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Analysis of physico-chemical parameters and bacteriology study of Vaigai river water Madurai district, Tamil Nadu, India-2025

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Abstract
The study aimed to evaluate the physico-chemical parameters of Vaigai River water at five selected stations in Madurai District, Tamil Nadu, during 2025. A total of 18 parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, hardness, calcium, magnesium, iron, chloride, nitrate, nitrite, phosphate, fluoride, sulphate and free ammonia were analysed following APHA (2005) standard methods. The results revealed considerable variations across stations, reflecting the impact of domestic sewage, industrial effluents and agricultural runoff. The pH ranged from 6.0 to 7.75, indicating slightly acidic to alkaline conditions. EC values varied between 474 and 520 µS/cm, while TDS levels ranged from 355 to 677 mg/L. Dissolved oxygen was consistently low (0.93-1.52 mg/L), whereas BOD (23.8-32.5 mg/L) and COD (60.3-81.2 mg/L) exceeded permissible limits, suggesting heavy organic load. Alkalinity (140-172 mg/L) remained below the undesirable limit for drinking water, whereas hardness (140-208 mg/L), calcium (35-52 mg/L) and magnesium (14.6-21.7 mg/L) showed moderate values. Chloride concentration (40-66 mg/L) was within BIS standards, while nitrate (3-8 mg/L), phosphate (0.3-0.8 mg/L) and sulphate (7-20 mg/L) indicated nutrient enrichment. Elevated iron levels (0.6-3 mg/L) at some stations exceeded acceptable limits, posing risks for potability. Overall, the results highlight that the Vaigai River water in 2025 is under considerable pollution stress primarily from anthropogenic activities.

Keywords: Physico-chemical, Vaigai River, anthropogenic activities

1. Introduction

Water is regarded as the elixir of life, playing an indispensable role in sustaining ecosystems and human survival. However, with rapid industrialization, urbanization and population growth, water bodies such as rivers, streams and lakes are increasingly subjected to pollution, threatening environmental balance, human welfare and even the very existence of mankind. In recent years, emerging environmental concerns such as hazardous waste management, groundwater contamination, global climate change, ozone depletion, and disaster mitigation have further highlighted the urgency of protecting freshwater resources. Though multiple components of the environment are affected by pollution, water pollution is of particular concern, as water is not only the most abundant liquid but also one of the most unusual due to its unique physical and chemical properties. In India, the situation is particularly alarming, with approximately 36% of the urban population and 65% of the rural population lacking access to safe drinking water [1]. The majority of water bodies are contaminated due to defective sewerage systems, effluents from septic tanks, untreated municipal sewage and domestic wastewater discharge. Additional sources include storm water runoff, cattle feedlot discharge, and agricultural effluents [2]. These inputs often carry pathogenic microorganisms of human and animal origin, posing severe risks to public health. So, analysis for the presence of water borne pathogens become extremely important to further screen and treat the water to make it fit for human use. The utility of river water for various purposes is governed by physico-chemical parameters.

Rivers are one of the most vital natural resources, sustaining ecosystems and supporting human civilization through irrigation, drinking water, agriculture, industry, and cultural practices. In India, rivers have historically shaped the socio-economic and cultural development of regions, while also serving as the backbone of agriculture and livelihoods. However, in recent decades, rapid urbanization, industrialization, and indiscriminate use of chemical fertilizers and pesticides have led to a decline in river water quality, resulting in ecological imbalance and health hazards. Continuous monitoring of water quality is therefore crucial to assess the extent of pollution and ensure the sustainable use of river systems.

