National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Pilot for initiating Monitoring and Feedback

PERIYAR

December 2025

cPeriyar

IIT PALAKKAD

Centres for Periyar River Basin Management Studies
IIT Palakkad & NIT Calicut

Centre for Ganga River Basin Management and Studies

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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Periyar River Basin Management Studies (cPeriyar)

The Centres for Periyar River Basin Management Studies (cPeriyar) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Palakkad and NIT Calicut, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cPeriyar is committed to restoring and conserving the Periyar River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

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Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report outlines a plan for implementing a pilot programme for monitoring and feedback in the Periyar Basin, prepared by cPeriyar at the Indian Institute of Technology Palakkad, under the supervision of cGanga at IIT Kanpur. The report was submitted to the National River Conservation Directorate (NRCD) in 2025. We gratefully acknowledge the individuals and stakeholders who provided data, inputs, and support for the preparation of this report. ChatGPT was utilized for language refinement and to enhance textual clarity, the author takes full responsibility for the content.

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PREFACE

The Periyar Basin plays a critical role in sustaining the environmental integrity and socio-economic wellbeing of Kerala. It supports drinking water supply, agriculture, hydropower production, fisheries, industry, biodiversity, and the livelihood of thousands of households across its upstream highland forests and downstream urbanised floodplains. However, the basin is increasingly exposed to complex pressures including unregulated abstraction, changing flow regimes, industrial and domestic pollution, sand mining, habitat degradation, and climate-driven extremes such as the 2018 and 2019 floods. These emerging challenges highlight the urgent need for systematic, science-based river health monitoring and informed management.

The Centre for Periyar River Basin Management and Studies (cPeriyar), established in 2024 by National River Conservation Directorate (NRCD) is aligned with the national mission to apply basin-level approaches in river rejuvenation and natural resource management. The cPeriyar at IIT Palakkad, has prepared this Pilot for initiating Monitoring and Feedback with the broader goal of strengthening basin-scale decision-making.

The framework integrates hydrological, water quality, ecological, and community-based observation systems to complement existing monitoring efforts led by national and state agencies. By combining spatially distributed monitoring with structured feedback loops, the pilot seeks to enhance early-warning capability, track ecological change, and support adaptive and transparent governance. The proposed initiative is envisaged as a first step towards establishing a comprehensive and collaborative basin-wide monitoring network that strengthens resilience, safeguards ecosystem services, and ensures sustainable management of the Periyar River for future generations. This document is intended to serve as a practical and credible resource for Central, State, and local agencies engaged in water resource management, basin planning, and environmental governance in the Periyar Basin. Much of the hydrological, ecological, and monitoring-related information presented here is otherwise fragmented across multiple records, this report consolidates that knowledge to support scientifically informed planning and policy development for basin-wide monitoring.

In developing this framework, the cPeriyar team invested significant effort in compiling, validating, and integrating information from a wide range of primary and secondary sources. We gratefully acknowledge the valuable support of researchers, government agencies, and technical experts whose inputs strengthened this work. We also recognise the commitment of the cPeriyar team in shaping this pilot initiative, which marks an important first step toward a comprehensive, basin-wide monitoring programme for the Periyar.

Centre for Periyar River Basin Management Studies
(cPeriyar) IIT Palakkad & NIT Calicut

ACRONYMS AND ABBREVIATIONS

BIS	:	Bureau of Indian Standards
BMWP	:	Biological Monitoring Working Party
BOD	:	Biological Oxygen Demand
BOD_5	:	Biochemical Oxygen Demand after 5 days
CGWB	:	Central Ground Water Board
CIFRI	:	Central Inland Fisheries Research Institute
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CWC	:	Central Water Commission
DO	:	Dissolved Oxygen
EC	:	Electrical Conductivity
EF, e-flow	:	Environmental Flow
EFA	:	Environmental Flow Assessment
EPT Index	:	Ephemeroptera, Plecoptera, Trichoptera Index
EU	:	European Union
F-IBI	:	Fish Index of Biotic Integrity
IDRB	:	Irrigation Design and Research Board
IHR	:	Integrated Ecological River Health Assessment
IIRS	:	Indian Institute of Remote Sensing
IIT	:	Indian Institutes of Technology
IMD	:	India Meteorological Department
ISC	:	Index of Stream Condition
IWRM	:	Integrated Water Resources Management
Km	:	Kilometer
Km^2	:	Square Kilometer
KSCSTE	:	Kerala State Council for Science, Technology and Environment
KSEB	:	Kerala State Electricity Board Ltd
KSPCB	:	Kerala State Pollution Control Board
KUFOS	:	Kerala University of Fisheries and Ocean Studies
KWA	:	Kerala Water Authority

LULC	:	Land use and land cover
MCM	:	Million Cubic Meter
MoEFCC	:	Ministry of Environment, Forests and Climate Change
MoWR	:	Ministry of Water Resources
NGT	:	National Green Tribunal
NIH	:	National Institute of Hydrology
NIO	:	National Institute of Oceanography
NIT	:	National Institutes of Technology
NMCG	:	National Mission for Clean Ganga
NPCA	:	National Plan for Conservation of Aquatic Ecosystems
NRCD	:	National River Conservation Directorate
NRCP	:	National River Conservation Plan
NTU	:	Nephelometric Turbidity Unit
NWMP	:	National Water Quality Monitoring Programme
PCC	:	Pollution Control Committees
Ph	:	Potential of Hydrogen
PR1	:	Periyar River Stretch 1
PR2	:	Periyar River Stretch 2
PR3	:	Periyar River Stretch 3
PR4	:	Periyar River Stretch 4
PRS	:	Polluted River Stretches
RHA	:	River Health Assessment
RHM	:	River Health Monitoring
RHP	:	River Health Programme
SPCB	:	State Pollution Control Board
SS	:	Suspended Solids
STP	:	Sewage Treatment Plants
TDS	:	Total Dissolved Solids
TSS	:	Total Suspended Solids
UNICEF	:	United Nations International Children's Emergency Fund
WFD	:	Water Framework Directive
WII	:	Wildlife Institute of India
WMO	:	World Meteorological Organization
WWF	:	World Wide Fund for Nature

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1. Introduction

Beyond their geographic presence, rivers represent a state's most strategic natural asset, anchoring its food security, industrial capacity, and energy independence within a single, interconnected ecosystem. In Kerala, the Periyar River serves as this fundamental backbone, driving the state's hydroelectric output and industrial productivity while ensuring a steady water supply for both agriculture and urban centers. However, the basin is under increasing stress from multiple pressures such as regulated flows from multiple dams, water quality degradation from untreated effluents, solid waste and agricultural runoff, habitat loss from encroachments, and heightened flood and drought risks due to climate variability. These challenges underscore the urgent need for a systematic, transparent, and participatory approach to monitor river health and provide timely feedback for sustainable management. Despite the presence of multiple agencies including CWC, CGWB, IMD, KSPCB, and IDRB, monitoring remains fragmented, with limited integration and persistent gaps in ecological health indicators, continuous water quality measurements, and local-scale observations.

A well-defined protocol for river basin management is crucial to set standardized procedures, delineate stakeholder responsibilities, and create an institutional framework for resolving conflicts. When combined with systematic monitoring of hydrology, water quality, biodiversity, and human impacts, it allows for the timely identification of changes, trends and emerging threats. A participatory Feedback mechanism then ensures that monitoring outcomes inform corrective actions, protocol revisions, and stakeholder engagement, making the system adaptive, transparent, and resilient to competing demands and climate-induced stress. A unified, centralized monitoring and feedback system would further integrate fragmented efforts, reduce duplication, and provide a single, reliable knowledge base for timely and coordinated decision-making across sectors. To bridge current gaps and build an integrated framework, this report proposes a pilot Monitoring and Feedback (M&F) program as a practical, scalable blueprint for basin-wide monitoring. The pilot will identify critical parameters, adopt modern tools and participatory methods for data collection and analysis, and establish a training ground for engaging government agencies, panchayats, fisher groups, schools, and civil society ensuring that river basin management in the Periyar is not only technically sound but also socially embedded and sustainable.

1.1. River Conservation and Institutional Governance in India

India's river conservation framework is shaped by centrally sponsored schemes, environmental legislation, and multi-agency governance. The National River Conservation Plan (NRCP) (1995) was the first programmatic attempt to reduce pollution through sewage interception, diversion, and treatment plants, but its outcomes were constrained by delays, poor operation and maintenance, and lack of catchment-level integration. The Namami Gange Programme (2014), implemented by the National Mission for Clean Ganga (NMCG) under the Ministry of Jal Shakti, broadened the scope to biodiversity conservation, sanitation in riverine villages, riverfront development, and public engagement. Complementary initiatives including the Yamuna Action Plan, Jal Shakti Abhiyan, and state-level wetland restoration projects reflect a gradual transition from infrastructure-centric approaches to integrated basin management.

National and State water policies, developed by the Ministry of Water Resources and respective State Water Resource Departments, along with River Action Plans from the Ministry of Environment, Forests and Climate Change (MoEFCC), reflect a commitment to Integrated Water Resources Management (IWRM). The Ministry of Jal Shakti provides overall policy direction and coordination, while the National River Conservation Directorate (NRCD) implements projects such as the National River Conservation Plan (NRCP) and the National Plan for Conservation of Aquatic Ecosystems (NPCA). The Central Water Commission (CWC) supports with technical expertise in hydrology, water allocation, and basin planning. Pollution regulation and water quality monitoring are carried out by the Central and State Pollution Control Boards (CPCB/SPCBs) through the National Water Quality Monitoring Programme (NWMP). Oversight is reinforced by the National Green Tribunal (NGT), which enforces compliance on sewage treatment, illegal sand mining, and ecological flow mandates. Together, these institutions operate under key legislations such as the Water (Prevention and Control of Pollution) Act, 1974, the Environment Protection Act, 1986, and the National Green Tribunal Act, 2010.

Despite this comprehensive framework, overlapping mandates and weak inter-agency coordination continue to constrain effective river rejuvenation. Achieving genuine integrated management requires bridging the gap between policy intent and implementation, strengthening institutional coordination, and fostering multi-stakeholder engagement across social, environmental, and economic dimensions.

1.2. Physical and Environmental Setting of the Periyar

The Periyar basin, with a geographical extent of about 5216 km², is the largest perennial river basin in Kerala. The basin is predominantly situated within Kerala (97.7%), with a minor portion extending into Tamil Nadu (2.3%). It originates from the Chokkampatti Mala, Western Ghats and traverses a wide range of physiographic zones, flowing from high-elevation forested uplands to densely populated midlands and lowlands, and eventually drains into the Arabian Sea. Physiographically, the Periyar river basin can be divided into the highlands (3,908 km²), comprising the rugged mountainous terrain of the Western Ghats, and the lowlands (1,308 km²), consisting of the midland valleys and coastal plains. Elevations range from sea level in the coastal stretches to about 2,681 m at peak of Anamudi hill ranges. The basin experiences a humid tropical climate characterized by heavy monsoonal rainfall, with average annual precipitation ranging from 1,800 mm in the lower reaches to over 4,200 mm in the high rainfall zones of the Ghats. The temperature varies seasonally from 14°C in the high ranges to 32°C in the plains, providing diverse micro-climatic conditions across the basin. Groundwater occurrence is limited in the crystalline hard rock formations of the upper catchments, but higher yields are observed in the alluvial deposits of the plains near Aluva and downstream areas (CGWB, 2021).

The Periyar is the longest river in Kerala, extending over 260 km and forming one of the state’s most significant river systems. Its major tributaries include the Muthirapuzha, Mullayar, Chinnar, Cheruthoni, and Idamalayar. The hydrology of the river is extensively modified by large-scale water infrastructure, notably the Idukki, Mullaperiyar, Idamalayar, and Lower Periyar dams, which collectively support irrigation, hydroelectric power generation, and inter-basin water transfers. Land use and land cover (LULC) within the Periyar basin illustrate a dynamic interface between ecological integrity and anthropogenic pressures. Forest ecosystems occupy approximately 1,799 km², consisting of tropical evergreen, semi-evergreen, and moist deciduous formations in the highland zones of the Western Ghats. In contrast, the mid- and high-altitude regions are characterized by extensive plantation landscapes dominated by tea, rubber, cardamom, and pepper. The lowland plains support intensive agriculture, including paddy, banana, and coconut cultivation, alongside urban settlements (KSCSTE, 2017). The lower reaches of the basin, particularly the Kochi metropolitan region, exhibit pronounced urbanization and industrialization trends, exerting cumulative stress on the riverine environment (KSPCB, 2020). In terms of population, the basin sustains nearly five million people, with dense concentrations in the coastal and midland tracts, while the high ranges and protected forests remain sparsely populated. The key water users of the basin include domestic and municipal water supply, notably for Kochi city and adjoining municipalities, irrigation for agriculture and plantations, large-scale industries such as fertilizers, petrochemicals, seafood processing, shipping, and refineries concentrated in the Cochin industrial belt, as well as hydropower projects (Kerala State Planning Board, 2018). In addition, the basin has an interstate dimension, with the Mullaperiyar dam diverting a significant share of the upper basin flows to Tamil Nadu for irrigation and drinking water (MoWR, 2019).

