

Groundwater Quality and Water Quality Index in Coastal Bapatla, Andhra Pradesh, India: A Critical Review of Historical Data, Updated Drinking-Water Standards, and Management Perspectives

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Abstract

Groundwater is a critical source of drinking and domestic water in coastal Andhra Pradesh, where intensive abstraction, agriculture, urban development and proximity to the Bay of Bengal can influence groundwater chemistry. This review re-examines the groundwater-quality dataset reported for nine sampling locations in the former Bapatla mandal and places the historical findings in the context of current drinking-water standards and recent regional evidence. The original study measured pH, total hardness (TH), total dissolved solids (TDS), chloride, nitrate, sulphate, potassium, magnesium, iron and turbidity. The reported station data were retained without alteration because they represent the original laboratory observations. However, several summary values and interpretations in the original article are internally inconsistent; therefore, descriptive statistics were recalculated directly from the station-level data. The recalculated means were 7.53 for pH, 492.44 mg/L for TH, 1749.11 mg/L for TDS, 294.76 mg/L for chloride, 0.72 mg/L for nitrate, 151.08 mg/L for sulphate, 5.38 mg/L for potassium, 181.56 mg/L for magnesium, 0.005 mg/L for iron and 2.17 NTU for turbidity. When compared with IS 10500:2012, the historical dataset shows widespread exceedance of the acceptable limits for TDS, total hardness, magnesium and turbidity, while chloride exceeds the acceptable limit at five of nine sites. The nitrate, sulphate, iron and pH values remain within the applicable limits. A transparent recalculation of the weighted-arithmetic WQI, using the same general framework but current BIS permissible limits and excluding potassium from the index because no BIS drinking-water limit is specified for it, gives WQI values of 40.58–62.35. Four stations (S1, S7, S8 and S9) fall in the poor category and the remaining five fall in the good category under the stated classification. Recent official and peer-reviewed evidence indicates that Bapatla continues to face groundwater-quality and salinity-management challenges. The review therefore emphasizes that the 2014 dataset should be treated as a historical baseline rather than as evidence of present-day water quality, and recommends renewed seasonal sampling, inclusion of electrical conductivity, major ions, fluoride, arsenic and microbiological indicators, and GIS-based monitoring for contemporary assessment.

Keywords: Bapatla; coastal groundwater; water quality index; IS 10500:2012; salinity; total dissolved solids; magnesium; groundwater management

1. Introduction

Groundwater quality is governed by interactions among aquifer lithology, recharge, residence time, seawater influence, agricultural return flow, domestic wastewater and groundwater abstraction. In coastal aquifers, excessive pumping may increase the vulnerability of freshwater systems to salinity and other geochemical changes. Water Quality Index (WQI) methods are useful because they condense several analytical variables into a single numerical

indicator, although the resulting index is highly dependent on the selected parameters, standard limits, weights and mathematical formulation.

The uploaded study investigated groundwater in Bapatla mandal, then part of Guntur district, Andhra Pradesh, using nine sampling stations and ten physicochemical parameters. The article described the water as generally suitable but also identified high WQI conditions and suggested that some locations required treatment. The original station-level table is valuable as a historical baseline; however, the paper contains apparent transcription/calculation problems in its mean-value table and WQI discussion. For example, the station-level pH values average approximately 7.53, not 2.29, and the station-level TDS values average approximately 1749 mg/L, not 84.86 mg/L. A review-oriented revision should therefore preserve the raw observations while recalculating derived quantities transparently.

The regulatory context has also evolved. BIS IS 10500:2012 remains the relevant Indian drinking-water specification and distinguishes an acceptable limit from a permissible limit in the absence of an alternate source. The current WHO drinking-water guidance emphasizes health-based targets, risk management and water-safety planning rather than a single universal WQI threshold. Recent Bapatla district documentation and regional studies further indicate continuing groundwater stress, salinity concerns and the need for systematic monitoring.

2. Scope and Review Approach

This paper is a critical review and re-analysis rather than a new field investigation. The original Bapatla station-level measurements were extracted from the uploaded article and rechecked mathematically. No new laboratory measurements have been invented or substituted. Updated regulatory values were obtained from current official or authoritative sources, principally BIS IS 10500:2012 and current WHO drinking-water guidance. Recent Bapatla and coastal-Andhra evidence was used to place the historical dataset in a contemporary management context.

The weighted-arithmetic WQI was recalculated using the original study's general concept of unit weighting and quality rating. For the updated calculation, current BIS permissible limits were used as the standard values because the original study's interpretation mixed acceptable and permissible criteria. Potassium was excluded from the recalculated WQI because IS 10500:2012 does not specify a drinking-water limit for potassium. The ideal value was taken as 7 for pH and zero for the remaining parameters. The result is presented as a reproducible comparative index, not as a claim that the original authors used the same updated standard set.

