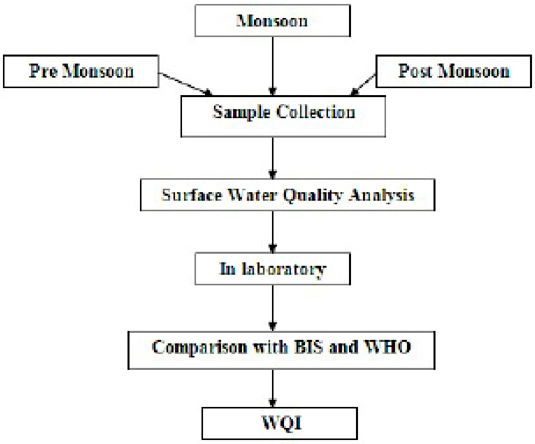

Fig. 2: Flow Chart

Methodology

The surface water samples from the locations (Fig 2) were collected from seven locations during the monsoon, before and after the year 2019 monsoon. July to September was taken as monsoon, and pre monsoon season from march to may, while October to December as the post-monsoon season. In accordance with the protocol recommended from APHA (American Public Health Association) (APHA, 2005),[11] total 84 surface water samples were collected. The methodology flow chart shown in Fig 2. The samples were drawn from the locations by using composite sampling methodology. Since water levels and depths vary with the seasons, rainfall, and location along the river, there is no single depth for the Netravati and Gurupur River; instead, the average depth, 1.5 m, is set for the duration of the study.

Study Area

The research area shown in Figure 3 is the seaside area of the DK regionin the Karnataka state of India. It is positioned in between latitudes 12°45' N and 13°7'30" N and longitudes 74°45' E and 75° E. Nethravati and Gurpur are the study area's two principal rivers. We solely took into account the city's Central and Southern regions for our analysis. The quality assessment in this study was limited to Netravati and Gurupura River. The locations of the samples are shown in Table 1 in addition to longitude and latitude data, providing a brief overview of the sample locations.

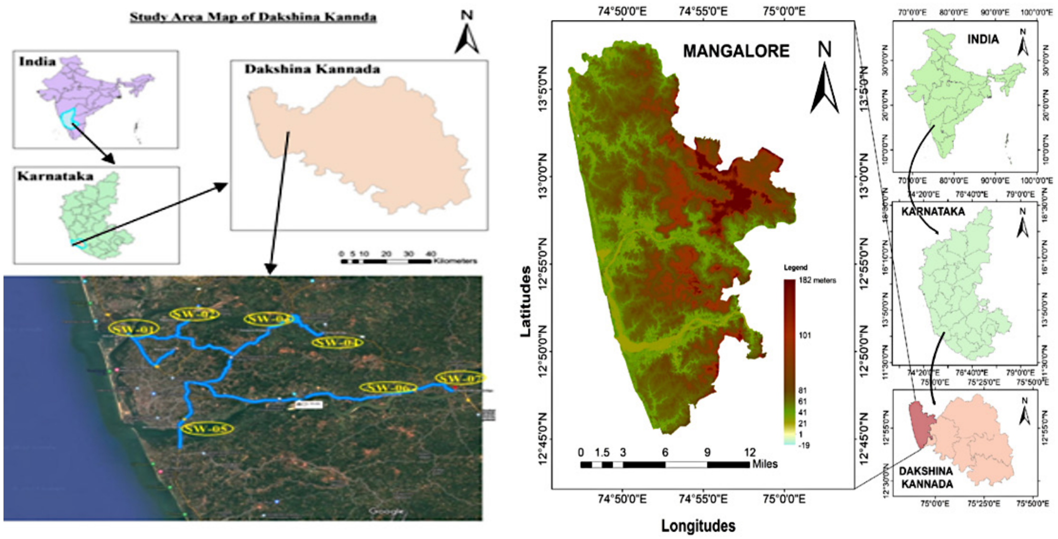

Fig. 3: Study area map of Mangalore showing the locations of samples.

Table 1: List of Surface Water Sampling Locations with Latitude and Longitude

Sample Names	Sample Location	Latitude	Longitude
SW- 01	Gurpur River- Kulur Bridge	12°55' 34.79"N	74°49' 37.4"E
SW- 02	Gurpur River –Maravoor Bridge	12º 56' 27.157" N	74º 51' 57.710" E
SW- 03	Gurpur River- Gurpura Bridge	12º 55' 56.427" N	74º 55' 06.076" E
SW- 04	Gurpur River- Addur Bridge	12º 55' 44.205" N	74º 57' 13.958" E
SW- 05	Nethravati River- NethravatiBridge	12º 50' 25.328" N	74º 51' 35.756" E
SW- 06	Nethravati River- Thumbe Vented Dam	12º 52' 20.341" N	75º 00' 17.912" E
SW- 07	Nethravati River- Pane Mangalore Bridge	12º 52' 48.487" N	75º 02' 22.316" E

Topography and Climate

The research area receives 3955 mm of rainfall on average annually, with 87% of that amount falling between June and September during the South-West monsoon. Temperature ranges from 17 to 37 degrees Celsius are typical for the tropical climate, which is also rather humid. Dense vegetation coexists with undulating topography in the research region. On top of friable sandstones and granitic gneisses is lateritic soil. On the banks of rivers, alluvial deposits are found. Sand accumulations make up the beaches. Mean fluctuation is between 6 and 7 m, and the average depth to the water table is between 7 and 9 m.

Results and Discussions

The samples were drawn from the locations by using composite sampling methodology. Samples of surface water were taken throughout the monsoon, postmonsoon, and pre-monsoon seasons. Following extensive cleaning, 84 surface water samples were meticulously gathered in sterile polythene bottles, each of which was appropriately labeled. GPS coordinates were taken at each site to determine precise sampling positions, and after then, these coordinates were used to generate a sampling site map using Arc GIS 10.8. Every collected sample was analyzed in a lab, and the outcomes are compared with BIS and WHO guidelines. Weighted Arithmetic Index Method was used to calculate water's WQI.[12]

Water Quality Analysis

Seventeen physicochemical parameters of water samples were analyzed utilizing the protocols outlined in Standard Methods (APHA, 2017).[13] Table 2 shows the list of tests that were conducted as well as the methodology.

Table 2 : Methods used for water quality analysis

Number	Parameters	Method Used
1	Cadmium	Anodic Stripping Voltammetry
2	Chlorides	Argentometric Method
3	Copper	Anodic Stripping Voltammetry
4	EC	Conductivity Meter
5	DO	Membrane Electrode Method
6	Fluorides	Ion- Selective Electrode Method
7	Hardness	EDTA Titrimetric Method
8	Iron	Phenanthroline Method
9	Lead	Anodic Stripping Voltammetry
10	Manganese	Persulfate Method
11	Nitrates	Brucine Method
12	pH	Electrode
13	Sodium	Flame Photometric Method
14	Sulfates	Turbidimetric Method
15	TDS	Conductivity -TDS Meter
16	Turbidity	Nepholometric Method
17	Zinc	Anodic Stripping Voltammetry

Table 3: BIS and WHO : Specification for Drinking Water (BIS- 10500: 2012), (WHO, 2017)

Parameter	Unit	BIS Guideline	Guideline Type	WHO Guideline	Guideline Pattern
Cadmium, Cd	µg / L	3	Acceptable	3	Health
Chlorides, Cl^-	Mg/L	250	Acceptable	250	Acceptability
Copper , Cu	Mg/L	0.05	Acceptable	2.0	Health
EC	µS / cm	300	Acceptable	400	Acceptability
DO	Mg /L	6	Acceptable	6.5-8	Acceptability
Fluorides, F^-	Mg/L	1	Acceptable	1.50	Health
Hardness	Mg/L	200	Acceptable	200	Acceptability
Iron, Fe	Mg/L	0.3	Acceptable	0.3	Acceptability
Lead, Pb	µg/ L	10	Acceptable	10	Health
Manganese, Mn	µg/ L	100	Acceptable	400	Health

