

## **PHYSICOCHEMICAL ASSESSMENT OF BOREWELL WATER QUALITY IN MARAKANAM, PUDUCHERRY: A COMPARATIVE STUDY AGAINST IS 10500:2012 STANDARDS**

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### **ABSTRACT**

Groundwater is the primary source of drinking water in rural India, yet its quality varies widely depending on geology, land use, and anthropogenic pressures. This study investigates the physicochemical quality of borewell water from Marakanam, Puducherry, analysed by SMS Labs Services Pvt. Ltd. Twenty eight parameters were tested, including pH, total dissolved solids, hardness, major ions, and trace metals. All values conformed to acceptable limits of IS 10500:2012 standards, indicating potable quality. Unlike industrial belts, Marakanam's aquifers are relatively free from anthropogenic contamination, with negligible pesticide use and no nearby factories. Microbiological threats are minimal, but seasonal monitoring remains essential. Public health implications are discussed in relation to rural disease patterns, while risk assessment models, such as the Water Quality Index (WQI) and Heavy Metal Pollution Index (HPI), contextualize the findings. The paper concludes that Marakanam's groundwater is safe but requires proactive community level management to sustain quality amid coastal development pressures.

**KEYWORDS:** *Drinking Water in Rural India*

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### **INTRODUCTION**

Groundwater is a lifeline for rural communities across India, particularly in coastal regions where municipal supply is limited. In Puducherry, borewells serve as the primary drinking water source for households, schools, and small industries. Yet groundwater quality is highly variable, influenced by aquifer geology, rainfall, and human activity. While industrial belts such as Ranipet and Cuddalore have documented contamination from tanneries and chemical plants, rural zones like Marakanam present a contrasting picture. Here, the absence of factories and minimal pesticide use creates a unique baseline for studying aquifer chemistry.

Marakanam lies along the East Coast Road, with aquifers tapping into sandy coastal deposits. The community depends heavily on borewells, making water quality a public health concern. Previous studies in Tamil Nadu have highlighted the risks of fluoride, nitrate, and heavy metal contamination. However, Marakanam's relative isolation from industrial activity offers an opportunity to assess natural aquifer chemistry without anthropogenic interference. This study fills a research gap by systematically analysing borewell water quality in Marakanam, comparing results with IS 10500:2012 standards, and applying risk assessment models to contextualize findings.

## OBJECTIVES

- To evaluate the physicochemical characteristics of borewell water in Marakanam.
- To compare observed values with IS 10500:2012 standards.
- To apply Water Quality Index (WQI) and Heavy-Metal Pollution Index (HPI) models.
- To assess public health implications in a rural context.
- To recommend sustainable water management practices.

## METHODOLOGY

A borewell water sample (B3) was collected from Marakanam, Puducherry, on 17 April 2026. The sample was analyzed by SMS Labs Services Pvt. Ltd., Chennai, using IS 3025 series and APHA 24th edition methods. Twenty-eight parameters were tested, including pH, total dissolved solids (TDS), hardness, major ions (chloride, sulphate, nitrate), trace metals (lead, mercury, arsenic, chromium), and organoleptic properties. Results were compared against IS 10500:2012 standards, which specify acceptable and permissible limits for drinking water. Risk assessment models—WQI and HPI—were applied to contextualize findings. Limitations include the absence of microbiological testing, though contextual analysis addresses potential microbial risks.

**Table 1**

Parameter	Result	Acceptable Limit	Permissible Limit
pH at 25°C	6.62	6.5–8.5	No relaxation
TDS	104 mg/L	500 mg/L	2000 mg/L
Hardness (CaCO <sub>3</sub> )	63 mg/L	200 mg/L	600 mg/L
Chloride	20 mg/L	250 mg/L	1000 mg/L
Lead	BLQ (0.001 mg/L)	0.01 mg/L	No relaxation

## RESULTS

The borewell water sample conformed to IS 10500:2012 standards across all parameters. Key findings include:

- **pH:** 6.62, within the acceptable range of 6.5–8.5.
- **TDS:** 104 mg/L, well below the 500 mg/L limit, indicating low mineralization.
- **Hardness:** 63 mg/L, classifying the water as soft.
- **Calcium & Magnesium:** 14 mg/L and 6.6 mg/L respectively, both within safe limits.
- **Chloride & Sulphate:** 20 mg/L and 6.4 mg/L, far below permissible limits.
- **Heavy Metals:** Lead, mercury, arsenic, and chromium were below quantification limits.
- **Fluoride & Iron:** Below detection limits, eliminating risks of fluorosis or iron overload.
- **Organoleptic Properties:** Clear appearance, acceptable taste.

Risk assessment confirmed safety: WQI classified the water as “excellent,” while HPI indicated negligible risk due to BLQ values for heavy metals.

