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Physicochemical Assessment of Water Quality in the Thamirabarani River Basin

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aims to assess the water quality of the Tamirabarani River by analyzing a comprehensive set of parameters to understand the extent of pollution from anthropogenic sources and to identify potential areas for conservation efforts.

Study Design: This is a cross-sectional observational study.Place and Duration of Study: The study was conducted along four stations of the Tamirabarani River, Tamil Nadu, India, between January 2022 and December 2022.

Methodology: Water samples were collected from four different stations along the Tamirabarani River. The parameters analyzed included pH, total dissolved solids (TDS), hardness, chloride, calcium, magnesium, electrical conductivity, ammonia, nitrate, turbidity, alkalinity, fluoride, and iron, using standard analytical methods. These parameters were compared against permissible limits to

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evaluate the extent of water pollution. The sources of contamination, such as untreated sewage, industrial effluents, and agricultural runoff, were also identified.

Results: The analysis revealed significant deviations from permissible limits at Stations 1 and 2, indicating severe contamination. For example, the pH level was 8.11 at Station 1 and 7.89 at Station 2, both residing within the acceptable range of 6.5 to 8.5. Total dissolved solids (TDS) exceeded 500 mg/L at these stations, suggesting high levels of contamination from anthropogenic sources. In contrast, Station 4 showed acceptable levels across all parameters, indicating better water quality. These findings suggest significant spatial variability in water quality along the river, largely attributed to human activities.

Conclusion: The study highlights the critical need for sustainable water management practices in the Tamirabarani River to mitigate pollution from anthropogenic sources. Remedial measures, such as treatment of effluents, public education, and source water protection, are essential to safeguard public health and maintain ecosystem integrity. Further research is needed to monitor water quality trends and evaluate the effectiveness of implemented conservation strategies.

Keywords: Water quality assessment; Tamirabarani river; anthropogenic pollution; environmental impact; sustainable water management.

1. INTRODUCTION

Water, often hailed as the essence of life on Earth, is an indispensable resource that underpins the existence of all living organisms and ecosystems. Its significance extends far beyond mere sustenance, playing a pivotal role in shaping human civilization, economic development, and environmental sustainability [1]. The Tamiraparani River, originating in the Western Ghats and flowing through the Tirunelveli district of Tamil Nadu, India, exemplifies the critical importance of water resources in supporting local communities and ecosystems [2]. However, the stark reality of water scarcity and contamination casts a shadow over this life-giving resource, with billions of people worldwide lacking access to clean, potable water. This global crisis is acutely felt in rapidly developing regions like Tirunelveli, where the Tamiraparani River serves as a lifeline for millions [3].

The quality and availability of water resources, including the Tamiraparani River, are increasingly threatened by a myriad of human activities collectively termed anthropogenic influences. Industrialization, marked by the establishment of manufacturing units and power plants along the river's course, has introduced various pollutants into its waters [4]. Urbanization, particularly in cities like Tirunelveli, has led to increased domestic wastewater discharge and solid waste dumping, further compromising the river's water quality [5]. Agricultural practices, while essential for food security, contribute to water pollution through the runoff of fertilizers, pesticides, and sediments into the Tamiraparani and its tributaries [6].

The cumulative effect of these anthropogenic activities is the introduction of a complex mixture of biochemical components and pollutants into water bodies like the Tamiraparani River. These contaminants range from heavy metals and organic compounds to microplastics and emerging pollutants, altering the physical, chemical, and biological characteristics of the water [7]. The presence of these pollutants not only degrades water quality but also poses significant health risks to humans and other living organisms dependent on the river ecosystem. Waterborne diseases, chronic health issues, and the bioaccumulation of toxins in the food chain are just a few of the potential consequences of consuming or interacting with contaminated water from the Tamiraparani [8].

