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Statistical Analysis for Assessment of Water Quality- Arkavathi River in India

Kalpana Polisetty

Department of Mathematics and Statistics, School of Applied Science and Humanities, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur, India-522213.

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Abstract

This study assessed the water quality of the Arkavathi River in India across three time scales (2019, 2020, and the combined period 2019–2020) using the Weighted Arithmetic Water Quality Index (WAWQI). Thirteen physicochemical parameters were monitored twice a month at five sampling stations between August 2019 and July 2020. In all cases, only the Koggedoddy station met drinking water standards (WAWQI ≈ 45). In contrast, the other four stations were heavily polluted (WAWQI 60–90), with pollution severity following the order Thymasandra > Doddamuduvadi > Gogeredoddi > Tavarekere Bekuppe. Correlation analysis was conducted to characterize relationships among the parameters, which revealed that pH–DO (r = 0.815), EC–Na (r = 0.745), and EC–TDS (r = 0.71) were strongly related, indicating that ionic and oxygen-related factors largely control water quality. Moreover, ANOVA results revealed significant spatial differences in BOD, DO, pH, Cl, and F across the sampling stations. Hence, the study effectively identified the main causes of pollution in the Arkavathi River and showed which stations need quick action. Overall, the findings will help support effective river management and protection.

Keywords: *Arkavathi River, Water quality, WAWQI, Correlation analysis, One-way ANOVA*

1. Introduction

One of the pressing global issues is water quality, and continuously monitoring it presents a significant challenge for effective water resource management. To address this, water quality is typically assessed using three important parameters: physical, chemical, and biological. Understanding the interplay of these factors is crucial for determining whether water is safe for drinking, suitable for other uses, or unsafe for any purpose. Integrating the effects of various physicochemical and biological parameters into a single representative measure is only possible through the Water Quality Index (WQI).

Initially, WQI was proposed by Horton (1965); it was later improved by Brown et al. (1970) through the use of arithmetic weights, leading to the development of the Weighted Arithmetic Water Quality Index (WAWQI). In subsequent years, numerous studies have developed and applied different index aggregation functions, including the Chemical WQI, the Canadian Council of Ministers of the Environment WQI, the NSF WQI, the Oregon WQI, and the Overall Index of Pollution. However, several researchers have extensively applied the WAWQI to assess water quality in both surface and groundwater systems due to its ease of computation, flexibility, and ability to effectively provide an interpretable measure of overall water quality.

For example, WAWQI has been used to evaluate the water quality of the Gharraf River in southern Iraq (Ewaid & Abed, 2017), the Sabarmati River Basin (Kosha & Geeta, 2017), the Yamuna River (Anshu & Vinita, 2019), the Tigris River in Iraq (Chabuk et al., 2020), and the Arkavathi River and the groundwater around it (Bharath et al., 2024). It has also been applied to assess groundwater quality in Vijayawada, Andhra Pradesh (Satish et al., 2017), and South Gujarat (Divya et al., 2023). Other studies have examined the impacts of mining and industrial activities on water quality, such as gold mining areas in the southeastern region (Diop, 2023) and irrigation water in Basra City (Faroon et al., 2023). Additionally, many other researchers have used this approach (Tyagi et al., 2013; Oni & Fasakin, 2016; Kosha & Geeta, 2017; Kachroud et al., 2019; Tasneem & Mustafa, 2021; Khushbu et al., 2021; Sandra et al., 2023; Shirodkar et al., 2010; Lumb et al., 2011; Gazzaz et al., 2012; Dede et al., 2013). Collectively, these studies demonstrate the effectiveness of WAWQI in capturing spatial and temporal variations in water quality across diverse regions and sources.

Along with WAWQI, multivariate and statistical methods have been widely employed to analyze complex water quality datasets and identify pollution sources. Techniques such as Principal Component Analysis (PCA), Cluster Analysis (CA), and Discriminant Analysis (DA) have been applied to the Daliao River Basin (Zhang et al., 2009), Manchar Lake (Kazi et al., 2009), and the Haraz River Basin (Pejman et al., 2009) to identify potential pollution sources. Similarly, Ammar et al. (2017) applied CA and ANOVA to water samples from the Koudiat Medouar watershed to identify differences between sampling stations and assess the influence of pollution sources. VishnuRadhan et al. (2017) investigated the water quality of the Sg. Malim urban river in Peninsular Malaysia using various statistical approaches. In India, Loganathan and Ahamed (2017) assessed the Amaravati River using CA, PCA, and correlation analysis, while Prasad et al. (2020)

* Corresponding author e-mail: drkalpanastat@gmail.com

implemented an Internet of Things (IoT) based monitoring system for the Krishna River, using ANOVA to validate seasonal variations in water quality.

