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Comparative Study of Groundwater and Surface Water Quality with Biological Treatment Approaches in Bharatpur, Rajasthan

Chitra chaudhary[1], Dr Naresh Kumar Sharma [2] ,Reena saini3

1,3Research scholar, Lords university Alwar

2Professor ,Lords university Alwar

Abstract

Water security in Bharatpur, Rajasthan, is shaped by two contrasting but interconnected resources: mineral-rich groundwater and seasonally variable surface-water systems, including the wetlands of Keoladeo National Park. This paper presents a literature-based comparative assessment of their quality and evaluates biological treatment approaches suitable for local conditions. Evidence from the Hydrogeological Atlas of Rajasthan, field studies in Bharatpur, Keoladeo water-quality investigations, drinking-water standards, and wastewater project documents was synthesized. Groundwater shows persistent problems of salinity, total dissolved solids, chloride, hardness, fluoride, and nitrate. The 2013 district atlas reported that approximately 77% of the mapped area had electrical conductivity above 2,000 µS/cm, while 54% had nitrate above 50 mg/L and about one-third had fluoride at or above 1.5 mg/L. Surface water shows a different risk profile, characterized more strongly by suspended matter, nutrient enrichment, variable dissolved oxygen, organic loading, and microbial contamination. Biological processes—particularly sequencing batch reactors, constructed wetlands, biofiltration, and biological denitrification—can substantially address biodegradable organic matter and nitrogen pollution. However, they cannot by themselves correct high salinity, fluoride, hardness, or dissolved mineral loads. The study therefore proposes a source-specific hybrid strategy combining biological treatment, pollution interception, appropriate physicochemical polishing, and routine monitoring.

Keywords: groundwater; surface water; water quality; biological treatment; constructed wetlands; sequencing batch reactor; nitrate; Bharatpur; Rajasthan

1. Introduction

Bharatpur lies in eastern Rajasthan, a semi-arid setting where water availability and water quality are both major management concerns. The district contains extensive alluvial aquifers, seasonal river systems associated with the Ruparel, Banganga and Gambhir basins, reservoirs such as Bandh Baretha, and the internationally important Keoladeo National Park wetland. The average annual rainfall reported in the district hydrogeological atlas is about 582.9 mm, while high summer temperatures promote evaporation and concentration of dissolved salts (Ground Water Department, Rajasthan, 2013). These climatic and hydrogeological conditions make groundwater dependable in quantity at many locations but chemically vulnerable to salinity and geogenic contaminants.

The quality problem is not uniform across water sources. Groundwater interacts for long periods with minerals in alluvial and hard-rock formations and therefore tends to accumulate dissolved ions. In contrast, surface waters respond more rapidly to runoff, sewage inflow, agricultural nutrients, sediment movement, evaporation, and seasonal changes in water volume. Earlier work in Bharatpur reported hard groundwater with high total dissolved solids (TDS), and localized nitrate problems (Garg et al., 2008). A later survey of drinking-water supplies in urban towns of Bharatpur district found that fluoride, nitrate, hardness, and TDS exceeded desirable or permissible standards at a number of locations (Gupta & Meena, 2014). A recent Water Quality Index assessment in Rupbas Tehsil similarly identified local elevations of electrical conductivity (EC), TDS, salinity, chloride, hardness and alkalinity, demonstrating that the problem remains spatially heterogeneous (Sharma & Gupta, 2025).

Surface-water quality is equally important because Bharatpur includes ecologically sensitive wetland systems and because surface water supplements urban supplies. Keoladeo National Park is especially sensitive to water-quality deterioration because dissolved oxygen, nutrient concentrations, turbidity and microbial contamination directly influence aquatic food webs and bird habitat. The purpose of this paper is therefore threefold: (1) to compare the dominant quality characteristics of groundwater and surface water in Bharatpur; (2) to identify the main contamination pathways and risks; and (3) to assess biological treatment options that can be realistically applied, while recognizing contaminants that require non-biological treatment.

2. Study area and hydroenvironmental setting

Bharatpur district covers about 5,079 km² in the eastern part of Rajasthan. Much of the district is a plain underlain by alluvial deposits, while sandstone, limestone, quartzite and other hard-rock formations occur mainly toward the south and southwest. Groundwater generally flows from the southwest toward the northeast and east. The alluvial aquifer is widespread and, in many locations, unconfined; this increases its potential hydraulic connection with surface features and also its vulnerability to contaminants introduced from the land surface (Ground Water Department, Rajasthan, 2013).

