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Assessment of Physico-Chemical and Biological Parameters of Water Quality in the Indira Gandhi Canal, Hanumangarh District, Rajasthan

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Abstract

Reliable monitoring of freshwater bodies is central to the sustainable management of resources that support irrigation, drinking supply and rural livelihoods. This paper reports an assessment of the physico-chemical and biological condition of water drawn from the Indira Gandhi Canal as it passes through Hanumangarh District, Rajasthan. Samples were examined for pH, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids, hardness, alkalinity, chlorides, nitrates, coliform bacteria and a set of trace metals, with collection spread across the pre-monsoon, monsoon and post-monsoon seasons at several points along the canal. Recognised analytical protocols were followed throughout so that results could be benchmarked against national and international water-quality thresholds. The data reveal marked seasonal shifts in a number of parameters, consistent with the combined effects of changing hydrology, farm runoff and localised human activity along the canal command area. Concentrations of dissolved solids and nutrients rose during low-flow periods, most plausibly through evaporative concentration and inflow effects, whereas microbial counts climbed sharply during the monsoon, pointing to runoff-borne contamination. A subset of readings breached the limits set for drinking and irrigation use. Taken together, the findings signal growing pressure on the canal's ecological and public-health functions and argue for sustained monitoring, tighter pollution control, better wastewater handling and coordinated water-resource planning to safeguard this resource over the long term.

Keywords: Water quality, Indira Gandhi Canal, physico-chemical parameters, biological indicators, seasonal variation, Hanumangarh District, water pollution, environmental monitoring

1. Introduction

Water underpins every dimension of ecological function and human activity, from crop production and industrial processing to daily domestic use. The condition of a freshwater body at any given time is the product of both natural forces and human interference, and it is the interplay of these two influences that determines its physical, chemical and biological make-up. Systematic measurement of these attributes serves two purposes: it tells us whether a water source remains fit for its intended use, and it flags emerging contamination before it becomes severe. Beyond immediate suitability, long-run monitoring records feed into resource planning, inform public-health safeguards and support broader conservation goals. Natural drivers such as rainfall patterns, ambient temperature, underlying geology and soil type shape baseline water chemistry, while anthropogenic pressures - agricultural runoff, effluent discharge, expanding settlements and inadequate waste disposal - layer additional, often more volatile, changes on top of that baseline. Shifts in nutrient loading, oxygen availability and microbial density that follow from these pressures can ripple through aquatic food webs and erode biodiversity. For this reason, freshwater systems warrant continuous, methodologically sound surveillance capable of catching early warning signs, verifying regulatory compliance and steering water management toward long-term sustainability.

Among Rajasthan's engineered water systems, the Indira Gandhi Canal (IGC) stands out for its scale: it is among the largest irrigation canal networks in the country and is the lifeline that brings water into the state's arid northwest, including Hanumangarh District. While its principal function is agricultural, the canal also feeds drinking-water and livestock needs in the areas it traverses. Earlier work on canal systems generally has shown that water quality along such channels is vulnerable to pollution introduced upstream, to seasonal hydrological swings and to runoff generated within the farmed catchment. The IGC's contribution, however, extends well past irrigation alone - it underwrites groundwater recharge, sustains crop yields and anchors rural livelihoods across a landscape that would otherwise be water-stressed, giving it an outsized role in the region's socio-economic fabric. That role is now under strain. Intensifying agriculture and the steady growth of settlements along the canal corridor have heightened the risk of quality decline: residues of fertiliser and pesticide, sediment loads and untreated domestic wastewater are all capable of disturbing the canal's physico-chemical equilibrium. Seasonal changes in discharge compound this risk by altering how effectively pollutants are diluted and transported. Together, these pressures can compromise the canal's suitability for domestic and livestock use and threaten the ecological balance it supports, which is why a structured, evidence-based appraisal of its water quality is both timely and necessary.

The parameters conventionally used to characterise such water - pH, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, nutrient concentrations and trace-metal loads - jointly describe the chemical stability and contamination status of an aquatic system, while biological markers such as total and faecal coliform counts speak more directly to microbial risk and public-health implications. pH, for instance, governs the pace of many biochemical reactions and controls how readily metals dissolve; conductivity and dissolved-solids readings reveal how much dissolved salt and inorganic material the water is carrying. Dissolved oxygen availability is a precondition for aquatic life, and a rise in biochemical oxygen demand is a fairly direct signal that organic matter is being broken down at an elevated rate. Excess nitrate and phosphate can push a system toward eutrophication by fuelling algal overgrowth, while accumulated heavy metals pose a toxicity risk that can propagate up the food chain. Because no single measurement tells the whole story, a combined physico-chemical and biological assessment is the only reliable way to judge both the ecological health of a water body and its practical usability, and it is this integrated approach that the present study adopts for the Indira Gandhi Canal in Hanumangarh District.

2. Literature Review

2.1 Physico-Chemical Water Quality Indicators

The physico-chemical profile of a water sample - its chemical make-up together with measurable physical properties - remains the starting point for judging its suitability across uses. pH sits at the center of this profile because it shapes the rate and direction of chemical reactions, governs metal solubility and constrains which biological processes can proceed. Dissolved oxygen is an equally central measure, since respiration and metabolism in fish and other aquatic organisms depend directly on adequate oxygen availability; biochemical oxygen demand complements this by quantifying how much oxygen microbial communities consume while breaking down organic matter, making it a practical proxy for organic pollution load.

