

## WATER QUALITY ASSESSMENT IN PERI-URBAN SETTLEMENTS

**Dr. Mayuri Chabukdhara**

Associate Professor & Head

Department of Environmental Biology and Wildlife Sciences

Cotton University, Guwahati, Assam, India

### **Abstract**

Peri-urban settlements occupy the changing interface between cities and rural landscapes. Their water environments are affected by rapid land conversion, dispersed housing, incomplete sanitation networks, mixed water supplies, informal economic activity, agricultural runoff, and uneven local governance. In these settings, water-quality assessment is not merely a laboratory exercise. It is a public-health, environmental-planning, and service-delivery function that must identify both the condition of water sources and the pathways through which contamination reaches households, ecosystems, and food-production areas. Surface water, shallow groundwater, borewells, piped supplies, tanker water, household storage, ponds, and drainage channels may coexist within a small area, making a single-source interpretation inadequate.

This paper presents a qualitative, literature-based assessment framework for understanding water quality in peri-urban settlements. It reviews the physical, chemical, microbiological, and contextual indicators needed for systematic assessment; examines source-specific and seasonal risks; and relates monitoring design to the practical realities of informal infrastructure. The discussion draws on drinking-water guidance, water-quality criteria, standard analytical methods, water-safety planning, and research on peri-urban environmental change. The analytical sequence covers reconnaissance, source mapping, sampling design, field measurement, laboratory analysis, comparison with applicable benchmarks, interpretation of contamination pathways, and communication of results to communities and local institutions.

The study finds that effective assessment requires more than isolated testing of pH, total dissolved solids, or coliform bacteria. Reliable interpretation depends on repeated sampling across seasons, source protection review, sanitation and drainage mapping, safe sample handling, quality assurance, and clear distinction between drinking-water suitability, domestic-use suitability, irrigation considerations, and aquatic-environment conditions. Microbiological contamination often requires immediate attention where sanitation is inadequate, while nutrients, salinity, fluoride, iron, and selected metals may reflect a combination of geogenic and anthropogenic processes. The paper concludes that peri-urban water-quality assessment should be organised as a risk-based and locally accountable process. It should link evidence to feasible action, including source protection, sanitation upgrades, drainage management, treatment, safe storage, surveillance, and transparent public communication.

**Keywords:** Water Quality, Peri-Urban Settlements, Drinking Water Safety, Groundwater, Microbiological Contamination, Water Quality Index, Sanitation, Environmental Monitoring, Urbanisation, Public Health

### **1. INTRODUCTION**

Peri-urban settlements are neither fully rural nor fully urban. They are dynamic territories where agricultural land, new housing, industrial or commercial activities, transport corridors, water bodies, and informal service arrangements overlap. Their population growth may be faster than the expansion of public infrastructure, producing gaps in wastewater collection, solid-waste management, drainage, and reliable water

supply. Such conditions create multiple exposure routes for water contamination. Households may draw water from shallow wells, municipal standposts, private borewells, tankers, streams, ponds, or stored supplies, and the quality of one source may differ sharply from another within the same locality. Water-quality assessment must therefore recognise spatial diversity, service intermittency, and the role of season in shaping exposure.

Water quality refers to the physical, chemical, biological, and radiological characteristics of water in relation to a particular use. A result that is acceptable for one purpose may be unsuitable for another. For example, water used for domestic cleaning may require a different interpretation than drinking water, irrigation, livestock use, recreation, or protection of aquatic ecosystems. Drinking-water assessment is particularly sensitive because contamination can lead to immediate health risks, especially where faecal indicators are present. The World Health Organization promotes a risk-management approach that considers the whole system from catchment and source to collection, storage, and point of use [1]. In India, water-quality comparison may also require reference to applicable Bureau of Indian Standards specifications and Central Pollution Control Board criteria [2, 3]. Rapid peri-urban change can intensify both point and non-point pollution. Leaking septic tanks, poorly maintained pits, open drains, uncollected waste, wastewater discharge, livestock areas, small workshops, brick kilns, construction sites, and fertilizer application can affect nearby water sources. Flooding and monsoon runoff may carry contaminants across settlement boundaries, while dry-season scarcity can increase dependence on shallow or previously unused sources. The health and environmental consequences are often unequally distributed. Lower-income households, renters, migrant workers, women responsible for water collection, and communities located close to drains or waste-disposal sites may have fewer options to avoid unsafe supplies. The assessment process should consequently combine laboratory findings with an understanding of access, affordability, source reliability, and local vulnerability.