Moreover, the contamination of the Tamiraparani River has far-reaching implications for the ecological balance of the region. Aquatic ecosystems are particularly vulnerable to changes in water quality, with pollution leading to the loss of biodiversity, altered food webs, and the proliferation of invasive species [9]. The river's role in supporting agriculture, fisheries, and other economic activities in the Tirunelveli district is also compromised, highlighting the intricate connections between environmental health and human well-being [10].

In light of these pressing concerns, the present investigation aims to conduct a comprehensive assessment of water quality in the Tamiraparani River basin. By focusing on four strategically selected sampling stations along the river's course, this study will evaluate key physical and chemical parameters of water quality. These parameters include, but are not limited to, pH, dissolved oxygen, biochemical oxygen demand, electrical conductivity, and the presence of various pollutants [11]. Through this analysis, the research seeks to provide a detailed picture of the current state of the Tamiraparani River, identify potential sources of contamination, and offer insights that can inform water management strategies and conservation efforts in the Tirunelveli district and beyond [12].

2. MATERIALS AND METHODS

2.1 Study Area

The study has been conducted in the basin of the Thamirabarani River, situated between Latitude 08° 8'N and 09° 23'N, and Longitude 77° 09'E and 77° 54'E. Samples were collected in September 2023 at four stations. The first three stations were selected based on the presence of visible contamination, while the fourth station was considered as the control. Station 1 is located at 8.717177°N latitude and 77.701308°E longitude. Station 2 is situated at 8.721217°N latitude and 77.706396°E longitude. Station 3 is found at 8°43'42"N latitude and 77°42'52"E longitude. Station 4 (control) is positioned at 8.708648°N latitude and 77.367435°E longitude.

Water samples were collected in bottles with precautions. They were analyzed for different Physicochemical parameters (Table 1) such as Total solids, turbidity, pH, hardness, chloride ion, dissolved oxygen, iron ion, and alkalinity by the standard protocols of IS: 3025. The Permissible amount of each parameter was tabulated in Table 2.

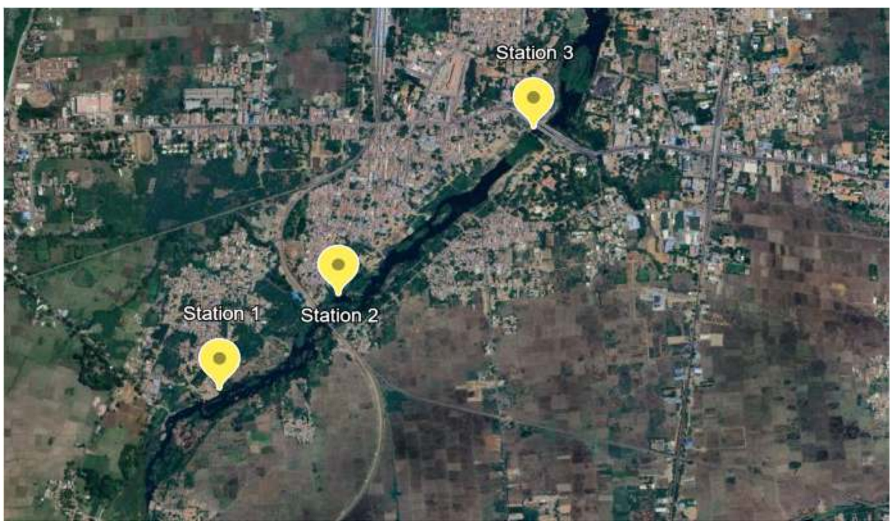

Fig. 1. Map Showing Sampling Sites

Table 1. Methods used to analyze various water quality parameters

S. No	Water Quality Parameter	Method of Analysis
1.	Solid (TDS, TSS, and volatile solids)	Water and soil analysis kit model no 161
2.	Turbidity	Turbidity meter
3.	pH	pH meter
4.	Hardness	EDTA method
5.	Chloride	Chemical method
6.	Dissolved Oxygen	Winkler's method
7.	Iron	Chemical method
8.	Calcium (Ca)	Flame photometer
9.	Magnesium (Mg)	Flame photometer
10.	Nitrate (NO3)	Spectrophotometric methods
11.	Fluoride (F)	Ion-selective electrode method
12.	Ammonia (NH3)	Ion-selective electrode method
13.	Conductivity	Conductivity meter

