Rejuvenating Nethravathi River: The Enhancement of Water Quality Amidst the Covid-19 Pandemic Using Remote Sensing and Gis Approach

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Abstract*— The global COVID-19 epidemic caused lockdowns to prevent viral transmission. These creative ideas provided unexpected environmental benefits. Industry, transportation, and human mobility all declined, resulting in less worldwide water and air pollution. India represents an important pandemic case study. This study investigates the impact of the lockdown on the Nethravathi River in Karnataka, India's Western Ghats. Following the lockout, 14 physicochemical surface water samples at twelve locations along the river revealed interesting ecosystem dynamics. The river's water quality was tested using the Weighted Arithmetic Water Quality Index (WAWQI) and the BIS 2012 Standards. Before the monsoon, many sampling locations (S1, S2, S3, S4, S8, and S12) had 'poor water quality', while others were 'unfit for drinking'. After the monsoon, 58.34% of samples from S1, S2, S3, S4, S5, S7, S11, and S12 locations met the 'excellent water quality' standard. Less than 25% of the samples contained poor water quality. River health improved dramatically following the monsoon season. According to the study, the water quality of the Nethravathi River improved after the monsoon. These findings suggest that riverbank bathing and washing should be supervised and controlled. This study reveals that the COVID-19 lockout affects ambient air quality, even in less industrialized and urbanized areas. This study also found that rejuvenating river health during lockdown allows politicians, administrators, and environmentalists to design effective measures for restoring river quality following anthropogenic stress.

Keywords*— *river health assessment; water quality; RS & GIS; environmental chemistry; COVID-19

I. Introduction

Untreated municipal and industrial wastewater is a major contributor to water contamination in developed as well as developing countries [1]. Evaluation of river health is crucial for identifying the condition of river water ecosystems, and research in this field is necessary for the efficient management and restoration of rivers thereby, river health evaluation is critical [2]. River basin management in India involves consideration of scientific, political, economic, environmental, social, cultural, racial, religious, and literary aspects [3].

An accurate assessment of the ecological well-being of rivers requires a meticulous examination of how biological indicators react to chemical agents that cause harm, in order to obtain crucial information for implementing successful conservation strategies [4]. Considering the crucial role rivers have played in human evolution and development, it is no surprise that human well-being is closely linked to them. However, rapid urbanization, industrialization, and intensive farming have negatively affected the chemical water quality and physical habitats of rivers and streams worldwide [5]. This is due to rivers' ability to connect human habitats with those of other living creatures, promoting and conserving diverse cultural beliefs and a sense of national security [6]. Numerous anthropogenic toxins could destroy these extraordinary resources, putting the health and functioning of the biological systems at risk [7]. Reduced industrial and tourist activity worldwide has reduced human migration, which is good for ecosystems and our environment. Especially, emissions from industry and transportation have decreased dramatically, which has reduced the amount of pollution in the environment [8] [9]. An evaluation of India's major rivers' water quality revealed that during the COVID-19 lockdown, the river water quality had increased by 40% to 50% [10].

Numerous relevant studies have also been carried out on the quality of surface water bodies in various locations around India, and they have demonstrated a considerable improvement in water quality parameters like pH, DO, BOD, and TC [11]. During the initial stages of India's COVID-19 outbreak, Kerala was one of the states most affected [12]. The government declared a state of lockdown. More than 1.38 billion people in India were placed under a nationwide lockdown on March 23, 2020, and it continued through May 31, 2020 [13]. The water balance of the typical watershed has been dramatically altered by anthropogenic activities to obtain significant water balance components like surface runoff, groundwater, and evapotranspiration (ET), the researchers are likely to use a modelling approach in their research to gain a deeper understanding of complex watershed processes and their interactions with topography, land use management, soils, and climate [14]. The idea of river health evolved from the overall health of river ecosystems, rather than just river ecosystems. Each natural and social aspect of a river influences the overall health of water systems. The relationship between river biota and individual river chemical and physical parameters affects the health of the ecosystem. The health of a river can be assessed by the diversity of its ecological systems, plant and animal species, and interactions, as well as the maintenance of biological processes [15]. The goal of the study is to find out how post-lockdown relationships and physicochemical factors affect the ecological health of the river Nethravathi, which has been influenced by humans. In particular, the review centers around looking at the overflow of these elements and their impact on the stream's biological system. The year 2022 has been selected as the evaluation period for this study and compared the water quality before and after COVID-19.