The Vaigai is a river in Madurai, Tamil Nadu state of southern India. It originates in Varusanadu hills, the Periyar Plateau of the Western Ghats range, and flows northeast through the Kambam Valley, which lies between the Palani Hills to the north and the Varushanad Hills to the south. The Vattaparai Falls are located on this river. As it rounds the eastern corner of the Varushanad Hills, the river turns southeast, running through the region of Pandya Nadu. Madurai, the largest city in the Pandya Nadu region and its ancient capital, lies on the Vaigai. The present study titled *"Analysis of Physico-Chemical Parameters of Vaigai River Water, Madurai District, Tamil Nadu, India"* aims to evaluate the water quality of the river by analysing key physico-chemical parameters including turbidity, pH, dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity, total dissolved solids (TDS), alkalinity, hardness and the presence of ions like calcium, magnesium, nitrate, chloride and sulphate and comparing them with standard guidelines.

Study area

Water samples were collected from Sholavandan (S1), Thiruvedagam (S2), Thenur (S3), Thuvariman (S4) and Kochadai (S5). These stations were chosen to assess spatial variations in water quality and to evaluate the impact of urban and agricultural discharges on the river ecosystem.

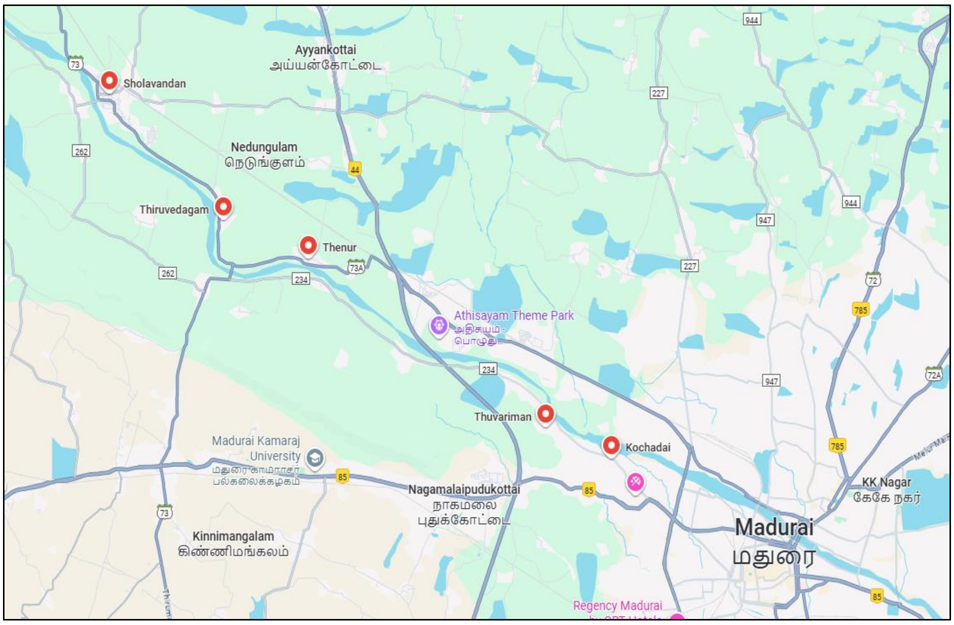

Fig 1: Sampling stations of Vaigai River, Madurai District.

Materials and Methods

Collection of sample

Water samples from the Vaigai River were collected at five stations in Madurai District from July to September 2016 for the analysis of physico-chemical parameters and bacterial populations. Sampling was collected using sterile two-litre polythene bottles. During collection, the bottles were immersed below the water surface and uncapped underwater to minimize contamination. On-site measurements of temperature and pH were taken using a digital thermometer and a digital pH meter, respectively. After collection, the samples were stored in ice boxes and immediately transported to the laboratory for detailed analysis.

Analysis of water

The laboratory analysis of the Vaigai River water samples was carried out following the standard procedures recommended by the American Public Health Association (APHA) [2] and the World Health Organization (WHO) [1]. A total of fifteen physico-chemical parameters were examined, including pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness, calcium hardness, magnesium, nitrate, nitrite, chloride and iron.

