EVALUATING WATER QUALITY BY EXAMINING MACROINVERTEBRATES

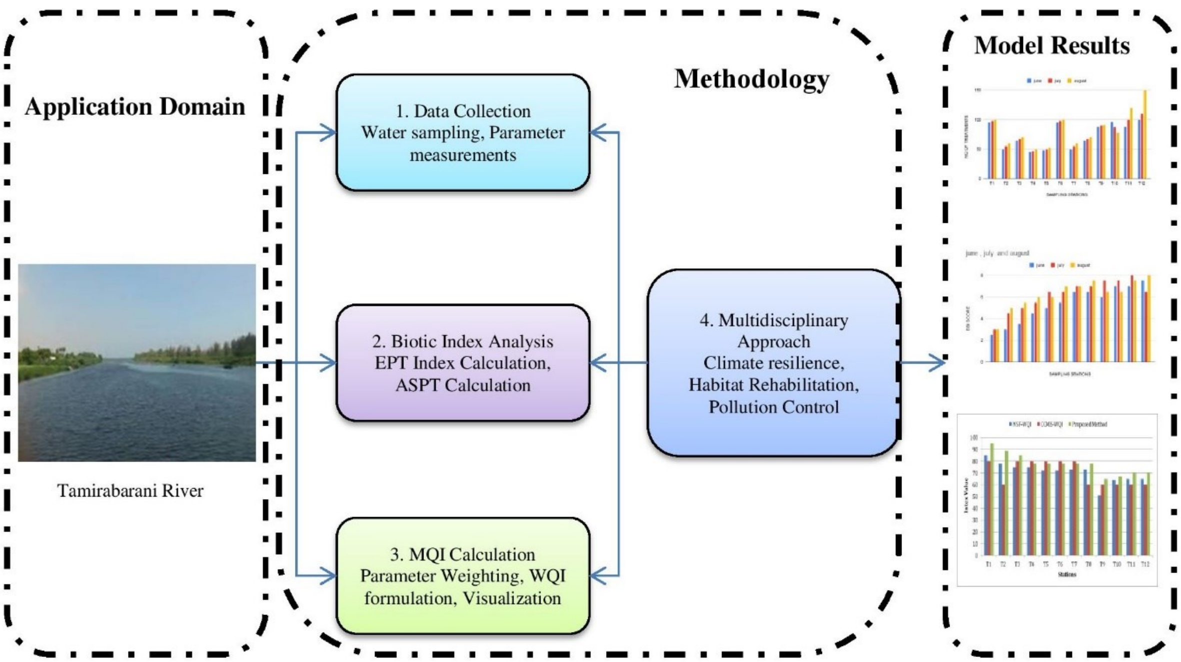
Yuwen Ning [1a], Ziye Liu[2b*]

[1.]School of Military Preventive Medicine, Air Force Medical University, Xi'an, Shaanxi 710032, China.

[2.]School of Mechanical and Materials Engineering, Xi'an University, Xi'an, Shaanxi 710065, China.

sgayathridevi2001@gmail.com

Graphical Abstract



Abstract

The work involves the diversity and number of macro invertebrate animal using these variables as indicators of the water quality of urban streams that negatively impacts ecological health. Conventional methods often overlook these indicators that essential to understand the ecological conditions. The sampling system for urban streams uses a stratified sampling technique not only along stream sections but all-around urban streams to result in a wide range of ecological conditions also captured. Repeated sampling methods of kick net sampling and pick net collection would be used to determine the presence and abundance of macroinvertebrate taxa. The system objective is to offer an improved water resource management and inform sustainable urban development's practices. Simultaneous measurement of water quality indicators like pH, water oxygen content, water temperature, conductivity, and nutrient levels will give a useful

bank of data for future analysis. These species that are particularly discerning in variations of the quality of water will constitute the central part of the research, denominated mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) respectively. The occurrence, number of species, and populations in the water of streams will be recorded to determine the good health of a stream and the overall ecological condition. Conclusions from this research will add to the knowledge of the influence of macro bacterial diversity mixed in the material of urban streams, thus getting valuable input for water resource management, conservation, and sustainable urban development instruments.

Keywords: *Macroinvertebrates, urban streams, water quality, Trichoptera, Plecoptera, monitoring, Ephemeroptera, Urbanization impacts, and Biodiversity assessment*

1. Introduction

Macroinvertebrates are a large group of organisms that are mirrorless and of a size that they can be spotted with the bare eyes. They are an absolute part of freshwater ecology playing unique roles in nutrient cycling, food webs, and ecosystem services. Species diversity within the aquarium is a high level that consists of insects, crustaceans, mollusks, and worms, which play distinct ecological roles in habitats such as streams, rivers, lakes, and wetlands. Macroinvertebrates are one of the main, if not the leading elements of the ecosystem with their bioindicator role of water quality and environment state in freshwater. By their variety, this presence, and abundance can be summarized as aliases of the all-around condition of aquatic ecosystems. Take, e.g. the macroinvertebrates that are intolerable to pollution or habitat destruction, which serve as good indicators providing a simple answer to the question of water quality. The shift of key stages of the macroinvertebrate communities over some time could be an indication of higher pollutant levels or habitat disturbance in the aquatic habitat. Also, it shows why macroinvertebrate populations are a major focus of the ecological assessment which establishes their significance. Water quality factors, including pH, dissolved oxygen, temperature, conductivity, and nutrient concentration, to name a few, have a great influence on the succession of the macroinvertebrate community. For instance, pollution-intolerant species may be common in degraded areas, while oxygenated waters, on the contrary, are favorable for thriving but sensitive ones. Complexity of habitat, including rifles, pools, and plant vegetation ensures an equipped community of different microhabitats for macroinvertebrates within streams, and these microhabitats determine the distribution and abundance of the various organisms.