1.3. Key Challenges in the Basin

1.3.1. Industrial Pollution & Toxic Discharges

The middle stretches of the Periyar River, particularly Edayar, Pathalam, and downstream areas toward Aluva and Kochi, face significant industrial pollution. The river has been subject to repeated toxic effluent releases from nearby industrial clusters, including chemical and rubber processing units. A notable incident occurred in May 2024, when the sudden opening of the Pathalam bund released accumulated low-dissolved oxygen (DO) water, causing a mass fish kill that impacted local fisheries and livelihoods. Real-time water quality monitoring by the Kerala State Pollution Control Board (KSPCB) at Edayar shows elevated levels of chemical oxygen demand (COD) and biological oxygen demand

(BOD), alongside occasional spikes in heavy metals, indicating persistent pollution risk (KUFOS, 2024).

Figure 1: Dead fish were found floating in the Periyar river near Eloor-Edayar industrial area in Ernakulam. (*Source: Press Trust of India; ABP News (2024))*

1.3.2. Microplastics & Persistent Contamination

Significant microplastic contamination has been documented in the Periyar River, with the highest concentrations localized within the soil near the M/s Sree Sakthi Paper Mill industrial site at Edayar, which was closed down in 2016. Pursuant to the investigations directed in O.A. No. 262 of 2017 (SZ) before the Hon'ble NGT, Chennai, it has been observed that these contaminants originating from historical industrial discharge and untreated residues pose a continuous risk to the river's ecological health. Studies have detected significant concentrations of microplastic particles, particularly in depositional zones and riverbanks where flow velocity is reduced. The current lack of standardized remediation protocols for microplastics in riverine environments has left this contamination largely unmitigated, presenting a critical, unaddressed challenge to the state's long-term water security and the health of downstream aquatic ecosystems.

1.3.3. Sedimentation & Flood Risk

Sedimentation along the Periyar River is substantial, with approximately 12.18 MCM of sediment deposited along the river course. Flood-prone zones, particularly in downstream stretches such as Piravom and Aluva, experience altered river morphology due to sediment accumulation, which reduces channel capacity and increases flood risk. Geospatial flood susceptibility mapping indicates that sediment pulses from upstream landslides and deforestation further exacerbate these risks. Regular monitoring and riverbank stabilization are critical to mitigating flood impacts and preserving channel function. (Kerala State Irrigation Department, 2022; Nair et al., 2023)

1.3.4. Urban Runoff & Sewage Pollution

Urban and peri-urban stretches of the Periyar River, particularly Aluva to the Kochi estuary, are heavily affected by untreated or partially treated sewage and surface runoff.

Figure 2: Discolored river water at KWA intake disrupting water supply at Aluva and Chembaracky (*Source: Times of India*)

According to media reports, severe pollution in the Periyar river led to repeated shutdowns of Kerala Water Authority treatment plants at Aluva and Chembaracky due to discoloured and contaminated raw water (Sunil Kumar, 2020).The Aluva Municipality relies on the river as its primary water source, yet inefficiencies in sewage treatment plants (STPs) allow high BOD, suspended solids (SS), and nutrient loads to enter the river. The National Mission for Clean Ganga (NMCG) has directed the installation of online monitoring for pH, BOD, and SS in STPs, but non-point pollution from urban stormwater and solid waste dumping continues to degrade water quality.

1.3.5. Illegal and Excessive Sand Mining & Bed Degradation

The middle to lower stretches of the Periyar river particularly Aluva, Chengamanad, and Mambrakkadavu experience extensive sand mining, much of it illegal. Excessive extraction has resulted in riverbed incision, bank collapse, and reduced groundwater levels.

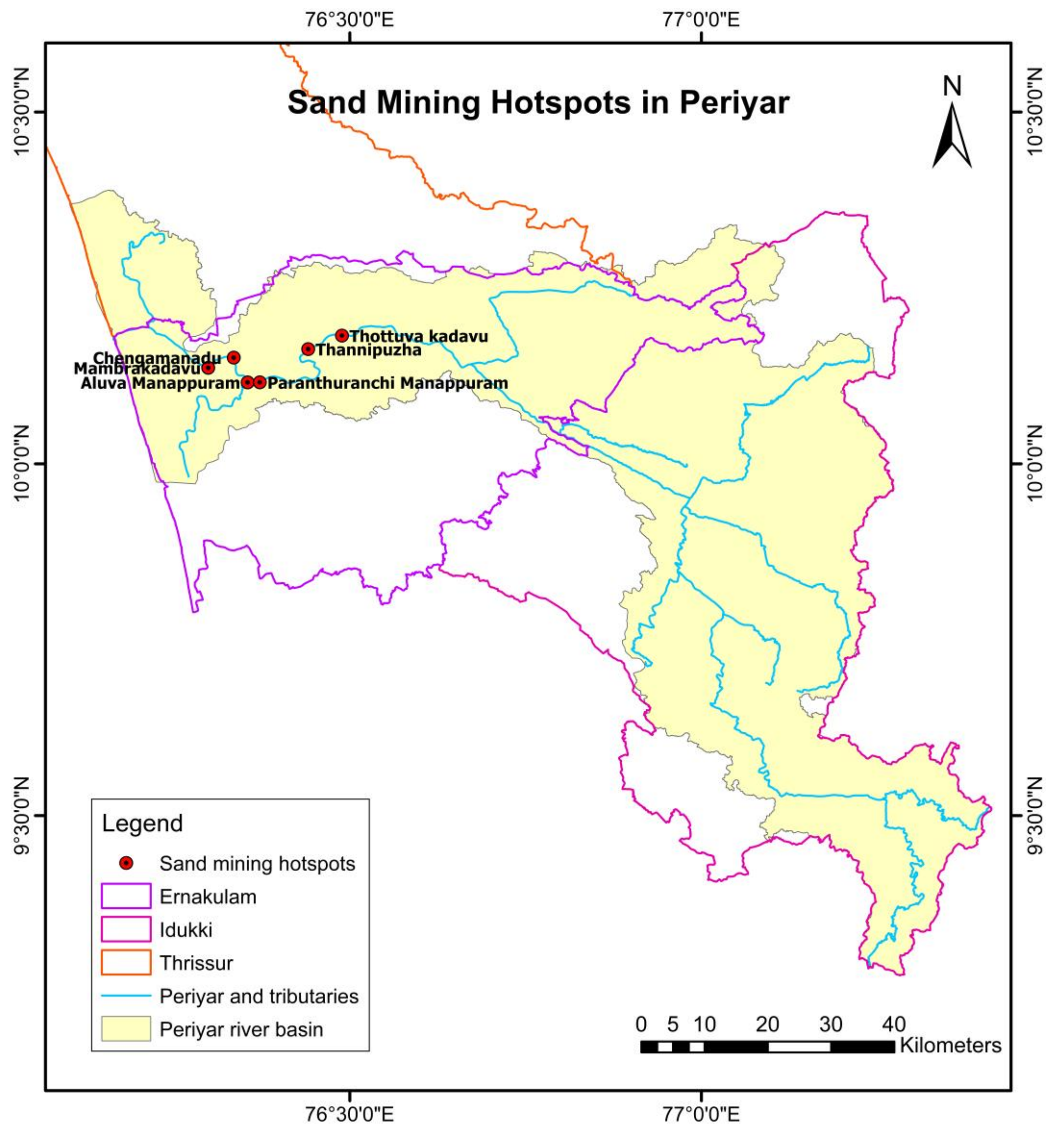


Figure 3: Illegal Sand Mining Hotspots in Periyar

Unauthorized extraction from riverbeds contributes to riverbank erosion, loss of riparian habitat, and lowering of river beds, which alters river morphology and degrades aquatic ecosystems (Shaji, 2021).

1.3.6. Flow Regulation & Altered Hydrology

Upstream dams and local bunds, notably the Idukki Reservoir and Pathalam bund, significantly alter the natural flow regime of the river. The controlled storage and sudden release of water can mobilize accumulated sediments and pollutants, leading to DO depletion and fish mortality downstream. Hydrological studies highlight that regulated flows disrupt sediment transport and aquatic habitat connectivity, which, combined with altered seasonal discharge patterns, compromise the river's ecological integrity. Jain & Kumar explicitly review environmental flow assessment (EFA) in India, highlighting the need for minimum ecological flows to maintain river ecosystem health and sustainable water management under regulated flow conditions.

1.3.7. Impact on Biodiversity

The Periyar river supports a rich assemblage of freshwater fish, including 36 identified species, 22 of which are endemic to the Western Ghats. However, surveys show that 46 species are now present in less than four sampling sites, indicating a decline in biodiversity (Radhakrishnan & Kurup, 2010). The May 2024 mass fish kill, triggered by the sudden release of low-DO water from the Pathalam bund, further underscores the vulnerability of aquatic life. Habitat degradation, pollution, and altered flow regimes collectively threaten fisheries and reduce the ecological resilience of the river basin.

2. River Health Assessment (RHA)

River health is one of the most comprehensive approaches to studying the river. Early-stage studies primarily focused on water quality analysis and later the same was named river health. Since 1995, scientists have updated their methodology by including biological parameters and heavy metals to evaluate river health. At present, these are found to be inadequate in fully addressing contemporary river management challenges. This gives rise to the notion of identifying those elements that have not yet received credit and are missing from the creation of an adequate RHA inventory. Hydrology and geomorphology are fundamental factors in regulating the structure, functions, services, and health of a riverine ecosystem (Tiwari et al., 2024).

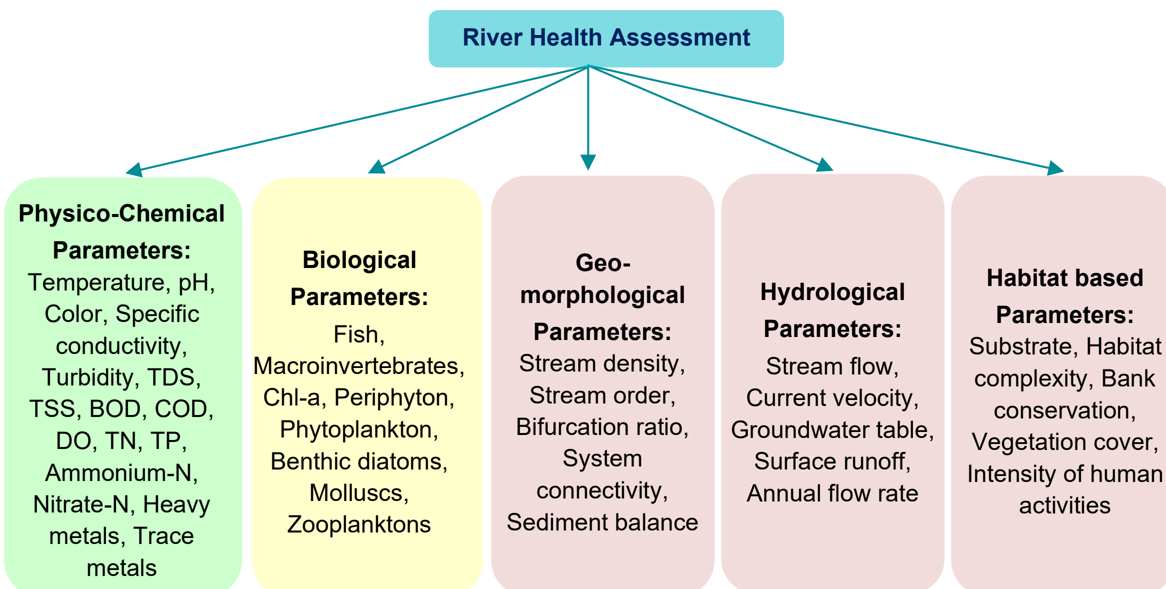


Figure 4: Illustration of Key Parameters for River Health Assessment

2.1. Global Models and Monitoring Parameters

Globally, River Health Assessment (RHA) has evolved as a multidisciplinary framework integrating hydrology, ecology, geomorphology, and water chemistry to evaluate the ecological condition of rivers. Notable examples include the European Union (EU) Water Framework Directive, South Africa’s River Health Programme, Australia’s Index of Stream Condition, and New Zealand’s River Health Index, all of which embed biological, physico-chemical, and hydro morphological indicators within basin-scale assessment and management frameworks. These systems emphasize the use of biological indicators (f*ish, macroinvertebrates, periphyton, macrophytes*), physico-chemical variables (*nutrients, dissolved oxygen, conductivity, temperature*), and hydromorphological features (*flow regime, sediment transport, channel form, riparian structure*) as key monitoring parameters. Dallas (2007) observed that South Africa's River Health Programme and Australian river assessment frameworks provide practical examples of integrated, management-oriented ecological assessment, where biological indicators are systematically combined with habitat and water quality information to support decision-making, in contrast to purely descriptive monitoring approaches.

