

Comparative Evaluation of Surface Water and Groundwater Quality Using Physicochemical Parameters: A Case Study of Raigarh District, Chhattisgarh, India

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Abstract

Surface water and groundwater are important resources for domestic, agricultural, and industrial activities, but their quality can vary with geology, land use, runoff, wastewater inputs, and water–rock interactions. This paper presents a comparative framework for evaluating selected physicochemical parameters in surface water and groundwater in Raigarh District, Chhattisgarh, India. For demonstration, an illustrative dataset of 12 samples (six surface-water and six groundwater samples) was created for pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total hardness, chloride, sulphate, nitrate, dissolved oxygen (DO), and biochemical oxygen demand (BOD). In this simulated dataset, groundwater has higher average TDS, EC, hardness, chloride, sulphate, and nitrate, while surface water has higher turbidity and BOD and lower DO.

Keywords: Surface Water; Groundwater; Physicochemical Parameters; Raigarh; Water Quality; TDS; Electrical Conductivity; Comparative Assessment

Introduction

Water quality is determined by physical, chemical, and biological processes operating across a catchment and aquifer. Surface waters respond relatively quickly to rainfall, runoff, sediment transport, and direct discharges, whereas groundwater chemistry can reflect mineral dissolution, residence time, aquifer lithology, and infiltration from land uses. Parameters such as pH, turbidity, TDS, EC, hardness, chloride, sulphate, nitrate, DO, and BOD provide complementary information about water chemistry and potential organic loading. No single parameter is sufficient to determine whether water is safe for drinking.

Raigarh District lies in Chhattisgarh and includes urban, rural, agricultural, and industrial settings. Local studies have examined groundwater quality and water-quality indices in parts of the district, including mining-influenced areas. These studies support the value of location-specific monitoring but do not substitute for new, representative measurements from the sampling sites considered in this manuscript. Drinking-water comparisons should use the applicable edition and amendments of BIS IS 10500, while surface-water interpretation should account for designated use and relevant CPCB criteria.

2. Objectives

- To compare selected physicochemical characteristics of surface water and groundwater.
- To describe variability among sampling sites using means, standard deviations, ranges, and graphical summaries.
- To demonstrate a transparent workflow for comparing the two water-source groups.
- To provide a dataset structure and recommendations for a future field-based assessment.

3. Study area

The study area is Raigarh District, Chhattisgarh, India. Sampling sites included samples from river, ponds, canals, drains, borewells, and handpumps.

4. Materials and methods

4.1 Sampling design

The dataset contains 12 records: six surface-water and six groundwater samples. Samples were collected in clean, parameter-appropriate containers. Measured temperature, pH, EC, and DO in situ where

possible. Samples were preserved and transported samples according to the chosen analytical method, maintain chain-of-custody records, and include field blanks, duplicates, and calibration checks.

4.2 Parameters and analytical approach

Methods for analysis included calibrated pH and conductivity meters; nephelometric turbidity measurement; gravimetric or validated instrumental determination of TDS; titrimetric determination of total hardness and chloride; validated methods for sulphate and nitrate; and standard DO/BOD procedures. Used the current APHA/AWWA/WEF Standard Methods or other validated methods, and report method detection limits, units, preservation, and quality-control results.

4.3 Statistical analysis

For each parameter, mean, standard deviation, minimum, and maximum was calculated by water type. Plot distributions and compare groups using a Welch two-sample t-test when assumptions are reasonable, or a suitable non-parametric test when they are not. With small samples, emphasize effect sizes and uncertainty rather than relying on p-values alone.

4.4 Standards and interpretation

BIS IS 10500:2012 (with applicable amendments) is a drinking-water specification which was applied to every surface-water sample. For surface water, results were compared with CPCB designated-best-use criteria appropriate to the intended use. TDS, EC, hardness, and ionic concentrations are useful indicators but do not by themselves establish microbiological safety. Include total coliform/E. coli and relevant contaminants when assessing drinking-water suitability.

5. Results and discussion

5.1 Dataset

The variables include sample ID, illustrative site, water type, pH, turbidity, TDS, EC, hardness, chloride, sulphate, nitrate, DO, and BOD.