3. RESULTS AND DISCUSSION

The maximum pH was observed to be 8.11 in station 1 and a minimum of 7.24 was observed in station 4. This range falls within the permissible limits but suggests potential anthropogenic influences at station 1. Comparatively, Saravanan et al. [13] had reported a wider pH range of 6.70-8.30 in the Thamirabarani River, attributing fluctuations to agricultural runoff and industrial effluents. Variations in both studies likely stem from diverse pollutant sources and seasonal changes (Table 2).

The maximum TDS was found to be 979 mg/L in station 2 and the minimum of 23 mg/L in station 4. This range is highly deviated compared to other Thamiraparani studies, such as 185-384 mg/L reported by [14] and 254-462 mg/L by [15]. The higher maximum in our study suggests increased pollution at certain points, possibly due to intensified agricultural runoff or industrial discharge (Table 2).

The maximum total hardness was found to be 288 mg/L in station 1 and minimum of 13 mg/L observed in station 4, wider than the 98-236 mg/L reported by [16]. The higher maximum suggests increased mineral content, possibly due to geological variations or anthropogenic activities. Fluctuations may result from seasonal changes in water flow and pollutant concentrations (Table 2).

The maximum chloride level was found to be 268 mg/L in station 2 and minimum of 8 mg/L was observed in station 4, exceeding the range of 32-186 mg/L reported by [17]. The higher maximum suggests increased pollution, possibly from urban runoff or industrial discharge. Fluctuations may be due to seasonal variations in water flow and localized anthropogenic activities along the river (Table 2).

The maximum calcium level was to be found to be 52 mg/L in station 1 and minimum of 2 mg/L in station 4. The lower range suggests less geological influence or reduced agricultural runoff. Fluctuations may result from seasonal variations in water flow and localized erosion patterns (Table 2).

The maximum magnesium level was found to be 38 mg/L (Station 1) and a minimum of 2 mg/L was observed in station 4., which differs from the range of 12-29 mg/L reported by [18]. Our wider range suggests greater variability in magnesium concentrations along the river. Fluctuations may be due to differences in sampling locations, seasonal variations in water flow, and localized impacts of agricultural runoff or industrial discharges (Table 2).

The maximum of observed EC level was found in station 1 and minimum EC was observed in station 4., significantly that are wider than the 310-820 µS/cm reported by [19]. Our higher maximum suggests increased ionic concentrations, possibly due to greater pollution loads. Fluctuations may result from variations in discharge points, seasonal changes, and differing land use patterns along the river course (Table 2).

The maximum ammonium level was found to be 27.4 mg/L (station 2) and the minimum of 0.32 was observed in station 3 & 4. This is higher than the 0.028 to 1.96 mg/L found in Thamiraparani River reported by [20]. Changes may be due to farm runoff, sewage, or factory waste (Table 2).

Our study found controlled nitrate levels below 45 mg/L across all stations, meeting the acceptable limit. This range is lower than the 0.9-48.0 mg/L reported by [20]. Fluctuations may be attributed to seasonal changes in agricultural activities, rainfall patterns, and variations in industrial discharges (Table 2).

The maximum turbidity was found to be 9 mg/L in 2 and the minimum of 1 mg/L in station 4. This range differs from the 1.8-4.2 NTU reported by [20]. Fluctuations may result from erosion, runoff, and algal growth (Table 2).

The maximum of Total alkaline level was found to be 332 mg/L in station 2 and the minimum of 4 mg/L was observed in station 4. This range differs from the 92-240 mg/L reported by [20]. Fluctuations may be due to variations in carbonate-rich rock weathering, industrial effluents, and agricultural runoff. Higher alkalinity often correlates with higher pH levels in water bodies (Table 2).