2.1.1. European Union: Water Framework Directive (WFD)

The EU Water Framework Directive (WFD) introduced a legally binding, ecosystem-based approach to river basin management by shifting assessment from individual water quality parameters to an integrated evaluation of ecological status, combining biological, physico-chemical, and hydromorphological elements at the basin scale, and institutionalizing River Basin Management Plans with mandatory monitoring and reporting across member states (European Commission, 2000).

2.1.2. South Africa: River Health Programme (RHP)

The River Health Programme (RHP) is a national monitoring and reporting framework established by the Government of South Africa to assess river condition using an integrated set of biological, physico-chemical, and habitat indicators. It combines fish and macroinvertebrate indices with riparian vegetation condition, geomorphology, and water quality to evaluate ecological integrity and inform water resource management, restoration priorities, and policy decisions at basin and national scales (Department of Water Affairs and Forestry, 2008).

2.1.3. Australia: Index of Stream Condition (ISC)

The Index of Stream Condition (ISC) is a state-level river assessment framework applied in Victoria, Australia, that derives a composite measure of river condition by integrating hydrology, water quality, physical form, riparian vegetation, and aquatic biota, and is used for statutory reporting, condition benchmarking, and guiding river management and investment decisions (Department of Environment, Land, Water and Planning, 2015; White & Ladson, 1997).

2.1.4. South Korea: Integrated Ecological River Health (IHR) Framework

Kim and An (2015) developed and applied an Integrated Ecological River Health Assessment (IHR) framework combining water chemistry, physical habitat quality, and biological integrity to river systems in South Korea, demonstrating its usefulness for diagnosing cumulative ecological degradation in regulated and impacted rivers.

Collectively, these approaches underscore that river health is not merely about water quality but about maintaining the ecological integrity the capacity of rivers to support self-sustaining biotic communities, natural flow variability, and ecosystem services. The application of global RHA frameworks in developing regions like India requires careful contextualization, including the redefinition of reference conditions, consideration of monsoonal flow dynamics, and incorporating community-based ecological insights to achieve reliable and scalable assessments.

2.2. State-of-the-Art in India

In India, efforts toward River Health Assessment (RHA) remain fragmented across multiple agencies and research initiatives. The Pollution Control Boards (CPCB and SPCBs) operate an extensive network of water quality monitoring stations (> 2500), primarily focusing on physicochemical parameters such as pH, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and Total/Faecal Coliform counts. The Central Water Commission (CWC) manages hydrological and sediment monitoring stations across major river basins, generating valuable long-term data on flow and sediment transport but with limited ecological integration.

Several research and academic institutions including IITs, the Wildlife Institute of India (WII), the World Wide Fund for Nature (WWF-India), and the Indian Institute of Remote Sensing (IIRS) are conducting pilot studies on riverine ecology, habitat mapping, and biomonitoring using macroinvertebrates and fish-based indices. Recently, cGanga's River

Health Monitoring (RHM) Pilot under the Namami Gange programme has pioneered an integrated approach that combines real-time sensor networks, river rangers or "river scouts," and multi-parameter health indices across select stretches of the Ganga River. This initiative represents one of the first large-scale attempts in India to operationalize a holistic, data-driven RHA framework that blends traditional field-based assessments with advanced digital monitoring systems. Building on this model, a similar integrated monitoring and assessment framework is proposed for the Periyar river basin to strengthen comprehensive river health monitoring.

2.3. Salient Features of Monitoring and Feedback Plan for Periyar

The Periyar Pilot Monitoring and Feedback is designed to complement and strengthen the existing monitoring framework implemented by the Central Pollution Control Board (CPCB) and the Kerala State Pollution Control Board. While the national network provides valuable long-term baseline data, its spatial density and sampling frequency are limited particularly in complex, ecologically sensitive, and highly impacted basins like the Periyar. The proposed pilot addresses this gap by establishing a more detailed network of monitoring locations, spanning headwaters, midstream regulated reaches, major tributaries, and densely populated downstream stretches. This denser spatial coverage and higher sampling frequency will enable more granular, near-real-time insights into water quality patterns and pollution dynamics.

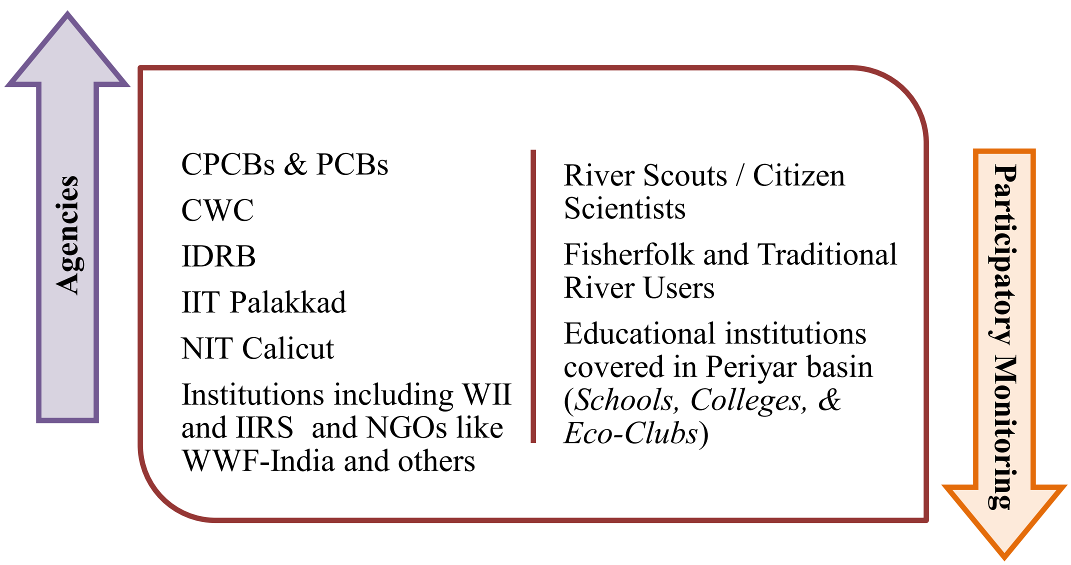


Figure 5: Proposed agency and participatory monitoring framework for the Periyar basin

A key innovation of the pilot is its integration of local stakeholders and communities into the monitoring cycle. The plan strengthens the institutional framework by combining CPCB/KSPCB protocols with basin-level observations from communities that are closest to the river. This approach enhances the contextual accuracy of the data collected, ensures regular reporting even in remote stretches, and builds a collective sense of responsibility towards river protection. By linking field observations with digital platforms and feedback mechanisms, the programme supports timely decision-making, scenario analysis, and rapid response to emerging pollution events.

2.4. Inclusion of Citizen Science and Participatory Monitoring

Citizen science plays a pivotal role in the Periyar pilot because expanding the formal institutional monitoring network alone is financially and logistically impractical. Establishing large numbers of agency-managed stations across the entire basin would require significant infrastructure, staffing, and recurring operational costs. Participatory monitoring offers a practical and scalable alternative by mobilising local knowledge, improving spatial coverage, and generating high-frequency observations at minimal cost.

The deployment of trained River Scouts selected from local communities and educational institutions in Periyar basin forms the backbone of this approach. Through structured training, these scouts learn to measure key water quality parameters, observe changes in river conditions, identify pollution events, and report data through mobile applications. Their participation brings several advantages:

- Greater temporal coverage with daily or twice-daily measurements
- Increased accountability and transparency
- Improved reliability of on-ground observations
- Deepened community ownership of river health

By embedding citizen science within the monitoring framework, the Periyar pilot creates a resilient, inclusive, and cost-effective system that complements institutional efforts and supports long-term river conservation.

3. Rain Gauge Network in Periyar

Rain gauges are instruments used by meteorologists and hydrologists to measure the amount of liquid precipitation over a specific area and time period. Recording rainfall at multiple key points within a basin is crucial due to its high spatial variability. In the Periyar basin, capturing rainfall at several strategically important locations is essential because rainfall varies significantly across the region. The accuracy of rainfall estimation in such a spatially diverse basin depends greatly on how well rain gauges are distributed. Therefore, rain-gauge density becomes a key factor in determining the reliability of rainfall measurements in the Periyar Basin.

3.1. Existing Observational Network

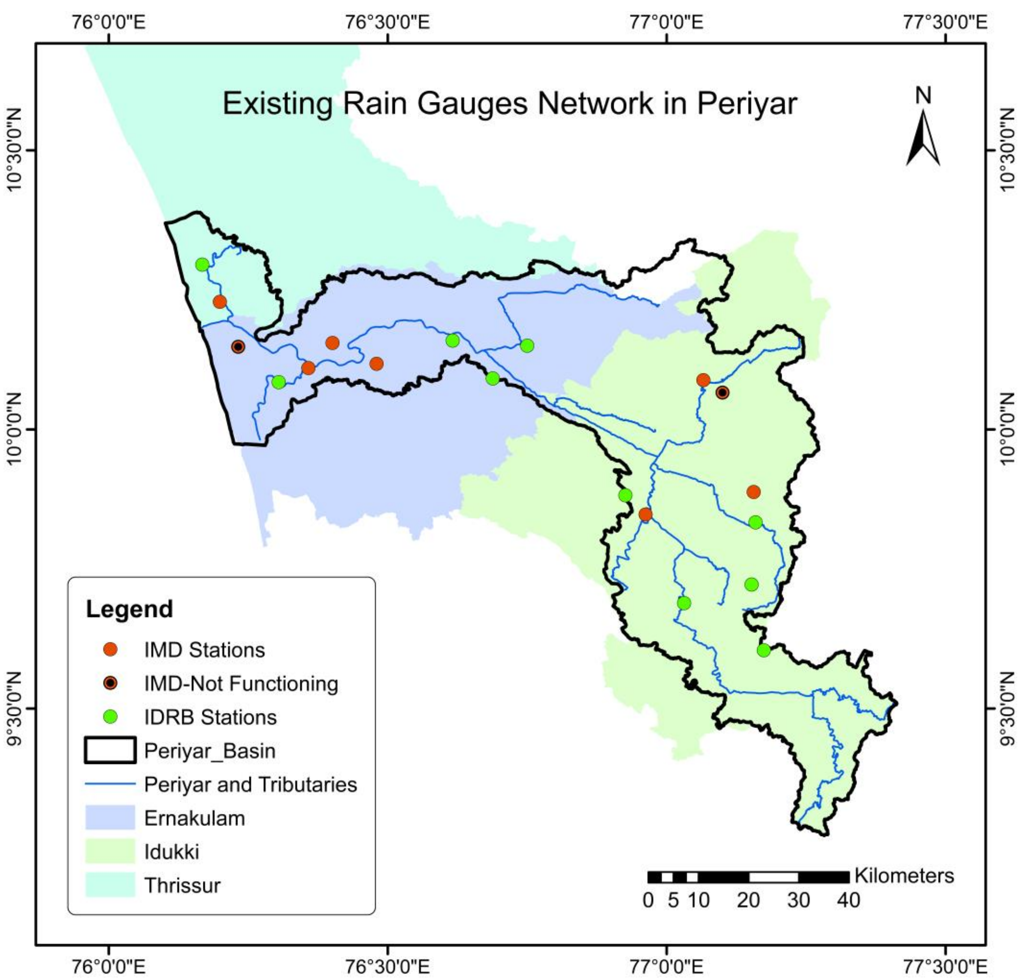


Figure 6: Existing rainfall monitoring network in the Periyar Basin

The existing rainfall monitoring network in the Periyar Basin consists of a total of 19 rain gauges, 10 rain gauges operated by IDRB and 9 stations under IMD. However, 2 of the IMD stations are currently non-functional.

Table 1: Required rain gauge density in Periyar basin

Zone / Region	Approx. Area (km²)	Recommended Density (km^2/ gauge)	Estimated No. of Gauges Required	Existing IMD Gauges
Upper Basin (Idukki high ranges)	2,000	150	14	3
Mid Basin	1,816	150	12	0
Lower Basin (Aluva–Kochi / deltaic zone)	1400	500	3	4
Total Periyar River Basin	5,216	Composite density	29	9

3.2. Coverage Gaps and Implications

Periyar basin is characterized largely as a hilly terrain up to Neeleswaram and receives heavy rainfall. Therefore, according to the IS 4987:1994 one rain gauge per 150 km^2 is required in the basin, up to Neeleswaram (Region type III), whereas, the area downstream of Neeleswaram lies in the Region type I (plains) and therefore requires one rain gauge per 500 sq. km. The existing monitoring network falls far short of the norms prescribed by the Bureau of Indian Standards (BIS), India Meteorological Department (IMD), and the World Meteorological Organization (WMO). Against an estimated requirement of 29 gauges, Periyar basin only has 7 operational IMD stations, this highlights substantial coverage gaps.

This has several implications:

- Flood forecasting is weakened by lack of dense hill-top rain data
- Dam inflow estimates (Idukki, Idamalayar) are less reliable

- Climate monitoring is not adequate due to lack of long-term stations
- Early warning systems fails in providing timely alerts and location-specific detail required under WMO standards.