The district's water environment is strongly seasonal. Rivers and wetlands may receive concentrated monsoon inflows and experience low volumes or dry conditions during other periods. Keoladeo National Park illustrates this variability. A UNESCO-linked technical assessment noted that surface-water monitoring could not be continuous during a dry period because wetland areas lacked water, while groundwater was monitored in zones at different distances from the wetland (Wildlife Institute of India, n.d.). Azeez et al. (2000) also showed that the monsoonal wetland can influence nearby groundwater chemistry and water levels. Consequently, groundwater and surface water should not be managed as completely independent resources: recharge, seepage, wastewater infiltration, irrigation return flow and wetland inundation can connect their quality over time.

3. Materials and methods

This paper uses a comparative secondary-data design rather than presenting new field sampling. Bharatpur-specific evidence was drawn from government hydrogeological mapping, peer-reviewed or scholarly water-quality studies, Keoladeo investigations, and urban wastewater planning documents. The principal groundwater sources were the Hydrogeological Atlas of Rajasthan for Bharatpur District (2013), the post-monsoon Bharatpur study of Garg et al. (2008), the urban drinking-water study of Gupta and Meena (2014), and the Rupbas assessment of Sharma and Gupta (2025). Surface-water interpretation relied mainly on the Keoladeo technical assessment and the 2013–2014 investigation by Choudhary and Nama (2014).

For drinking-water interpretation, the study uses the framework of IS 10500:2012 as summarized by the Jal Jeevan Mission. Key reference values include pH 6.5–8.5, TDS 500 mg/L as the acceptable limit and 2,000 mg/L as the permissible limit in the absence of an alternative source, total hardness 200/600 mg/L, chloride 250/1,000 mg/L, fluoride 1.0/1.5 mg/L, and nitrate 45 mg/L with no relaxation (Department of Drinking Water and Sanitation, 2021). Surface-water interpretation additionally considers the Central Pollution Control Board (CPCB) designated-best-use concept, under which dissolved oxygen (DO), biochemical oxygen demand (BOD), pH and coliform counts are major indicators of whether water is suitable for drinking-water abstraction after conventional treatment, bathing, fisheries, or other uses.

The comparison emphasizes patterns rather than combining unlike datasets statistically. Historical datasets differ in sampling season, analytical methods, locations and intended use, so values are interpreted as evidence of recurring problems rather than as a single contemporary survey. Treatment approaches were then matched to contaminant type: biodegradable organic matter and ammonia/nitrogen, pathogens, suspended solids, nitrate, dissolved mineral salts, and fluoride.

Table 1. Key drinking-water reference limits used in the comparison

Parameter	Unit	Acceptable limit	Permissible limit*
pH	—	6.5–8.5	No relaxation
TDS	mg/L	500	2,000
Total hardness (as $CaCO_3$)	mg/L	200	600
Chloride	mg/L	250	1,000
Fluoride	mg/L	1.0	1.5
Nitrate	mg/L	45	No relaxation

**Permissible limit in the absence of an alternate source. Source: IS 10500:2012 framework summarized by Jal Jeevan Mission.*

4. Comparative assessment of water quality

Groundwater in Bharatpur is dominated by dissolved-mineral problems. The district atlas, based on pre-monsoon averages from 2005–2009, showed that about 41% of the mapped district area had EC of 2,000–4,000 µS/cm and another 36% exceeded 4,000 µS/cm. Only about 23% was below 2,000 µS/cm. Chloride displayed a similar pattern: approximately 48% of the area contained 250–1,000 mg/L and about 34% exceeded 1,000 mg/L. The atlas also mapped fluoride below 1.5 mg/L over about 67% of the district, 1.5–3.0 mg/L over roughly 28%, and above 3.0 mg/L over about 5%. Nitrate was below 50 mg/L over approximately 46% of the district, while 34% lay between 50 and 100 mg/L and 20% exceeded 100 mg/L (Ground Water Department, Rajasthan, 2013). Although these maps are historical, their spatial extent demonstrates a structural groundwater-quality constraint rather than an isolated well problem.

Site-based studies reinforce this picture. Garg et al. (2008) examined open wells, bore wells and hand pumps across Bharatpur and concluded that most samples were hard and highly affected by TDS, with nitrate exceeding acceptable levels at some points. Gupta and Meena (2014) reported substantial variation among public water-supply sources. In Bharatpur city, the sampled TDS values ranged from 255 mg/L at Mallah Head Works to 2,317 mg/L at Ranjeet Nagar, while total hardness ranged from 90 to 860 mg/L. In Deeg, several supplies were much more mineralized: TDS reached 6,305 mg/L and hardness reached 2,360 mg/L at the most affected reported location. Bhusawer showed a different concern, with nitrate reaching 98 mg/L in one supply. These contrasts demonstrate why source-by-source monitoring is essential. A district-wide label such as "groundwater" can conceal very different treatment needs.