These studies highlight the usefulness of WAWQI, multivariate, and statistical methods for simplifying complex datasets, identifying key pollution sources, and supporting decisions on water quality management. Despite extensive studies on water quality using WAWQI and statistical analyses, the Arkavathi River, an important water source in the region, has not been systematically evaluated for various stations with different time intervals. This study addresses this gap by combining WAWQI, correlation, and ANOVA. The primary objectives of this study are i) to analyze physicochemical parameters, ii) to assess the river water status periodically, iii) to examine correlations between physicochemical parameters, and iv) to determine significant differences in parameters across sampling stations.

2. Material and Methods:

The Arkavathi River, a non-perennial river originating in the Nandi Hills of the Chikkaballapura district in Karnataka, southern India, is the focus of this study. Five sampling stations, namely Doddamuduvadi, Gogeredoddi, Thymasandra, Tavarekere Bekuppe and Koggedoddy, are selected. These stations are positioned along the river, spanning up to 5 km from its confluence. Data on 13 physicochemical characteristics: Bio-chemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Nitrate (NO_3), pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Chloride (Cl), Sulfate (SO_4), Iron (Fe), Fluoride (F), Boron (BH_3) and Sodium (Na) were collected twice a month from the Arkavathi River during the period from August 2019 to July 2020.

2.1 WAWQI method:

A notable feature of this method is that it classifies water quality based on the degree of purity as assessed through various water quality parameters (Singh et al. 2013; Kizar, 2018). This method contains three major components, which are the proportionality constant , unit weight factor (W_i), and sub-index or Ciphering water quality rating (Q_i) mathematical forms given below:

1. The proportionality constant is $K = \left(\sum_{i=1}^{n} \frac{1}{S_i} \right)^{-1}$
2. Unit weight factor is $W_i = \frac{K}{S_i};\ i = 1, 2, 3, \ldots n$
3. Ciphering the water quality rating is $Q_i = \left[\frac{V_i - V_{i0}}{S_i - V_{i0}} \right] X100$

   Where,

V_i = Observed value of the ith parameter of water for a particular sample station

V_{i0} = Ideal value of the ith parameter of pure water

S_i = Standard acceptable value of the ith parameter of water as per BIS 10500: 2012

n = Number of Physicochemical parameters

The mathematical expression of WAWQI is defined as

$$WAWQI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$$

The ideal values (V_{i0}) are pH = 7.0 and DO =14.6 mg/L, and all other parameters are assumed to be zero. According to the WAWQI methodology, water quality is classified in five classes as follows: i) 0–25 indicates excellent quality; ii) 26–50 indicates good quality; iii) 51–75 indicates poor quality; iv) 76–100 indicates inferior quality; and v) above 100 indicates unsuitable for drinking (Yogendra and Puttaiah, 2008; Nayar, 2020).

3. Results and Discussion:

The measured physicochemical parameters of water at various stations of the Arkavathi River are analyzed using descriptive statistics and presented in Table 1. As per the results, the lowest BOD of 0.2 mg/L is recorded in June at Koggedoddy station, while the highest BOD of 38.4 mg/L is observed in September at Gogeredoddi station. The average BOD ranged from 2.15 mg/L at Koggedoddy to 13.15 mg/L at Gogeredoddi. All stations exhibited BOD levels exceeding 2 mg/L, indicating severe pollution of the river water.

The minimum DO of 1 mg/L is recorded in August at Gogeredoddi station, and the maximum DO of 9.4 mg/L is observed in February at Koggedoddy station. The average DO ranges from 2.26 mg/L at Gogeredoddi to 7.66 mg/L at Koggedoddy. Except for Koggedoddy station, the average DO levels at the remaining stations are below 5 mg/L, suggesting contamination of the river water. The lowest EC, 935 µS/cm, is recorded in June at the Doddamuduvadi station, and the highest, 1584 µS/cm, is observed in March at the Thymasandra station. The average EC ranged from 1172.8 µS/cm at Koggedoddy to 1273.4 mg/L at Doddamuduvadi.