3.3. Recent Initiatives

IMD has proposed to install 39 manual rain gauges and 100 automatic weather stations across Kerala after 2018 floods. *Equinoct*, a Kochi-based tech startup, has partnered with UNICEF on a project centered around the Periyar and Chalakudy river basins in Kerala. This collaboration aims to develop a, impact-based flood forecasting and early warning system involving community to enhance climate resilience. These initiatives will help to fill spatial gaps in rainfall monitoring, especially in flood-prone zones.

3.4. Recommendations

- Accelerate IMD's planned installations, prioritizing upper catchments
- Expand community-based monitoring to sustain 80–100 additional local stations
- Ensure inter-agency coordination (IMD, CWC, IDRB, KSEB) and data sharing through a common portal
- Integrate gauge data with radar and satellite rainfall products for validation and improved forecasts
- Public outreach to strengthen citizen science and local resilience

4. Stream Gauging Requirements in the Periyar River Basin

Stream gauging is the foundation of hydrological monitoring, providing long-term data on river stage and discharge. These measurements are vital for flood forecasting and early warning, dam safety and reservoir operation, irrigation and drinking water supply planning, pollution control and sediment studies, and environmental flow (EF) assessments. The World Meteorological Organization (WMO, 2008) and the Central Water Commission (CWC) stress that reliable gauging networks are indispensable for water resources planning and disaster risk reduction.

As per the CWC Handbook for Hydrometeorological Observations, stream-gauge sites should be located on straight and stable reaches, with uniform bed and banks free from progressive aggradation or degradation, pools, rapids, or other local disturbances. Water should flow in a single channel throughout the year, and the site must be easily accessible year-round, free from bushes, trees, aquatic growth, or other obstructions, ensuring safe and practical conditions for installation, maintenance, and monitoring equipment. These criteria ensure that the gauge accurately represents the river's hydrological behavior and provides reliable stage–discharge data. Additional gauges are recommended in upper catchments, regulated reaches, and tidal/urban zones due to higher hydrological variability and operational importance.

4.1. Existing River gauge stations in Periyar basin

The existing network in the Periyar basin consists of five operational stream gauging stations managed by two agencies.

- The Central Water Commission (CWC) operates the Vandiperiyar and Neeleswaram stations
- The Irrigation Department of Kerala (IDRB) manages the gauge stations at Kalady, Aluva, and Mangalapuzha.

The CWC station at Vandiperiyar monitors regulated releases from the Mullaperiyar reservoir and the behaviour of the upper Periyar after dam discharge, while Neeleswaram (CWC) tracks flow conditions in the mid–lower basin for flood monitoring. The IDRB stations at Kalady, Aluva, and Mangalapuzha are positioned in densely populated and sensitive downstream stretches to observe floodplain response, urban inundation patterns, drinking-water abstraction conditions, pollution levels, and tidal or estuarine influences.

4.2. Recommendations

According to World Meteorological Organization (2008) norms, recommends one flow gauge per 1,875 km² in hilly terrain, the existing number of flow gauges in the Periyar Basin is generally adequate. However, there is a shortfall in the free Periyar catchment, which covers 2,367.22 km² of hilly terrain. Therefore, in addition to the Neeleswaram gauge, it is recommended to install an additional flow gauge upstream of the Bhoothathankettu barrage, a major control point in the basin, to ensure comprehensive monitoring and effective flood management (Comptroller and Auditor General of India, 2021).

To strengthen monitoring across the basin and address current gaps in spatial coverage, the installation of three additional stream-gauge stations is recommended at key hydrological locations within the Periyar Basin.

- A gauge station on the Muthirapuzha tributary, located just upstream of its confluence with the Periyar river, is required to directly measure runoff contributions from the Muthirapuzha sub-basin. This gauge is essential for accurately quantifying inflows to the Idukki reservoir system
- In addition, a second gauge station between the Idukki Dam and the Chinnar confluence is recommended to capture regulated releases from the Idukki–Cheruthoni dam system. This will support better dam-operation planning, enable improved reconstruction of natural flows, and strengthen flood forecasting.
- It is recommended to install a gauge station upstream of the Bhoothathankettu barrage on the Periyar mainstem to better understand how flood waves from the steep upper catchments weaken and change as the river enters the alluvial plains. Improving flood early-warning lead times and clearly separate flood contributions from the upper basin and within the floodplain. Overall, this addition will greatly strengthen hydrological monitoring and enhance the basin's preparedness for flood events.

5. Environmental flow Monitoring in Periyar

The Periyar basin currently experiences severe alteration of its natural flow regime, with no structured environmental flow (e-flow) monitoring or water-allocation system. As per the National Green Tribunal (NGT**)** directives on environmental flows (2017–2021), all river basins with major dams must maintain minimum ecological releases to ensure longitudinal connectivity, sustain aquatic life, and prevent downstream ecological degradation. The NGT has repeatedly emphasized that zero-flow stretches downstream of reservoirs violate environmental compliance, requiring dam operators to maintain scientifically determined monthly e-flows, typically ranging from 10–30% of average lean-season flow depending on basin characteristics. In line with this, the Government of India issued the *Ganga River e-flow notification* (2018), which specifies minimum flow releases across seasons for all existing, under-construction, and future projects in the basin, with compliance monitored by the Central Water Commission. While the National River Conservation Plan (NRCP), implemented by the National River Conservation Directorate (NRCD), primarily focuses on pollution abatement and riverfront restoration, these interventions enhance river health and indirectly support the effectiveness of e-flow requirements.

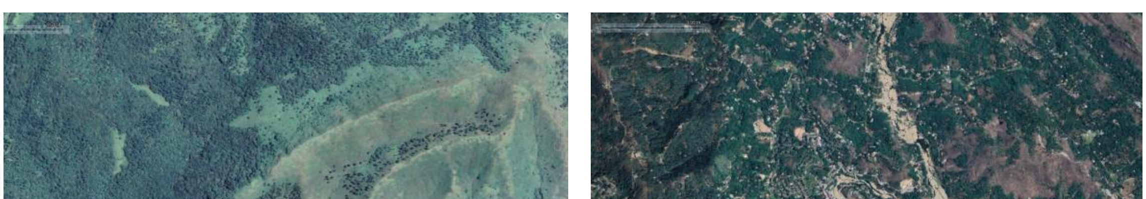


Figure 7: Discontinuity in Flow Downstream of (a) Mullaperiyar (Google Earth - 04/09/2018) and (b)Idukki- Cheruthoni Dams (Google Earth -30/01/2019)

Downstream of Idukki Reservoir, flows are significantly reduced due to diversion of hydropower releases from Moolamattom to the Muvattupuzha river, leading to long dry stretches. Environmental flows are currently not maintained in the Mullaperiyar–Idukki stretch as per NGT norms (Room for River, 2022). Ponniah and Gopalakrishnan (2002) reported that hydrological regulation of the Mullayar–Periyar streams associated with the Mullaperiyar Dam (constructed in 1895) may have altered natural longitudinal connectivity, thereby affecting the migration of catadromous and anadromous fishes, including eel species. The basin also lacks long-term ecological baseline data, making it difficult to quantify past ecosystem health. Further downstream, regulatory structures such as the Pathalam bund restrict freshwater movement, leading to increased pollutant accumulation and accelerating ecological degradation.

5.1. Recommendations

Maintaining minimum downstream flows below major reservoirs is critical for sustaining riverine ecosystems, ensuring longitudinal connectivity, and preserving the natural hydrological regime.

- It is recommended that reservoir-specific minimum environmental flow releases be defined for the Mullaperiyar and Idukki reservoirs to support downstream ecological functions throughout the year.
- Reservoir operation schedules should also be aligned to support fish movement, particularly during key breeding and recruitment periods.
- In addition, operational practices at the Pathalam regulator bund should be revised to allow periodic freshwater flushing, which will help reduce pollutant accumulation in the downstream industrial stretches.

Integrating environmental-flow obligations into reservoir operations, flood-management frameworks, and water-quality improvement strategies will improve ecological health and secure long-term sustainability of the Periyar river system.

6. Water Quality Monitoring in India

Water quality monitoring in India is primarily carried out under the National Water Quality Monitoring Programme (NWMP), coordinated by the Central Pollution Control Board (CPCB) in collaboration with State Pollution Control Boards (SPCBs). NWMP assesses the status and trends of water quality in rivers, lakes, canals, groundwater, and coastal waters across the country. Monitoring is conducted on key physico-chemical, biological, and microbiological parameters to detect pollution, evaluate compliance with water quality standards, and support management interventions.

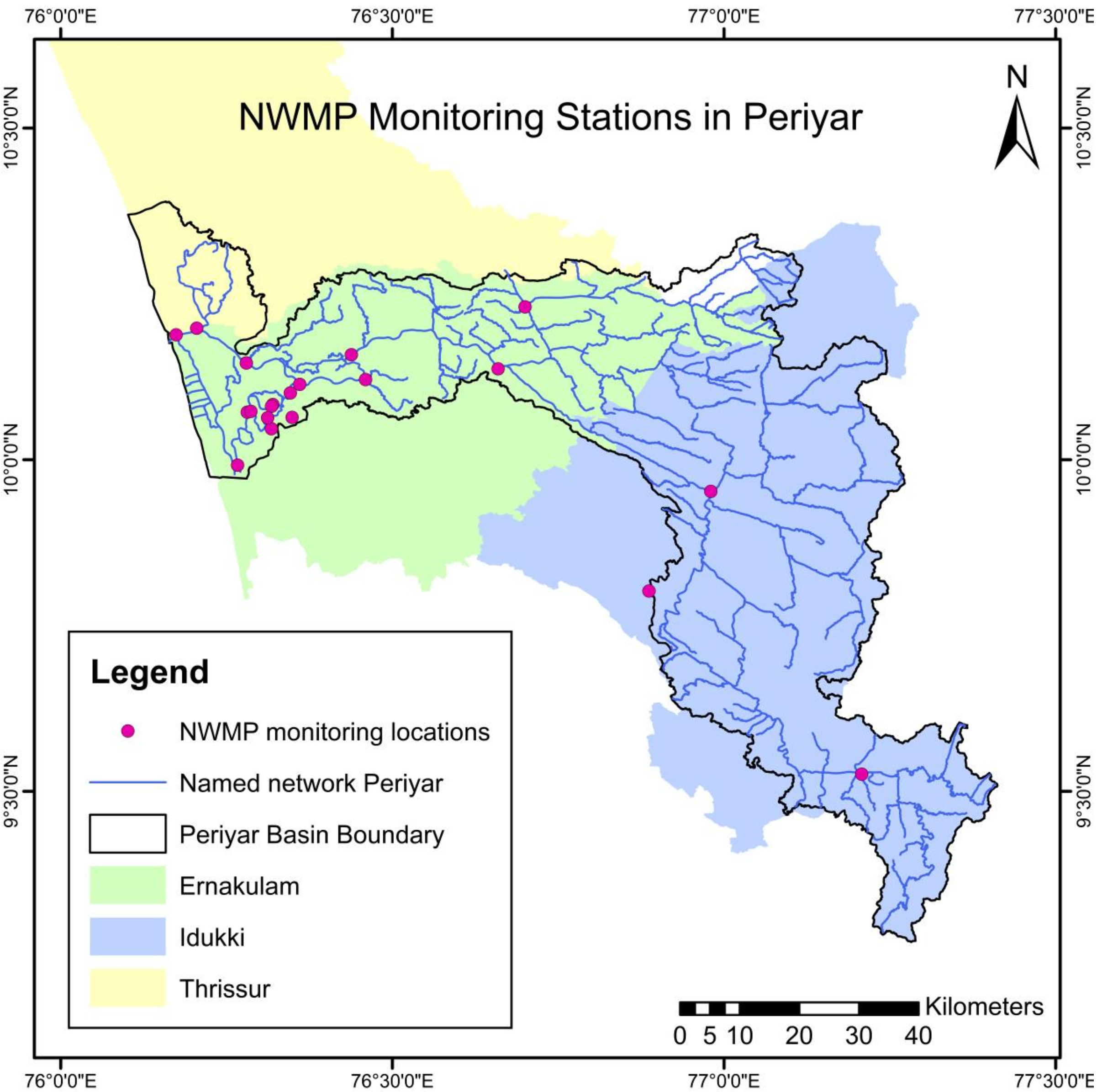


Figure 8: Spatial distribution of NWMP water quality monitoring locations in the Periyar

A total of 20 NWMP stations fall within the Periyar Basin, and their details are provided in the table 2.