II. MATERIALS AND METHODS

A. Study area

Dakshina Kannada is a coastal district of Karnataka state in India that shares a border with the Arabian Sea. The topographical region covers 4770 square kilometers and extends between 12˚30',00" and 13˚ 11' 00" North scope and 74˚35"& 75˚ 33' 30" East longitude. The district is drained by the rivers Nethravathi, Gurupura, Mulki, Kumaradhara, Payasvini, and Shambhavi, which originate in the Western Ghats and flow towards the west for about 80-100 km distance and join the Arabian Sea.

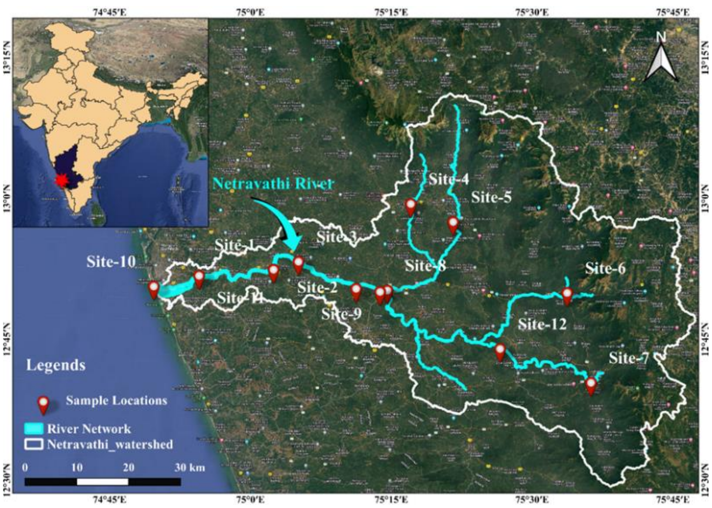


Fig. 1. Location Map of Nethravathi River with sampling sites

The Nethravathi River originates in the Chikkamagaluru district of Karnataka, India, specifically from the Bangrabalige valley and Yelaneeru Ghat in Kudremukh. The Nethravathi River originates at an elevation of approximately 1680 meters in the northeastern corner of its basin. The Nethravathi river basin network consists primarily of three main streams: Nethravathi (within the Nethravathi sub-river basin), Kumaradhara (within the Kumaradhara sub-river basin), and Gurupura (within the Gurupura sub-river basin) streams.

B. River Health Assessment

The term 'river health' is often associated with human health, and many people understand it in that context. A river's health primarily refers to its water quantity, water quality, physical form, and aquatic life. River health assessment (RHA) is a tool for river management that examines the condition of the river and provides a scientific basis for monitoring and coordinating the environmentally friendly utilization of water functions and economic development. It is important to determine the ecosystem-level indicators that truly represent the components of river health and how physical, chemical, and biological properties can be combined into meaningful measurements, rather than relying solely on casual observations [16]. At present, it remains uncertain whether the existing understanding of river health adequately addresses these concerns [17]. Assessing the health of a river and its biological integrity becomes challenging when we seek indicators that indicate deviations from its natural, undisturbed state, surpassing the usual background variability. This difficulty becomes especially apparent when there is no existing reference state that remains undisturbed to serve as a comparison [18] [19]. The assessment of river health typically involves making comparisons between different sites that are assumed to be similar and free from degradation. Indicators believed to reflect river health are compared among these sites to evaluate their condition and potential deviations from the expected state of non-degradation [20] [21].

C. Water Quality Index

In 1970, the National Sanitation Foundation developed a mathematical formula called the Water Quality Index (WQI) [22]. This index considers essential physical and chemical components and provides a quantifiable measure that effectively captures changes in water quality. By combining relevant factors, the Water Quality Index offers a standardized and comprehensible unit of measurement to assess water quality [23]. Various national and international organizations have produced an extensive range of water quality indices such as The Weighted Arithmetic Water Quality Index (WAWQI), the National Sanitation Foundation Water Quality Index (NSFWQI), the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), and the Oregon Water Quality Index (OWQI). Each of these indices serves as a unique framework for assessing water quality, reflecting the variety of methodologies used by various organizations [24] [25] [26].