The lowest TH of 198 mg/L is recorded in October at Tavarekere Bekuppe station, while the highest TH of 485 mg/L is observed in June at Koggedoddy station. The average TH ranged from 308.25 at Tavarekere Bekuppe to 349.2667 at Doddamuduvadi. Fe levels are consistently low, with the minimum recorded around 0.01 mg/L across all stations. The highest Fe concentration, 0.45 mg/L, was observed in October at the Tavarekere Bekuppe station. The average Fe concentration ranged from 0.0973 mg/L at Doddamuduvadi to 0.1313 mg/L at Koggedoddy.

Table 1. Descriptive statistics for measured physicochemical parameters of Arkavathi River (August 2019 – July 2020)

Parameters	Station	Min	Max	Mean	S.D.	Skewness	Parameters	Station	Min	Max	Mean	S.D.	Skewness
BOD	Doddamuduvadi	0.9	17.4	9.3357	5.5468	0.1621	Cl	Doddamuduvadi	138	246	214.4	27.3909	-1.9166
	Gogeredoddi	5	38.4	13.1526	7.6206	2.1191		Gogeredoddi	106	439	166.9	70.9948	3.4393
	Thymasandra	3.9	26.5	12.2368	5.4548	0.8924		Thymasandra	124	196	159.65	22.1858	-0.0127
	Tavarekere Bekuppe	2	25.3	11.5105	5.3807	0.6752		Tavarekere Bekuppe	126	202	163.35	24.4787	0.0511
	Koggedoddy	0.2	6.5	2.1526	1.9366	1.1140		Koggedoddy	122	225	170.65	33.2331	-0.3421
DO	Doddamuduvadi	1.5	5.5	3.3133	1.1127	0.1799	SO_4	Doddamuduvadi	14	58	29.6	10.7859	0.7124
	Gogeredoddi	1	4.8	2.2550	0.9568	1.2247		Gogeredoddi	21	55	36.1	9.9390	0.2354
	Thymasandra	1.7	5.3	3.345	1.1338	0.0870		Thymasandra	19	79	38.3	15.1468	1.3012
	Tavarekere Bekuppe	2	4.3	2.88	0.7218	0.4897		Tavarekere Bekuppe	19	77	36.85	15.2542	1.2420
	Koggedoddy	4.8	9.4	7.66	1.1476	-0.5747		Koggedoddy	15	85	33.55	16.4885	1.7013
NO_3	Doddamuduvadi	2.1	26.5	10.65	6.1226	1.5171	Fe	Doddamuduvadi	0.02	0.38	0.0973	0.1251	1.3635
	Gogeredoddi	0.5	64.5	9.7185	13.8246	3.8667		Gogeredoddi	0.005	0.4	0.1313	0.1194	0.882
	Thymasandra	0.6	36.5	10.6485	9.3623	1.7857		Thymasandra	0.009	0.42	0.117	0.1182	1.1655
	Tavarekere Bekuppe	1	63	15.2915	13.7394	2.6343		Tavarekere Bekuppe	0.001	0.45	0.1056	0.1203	1.6539
	Koggedoddy	3.5	31.2	15.6155	8.2343	0.3497		Koggedoddy	0.007	0.38	0.1019	0.1243	1.2819
pH	Doddamuduvadi	7.4	7.8	7.6533	0.1336	-0.1557	F	Doddamuduvadi	0.059	1.31	0.6053	0.3636	0.2245
	Gogeredoddi	7.2	7.9	7.655	0.1837	-1.1898		Gogeredoddi	0.05	0.714	0.3852	0.1706	-0.1440
	Thymasandra	7.3	7.9	7.71	0.1537	-0.9884		Thymasandra	0.052	0.779	0.4133	0.1667	-0.3643
	Tavarekere Bekuppe	7.3	7.9	7.715	0.1779	-0.8050		Tavarekere Bekuppe	0.053	0.795	0.4178	0.1856	-0.1524
	Koggedoddy	8.1	8.9	8.475	0.2433	-0.3807		Koggedoddy	0.082	1.21	0.6872	0.3369	-0.7107
EC	Doddamuduvadi	935	1447	1273.4	129.4565	-1.4085	BH_3	Doddamuduvadi	0.09	0.28	0.174	0.058	0.5562
	Gogeredoddi	967	1583	1272.05	196.3159	0.2465		Gogeredoddi	0.11	0.36	0.1955	0.0766	0.9308
	Thymasandra	996	1584	1272.45	194.4671	0.238		Thymasandra	0.1	0.29	0.187	0.0584	0.2599
	Tavarekere Bekuppe	965	1579	1271.05	194.9944	0.2216		Tavarekere Bekuppe	0.11	0.45	0.205	0.0860	1.4793
	Koggedoddy	954	1382	1172.8	148.623	-0.3551		Koggedoddy	0.06	0.4	0.191	0.1013	1.1117
TDS	Doddamuduvadi	570	1040	803.2	141.0984	0.2048	Na	Doddamuduvadi	84	156	124.1333	23.4127	-0.4866
	Gogeredoddi	544	1050	796.5	142.8258	0.1544		Gogeredoddi	83	181	129.85	29.2382	0.2861
	Thymasandra	548	1050	799.5	140.7067	0.1461		Thymasandra	90	200	133.55	29.6878	0.5153
	Tavarekere Bekuppe	540	1030	778.3	138.6416	0.3976		Tavarekere Bekuppe	94	194	133.25	29.3759	0.4939
	Koggedoddy	558	928	746.75	85.2212	-1.1614		Koggedoddy	48	181	125.5	36.8896	-0.5382
TH (as CaCO3)	Doddamuduvadi	267	465	349.2667	54.0763	0.7497							
	Gogeredoddi	202	404	318.25	58.9123	-0.3458							
	Thymasandra	213	423	318.3	53.2180	-0.0038							
	Tavarekere Bekuppe	198	377	308.25	47.6588	-0.5746							
	Koggedoddy	238	485	319.95	58.4488	0.8718							