Nitrates, NO_3	Mg/ L	45	Acceptable	50	Health
pH		6.5-8.5	Acceptable	6.5-8.0	Acceptability
Sodium, Na	Mg/L	20	Acceptable	200	Acceptability
Sulfates, SO_4	Mg/L	200	Acceptable	250	Acceptability
TDS	Mg/L	500	Acceptable	600	Acceptability
Turbidity	NTU	1	Acceptable	5	Acceptability
Zinc, Zn	mg/L	5	Acceptable	3	Acceptability

Table 4: Water quality analysis results for Surface water- Gurpur River (Kulur Bridge)(SW-01)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	mg/L	0.003	3	0.01	0.01	0.12	0.02	0.13	0.69	2.10	1.26	0.10	0.42	0.60	0.41
Chlorides	mg/L	250	250	28	29	26	25	24	25	185	196	189	10	23	12
Copper	mg/L	2	0.05	4.26	6.10	3.12	1.20	3.24	4.26	2.26	1.68	1.20	2.20	1.65	1.18
Electrical Conductivity (EC)	µS/cm	400	300	200	540	220	800	320	580	300	320	280	350	590	540
DO	mg/L	6	6	7.4	7.5	6.2	7.4	8.5	6.4	7.6	7.6	6.7	6.3	6.1	6.1
Fluorides(F)	mg/L	1.50	1	0.06	0.10	0.14	0.10	0.60	0.06	0.16	0.03	0.06	0.04	0.08	0.06
Hardness	mg/L	200	200	21	23	20	24	24	25	58	72	10	10	12	10
Iron(Fe)	mg/L	0.30	0.30	0.120	0.100	0.060	0.020	0.04	0.05	0.11	0.67	1.25	1.21	0.14	0.19
Lead	µg/L	10	10	1.20	1.86	2.21	1.46	2.0	1.46	1.23	1.90	2.60	1.68	2.16	2.01
Manganese	µg/L	400	100	0.01	0.02	0.02	0.06	1.08	0.08	1.28	0.13	0.01	0.06	2.18	1.83
Nitrates	mg/L	50	45	3.53	3.10	2.65	1.52	3.10	3.26	1.21	1.92	1.12	1.62	2.39	2.16
pH		6.5 -8	6.5-8.5	7.45	7.52	7.26	6.61	6.86	6.65	6.61	6.23	6.56	6.50	6.8	6.48
Sodium	mg/L	200	20	5.2	6.1	7.0	12.2	35.6	98	12.2	10.8	5.8	6.9	5.9	8.8
Sulfates	mg/L	250	200	6.98	6.2	5.86	3.98	7.95	9.98	6.86	2.98	5.86	3.68	2.85	0.09
TDS	mg/L	600	500	50	60	60	65	377	298	698	296	58	47	17	12
Turbidity	NTU	5	1	4.9	3.9	4.8	3.5	4.8	4.6	5.2	26.8	30.1	19.8	8.9	6.8
Zinc	mg/L	3	5	4.65	4.21	6.89	5.98	6.86	2.98	4.86	6.82	7.93	4.09	5.96	6.98

WHO and BIS Guidelines

There are two categories of water quality parameters, according WHO guidelines. Health criteria take into account chemical and radioactive components that have the potential to directly harm human health, while acceptance guidelines include characteristics that may not have any direct health consequences but cause an unpleasant taste or odor in the water (WHO 2017). The BIS water quality and World Health Organization's (WHO) recommendations are listed in Tables 3.[14]

An important step in the growth of water assests is the analysis of water quality. Quality of Water can be described in terms of certain features of the water, typically physical, chemical, and biological (including bacteriological) that are significant for a particular service and that pose a hazard to human health if values beyond acceptable limits.[15]

The outcomes of water quality analysis in monsoon, pre monsoon and post monsoon months shown in the Table 4, 9, 12, 15, 18, 21 and 24.

The Descriptive Statistics of Water Quality Parameters of Gurupur River and Netravati River are Shown in Table 5, 10, 13, 16, 19, 22 & 25.

Temporal Distribution of water quality of Gurupura River and Netravati River by Weighted Arithematic Index Method are shown in Table 8, 11, 14, 17, 20, 23, and 26.

Graphical Variation of Reults of water quality anaysis of different sampling locations of Gurupura and Netravati River are shown in Figure 5 to 11.

Overall water quality analyis by Weighed Arithmetic Method of both Gurupura River and Netravati River, Before, during, and after the monsoon are shown in Table 27. Whereas Table 6 indicates the limitations of Weighted Arithmetic Index Method (WAI) Developed by Brown and co-workers in 1972.[16]

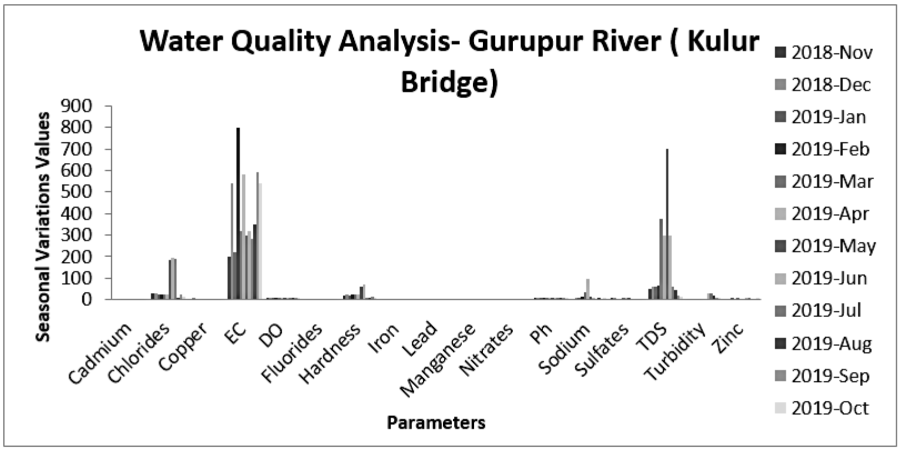

Fig 4: Results of water quality analysis for Surface water - Gurupur River (Kulur Bridge) from Nov 2018 to Sep 2019

Table 5: Water Quality Parameter Descriptive Statistics for the Gurupur River (Kulur Bridge)

No.	Parameter	Unit	Mean	WHO	BIS	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	μg / L	0.49	3	3	1.395	0.40	0.01	2.10
2	Chlorides (Cl-)	Mg / L	64.33	250	250	105	5781.52	10	196
3	Copper(Cu)	Mg /L	2.70	2.0	0.05	3.26	2.39	1.18	6.10
4	EC	μS /cm	420	400	300	440	34.09	200	800
5	DO	Mg /L	6.98	6.5-8	6	7	0.61	6.1	8.5
6	Fluorides (F−)	Mg/L	0.120	1.50	1.00	0.110	0.020	0.03	0.60
7	Hardness	Mg/L	25.75	200	200	41.5	380.20	10	72
8	Iron(Fe)	Mg/L	0.33	0.3	0.3	0.08	0.21	0.02	1.25
9	Lead (Pb)	μg /L	1.81	10	10	1.345	0.18	1.20	2.60
10	Manganese,Mn	μg /L	0.56	400	100	0.68	0.65	0.01	2.18
11	Nitrates, NO_3	Mg/L	2.30	50	45	2.235	0.70	1.12	3.53
12	pH		6.79	6.5-8.0	6.5-8.5	6.63	0.17	6.23	7.45
13	Sodium,Na	Mg/L	17.88	200	20	55.1	705.29	5.2	98
14	Sulfates, SO_4	Mg/L	5.27	250	200	8.42	7.14	0.09	9.98
15	TDS	Mg/L	169.83	600	500	498	43.60	12	6.98
16	Turbidity	NTU	10.34	5	1	4.9	91.28	3.5	30.1
17	Zinc,Zn	μg /L	5.68	3	5	3.92	2.25	2.98	7.93

Tidal variations in the Arabian Sea have an influence on the Gurpur River's water quality at the time of sample station SW-01 (Kulur bridge) (Fig. 3). During the study period, the results of parameters like turbidity, iron, and EC exceeded the WHO and BIS guideline limits.

Table 6: Weighted Arithmetic Index Method

Index of Quality	Quality Conditions
0 to 25	Excellent
26 to 50	Good
51 to 75	Poor
76 to 100	Very Poor
> 100	Unfit For Use.