A technically sound assessment begins with a clear question. Is the purpose to assess drinking-water safety, identify contamination of groundwater, evaluate surface-water degradation, prioritise sanitation improvements, monitor a restoration programme, or compare conditions across neighbourhoods? The question determines which sources, parameters, methods, and sampling periods are relevant. A test result without context can be misleading. For

instance, elevated turbidity after a heavy rainfall event may reveal runoff intrusion; elevated nitrate in a shallow well may suggest a sanitation or agricultural pathway; and recurring coliform contamination in household samples may signal storage or distribution problems even when the source is relatively protected. Monitoring must therefore be designed to trace plausible pathways rather than simply produce a list of concentrations.

This paper examines water-quality assessment as an integrated process for peri-urban settlements. It synthesises established guidance and research to identify core indicators, recurring pressures, and practical monitoring steps. The aim is not to claim site-specific field results. Instead, the study provides a structured framework that researchers, local authorities, civil-society organisations, and service providers can adapt to a defined locality while maintaining transparent methods, quality assurance, and responsible communication of findings.

## 2. LITERATURE REVIEW

Water-quality research has consistently shown that urban expansion can modify hydrology, intensify pollutant loading, and expose water supplies to multiple contamination sources. The peri-urban interface is especially complex because land-use change often moves faster than formal infrastructure planning. Studies of peri-urban water quality emphasise that contamination is shaped not only by chemical loads and microbial hazards but also by inequalities in access to sanitation, drainage, service regulation, and political representation. Karpouzoglou and colleagues describe water-quality decline in peri-urban areas as linked to both environmental pressures and social or land-use inequalities [11]. This perspective is important because it directs assessment beyond a narrow laboratory model toward the social and institutional conditions that allow risks to persist.

A second stream of literature concerns the selection and interpretation of indicators. Standard physical measures such as pH, temperature, turbidity, electrical conductivity, and total dissolved solids provide immediate information about source conditions and possible changes in water chemistry. Chemical indicators such as nitrate, fluoride, chloride, sulphate, iron, hardness, ammonia, phosphate,

and selected metals may identify agricultural runoff, wastewater influence, geogenic conditions, industrial sources, or saline intrusion. Microbiological indicators, including *E. coli* and thermotolerant coliforms, are central where drinking-water safety is considered because they can reveal faecal contamination and the need for urgent risk control. Standard methods guidance stresses that sampling, preservation, analytical procedures, and laboratory quality control all influence the reliability of results [4].

Water-quality indices and multivariate methods are also frequently used to summarise complex data. Classical index approaches aim to communicate overall conditions in a form understandable to decision-makers and communities, while statistical methods can identify spatial, seasonal, and parameter-level patterns. However, an index should not conceal critical health hazards or replace source-specific interpretation. A water source with acceptable overall index values may still be unsafe for drinking if microbiological results indicate contamination. The literature therefore supports a combined approach: use transparent indicators and, where appropriate, an index or statistical summary; retain raw parameter results; and interpret outcomes in relation to intended use, seasonal context, and likely contamination pathways [14-20].

## 2.1 CONCEPT AND SCOPE OF WATER-QUALITY ASSESSMENT

- Water-quality assessment is the systematic examination of water characteristics in relation to a defined use, environmental condition, or risk-management objective.
- It includes planning, site reconnaissance, source mapping, sample collection, field measurement, laboratory analysis, data validation, comparison with applicable benchmarks, and communication of results.
- In peri-urban areas, assessment should include both water sources and the surrounding exposure environment, such as sanitation systems, drains, waste sites, livestock areas, industrial activity, agricultural plots, and household storage practices.
- The assessment must distinguish between source quality, distribution quality, stored-

water quality, and the broader ecological condition of receiving water bodies.