Our study found consistent fluoride levels of 0.2 mg/L across all stations, below the 1 mg/L limit. This contrasts with the 0.2-1.5 mg/L range in [20]. Consistency suggests minimal geological or anthropogenic fluoride sources (Table 2).

The maximum of iron level was found to be 0.35 mg/L (Station 1, 3&4) and the minimum of 0.25 mg/L in station 2. This differs from the 0.01-0.03 studied by [11]. Fluctuations may result from geological sources, industrial effluents, or corrosion of water distribution systems (Table 2).

Table 2. Water quality Parameters and Acceptable limit

S.no	Parameters	Unit	Test Method	Result Station 1	Result Station 2	Result Station 3	Result Station 4	Acceptable limit
1	**pH**	-	IS 3025 Part 11-1983	8.11	7.89	7.69	7.24	6.5-8.5
2	**Total Hardness**	mg/L	IS 3025 Part 21-2009	288	260	35	13	200
3	**Total Alkalinity**	mg/L	IS 3025 Part 23-1986	224	332	39	4	200
4	**Chloride(Cl)**	mg/L	IS 3025 Part 32-1988	178	268	19	8	250
5	**Nitrate(NO3)**	mg/L	APHA 23rd Edition 2017-4500-NO3 B	2	<2	<2	<2	45
6	**Fluoride (F)**	mg/L	APHA 23rd Edition 2017-4500-F-D	<0.2	<0.2	<0.2	<0.2	1.0
7	**Turbidity**	NTU	APHA 23rd Edition 2017-2130 B	4	9	6	1	1
8	**Total Dissolved solid (TDS)**	mg/L	APHA 23rd Edition 2017-2540 B	699	979	94	23	500
9	**Conductivity**	µS/cm	APHA 23rd Edition 2017-2510 B	1029	1440	138	34	-
10	**Calcium (Ca)**	mg/L	APHA 23rd Edition 2017-3500 Ca B	51	48	6	2	75
11	**Magnesium (Mg)**	mg/L	APHA 23rd Editon 2017-3500 Mg B	38	34	5	2	30
12	**Iron (Fe)**	mg/L	APHA 23rd Edition 2017-3500 Fe B	0.35	0.25	0.35	0.35	0.3
13	**Ammonia (NH3)**	mg/L	APHA 23rd Edition 1989-4500 NH3C	4.32	27.4	0.32	0.32	0.5
14	**Nitrate (NO2)**	mg/L	APHA 23rd Edition 2017-4500-NO2 B	0.62	0.08	0.02	0.00	-

Station 1 - Murugankoil Road, CN Village, Tirunelveli
Station 2 - Pulenthoppu Street, Meenakshipuram, Tirunelveli
Station 3 - Tirunelveli town, CN Village, Tirunelveli
Station 4 - Papanasam Dam, Papanasam