Calculation of Weighted Arithmetic Water Quality Index, (WAWQI) (Source- Brown *et al*. (1970).
Formula for the Overall Water Quality Index is WQI=∑WnQn / ∑WnWQI, is employed to assess a water body's general quality using a variety of criteria.

The Weighted Arithmetic Water Quality Index (WAWQI) technique is the most commonly used approach.

There are three primary steps in the calculation

- Give every water quality metric a relative weight (Wn).
- Based on each parameter's concentration in the sample, assign a quality rating (*Qn*) to it.
- To obtain the overall WQI, add these values together.

First, give it a relative weight (*Wn*).
For the parameter used to calculate the unit weight (*Wn*), the value is inversely proportional to the recommended Standard value (*Sn*).
Wn = K/Sn where *K* is a proportionality constant.

According to drinking water regulations from an appropriate organization, such as the BIS or the WHO, *Sn* is the standard allowable value for the n^{th} parameter.

K is computed as follows: K=1/∑(1/Sn)
The value of guarantees that all weights added together equal one.

In Step Two
find the quality rating (Qn=100×(Vn-Videal)/(Sn-Videal), where *Vn* is the water sample's estimated concentration of the n^{th} parameter. Videal is the parameter's optimal value for pure water.

This is zero for the majority of parameters.
There are notable exceptions.
PH: 7.0 is the optimal value.
The optimal level of dissolved oxygen (DO) is 14.60 mg/l.
The standard acceptable value for the n^{th} parameter is *Sn*.

Determine the Total WQI
A weighted sum of the quality ratings for each parameter divided by the total of their relative weights yields the final WQI value.

WQI = ∑WnQn/∑Wn
The formula becomes WQI=∑WnQn as the sum of the weights (∑Wn) usually equals 1.

Water quality is then classified into a variety of categories (such as Excellent, Good, Satisfactory, Extremely poor, or Unsuitable) based on the final WQI score; however, the precise range definitions may differ depending on the index. Below, Nov 2018 Sample calculation are shown for reference.

Table 7: Results of Weighted Arithmetic Water Quality Index for November 2018 Samples

Parameter	WHO	1/Sn	∑ 1/Sn	k=1/(sum1/Sn)	Wn=K/Sn	Sn	Vn/Sn	Qn	WnQn
Cadmium	3	0.333	25.801	0.038759	0.01292	0.01	0.003	0.33	0.00
Chlorides	250	0.004	25.801	0.038759	0.000155	20	0.08	8	0.00
Copper	2	0.500	25.801	0.038759	0.019379	4.26	2.13	213	4.13
EC	400	0.003	25.801	0.038759	0.025839	290	0.72	72.5	0.01
DO	6	0.167	25.801	0.038759	0.00646	7.1	1.18	118.3	0.76
Fluorides	1.5	0.667	25.801	0.038759	0.025839	0.06	0.04	4	0.10
Hardness	200	0.005	25.801	0.038759	0.000194	21	0.105	10.5	0.00
Iron	0.3	3.333	25.801	0.038759	0.129196	0.12	0.4	40	5.17
Lead	10	0.100	25.801	0.038759	0.003876	1.2	0.12	12	0.05

Manganese	0.05	20.000	25.801	0.038759	0.775179	0.01	0.2	11	8.53
Nitrates	50	0.020	25.801	0.038759	0.000775	3.53	0.07	7.06	0.01
pH	8	0.125	25.801	0.038759	0.004845	7.45	0.93	93.12	0.45
Sodium	200	0.005	25.801	0.038759	0.000194	5.2	0.026	2.6	0.00
Sulfates	250	0.004	25.801	0.038759	0.000155	6.98	0.02	2.79	0.00
TDS	600	0.002	25.801	0.038759	0.025839	50	0.08	8.3	0.00
Turbidity	5	0.200	25.801	0.038759	0.007752	4.9	0.98	98	0.76
Zinc	3	0.333	25.801	0.038759	0.01292	4.65	1.55	155	2.00
	25.801				1				28.97

Table 8: Temporal Distribution of Water Quality of Gurupur River (Kulur Bridge) by Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	28.97	45.17	41.81	99.62	87.83	109.09	112.30	102.26	72.99	68.99	43.38	45.04
Status	Good	Good	Good	Extre -mely poor	Extre -mely poor	Unfit	Unfit	Unfit	Poor	Poor	Good	Good

The above results (Table 8.0) shows that, the Water Quality of Gurupur river (Kulur Bridge) Vary from good to Unfit for the usage, based on the above results Gurupur River Water at Kulur Bridge can be used during monsoon and post monsoon.

The electrical Conductivity EC and TDS values are not within the BIS guidelines and these two parameters are varied in the post- monsoon and pre- monsoon shown in the Table 9.

Table 9: Results of Water Quality Analysis for Surface water- Gurpur River (Maravoor Bridge) (SW-02)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	µg/L	0.003	3	0.01	0.01	0.11	0.01	1.10	1.67	2.10	1.24	0.10	0.42	0.60	0.41
Chlorides	mg/L	250	250	20	23	20	21	24	25	154	194	180	12	10	12
Copper	µg/L	2	0.05	4.26	6.10	3.12	1.20	3.24	4.26	2.26	1.68	1.20	2.20	1.65	1.18
EC	µS/cm	400	300	290	310	300	190	210	200	510	520	280	600	300	200
DO	mg/L	6	6	7.1	7.3	7.4	6.1	6.2	7.3	7.4	8.2	6.9	7.6	7.9	7.8
Fluorides(F)	mg/L	1.5	1.0	0.06	0.10	0.14	0.10	0.60	0.06	0.16	0.03	0.06	0.04	0.08	0.06
Hardness	mg/L	200	200	21	23	20	24	24	25	58	72	10	10	12	10
Iron(Fe)	mg/L	0.3	0.30	0.120	0.100	0.060	0.02	0.04	0.05	0.11	0.67	1.25	1.21	0.14	0.19
Lead	µg/L	10	10	1.20	1.86	2.21	1.46	2.0	1.46	1.23	1.90	2.60	1.68	2.16	2.01
Manganese	µg/L	400	100	0.01	0.02	0.02	0.06	1.08	0.08	1.28	0.13	0.01	0.06	2.18	1.83
Nitrates	mg/L	50	45	3.53	3.10	2.65	1.52	3.10	3.26	1.21	1.92	1.12	1.62	2.39	2.16
pH		6.5 -8	6.5 -8.5	7.45	7.52	7.26	6.61	6.86	6.65	6.61	6.23	6.56	6.50	6.8	6.48
Sodium	mg/L	200	20	5.2	6.1	7.0	12.2	35.6	98	12.2	10.8	5.8	6.9	5.9	8.8
Sulfates	mg/L	250	200	6.98	6.2	5.86	3.98	7.95	9.98	6.86	2.98	5.86	3.68	2.85	0.09
TDS	mg/L	600	500	50	60	60	65	377	298	698	296	58	47	17	12
Turbidity	NTU	5	1	4.9	3.9	4.8	3.5	4.8	4.6	5.2	26.8	30.1	19.8	8.9	6.8
Zinc	µg/L	3	5	4.65	4.21	6.89	5.98	6.86	2.98	4.86	6.82	7.93	4.09	5.96	6.98

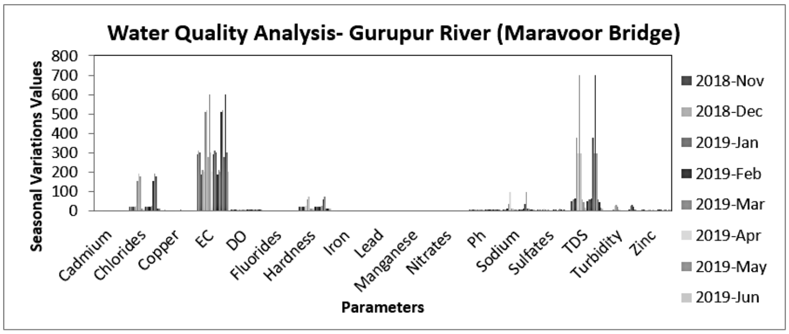

Fig 5: Results of water quality analysis for Surface water - Gurupur River (Maravoor Bridge) from Nov 2018 to Sep 2019.