Table 2. BIS and mean concentration values of physicochemical parameters of Arkavathi River

Parameters	BIS values	2019					2020					2019-2020				
		S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
BOD	2	8.06	14.24	11.36	13.32	2.98	12.53	11.94	13.21	9.5	1.23	9.3357	13.1526	12.23	11.5105	2.1526
DO	5	3.49	2.3	3.66	3.02	7.23	2.96	2.21	3.03	2.74	8.09	3.3133	2.255	3.345	2.88	7.66
NO_3	45	11.02	12.38	11.19	17	18.85	9.92	7.06	10.11	13.58	12.38	10.65	9.7185	10.6485	15.2915	15.6155
pH	8.5	7.69	7.64	7.75	7.7	8.42	7.58	7.67	7.67	7.73	8.53	7.6533	7.655	7.71	7.715	8.475
EC	750	1282.2	1203.7	1212.2	1209.9	1148.2	1255.8	1340.4	1332.7	1332.2	1197.4	1273.4	1272.05	1272.45	1271.05	1172.8
TDS	500	818.8	795.2	792.6	780.8	778.7	772	797.8	806.4	775.8	714.8	803.2	796.5	799.5	778.3	746.75
TH	300	336.1	296.7	316.5	295.2	303.3	375.6	339.8	320.1	321.3	336.6	349.2667	318.25	318.3	308.25	319.95
Cl	250	217.3	145.6	155.1	155.3	170.4	208.6	188.2	164.2	161.4	170.9	214.4	166.9	159.65	163.35	170.65
SO_4	200	32.7	34.4	34.6	32.2	33.3	23.4	37.8	42	41.5	33.8	29.6	36.1	38.3	36.85	33.55
Fe	0.3	0.09	0.14	0.11	0.11	0.09	0.11	0.127	0.126	0.103	0.112	0.0973	0.1313	0.117	0.1056	0.1019
F	1	0.59	0.36	0.38	0.39	0.55	0.65	0.41	0.44	0.45	0.83	0.6053	0.3852	0.4133	0.4178	0.6872
BH_3	0.5	0.18	0.19	0.18	0.22	0.22	0.17	0.2	0.19	0.19	0.16	0.174	0.1955	0.187	0.205	0.191
Na	200	129.4	122.7	123.3	123.2	128.2	113.6	137	143.8	143.3	122.8	124.1333	129.85	133.55	133.25	125.5

**Except pH and EC, all parameters are in mg/L*

The lowest NO_3 concentration, 0.5 mg/L, is observed in July at the Gogeredoddi station, while the highest NO_3 concentration,64.5 mg/L, is also recorded in November at the same station. The average NO_3 levels ranged from 9.72 mg/L at Gogeredoddi to 15.62 mg/L at Koggedoddy. The pH levels varied from a minimum of 7.2 in September at Gogeredoddi station to a maximum of 8.9 in August at Koggedoddy station. The average pH ranged from 7.65 at Doddamuduvadi to 8.48 at Koggedoddy.