The motivation behind this study is to improving stem of health threatening and well-being condition in urban streams. Initially, the conventional method omits the bio indicators for assessing water quality instead uses the physiochemical metrics. This system focus on macro invertebrates highly focused on the environmental conditions and this system fills the gap in water quality measurements techniques by showcasing effective environmental management methods. The objective of this study evaluates the quality of water in urban streams by leveraging the bio indicators with the help of stratified sample technique. The main contribution of this study as follows,

This study innovatively introduces a novel approach for assessing the urban stream by using the macro invertebrate bio indicators. The stratified sampling method developments tailored to urban streams allows for more precise ecological data collection. Furthermore, the integration of biological and physicochemical analyses enhances the understanding of urban stream health. The result of this study showcases the improved methodology for water resource management, conservation efforts and sustainable urban development policies with solutions to the urban water quality management tasks.

2. Review of literature

Chang et al. (2023), have designed the WQI is developed that enable us to discover the Potential risks to public health associated with drinking water, as well as the aspects that are important from the regulatory standpoint. Whilst bearing in mind issues like microbial contamination, toxic chemicals and nutrients in the system, the revised WQI delivers an all-encompassing instrument for the urban planners and environment authorities to conduct monitoring and managing of the sources of the people's safe drinking water with focus on health and environmental conservation.

Ghosh & Bandyopadhyay (2022), has conducted the work of WQI application to the tropical river basin reveals such complex links between diverse water quality informers which are, in fact, key to the preservation of the environment and the development of its management strategy. The result of the research provides valuable input into the study of variations of water quality over a certain space and time, which in turn could be used to come up with targeted conservation and pollution control measures aimed at preserving biological diversity and ecological services of freshwater bodies.

Thakur & Kumar (2023), has proposed the study on Semi-arid zones that rely on groundwater as their main source of water are the focus of this study, which uses the WQI to track and identify different quality patterns. The WQI is used to identify the pollution sources that cause degradation and ascertain water suitability for various purposes. Firstly, the research provides notice on such water resources as groundwater in semi-arid areas that are inherently vulnerable to depletion by any natural disaster. Secondly, the paper emphasizes combined water management practices which contribute to provision of water of both high quality and sufficient quantity for the use of agricultural and industrial purposes, as well as household.

Sahoo & Saha (2023), has investigated industrial zone water quality in terms of WQI. Besides that, this research discusses environmental consequences of industrial activities and pollution mitigation. This study can assess water quality parameters such as aquatic life and biological diversity that are impacted by industrial discharges and runoff. This makes it possible for stakeholders to formulate strategies addressing pollution and to minimize the damage to ecology and so to protect water resources in the regions where industry is well developed.

Zhao & Wang (2022), the study uses the WQI here to detect periods and areas of temporal and spatial displacement of water quality conditions at the large lake level that serves very well to comprehend environmental dynamics. Surface water quality assessment is the essential part of the research as it allows for understanding of abiotic factors that influence water quality changes, improves the wheat management strategies, and supports sustainable watershed practices.

Singh (2023), has applied a comparative approach to assessing existing WQI models. Refining our methodologies and improving the ability to detect development pressures is the research's contribution to determining the quality of river water. Employing a comparative approach in the study provides a basis to analyze the advantages and setbacks of different methods for the WQI calculation, which in turn offers an opportunity for water resource managers and researchers to select suitable assessment tools that are adjusted to their specific hydrological and environmental surroundings, securing potential misdiagnosis.

Rahmati & Alibi (2023), has proposed the hybridization of the WQI with the multivariate statistics in the parts dealing with agriculture rules, this study now opens the opportunity to watch for or watch any kinds of associations that exist between the farming practices and water quality that would lead to the sustainable management of the water resources. The research demonstrates the extreme vulnerability of water resources due to widespread agricultural activities and the grim consequences of poor water quality associated with land use patterns. Thus, it highlights the need to adopt ecologically appropriate farming techniques as well as efficient land management strategies to address the problem of water pollution and safeguarding the water resources for future generations.

Sahour, S et al (2023), has proposed a machine learning method for mapping the quality of groundwater in an unconfined aquifer in northern Iran. Based on the various environmental factor and help of machine learning techniques, this study ultimately predicts the groundwater quality with the influences of key factors. The system provides an improved technique with cost effective than the conventional methods.

