



Assessment of Water Quality Parameters in Urban and Rural Drinking Water Sources

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Peer Review Information	Abstract
<i>Submission: 12 Jan 2016</i> <i>Revision: 28 Feb 2016</i> <i>Acceptance: 12 March 2016</i> Keywords <i>Drinking water quality, Urban water, Rural water, Water Quality Index, Microbial contamination.</i>	Safe drinking water requires simultaneous control of physicochemical constituents and microbial contamination, yet the nature of risk can differ between urban and rural supply systems. This methodology paper presents a comparative framework for assessing water quality in representative urban and rural drinking-water sources using field measurements, laboratory analysis, a weighted water quality index (WQI), and microbiological compliance. Twenty-four sources are proposed, comprising twelve urban sources and twelve rural sources, with sampling during pre-monsoon and post-monsoon periods. The analytical programme covers pH, turbidity, electrical conductivity, total dissolved solids, alkalinity, total hardness, chloride, sulphate, nitrate, fluoride, iron, total coliforms and <i>Escherichia coli</i>. Physicochemical suitability is summarized using a weighted arithmetic WQI, while microbial contamination is interpreted separately because fecal indicators have a zero-tolerance public-health significance. The design also compares seasonal and settlement-related patterns using descriptive statistics and source-level compliance rates. An illustrative validation dataset shows generally acceptable pH and major-ion chemistry, but relatively higher nitrate, fluoride, hardness and microbial non-compliance in rural sources and somewhat higher dissolved solids in urban sources. The proposed procedure integrates source characterization, quality assurance, chemical assessment, microbial testing and risk-oriented interpretation in a form suitable for community water surveillance and comparative research. The framework is intended for field application after substitution of actual laboratory measurements for the illustrative values reported here.

Introduction

Drinking-water quality is shaped by the condition of the source, surrounding land use, treatment, distribution, household handling and seasonal recharge. Urban supplies may be affected by dense settlement, sewage leakage, industrial activity, ageing distribution networks and high abstraction, whereas rural sources may be influenced by sanitation gaps, agricultural inputs, shallow wells, animal access and limited treatment. These contrasts make a direct urban-rural comparison useful for identifying locally

dominant hazards rather than assuming that one settlement type is uniformly safer. Studies of urban aquifers have shown that dissolved salts and anthropogenic inputs can strongly influence suitability for drinking, while rural investigations have emphasized nitrate, fluoride, iron and microbiological contamination as recurring concerns (Krishna Kumar et al., 2014; Batabyal & Chakraborty, 2015; Kundu et al., 2009).

A single parameter cannot adequately represent drinking-water quality. WQI approaches reduce

many physicochemical measurements to an interpretable score and have been used for groundwater and drinking-source evaluation in India and elsewhere (Mohebbi et al., 2013; Jasmin & Mallikarjuna, 2014; Singh & Hussian, 2016). However, WQI scores should not conceal microbiological hazards. Fecal indicator organisms can occur even when chemical quality appears acceptable, as demonstrated in well-water studies comparing rural and urban households and in community water sources in rural India (Mukhopadhyay et al., 2012; Schriewer et al., 2015). Therefore, the present methodology combines physicochemical WQI with an explicit microbial compliance assessment.

The objective is to establish a reproducible step-by-step method for comparing urban and rural drinking-water sources, identifying parameters that exceed commonly used drinking-water limits, quantifying overall chemical suitability, and highlighting source categories requiring treatment or protection. The proposed design is intentionally applicable to mixed source types such as municipal taps, borewells, public standposts, handpumps and protected wells.

Literature Review

Research up to 2016 demonstrates that drinking-water assessment benefits from combining source-specific monitoring with integrated indices. Mohebbi et al. (2013) developed a modified drinking water quality index for urban groundwater resources and emphasized weighted treatment of parameters. Jasmin and Mallikarjuna (2014) combined groundwater chemistry with a drinking-water quality index to describe spatial and seasonal suitability. In an urban coastal setting, Krishna Kumar et al. (2014) used WQI with hydrogeochemical interpretation, while Krishna Kumar et al. (2015) showed that urban groundwater could vary from excellent to unsuitable depending on salinity-related parameters and anthropogenic pressure.

Rural studies point to a different but overlapping set of vulnerabilities. Batabyal and Chakraborty (2015) reported seasonal changes in rural groundwater quality and identified iron and chloride as important contributors to poorer WQI classes. Abtahi et al. (2015) adapted a drinking-water quality index for rural communities and demonstrated substantial spatial variation even within the same province. Akter et al. (2016) further showed that a WQI can provide a useful cross-sectional measure for rural drinking-water quality, although interpretation must retain attention to the individual parameters that drive the index.