TDS was lowest at 540 mg/L, recorded in July at Tavarekere Bekuppe station and highest at 1050 mg/L, observed in December at both Thymasandra and Gogeredoddi stations. The average TDS values ranged from 746.75 mg/L at Koggedoddy to 803.2 mg/L at Doddamuduvadi.

Cl concentrations ranged from a minimum of 106 mg/L in June at Gogeredoddi to a maximum of 439 mg/L in April at the same station. The average Cl levels ranged from 159.65 mg/L at Thymasandra to 214.4 mg/L at Doddamuduvadi. SO_4 concentrations ranged from a minimum of 14 mg/L in June at Doddamuduvadi to a maximum of 85 mg/L in February at Koggedoddy. The average SO_4 levels ranged from 29.6 mg/L at Doddamuduvadi to 38.3 mg/L at Thymasandra. F levels ranged from a minimum of 0.05 mg/L in August at Gogeredoddi to a maximum of 1.31 mg/L in November at Doddamuduvadi. The average F concentrations were 0.39 mg/L at Gogeredoddi and 0.69 mg/L at Koggedoddy. BH_3 concentrations ranged from a minimum of 0.06 mg/L in December at Koggedoddy to a maximum of 0.45 mg/L in September at Tavarekere Bekuppe. The average BH_3 levels were 0.17 mg/L at Doddamuduvadi and 0.21 mg/L at Tavarekere Bekuppe. Na concentrations ranged from a minimum of 48 mg/L in June at Koggedoddy to a maximum of 200 mg/L in March at Thymasandra. The average Na levels varied from 124.13 mg/L at Doddamuduvadi to 133.55 mg/L at Thymasandra.

The descriptive statistics reveals that the average levels of few variables at all stations are within the BIS standards (Table 2): NO_3 (<45 mg/L), pH (6.5-8.5), TDS (<500 mg/L), Cl (<250 mg/L), SO_4 (<200 mg/L), F (<1.5 mg/L), BH_3 (<1 mg/L) and Na (<200 mg/L). However, certain physicochemical parameters, such as BOD, DO, EC, TH, and Fe, exceed the acceptable limits set by the standards.

Various factors contribute to changes in their concentrations. For example, BOD and DO are mainly affected by the direct discharge of domestic sewage, industrial effluents, and other anthropogenic activities. Additionally, cooking cocoons in hot water during silk processing and filature operations in Ramanagara town, along with contamination of the Vrushabhavathi River, further increases organic and inorganic load, thereby influencing BOD and DO levels. Elevated EC, TH, and Fe values generally occur due to natural geological deposits, dissolution of minerals such as limestone and dolomite, and corrosion of iron-containing materials (Aghazadeh et al. 2017). Notably, the river flows through a rocky bed, which aids in the natural self-purification of water to some extent.

Also, some variables exhibit high variability, as indicated by their high standard deviations (S.D.), suggesting considerable differences between the samples. This variability can be attributed to various factors, including spatial and temporal variations, climatic conditions, and pollution sources. Additionally, skewness values provide insight into the distribution patterns. For instance, the BOD distribution is positively skewed toward higher concentrations at Gogeredoddi, followed by Koggedoddy. The dispersion results are very useful for understanding the factors contributing to variations in water composition.

These results suggest varying levels of contamination in the river water, making it unsuitable for drinking. However, findings provide an initial indication of water contamination; further analysis is necessary for a comprehensive understanding of the issues.

The mean concentration levels of physicochemical parameters of the Arkavathi River from five locations, along with the BIS standards for these parameters, are presented in Table 2 for WAWQI analysis. Based on these values, the data are categorized into three time scales (2019, 2020, and the combined period 2019–2020) to analyze the water quality status. The corresponding WAWQI values and water quality status are presented in Table 3, and their distribution across the study locations and time scales is shown in Figure 1.