Zhang, F et al (2021), has utilized the Ebinur Lake basin in Xinjiang, China region to monitor the water quality by using the remote sensing method. The quality of water might affects by the impact of climate change and it deteriorates. This study links the water body reflectivity with the computation of water quality index (WQI) monitoring model response by integrating the water quality estimation over arid regions. By integrating spectral data and remote sensing indices, the study aims to enhance water quality detection and support sustainable water resource management in climate-impacted areas.

Hawari, H. F. B et al (2022), proposes a real-time IoT-based water quality monitoring system using sensors to measure temperature, turbidity, and pH levels. The purpose is to enable continuous monitoring, data collection, and immediate decision-making for water treatment, supported by cloud computing for remote data storage and access. The system includes power management techniques to extend battery life, can be deployed in multiple locations, and is accessible via a mobile application, ensuring reliable and practical water quality monitoring.

Prusty, P et al (2020), proposes an assessment of coastal water suitability for drinking and irrigation by analyzing seawater contamination in the eastern coastal plains of Odisha, India. Using hydrochemical data and mathematical methods, the study identifies the influence of seawater and ion-exchange processes on water quality. The analysis reveals that most water samples have high dissolved salts, making them unsuitable for drinking and irrigation, while a smaller percentage of samples are deemed suitable. The purpose is to identify and map areas with acceptable water quality for potential use in drinking and irrigation, thereby guiding resource management in the region.

Uslu, A et al (2024), proposes a comparative analysis of three water quality indices and a national water quality regulation to evaluate their effectiveness in assessing spatiotemporal variations in surface water quality. The purpose is to identify which indices provide the most accurate assessment of water quality dynamics in a region impacted by agricultural and wastewater pollution, with the goal of recommending improvements to water quality assessment methods using statistical analysis and artificial intelligence for better management strategies.

3. Materials and Methods

3.1. Study area description

Thamirabarani River Basin, a natural abode of southern Tamil Nadu covering a vast area in India, is a fascinating area of research due to the complex interrelation of geographical features, micro invertebrate populations, socio-environmental system. Sharing its boundary with the Districts of Tirunelveli and the locality of Thoothukudi, this basin provides the opportunity to scientists to explore and investigate the plants and animals in an ample space to a focused study. A total of 35 water samples were extracted from the Thamirabarani watershed. Foraging its path from the rich Agasthyamalai Mountains in the Western Ghats, Thamirabarani River seemingly effortlessly casts away toward its eastern course, cutting through a succession of different habitat types, from rough mountains to vast plains [20]. The culmination of its journey comes with the magnificent fusion of the river with the Bay of Bengal, thus adding to the significance of its role in maintaining the regional hydrological system. The basin's appeal for visitors not only lies in the incredible natural beauty but also in the complex weaving of activities by humans that overlap with the environment. The land acts as an anchor for survival spearheading in the provision of a multitude of organ and agricultural activities. Urbanization is a great contributor to urban-rural complexities. It adds an extra element which brings about challenges and opportunities. It is pursued while trying to sustain the water resources which continue to deteriorate with the increase in urbanization.

Forest areas that can be seen everywhere in the landscape are all-important for ecosystem services provision, biodiversity habitats, and manufacturing the region's ecological resilience. Running side by side with the natural constituents of our ecosystems are the water sources which range from serene and mesmerizing streams to the immense Thamirabarani River, a life blood on one side of humans and wildlife. In this organic abundance and people-sustaining setting, industrial areas can also be able to thrive, featuring the region's businesses as well as the linked environmental implications for their functioning. Sustainability and development come side by side in this socio-ecological system which means that the once-separate issues need to be tackled comprehensively and this approach requires integrated approaches to resource management and communication among the stakeholders.

3.2. Data collection

1. Remote Sensing Data: Videos of high spatial resolution satellite imaging and remote sensing data were requested from trustworthy sources ranging from ISRO and other institutions. Specifically, IRS ID LISS-III satellite imagery with a resolution of 23.5 meters was used to capture various aspects of the Thamirabarani Delta's land use and cover patterns. Additionally, two full scenes of IRS-P6 LISS-IV data from January and August 2014 were used to generate a satellite mosaic of the basin. We gathered the data sets of the image seal covering the basin’s land use/cover pattern, spectral data which could be used for the quality of water analysis and other spatial information we deemed necessary.
2. Field Measurements: The main study area was explored using extensive on-site research, and we were able to directly collect the ground truth data. The monitoring process had the measurements on four fundamental water quality indicators such as pH, dissolved oxygen, biochemical oxygen demand, and total suspended solids. Furthermore, measurements – like changes in land use, as well as hydrological signs, for example river flow rates – were registered during field surveys.
3. Historical Data: Tables would be built from extensive historical datasets obtained from governments, research organizations and past studies over a period of several years. Key datasets contained information on rainfall recurrence patterns, rivers discharge rates, land use area changes and social and economic determinants driving the basin system.

3.3. WQI calculation and hybrid modeling

The hybrid computing of the Water Quality Index (WQI) study for the Thamirabarani River Basin study reflects a wise methodology which features the strengths of both remote sensing based data maturity as well as field performance verified data. This approach is the critical component of getting a more precise and comprehensive water quality assessment, which is done jointly by direct, on-the-ground inspections and positional data provided by the remote sensing technologies.