Bacteriological methods

The bacterial population in the Vaigai River water samples was assessed using standard microbiological techniques recommended by the World Health Organization (WHO) and the Bureau of Indian Standards (BIS) [12]. These tests were conducted to evaluate the microbial quality of the water. The samples were serially diluted from 10^{-1} to 10^{-6}, and the total heterotrophic bacterial colonies were enumerated using the pour plate method on nutrient agar medium, followed by incubation at 37 °C for 24 hours. After incubation, colonies were counted using a Quebec colony counter and expressed as colony forming units per millilitre (CFU/ml). Total coliforms were determined by the standard plate count (SPC) method, while faecal coliforms were enumerated using the membrane filter technique on m-FC agar plates.

Result

Physico-chemical parameters

The water quality of the Vaigai River was assessed by analysing physico-chemical parameters and bacterial populations at five selected stations from June 2025 to August 2025. The results revealed considerable deviations from the standard values, indicating a continuous pollution load in the river. Both physico-chemical and microbiological parameters were found to exceed the permissible limits prescribed by APHA (2005) [3], WHO (2004) [1], and BIS (2012) [6]. The mean values of the physico-chemical parameters of the Vaigai River water are presented in Table 1. Among these, pH and temperature are critical physical factors influencing chemical reactions and biological activities in aquatic environments. The pH and temperature, measured on-site using a digital pH meter and thermometer, ranged from 6.0 to 7.75 and 24 to 28 °C across the five stations, respectively. The lower water temperature observed during the rainy season may be attributed to reduced sunlight penetration. Electrical conductivity (EC) values varied considerably, with a minimum of 474 µS/cm recorded at Station 5 and a maximum of 520 µS/cm at Station 1.

Dissolved Oxygen (DO) is a key parameter in determining river health, as its deficiency can disrupt aquatic ecosystems through processes such as bioaccumulation and bio magnification. The DO content of river water is influenced by various physical, chemical, biological and microbiological factors. In the present study, DO was estimated using Winkler's method, with values ranging from a maximum of 1.52 mg/L at Station 1 to a minimum of 0.93 mg/L at Station 2. Lower DO levels were recorded at sites receiving higher loads of sewage discharge, indicating increased organic matter concentration. Such conditions favour the growth of pathogenic bacteria, thereby further deteriorating water quality [4].

Biological Oxygen Demand (BOD) represents the amount of dissolved oxygen required by aerobic organisms to decompose organic matter in water. The biodegradation of these organic materials places stress on available oxygen, thereby increasing BOD levels [5]. In general, rivers with low BOD values contain fewer nutrients, allowing higher oxygen availability, whereas unpolluted natural waters typically have a BOD of 5 mg/L or less. Since BOD directly influences dissolved oxygen content, elevated levels can severely impact river and stream ecosystems. Major sources of BOD include plant debris, dead organisms, animal waste, industrial effluents (such as those from pulp and paper mills, food processing industries and wastewater treatment plants), and runoff from feedlots, septic system failures and urban storm water. According to BIS, the permissible limit of BOD in drinking water is 5 mg/L. In the present study, BOD values exceeded this standard at all stations ranging from 23.8 to 32.5 mg/L in the Vaigai River water samples. These elevated values indicate significant organic pollution, particularly at downstream stations, reflecting the impact of domestic and industrial effluent discharge.

Chemical Oxygen Demand (COD) represents the amount of oxygen required to chemically oxidize reduced compounds in water. It is widely used as an indirect measure of the concentration of organic matter present in aquatic systems. Since COD quantifies both biodegradable and non-biodegradable organic substances, it serves as a valuable indicator of organic pollution in surface waters. When assessed alongside Biological Oxygen Demand (BOD), COD provides insight into the presence of toxic conditions and biologically resistant organic pollutants [12]. The permissible limit of COD in water is 50-100 mg/L [6]. In the study, COD values falls within this standard at all stations ranging from 60.3 to 81.2 mg/L in the samples. Elevated COD values, reflect significant levels of organic contamination and reduced water quality, often linked to industrial effluents, sewage discharge and urban runoff. In addition, activities such as bleaching and dyeing of clothes along the riverbanks and within the river further contribute to the elevated COD levels.