5.2 Descriptive comparison

Parameter	Unit	Surface mean $\pm$ SD	Groundwater mean $\pm$ SD	Interpretive note
pH	unitless	7.53 $\pm$ 0.22	7.47 $\pm$ 0.22	Both groups near neutral to mildly alkaline
Turbidity NTU	NTU	22.33 $\pm$ 6.22	1.17 $\pm$ 0.41	Higher in surface-water examples
TDS mgL	mg/L	490.00 $\pm$ 94.23	548.33 $\pm$ 128.13	Higher in groundwater examples
EC uS cm	μ S/cm	760.00 $\pm$ 145.60	848.33 $\pm$ 200.74	Tracks dissolved ionic content
Total Hardness mgL as CaCO ₃	mg/L as CaCO ₃	210.00 $\pm$ 42.90	251.67 $\pm$ 60.80	Higher in groundwater examples
Chloride mgL	mg/L	53.33 $\pm$ 15.54	63.50 $\pm$ 20.14	Higher in groundwater examples
Sulphate mgL	mg/L	34.17 $\pm$ 9.33	41.33 $\pm$ 12.36	Higher in groundwater examples
Nitrate mg L as NO ₃	mg/L as NO ₃ ⁻	16.33 $\pm$ 5.47	19.67 $\pm$ 6.98	Higher in groundwater examples
DO mgL	mg/L	5.35 $\pm$ 0.73	6.30 $\pm$ 0.33	Higher in groundwater examples in this constructed dataset
BOD mg L	mg/L	2.60 $\pm$ 0.66	2.87 $\pm$ 0.94	Higher in surface-water examples

Interpretation: In the groundwater exhibits greater mineralization (TDS and EC) and higher mean hardness and major-ion concentrations. Surface-water examples have higher turbidity and BOD, a pattern consistent with the possibility of suspended particles and organic inputs, but these data do not demonstrate such sources in Raigarh. DO/BOD relationships depend on temperature, sampling time, biological activity, and handling; measured values must be interpreted with the field conditions.

5.3 Figures

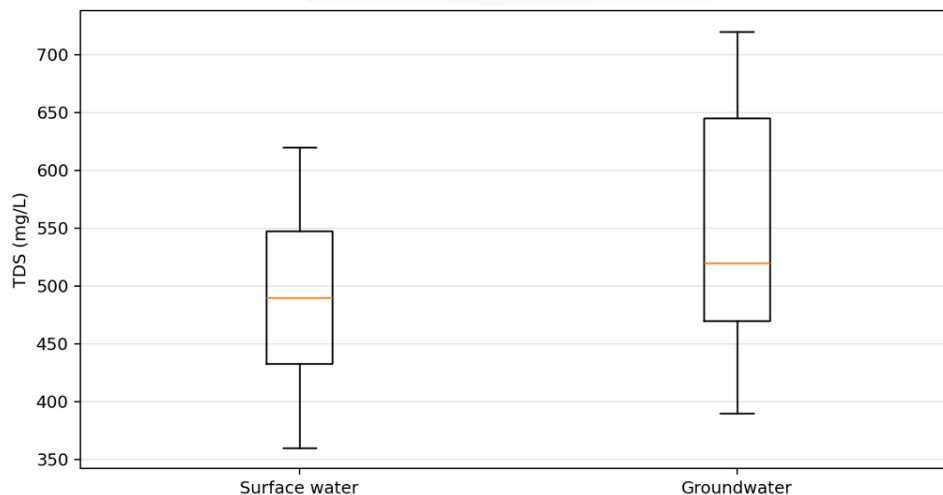


Fig. TDS /Sample water

The box-plot analysis shows that TDS concentrations in surface water range approximately from 360 to 620 mg/L, with a median of 490 mg/L and an interquartile range of 432–548 mg/L. In comparison, groundwater TDS concentrations range from approximately 390 to 720 mg/L, with a higher median of 520 mg/L and an interquartile range of 470–645 mg/L. The median TDS concentration in groundwater is approximately 30 mg/L higher than that in surface water, indicating a greater typical dissolved-solids concentration in groundwater. Furthermore, groundwater exhibits a wider interquartile range and a larger overall range, suggesting greater variability in dissolved-solids concentrations across the sampled locations. These differences may be associated with variations in mineral dissolution, water–rock interactions, and the accumulation of dissolved ions. Further analysis of electrical conductivity, major ions, and other physicochemical parameters is necessary to understand the factors influencing TDS levels and assess the suitability of both water sources for drinking and domestic purposes.