Table 2: NWMP- Monitoring network in Periyar basin

NWMP Station Code	Name or Location of Monitoring Station	State	Type of Water Body	Latitude	Longitude
17	River Periyar near Aluva-Eloor	Kerala	River	10.07191	76.28125
18	River Periyar at Kalady	Kerala	River	10.15851	76.4381
1338	River Periyar at SDP Aluva	Kerala	River	10.10083	76.34611
1576	Thekkady	Kerala	Lake	9.525958	77.20763
1577	Kodungalloor	Kerala	Lake	10.19844	76.20502
1587	Well at Kalamassery	Kerala	Ground water	10.04683	76.31771
2329	Bhoothathankettu	Kerala	Reservoir	10.13716	76.65939
2330	Edamalayar	Kerala	Reservoir	10.23059	76.7
2333	Periyar at Muppathadam	Kerala	River	10.08339	76.31982
2334	Periyar at Pathalam(Vettukadavu)	Kerala	River	10.08082	76.31791
2335	Periyar at Kalamassery	Kerala	River	10.06338	76.31192
2336	Periyar at Purappillikkadavu	Kerala	River	10.14593	76.27986
3467	Unthithodu at Eloor,Ernakulam	Kerala	River	10.07305	76.28671
3468	Periyar at KWA intake, Aluva, Ernakulam	Kerala	River	10.11384	76.3603
3469	Palakkatuthazhamthodu at Perumbavoor	Kerala	River	10.12099	76.45953
5182	Kochi lake at goshree bridge, kochi	Kerala	Lake	9.991952	76.2666
5193	River Periyar at azhikode ferry, kodungallur,thrissur	Kerala	River	10.18842	76.17403

5208	River periyar at kulamavu resevoir at idukki	Kerala	River	9.802226	76.88684
5209	River periyar at panamkutty bridge, idukki	Kerala	River	9.952427	76.98007
5212	Pond, hmt colony-north kalamasery palam, Ernakulam	Kerala	Pond	10.06405	76.34873

Since 2009, the Central Pollution Control Board (CPCB) has been identifying Polluted River Stretches (PRS) across the country using the river water quality data monitored by State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs).

Locations or stretches of rivers that do not meet the primary water quality standards for outdoor bathing, specifically where Biochemical Oxygen Demand (BOD) exceeds 3 mg/L, are classified as polluted.

- If there is a single location on river, rivulet or stream and the location is not complying to BOD, it is identified as Polluted location.
- Two or more polluted locations identified on a river in a continuous sequence are considered as a stretch and defined as Polluted River Stretch.

PRS are categorized under five Priority Classes (I to V) based on maximum BOD level observed. The criteria for prioritization of river stretches is given in table 3:

Table 3: Priority classification (I–V) of polluted river stretches according to maximum BOD concentrations (Central Pollution Control Board, 2018)

Priority class	Maximum BOD level observed in mg/L
I	30.0
II	20.0 – 30.0
III	10.0 – 20.0
IV	6.0 – 10.0
V	M3.0 – 6.0

River Water quality monitoring at identified locations is done by collecting and analysing river samples with respect to various field observations, physico-chemical, bacteriological, Metals and Pesticide parameters on monthly basis as per *The Guidelines for Water Quality Monitoring, 2017* issued by *Ministry of Environment, Forest & Climate Change*. The water quality data generated is submitted by SPCBs/ PCCs through online data entry portal namely Environmental Water Quality Data Entry System - EWQDES and stored centrally at CPCB server. For identification of polluted river stretches, the water quality data for river monitoring locations is reviewed and the monitoring locations non-compliant with the desired criteria for Biochemical Oxygen Demand (BOD) i.e. > 3.0 mg/L are identified as polluted locations.

Water Quality of 49 rivers in Kerala was monitored at 75 locations during the year 2019 and 2021, out of which, 25 locations on 18 rivers were found non-complying to the prescribed Water Quality Criteria with respect to BOD. Out of which, 3 locations in the Periyar river are included in this list. List of the polluted stretches in Periyar is given in the table 4.

Table 4: Priority-wise classification of polluted stretches in the Periyar River

River	NWMP Station Code	Polluted River Stretch/ Location	Max BOD Observed (mg/L)	Priority Class
Periyar	17	Periyar along Alwaye-Eloor	3.3	V
	2335	Along Kalamassery	3.6	
	2336	Along Purappallikavu	3.9	

6.1. Gaps in Existing Monitoring Network

The existing water quality monitoring network in the Periyar basin shows significant spatial gaps, particularly in critical and populated regions. The map (Figure 9) clearly highlights significant monitoring gaps, including the absence of stations in upper reaches of basin, major tributaries flowing through key tourist hotspots and ecologically sensitive zone.

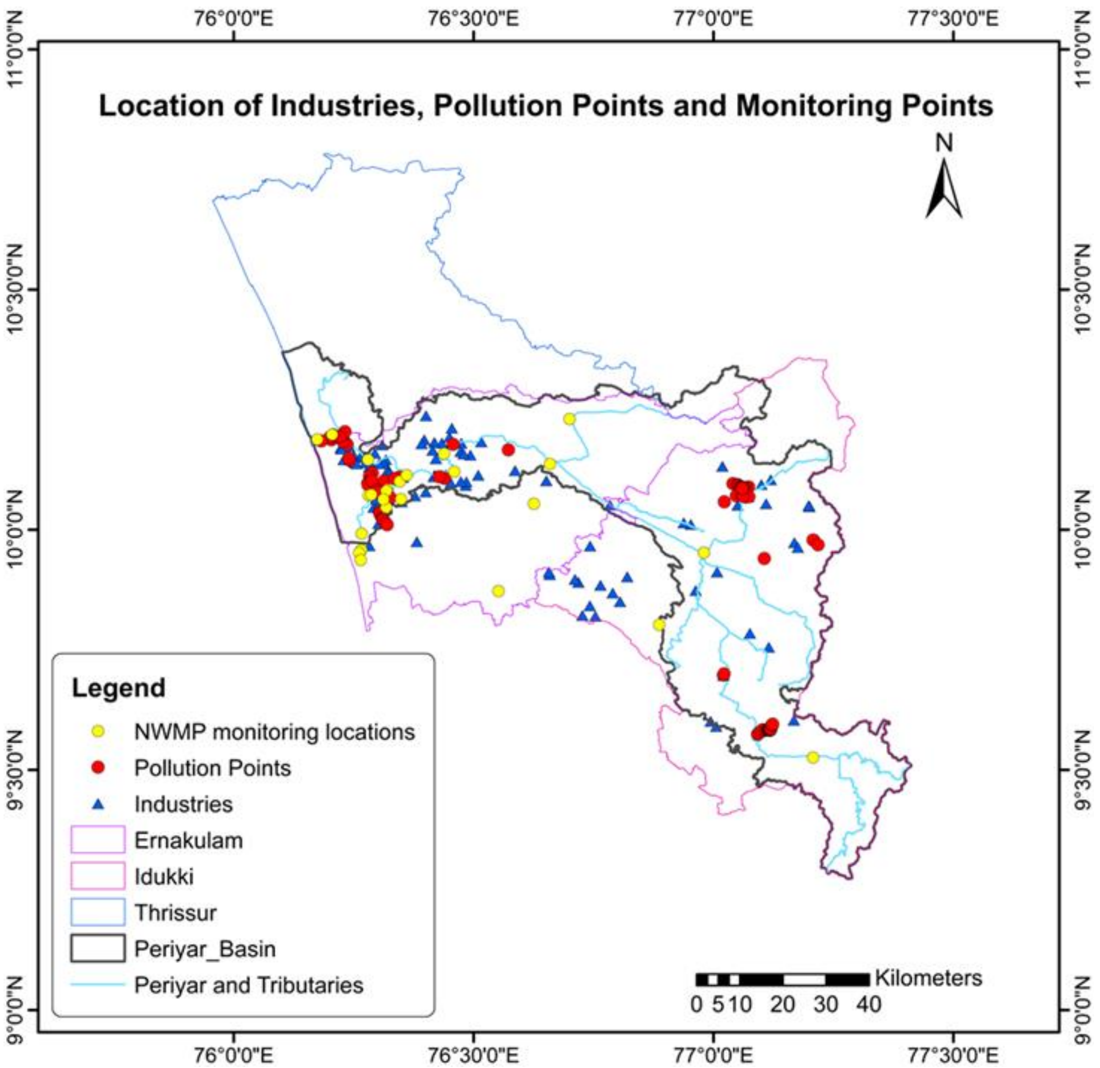


Figure 9: Locations of Industries, pollution points, and existing monitoring stations in the Periyar

In the downstream reaches of the Periyar river, the Eloor–Edayar industrial belt continues to remain as a major pollution hotspot, driven largely by effluent discharge from chemical and manufacturing industries. At the Pathalam Bund, the problem is further amplified, when the shutters remain closed, water stagnation leads to the accumulation of industrial waste and chemical contaminants, and once the shutters are opened, this polluted water is suddenly released downstream. This episodic flushing causes acute ecological stress, degrades aquatic habitats, and complicates pollution management.

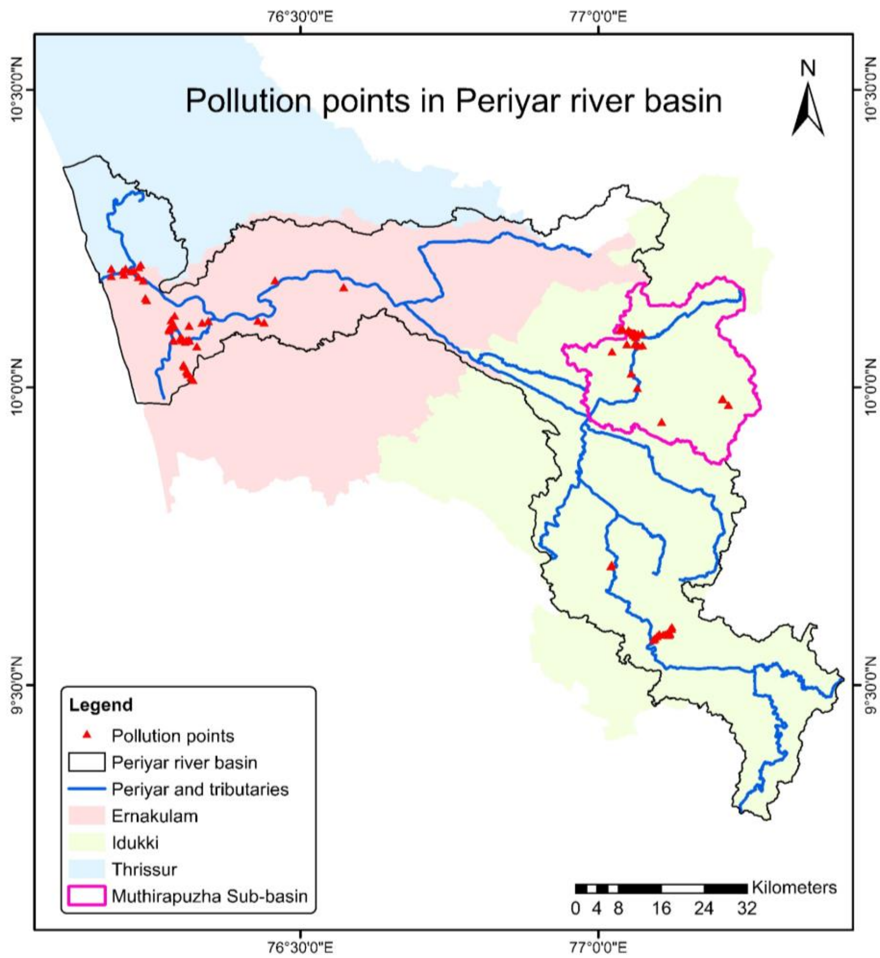


Figure 10: Locations of Pollution points in Periyar

In addition to industrial pressures, urban centres such as Puthenvelikkara, Perumbavoor, and the Edappally contribute substantial domestic and commercial waste generation.

Together, these industrial and urban pollution sources significantly deteriorate water quality in the lower Periyar (the major pollution locations are given in Figure. 11).

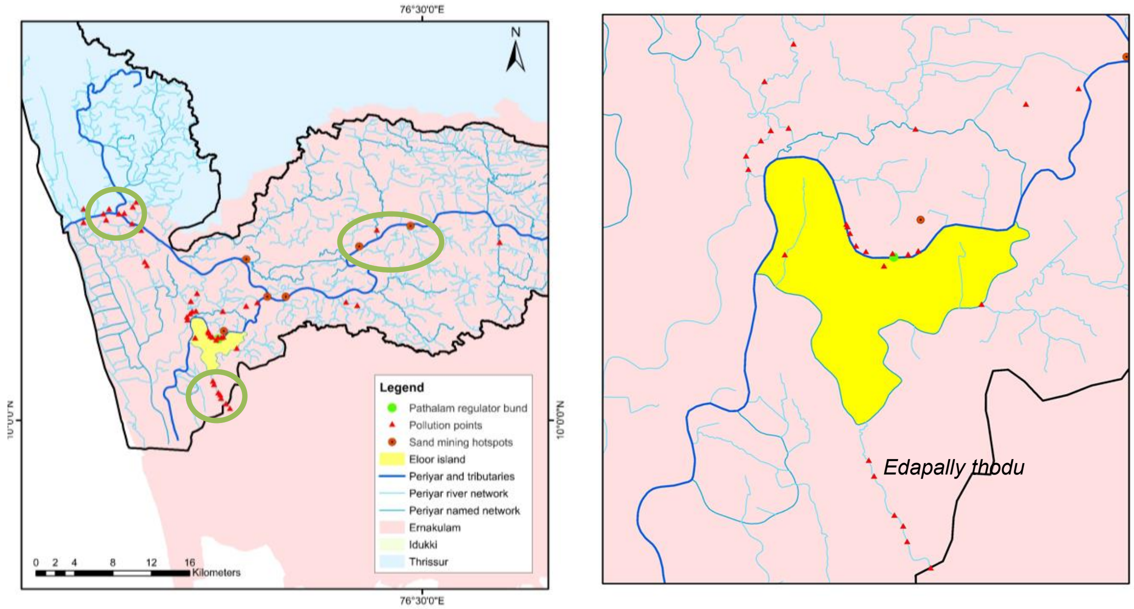


Figure 11: (a) Locations of Pollution points in downstream stretch of Periyar (b) Pollution in Eloor industrial area

The Muthirapuzha river which drains through major tourist destination like Munnar, receives substantial anthropogenic pressures. The pollution points are shown in Figure 12.