Alkalinity in natural waters is primarily derived from the salts of weak acids, though contributions from weak or strong bases may also occur. Among these, bicarbonates represent the major component, followed by carbonates and hydroxides. Total Alkalinity (TA) plays an important role in determining the appropriate dosage of chemicals during water and wastewater treatment processes, particularly in coagulation, softening, and the operational control of anaerobic digestion. For drinking purposes, water with TA values exceeding 200 mg/L is generally considered undesirable [6]. In the present study, TA levels in the Sample ranged between 140 and 172 mg/L during the sampling period. These values fall within the desirable limit, indicating that the water is suitable for drinking with respect to alkalinity.

Hardness is the property of water that inhibits lather formation with soap and increases the boiling point of water. It is mainly caused by the presence of calcium and magnesium salts. According to standards, water containing more than 200 mg/L of Total Hardness (TH) is not desirable for drinking purposes. In the present study, TH values in the Vaigai River ranged from 140 to 208 mg/L, with the highest value recorded at Station 1. This reflecting slight deviation in mineral content.

Calcium contributes directly to hardness and is commonly derived from the leaching of rocks. It is the fifth most abundant element in natural waters and is essential for bone and tooth formation as well as nervous system functions. However, concentrations above 75 mg/L are not considered desirable for drinking water [7]. In the present study, calcium levels ranged from 35 to 52 mg/L, with the lowest concentration at Station 4 and the highest at Station 1. These findings suggest that calcium lies with permissible level allowing the suitability of the water for direct consumption.

Magnesium also contributes to hardness and plays a key role as a co-factor in various enzymatic processes, particularly in algal, fungal, and bacterial cells [1]. For drinking purposes, concentrations above 30 mg/L are not considered desirable. In the Vaigai River, magnesium levels ranged from 14.6 to 21.7 mg/L.

Chlorides are the most common inorganic anions found naturally in all types of water. Elevated chloride concentrations are often indicative of pollution from organic wastes of animal or industrial origin. Excess chloride is also problematic in irrigation water and can be harmful to aquatic life [1, 8]. According to BIS, the permissible limit of chloride in drinking water is 250 mg/L. In the present study, chloride concentrations in the Vaigai River ranged from 54 to 66 mg/L. These values are well within the acceptable limit, indicating that chloride does not pose a major concern for drinking purposes in this stretch of the river.

Table 1: Physico-chemical parameters of Vaigai River water

Parameters	S1	S2	S3	S4	S5
pH	7.01	6.78	7.53	7.75	6
Electrical Conductivity (µS/cm)	520	507	477	497	474
Dissolved Oxygen (mg/L)	1.4	0.93	1.27	1.3	1.52
BOD (mg/L)	25	32.5	28.2	25	23.8
COD (mg/L)	62.5	81.2	70.6	63	60.3
TDS (mg/L)	364	355	477	497	677
Total Alkalinity (mg/L)	160	140	140	148	172
Total Hardness (mg/L)	208	180	200	140	140
Calcium (mg/L)	52	45	50	35	35
Magnesium (mg/L)	21.7	18.8	20.8	14.6	14.6
Iron (mg/L)	2	3	2	1	0.6
Manganese (mg/L)	0	0	0	0	0
Free ammonia (mg/L)	0.9	0.9	0.8	0.7	0.8
Nitrite (mg/L)	0.8	0.5	1	0.7	0.4
Nitrate (mg/L)	5	4	3	4	8
Chloride (mg/L)	64	66	54	40	60
Fluoride (mg/L)	1.02	1.05	1.12	1.32	1.22
Sulphate (mg/L)	7	17	10	12	20
Phosphate (mg/L)	0.6	0.6	0.8	0.7	0.3
Tidy's test (mg/L)	10	13	11.3	10.5	0.6
Residual Chlorine (mg/L)	0	0	0	0	0

(Mean values of physical and chemical parameters of Vaigai River water in Madurai District, (S1-Sholavandan, S2-Thiruvedagam, S3-Thenur, S4-Thuvariman and S5-Kochadai).