Table 3. Periodical assessment of water quality status in the Arkavathi River based on WAWQI

Station	2019	Status of water quality	2020	Status of water quality	201-2020	Status of water quality
Doddamuduvadi	64.37	Poor water quality	83.02	Very Poor water quality	69.85	Poor water quality
Gogeredoddi	90.66	Very Poor water quality	82.48	Very Poor water quality	86.78	Very Poor water quality
Thymasandra	75.94	Very Poor water quality	86.51	Very Poor water quality	81.06	Very Poor water quality
Tavarekere Bekuppe	85.25	Very Poor water quality	70.06	Poor water quality	78.01	Very Poor water quality
Koggedoddy	48.46	Good water quality	45.86	Good water quality	47.32	Good water quality

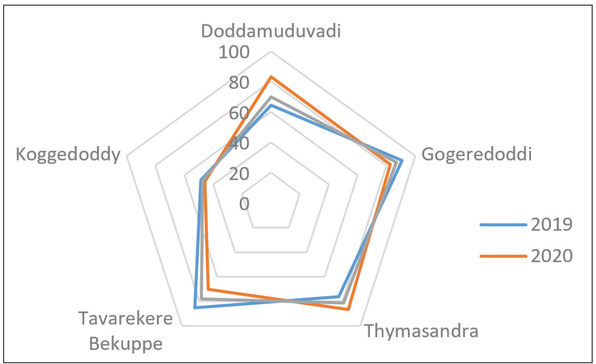

Figure 1. Comparison of WAWQI trends across stations and three-time scales

In 2019, the WAWQI analysis reveals that Gogeredoddi, with a measurement of 90.66, is categorized as exhibiting "very poor" water quality, followed by Tavarekere Bekuppe (WAWQI = 85.25) and Thymasandra (WAWQI = 75.94), both of which fall within the suboptimal water quality range. The Doddamuduvadi station, with a WAWQI of 64.37, is classified as having "poor" water quality. In contrast, Koggedoddy, with a WAWQI of 48.46, maintains "good" water quality, suitable for human consumption.

The 2020 WAWQI analysis shows that Thymasandra, with a WAWQI of 86.51, continues to exhibit "very poor" water quality, followed by Doddamuduvadi (WQI = 83.02), Gogeredoddi (WAWQI = 82.48), and Tavarekere Bekuppe (WAWQI = 70.06), all of which remain in the "poor" water quality category. Koggedoddy, with a WAWQI of 45.86, again shows "good" water quality, indicating lower contamination and suitability for drinking.

For the combined period of 2019-2020, Gogeredoddi recorded the highest WAWQI value of 86.7795, denoting "very poor" water quality, followed by Thymasandra (WAWQI = 81.06) and Tavarekere Bekuppe (WAWQI = 78.01), which also indicate "poor" water quality. Doddamuduvadi (WAWQI = 69.85) remains within the "poor" category. Conversely, Koggedoddy consistently demonstrated "good" water quality across both years, with a WQI of 47.32, signifying a consistently high standard of water purity and minimal contamination throughout the study period.

In all three analyses, all stations show that the river water is polluted and the water quality is generally very poor. Koggedoddy is a notable exception, with WAWQI values consistently below 50, indicating that the water quality there is good and suitable for drinking. The analysis focused on the results for 2020, as it offers accurate insights into water quality at various river stations. The findings reveal that the station Thymasandra has the poorest water quality, ranking highest in terms of contamination, followed by the stations Doddamuduvadi and Gogeredoddi, whereas Tavarekere Bekuppe station shows moderate contamination. In contrast, Koggedoddy Station's water is free from pollutants, with the quality being good. This higher water quality at Koggedoddy may be due to its proximity to the Cauvery River confluence, which likely enhances water quality at this site. The clear water near the confluence is crucial for both local residents and domestic animals.

The variability in water quality across stations highlights the fluctuating conditions in different parts of the river, with some stations showing a consistent decline while others maintain relatively better quality. Continuous monitoring and targeted interventions are essential to address these disparities and improve water safety. Despite the current challenges, there is potential for revitalizing the Arkavathi River. With focused efforts in water management and pollution control, the river's water quality can be significantly improved, ensuring both environmental sustainability and public health.

In addition, correlation analysis helps determine how variations in water quality parameters affect overall water quality across different sites. Here, average values from five sampling stations were used to analyze the relationships between 13 physicochemical attributes, and the results are presented in Table 4.