Table 10: Descriptive Statistics of Water Quality Parameters for Gurupur River (Maravoor Bridge)

No.	Parameter	Unit	Mean	WHO	BIS	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	µg /L	0.65	3	3	1.885	0.51	0.01	2.10
2	Chlorides (Cl-)	mg/L	57.92	250	250	89.5	5168.99	10	194
3	Copper(Cu)	µg /L	2.70	2.0	0.05	3.26	2.39	1.18	6.10
4	EC	µS /cm	325.83	400	300	355	19.57	190	600
5	DO	mg /L	7.27	6.5-8	6	7.35	0.40	6.1	8.2
6	Fluorides (F−)	mg/L	0.120	1.50	1.00	0.110	0.020	0.60	0.03
7	Hardness	mg/L	25.75	200	200	41.5	380.20	10	72
8	Iron(Fe)	mg/L	0.33	0.3	0.3	0.08	0.21	0.02	1.25
9	Lead(Pb)	µg /L	1.81	10	10	1.345	0.18	1.20	2.60
10	Manganese,Mn	µg /L	0.56	400	100	0.68	0.65	0.01	2.18
11	Nitrates, NO_3	mg/L	2.30	50	45	2.235	0.70	1.12	3.53
12	pH		6.79	6.5-8.0	6.5-8.5	6.63	0.17	6.23	7.45
13	Sodium,Na	mg/L	17.88	200	20	55.1	705.29	5.2	98
14	Sulfates, SO_4	mg/L	5.27	250	200	8.42	7.14	0.09	9.98
15	TDS	mg/L	169.83	600	500	498	43.60	12	698
16	Turbidity	NTU	10.34	5	1	4.9	91.28	3.5	30.1
17	Zinc,Zn	µg /L	5.68	3	5	3.92	2.25	2.98	7.93

Table 11: Temporal Distribution of Water Quality of Gurupur River (Maravoor Bridge) by Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	21.91	22.66	19.47	14.97	19.77	18.89	20.81	48.05	47.19	41.21	21.85	23.51
Status	Exce -llent	Exce -llent	Exce -llent	Exce -llent	Exce -llent	Exce -llent	Exce -llent	Good	Good	Good	Exce -llent	Exce -llent

As per the Descriptive Statistics of Water Quality Parameters shown in the table 10, The Gurpur River's water quality at the sampling site SW-02 (Maravoor Bridge) (Fig. 5.0) meets the desirable limits of WHO and BIS guideline values during the study period. Only minor changes observed in Turbidity, DO, EC and Copper.

The outcomes displayed in Table 11. Demonstrates that the Gurupur River's (Maravoor Bridge) water quality varies from excellent to good in throughout the year.

Table 12: Results of Water Quality Analysis for Surface water- Gurpur River (Gurpura Bridge) (SW-03)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	µg/L	0.003	3	0.01	0.01	0.11	0.01	1.10	1.65	2.10	1.26	0.11	0.48	0.60	0.41
Chlorides	mg/L	250	250	20	23	20	21	25	25	154	194	180	12	10	10
Copper	µg/L	2	0.05	4.26	6.10	3.12	1.20	3.24	4.26	2.26	1.68	1.20	2.20	1.65	1.18
EC	µS/cm	400	300	290	280	330	350	300	460	490	530	280	260	250	250
DO	mg/L	6	6	6.9	6.8	7.3	7.8	7.6	6.9	5.9	6.3	6.1	6.1	6.3	6.2
Fluorides(F)	mg/L	1.5	1.0	0.06	0.12	0.14	0.10	0.62	0.06	0.16	0.03	0.06	0.04	0.08	0.06
Hardness	mg/L	200	200	21	23	20	24	24	25	58	72	10	10	12	10
Iron(Fe)	mg/l	0.3	0.30	0.120	0.100	0.06	0.02	0.04	0.05	0.11	0.67	1.25	1.21	0.14	0.19
Lead	µg/L	10	10	1.20	1.86	2.21	1.46	2.0	1.46	1.23	1.90	2.60	1.68	2.16	2.01
Manganese	µg/L	400	100	0.01	0.02	0.02	0.06	1.08	0.08	1.28	0.13	0.01	0.06	2.18	1.83
Nitrates	mg/L	50	45	3.53	3.10	2.65	1.52	3.10	3.26	1.21	1.92	1.12	1.62	2.39	2.16
pH		6.5 -8	6.5-8.5	7.55	7.58	7.26	6.60	6.86	6.65	6.61	6.25	6.56	6.50	6.8	6.48
Sodium	mg/L	200	20	5.2	6.1	7.0	12.2	35.6	98	12.2	10.8	5.8	6.9	5.9	8.8
Sulfates	mg/L	250	200	6.98	6.2	5.86	3.98	7.95	9.98	6.86	2.98	5.86	3.68	2.85	0.09
TDS	mg/L	600	500	50	60	60	65	377	298	698	296	58	47	17	12
Turbidity	NTU	5	1	4.9	3.9	4.8	3.5	4.8	4.6	5.2	26.8	30.1	19.8	8.9	6.8
Zinc	µg/L	3	5	4.65	4.21	6.89	5.98	6.86	2.98	4.86	6.82	7.93	4.09	5.96	6.98

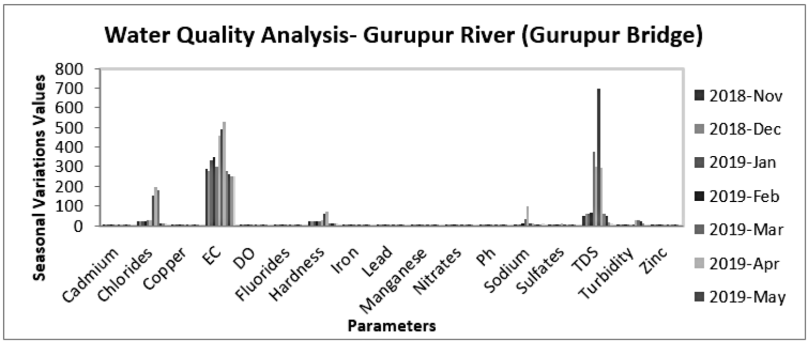

Fig 6: Results of water quality analysis for Surface water - Gurupur River (Gurupur Bridge) from Nov 2018 to Sep 2019.

Table 13: Descriptive Statistics of Water Quality Parameters for Gurupur River (Gurupur Bridge)

No.	Parameter	Unit	Mean	WHO	BIS	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	µg /L	0.65	3	3	1.88	0.51	0.01	2.10
2	Chlorides (Cl-)	mg/L	57.83	250	250	89.50	5179.97	10	194
3	Copper(Cu)	µg /L	2.70	2.0	0.05	3.26	2.39	1.18	6.10
4	EC	µS/cm	339.17	400	300	475.00	9.74	250	490

5	DO	mg /L	6.68	6.5-8	6	6.40	0.40	5.9	7.8
6	Fluorides (F−)	mg/L	0.13	1.5	1.0	0.11	0.03	0.03	0.62
7	Hardness	mg/L	25.75	200	200	41.50	380.20	10	72
8	Iron(Fe)	mg/L	0.33	0.3	0.3	0.08	0.21	0.02	1.25
9	Lead(Pb)	µg /L	1.81	10	10	1.35	0.18	1.20	2.60
10	Manganese,Mn	µg /L	0.56	400	100	0.68	0.65	0.01	2.18
11	Nitrates, NO_3	mg/L	2.30	50	45	2.24	0.70	1.12	3.53
12	pH		6.81	6.5-8.0	6.5-8.5	6.63	0.19	6.25	7.55
13	Sodium,Na	mg/L	17.88	200	20	55.10	705.29	5.2	98
14	Sulfates, SO_4	mg/L	5.27	250	200	8.42	7.14	0.09	9.98
15	TDS	mg/L	169.83	600	500	498.00	43.60	12	698
16	Turbidity	NTU	10.34	5	1	4.90	91.28	3.5	30.1
17	Zinc,Zn	µg /L	5.68	3	5	3.92	2.25	2.98	7.93

The pH of the water can reveal whether heavy metals are present as well as the bioavailability and solubility of nutrients.[16,17] In the current analysis, the pH of the water samples in Gurupur River (Gurupur Bridge) showed basic pH (Fig 6.0) and neutralin pH (7.1to7.9). Few parameters like EC, DO, TDS and Turbidity values exceed the WHO and BIS acceptable limits because of solubility of nutrients.