D. Calculation of Weighted Arithmetic Water Quality Index

The Weighted Arithmetic Water Quality Index approach ranks water quality based on purity using commonly observed indicators of water quality. Therefore this method is used to assess the health of Nethravathi River, by assigning weights to different parameters, this method calculates a composite score that reflects the overall quality of the water. The selected indicators are typically those that are frequently monitored and considered essential in assessing water quality. The WAWQI provides a practical and straightforward approach to evaluating water purity based on these commonly observed parameters [27] [28].

$$WQI = \frac{\sum QiWi}{\sum Wi} \quad (1)$$

Utilizing this equation (1), the quality rating scale (Qi) for each parameter is determined using equation (2).

$$Qi = 100\{(Vi - \frac{Vo}{Si} - Vo)\} \quad (2)$$

Where Vi is estimated concentrated of i^{th} water quality parameter in the analysed water sample

Vo is the ideal value of water quality parameters in pure water

Vo = 0 (Except pH=7 and DO = 14.6 mg/l)

Si is recommendation standard value of the i^{th} parameter

The unit weight (Wi) for each water quality parameter is calculated by using the following equation (3).

$$Wi = \frac{K}{Si} \quad (3)$$

K = Proportionality constant and can also be calculated by using the following equation (1).

$$K = \frac{1}{\Sigma(\frac{1}{Si})} \quad (4)$$

III. METHODOLOGY

In this research work, WAWQI method is implemented, and an standardized methodology based on the guidelines outlined in [29] to assess the water quality of the Nethravathi River The physical parameters of the river water samples were measured on-site using handheld water quality testing instruments, while surface water samples were collected using polyethylene bottles positioned 0.5 meters below the water surface at various locations along the river as shown in Fig. 1. To assess the chemical

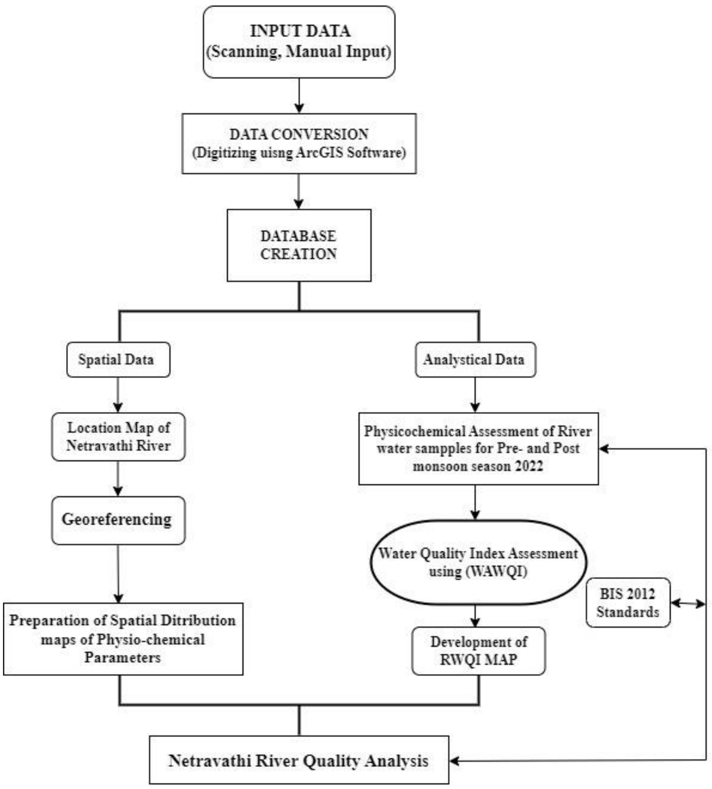


Fig. 2. Flow chart of Methodology

parameters of the flowing water, samples were collected before and after the monsoon season in the year 2022. The data obtained from these samples were then compiled and presented in Tables 2 and 3 respectively for the pre-monsoon and post-monsoon periods. The Google Earth Engine was used to determine the geographical coordinates of the sampling sites, as shown in Fig. 1.

Which were then used to develop a spatial distribution map of all physicochemical parameters. The post-processing and mapping were carried out using ArcGIS software, enabling a visual representation of the spatial patterns of the water quality parameters along the Nethravathi River. To calculate the water quality index (WQI) of the Nethravathi River, the weighted arithmetic water quality index method (WAWQI) considers both physical and chemical parameters of the flowing water and compares them with the recommendations outlined in the BIS Standards [30]. Fig. 7 displays the developed Water Quality Index of the Nethravathi River, providing an overview of the overall water quality status. Additionally, Fig 3, 4, 5, and 6 illustrate the comparison of water quality parameters between the pre-monsoon and post-monsoon seasons, allowing for an assessment of any variations or improvements in water quality following the southwest monsoon.