3. Study Area and Historical Dataset

The original study described Bapatla mandal as a coastal part of Andhra Pradesh and sampled nine villages: Marripudi (S1), Appikatla (S2), Poondla (S3), Kondubotlavaripalem (S4), Devinuthala (S5), Pandurangapuram (S6), Gopapuram (S7), Gudipudi (S8) and Chundurupalli (S9). Samples were collected in 500-mL plastic bottles and analyzed for pH, TDS, TH, chloride, nitrate, sulphate, potassium, magnesium, iron and turbidity.

Bapatla became a separate district in 2022 after reorganization of the former Guntur and Prakasam administrative areas. Contemporary district documentation describes Bapatla as a coastal district bounded by the Bay of Bengal to the south. This administrative change is important when comparing historical literature: older papers use 'Bapatla mandal, Guntur district', whereas current government reports refer to Bapatla district.

4. Historical Physicochemical Dataset

Station	pH	TH	TDS	Cl	NO3	SO4	K	Mg	Fe	Turbidity
S1	7.59	695	2088	446.49	0.2	181.12	6.5	215	0.001	2.3
S2	7.32	460	1560	176.19	0.1	169.24	4.2	155	0.01	1.4
S3	7.38	395	1488	240.26	1.1	160	3.9	130	0.004	1.7
S4	7.5	549	549	447.39	1.5	143.4	2.5	120	0.001	2.5
S5	7.3	450	1600	159.75	0.2	140.27	4.5	150	0.002	2.4
S6	7.9	400	1270	205.85	0.1	160.72	6.9	145	0.004	2.1
S7	7.58	478	2156	389.51	0.2	121.12	7.2	240	0.001	2.5
S8	7.28	512	2045	276.48	1.6	135.23	6.8	341	0.01	1.9
S9	7.95	493	2986	310.89	1.5	148.65	5.9	138	0.01	2.7

Table 1. Historical station-level groundwater measurements reproduced from the uploaded article. These are original observations and are not presented as contemporary 2026 measurements.

5. Corrected Descriptive Statistics

Parameter	Unit	Minimum	Maximum	Mean	SD
pH	—	7.280	7.950	7.533	0.251
TH	mg/L	395.000	695.000	492.444	90.633
TDS	mg/L	549.000	2986.000	1749.111	679.507
Cl	mg/L	159.750	447.390	294.757	111.272
NO3	mg/L	0.100	1.600	0.722	0.682
SO4	mg/L	121.120	181.120	151.083	18.491
K	mg/L	2.500	7.200	5.378	1.651
Mg	mg/L	120.000	341.000	181.556	71.884
Fe	mg/L	0.001	0.010	0.005	0.004
Turbidity	NTU	1.400	2.700	2.167	0.427

The corrected mean values above are calculated directly from the nine station-level observations. They replace the internally inconsistent mean values reproduced in the original WQI table. The most prominent features of the historical dataset are high TDS and hardness, elevated magnesium, moderate chloride enrichment and turbidity above the current acceptable limit. Nitrate and sulphate are comparatively low, and iron is very low.

6. Updated Drinking-Water Standards

The current Indian comparison should use IS 10500:2012 (Second Revision). The standard specifies acceptable limits and, where permitted, higher limits that may be tolerated only in the absence of an alternate source. The values below are therefore more appropriate for a revised review than the older mixed set of limits used in the original article.

Parameter	Unit	Acceptable limit	Permissible limit	Ideal value
pH	—	6.5–8.5	No relaxation	7.0
Turbidity	NTU	1	5	0
TDS	mg/L	500	2000	0

Total hardness (as CaCO ₃)	mg/L	200	600	0
Magnesium (as Mg)	mg/L	30	100	0
Chloride (as Cl)	mg/L	250	1000	0
Sulphate (as SO ₄)	mg/L	200	400	0
Nitrate (as NO ₃)	mg/L	45	No relaxation	0
Iron (as Fe)	mg/L	0.3	No relaxation	0

Table 3. Updated comparison framework based on IS 10500:2012. Potassium is not included because the standard does not prescribe a drinking-water limit for it.