Bacteriological parameters

Bacteriological parameters are critical indicators for assessing river water quality. The bacteriological analysis of Vaigai River water revealed heavy contamination with total heterotrophic bacteria, total coliforms, and fecal coliforms. Across the five sampling stations, from Sholavandan to Kochadai higher concentrations of heterotrophic bacterial colonies were consistently recorded. The mean values of total heterotrophic and total coliform bacterial colonies are presented in Table 2. The heterotrophic bacterial counts ranged from a minimum of 1.8×10^4 CFU/ml at Sholavandan to a maximum of 3.6×10^4 CFU/ml at Kochadai. Similarly, total coliform counts ranged between 3.0×10^4 CFU/ml and 14.7×10^4 CFU/ml during the study period (June-August 2025). The high bacterial load is largely attributable to the presence of excess organic matter in polluted water, which serves as a rich nutrient source for microbial growth and multiplication [9].

For bacterial identification, total coliforms were isolated on MacConkey agar, where *Escherichia coli* appeared as small pink colonies and *Klebsiella* spp. as large, mucoid pink colonies. On EMB agar plates, *E. coli* and *Klebsiella* produced characteristic green metallic sheen colonies, while *Enterobacter* spp. formed pink colonies without sheen. Fecal coliforms were enumerated on m-FC agar plates, where they appeared as dark blue colonies, confirming the presence of *E. coli*. The high concentration of *E. coli* strongly indicates contamination from municipal sewage and septic tank discharges, rendering the water unfit for human consumption [10]. Additionally, *Streptococcus* spp. were identified on blood agar plates by the presence of small pinpoint haemolytic colonies.

These findings highlight the severe microbial contamination of the Vaigai River, suggesting constant inflow of untreated domestic sewage and waste effluents. The presence of fecal coliforms and pathogenic bacteria not only degrades water quality but also poses significant public health risks by increasing the likelihood of waterborne diseases such as diarrhoea, typhoid, dysentery and cholera. Regular bacteriological monitoring and effective sewage treatment are therefore essential to safeguard both ecosystem health and community welfare.

Table 2: Mean values of total heterotrophic and total coliform bacterial population colony counting in Vaigai River water from Madurai District.

Sampling sites	Total heterotrophic bacteria (total colony count x 10^4CFU/ml)			Total coliform bacteria (total colony count x 10^4CFU/ml)		
	June 2025	July 2025	August 2025	June 2025	July 2025	August 2025
S1	1.8	1.9	1.6	3.0	3.6	4.3
S2	1.7	2.1	2.3	5.4	5.9	5.5
S3	2.0	2.5	2.6	6.6	8.3	6.9
S4	2.3	3.0	2.8	8.9	11.0	9.9
S5	2.7	3.4	3.6	14.7	14.1	13.9

Conclusion

The assessment of the Vaigai River water in Madurai District during 2025 revealed significant physico-chemical and bacteriological pollution, primarily due to domestic sewage, industrial effluents, and agricultural runoff. Low dissolved oxygen, coupled with elevated BOD and COD levels, highlights a heavy organic load, while microbial analyses confirmed severe fecal contamination, rendering the water unfit for direct consumption. Although some parameters such as alkalinity, chloride, calcium, and magnesium remained within permissible limits, excess iron and bacterial counts pose serious health risks. The findings underscore the urgent need for continuous monitoring, effective sewage treatment, and stricter regulatory measures. Future research should explore advanced treatment technologies and community-based interventions to ensure sustainable river water management.

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