IV. RESULT AND ANALYSIS

A. *Water Quality Index Assessment*

This study aims to evaluate the impact of the COVID-19 pandemic on the water quality of the Nethravathi River, specifically in the upstream, downstream, and coastal areas of Mangalore. The study involved monitoring the surface water quality at 12 sampling locations along the Nethravathi River, focusing on the pre-monsoon and post-monsoon periods of 2022. Various physical water quality parameters of the Nethravathi River as shown in Fig. 3 and 5, including pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), water temperature, oxidation-reduction potential (ORP), and salinity, were measured on-site at regular intervals of 10-15 km using a calibrated multiparameter water quality meter with 90% accuracy. Additionally, river water samples were collected from 12 different locations in 500 ml polyethylene bottles to assess chemical parameters as shown in Fig.4 and 6. such as calcium (Ca), total hardness (TH), chloride (Cl), potassium (K), sodium (Na), sulfate, and bicarbonate (CHO_3). The objective was to examine the physico-chemical health condition of the Nethravathi River during the pre-monsoon and post-monsoon periods of 2022, taking into consideration the impact of the countrywide COVID-19 lockdown.

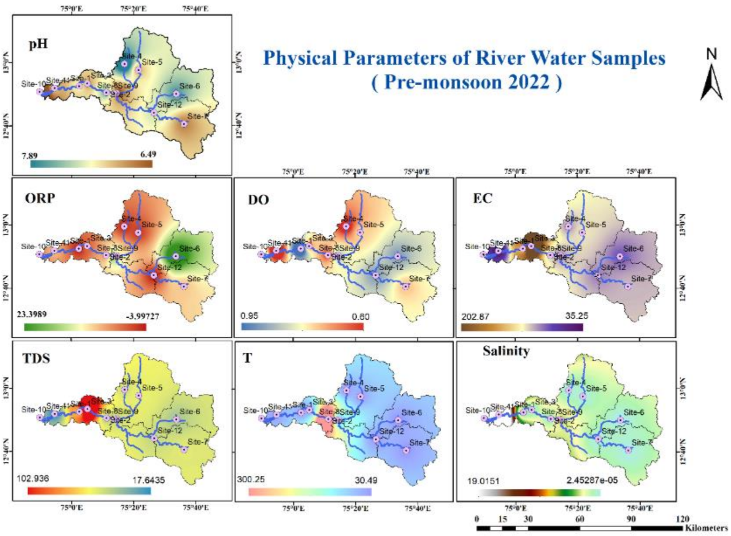


Fig. 3. Spatial distribution map of physical parameters of river water (Pre-monsoon, 2022)

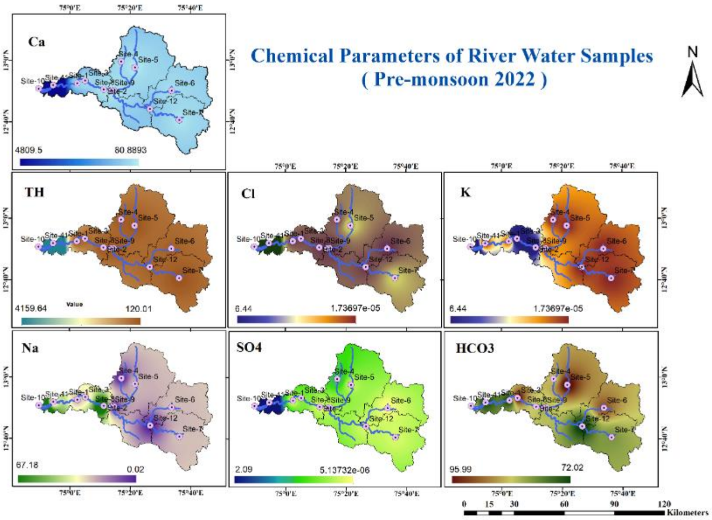


Fig. 4. Spatial distribution map of Chemical parameter of river water (Pre-monsoon, 2022)