7. Compliance of the Historical Samples with Current BIS Criteria

Parameter	Exceeding acceptable limit (n/9)	Exceeding permissible limit (n/9)	Samples
pH	0	0	9
TH	9	1	9
TDS	9	4	9
Cl	5	0	9
NO ₃	0	0	9
SO ₄	0	0	9
Mg	9	9	9
Fe	0	0	9
Turbidity	9	0	9

Nine of nine historical samples exceed the current acceptable limits for total hardness, TDS, magnesium and turbidity. Five of nine exceed the acceptable chloride limit. Only one sample exceeds the permissible total-hardness limit, and four exceed the permissible TDS limit. Magnesium exceeds even the permissible limit at all nine stations. No sample exceeds the BIS pH, nitrate, sulphate or iron limits in the historical dataset. This pattern indicates that the principal concern is mineralization/hardness rather than nitrate or iron contamination.

8. Recalculated Water Quality Index

A revised weighted-arithmetic WQI was calculated from nine parameters: pH, TH, TDS, chloride, nitrate, sulphate, magnesium, iron and turbidity. The original study's qualitative weighting scheme was retained as far as possible (weights 4, 5, 4, 3, 5, 3, 2, 3 and 3, respectively), but the standard values were updated to the current BIS permissible limits. The quality rating was calculated as $qi = |Va - Vi| / (Si - Vi) \times 100$, where Va is the measured value, Vi is the ideal value and Si is the selected standard value. The final WQI is the sum of wiqi, where wi is the normalized unit weight. This formulation is explicitly stated so that the index can be reproduced.

Station	Updated WQI	Water-quality class
S1	62.35	Poor
S2	42.67	Good
S3	40.58	Good

S4	42.19	Good
S5	43.01	Good
S6	44.71	Good
S7	57.03	Poor
S8	59.95	Poor
S9	60.34	Poor

The updated calculation changes the interpretation substantially compared with the published WQI discussion. S1, S7, S8 and S9 fall in the poor category, whereas S2–S6 fall in the good category. The relatively higher WQI values at S1, S7, S8 and S9 are consistent with their higher combinations of TDS, hardness and/or magnesium. The recalculated index should be viewed as a standardized re-analysis of historical data, not as a replacement for a new field survey.

9. Interpretation of Major Water-Quality Parameters

pH: The historical pH range of 7.28–7.95 is within the BIS range of 6.5–8.5. The values indicate neutral to mildly alkaline groundwater and do not constitute the principal drinking-water constraint.

Total dissolved solids: TDS ranged from 549 to 2986 mg/L, with a mean of approximately 1749 mg/L. Four sites exceed the permissible limit of 2000 mg/L, while all nine exceed the 500 mg/L acceptable limit. Elevated TDS is an important indicator of mineralization and, in a coastal setting, warrants evaluation alongside electrical conductivity and major-ion ratios.

Total hardness and magnesium: TH ranged from 395 to 695 mg/L, and magnesium ranged from 120 to 341 mg/L. These are the strongest chemical indicators of the historical dataset. The magnesium values exceed both the acceptable and permissible BIS limits at every station. High hardness can affect taste, scaling and domestic appliances, while high magnesium may contribute to overall mineralization.

Chloride: Chloride ranged from 159.75 to 447.39 mg/L. Five sites exceed the 250 mg/L acceptable limit, but none exceed 1000 mg/L. Chloride is particularly informative in coastal aquifers because it can be used with EC, TDS, sodium and hydrochemical ratios to evaluate salinity sources and possible seawater influence.

Sulphate and nitrate: Sulphate remained below 200 mg/L at all nine sites and nitrate was exceptionally low relative to the 45 mg/L BIS limit. Thus, these parameters do not explain the elevated WQI values in the historical dataset.

Iron and turbidity: Iron concentrations were very low (0.001–0.010 mg/L), well below the current BIS value of 0.3 mg/L. Turbidity ranged from 1.4 to 2.7 NTU: all sites exceed the current acceptable value of 1 NTU, although all remain below the permissible value of 5 NTU. Turbidity therefore contributes to the index but is not a severe regulatory exceedance under the permissible criterion.

10. Comparison with Recent Bapatla Evidence

The historical dataset should not be interpreted as a current assessment. A 2023 District Survey Report prepared by the Andhra Pradesh Space Applications Centre and the Department of Mines and Geology includes a groundwater-quality map for Bapatla based on legacy groundwater-quality data from 2018–2020. The report identifies total hardness, fluoride, nitrate, iron, TDS and alkalinity among the groundwater-quality concerns represented in the

district. This official evidence supports the need to continue monitoring rather than assuming that the 2014 conditions remain unchanged.

The Central Ground Water Board's 2024 aquifer-mapping publication for Bapatla district provides a contemporary framework for groundwater-quality monitoring, aquifer characterization and sustainable groundwater management. Recent regional research also emphasizes the vulnerability of coastal Andhra aquifers to saltwater intrusion and the role of groundwater abstraction in changing salinity patterns. A 2025 study specifically addressing managed aquifer recharge in Bapatla identified groundwater stress and salinity ingress as important management concerns.