Table 14: Temporal Distribution of Water Quality of Gurupur River (Gurupur Bridge) by Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	28.93	45.13	41.94	99.65	91.01	95.32	91.81	108.3	49.72	44.98	46.95	43.1
Status	Good	Good	Good	Extre -mely poor	Extre -mely poor	Extre -mely poor	Extre -mely poor	Unfit For use	Good	Good	Good	Good

The above results (Table 14.) show that, the Water Quality of Gurupur river water sample collected in the location of Gurupur bridge is Vary from Very poor to Good.

Table 15: Results of Water Quality Analysis for Surface water- Gurpur River (Addur Bridge) (SW-04)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	µg/L	0.003	3	0.01	0.01	0.11	0.01	1.10	1.63	2.11	1.20	0.10	0.32	0.60	0.41
Chlorides	mg/L	250	250	22	21	23	21	24	24	150	184	180	12	10	12
Copper	µg/L	2	0.05	4.26	6.20	3.10	1.28	3.26	4.36	2.16	1.66	1.20	2.21	1.65	1.19
EC	µS/cm	400	300	310	320	300	280	290	300	450	490	360	280	240	270
DO	mg/L	6	6	7.3	7.1	7.5	7.1	6.9	6.8	7.0	7.1	6.9	7.4	7.2	7.1
Fluorides(F)	mg/L	1.5	1.0	0.06	0.10	0.14	0.10	0.60	0.06	0.16	0.03	0.06	0.04	0.08	0.06
Hardness	mg/L	200	200	21	23	20	24	24	25	58	72	10	10	12	10
Iron(Fe)	mg/L	0.3	0.30	0.120	0.100	0.060	0.020	0.04	0.05	0.11	0.67	1.25	1.21	0.14	0.19
Lead	µg/L	10	10	1.20	1.86	2.21	1.46	2.0	1.46	1.23	1.90	2.60	1.68	2.16	2.01
Manganese	µg/L	400	100	0.01	0.02	0.02	0.06	1.08	0.08	1.28	0.13	0.01	0.06	2.18	1.83
Nitrates	mg/L	50	45	3.53	3.10	2.65	1.52	3.10	3.26	1.21	1.92	1.12	1.62	2.39	2.16

pH		6.5 -8	6.5-8.5	7.66	7.52	7.26	6.60	6.86	6.63	6.63	6.33	6.66	6.60	6.8	6.48
Sodium	mg/L	200	20	5.2	6.1	7.0	12.2	35.6	98	12.2	10.8	5.8	6.9	5.9	8.8
Sulfates	mg/L	250	200	6.98	6.2	5.86	3.98	7.95	9.98	6.86	2.98	5.86	3.68	2.85	0.09
TDS	mg/L	600	500	60	66	65	68	379	292	696	290	58	47	17	12
Turbidity	NTU	5	1	4.7	3.8	4.9	3.8	4.8	4.6	5.6	26.9	30.3	19.3	8.6	6.5
Zinc	µg/L	3	5	4.60	4.21	6.87	5.96	6.66	2.88	4.86	6.62	7.95	4.09	5.96	6.98

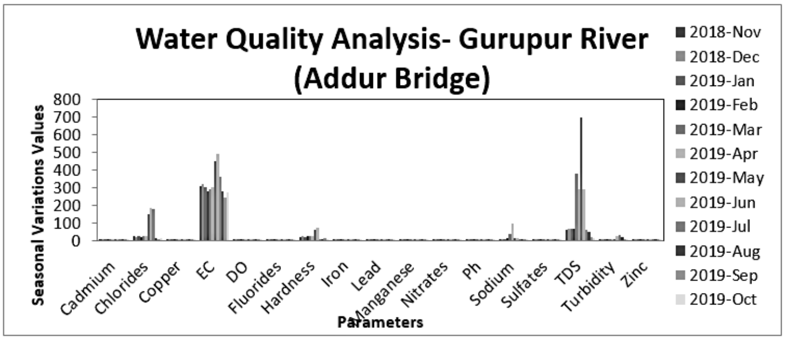

Fig 7: Results of Water Quality Analysis for Surface water-Gurpur River (Addur Bridge) from Nov 2018 to Sep 2019.

In the current analysis few parameters like EC, TDS and Chlorides values exceed the WHO and BIS acceptable limits as shown in Figure 7. This may be due Arabian Sea located nearer to the study area. Hence there may be chances of salt water intrusion that makes surface fresh water contamination and make it unfit for the use.[18,19]

Table 16: Descriptive Statistics of Water Quality Parameters for Gurpur River (Addur Bridge)

No.	Parameter	Unit	Mean	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	µg /L	0.63	1.87	0.51	0.01	2.11
2	Chlorides (Cl-)	mg/L	56.92	87.00	50.29	10	184
3	Copper(Cu)	µg /L	2.71	3.26	2.47	1.19	6.20
4	EC	µS /cm	324.17	375.00	55.54	490	240
5	DO	mg /L	7.12	6.90	0.04	7.4	6.8
6	Fluorides (F−)	mg/L	0.120	0.110	0.020	0.030	0.600
7	Hardness	mg/L	25.75	41.50	380.20	10	72
8	Iron(fe)	mg/l	0.330	0.080	0.210	0.02	1.25
9	Lead(Pb)	µg /L	1.81	1.35	0.18	1.20	2.60
10	Manganese,Mn	µg /L	0.56	0.68	0.65	0.01	2.18
11	Nitrates, NO_3	mg/L	2.30	2.24	0.70	1.12	3.53
12	pH	6.84	6.63	0.18	6.33	7.66	
13	Sodium,Na	mg/L	17.88	55.10	705.29	5.2	98
14	Sulfates, SO_4	mg/L	5.27	8.42	7.14	0.09	9.98
15	TDS	mg/L	170.83	494.00	42.73	12	696
16	Turbidity	NTU	10.32	5.10	91.25	3.8	30.3
17	Zinc,Zn	µg /L	5.64	3.87	2.24	2.88	7.95

Table 17: Temporal Distribution of Water Quality of Gurpur River (Addur Bridge) By Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	28.93	45.20	41.95	99.69	81.03	79.34	65.70	90.98	80.03	66.20	47.0	57.9
Status	Good	Good	Good	Extre -mely Poor	Extre -mely Poor	Extre -mely Poor	Poor	Extre -mely Poor	Extre -mely Poor	Poor	Good	Poor