## 2.2 WATER-QUALITY CHALLENGES IN PERI-URBAN SETTLEMENTS

- Rapid land conversion can reduce natural infiltration areas, alter drainage pathways, and increase contaminated runoff during rainfall events.
- On-site sanitation, leaking sewers, unlined drains, and unmanaged wastewater may introduce pathogens, nutrients, ammonia, and organic pollution into shallow groundwater and surface water.
- Intermittent piped supplies, tanker dependence, and household storage can create additional risks through contamination during transport, low-pressure intrusion, or inadequate cleaning of containers.
- Geogenic conditions such as fluoride, iron, salinity, or hardness may coexist with anthropogenic contamination and require careful interpretation rather than a single-cause explanation.
- Limited laboratory access, short monitoring periods, lack of source inventories, and weak communication of results may prevent communities from converting water-quality information into protective action.

## 2.3 MONITORING FRAMEWORKS AND ASSESSMENT TOOLS

- Risk-based drinking-water management links catchment conditions, source protection, treatment, distribution, storage, and consumer practices rather than relying only on end-point testing [1, 5].
- Water-quality criteria and standards provide benchmarks, but the choice of benchmark must match the intended use and the relevant national or local regulatory context [2, 3].
- Field instruments, laboratory analysis, sanitary inspection, geographic mapping, seasonal sampling, and community reporting complement one another in understanding both condition and cause.
- Water-quality indices and multivariate techniques can assist communication and pattern recognition, provided that individual microbiological and chemical risks remain visible [14-20].

## 3. OBJECT OF STUDY

The present study examines water-quality assessment in peri-urban settlements as a combined environmental and public-health activity. The object of study is not a single settlement or a specific dataset. Rather, it is the assessment process needed to evaluate diverse water sources and exposure pathways in rapidly changing urban-rural fringe areas. The analysis considers the interaction between water-source characteristics, local land use, sanitation arrangements, drainage, household practices, and seasonal conditions. It treats water quality as a property that must be assessed in relation to use, risk, and context rather than as a universal score.

The theoretical basis of the study is that safe and sustainable water management depends on

linking measurement with preventive action. A borewell result without information about nearby sanitation, a drainage-channel result without catchment context, or a household-storage result without knowledge of collection practices cannot adequately explain risk. The analysis therefore views each sample as part of a wider system involving source protection, infrastructure, behaviour, local governance, and ecological conditions. This approach supports more meaningful interpretation and helps avoid recommendations that are technically correct but infeasible for local communities.

### 3.1 WATER-QUALITY PARAMETERS AND ASSESSMENT PRIORITIES

| S. No. | Water-Quality Parameter Group     | Primary Indicators                                                                            | Typical Peri-Urban Pressure                                                                | Assessment and Management Relevance                                                                                 |
|--------|-----------------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 1      | Physical characteristics          | pH, temperature, turbidity, electrical conductivity, total dissolved solids                   | Road dust, construction runoff, shallow wells, intermittent supply and poor storage        | Indicates aesthetic quality, salinity-related stress, source disturbance and the need for immediate field screening |
| 2      | Microbiological quality           | E. coli, thermotolerant coliforms, total coliforms                                            | On-site sanitation, leaking sewers, open drains, animal waste and flooding                 | Identifies faecal contamination and supports risk-based action for drinking-water safety                            |
| 3      | Nutrients and organic pollution   | Nitrate, ammonia, phosphate, dissolved oxygen, BOD and COD                                    | Domestic wastewater, fertilizer runoff, informal commercial activity and stagnant drainage | Reveals nutrient enrichment, oxygen depletion and the likely contribution of untreated wastewater                   |
| 4      | Major ions and selected chemicals | Fluoride, chloride, sulphate, iron, hardness and selected metals where relevant               | Geogenic conditions, landfill leachate, industrial clusters and saline intrusion           | Supports comparison with applicable standards and helps distinguish natural from anthropogenic influences           |
| 5      | Site and service context          | Land use, sanitation type, distance to drains, source protection, storage practice and season | Rapid land conversion, mixed service arrangements and weak waste management                | Explains the pathways behind measured results and assists in prioritising interventions                             |

### 3.2 STUDY OBJECTIVES

- To examine the principal water-quality risks affecting peri-urban settlements and

the environmental pathways through which contamination may occur.