Together, these sources suggest that the most defensible interpretation is not simply 'safe' or 'unsafe', but spatially and seasonally variable groundwater quality requiring periodic surveillance. The historical Bapatla dataset provides a useful baseline for trend analysis, but current conclusions should be based on newly collected samples.

11. Limitations of the Original Study and Improvements for a Review-Oriented Version

- The sampling date/season and exact sampling coordinates are not sufficiently documented in the uploaded article for robust contemporary spatial comparison.
- The original paper reports nine station-level datasets but contains inconsistent mean values and WQI calculations; all derived statistics should therefore be recomputed from the raw station values.
- The original parameter set lacks several high-value indicators for coastal groundwater assessment, especially electrical conductivity, sodium, calcium, bicarbonate/alkalinity, fluoride and major-ion ratios.
- Microbiological indicators such as *E. coli* and total coliforms are absent from the dataset, so the study cannot establish microbiological potability.
- The original use of potassium as a weighted drinking-water parameter should be reconsidered because IS 10500:2012 does not provide a corresponding drinking-water limit.
- A single WQI value can conceal which parameters drive poor quality; parameter-by-parameter exceedance analysis should always accompany WQI.
- The historical observations should not be described as 'updated values'. Updated values in this revision refer to standards, recalculated statistics and contemporary literature; new field measurements require a new sampling campaign.

12. Recommended Contemporary Monitoring Framework

A modern Bapatla groundwater-quality programme should use seasonal pre-monsoon and post-monsoon sampling and retain fixed georeferenced wells to enable time-series comparison. Core field parameters should include pH, electrical conductivity, temperature, TDS and turbidity. Laboratory parameters should include TH, calcium, magnesium, sodium, potassium, chloride, sulphate, bicarbonate/alkalinity, nitrate, fluoride, iron, manganese and selected trace elements such as arsenic where geologically or anthropogenically justified. Microbiological analysis for *E. coli* and total coliforms should be included for drinking-water risk assessment.

For coastal salinity assessment, EC, TDS and chloride should be interpreted together with sodium, calcium and hydrochemical ratios rather than relying on WQI alone. GIS interpolation, multivariate statistics, Piper diagrams, Gibbs plots and seawater-mixing indicators can help distinguish natural mineralization from salinity ingress and anthropogenic inputs. Recharge planning, groundwater abstraction control and managed aquifer recharge should be considered alongside water treatment.

13. Treatment and Management Implications

Where TDS and hardness are high, treatment should be selected according to the actual ionic composition and intended use. Conventional softening may address hardness, while membrane processes such as reverse osmosis can reduce TDS when technically and economically justified. Turbidity should be controlled by appropriate filtration or clarification. Treatment should not be selected solely from WQI; raw-water chemistry, recovery, concentrate disposal, microbiological risk and household operating conditions must be considered.

At the aquifer scale, reducing excessive abstraction, protecting recharge areas, maintaining drainage, managing agricultural inputs and implementing appropriately located recharge structures can reduce long-term vulnerability. In coastal zones, groundwater extraction should be balanced against recharge to reduce the risk of saline-water movement toward freshwater wells.

14. Future Research Directions

- Repeat the nine historical sites using GPS-referenced wells to establish a direct temporal comparison.
- Collect at least two seasonal datasets per year for several consecutive years.
- Measure EC, Na⁺, Ca²⁺, HCO₃⁻/alkalinity and F⁻ in addition to the historical parameter set.
- Add microbiological indicators and selected trace contaminants to establish drinking-water safety.
- Use GIS and multivariate statistics to identify spatial clusters and likely contamination sources.
- Develop a Bapatla-specific groundwater-quality dashboard combining WQI, salinity indicators and regulatory exceedances.
- Evaluate managed aquifer recharge and abstraction-management options in high-stress zones.

15. Conclusion

This revised review demonstrates that the original Bapatla groundwater study remains useful as a historical baseline, but its derived statistics and WQI interpretation require correction before being reused. Direct recalculation of the station-level observations gives mean values of 7.53 pH, 492.44 mg/L TH, 1749.11 mg/L TDS, 294.76 mg/L chloride, 0.72 mg/L nitrate, 151.08 mg/L sulphate, 5.38 mg/L potassium, 181.56 mg/L magnesium, 0.005 mg/L iron and 2.17 NTU turbidity. Comparison with current BIS criteria shows that mineralization, hardness, magnesium and turbidity are the dominant historical concerns. A transparent recalculation using current permissible limits gives WQI values from 40.58 to 62.35, placing five stations in the good category and four in the poor category under the stated classification.