Surface water exhibits a more dynamic contamination signature. Choudhary and Nama (2014) studied six blocks of Keoladeo National Park during December 2013 to February 2014. They reported pH values of 7.6–7.9, DO of 3.3–4.8 mg/L, turbidity of 2.15–38.4 NTU, TDS of approximately 492–675 mg/L, BOD ranging up to about 3.48 mg/L, COD of 7.5–34.16 mg/L, ammoniacal nitrogen of 0.45–2.25 mg/L, and nitrate-nitrogen of 2.16–11.33 mg/L. Coliform bacteria were reported as high across the studied samples. The low end of the DO range and the upper end of BOD indicate oxygen stress and organic loading at some locations, while elevated turbidity and microbial contamination point to runoff, sediment, animal activity and/or wastewater influence. Earlier Keoladeo monitoring recorded comparatively low nitrate and chloride at selected surface-water points, illustrating the strong temporal and spatial variability of wetland water quality (Wildlife Institute of India, n.d.).

The comparison therefore shows two distinct management priorities. Groundwater is generally less exposed to short-term turbidity changes but can be chronically unsuitable because dissolved ions are difficult to remove and can persist for years. Surface water is more responsive to seasonal flow, sewage, nutrients and ecological processes; its quality may deteriorate quickly but can also improve when pollution inflows are intercepted and adequate flushing occurs. Groundwater nitrate represents an important overlap between the two systems because agricultural fertilizer, leaking sanitation, sewage infiltration and contaminated recharge can transport nitrogen from the surface into aquifers. Similarly, polluted drains that discharge untreated wastewater can degrade surface water directly and create long-term groundwater risks through infiltration.

Table 2. Comparative water-quality pattern in Bharatpur

Characteristic	Groundwater	Surface water/wetlands	Management implication
Dissolved salts	Often high; EC/TDS and chloride are major constraints	Variable; generally more responsive to inflow and evaporation	Groundwater may need desalination/blending; surface sources need catchment control
Hardness/fluoride	Important localized to widespread concern	Usually not the dominant ecological stressor	Primarily physicochemical treatment
Nitrate/nutrients	Nitrate can be chronically elevated	Nutrients vary with runoff, sewage and wetland processes	Source control plus denitrification/nutrient removal
Organic load/DO	Usually secondary unless sewage infiltration occurs	BOD and low DO can indicate ecological stress	Sewage interception and biological treatment
Microbial risk	Higher in shallow/unprotected sources	Potentially high in contaminated surface water	Disinfection and sanitation barriers
Seasonality	Chemistry changes more slowly	Strong seasonal and hydrological variation	Different monitoring frequencies are required

Note. The table synthesizes the cited Bharatpur studies; it does not represent a new field-sampling dataset.

5. Biological treatment approaches and their suitability

Biological treatment is most effective when contaminants can be transformed or captured through microbial metabolism, plant uptake, filtration through biologically active media, or attached-growth processes. For Bharatpur, four approaches are particularly relevant, but their roles differ by water source.

First, sequencing batch reactor (SBR) technology is appropriate for municipal sewage before it reaches drains, wetlands or recharge zones. SBRs are activated-sludge systems that carry out filling, biological reaction, settling and decanting in a controlled sequence. With proper aeration and anoxic phases, they can reduce BOD, COD, suspended solids, ammonia and nitrogen while using a relatively compact footprint. Bharatpur wastewater planning documents identify existing 8 and 5 MLD SBR-based treatment plants at Ikran and a further 9.4 MLD SBR plant proposed under the Rajasthan Secondary Towns Development Sector Project (RUDSICO-EAP, 2023, 2024). This is significant for water-quality protection because preventing untreated sewage from entering open drains is more effective than attempting to restore polluted surface water after contamination has spread.

Second, constructed wetlands can provide low-energy secondary or tertiary polishing where land is available. National guidance in India recognizes constructed wetlands as a sewage-treatment option that combines sedimentation, filtration, microbial degradation, nitrification-denitrification, adsorption and plant-associated processes (CPCB, 2019; IIT Roorkee & NMCG, 2023). In Bharatpur, a carefully designed subsurface-flow wetland could polish treated sewage, decentralized wastewater or selected drainage flows before reuse. Such systems are especially relevant to BOD, suspended solids, ammonia and nitrogen reduction, and they can reduce some microbial loads. They must not, however, be confused with discharging wastewater into a natural protected wetland. Treatment wetlands should be engineered outside sensitive habitat, with hydraulic controls and vegetation selected to avoid invasive-species risks.