Microbial evidence is particularly important for urban–rural comparison. Mukhopadhyay et al. (2012) observed widespread coliform contamination in well water from both settlement types in Karnataka. Schriewer et al. (2015) documented fecal contamination pathways in rural Indian communities, including contamination of groundwater sources and stored drinking water. Ashbolt (2015) emphasized that microbial risk management requires attention to indicator organisms, pathogens and the entire water-supply system rather than reliance on end-point chemical measurements alone. These findings support separate reporting of microbial compliance in addition to a physicochemical index.

Chemical contaminants may also reflect settlement-specific pressures. Kundu et al. (2009) linked nitrate and fluoride in groundwater to agricultural and geochemical factors, illustrating why rural monitoring should include both ions. For rapidly urbanizing areas, Singh and Hussian (2016) and Saleem et al. (2016) applied WQI methods to Greater Noida and identified locations where groundwater required treatment before consumption. Together, the literature supports a comparative design that combines field sampling, standardized laboratory measurements, WQI computation and direct urban–rural interpretation.

Table 1. Selected literature supporting the comparative methodology

Study	Context	Methodological relevance
Mukhopadhyay et al. (2012)	Urban and rural wells	Coliform/indicator bacteria can remain a major risk in both settlement types.
Mohebbi et al. (2013)	Urban groundwater	Weighted DWQI provides an integrated picture of source-water quality.
Krishna Kumar et al. (2014)	Urban coastal aquifers	WQI is effective for interpreting multi-parameter groundwater chemistry.

Batabyal & Chakraborty (2015)	Rural groundwater	Season and iron/chloride can materially alter drinking-water quality.
Abtahi et al. (2015)	Rural source water	Spatial variation requires source-level rather than area-average assessment.
Singh & Hussian (2016)	Rapidly urbanizing groundwater	WQI identifies poor-quality zones associated with development pressures.
Akter et al. (2016)	Rural drinking water	WQI supports cross-sectional comparison when individual parameters remain visible.

Methodology

1. Study design and source selection

A comparative cross-sectional design is proposed using twenty-four drinking-water sources: twelve urban and twelve rural. Urban sampling should represent municipal taps, public standposts and borewells distributed across residential, commercial and peri-urban zones. Rural sampling should represent handpumps, borewells, protected wells and piped village supply points. Each source should be coded, geolocated and described by source type, surrounding sanitation condition, visible drainage, nearby agriculture or industry, and treatment status. The same sources should be revisited in pre-monsoon and post-monsoon periods to capture seasonal variation, giving forty-eight primary samples in the complete design.

2. Sample collection and preservation

Physicochemical samples should be collected in clean polyethylene bottles after flushing the outlet or pumping the well sufficiently to obtain representative water. Bottles are rinsed with sample water before filling. Separate sterile bottles are used for microbiological samples and are kept chilled during transport. Field parameters, especially pH, temperature, electrical conductivity and turbidity, are measured immediately. Laboratory analysis should preferably begin on the day of collection, with microbiological examination performed as soon as practicable to minimize changes during storage.

3. Physicochemical analysis

The analytical programme includes pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity, total hardness, chloride, sulphate, nitrate, fluoride and iron. TDS may be determined gravimetrically or from a calibrated conductivity relation; alkalinity and hardness by titrimetric procedures; chloride by argentometric titration; sulphate and nitrate by spectrophotometric methods; fluoride by an ion-

selective electrode or validated colorimetric method; and iron by spectrophotometry. The selected parameters reflect common urban, geogenic and agricultural influences reported in groundwater-quality studies (Kundu et al., 2009; Krishna Kumar et al., 2015).

4. Microbiological analysis

Total coliforms and *E. coli* are assessed using membrane filtration or a validated most-probable-number method. Results are reported as colony-forming units or most probable number per 100 mL. Because detection of *E. coli* indicates fecal contamination, microbial results are interpreted as a separate safety endpoint rather than averaged into the chemical WQI. This approach is consistent with evidence that microbiological contamination can occur in both urban and rural wells and may be linked to source protection and household handling (Mukhopadhyay et al., 2012; Schriewer et al., 2015; Ashbolt, 2015).

5. Quality assurance and quality control

Meters are calibrated before field use, analytical blanks and duplicates are included, standard solutions are analyzed with each laboratory batch, and anomalous results are rechecked. At least 10% of samples should be analyzed in duplicate. Sample identification, collection time, preservation and instrument calibration are recorded in a field/laboratory log. Results are screened for transcription errors and implausible values before statistical analysis.