Recent government documentation confirms that groundwater-quality and salinity issues remain relevant in Bapatla. The principal scientific priority is therefore to replace assumptions of present-day quality with a new, seasonal, georeferenced monitoring programme. The combination of updated standards, parameter-specific assessment, WQI, hydrochemical interpretation and GIS-based management offers a stronger framework for protecting groundwater resources and drinking-water security in coastal Bapatla.

References

1. American Public Health Association, American Water Works Association, & Water Environment Federation. (2017). Standard methods for the examination of water and wastewater (23rd ed.). APHA.
2. Bureau of Indian Standards. (2012). IS 10500:2012: Drinking water—Specification (Second Revision). BIS, New Delhi.
3. Central Ground Water Board. (2024). Aquifer mapping for sustainable management of ground water resources in Bapatla district, Andhra Pradesh state. Ministry of Jal Shakti, Government of India.
4. Central Ground Water Board. (2025). Ground water quality issues and management reports. Ministry of Jal Shakti, Government of India.
5. Dandge, K. P., & Patil, S. S. (2021). Spatial distribution of ground water quality index using remote sensing and GIS techniques. *Applied Water Science*.
6. Gummadi, S., Swarnalatha, G., Venkataratnamma, V., & Vishnuvardhan, Z. (2014). Determination of water quality index for groundwater of Bapatla mandal, Guntur district, Andhra Pradesh, India. *International Journal of Engineering Research & Technology*, 3(3).
7. Gummadi, S., Swarnalatha, G., Venkataratnamma, V., & Vishnuvardhan, Z. (2014/2015). Water quality index for groundwater of Bapatla Mandal, coastal Andhra Pradesh, India. *International Journal of Environmental Sciences*, 5(1), 23–33.
8. Horton, R. K. (1965). An index number system for rating water quality. *Journal of Water Pollution Control Federation*, 37(3), 300–306.
9. Kannan Rajaiah, K., Appala Naidu, K., Kanungo, A., & colleagues. (2022). Hydrochemical characteristics of groundwater—Assessment of saltwater intrusion along Krishna and Godavari delta region, Andhra Pradesh, India. Springer.
10. Patel, D. D., Mehta, D. J., Azamathulla, H. M., Shaikh, M. M., Jha, S., & Rathnayake, U. (2023). Application of the weighted arithmetic water quality index in assessing groundwater quality: A case study of the South Gujarat Region. *Water*, 15(19), 3512.
11. Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. *E-Journal of Chemistry*, 6(2), 523–530.
12. Swarna Latha, P., Nageswara Rao, K., Ramesh Kumar, P. V., & Hari Krishna, M. (2007). Water quality assessment at village level: A case study. *Indian Journal of Environmental Protection*, 27(11), 996–1000.
13. World Health Organization. (2022). Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. WHO.
14. World Health Organization. (2026). Guidelines for drinking-water quality: Fourth edition incorporating the first, second and third addenda. WHO.
15. Andhra Pradesh Space Applications Centre & Department of Mines and Geology, Government of Andhra Pradesh. (2023). District Survey Report—Bapatla District 2023.

16. Naik, S. R., Sreerama, T. K. Prasad, & Jayapal, G. (2025). A GIS and AHP-based suitability assessment for managed aquifer recharge in Bapatla District, Andhra Pradesh, India. *Asian Journal of Geological Research*, 8(3), 501–514.
17. Helstrup, T., Jørgensen, N. O., & Banoeng-Yakubo, B. (2007). Investigation of hydrochemical characteristics of groundwater from the Cretaceous–Eocene limestone in southern Ghana and southern Togo using hierarchical cluster analysis. *Hydrogeology Journal*, 15, 977–989.
18. Mangukiya, R., Bhattacharya, T., & Chakraborty, S. (2012). Quality characterization of groundwater using water quality index in Surat city, Gujarat, India. *International Research Journal of Environment Sciences*, 1(4), 14–23.
19. Yisa, J., & Jimoh, T. (2010). Analytical studies on water quality index of River Landzu. *American Journal of Applied Sciences*, 7(4), 453–458.
20. Tyagi, P. D., Buddhi, R., Chaudhary, K. C., & Sawhney, R. L. (2002). Degradation of ground water quality in industrial area in India. *Indian Journal of Environmental Protection*.
21. Dhakad, N. K., Shinde, D., & Choudhary, P. (2008). Water quality index of groundwater of Jhabua town, M.P., India. *Journal of Environmental Research and Development*, 2(3).