The water quality index (WQI) was established to data these four parameters- pH (Potential of Hydrogen), dissolved oxygen (DO), biochemical oxygen demand (BOD) and total suspended solids (TSS)- that were obtained either through measurements or derivations. From field measurements and remote sensing data analysis, these values were realized. Firstly, laboratory investigations carried out in the Tamirabarani basin began with water sample collection from different portions of the river thereby enabling actual determination of these physical parameters. This highly quantitative method made it possible for us to collect data that was, to a great extent, precise and accurate regarding the study area because it enabled us to determine the degree of reliability of the assessment undertaken.

In addition, remote sensing-based data gave a chance to know about water quality fluctuations across the basin involved in the investigation as a whole. A combination of the satellite images and the spectral analysis techniques was applied to get information such as water clarity, vegetation cover, and so on that was related to water quality. This space data was coupled with the data obtained in the field to give a clear idea of how the whole basin is affected. After the collection of all data points for every parameter, we compared them against professional standards or regulatory agency thresholds for permissible levels of environmental variables. Such a comparison enabled one to detect discrepancies with standard conditions of water and obtain critical points as regards water quality.

Water parameter weightage then represented the score of each parameter depending on its importance to water quality. Stronger parameters that are more important ecologically or greatly affect the health of humans were given larger weighting systems in the computation of WQI.

3.4. Hybrid modeling

The usage of remote sensing data-derived information, along with comprehensive field-based data makes hybrid methodology an important and comprehensive water quality indicator for the WQI study of the Thamirabarani River Basin. Remote sensing-based continuous data supplies with many roles such as obtaining snapshots from across the entire catchment area and identifying the spatial elements of the entire basin. Such data gives very unique insights into the special features like water clarity, vegetation cover, etc., and is very crucial for the study of water quality. Alternatively, data acquired from the field is characterized by improved accuracy and specificity, which in turn renders it more precise in terms of accurately measuring some crucial water quality parameters such as the concentration of nutrients observed and the level of pollutants on various spots of the basin.

The hybrid methodology, as our proposed, integrates both datasets by calculating each hydrologic parameter with fusion of remote sensing and field measurement data. An instance could therefore be obvious, for given cases remote sensing data can help to detect trends of water clarity and spot places with healthy vegetation cover. Concurrently, laboratory experiments confirm findings by directly monitoring nutrient amounts, dissolved oxygen levels, and more critical parameters employed in water quality assessment. The hybrid methodology comprises a method in which the water quality criteria is assigned a different weight that reflects the relative importance in the overall water quality assessment. Such matters as ecological significance, regulatory standards, and human health impacts are taken into consideration before making weighting of specific items. To avert this, a Pahoa's impact on water quality and ecosystem health is measured by the parameters with higher weightage in the WQI calculation, resulting in a more correct and significant analysis.

4. Results and discussion

4.1. Physicochemical properties

In Table 1, physicochemical variables help us to depict the rich and diverse features of humans and other forms of life in this case study of Thamirabarani River Basin. The parameters to be considered are temperature, flow, pH, electrical conductivity (EC), dissolved oxygen (DO), Turbidity (TDY), ammonia nitrogen (NH4N), nitrite-nitrogen (NO2), nitrate-nitrogen (NO3), phosphate (PO4), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total Kjeldahl Water quality and ecological health are critically influenced by how excellently each of these parameters is taken care of. Temperature is the regulating parameter controlling biochemical reactions, nutrient completions and species distribution among aquatic systems. The recorded temperatures range is a product of the seasonal manifestation and overall thermal balance of the river basin. Besides that velocity and discharge show dynamics in the river velocity and influence sediment movement, habitat structure, nutrient transport accordingly. Values of pH and EC indicate water chemistry and reflect the potential hydroxide or hydrogen ions, the fastest ionization constant in any aqueous solution. These values are principal parameters of choosing water for aquatic life, irrigation, and other aims. The wide variety of pH values shows the conditions to be slightly alkaline ones which are mostly friendly to many aquatic organisms instead.