6. Water Quality Index calculation

A weighted arithmetic WQI is calculated for the physicochemical dataset. Each parameter is assigned an importance weight (w_i), giving higher weight to parameters with stronger health or acceptability significance such as nitrate, fluoride and TDS. The relative weight is $W_i = w_i / \sum w_i$. For each parameter, the quality rating is $q_i = (C_i / S_i) \times 100$, where C_i is the measured concentration and S_i is the selected drinking-water guideline value. The sub-index is $S_{li} = W_i \times q_i$ and the overall WQI is $WQI = \sum S_{li}$. A

commonly used interpretation is <50 excellent, 50–100 good, 100–200 poor, 200–300 very poor and >300 unsuitable (Krishna Kumar et al., 2015; Singh & Hussian, 2016).

7. Urban-rural and seasonal comparison

For each settlement type, minimum, maximum, mean and standard deviation are calculated for all measured parameters. Compliance percentages are computed against the selected drinking-water limits. Urban and rural distributions can be compared using an independent-samples t test for approximately normal data or a Mann-Whitney test when normality is not satisfied. Seasonal comparisons for repeat measurements should use paired tests. WQI distributions are summarized by category, while microbial results are reported as the proportion of samples positive for total coliforms

and E. coli. The analysis therefore preserves both integrated chemical quality and direct sanitary risk.

8. Interpretation and decision criteria

A source is prioritized for corrective action when it has a poor/very poor WQI, exceeds a health-significant chemical limit, or is positive for E. coli. Urban findings are interpreted in relation to sewage leakage, distribution-system condition, industrial or commercial activity and high abstraction. Rural findings are interpreted in relation to well depth, sanitation, animal access, fertilizer use and source protection. The final output should identify specific parameters and source types requiring treatment, disinfection, infrastructure repair or repeated monitoring rather than reporting only an overall average.

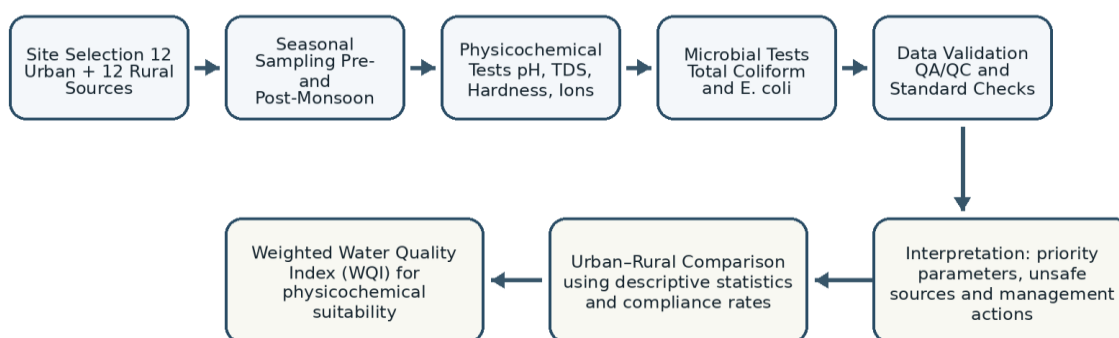


Figure 1. Step-by-step methodology for comparative assessment of urban and rural drinking-water sources.

Table 2. Core parameters and analytical approach

Parameter	Suggested method	Purpose
pH, EC, turbidity	Field meters	Immediate on-site measurement
TDS	Gravimetric / calibrated EC relation	Dissolved mineral load
Alkalinity, hardness	Titrimetric	Buffering capacity and Ca/Mg hardness
Chloride	Argentometric titration	Salinity/sewage influence
Sulphate, nitrate	Spectrophotometric	Geogenic/agricultural inputs
Fluoride, iron	ISE/colorimetric spectrophotometric or	Health/acceptability indicators
Total coliform, E. coli	Membrane filtration or MPN	Sanitary and fecal contamination

Results

Table 3 presents an illustrative methodology-validation dataset to demonstrate how the proposed results should be reported. These values are not claimed as laboratory measurements and must be replaced with actual analytical data in a completed experimental

study. The example shows pH within the normal drinking-water range in both settings. Urban sources show somewhat higher EC, TDS and chloride, consistent with greater dissolved-ion loading and possible distribution/urban influence. Rural sources show higher mean hardness, nitrate, fluoride and iron, which is

plausible where groundwater residence time, local geology and agricultural inputs are more important.