Third, biological denitrification is specifically relevant to nitrate-contaminated groundwater. Denitrifying bacteria convert nitrate to nitrogen gas under low-oxygen conditions. Heterotrophic systems use an organic carbon source, while autotrophic systems use inorganic electron donors. Reviews of drinking-water denitrification show that the process can remove nitrate rather than merely transferring it to another waste stream (Mohseni-Bandpi et al., 2013). For Bharatpur, this approach could be considered at community or treatment-plant scale where nitrate is the principal exceedance and salinity is otherwise manageable. Reliable operation requires control of residual nitrite, carbon dosage or electron donor, biomass, dissolved oxygen, and final disinfection.

Fourth, biologically active filtration and nature-based polishing can be used for surface-water or treated-effluent improvement. Biofilms growing on sand, gravel or carrier media can oxidize biodegradable organics and ammonia, while riparian vegetation and buffer strips can intercept sediments and nutrients before they reach water bodies. These approaches are useful as preventive and polishing measures, especially around agricultural drains and urban runoff pathways.

The major limitation is that biological treatment is not a universal remedy. Fluoride, chloride, hardness and high TDS are predominantly dissolved inorganic problems. Microorganisms cannot reliably remove the large mineral load represented by the high-EC zones mapped across Bharatpur. Where these parameters exceed permissible limits, treatment may require processes such as adsorption for fluoride, lime-based softening, ion exchange, electrodialysis or reverse osmosis, depending on raw-water chemistry and scale. Biological processes should therefore be integrated with physicochemical treatment rather than used as a substitute for it.

Table 3. Suitability of selected biological treatment approaches

Approach	Best suited to	Main strengths	Key limitation in Bharatpur
SBR	Municipal sewage	Compact; strong BOD/COD and nitrogen control	Requires reliable operation, power and disinfection
Constructed wetland	Treated sewage, decentralized flows, polishing	Low energy; nutrient and solids removal	Land requirement; not a fluoride/TDS solution
Biological denitrification	Nitrate-rich groundwater	Converts nitrate to nitrogen gas	Process control and post-treatment are necessary
Biofiltration/riparian buffers	Polishing, runoff and ammonia/organic control	Passive or low-energy barrier	Limited removal of dissolved mineral salts

6. Proposed integrated management framework for Bharatpur

A practical Bharatpur strategy should begin with source segregation. Groundwater sources should be mapped and tested at least for EC/TDS, hardness, chloride, fluoride and nitrate, with bacteriological testing where wells are shallow or sanitation risks exist. Sources that already comply with drinking-water limits should be protected rather than subjected to unnecessary treatment. Nitrate-dominant sources can be evaluated for biological denitrification, whereas fluoride- or salinity-dominant sources need targeted physicochemical treatment or blending with a safer source.

For surface water, the first priority is pollution interception. Sewer expansion, reliable SBR operation, faecal-sludge management and prevention of untreated drain discharge should reduce organic and microbial loading. Where treated effluent is reused, polishing through constructed wetlands or tertiary filtration can provide an additional barrier and reduce nutrient discharge. Surface-water monitoring should include DO, BOD, COD, turbidity, nutrients and faecal indicators, with higher sampling frequency during monsoon inflow and low-flow periods.

Keoladeo National Park requires a particularly conservative approach. Its natural wetland processes already provide nutrient retention and transformation, but the park should not function as a wastewater treatment unit. Water entering the protected ecosystem should meet appropriate environmental-quality objectives before entry. A catchment-scale program combining upstream sewage treatment, agricultural nutrient management, vegetated buffer zones, controlled inflows and ecological monitoring would protect both biodiversity and connected groundwater. The effectiveness of the overall system should be judged by trends across both water compartments rather than by treatment-plant effluent alone.

7. Conclusion

The available evidence demonstrates that groundwater and surface water in Bharatpur face different but connected quality pressures. Groundwater is characterized by persistent mineralization, with extensive areas affected by elevated EC, chloride, nitrate and fluoride and with some urban supplies showing very high TDS and hardness. Surface water, particularly within the Keoladeo wetland system, is more strongly influenced by seasonal flow, turbidity, oxygen balance, nutrient enrichment, organic matter and microbial contamination.

Biological treatment has an important but clearly bounded role. SBR systems can prevent municipal sewage from becoming a surface-water and groundwater pollutant; constructed wetlands can provide low-energy polishing; biofiltration can improve biodegradable and ammonia-related quality; and biological denitrification can treat nitrate-dominant groundwater. These methods are not sufficient for high fluoride, chloride, hardness or salinity. The most defensible strategy for Bharatpur is therefore a hybrid, source-specific framework combining pollution prevention, biological treatment where contaminants are biologically transformable, physicochemical polishing for dissolved minerals, and continuous monitoring. Such an approach can improve drinking-water safety while also protecting the ecological integrity of Bharatpur's wetlands and surface-water systems.

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