Table 1. Physicochemical properties

Variable	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Temperature	48˚C	8.80˚C	23.20˚C	32˚C	27.796˚C	4.838˚C^2
Velocity	48 m/s	1.38 m/s	0.00 m/s	1.38 m/s	0.373 m/s	0.066 m^2/s^2
Discharge	48 m^3/s	40.77 m^3/s	0.00 m^2/s	40.77 m^3/s	21.112 m^3/s	141.036 m^2/s^2
pH	48	7.10	8.38	7.775	0.34	0.118
EC	48 µS/cm	496.73 µS/cm	38.63 µS/cm	535.36 µS/cm	193.449 µS/cm	16848.235 μS^3/cm^2
DO	48 mg/l	3.30 mg/l	4.80 mg/l	8.10 mg/l	6.357 mg/l	0.705 mg^2/l^2
Turbidity	48 NTU	13.07 NTU	0.30 NTU	13.37 NTU	3.150 NTU	9.550 NTU^2
NH4N	48 mg/l	0.22 mg/l	0.00 mg/l	0.22 mg/l	0.064 mg/l	0.005 mg^2/l^2
NO2	48 mg/l	0.30 mg/l	0.00 mg/l	0.30 mg/l	0.015 mg/l	0.002 mg^2/l^2
NO3	48 mg/l	0.79 mg/l	0.02 mg/l	0.81 mg/l	0.346 mg/l	0.046 mg^2/l^2
PO4	48 mg/l	3.29 mg/l	0.00 mg/l	3.29 mg/l	1.122 mg/l	0.862 mg^2/l^2
COD	48 mg/l	12 mg/l	2 mg/l	14 mg/l	5.854 mg/l	10.766 mg^2/l^2
BOD	48 mg/l	6.70 mg/l	0.20 mg/l	6.90 mg/l	2.166 mg/l	1.641 mg^2/l^2
TKN	48 mg/l	0.78 mg/l	0.06 mg/l	0.84 mg/l	0.443 mg/l	0.046 mg^2/l^2
SO4	48 mg/l	17.59 mg/l	0.99 mg/l	18.58 mg/l	6.104 mg/l	7.573 mg^2/l^2
TC	48 MPN Count/100 ml	896 MPN Count/100 ml	4 MPN Count/100 ml	900 MPN Count/100 ml	80.458 MPN Count/100 ml	18651.445 MPN^2Count^2/100 ml^2
FC	48 MPN Count/100 ml	108 MPN Count/100 ml	2 MPN Count/100 ml	110 MPN Count/100 ml	16 MPN Count/100 ml	0.155 MPN^2 $Count^2/100ml^2$

OD becomes a vital factor for all water life becomes the oxygen for breathing. There are adequate oxygen levels to sustain varied aquatic communities is the conclusion yielded by the measured variation. The term "turbidity" (TDY) is indicative of the degree to which water is in its natural clarity state and is mainly due to sedimentation, organic matters, and manmade activities. High wineries are needed for the passage of light, algae growth and production of the whole ecosystem system.

Nutrients like ammonia nitrogen (NH\u004cN), nitrite (NO2), nitrate (NO3), and phosphate (PO\u004c) are indicators of enrichment which is not good for the ecosystem and they can lead to eutrophication. Rich nutrients can cause algal blooming, which might lead to depletion of oxygen and imbalance of the local ecosystem. Streamlining and tracking the use of nutrients is a fundamental requirement for watershed preservation and sustainable ecosystem. COD and BOD show levels of dissolved organic pollution that set the reference amount of required oxygen for the organic matter decomposition. Readings of high COD, BOD levels denote that waste is organic in nature, compelling remedial measures which are aimed at rectification to prevent impacts on water quality and aquatic fauna. Also, TKN and sulfates reflect on nitrogen and sulfur compound contents, respectively, of which, TKN is vital for nutrient cycling and chemical balancing.

In the end, the total coliform (TC) and fecal coliform (FC) can indicate the microbial contamination as well as the safety of the water which are important parameters in this regard. High fecal coliform levels can be seen as fecal contamination evidence, which states that there are the potential risks for human health brought by the polluted water and requires water treatment and sanitation certain measures.

4.2. Correlation matrix between physicochemical variables

The magnitudes and signs of these correlations help identify causal dynamics within the examined coastal ecosystem between the main biotic components of the system (plankton, zooplankton, and humans). Temperature is showing a slightly positive correlation with the FBI and DO, which indicates that the temperature can be among the factors of the high-quality biotic index parameters and increased amounts of dissolved oxygen in water. This implies a possibility that the deviations are the reason of a system regarding water quality and ecology are deteriorating.

The electrical conductivity shows the strongest positive correlation with Biochemical Oxygen Demand, Organic Material and Nitrate, which means that the levels of EC and water quality indicators are strongly related. However, there are incomplete and weak positive connections with IONC, Chironomides, Ephemeropterraelly, Transfers (EPT), Average Score per Taxon (ASPT), and Danish Biological Index (DBI), meaning that the relationships between EC and biotic indices might be complicated by other variables and factors. Nitrate (NO3) displays a moderately positive linear relationship with FBI and EC that is not high suggesting that NO3 levels can contribute to overall water quality and conductivity. Though NO3 shows a moderate inverse correlation with EPT, ASPT, and BMWP, evidence can be implied that it has the potential to cause ecological damage as a result of its variations with the environmental factors.

In a similar way, there is a very close relationship between TKN readings and FBI index, EC index and Total Coliform (TC) values. This shows that the chances of high TKN levels translating to unhealthy water quality and also a high microbial contamination. Similarly, TKN shares the strongest negative correlations with EPT, ASPT, and BMWP. This highlights, perhaps, ecological problems that have been generated by higher density of TKN. The TC and FC correlations with FBI, EC, and NH4N displays positive values thus suggesting potential correlations between microbial water contamination levels and water quality. Conductivity would also play a significant role in the equation. On the other hand, extremely poor turbidity index, algal poisoning toxicity index, and biotic measures index have been considerably decreased when coliform concentration is higher, which may be observed as ecological impacts of those biotic indices.