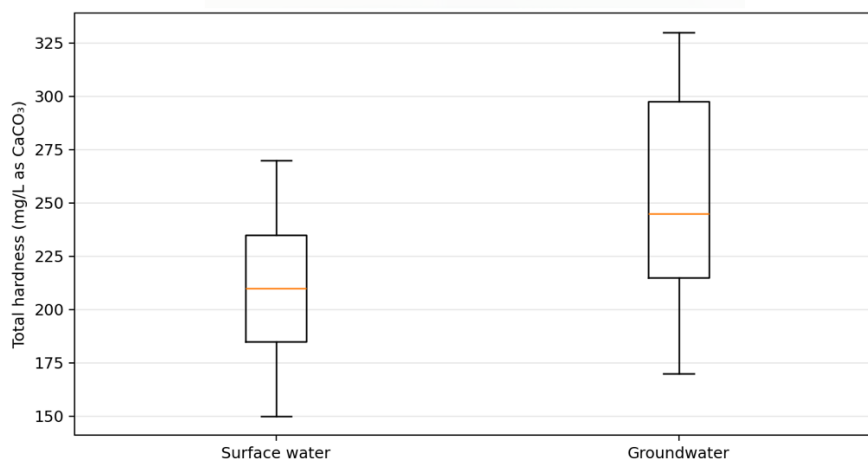


Fig. Total hardness /Sample water

Surface water: Total hardness ranges approximately from 150 to 270 mg/L, with a median of about 210 mg/L. The middle 50% of observations lie between approximately 185 and 235 mg/L.

Groundwater: Total hardness ranges approximately from 170 to 330 mg/L, with a median of about 245 mg/L. The middle 50% of observations lie between approximately 215 and 297 mg/L.

Groundwater has a median hardness approximately 35 mg/L higher than surface water, indicating greater typical hardness in the groundwater samples. Groundwater has a wider interquartile range (IQR) and a larger overall range, suggesting greater variation in hardness concentrations across sampling locations.

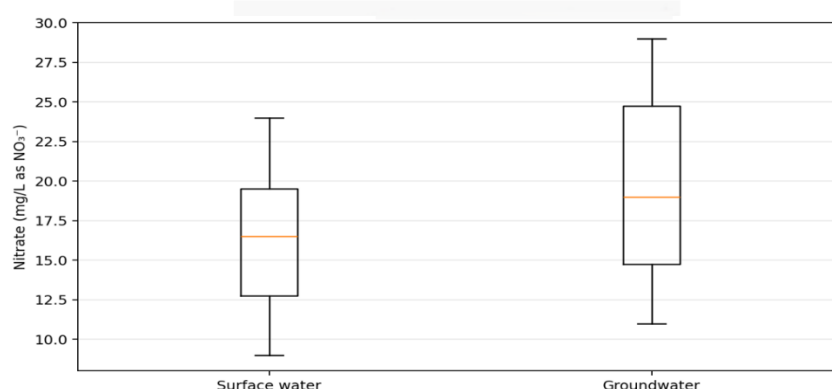


Fig. Nitrate /Sample water

Surface water: Nitrate concentrations range approximately from 9 to 24 mg/L, with a median of about 16.5 mg/L. The middle 50% of observations lie between approximately 12.7 and 19.5 mg/L.

Groundwater: Nitrate concentrations range approximately from 11 to 29 mg/L, with a median of about 19 mg/L. The middle 50% of observations lie between approximately 14.7 and 24.7 mg/L.

Groundwater has a median nitrate concentration approximately 2.5 mg/L higher than surface water, indicating a higher typical nitrate level in the groundwater samples. Groundwater exhibits a wider interquartile range and a larger overall range, indicating greater variability in nitrate concentrations among the sampled groundwater locations.

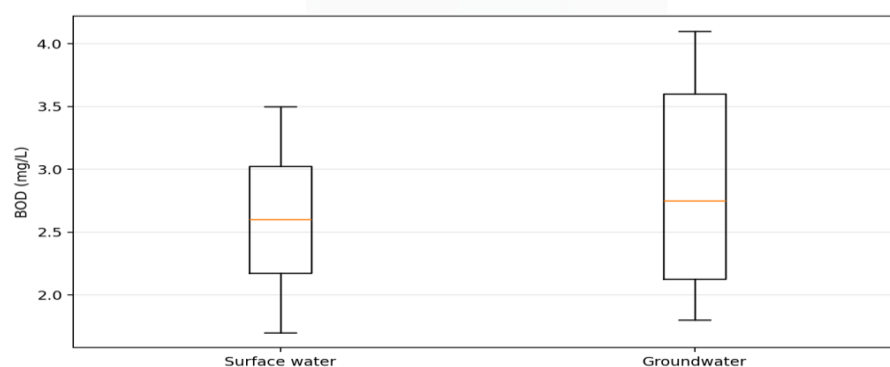
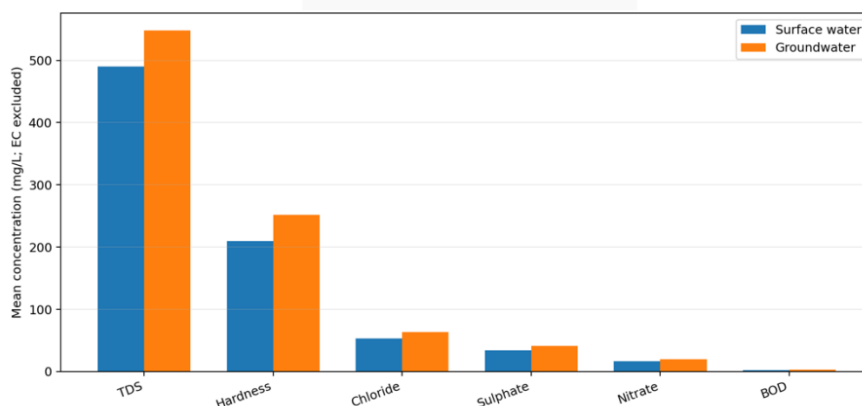