- To identify the physical, chemical, microbiological, and contextual parameters required for a practical assessment framework.
- To analyse how land-use change, sanitation, drainage, water-service arrangements, and seasonality influence water quality and exposure.
- To evaluate the role of sampling design, quality assurance, sanitary inspection, and benchmark selection in producing reliable results.
- To develop a risk-based framework that connects assessment findings with source protection, treatment, sanitation, monitoring, and community communication.

#### 4. RESEARCH METHODOLOGY

The study adopts a qualitative, literature-based research methodology. It synthesises international guidance, national water-quality criteria, standard analytical methods, and peer-reviewed studies on peri-urban environmental change and water-quality assessment. This approach is suitable because the paper seeks to organise an assessment framework rather than report numerical findings from a particular field campaign. The methodology focuses on how a sound assessment should be planned, implemented, interpreted, and translated into action in settlements where infrastructure and environmental conditions are heterogeneous.

The analytical framework follows a source-to-user perspective. It begins with mapping the water environment and identifying intended uses of water. It then considers sampling locations, parameters, field and laboratory procedures, seasonal timing, sanitary inspection, data validation, comparison with benchmarks, and communication of results. The framework recognises that water quality can change between source, distribution point, household storage, and use. It also recognises that a result can be influenced by both natural hydrogeology and human activity. For this reason, the methodology uses contextual interpretation rather than attributing all exceedances to a single cause.

##### 4.1 RESEARCH DESIGN (QUALITATIVE ANALYTICAL APPROACH)

- The study follows a qualitative and comparative research design based on established public-health, environmental-

monitoring, and water-management literature.

- It compares water sources and risk pathways according to source type, land-use setting, sanitation condition, exposure route, and expected seasonal variation.
- The design uses a systems perspective that links field measurements with source protection, service conditions, household practices, and institutional response.
- Findings are interpreted as a framework for assessment and action rather than as statistically generalisable measurements from one locality.

##### 4.2 WATER-QUALITY ASSESSMENT FRAMEWORK

- The framework begins with reconnaissance and mapping of wells, borewells, standposts, tankers, surface-water bodies, drains, sanitation facilities, waste sites, and land-use activities.
- Sampling should include representative sources and, where drinking water is used, both source and point-of-use samples when feasible.
- Core parameters include physical indicators, microbiological indicators, major ions and nutrients, and selected contaminants based on local risk screening.
- Quality assurance includes calibrated field instruments, sterile microbiological containers, appropriate preservation, chain-of-custody records, duplicate samples where feasible, and laboratory controls.
- Results should be interpreted against the applicable standard or guideline for the intended use and discussed with attention to uncertainty, seasonality, and possible contamination pathways.

##### 4.3 STUDY CONTEXT AND UNIT OF ANALYSIS

- The study considers peri-urban settlements that may rely on a combination of municipal, private, groundwater, surface-water, and stored-water supplies.
- The unit of analysis is the water-source and exposure setting, including the relationship among source condition, surrounding land use, service reliability, sanitation, drainage, and household handling.

- Potential water environments include shallow and deep groundwater, piped distribution points, tanker supplies, ponds, streams, stormwater channels, irrigation water, and domestic storage containers.
- The framework gives special attention to populations with limited ability to choose alternative sources or to afford household treatment and safe storage.