## **ARGUMENT**

### **Aquifer Chemistry**

Marakanam's aquifers are shaped by coastal geology, where sandy deposits and porous soils act as natural filters. The low Total Dissolved Solids (TDS) and soft water classification reflect minimal mineral dissolution, suggesting that the aquifer is not heavily influenced by carbonate or sulphate rocks. The absence of heavy metals such as lead, mercury, arsenic, and chromium indicates clean aquifer conditions, free from industrial effluents. Unlike belts such as Ranipet or Cuddalore, where tannery and chemical discharges seep into groundwater, Marakanam's aquifers remain pristine. This natural filtration process highlights the resilience of coastal aquifers when unburdened by anthropogenic stress.

### **Microbiological Angle**

Although industrial and pesticide threats are minimal, seasonal microbial risks cannot be ignored. During monsoon flooding, septic leakage and agricultural runoff can introduce coliform bacteria into borewells. Even in rural areas with low pesticide use, microbial intrusion can occur through poorly sealed borewell heads or stagnant water around collection points. Although microbiological testing was not performed in this study, the contextual analysis suggests that vigilance is necessary. Incorporating bacteriological parameters, such as *E. coli* and total coliform counts, into future studies would provide a more comprehensive assessment of potability.

### **Public Health Implications**

Safe borewell water reduces the risks of fluorosis, gastroenteritis, and heavy metal poisoning. In Marakanam, the absence of fluoride contamination eliminates the threat of dental and skeletal fluorosis, which is common in parts of Tamil Nadu. Similarly, negligible heavy-metal content reduces the risks of chronic poisoning. However, gastroenteritis and diarrheal diseases remain potential threats if microbial contamination occurs during seasonal changes. Rural households benefit from potable water, but awareness campaigns are needed to prevent contamination from poor sanitation practices. Linking water quality to disease prevalence strengthens the case for regular monitoring and community-level interventions.

### **Socio-Economic Context**

Marakanam's reliance on borewells underscores the importance of groundwater safety. Limited municipal supply means households depend on aquifers year-round, making water quality a determinant of rural livelihoods. Ensuring safe water reduces healthcare costs, improves productivity, and supports educational outcomes by minimizing absenteeism due to waterborne diseases. In socio-economic terms, potable groundwater is not just a health resource but a driver of rural development. Investments in monitoring and sustainable practices yield long-term economic benefits.

### **Comparative Analysis**

Contrasting Marakanam with contaminated belts highlights the importance of location. Industrial zones such as Ranipet and SIPCOT Cuddalore are severely affected by groundwater pollution from tannery effluents and chemical discharges. In these regions, aquifers are burdened with high levels of TDS, heavy metals, and other toxic substances. Marakanam, by contrast, remains pristine due to its isolation from industrial activity. This baseline study provides a benchmark for future monitoring, offering a comparative lens to understand how geography and land use shape water quality outcomes.

### **Risk Models**

Risk assessment models such as the Water Quality Index (WQI) and Heavy-Metal Pollution Index (HPI) confirm safety but emphasize vigilance. WQI places Marakanam's borewell water in the "excellent" category, while HPI indicates negligible risk due to below-quantification values for heavy metals. However, even in clean aquifers, seasonal changes or coastal development can alter water chemistry. Applying risk models ensures proactive management, allowing communities to anticipate risks rather than react to crises.

## **CLIMATE CHANGE & SUSTAINABILITY**

### **Saline Intrusion Risk**

Marakanam, being a coastal settlement, faces the long-term threat of saline intrusion as sea levels rise due to climate change. Saline intrusion occurs when seawater infiltrates freshwater aquifers, elevating chloride and sodium concentrations. This process can render groundwater unfit for drinking and irrigation, posing health risks and threatening agricultural production. Early indicators include gradual increases in electrical conductivity and chloride levels, which must be monitored regularly.

### **Aquifer Recharge & Rainfall Variability**

Climate change also alters rainfall patterns. Reduced monsoon intensity or irregular distribution can lower aquifer recharge rates, while extreme rainfall events may cause flooding and microbial contamination. Sustainable recharge practices such as percolation ponds, recharge wells, and check dams can help stabilize aquifer levels and dilute potential contaminants.

### **Community-Level Practices**

Local participation is critical. Community-driven rainwater harvesting, rooftop collection systems, and shared recharge structures can ensure resilience. Awareness campaigns should emphasize the importance of sealing borewell heads, maintaining sanitation near water sources, and adopting eco-friendly agricultural practices to prevent aquifer stress.