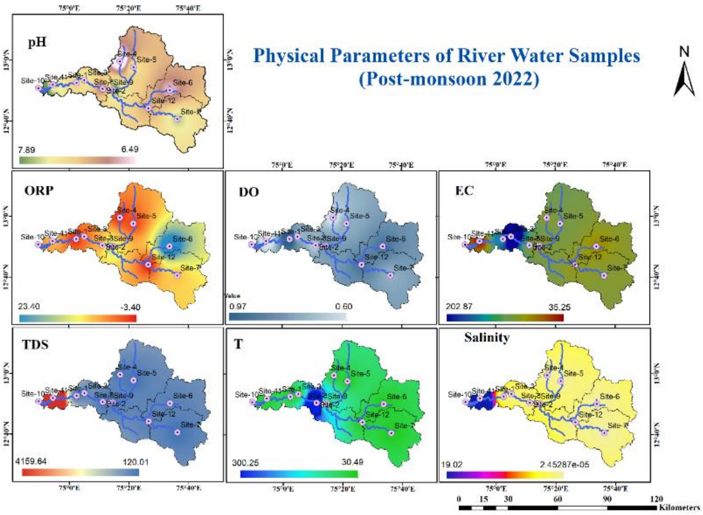


Fig. 5. Spatial distribution map of physical parameter of river water (Post-monsoon, 2022)

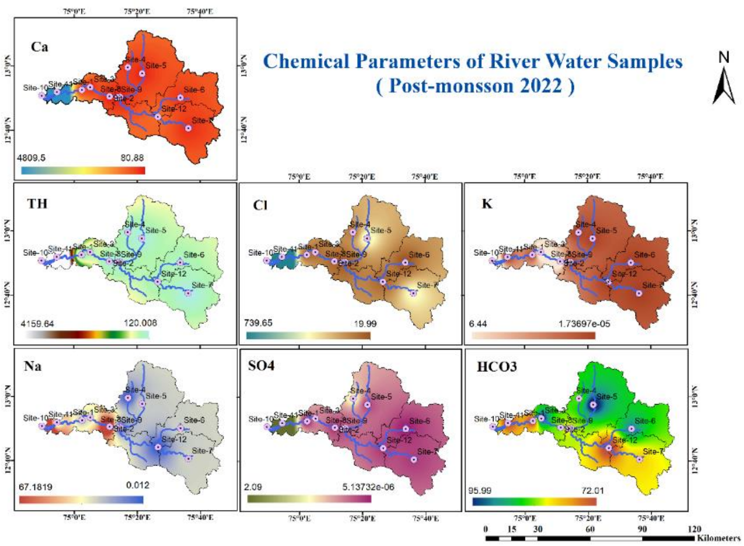


Fig. 6. Spatial distribution map of Chemical parameter of river water (Post-monsoon, 2022)

The study indicates that during the lockdown period, reduced human interaction and minimal damage to natural resources contributed to the regeneration of aquatic life and ecosystems. As a result, streams and lakes underwent a natural purification and healing process

B. Calculated Index Weights

The water quality index for the Nethravathi River was evaluated using the BIS 2012 standards for drinking and domestic purposes, considering around ten most influential water quality parameters. The unit weights of each water parameter were calculated using Equation 3 as represented in Table 1. Subsequently, the unit weight value was utilized to evaluate the overall health quality of the river water using Equation 1, categorizing WQI values ranging from 0 to 100.

TABLE I. Unit Weight of parameters based on Indian drinking water standard (WAWQI)

Sl. No	Parameter	Std. Values as per BSI 2012	unit Weight (Wi)
1	pH	8.5	0.222234717
2	DO	6	0.314832515
3	TDS	500	0.00377799
4	Temp	15	0.125933006
5	Cl	250	0.00755598
6	TH	200	0.009444975
7	Na	45	0.041977669
8	K	200	0.009444975
9	HCo_3	200	0.009444975
10	SO_4	200	0.009444975

The purity of water experiences a substantial improvement following the monsoon. Pollutants may be diluted by the monsoon as a result of the increased water flow. Improved pollution management is necessary due to the fact that certain segments have substandard water quality, despite the general improvement. Figure 7 illustrates the impact of monsoon rainfall on the water quality of the Netravathi River both before and after the monsoon. The river's water quality has improved post-monsoon; however, additional monitoring and targeted interventions are required to resolve the remaining low-quality areas. Figure 8a displays the pre-monsoon Water Quality Index (WQI) for several locations 2022. The Water Quality Index (WQI) categorizes water quality in various places as good, poor, or bad. In the pre-monsoon season of 2022, the data indicates that most sites exhibit unsatisfactory water quality, while only a small number demonstrate adequate water quality. This information is necessary for environmental monitoring and improving water quality in impacted regions. Figure 8b highlights 2022 post-monsoon water quality at several areas. Most sites have better water quality than pre-monsoon. Monsoon showers tend to dilute pollutants due to their scouring action. However, some water quality remains poor, requiring continual monitoring and restoration.