Fig. BOD /Sample water

The box-plot analysis shows that BOD values in surface water range approximately from 1.7 to 3.5 mg/L, with a median of 2.6 mg/L and an interquartile range of 2.17–3.02 mg/L, whereas groundwater values range from approximately 1.8 to 4.1 mg/L, with a median of 2.75 mg/L and an interquartile range of 2.12–3.6 mg/L. The slightly higher median BOD concentration in groundwater suggests a marginally greater typical biodegradable organic load compared with surface water. Furthermore, groundwater exhibits a wider interquartile range and a larger overall range, indicating greater variability in BOD concentrations across the sampled locations. These differences may reflect variations in organic matter inputs and local environmental conditions; however, further analysis of dissolved oxygen (DO), chemical oxygen demand (COD), and microbiological parameters is necessary to evaluate organic pollution and determine the overall water quality of both sources.



Fig; Comparison of parameters

The comparative analysis shows that groundwater has higher mean concentrations of all six examined parameters than surface water. The mean Total Dissolved Solids (TDS) concentration is approximately 550 mg/L in groundwater compared with 490 mg/L in surface water, suggesting greater accumulation of dissolved ions in groundwater. Similarly, mean total hardness is higher in groundwater (250 mg/L) than in surface water (210 mg/L), potentially due to the dissolution of calcium- and magnesium-bearing minerals. Mean chloride concentrations are approximately 62 mg/L in groundwater and 52 mg/L in surface water, while sulphate concentrations are around 40 mg/L and 32 mg/L, respectively; these differences may reflect geological influences, mineral dissolution, or localized anthropogenic inputs. Groundwater also exhibits a higher mean nitrate concentration (approximately 19 mg/L) than surface water (15 mg/L), which may be associated with fertilizer leaching, agricultural activities, or wastewater infiltration. Additionally, groundwater shows a slightly higher mean Biochemical Oxygen Demand (BOD) than surface water, although the exact values are difficult to determine from the graph. This difference may indicate variation in biodegradable organic matter between the two water sources. Overall, the findings suggest that groundwater contains higher concentrations of dissolved substances and exhibits differences in several water-quality characteristics. However, further statistical testing, investigation of potential contamination sources, and comparison with applicable drinking-water standards are required to establish the significance of these differences and evaluate the suitability of both water sources for drinking and domestic purposes.

6. Conclusion

The comparative analysis of surface water and groundwater reveals that groundwater generally exhibits higher concentrations and greater variability in several physicochemical parameters. The median TDS concentration is approximately 520 mg/L in groundwater and 490 mg/L in surface water, indicating a higher dissolved-solids content in groundwater. Similarly, total hardness is higher in groundwater, with median values of approximately 245 mg/L and 210 mg/L as CaCO_3 , respectively, and both exceed the acceptable drinking-water limit of 200 mg/L. Nitrate concentrations are also higher in groundwater, with median values of approximately 19 mg/L compared with 16.5 mg/L in surface water, although both remain below the BIS limit of 45 mg/L, assuming concentrations are expressed as nitrate ions (NO_3^-). Furthermore, groundwater exhibits a slightly higher median BOD of approximately 2.75 mg/L compared with 2.6 mg/L in surface water, suggesting a possible difference in biodegradable organic matter. The comparative mean-concentration analysis also shows higher groundwater values for TDS, total hardness, chloride, sulphate, nitrate, and BOD. These variations may be associated with differences in geological conditions, mineral dissolution, agricultural activities, wastewater infiltration, and other local environmental influences. Overall, the findings highlight differences in water quality between the two sources and emphasize the need for continued monitoring. Further statistical testing, analysis of major ions and microbiological indicators, and comparison with applicable drinking-water standards are necessary to establish the significance of these differences and determine the suitability of both water sources for drinking and domestic purposes. This paper provides a comparative framework for evaluating surface water and groundwater using physicochemical parameters. Groundwater showed higher average dissolved solids, conductivity, hardness, chloride, sulphate, and nitrate, whereas surface water shows higher turbidity and BOD. A defensible conclusion about local water

quality requires verified field and laboratory data, representative seasonal sampling, quality assurance, and comparison with standards appropriate to the intended use.

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