### **Policy & Governance**

Government frameworks, such as the National Water Policy and state-level groundwater regulations, must integrate climate resilience. Policies should incentivize sustainable water use, mandate periodic water quality testing, and support rural water surveillance units. Collaboration between local panchayats, NGOs, and universities can strengthen monitoring and intervention.

### **Technological Innovations**

Emerging technologies can enhance sustainability:

- **GIS Mapping:** Identifies vulnerable aquifer zones and saline intrusion hotspots.
- **Sensor Networks:** Real-time monitoring of pH, conductivity, and microbial indicators.
- **Community Filtration Units:** Low-cost sand or membrane filters for villages.
- **Solar Desalination:** A potential solution if saline intrusion worsens.

### **Socio-Economic Implications**

Water scarcity or salinization directly impacts rural livelihoods. Agriculture, fisheries, and household consumption all depend on reliable groundwater. Sustainable water management reduces healthcare costs, prevents migration due to resource stress, and supports long-term economic stability.

### **Global & Regional Context**

Marakanam's challenges mirror those of other coastal belts worldwide, from Kerala to Bangladesh. Comparative studies show that proactive measures, rainwater harvesting, aquifer recharge, and community monitoring are more effective than reactive desalination once aquifers are compromised. Positioning Marakanam as a model of resilience can contribute to regional water security strategies.

Climate change introduces **two major risks**: saline intrusion and rainfall variability. Sustainable practices, rainwater harvesting, recharge wells, community filtration, and policy support are essential to safeguard aquifer health. Integrating technology, governance, and community participation ensures that Marakanam's aquifers remain viable sources of potable water despite environmental pressures.

## **INTEGRATED RESILIENCE STRATEGIES**

### **Energy–Water Nexus**

Groundwater sustainability is closely tied to energy use. Traditional diesel or electric pumps often strain rural households financially and contribute to carbon emissions. Renewable energy solutions, such as **solar-powered pumps**, offer a dual benefit: they reduce dependence on fossil fuels while ensuring reliable water extraction even in remote areas. In regions where saline intrusion becomes severe, **solar desalination units** can provide decentralized treatment, converting brackish water into potable water at low operational cost. Integrating renewable energy into water management thus strengthens both environmental resilience and economic sustainability.

### **Agricultural Practices**

Agriculture is the largest consumer of groundwater in coastal India. Climate change and saline intrusion threaten crop yields by increasing soil salinity. To counter this, farmers can adopt **salt-tolerant crop varieties** (such as certain strains of rice, millet, and pulses) that thrive in semi-saline conditions. Additionally, **organic farming practices** reduce chemical load on aquifers, preventing nitrate and pesticide contamination. Techniques such as mulching, crop rotation, and biofertilizers enhance soil health and reduce water demand, helping prevent aquifer overexploitation. Linking water quality management with sustainable agriculture creates a holistic resilience framework.

### **Regional Collaboration**

Aquifers do not follow administrative boundaries; they extend across districts and states. Effective resilience, therefore, requires **cross-district monitoring networks**. By sharing aquifer data, such as chloride levels, recharge rates, and microbial indicators, neighbouring regions can collectively anticipate risks. Regional collaboration also enables resource pooling for infrastructure like recharge wells and filtration units. In Tamil Nadu and Puducherry, collaboration between local panchayats, universities, and NGOs could create a **community-based aquifer observatory**, ensuring transparency and accountability in water management.

## Global Comparisons

Marakanam's challenges mirror those faced by coastal belts worldwide. In **Bangladesh**, saline intrusion has been managed through large-scale rainwater harvesting and pond sand filtration systems, which provide safe drinking water even in flood-prone areas. In **Gujarat**, community-driven recharge wells and check dams have successfully reduced aquifer salinity and improved groundwater levels. These case studies demonstrate that proactive measures, rainwater harvesting, aquifer recharge, and community monitoring are more effective than reactive solutions like desalination once aquifers are compromised. Positioning Marakanam within this global context highlights its potential to serve as a **model of resilience for coastal India**.

Integrated resilience strategies emphasize that aquifer sustainability is not just a technical issue but a socio-economic and environmental challenge. By combining **renewable energy solutions, sustainable agriculture, regional collaboration, and lessons from global case studies**, Marakanam can safeguard its aquifers from the pressures of climate change. These strategies ensure that groundwater remains a viable source of potable water, supporting both community health and long-term rural development.

The **comparative chart of resilience strategies** fits best in your paper's *Climate Change & Sustainability* section, right after the **Global & Regional Context** subsection. Here's why and how to place it:

## PLACEMENT RECOMMENDATION

- **Section:** *Climate Change & Sustainability*
- **Subsection:** *After Global & Regional Context*
- **New Subheading:** *Integrated Resilience Strategies: Comparative Insights*

This placement ensures the chart flows naturally:

- You first explain Marakanam's risks (saline intrusion, rainfall variability).
- Then you discuss local practices and governance.
- Finally, you broaden the scope with **comparative strategies** from Bangladesh and Gujarat, showing how Marakanam can learn from global and regional experiences.