Ultimately, the whole correlation matrix reveals the very existence of intricate communications between physicochemical things and the biotic indicators in the water system of Thamirabarani River Basin, shedding the light on the probably ecological sensibility of the river and possible water quality repercussions for the environment and human health.

4.3. Total number of organisms observed during this study

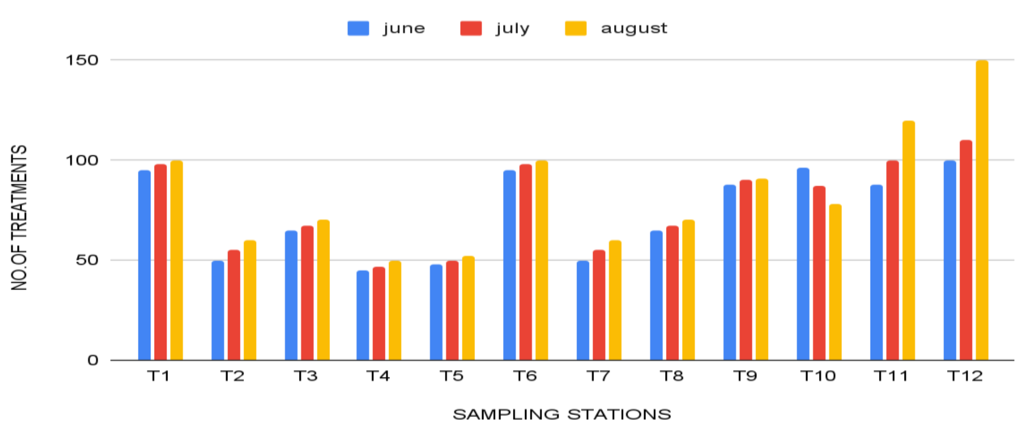


Figure 1: Total number of organisms during this study

The results of diverse treatments are depicted in figure 1 covering the period from June to August, which are presented regularly. The treatments, which are designated from T1 to T12, behave differently within the course of the three months and may suggest possible actions as well as changes connected to instrument application. When data exploratory analysis is made, some trends and phenomena become visible. T1, T6, T7, and T8 treatments often record high values each of the 3 months. This indicates a long-term positive impact or effectiveness, the scalability of the treatments. On the contrary T2, T4, and T5 treatments, the responses are lower than the other ones. This can be explained either by their minimal effectiveness or by their responses to certain conditions in a specific social group. I found an interesting fact which is that these four treatments (T9, T10, T11, and T12) that we assessed had continually varied in value during the rime. Such treatments often present with values ranging from one month to another month, thus, coming with higher and lower interim results. This uncertainty might be caused by several factors such as different environmental conditions, methods of applying the treatment, or the innate variability in the responses to the same treatment which often arises over time.

In every month of comparison, treatment discrepancies are showcasing a bad rate of them both at the previous level and the current one. On the other hand, the treatments of June like T1, T6, and T12 have more advanced values compared with treatments like T2, T4, and T5 that are offered during the month. Yet in August, the picture may vary, but this time that may be a signal of either the presence of some new drugs or a change in patient response to treatment.

For example, using t-tests and ANOVA the data is used to validate these observed differences between different treatments and observed months. These tests enable us to see if the observed differences in treatment response are statistically significant or if the deviations may be attributed to chance rather than to the treatment.

4.4. Variations in the family biotic index level of river Tamirabarani

From the given information figure 2 shows that the treatments with values under 3 can be termed "Excellent," the others with values ranging from 4 to 5 are called "Good," treatments whose values oscillate in the range 5 to 6 can be referred to as "Fair," and the rest with the value more than 7 are considered as “Poor.”