Table 3. Correlation coefficient between parameters

S.No	Parameter	pH	Total Hardness	Total Alkalinity	Chloride (Cl)	Nitrate(NO3)	Turbidity	Total Dissolved solid	Conductivity	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Ammonia (NH3)	Nitrate (NO2)
1	**pH**	1												
2	**Total Hardness**	**0.8794**	1											
3	**Total Alkalinity**	**0.7725**	**0.9329**	1										
4	**Chloride(Cl)**	**0.7749**	**0.926**	**0.9996**	1									
5	**Nitrate(NO3)**	0.6794	0.6388	0.319	0.3026	1								
6	**Turbidity**	0.5827	0.5017	0.7191	0.7392	-0.198	1							
7	**Total Dissolved solid (TDS)**	**0.778**	**0.9471**	**0.9987**	**0.9969**	0.3582	0.6843	1						
8	**Conductivity**	**0.7782**	**0.9473**	**0.9987**	**0.9968**	0.3587	0.6838	1	1					
9	**Calcium (Ca)**	**0.8733**	**0.9995**	**0.944**	**0.9376**	0.6136	0.5223	**0.957**	**0.9571**	1				
10	**Magnesium (Mg)**	**0.8821**	**1**	0.9301	**0.9232**	0.6446	0.4984	**0.9455**	**0.9447**	**0.9992**	1			
11	**Iron(Fe)**	-0.2834	-0.5101	-0.783	-0.791	0.3333	-0.7921	-0.7559	-0.7585	-0.5377	-0.5033	1		
12	**Ammonia (NH3)**	0.3994	0.6291	**0.8631**	**0.8697**	-0.1932	**0.7939**	**0.8421**	**0.8445**	0.6539	0.6229	-0.9894	1	
13	**Nitrate (NO2)**	0.749	0.7219	0.4248	0.4095	**0.9934**	-0.09389	0.4643	0.4621	0.6993	0.7272	0.2258	-0.08225	1

The water quality assessment conducted at various stations provides valuable insights into the environmental conditions and potential risks associated with water resources.

The correlation analysis of water quality parameters in the Tamiraparani river basin reveals key insights into its hydrochemistry. Strong correlations between hardness, alkalinity, and ionic components align with established water chemistry principles [21,22] indicating anthropogenic influences [23]. Iron's negative correlations with other parameters, particularly ammonia, point to complex geochemical processes warranting further study [24]. The absence of fluoride correlations highlights a potential data gap [25].

Station 1: (Murugankoil Road, CN Village, Tirunelveli)

It exhibited deviations from permissible limits in several parameters, including total hardness, alkalinity, chloride, total dissolved solids (TDS), conductivity, calcium, and magnesium, indicating potential contamination from anthropogenic sources. Conversely,

Station 2: (Pulenthoppu Street, Meenakshipuram, Tirunelveli)

It demonstrated elevated levels of most parameters, such as total hardness, alkalinity, chloride, turbidity, TDS, conductivity, calcium, magnesium, and ammonia, suggesting significant anthropogenic influence and potential health hazards.

Station 3: (Tirunelveli town, CN Village, Tirunelveli)

It presented a mix of parameters within and exceeding permissible limits, indicating a moderate level of contamination and environmental stressors.

Station 4: (Papanasam Dam, Papanasam)

The results demonstrated a strong compliance with acceptable limits across all parameters, indicating excellent water quality with minimal human impact. Consequently, station four, located at the start of the river's core belt, was designated as the control site. These findings highlight the crucial need for ongoing monitoring and conservation efforts to protect water resources, ensuring the health of both the public and the ecosystem.

4. CONCLUSION

The water quality assessment conducted in this study provides valuable insights into the environmental conditions and potential risks associated with water resources in the Thamirabarani River basin. The results highlight areas of concern where certain water quality parameters exceed permissible limits, as well as locations where the water quality is relatively pristine. Station 1 and Station 2 exhibited deviations from acceptable limits across multiple parameters, indicating potential contamination from anthropogenic sources such as untreated sewage, industrial effluents, and agricultural runoff. These findings underscore the need for better management of waste discharges and implementation of appropriate treatment measures to protect water resources.

5. SUGGESTIONS

In contrast, Station 4 showcased commendable adherence to water quality standards, reflecting a relatively undisturbed environment with minimal anthropogenic impact. This station can serve as a benchmark for assessing the effectiveness of conservation and remediation efforts in the other affected areas. The study highlights the importance of ongoing monitoring, implementation of remedial actions, and enhanced source water protection measures to maintain and improve water quality in the region. A comprehensive, long-term water quality management plan that incorporates continuous monitoring, public education, and sustainable practices is essential for safeguarding aquatic ecosystems, preserving this valuable natural resource, and ensuring the health and well-being of local communities.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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