Table 18: Results of water quality analysis for Surface water - Nethravati River (Netravati River Bridge) (SW-05)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	µg/L	0.003	3	2.37	2.25	2.21	2.87	2.75	2.57	2.85	2.12	1.26	1.29	2.48	2.10
Chlorides	mg/L	250	250	9	9	10	10	8	9	14	10	12	10	12	9
Copper	µg/L	2	0.05	5.49	7.32	6.26	4.32	6.57	8.95	4.35	3.51	2.65	3.12	4.36	5.10
EC	µS/cm	400	300	340	310	300	420	440	460	510	530	550	590	580	390
DO	mg/L	6	6	6.5	6.6	6.7	6.8	6.3	6.7	6.9	6.9	7.0	7.1	7.2	6.9
Fluorides	mg/L	1.5	1.0	0.06	0.03	0.04	0.07	0.01	0.02	0.03	0.01	0.08	0.06	0.08	0.09
Hardness	mg/L	200	200	21	23	23	22	24	24	25	14	12	10	12	14
Iron(Fe)	mg/L	0.30	0.30	0.120	0.130	0.150	0.160	0.080	0.160	0.140	1.63	2.86	0.19	0.20	0.24
Lead	µg/L	10	10	5.42	4.12	6.25	3.21	7.15	8.24	6.25	5.20	4.32	3.62	4.13	4.96
Manganese	µg/L	400	100	0.05	0.06	1.10	1.12	2.13	2.20	2.26	1.02	1.06	0.06	3.25	4.06
Nitrates	mg/L	50	45	1.26	2.26	1.64	2.10	1.06	2.10	0.08	1.15	2.12	3.34	3.24	5.02
Ph		6.5 -8	6.5 -8.5	7.80	7.83	7.85	7.98	7.78	7.62	7.63	7.80	7.24	7.10	7.26	6.98
Sodium	mg/L	200	20	5.8	5.6	6.0	4.6	5.10	5.30	4.8	3.2	4.0	5.10	5.40	7.90
Sulfates	mg/L	250	200	2.04	2.69	2.12	1.69	1.46	1.12	4.63	1.20	12.2	2.26	2.10	0.18
TDS	mg/L	600	500	23	21	24	26	28	31	25	12	12	16	30	11
Turbidity	NTU	5	1	1.4	1.0	1.10	2.20	1.62	2.98	3.0	12.6	32.7	16.9	3.9	10.0
Zinc	µg/L	3	5	8.24	11.10	12.90	13.48	15.10	14.13	6.96	7.62	16.27	16.86	8.65	11.46

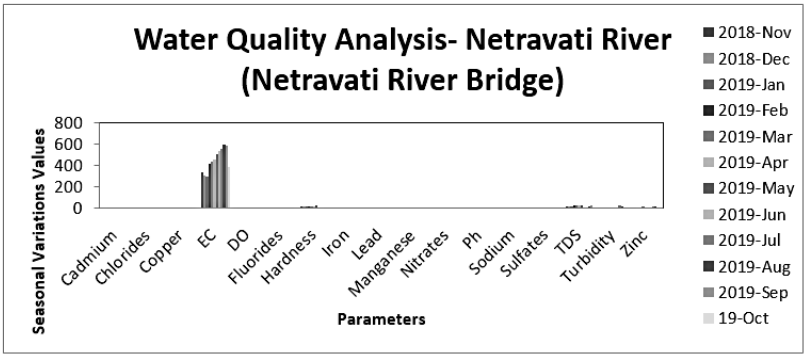

Fig. 8: Results of Water Quality Analysis for Surface water- Netravati River (Netravati River Bridge) from Nov 2018 to Sep 2019.

In the current analysis EC values exceed the WHO and BIS acceptable limits as shown in Figure 8. This may be due to increase charged particles (ions) and higher temperature.[20,21]

Table 19: Descriptive Statistics of Water Quality Parameters for Netravati River (Netravati River Bridge)

No.	Parameter	Unit	Mean	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	μg /L	2.26	2.71	0.28	1.26	2.87
2	Chlorides (Cl-)	mg/L	10.17	11.50	2.88	8	14
3	Copper(Cu)	μg /L	5.17	6.65	3.41	2.65	8.95
4	EC	μS /cm	451.67	485.00	10.49	300	590
5	DO	mg /L	6.80	6.80	0.07	6.3	7.2
6	Fluorides (F−)	mg/L	0.05	0.03	0.00	0.01	0.09
7	Hardness	mg/L	18.67	24.50	32.61	10	25
8	Iron(Fe)	mg/L	0.51	0.15	0.73	0.08	2.86
9	Lead(Pb)	μg /L	5.24	7.25	2.26	3.21	8.24
10	Manganese,Mn	μg /L	1.53	2.23	1.64	0.05	4.06
11	Nitrates, NO_3	mg/L	2.11	1.09	1.67	0.08	5.02
12	pH	7.57	7.63	0.11	6.98	7.98	
13	Sodium,Na	mg/L	5.23	5.05	1.32	3.2	7.90
14	Sulfates, SO_4	mg/L	2.81	2.88	9.89	0.18	12.2
15	TDS	mg/L	21.58	28.00	51.54	11	31
16	Turbidity	NTU	7.45	2.99	90.21	1.0	32.7
17	Zinc,Zn	μg /L	11.90	10.55	11.81	6.96	16.86

Table 20: Temporal Distribution of Water Quality of Netravati River (Netravati River Bridge) By Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	61.41	73.49	89.72	89.70	71.84	59.19	69.86	89.16	51.50	53.33	57.75	46.68
Status	Poor	Poor	Extre -mely Poor	Extre -mely Poor	Poor	Poor	Extre -mely Poor	Extre -mely Poor	Poor	Poor	Poor	Good

Table 21: Results of water quality analysis for Surface water - Nethravati River (Thumbe Vented Dam) (SW-06)

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	μg/L	0.003	3	2.36	2.26	2.20	2.89	2.75	2.56	2.85	2.11	1.25	1.26	2.48	2.20
Chlorides	mg/L	250	250	10	9	10	8	8	9	14	10	12	10	12	10
Copper	μg/L	2	0.05	5.46	7.30	6.25	4.30	6.59	8.98	4.35	3.51	2.63	3.12	4.36	5.20
EC	μS /cm	400	300	320	360	390	420	450	510	530	610	600	390	480	390
DO	mg /L	6	6	5.6	5.8	5.9	6.1	6.3	6.8	7.0	7.1	7.3	6.9	6.8	6.6

Fluorides	mg/L	1.5	1.0	0.04	0.02	0.06	0.07	0.01	0.02	0.03	0.02	0.08	0.06	0.08	0.09
Hardness	mg/L	200	200	22	23	24	22	23	23	25	14	12	10	14	12
Iron(Fe)	mg/L	0.30	0.30	0.120	0.120	0.140	0.130	0.080	0.160	0.140	1.63	2.86	0.19	0.20	0.24
Lead	µg/L	10	10	5.40	4.12	6.25	3.21	7.15	8.24	6.25	5.20	4.32	3.62	4.13	4.96
Manganese	µg/L	400	100	0.04	0.06	1.0	1.10	2.12	2.20	2.23	1.02	1.02	0.06	3.25	4.02
Nitrates	mg/L	50	45	1.24	2.22	1.60	2.0	1.02	2.10	0.06	1.15	2.12	3.34	3.34	5.0
pH		6.5 -8	6.5 -8.5	7.60	7.80	7.83	7.96	7.70	7.60	7.60	7.80	7.22	7.12	7.26	6.98
Sodium	mg/L	200	20	5.8	5.6	6.0	4.6	5.10	5.30	4.8	3.2	4.0	5.10	5.40	7.90
Sulfates	mg/L	250	200	2.04	2.69	2.12	1.69	1.46	1.12	4.63	1.20	12.2	2.26	2.10	0.18
TDS	mg/L	600	500	23	21	24	26	28	31	25	12	12	16	30	11
Turbidity	NTU	5	1	1.4	1.0	1.10	2.20	1.62	2.98	3.0	12.6	32.7	16.9	3.9	10.0
Zinc	µg/L	3	5	8.24	11.10	12.90	13.48	15.10	14.13	6.96	7.62	16.27	16.86	8.65	11.46

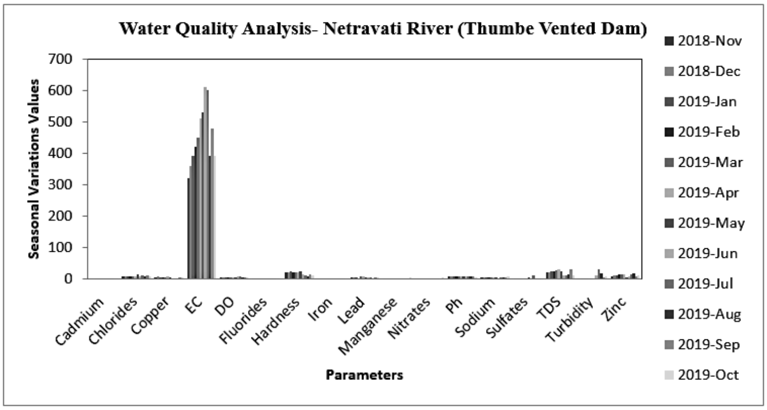

Fig 9: Results of Water Quality Analysis for Surface water-Netravati River (Thumbe Vented Dam) from Nov 2018 to Sep 2019.