#### 4.4 PARAMETERS OF ANALYSIS

The following parameters are evaluated within the proposed assessment framework:

- Physical appearance and field characteristics, including turbidity, pH, temperature, electrical conductivity, and total dissolved solids.
- Microbiological indicators, particularly *E. coli* or equivalent faecal indicators where drinking-water safety is under consideration.
- Chemical indicators selected through local risk screening, including nitrate, fluoride, iron, chloride, sulphate, hardness, ammonia, phosphate, and selected metals where justified.
- Organic-pollution and ecological indicators for surface waters, including dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, and nutrient status.
- Contextual variables, including proximity to sanitation, drainage, landfills, livestock areas, agricultural activity, industrial clusters, flood-prone zones, and water-storage conditions.
- Governance and service variables, including supply intermittency, treatment arrangements, maintenance responsibilities, reporting systems, and community access to information.

#### 4.5 PROCEDURE OF STUDY

- Review water-quality guidance, monitoring standards, and research on peri-urban environmental change.
- Identify major exposure pathways and map the relationship between sources, sanitation, drainage, land use, and household water practices.
- Develop a sampling and analysis plan that specifies source types, locations, timing, parameters, containers, preservation requirements, and quality-assurance procedures.

- Interpret physical, chemical, and microbiological results alongside sanitary inspection observations and site context.
- Compare results with appropriate use-based benchmarks while documenting uncertainty and limitations.
- Develop recommendations that prioritise immediate health protection, source protection, sanitation and drainage improvement, monitoring continuity, and public communication.

#### 4.6 ANALYTICAL APPROACH

- Qualitative comparison of water-quality risks and contamination pathways across different source and settlement conditions.
- Interpretation of how physical, chemical, microbiological, and contextual evidence can be combined to identify probable sources of risk.
- Assessment of how seasonality, source intermittency, and household storage may alter exposure even when one-time laboratory results appear satisfactory.
- Identification of interventions that are scalable for communities, local governments, utilities, and environmental agencies.

#### 5. DATA ANALYSIS

The qualitative analysis indicates that peri-urban water-quality assessment must be designed around heterogeneity. Water sources within the same settlement may be influenced by different hydrogeological conditions, infrastructure failures, and contamination pathways. Shallow groundwater can be vulnerable to sanitation leakage and runoff, while deep borewells may be less exposed to microbial contamination but can still contain naturally occurring constituents such as fluoride, iron, salinity, or hardness. Piped water may meet source-level expectations yet become contaminated during intermittent distribution, illegal connections, low-pressure intrusion, or household storage. Surface water often reflects cumulative catchment pressures and is particularly sensitive to untreated wastewater, solid waste, nutrient inputs, and stormwater flows.

Microbiological quality requires special attention where water is consumed without effective treatment. The presence of faecal indicators should not be treated as a minor deviation because it signals a potential route

for waterborne disease. Its interpretation should be linked to sanitary inspection: the distance between a well and a sanitation facility, the integrity of the wellhead, drainage direction, flooding history, animal access, collection and storage practices, and the maintenance of distribution systems. A risk-based response may include immediate household guidance on boiling, chlorination, filtration, safe storage, or source substitution, alongside longer-term measures such as drainage repair, source protection, sanitation upgrading, and monitoring.

Chemical results require a similarly contextual reading. Nitrate and ammonia can indicate wastewater or agricultural influence, but the likely pathway depends on land use, season, depth of groundwater, and local geochemistry. Elevated electrical conductivity, chloride, sulphate, or total dissolved solids can reflect natural mineralisation, wastewater inputs, salinity, or mixing between sources. Fluoride and iron may be primarily geogenic in some regions but still create significant public-health or acceptability concerns. For this reason, one-size-fits-all explanations should be avoided. Results should be verified through repeat sampling, cross-checking of field and laboratory measurements, and comparison with local background conditions when available.

Surface-water assessment benefits from examining relationships among dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nutrients, turbidity, and microbial indicators. Low dissolved oxygen in combination with elevated organic load may suggest wastewater influence, while nutrient enrichment can promote algal growth and reduce ecological quality. In peri-urban wetlands, ponds, and streams, these patterns may be seasonal and can be affected by both formal and informal discharge points. Mapping outfalls, drains, and upstream activities can be as important as sampling the receiving water itself. The most useful analysis therefore combines numerical results with a visual and spatial record of likely inputs.