Nethravathi River Health Status

TABLE II. Statistical Summary of River water samples during Pre-monsoon 2022

Sl. No	River Name	Location ID	Water Quality Data (Pre-monsoon 2022)														Water Quality Analysis	
			Physical Parameters							Chemical Parameters								
			pH	ORP	DO	EC	TDS	Temp	Salinity	Ca	TH	Cl	K	Na	SO4	HCO3	WQI Value	Water Quality Status
1		Site-1	7.02	-3.9 1	0.96	77 68	38	34	0	200	120	39.97	0	6.82	0	72	59	Poor Water Quality Poor
2		Site-2	6.8		0.68	203 64	29	300.8	0	120	120	38.59	4.21	37.83	0.029	84	59	Water Quality Poor
3		Site-3	7.17	-0.2	0.72	71 57	103	30.46	0	120	200	39.99	4.2	8.01	0.145	96	58	Water Quality Poor
4		Site-4	6.49	-3.3	0.65	67 63	32	32.47	0	200	160	59.96	0	0	0.33	84	72	Water Quality Bad
5		Site-5	7.14	-2.6	0.76	65	35	32.91	0	120	120	199.96	0	7.34	0.054	96	192	Water Quality Good
6	NETHRAVATHI	Site-6	6.78	23.4	0.84	50.15	28	31.82	0	200	200	19.99	0	7.47	0	90	41	Water Quality Bad
7		Site-7	7.22	4	0.75	35.25	34	32.46	0	160	120	179.89	0	7.49	0.044	80	176	Water Quality Poor
8		Site-8	7.53	1.2	0.82	62	31	34.68	1	80	120	39.99	0	0	0.12	84	59	Water Quality Good
9		Site-9	6.97	18.4	0.79		33	35	1	160	200	19.99	0	0	0.031	80	41	Water Quality Bad
10		Site-10	7.9	0.9	0.86		25.08	32.41	19.1	3810	4080	299.98	6.49	67.61	2.1	84	199	Water Quality Bad
11		Site-11	7.1	3.7	0.6		17.64	34.22	10.5	4810	4160	739.76	0	6.82	0.996	74	163	Water Quality Poor
12		Site-12	6.96	-4	0.84		31	32.32	0	400	200	39.99	0	0	0.041	72	58	Water Quality

TABLE III. Statistical Summary of River water samples during Post-monsoon 2022

Sl. No	River Name	Location ID	Water Quality Data (Post-monsoon 2022)														Water Quality Analysis	
			Physical Parameter EC							Chemical Parameter								
			pH	ORP	DO		TDS	Temp	Salinity	Ca	TH	Cl	K	Na	SO4	HCO3	WQI Value	Water Quality Status
1		Site-1	6.4	6	0.93	31	16	26.7	0	240	280	39.99	4.69	3.78	6.07	72	46	Good Water Quality
2		Site-2	6.5	18.4	1.4	78	41.5	29	0	164.3	260	39.99	4.18	1.8	4.64	73	51	Poor Water Quality
3		Site-3	6.7	17.9	1.23	73	37	28	0	160	200	39.99	5.05	3.12	10.1	84	49	Good Water Quality
4		Site-4	6.1	18.2	0.89	12	6	26.31	0	120	200	59.98	4.6	2.14	5.6	79	44	Good Water Quality
5		Site-5	6.67	11.5	1.31	30	15	25.7	0	120	200	180	5.36	2.07	4.64	96	48	Good Water Quality Bad
6	NETHRAVATHI	Site-6	6.65	26.5	6.7	19	10	25	0	140	167	170.1	4.4	2.5	4.15	82	76	Water Quality Good
7		Site-7	5.9	-1.6	0.99	16	8	24.77	0	120	160	39.99	4.06	1.93	2.15	80	43	Water Quality Bad
8		Site-8	6.61	4.5	6.45	42	22	30.15	0	246	200	40.6	4.68	2.08	3	84	78	Water Quality Poor
9		Site-9	6.76	5.1	5.46	57	29	30.46	0	189	215	39.87	5.81	2.01	3.1	81	74	Water Quality Poor
10		Site-10	7.84	-12	1.05	4700	2351	28.6	30	184	480	1299	5.49	2.9	5.09	84	59	Water Quality Good
11		Site-11	6.9	26.5	0.94	44	22	26.24	0	120	200	39.99	5.96	4.26	62.17	80	47	Water Quality Good
12		Site-12	6.8	25.5	1.4	42	21	26.81	0	160	240	39.99	4.26	4.34	2.46	96	50	Water Quality