## Suggested Narrative to Introduce the Chart

To contextualize Marakanam's resilience strategies, it is useful to compare them with approaches adopted in other coastal regions. Bangladesh and Gujarat provide instructive case studies, demonstrating how community-driven practices, renewable energy solutions, and agricultural adaptations can mitigate saline intrusion and sustain aquifer health. The following chart summarizes integrated resilience strategies across four dimensions.

### Integrated Resilience Strategies: Comparative Insights

Table 2

Dimension	India (Marakanam)	Bangladesh	Gujarat
Energy–Water Nexus	Solar pumps; solar desalination potential	Rainwater harvesting, pond sand filtration	Community recharge wells; check dams
Agricultural Practices	Salt-tolerant rice, millet, and organic farming	Salt-tolerant rice; flood-resilient cropping	Salt-tolerant millet, pulses, and crop rotation
Regional Collaboration	Cross-district monitoring networks; aquifer observatories	Community-based monitoring groups; NGO support	NGO-led aquifer monitoring; village committees
Global Comparisons	Positioned as a model of resilience for coastal India	Pond sand filtration as a low-cost resilience	Successful salinity reduction via recharge wells

This comparative analysis highlights that while Marakanam is well-positioned to integrate renewable energy and sustainable agriculture, lessons from Bangladesh emphasize the importance of decentralized filtration systems, and Gujarat demonstrates the effectiveness of recharge wells and check dams. Together, these strategies form a holistic resilience framework that can safeguard Marakanam’s aquifers against the pressures of climate change.

### CONCLUSION

The borewell water sample from Marakanam meets the IS 10500:2012 standards, indicating safe, potable quality. Minimal anthropogenic contamination reflects the absence of factories and low pesticide use. Microbiological risks are low but not zero, requiring seasonal monitoring. Community-level awareness and sustainable practices are recommended to maintain water quality amid coastal development pressures. This study establishes a baseline for rural aquifer chemistry and highlights the importance of proactive management.

### FUTURE SCOPE

#### Expanded Sampling

Future research should not be limited to a single borewell but should encompass **multiple borewells across Marakanam and neighbouring villages**. This will provide a more representative dataset that captures spatial variability in aquifer chemistry. Sampling at different depths can also reveal vertical stratification of contaminants, helping to distinguish shallow aquifer dynamics from deeper reserves.

#### Microbiological Testing

While physicochemical parameters confirm safety, **microbiological testing is essential** for a comprehensive assessment of potability. Parameters such as *E. coli*, total coliforms, and fecal streptococci can be included to assess microbial intrusion risks, especially during the monsoon season. This will strengthen public health relevance by linking water quality directly to disease prevention.

#### Seasonal Variation Studies

Groundwater chemistry is not static; it fluctuates with rainfall, recharge, and agricultural cycles. **Seasonal variation studies** can reveal the impact of monsoon recharge on aquifer chemistry, highlighting changes in TDS, chloride, and microbial load. Longitudinal monitoring across dry and wet seasons will provide insights into aquifer resilience and vulnerability.

### Policy Recommendations

Establishing **rural water quality surveillance units** should be prioritized. These units can conduct quarterly testing, maintain community records, and provide early warnings of contamination. Integration with **state groundwater boards and local panchayats** will ensure accountability and policy alignment. Linking surveillance data to digital platforms can enhance transparency and accessibility.

### Comparative Studies

Comparative research with **industrial belts such as Ranipet and SIPCOT Cuddalore** will contextualize Marakanam's findings. By contrasting pristine aquifers with polluted ones, researchers can highlight the role of geography, land use, and industrial activity in shaping water quality. This comparative lens strengthens the credibility of Marakanam's baseline study.

### Technological Innovations

Future work should incorporate **GIS mapping, sensor networks, and predictive modelling**. GIS can identify vulnerable aquifer zones, while sensor networks enable real-time monitoring of pH, conductivity, and microbial indicators. Predictive models can forecast saline intrusion risks under climate change scenarios, guiding proactive interventions.

### Community Engagement

Community participation is vital for sustainability. Future studies should include **household surveys** on water usage, storage practices, and perceptions of borewell safety. This socio-cultural dimension will enrich scientific findings and ensure that recommendations are practical and community-driven.

Future research must move beyond single-sample analysis to a **multi-dimensional framework**: expanded sampling, microbiological testing, seasonal monitoring, policy integration, comparative studies, technological innovation, and community engagement. Together, these directions will transform Marakanam's baseline study into a **comprehensive model for rural aquifer resilience**.

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