In the current analysis EC values exceed the WHO and BIS acceptable limits as shown in Figure 9. This may be due to an increase charged particles (ions) and higher temperature.[21,22]

Table 22: Descriptive Statistics of Water Quality Parameters for Netravati River (Thumbe Vented Dam)

No.	Parameter	Unit	Mean	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	µg /L	2.26	2.71	0.29	1.25	2.89
2	Chlorides (Cl-)	mg/L	10.17	11.50	3.06	8	14
3	Copper(Cu)	µg /L	5.17	6.67	3.44	2.63	8.98
4	EC	µS /cm	454.17	520.00	86.81	320	610
5	DO	mg /L	6.52	6.90	0.31	5.6	7.3
6	Fluorides (F)	mg/L	0.05	0.03	0.00	0.010	0.090
7	Hardness	mg/L	18.67	24.00	32.24	10	25
8	Iron(Fe)	mg/L	0.50	0.15	0.73	0.08	2.86
9	Lead(Pb)	µg /L	5.24	7.25	2.26	3.21	8.24
10	Manganese,Mn	µg /L	1.51	2.22	1.63	0.04	4.02

11	Nitrates, NO_3	mg/L	2.10	1.08	1.70	0.06	5.0
12	pH		7.54	7.60	0.10	6.98	7.96
13	Sodium,Na	mg/L	5.23	5.05	1.32	3.2	7.90
14	Sulfates, SO_4	mg/L	2.81	2.88	9.89	0.18	12.2
15	TDS	mg/L	21.58	28.00	51.54	11	31
16	Turbidity	NTU	7.45	2.99	90.21	1.0	32.7
17	Zinc,Zn	µg /L	11.90	10.55	11.81	6.96	16.86

Table 23: Temporal Distribution of Water Quality of Netravati River (Thumbe Vented Dam) By Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	78.60	57.44	50.46	57.24	57.67	60.16	58.78	89.76	45.30	46.07	49.95	47.40
Status	Extre -mely Poor	Poor	Poor	Poor	Poor	Poor	Poor	Extre -mely Poor	Good	Good	Good	Good

Table 24: Results of water quality analysis for Surface water - Nethravati River (Pane Mangalore Bridge) (SW-07

Parameter	Unit	WHO	BIS	Nov-2018	Dec-2018	Jan-2019	Feb-2019	Mar-2019	Apr-2019	May-2019	Jun-2019	Jul-2019	Aug-2019	Sep-2019	Oct-2019
Cadmium	µg/L	0.003	3	2.26	2.26	2.60	2.80	2.95	2.56	2.85	2.11	1.23	1.26	2.48	2.20
Chlorides	mg/L	250	250	10	9	10	8	8	9	14	10	12	10	12	10
Copper	µg/L	2	0.05	5.46	7.30	6.25	4.30	6.59	8.98	4.35	3.51	2.63	3.12	4.36	5.20
EC	µS /cm	400	300	380	390	400	420	360	380	390	430	460	490	390	370
DO	mg /L	6	6	6.1	6.3	6.1	6.0	6.5	7.1	6.8	6.2	6.3	6.1	6.1	6.1
Fluorides	mg/L	1.5	1.0	0.04	0.02	0.06	0.07	0.01	0.02	0.03	0.02	0.08	0.06	0.08	0.08
Hardness	mg/L	200	200	23	23	25	22	23	23	25	14	12	10	12	12
Iron(Fe)	mg/L	0.3	0.3	0.120	0.120	0.140	0.130	0.080	0.160	0.140	1.63	2.86	0.19	0.20	0.24
Lead	µg/L	10	10	5.40	4.12	6.25	3.21	7.15	8.24	6.25	5.20	4.32	3.62	4.13	4.96
Manganese	µg/L	400	100	0.04	0.06	1.0	1.10	2.12	2.20	2.23	1.02	1.02	0.06	3.25	4.02
Nitrates	mg/L	50	45	1.24	2.22	1.60	2.0	1.02	2.10	0.06	1.15	2.12	3.34	3.34	5.0
Ph		6.5 -8	6.5 -8.5	7.80	7.80	7.86	7.98	7.70	7.60	7.60	7.80	7.22	7.12	7.26	6.96
Sodium	mg/L	200	20	5.8	5.6	6.0	4.6	5.10	5.30	4.8	3.2	4.0	5.10	5.40	7.90
Sulfates	mg/L	250	200	2.04	2.69	2.12	1.69	1.46	1.12	4.63	1.20	12.2	2.26	2.10	0.18
TDS	mg/L	600	500	23	21	24	26	28	31	25	12	12	16	30	11
Turbidity	NTU	5	1	1.4	1.0	1.10	2.20	1.62	2.98	3.0	12.6	32.7	16.9	3.9	10.0
Zinc	µg/L	3	5	8.24	11.10	12.90	13.48	15.10	14.13	6.96	7.62	16.27	16.86	8.65	11.46

In the current analysis EC values exceed the WHO and BIS acceptable limits as shown in Figure 10. This may be due increase charged particles (ions) and higher temperature and change in climate due to urbanization.[21,22]

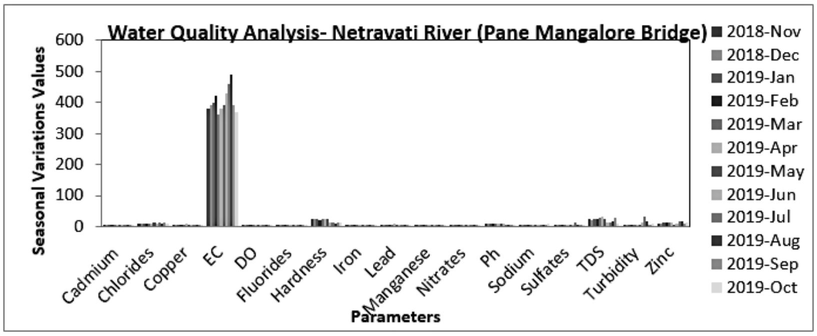

Fig 10: Results of Water Quality Analysis for Surface water- Netravati River (Pane Mangalore Bridge) from Nov 2018 to Sep 2019.

Table 25: Netravati River Water Quality Parameter Descriptive Statistics (Pane Mangalore Bridge)

No.	Parameter	Unit	Mean	Median	Standard Deviation	Min	Max
1	Cadmium (Cd)	µg /L	2.30	2.71	0.31	1.23	2.95
2	Chlorides						
(Cl-)	mg/L	10.17	11.50	3.06	8	14	
3	Copper(Cu)	µg /L	5.17	6.67	3.44	2.63	8.98
4	EC	µS /cm	405.00	385.00	14.82	360	490
5	DO	mg /L	6.31	6.95	0.11	6.0	7.1
6	Fluorides (F−)	mg/L	0.05	0.03	0.00	0.01	0.08
7	Hardness	mg/L	18.67	24.00	36.06	10	25
8	Iron(Fe)	mg/L	0.50	0.15	0.73	0.08	2.86
9	Lead(Pb)	µg /L	5.24	7.25	2.26	3.21	8.24
10	Manganese,Mn	µg /L	1.51	2.22	1.63	0.04	4.02
11	Nitrates, NO_3	mg/L	2.10	1.08	1.70	0.06	5.0
12	pH	7.56	7.60	0.11	6.96	7.98	
13	Sodium,Na	mg/L	5.23	5.05	1.32	3.2	7.90
14	Sulfates, SO_4	mg/L	2.81	2.88	9.89	0.18	12.2
15	TDS	mg/L	21.58	28.00	51.54	11	31
16	Turbidity	NTU	7.45	2.99	90.21	1.0	32.7
17	Zinc,Zn	µg /L	11.90	10.55	11.81	6.96	16.86

Table 26:Temporal Distribution of Water Quality of Netravati River (Pane Mangalore Bridge) By Weighted Arithmetic Index Method

Month, year	Nove -mber -2018	Dece -mber -2018	Janu -ary -2019	Febr -uary -2019	March -2019	April -2019	May -2019	June -2019	July -2019	Aug -ust -2019	Septe -mber -2019	Octo -ber -2019
WQI	78.63	87.72	73.91	76.64	52.19	62.81	54.88	50.90	49.54	41.58	49.87	46.72
Status	Extre -mely Poor	Extre -mely Poor	Poor	Extre -mely Poor	Poor	Poor	Poor	Good	Good	Good	Good	Good

The water quality of Netravathi River sample, shown in Table 25 and 26, collected in the location of pane Mangalore bridge varies from very poor and poor in pre -monsoon and post- monsoon but water quality is good in monsoon season because of the dilution.