TABLE VI. WQI status of Nethravathi River during Pre-monsoon 2022 (Weight Arithmetic Index Method, Brown et. al. 1972)

WQI Range	Water Quality Status	No Sampling Sites	% of Water Samples
0-25	Excellent Water Quality	Nil	Nil
26-50	Good Water Quality	2	16.67
51-75	Poor Water Quality	6	50
76-100	Bad Water Quality	4	33.33
>100	Unsuitable for drinking water	Nil	Nil

TABLE V. WQI status of Nethravathi River during Post-monsoon 22 (Weight Arithmetic Index Method, Brown et. al. 1972)

WQI Range	Water Quality Status	No Sampling Sites	% of Water Samples
0-25	Excellent Water Quality	Nil	Nil
26-50	Good Water Quality	7	58.34
51-75	Poor Water Quality	3	25
76-100	Bad Water Quality	2	16.66
>100	Unsuitable for drinking water	Nil	Nil

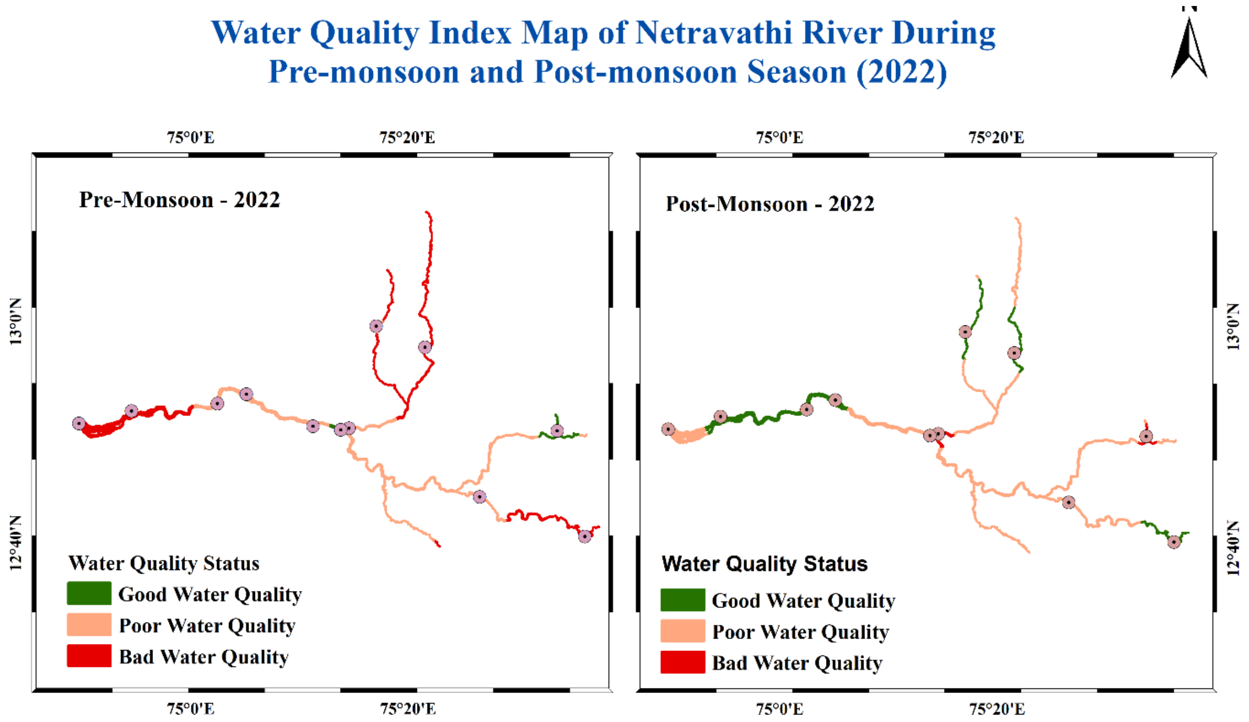
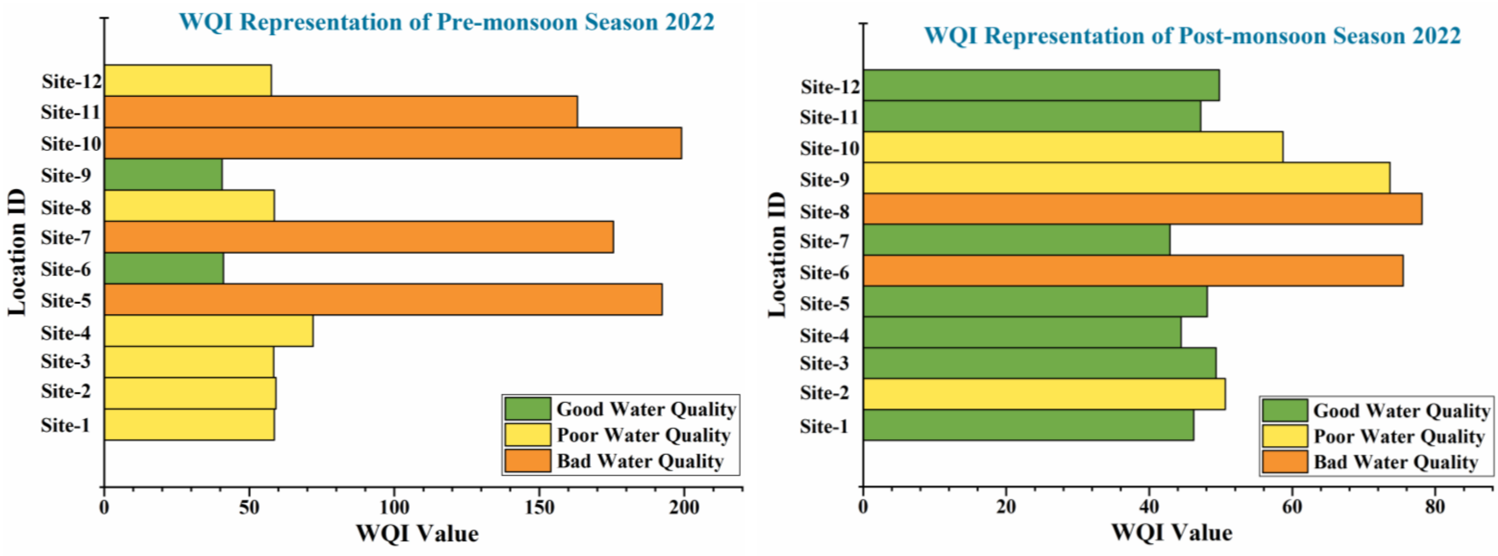