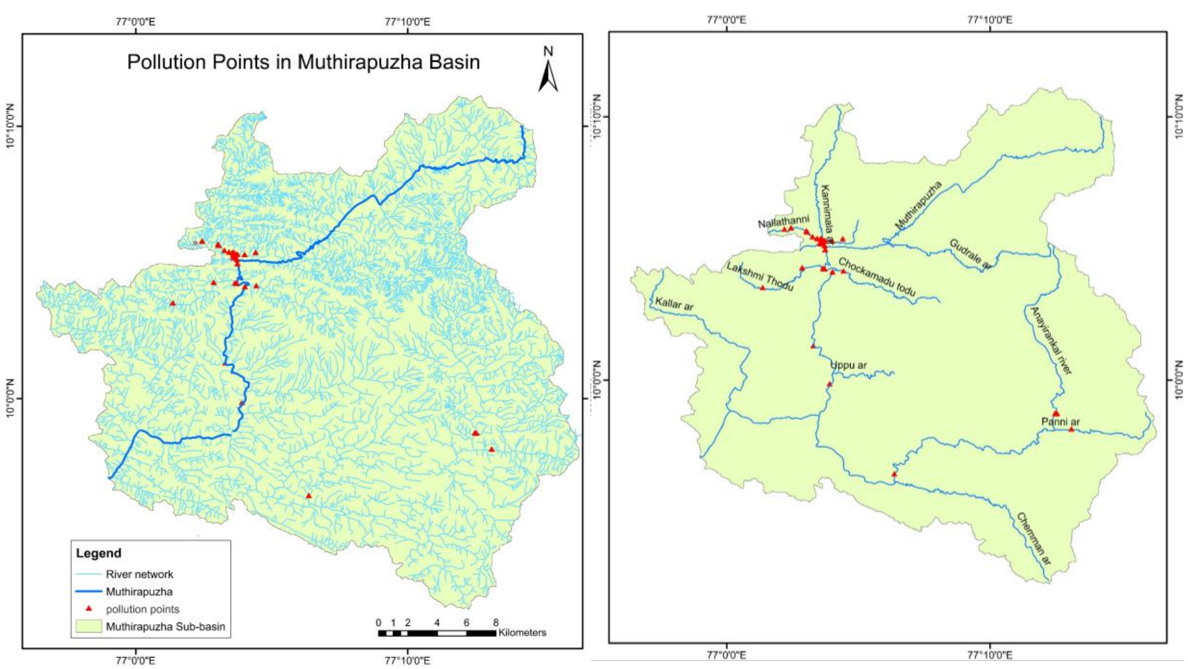


Figure 12: Locations of Pollution points in Muthirapuzha

Rapid expansion of tourism and associated commercial activities has increased the wastewater discharge into the river system. In addition to this, domestic sewage from upstream settlements and solid waste dumping along riverbanks exacerbate water quality deterioration. Despite these stressors the Muthirapuzha sub-basin has no NWMP monitoring station, leaving its pollution levels unassessed.

The Vandiperiyar–Upputhara reach in the upper Periyar basin is a critical segment of the river's main course, contributing to drinking water supply, irrigation, and storage in the Idukki reservoir. However, these upstream reaches are increasingly affected by agricultural runoff plantations, effluents from small-scale industries, and discharges from peri-urban settlements. Despite the need, there are no dedicated monitoring stations in this stretch, creating a significant blind spot in understanding pollutant transport, nutrient loading, and the cumulative impacts on water quality in downstream reservoirs such as Idukki.

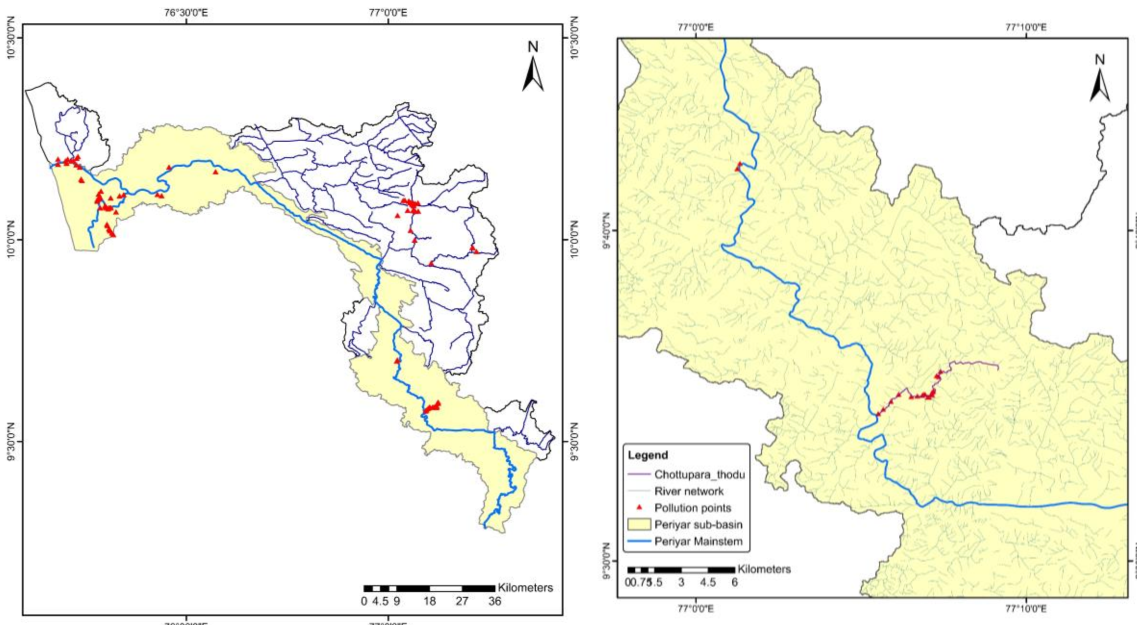


Figure 13: Locations of Pollution points in upper reaches of Periyar

6.2. Proposed Monitoring network

6.2.1. Objectives

- Track day-to-day changes in water quality at known polluted stretches of the river.

- Identify and map pollution hotspots linked to domestic sewage, local commercial activities, and runoff from agricultural and plantation areas.
- Provide timely information to authorities and local communities, while complementing CPCB laboratory results with more frequent, field-level and community monitoring.
- Build a baseline dataset to understand seasonal variations (pre- and post-monsoon) and support focused testing for pesticides and other toxic contaminants.

6.2.2. Monitoring locations

- Upstream stretches: Upputhara and Vandiperiyar:
  - These locations represent the upper reaches of the Periyar where domestic sewage, septic overflows, and wastewater from small commercial activities in hill settlements enter the river.
  - Monitoring at these points helps identify pollution at an early stage, before it travels downstream or mixes with major tributaries
- Munnar–Muthirapuzha tributary stretches: Nallathanni, Lakshmi Thodu, and Chokkamadu Thodu:
  - These tributary segments receive significant tourism-related discharges, plantation drainage, and potential pesticide-laden runoff.
  - Tracking these stretches is essential to understand pollutant contributions from the tourism component and plantation extend.
- Downstream stretches: Edapally Thodu, Perumbavoor, and Puthenvelikkara:
  - These areas lie within densely populated and highly industrialised areas where urban drains, small-scale industries, and cumulative upstream loads heavily impact water quality.
  - Monitoring these stretches helps in capturing the combined effects of urbanisation and industrial activity as the river approaches the estuary.

6.2.3. Monitoring matrix

- Daily monitoring (sampling by trained river-scouts using field kits)

- **Parameters** (onsite): temperature, pH, Dissolved Oxygen (DO), electrical conductivity (EC), turbidity, visual score (odour/foam/colour), flow/discharge estimate (visual/float method)
- **Frequency**: daily at high-priority points; if daily is not feasible then weekly.
- High resolution to detect point events (sewage spills, industrial discharge etc)

➢ Weekly / Twice weekly involving community using mobile labs

- **Parameters**: Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), ammonia (NH_3/NH_4^+), electrical conductivity (confirm), nitrate & phosphate
- **Frequency**: weekly at critical hotspots (Perumbavoor, Puthenvelikkara, Edapally); biweekly for upstream control points.

➢ Monthly multiparameter analysis in laboratories

- **Parameters**: BOD_5, COD, Total Coliform / E. coli (or faecal coliform), TSS, TDS, major ions (Na, K, Ca, Mg), total nitrogen, total phosphorus.
- **Frequency**: monthly at all selected sites

➢ Targeted seasonal testing by professional accredited labs

- **Toxic metals**: Twice a year, pre-monsoon (Apr–May) and post-monsoon (Oct–Nov)
- Metals to be analysed: Pb, Cd, Cr (total & hexavalent if relevant), As, Hg, Ni, Cu, Zn.
- **Pesticides**: Pre-monsoon screening for commonly used plantation pesticides (organophosphates, carbamates, selected persistent organochlorines if historically used). And one post-monsoon check if pre-monsoon test is positive
- **Frequency:** Twice a year for metals; pesticides testing in pre-monsoon (post-monsoon testing for validation if possible)

7. Biomonitoring for Rivers in India

Biomonitoring for rivers involves assessing water quality and ecological health using living organisms such as algae, benthic macroinvertebrates and fish, because these communities respond to pollution and environmental stress over extended periods. Chemical measurements only reveal conditions at the moment of sampling. In contrast, biological indicators reflect the cumulative effects of organic waste, toxic substances, habitat disturbance, altered flows, and sediment stress. This makes biomonitoring crucial for spotting intermittent or low-level pollution that routine water chemistry might overlook. It also helps us understand long-term ecological changes and evaluate the success of restoration or pollution-control efforts. Consequently, biomonitoring provides a complete and reliable view of river health that informs better river management and conservation decisions.

In India, the current biomonitoring network for rivers mainly operates under the Central Pollution Control Board (CPCB) through the National Water Quality Monitoring Programme (NWMP) and the National River Conservation Plan (NRCP). Biological assessments play a key role in evaluating river health. The CPCB and State Pollution Control Boards (SPCBs) regularly monitor biological indicators such as benthic macroinvertebrates, diatoms, phytoplankton, zooplankton, fish communities, and aquatic macrophytes at set stations across major rivers. The most organized and ongoing biomonitoring is in the Ganga basin, where the CPCB and the National Mission for Clean Ganga (NMCG) manage over forty stations for ecological assessments based on macroinvertebrates and fish. Other major rivers like the Yamuna, Godavari, Krishna, Cauvery, and Brahmaputra have less uniform biomonitoring, often occurring seasonally or as part of specific studies led by SPCBs or educational institutions.

CPCB uses Biological Water Quality Criteria with indices such as the BMWP-India score, Family Biotic Index, EPT richness, and Fish Index of Biotic Integrity (F-IBI) to classify river stretches from excellent to heavily polluted. The Central Water Commission (CWC) backs this network by gathering hydrological and physico-chemical data at more than a thousand stations across India's rivers, some of which also include biological observations. Additionally, research agencies like IITs, the National Institute of Hydrology (NIH), CIFRI, WII, NIO, and various universities contribute diatom and macroinvertebrate surveys, especially in ecologically sensitive areas such as the Western Ghats, Himalayas, and northeast India.

7.1. Biomonitoring for Periyar river

Implementing biomonitoring in the Periyar river is very crucial. Existing national and state networks are limited in smaller, ecologically sensitive rivers. This leaves important gaps in understanding long-term ecosystem health. Although CPCB, SPCBs, CWC, and research institutions run a broad national biomonitoring framework, they mostly focus on major rivers. As a result, we have little ecological data for complex basins like the Periyar, which face pressures from tourism, plantations, urbanization, and industry. Establishing a specific biomonitoring program for the Periyar would address this gap. It would provide ongoing insight into biological responses to pollution. This would help us better understand river health and guide focused restoration and management efforts.