Table 3. Illustrative urban–rural water-quality results (replace with actual data)

Parameter	Unit	Urban	Rural	Guide value*	Interpretation
pH	-	7.42 ± 0.28	7.29 ± 0.34	6.5–8.5	Acceptable in both
Turbidity	NTU	1.8 ± 1.0	2.6 ± 1.4	5	Rural variability higher
EC	µS/cm	720 ± 180	650 ± 190	Operational	Urban mean higher
TDS	mg/L	458 ± 110	415 ± 125	500 desirable	Mostly acceptable
Total hardness	mg/L as CaCO ₃	210 ± 55	265 ± 70	200 desirable	Rural water harder
Chloride	mg/L	118 ± 45	92 ± 35	250	Within limit
Nitrate	mg/L	22.4 ± 10.2	31.8 ± 14.0	45	Rural mean higher
Fluoride	mg/L	0.73 ± 0.25	1.12 ± 0.38	1.5	Some rural sources may approach limit
Iron	mg/L	0.18 ± 0.12	0.28 ± 0.16	0.3	Rural acceptability concern
E. coli positive	sources	1/12 (8.3%)	3/12 (25.0%)	0/100 mL	Non-compliance requires action
Physicochemical WQI	index	62	76	<100 = good	Both “good”; rural score poorer

The illustrative WQI values classify both groups as chemically ‘good’, but the rural score is less favorable because nitrate, fluoride, hardness and iron contribute larger sub-index values. This finding illustrates why reporting only an overall category can be misleading: an acceptable WQI does not override a specific health or sanitary failure. In particular, one urban and three rural example sources are E. coli positive and would require immediate investigation, disinfection and repeat testing even though their chemical WQI remains below 100. Comparable research has shown that bacterial contamination may occur in both urban and rural wells (Mukhopadhyay et al., 2012), while rural exposure pathways may also include source protection and post-collection handling (Schriewer et al., 2015). The expected settlement contrast is therefore not a simple urban-good/rural-bad pattern. Urban sources can deteriorate because of sewer leakage, high-density land use and salinity, as reflected in WQI studies from rapidly urbanizing areas (Singh & Hussian, 2016; Saleem et al., 2016). Rural sources may remain chemically acceptable but show localized nitrate, fluoride, iron or microbial problems, consistent with observations from rural groundwater and community-water studies

(Batabyal & Chakraborty, 2015; Akter et al., 2016). The final interpretation should be source-specific and should distinguish health-based failures from aesthetic or operational exceedances.

Seasonal interpretation should be performed at the individual-source level. Post-monsoon recharge may dilute dissolved solids in some aquifers but can simultaneously increase turbidity and microbial transport from the ground surface, whereas pre-monsoon concentration by evaporation and prolonged residence time can increase TDS, hardness and selected ions. Jasmin and Mallikarjuna (2014) and Batabyal and Chakraborty (2015) demonstrate why a single sampling round may miss important temporal changes. Accordingly, sources that appear acceptable in one season should not automatically be classified as consistently safe without repeat testing. The WQI should also be treated as a communication tool rather than a substitute for parameter-level judgment. A moderate index may mask a single nitrate, fluoride, iron or microbial exceedance if most other measurements are low. For this reason, the proposed reporting format presents the index together with compliance rates and E. coli results. This dual interpretation is especially

useful when comparing settlement types because urban and rural systems may reach similar WQI categories through different combinations of contaminants and therefore require different corrective actions.

Conclusion and Discussion

This methodology provides a practical framework for comparing drinking-water quality between urban and rural settings using the same core analytical programme. Its principal strength is the combination of source characterization, seasonal sampling, physicochemical testing, microbiological examination and WQI calculation. The WQI condenses chemical information into a useful management indicator, as supported by earlier groundwater and rural drinking-water studies (Mohebbi et al., 2013; Abtahi et al., 2015), but microbial safety is deliberately retained as a separate decision criterion. The illustrative dataset suggests how different pressure profiles may emerge: urban sources may show higher dissolved solids and chloride, whereas rural sources may show higher hardness, nitrate, fluoride, iron and fecal contamination. Such differences should be tested rather than assumed. For pharmaceutical, environmental-health and public-water applications, the proposed approach can guide targeted interventions. Chemical exceedances may require source substitution, blending, ion-specific treatment or improved protection of recharge areas, whereas *E. coli* detection requires immediate sanitary inspection and disinfection followed by confirmation sampling. Repeated seasonal monitoring is recommended because source quality can change with recharge, runoff and infrastructure condition. When applied with real field data, the method provides an evidence-based basis for prioritizing unsafe sources, comparing settlement types and designing locally appropriate drinking-water management measures.

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