Table 4. Correlation matrix of thirteen parameters of water quality

	DO	NO_3	pH	EC	TDS	TH	Cl	SO_4	Fe	F	BH_3	Na	BCOD
DO	1												
NO_3	0.160	1											
pH	0.815*	0.153	1										
EC	-0.159	-0.099	-0.011	1									
TDS	0.016	0.142	0.048	0.711*	1								
TH	0.048	0.035	0.114	0.607*	0.414*	1							
Cl	0.070	-0.100	0.072	0.528*	0.369*	0.468*	1						
SO_4	0.001	-0.080	0.041	0.422*	0.331*	0.191	0.161	1					
Fe	-0.012	0.198	-0.141	-0.370*	-0.297*	-0.378*	-0.180	-0.009	1				
F	0.321*	0.251*	0.340*	-0.180	-0.279*	-0.040	0.025	-0.106	0.089	1			
BH_3	-0.040	-0.170	0.047	0.366*	0.142	0.232*	0.192	0.251*	-0.351*	-0.211*	1		
Na	-0.082	-0.146	0.087	0.745*	0.373*	0.058	0.369*	0.363*	-0.330*	-0.033	0.342*	1	
BOD	-0.576*	-0.180	-0.651*	0.181	0.058	-0.047	-0.097	0.163	-0.116	-0.313*	0.163	0.108	1

** Correlation is significant at 95% level (2-tailed).*

DO is strongly positively correlated with pH ($r = 0.815$, $p < 0.05$), weakly positively correlated with F ($r = 0.321$, $p < 0.05$), and moderately negatively correlated with BOD ($r = -0.576$, $p < 0.05$). NO_3 and F exhibit a weak positive association ($r = 0.251$, $p < 0.05$). pH shows a weak positive correlation with F ($r = 0.321$, $p = 0.05$) and a moderate negative correlation with BOD ($r = -0.651$, $p < 0.05$).

EC is moderately positively correlated with several parameters: TDS ($r = 0.711$, $p < 0.05$), TH ($r = 0.607$, $p < 0.05$), Cl ($r = 0.528$, $p < 0.05$), SO_4 ($r = 0.422$, $p < 0.05$), and BH_3 ($r = 0.366$, $p < 0.05$). EC shows a high positive correlation with Na ($r = 0.745$, $p < 0.05$) and a weak negative correlation with Fe ($r = -0.37$, $p < 0.05$). TDS exhibits weak associations with TH ($r = 0.414$, $p < 0.05$), Cl ($r = 0.369$, $p < 0.05$), SO_4 ($r = 0.331$, $p < 0.05$), and Na ($r = 0.373$, $p < 0.05$). TDS also has a weak negative association with Fe ($r = -0.297$, $p < 0.05$) and F ($r = -0.279$, $p < 0.05$). TH is weakly associated with Cl ($r = 0.468$, $p < 0.05$), Fe ($r = -0.378$, $p < 0.05$), and BH_3 ($r = 0.232$, $p < 0.05$).

Additionally, there is a weak positive association between Cl and Na ($r = 0.369$, $p < 0.05$), SO_4 and BH_3 ($r = 0.251$, $p < 0.05$), and Na ($r = 0.363$, $p < 0.05$). BH_3 shows weak positive associations with Na ($r = 0.342$, $p < 0.05$) and negative associations with F ($r = -0.211$, $p < 0.05$) and BOD ($r = -0.313$, $p < 0.05$).

From the overall analysis, the notable observation is that most physicochemical parameters show weak associations at the 95% confidence level. Also, both positive and negative associations are detected between the different types of variables. The positive correlations suggest that reducing certain parameter levels could help maintain permissible limits as directed by BIS (2012). The significant correlation coefficients identified in this analysis will aid in selecting appropriate treatments to reduce pollution levels in the Arkavathi River. To further interpret these relationships environmentally, the correlation analysis highlights the key factors influencing water quality and aquatic ecosystem health. Strong associations (DO–pH, EC–TDS, and EC–Na) indicate that oxygen availability and ionic content are primary drivers of water chemistry, directly affecting salinity and aquatic life.

Moderate correlations (DO–BOD, EC–TH, and EC–Cl) suggest secondary contributions from organic matter and mineral ions, reflecting combined natural and anthropogenic influences. Weak associations, such as those among fluoride, boron, and sulfate, indicate independent geochemical behavior, which has a limited impact on overall water quality. Collectively, these relationships emphasize that ionic strength, organic loading, and pH regulate the environmental quality of river water and its suitability for irrigation and other ecosystem services.