The analysis also shows the importance of communicating results in a way that does not create false reassurance or unnecessary alarm. Water-quality reports should clearly state the sampled source, date, parameters, methods,

intended use, applicable benchmark, uncertainties, and recommended action. An overall index may assist community communication, but it should never replace disclosure of critical results such as microbiological contamination or a significant chemical exceedance. Transparent reporting helps households, service providers, and local authorities understand what is known, what remains uncertain, and what actions are feasible in the short and long term.

## 6. DISCUSSION

The analysis confirms that peri-urban water quality is an infrastructure and governance issue as much as a laboratory issue. Rapid urban growth often creates a mismatch between population needs and the capacity of water, sanitation, drainage, and waste-management systems. Monitoring can reveal contamination, but monitoring alone cannot reduce risk unless it is connected to accountable response. Communities need clear information, utilities need maintenance capacity, local governments need coordinated land-use and sanitation planning, and environmental agencies need an ability to track sources that cross administrative boundaries. A fragmented institutional response can leave peri-urban residents dependent on temporary or unregulated water arrangements even when contamination is already known.

An effective assessment programme should be proportionate and risk-based. It is neither necessary nor feasible to test every possible parameter at every location in every sampling round. Instead, baseline reconnaissance should identify the most plausible hazards, representative sources, vulnerable populations, and critical times of year. Routine monitoring can then focus on a core set of indicators, while targeted investigations are used for known industrial risks, suspected geogenic contaminants, flood events, or unusual changes in field conditions. This approach makes better use of limited resources without ignoring local specificity.

The discussion also highlights the value of combining formal science with community knowledge. Residents often know which wells become turbid after rain, which drains overflow, where tanker water is sourced, or when water taste and colour change. Their

observations can guide sampling design and help explain patterns that laboratory results alone do not capture. Community participation should, however, be accompanied by transparent methods and professional laboratory practice. It should not transfer the burden of public-service failures to households. Rather, it should strengthen accountability and improve the relevance of monitoring decisions.

Climate variability and extreme weather add another layer of risk. Intense rainfall, flooding, prolonged dry spells, and heat can alter source availability, mobilise contaminants, concentrate dissolved constituents, and disrupt water-treatment or sanitation systems. Peri-urban monitoring plans should therefore include seasonal rounds and contingency procedures following flood or contamination events. In the longer term, source protection, decentralized wastewater management, improved drainage, recharge protection, reliable piped supply, and nature-based measures can reduce contamination pressure while strengthening local resilience. The strongest strategy is one that connects environmental protection, public health, and inclusive service planning.

## 7. CONCLUSION

This study examined water-quality assessment in peri-urban settlements through a qualitative, risk-based framework. It showed that meaningful assessment extends beyond single laboratory tests. Water sources must be evaluated in relation to their intended use, surrounding land use, sanitation and drainage

conditions, source protection, distribution reliability, household storage, and seasonal change. Physical, chemical, microbiological, and contextual indicators each contribute different evidence, and their interpretation is strongest when combined with sanitary inspection, mapping, quality assurance, and repeat monitoring.

The analysis found that fecal contamination, nutrient and organic pollution, salinity-related stress, geogenic constituents, and source intermittency can coexist in peri-urban settings. These risks cannot be addressed by one universal intervention. Depending on the pathway, responses may include immediate household risk reduction, treatment, wellhead protection, drainage repair, sanitation upgrading, wastewater management, supply maintenance, land-use controls, and transparent surveillance. The use of water-quality indices and summary tools can be helpful, but they should not obscure critical individual results or the uncertainty attached to a one-time sample.

Water-quality assessment should ultimately serve people and ecosystems, not only reporting requirements. When monitoring programmes communicate clearly, involve communities appropriately, use sound methods, and link findings to feasible institutional action, they can support safer drinking water, healthier local environments, and more equitable peri-urban development. Sustained assessment is therefore best understood as a continuing public-health and environmental-governance responsibility.

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