7.2. Criteria for Selecting Biomonitoring Stretches

i. Alignment with existing water-quality stations
   - Biological sampling locations and chemical sampling sites should overlap so that both datasets are comparable and these conclusions can be integrated for river health assessment.

ii. Ecological Representativeness
   - Sites should reflect typical habitat conditions of the stretch, geomorphologic of river, presence of riffles or pools etc to ensure that biological data is meaningful and comparable.

iii. Habitat Similarity across stations in a stretch
   - All biomonitoring stations within a given river stretch should have broadly similar substrate composition (sand, gravel, rock, or mud), flow conditions, channel width and bank characteristics

iv. Practicality of Macroinvertebrate Sampling
   - Locations should allow easy use of hand nets, stone-lifting, and kick sampling. Sites are preferred where substrate and fauna are relatively uniform and where it is accessible for sampling.

v. Representative Cross-Section

- Stations should typify the river's cross-sectional profile, enabling reliable estimation of parameters such as oxygen exchange and other relevant hydraulic characteristics.

vi. Ease of access under all conditions

- Sampling teams must be able to reach sites while carrying equipment, with locations remaining accessible across different seasons, weather conditions, and river-flow levels.

vii. Laboratory Proximity and Sample Transport Feasibility

- For parameters requiring rapid analysis (e.g. BOD), sites should be close enough to laboratories to ensure samples can be transported and processed within 24 hours, which will determine the range of analyses that can be realistically undertaken.

viii. Avoidance of Hazardous Locations

- Sites prone to dangerous conditions should be excluded for the safety of the sampling team.

ix. Avoidance of Highly Disturbed Zones

- Areas subject to frequent disturbances such as cattle wading, sand mining, intensive fishing, or melon cultivation should be excluded, as these activities significantly alter substrate conditions, biological communities, and water-quality processes.

x. Exclusion of Impounded or Altered Habitats

- Dams, barrages, and impounded reaches create artificial flow and habitat conditions and should not be selected for routine biomonitoring.

xi. Availability of Support Infrastructure

- Presence of bridges, boats, or safe wading areas is essential for consistent sampling and should be considered when finalising biomonitoring stations.

7.3. Proposed stretches for Biomonitoring in Periyar

The identified stretches of the Periyar river offer a logical basis for selecting biomonitoring sites that capture the basin's ecological diversity and pollution pressures.

Table 5: Details of Proposed stretches for biomonitoring in Periyar

Stretch	Start	End	Features
PR 1	Origin (Chokkampatti Malai)	Mullaperiyar Dam	Hilly terrain with slope > 15° River Margin and valley margin coinciding Boulders, cobbles and pebbles Straight and tortuous channel
PR 2	d/s of Mullaperiyar dam	Panamkutty Bridge	Pediment zone with slope 5 to 15° River margin and valley margin coinciding Near to straight channel
PR 3	Panamkutty Bridge	Bhoothathankettu Barrage	Combination of pediment and alluvial fan (slope < 5°) Gorges found Meandering channel Sinuosity – 1 to 1.4
PR 4	d/s of Bhoothathankettu Barrage	Outlet	Alluvial plain and coastal plain Slope <3° Laterally unconfined Meandering channel Sinuosity – 1.2 to 1.48

In the upper catchment (PR1), places like Periyar Lake and Thanikudi show mostly untouched headwater conditions and are important reference sites. The mid-basin area downstream of the Idukki Reservoir (PR 3), which includes Panamkutty, reflects the combined impacts of major tributaries like Muthirapuzha and Chinnar along with controlled flows from the Idukki Dam. This area is a key zone for monitoring ecological responses to changes in water flow. Further downstream (PR 4), Neriamangalam and

Malayattoor represent dynamic alluvial and mixed river styles where urban pressures and increased sediment loads begin to influence river health. Collectively, these sites create a representative biomonitoring network that spans headwaters to the river mouth, supporting comprehensive ecological assessment across the entire Periyar basin. The different river stretches along the main stem of Periyar and the bio-monitoring locations in the basin are given in Figure 14.

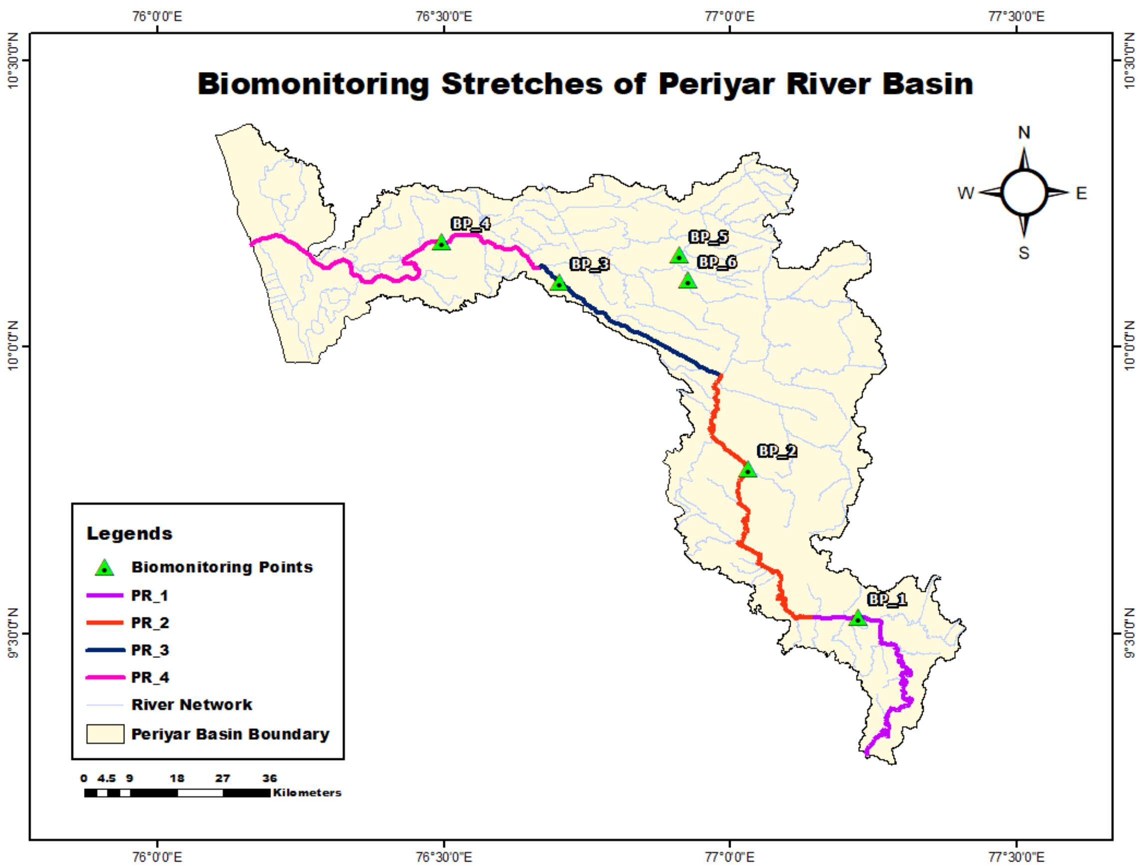


Figure 14: Proposed stretches for biomonitoring in Periyar

The other significant locations (Anakulam & Mankulam) in the tributaries are also included in the list of biomonitoring points, due to its species abundance.

8. Pilot Framework for Munnar Town

Munnar township has been selected as the pilot site for developing the Monitoring Plan due to its unique hydrological, environmental, socio-economic and touristic significance within the Periyar basin. The Muthirapuzha River is a 57-km-long headwater tributary of the Periyar Basin, originating above 2,000 m elevation in the Western Ghats and draining steep, landslide-prone terrain before flowing through Munnar town, the basin's primary high-altitude urban and tourism centre. The Munnar reach constitutes a critical hydrological junction formed by the confluence of major tributaries, including the Kannimala Ar, Nallathanni, and Kundala Ar. The immediate watershed surrounding Munnar town, covering approximately 98 km², is increasingly exposed to climate extremes such as intensified monsoon rainfall, frequent slope failures, and flash flooding.

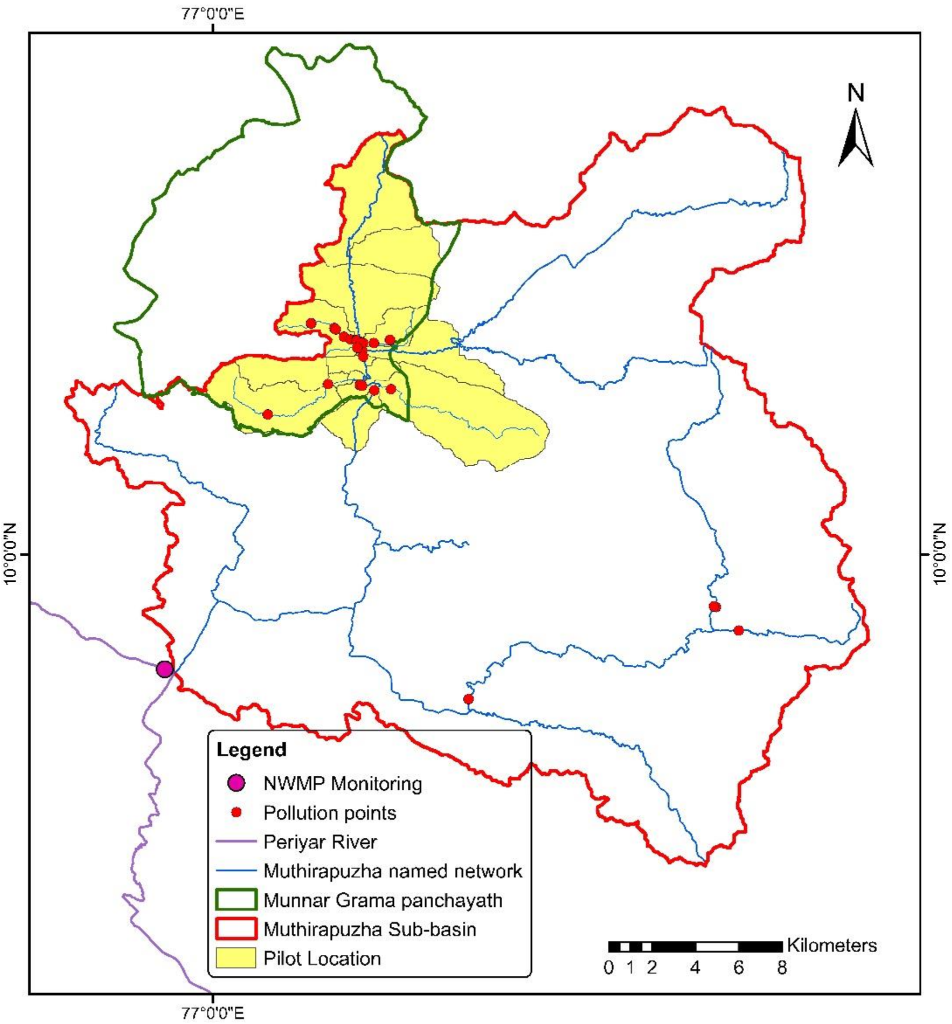


Figure 15: Proposed Pilot location for Implementing Monitoring framework

These hazards interact with human pressures from unplanned urban growth, inadequate sanitation, increased wastewater from tourism, and interference with riverside areas. These interactions lead to changes in water flow, localized flooding, and a steady decline in water quality and ecological health in a small but stressed catchment area. This study suggests a monitoring system that is spatially distributed and operates at high frequency, specifically designed for the Munnar region. This system aims to help manage water resources in response to climate change in an urban and tourism setting without sewer systems.

The study area falls within the Munnar, Devikulam, and Pallivasal Grama Panchayaths, which are administratively rural areas but intense tourism activity and a substantial floating population is to be considered during basin planning.