Fig. 7. Water Quality Index Map of Pre and Post monsoon for Nethravathi River



(a) (b)

Fig. 8. (a) Water Quality Index Map of Pre-monsoon for Nethravathi River, (b) Water Quality Index Map of Post monsoon for Nethravathi River

V. CONCLUSION

The study of river health based on physico-chemical parameters plays a major role in river conservation and protection. An attempt was made to study the impact of the COVID-19 lockdown on the river water quality of Nethravathi to assess physico-chemical river health. The data was collected in pre-monsoon and post-monsoon during COVID-19. The study results indicate that it experiences significant contamination during the pre-monsoon season due to anthropogenic activities. Approximately 50% of the river from the mid-region to the downstream region was found to be contaminated based on the assessment. Out of the twelve sampling locations, six regions namely (S1, S2, S3, S4, S8, and S12 were examined to have poor water quality.

This means that half of the sampling sites along the river showed signs of contamination. During the pre-monsoon season, the overall health of the Nethravathi River is negatively affected due to human activities such as washing and bathing on the river banks, discharge of treated wastewater, etc. These activities introduce pollutants and contaminants into the flowing water, leading to deteriorating water quality. It is important to observe that the contamination is primarily caused by human actions in this case. However, there is some Water quality has been enhanced due to a wide range of flora and self-healing microorganisms, less industrial waste contaminating river water, and a lack of human activity during the post-monsoon season. The assessment found that water quality improved by approximately 58.34% as compared to the pre-monsoon season. During the post-monsoon season, seven sampling sites were observed to have good water quality. This indicates that there is a positive change in the river's condition after the monsoon, potentially due to dilution and natural processes. The study identified that certain sampling sites experienced pollution of the flowing water due to activities such as bathing, washing clothes, and animals near the river's bank. It is essential to perform constant monitoring and implement suitable protection measures such as separate bathing and washing for pilgrims at Dharmastal and Subramanya towns located on the river bank. Adopting these steps close to the river's bank will improve EC, TDS, Salinity, and DO, thus enhancing the health of the river throughout the year.

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