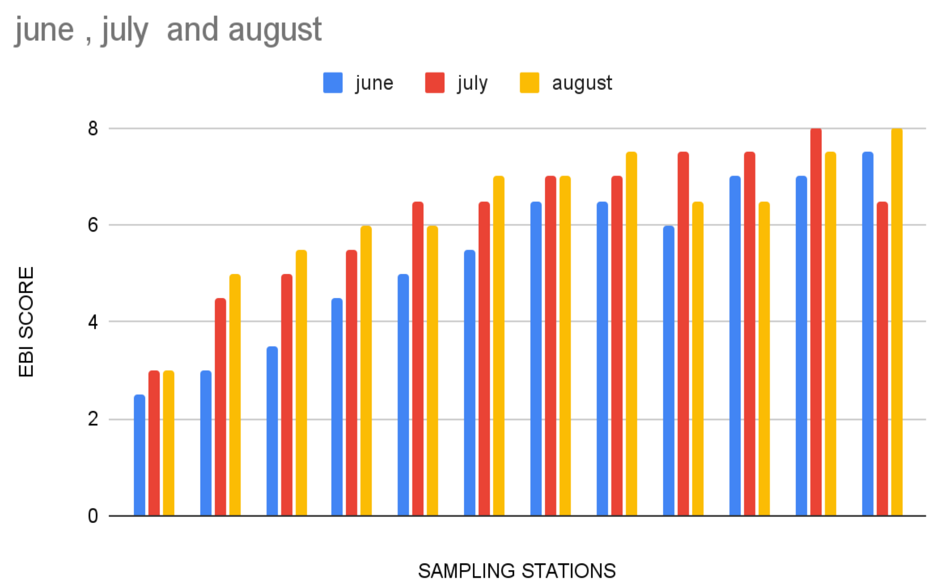


Fig. 2 Variations in the family biotic index level of river Thamirabarani

Illustratively, the treatments T1, T2, and T3 always fall within the “Excellent” square for all months, further demonstrating their consistently high performance. Treatment of regimes type 4, type 5, and type 6 fall generally in the discretionary bucket exclusive of making the grade although nevertheless possessing potential for improvement. Plans, T7, T8, and T9 implement the share category, which signifies quite effective options but needs some improvements. There are still three processes, T10, T11, and T12 whose returned grade is 'poor'. These processes require re-design or intervention since their performance is unsatisfying. The segregation of types of treatment to create clarity permits for a quick interpretation and a comparison between treatments which can further be deepened to assess performance levels. Which nuance as there may be additional studies or her text analysis to be checked to ensure total evaluation and decision-making.

4.5. Temperature and dissolved oxygen

The interaction of water temperature and dissolved oxygen levels constitutes the basis for drawing inferences concerning the water body's health. The research that demonstrates the strength of this relationship will generate a significant negative correlation, emphasizing the central role of temperature as a determining factor for the quantity of oxygenates in water bodies. With more warm water, the lesser oxygen dissolves which means that warmer water cannot contain the more Dissolved Oxygen. This involves the problem of oxygen for aquatic species like fish, invertebrates as well as various other aquatic life forms, which especially depends on oxygen as a crucial component of their respiration. A rise of temperature decreases the amount of oxygen for aquatic organisms and can increase the odds of oxygen-deprived conditions, toxic to some of the aquatic organisms.

The perils of decreased dissolvedness is that they can be very pronounced. Water creatures may feel stressed, were slower in their growth, lower population by breeding or more vulnerability to diseases and pollutants. There are fish kill cases and a fall in the number of different organisms which are commonly faced as a result of hypoxic condition, the ecological balance of aquatic ecosystem gets harmed as a result of this. Worth noticing is the fact that as water gets warmer, it creates temperature gradient causing oxygen deprivation commonly known as thermal stratification in lakes and reservoirs. Cold denser water remains at the bottom of the stratified water bodies and the surface water can be warmer and devoid of oxygen thus water levels gold contain hypomania (zone of depletion of oxygen). Rising global temperatures will heighten the frequency and severity of thermal stratification events and; these challenges will further be intensified due to the prolonged effect of low oxygen levels in aquatic life.

Briefly, this exposure to water temperature and the connected conservative dissolved oxygen situations shows the fragile quality of lakes, ponds, and oceans to climate-related changes. Mitigation measures, directed at alleviating high temperatures, growing riparian plantation, regulating riparian inputs, and enhancing freshwater quality monitoring are the fundamental measures that need to be taken to assure proper functioning and wide biodiversity of freshwater ecosystems under these climate exacerbating

4.6. Habitat fragmentation

Through the thread that connects aquatic biodiversity and the climate stressors, freshwater ecosystems are unable to hold against the climate forces. Biotic indices like EPT (Ephemeroptera, Plecoptera, Trichoptera) or ASPT (Average Score per Taxon) constitute useful indicators that portray the complicated dependence that exists between environmental parameters (they include water quality, pollution levels, and physical conditions) and aquatic life. High temperature is one of the main influencing factors of biological diversity of water organisms. Since water temperature rises due to the supply of heat from climate change, cold-water species like Ephemeroptera, Plecoptera, and Trichoptera face habitat issues with a high degree of chance. In fact, sensitive species such as migratory birds, reptiles, and insect populations may be negatively affected by climate change. These may be reflected in lower scores of ecological species trip (EPT) and aquatic species passage trip (ASPT). These relationships are directly undermined by the warming waters which could favor some taxa over others causing changes in the seasonal composition and diversity of freshwater communities.

Extreme precipitation (tightens up another tori rainfall and drought) resulting from climate change is associated with the disruptions of aquatic ecosystems. Such scenes disturb flow regimes, they could add pollutants to water bodies and make the environment less suitable for water creatures. Consequently, precipitation patterns shifts might direct changes in either species composition or biotic indices toward the disturbed leading ecologic systems under the precipitation change regime stressors. The amounts of nutrients in water bodies (which may be influenced by human activities) also strongly determine aquatic population extinction/ flourishing. Nutrients running into excess, thereby resulting in algal blooms and eutrophication, create competitive advantages of some species than the others. The nature reserves evaluated may be characterized by biotic indices sensitive to anthropogenic nutrients, which will show negative trends with the given nutrient concentrations, thus, highlighting the critical role of nutrient pollution in the degradation of water bodies and biodiversity. In addition, habitat isolation resulting from environmental change due to hydrological regimes shifts, the increase in the level of the sea is some of the challenging factors to aquatic organisms. Fragmented habitats restrict mobility and dispersal to the level insufficient for maintaining the genetic connectivity over a region, where isolation can lead to local extinction. Biotic indices which are dependent on ecosystem diversity and connectivity, may, largely, show a negative response to fragmentation which is a typical climate stressor, indicating the complex penalization of biodiversity of freshwater ecosystems as a result of climate change.