Table 27: Overall Water Quality analysis by Weighed Arithmetic Method in Monsoon, post-monsoon, and pre-monsoon.

SEASON	Months	SW - 1	SW - 2	SW - 3	SW - 4	SW- 5	SW-6	SW-7
Pre Monsoon	Jan	2	1	2	2	4	4	3
	Feb	4	1	4	4	4	4	4
	March	4	1	4	4	3	3	3
	April	4	1	4	4	3	3	3
	May	4	1	4	3	4	4	3
Monsoon	June	4	2	4	4	4	4	2
	July	3	2	2	4	3	4	2
	August	3	2	2	3	3	3	2
	September	2	1	2	2	3	3	2
Post Monsoon	October	2	1	2	2	2	2	2
	November	2	1	2	2	3	4	4
	December	2	2	2	2	3	3	4

Table 28: Comparative Studies

Study Area	Discussion and Results
River Nethravathi, Karnataka	The water quality was found to be declining during the festival season in November due to urbanization.[25]
Netravathi and Gurupura river estuary, in Dakshina Kannada District of Karnataka state, India.	Urban and agricultural runoff, industrial discharge, and polluted sewage effluents all enter the estuary of the Netravathi and Gurupura rivers. Thousands of people rely on this specific river, hence the ecosystem's quality is extremely important.[26]
Nethravathi, Kumaradhara and Gurupura (within the Gurupura sub-river basin) streams	The findings of the study show that anthropogenic activities cause considerable contamination during the pre-monsoon season. According to the evaluation, around 50% of the river from the mid-region to the downstream region was poisoned.[27]
Netravathi-Gurupur estuary located at latitude12° 51′ N and longitude 74° 50′ E in Mangalore, Karnataka, India.	The research aimed to evaluate the water quality of the Netravathi-Gurupur estuary as an indicator of environmental health across spatial and temporal scales, emphasizing the aquatic stress caused by surrounding industrial and agricultural activities. It also examined the trophic status of the estuary and the Water Quality Index (WQI) relevant to brackish water fisheries. Seasonal variations and human-induced inputs were found to significantly impact nutrient levels and salinity, with the results indicating elevated salinity in the region.[28]
Netravati and Gurupur River -Mangalore	Both Netravati and Gurupur river waters are suitable for consumption during the monsoon season; however, during the pre- and post-monsoon periods, they require a certain degree of treatment before being deemed safe for consumption

From Table 27, the universal water quality indices for River Gurupura River (Kulur Bridge) (SW-01) is Good in monsoon and post- monsoon season. Water quality of Gurupura river (Maravoor) (SW-02) is vary from Excellent to Good.Water quality of Gurupura River (Gurupura Bridge)(SW-03) is categorized as Good in Monsoon and Post Monsoon. Water quality of Gurupura River (Addur Bridge) (SW-04) is Good in Monsoon and in Post Monsoon.Water quality of Netravathi River (Netravathi Bridge) (SW-05) is vary from Fair to Very Poor in all the seasons.Water quality of Netravathi River (Thumbe Dam) (SW-6) is also vary from Fair to Very Poor.Water quality of Netravathi River (Pane Mangalore/Old Bridge) (SW-07) is Good in Monsoon Season.

Supporting theories for Urbanization

Obtained results evaluated the quality of the water both in the Netravati and Gurupur river. However, waters are suitable for consumption during the monsoon season; nevertheless, during the pre- and post-monsoon periods, they require a certain degree of treatment before being deemed safe for consumption, because of rapid urbanization in the Mangalore city. Which details the Industrial Growth: Establishment of Land-use changes and population growth have been facilitated by industries such as Mangalore Chemicals & Fertilizers (MCF), Mangalore Refinery and Petrochemicals Ltd. (MRPL), and other Special Economic Zones.[23] Port and Maritime Activities: The New Mangalore Port has boosted trade, transport, and industrial infrastructure, accelerating urban sprawl near the coastal belt and estuarine zones. Education and Health Hub:With institutions like NITK, KMC, and St. Aloysius College, Mangalore attracts students from across India, supporting rapid real estate and urban growth. Migration and Employment: In-migration from rural areas and other parts of India for jobs and education has caused increased demand for housing, transportation, and services. Transport Infrastructure: Development of highways (NH-66, NH-75), the international airport, and rail connectivity has enhanced urban-rural linkages and real estate development.[24] The present study results are compared with the previous other relevant studies done in the same location is shown in the Table 28.

Discussion

The above table 28 (Comparative Study) clearly shows that the quality of surface water resources degrading due to urbanization activities, and in 2024, even the aquatic bodies shrank to 32.2471 km². This is a result of both unplanned urbanization and population growth.[29] Significant effects on nearby water sources, such as the contamination of the Netravathi-Gurupur estuary, are revealed by comparing the findings of earlier research with those of the current study. The Netravathi, Gurupur, and their estuary are Mangalore's main surface water supplies, and urban activities are making them more polluted. Municipal solid waste, organic waste from the city, and untreated or partially treated home sewage all contribute to the pollution of the Netravathi-Gurupur estuary. This has been identified as a primary cause of habitat degradation in both past and present research. Industries along riverbanks release pollution loads that include chemicals, heavy metals, and other wastes. These are known as industrial effluents. The companies close to the Baikampady industrial cluster and Mangalore's coastline emit a lot of pollutants, which are also found in the Netravathi and Gurupur rivers, according to earlier and current research. Development initiatives-Proposed and ongoing infrastructure initiatives near riverbanks provide environmental hazards as well. The following effective treatments are suggested for both Netravathi and Gurupur river for the usage, Upgrading STPs for nutrient removal, Bioremediation with aquatic organisms, Zero effluent discharge from industries, Strict waste management, Control of urban runoff, and Limit harmful household chemicals.

Conclusion

Based on theWeighted Arithmetic Index Method, the two main rivers in the research area had their universal water quality indexes calculated. However, the research area's surface water quality assessment falls below the cap limit of both before and after the monsoon, but it is satisfactory during the monsoon. Based on the aforementioned findings, we can say that the water quality of the two main rivers, Netravati and Gurupura, is good during the rainy season because the water level has increased and the river's saturation level has increased. According to the current study, the water is unsafe for human consumption during the pre-monsoon and post-monsoon seasons. As a result, it is advised that efficient treatment should be performed in conjunction with ongoing monitoring during both of these periods. Nevertheless, the town of Mangalore has had remarkable growth over the last ten years, and it currently boasts a population of roughly 7,24,159. The industrial and tertiary sectors close to Mangalore are still expanding and drawing a lot of visitors. The city is undergoing physical and socioeconomic changes as a result of the commercial, industrial, and educational activities that have caused its fast expansion. Additional demand will need to be created in light of this developing scenario of higher development. As a result, an attempt must be made to address the problems through appropriate urban planning and city policy. Predicting urban expansion aids policymakers and urban planners in offering improved infrastructural services to a large number of newly arrived urban people. It is the responsibility of society to keep the fresh water resources clean by avoiding the flow of drainage water or by avoiding the throw of plastics waste to river, and also government has to make strict policy to control the discharge of effluents from the industries.

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Data Availability Statement
All data generated or analyzed during this study are included in this article [and its supplementary information files].

Ethics Statement
This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement
This study did not involve human participants, and therefore, informed consent was not required.

Permission to Reproduce Material from other Sources
Not Applicable

Author Contributions
- **Yogesha Doora Shivanna :** Executed the experiment and analyzed the obtained results.
- **Umesh Chandra:** Hypothesized and supervised the study.
- **Sandeep Nayak:** Assisted in the interpretations of the results.

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