Moreover, One-way ANOVA with post-hoc (LSD) tests was used to compare physicochemical attributes among Arkavathi River stations, and the results are shown in Tables 5 and 6.

Table 5. ANOVA results of physicochemical parameters

Parameters	Sum of Squares	df	Mean Square	F	Sig.
DO	368.962	4	92.240	85.764	0.000
NO_3	624.555	4	156.139	1.379	0.247
pH	9.909	4	2.477	73.154	0.000
EC	155929.782	4	38982.445	1.211	0.312
TDS	41859.376	4	10464.844	0.550	0.700
TH	15539.406	4	3884.852	1.293	0.279
Cl	31990.276	4	7997.569	4.870	0.001
SO_4	787.532	4	196.883	1.017	0.403
Fe	0.014	4	0.003	0.244	0.913
F	1.416	4	0.354	5.818	0.000
BH_3	0.009	4	0.002	0.379	0.823
Na	1363.701	4	340.925	0.384	0.820
BOD	1495.200	4	373.800	12.365	0.000

Table 6. Post-Hoc (LSD) analysis of parameters across sampling stations

Parameters	Station		Sig.
BOD	Koggedoddy	Doddamuduvadi	0
		Gogeredoddi	0
		Thymasandra	0
		Tavarekere Bekuppe	0
DO	Doddamuduvadi	Gogeredoddi	0.004
	Gogeredoddi	Thymasandra	0.001
	Koggedoddy	Gogeredoddi	0
		Thymasandra	0
		Tavarekere Bekuppe	0
pH	Koggedoddy	Doddamuduvadi	0
		Gogeredoddi	0
		Thymasandra	0
		Tavarekere Bekuppe	0
Cl	Doddamuduvadi	Gogeredoddi	0.001
		Thymasandra	0
		Tavarekere Bekuppe	0
		Koggedoddy	0.002
F	Doddamuduvadi	Gogeredoddi	0.010
		Thymasandra	0.025
		Tavarekere Bekuppe	0.028
	Koggedoddy	Thymasandra	0.001
		Gogeredoddi	0
		Tavarekere Bekuppe	0.001

ANOVA revealed no significant average differences among the stations for NO_3, EC, TDS, TH, SO_4, Fe, BH_3, and Na. However, the remaining physicochemical parameters—BOD, DO, pH, Cl, and F—showed significant average differences ($p < 0.05$) among the five stations. The post hoc analysis was conducted to better understand the significant differences among sample stations for BOD, DO, pH, Cl, and F. This analysis identified which pairs of stations differed significantly. For instance, significant differences are observed between Koggedoddy and Doddamuduvadi, Thymasandra, Gogeredoddi, and Tavarekere Bekuppe for parameters such as BOD and pH.

4. Conclusion:

This study includes different physicochemical parameters that exceeded permissible limits of BIS, indicating water quality deterioration across the study stations. The overall water quality assessment requires a comprehensive approach using the WQI. To address this, the WAWQI was computed to assess contamination in the Arkavathi River. The spatial variations showed higher pollution in downstream stations, particularly near Thymasandra and Doddamuduvadi.

In addition, the correlation analysis identified substantial associations among the parameters. ANOVA revealed that some parameters (BOD, DO, pH, Cl, and F) had statistically significant differences at the 95% confidence level among the stations. These variations are due to human activities, and natural factors may also influence them. Overall results showed that Thymasandra, Doddamuduvadi, Gogeredoddi, and Tavarekere Bekuppe were grappling with significant pollution from multiple sources. Based on the results, local authorities or policymakers need to focus on periodic monitoring, stricter enforcement, and treatment interventions (effluent control, sewage management, and awareness programs) for polluted stations or design targeted clean-up plans. Despite these insights, the study is limited by a lack of microbiological and seasonal data, which could be added along with advanced pollution modeling to enhance understanding in future research.

Declarations

Ethics approval

The author has read, understood, and complied as applicable with the statement on 'Ethical responsibilities of Authors' as found in the Instructions for Authors.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Authors Contributions

The author is responsible for study design, data collection, analysis, interpretation, and manuscript preparation.

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Availability of data and materials

This study analyzed publicly available datasets.

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