Climate change indeed results in the negative correlation seen by biotic indices with temperature, precipitation extremes, nutrient concentrations and habitat fragmentation among others. Consequently, this highlights the multiple threats our freshwater ecosystems are facing today. Conservation gives rise to adaptive management actions, such as mitigation strategies and interventions that are targeted to minimize the negative influences experienced by aquatic ecosystems. Therefore, biodiversity could be preserved.

4.7. Comparative Analysis

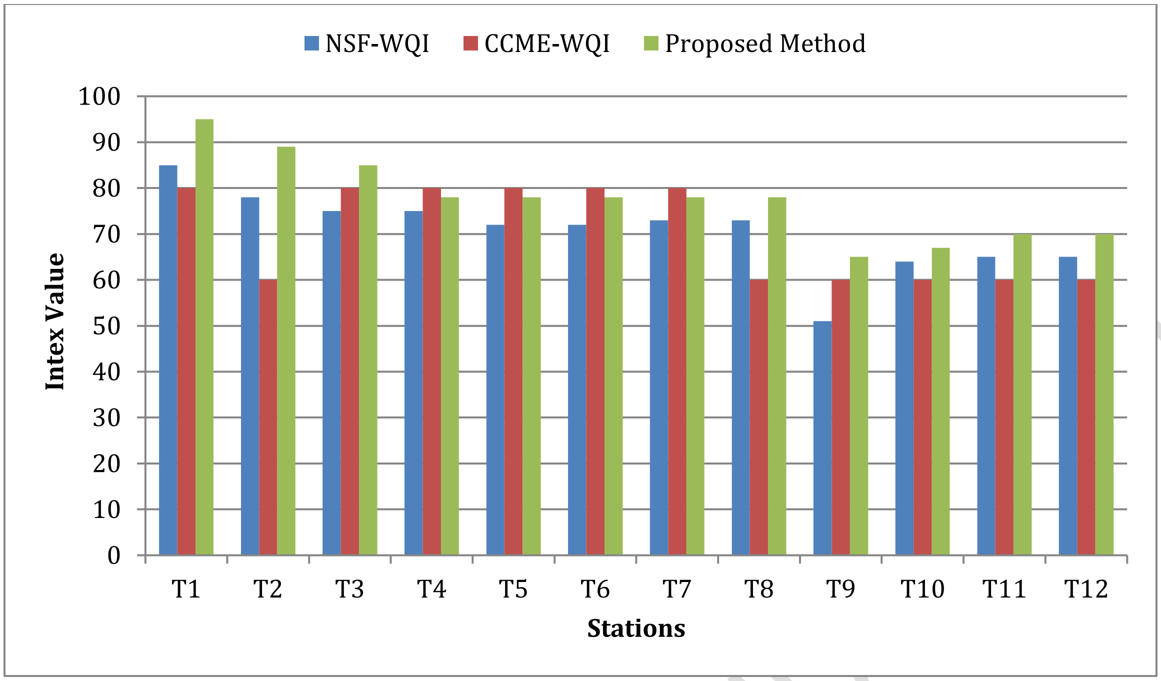


Fig.3 Comparison of WQI results of existing and proposed system

The performance of the proposed system compared with the existing method NSF-WQI and CCME-WQI s shown in figure 3 and the proposed system has improved results over several stations. From the observance of figure 3, the stations are increases with the water quality index of the methods also increased. For instance, at station T1, the existing NSF-WQI and CCME-WQI has a value of 85 and 80, which is comparatively smaller than the proposed method with the 95 of higher index values. This trend is increased to reach station of T6; the proposed method has 78 values with the existing NSF-WQI (78) and CCME-WQI (60). However, the proposed system performance improvements are evident for the T9, T10, T11, and T12 station compared to the existing methods. This remains the proposed system significant and more efficient and comprehensive for water quality evaluations than the existing methods, making the proposed system is a valuable method for water quality monitoring and management.

5. Conclusion

In conclusion, the proposed system assessed the water quality, biodiversity in the Tamirabarani River Basin, and impacts of various factors by employing the advanced methodologies across multiple monitoring stations. The proposed system has significant results of water quality index (WQI) with 95 at station T1 compared to existing methods and indicates effectiveness in identifying and managing water quality issues. To begin with, the relationship between temperature and dissolved oxygen (DO) levels raises concerns about potential thermal stress on aquatic organisms. As water temperature increases, the solubility of oxygen decreases, leading to lower oxygen content in water bodies. This decline can result in hypoxic or anoxic conditions, which can severely impact aquatic ecosystems by reducing populations of fish and macroinvertebrates, ultimately threatening the overall health of the ecosystem. The results of this study indicate that freshwater ecosystems will be negatively affected by climate change in complex ways. Therefore, there is a pressing need to adopt multidisciplinary approaches in water resource management. These approaches should include climate resilience strategies, habitat rehabilitation interventions, pollution control measures, and community engagement to promote sustainable conservation practices for aquatic environments in the face of climate change challenges.

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