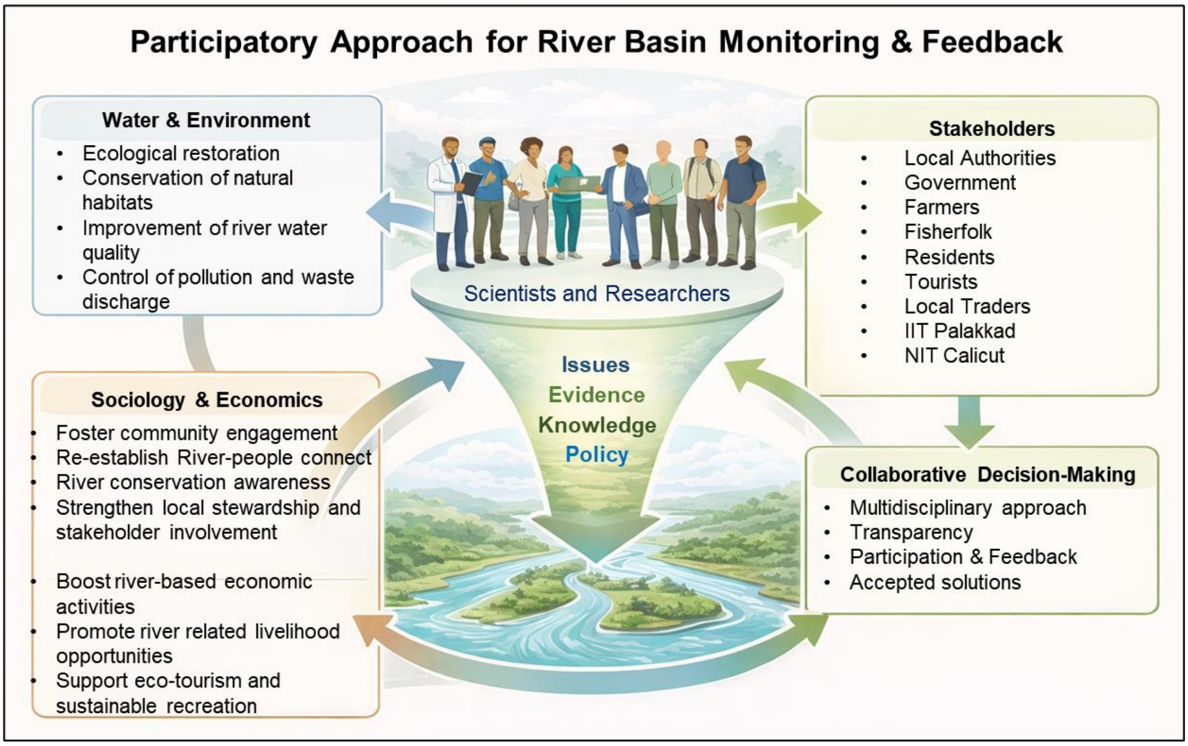


Figure 16: Illustration of framework involving all stakeholders

Effective basin planning in the Munnar region requires collaboration among different departments and authorities. With various institutions involved and independent bodies present, cooperation must be the main focus and should be built into the basin monitoring and planning process. For the Pilot Basin Monitoring Plan, close coordination among government departments, local self-governments, tourism authorities, environmental agencies, and community groups is crucial. This collaboration serves four main purposes:

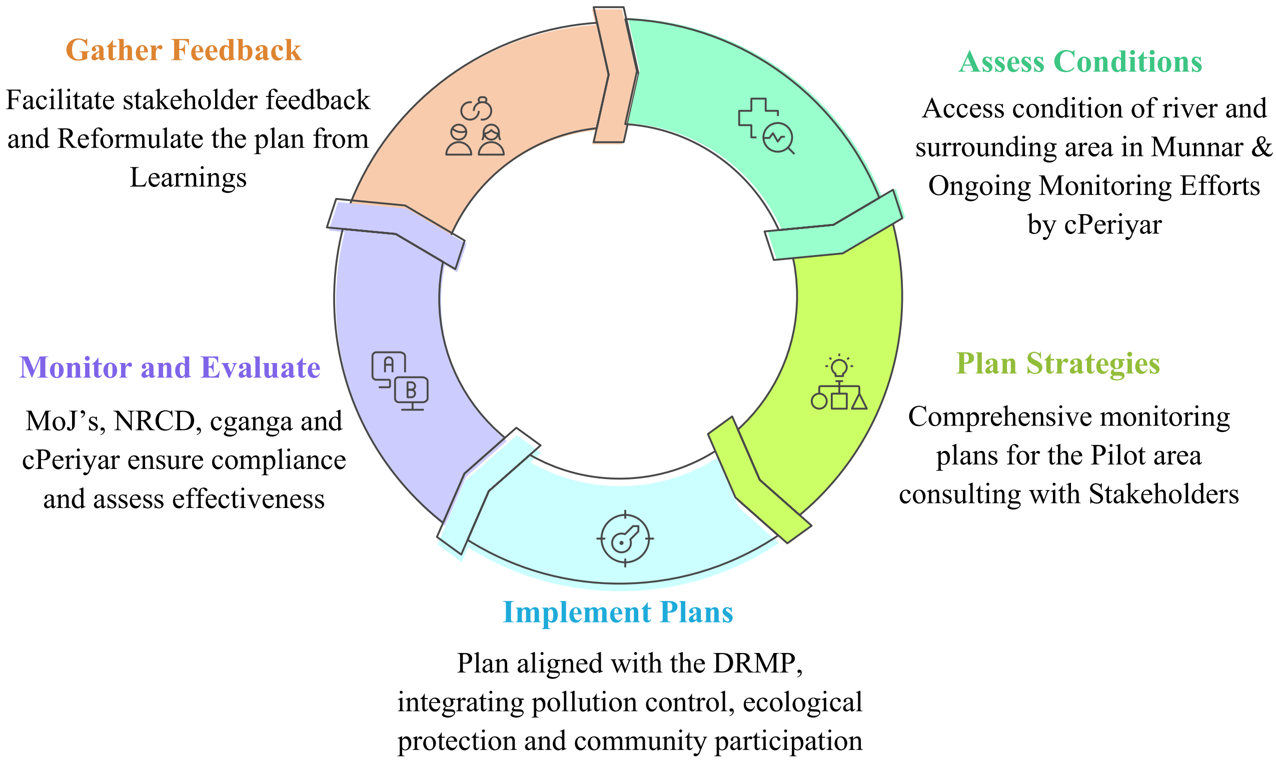
- **Engaging Local Institutions and Stakeholders and their perspectives:** Engaging with LSGDs, Kerala tourism departments, community groups and NGO’S working for

Periyar allows for a variety of viewpoints on river pressures, pollution sources, and possible management actions in Munnar.

- **Aligning with Existing Planning and Regulatory Processes:** Working with ongoing urban planning, tourism management, and environmental regulation in Munnar helps ensure that goals are in sync and supports long-lasting cooperation among institutions during implementation.
- **Shared Responsibility for River Protection:** Involving local institutions and communities in monitoring activities raises awareness of river health issues and promotes shared responsibility for protecting the Muthirapuzha headwaters.
- **Communication of Findings for Better Local Decision-making:** Regularly communicating monitoring findings to local agencies and sectors beyond water aids in making informed decisions and managing the Munnar pilot basin effectively.

This cooperative and participatory approach is vital for successful basin monitoring and long-term sustainability in the rapidly changing Munnar region.

Cyclic Process for River Basin Monitoring



The District River Basin Management Plan (DRMP) for the Periyar river takes an integrated, seasonal approach from source to sink. It aims to balance water availability, flood safety, and ecological health. The plan emphasizes reusing wastewater and decentralized treatment during the non-monsoon period, while focusing on flood control, groundwater recharge, and pollution management during the monsoon. This will promote a sustainable river system at the district level.

IIT Palakkad and NIT Calicut will work together to develop the DRMP for the Periyar. They will focus on creating proposals for decentralized sewage treatment plants (STPs) as a main outcome of the management plan. These proposals will be developed with input from relevant stakeholders. The capacity of the STPs will be based on confirmed outfall locations and measured domestic wastewater loads. This includes contributions from temporary populations, especially in tourist-heavy areas like Munnar. To aid effective planning, important datasets will be gathered. This will include pollution load details, waste data, and information about current sewer systems, faecal sludge treatment plants (FSTPs), and plastic recycling facilities.

As an initial step, domestic outfall points will be identified and assessed through close coordination with the respective Local Self Government Institutions (LSGIs) and State Pollution Control Board. A structured questionnaire, aligned with existing river rejuvenation and sanitation plans and incorporating additional assessment requirements, will be circulated to LSGIs, followed by ground-level data collection in coordination with Assistant Engineers of the Local Self Government Department (LSGD) and Panchayat Secretaries. Based on these inputs, identified outfall points will be physically verified through field visits, and field-based studies will be conducted to estimate the approximate discharge from drains entering the river.

To effectively track the implementation and performance of the proposed interventions, a spatially distributed and high-frequency monitoring plan is proposed. This plan will complement management actions by enabling regular assessment of water quality responses and the ecological health of the river basin. Monitoring locations will be strategically selected to represent major outfalls, sensitive river reaches, urban–rural interfaces, and confluence zones, with increased sampling frequency during critical periods to capture temporal variability. Such an approach will support adaptive management, early detection of emerging issues, and evidence-based refinement of the District River Management Plan over time.

Table 6: Details of Proposed Monitoring Plan for Munnar

<table>
<tr><th>Tier/ Level</th><th>Actors</th><th>Key Responsibilities</th><th>Monitoring Frequency</th><th>Monitoring Locations</th></tr>
<tr><td rowspan="3">Tier-1
Community Monitoring</td><td rowspan="2">River scouts/ Local communities/ NGO’s</td><td>Measure
• Turbidity
• Electrical Conductivity
• pH
• Dissolved Oxygen
• Temperature</td><td>Daily using River scouts</td><td rowspan="3">Water quality
1. Kannimala ar (Reference)
2. Nallathanni ar
3. Colony thodu
4. Nadayar thodu
5. Lakshmi thodu
6. Chockamadu thodu
7. River d/s of Pilot area

Biomonitoring
1. Nallathanni ar
2. lechmi ar
3. River stretch d/s of Pilot area</td></tr>
<tr><td>Measure
• Heavy metals
• Pesticides
• Microplastics
Biological Profiling for
• Macroinvertebrates
• Fish</td><td>Quarterly</td></tr>
<tr><td>Local communities/ Eco-club members/ Volunteers</td><td>Routine river stretch inspection
Visual pollution checks -oil films, foam, sewage discharge
Record flow conditions and bank erosion</td><td>Weekly or event based
(Use mobile apps for photo–GPS logging)</td></tr>
<tr><td>Tier-2
Zonal Academic Centres and Regional expert institutions</td><td>Educational institutes, IIT Palakkad, NITC, KUFOS</td><td>• Training river scouts
• Sample validation
• analysis</td><td>Monthly or quarterly</td><td></td></tr>
</table>

9. Summary

This report presents a comprehensive protocol for feedback and monitoring within the basin, integrating hydrological, water-quality, and ecological components. The report maps the existing network of rain gauge, stream gauges and water quality monitoring stations and identifying spatial gaps where coverage is inadequate. Based on these deficiencies, recommendations are made for the installation of additional stations to achieve improved spatial and temporal representation of data across the basin.

The Periyar Basin requires a significantly denser rainfall monitoring network of 29 gauges as per BIS/IMD/WMO norms, yet only 7 IMD stations exist, creating major gaps that weaken flood forecasting, inflow estimation, and early-warning systems. While the number of streamflow gauges meets WMO norms for most of the basin, the free Periyar catchment (2,367 km^2) lacks adequate coverage, making an additional flow gauge upstream of the Bhoothathankettu barrage essential for effective flood management. Maintaining minimum downstream environmental flows from key reservoirs such as Mullaperiyar and Idukki is crucial to preserve riverine ecology, sustain fish movement, and maintain longitudinal connectivity in the Periyar. Reservoir-specific minimum release rules, fish-supportive operation schedules, and periodic freshwater flushing at the Pathalam regulator bund are required to reduce pollutant accumulation and support ecological functions throughout the year. Integrating these e-flow obligations into reservoir operations, flood-management planning, and water-quality strategies will significantly enhance the long-term ecological health of the river system.

Water-quality monitoring is proposed at critical upstream locations such as Upputhara and Vandiperiyar to capture early pollution inputs from hill settlements, and along Muthirapuzha tributary stretches (including Nallathanni, Lakshmi Thodu, and Chokkamadu Thodu) to assess impacts from tourism, plantations, and pesticide runoff. Additional monitoring at downstream sites like Edapally Thodu, Perumbavoor, and Puthenvelikkara is essential to track the cumulative effects of urban wastewater and industrial discharges in the densely populated lower basin. Together, these stations provide comprehensive coverage of pollution sources from headwater settlements to industrialised estuarine reaches.

Biomonitoring sites in the Periyar Basin span from relatively undisturbed headwater reference locations such as Periyar Lake and Thanikudi (PR1), to mid-basin zones like Panamkutty (PR3) where ecological responses to regulated flows and major tributary inputs can be assessed. Further downstream, sites such as Neriamangalam and Malayattoor (PR4) capture shifts in river health linked to urban pressures, altered sediment dynamics, and changing channel conditions. Together, this network provides a representative framework for tracking ecological integrity and river health. Overall, the report outlines the existing monitoring systems operating within the basin, pinpoints critical gaps, and provides a set of additional monitoring locations needed to establish a comprehensive, basin-wide framework. These proposed stations across rainfall, streamflow, water quality, and fish diversity have been systematically included to strengthen long-term basin management and decision-making.

Role of this report in supporting stakeholders

This report provides government agencies, local bodies, researchers, and community organisations with a clear blueprint for where additional monitoring stations are required and how each component of the basin should be observed. It recognizes that government agencies alone cannot sustain basin-wide monitoring and therefore emphasizes the importance of community participation through trained river scouts to conduct daily and monthly measurements. All collected data should be shared through an online platform, ensuring open access for agencies, researchers, and communities while also increasing public awareness of pollution hotspots and emerging issues in the Periyar Basin. This collaborative, transparent approach strengthens both scientific decision-making and community stewardship.

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