Total dissolved solids and electrical conductivity round out the chemical picture by indicating how much dissolved ion and mineral content the water carries. Total hardness, driven mainly by calcium and magnesium content, has a bearing on how usable water is for household and industrial purposes, while alkalinity reflects the water's capacity to resist pH swings. Nutrients such as nitrate and phosphate are essential for plant growth in modest quantities but become a liability once concentrations climb high enough to trigger eutrophication. Read together, these measures give a rounded view of a water body's chemistry, its ecological equilibrium and the stresses acting upon it.

2.2 Biological Indicators

Faecal contamination and the human-health risk that follows from it are most commonly gauged through microbial markers - total and faecal coliform counts foremost among them - particularly where the water in question is destined for domestic use. These organisms are naturally abundant in the gut of warm-blooded animals, so their presence in a water sample is a strong hint that pathogenic bacteria, viruses or protozoa may also be present, even if those agents are not directly tested for. Coliform monitoring has therefore become a standard, widely trusted way of judging sanitary quality and tracing contamination back to its likely source. A spike in coliform counts is typically a sign that untreated or partially treated sewage, livestock waste or land runoff carrying organic debris has entered the system. Microbial survival and growth in these settings respond in turn to temperature, nutrient supply and flow conditions. When microbial loads climb too high, the consequences reach beyond drinking-water safety to recreational suitability and the broader ecological functioning of the water body, since microbial activity itself alters oxygen levels and nutrient cycling. Routine microbiological testing is thus indispensable - it protects public health, guides treatment decisions and keeps water bodies within regulatory bounds.

2.3 Water Quality in Canal Systems

Investigations of major irrigation networks, including the Sirhind Feeder and various Rajasthan feeder canals, generally find that physico-chemical readings stay within acceptable bounds where the system is relatively undisturbed. In such cases, the water largely mirrors the geochemistry of its source and the geology it passes through. Even so, temporal and spatial variability is common, driven by seasonal shifts in discharge, temperature and rainfall. When flow drops, evaporation tends to concentrate dissolved salts and nutrients, pushing up conductivity and total dissolved solids; when the monsoon arrives, inflow instead introduces sediment, organic material and microbial contaminants carried in by surface runoff.

Human activity compounds these natural swings. Fertiliser and pesticide residues carried by agricultural runoff raise nutrient concentrations and biochemical oxygen demand, while domestic wastewater lifts microbial loads and disturbs the oxygen balance. Industrial operations and land-use change within a canal's command area can introduce trace metals and other pollutants on top of this. The cumulative effect of these natural and human-driven pressures can meaningfully reshape a canal's chemistry and ecological standing, underscoring why periodic monitoring matters for irrigation, domestic supply and environmental sustainability alike. A study focused specifically on the Indira Gandhi Canal within Hanumangarh District previously reported significant variation in alkalinity and chlorinity, with some readings above permissible limits - an early indication of localised contamination that the present study builds on.

3. Materials and Methods

3.1 Study Area

Hanumangarh District occupies the northwestern edge of Rajasthan, an arid tract where both irrigation and domestic water needs are met largely through canal supply. The Indira Gandhi Canal channels water drawn from the Sutlej and Beas river systems in Punjab across the state boundary into Rajasthan, making it the principal water lifeline for the district.

3.2 Sampling Strategy

Samples were drawn from six sites positioned along the canal's course through Hanumangarh District, with collection repeated across three seasonal windows - pre-monsoon, monsoon and post-monsoon - to capture temporal variation. At every site, water was collected in sterilised glass containers following standard field-sampling protocols to avoid cross-contamination.

3.3 Analytical Procedures

Laboratory analysis covered the following parameter groups using established methods:

Physical parameters: temperature, pH and turbidity.

Chemical parameters: electrical conductivity, total dissolved solids, total hardness, alkalinity, chlorides, nitrates and phosphates.

Oxygen-related parameters: dissolved oxygen and biochemical oxygen demand.

Biological parameters: total and faecal coliform counts, determined through the membrane filtration technique.

All procedures conformed to the specifications set out in BIS 10500:2012 and the relevant CPCB guidelines.

4. Results

4.1 Physico-Chemical Parameters

pH: Values stayed within the range considered acceptable for drinking water (6.5–8.5) throughout the study, though modest seasonal drift was evident.

Electrical conductivity and TDS: Both measures rose during the summer months, consistent with increased evaporation and reduced canal discharge concentrating dissolved material.

Dissolved oxygen: Readings dipped in the warmer months, signalling a decline in the water's capacity to support aquatic life during that period.

Biochemical oxygen demand: Elevated BOD values pointed to organic loading consistent with runoff from surrounding agricultural land.

Nutrients: Nitrate and phosphate levels varied across sampling rounds, a pattern likely tied to residual fertiliser input from adjoining fields.

4.2 Biological Parameters

Coliform counts: Both total and faecal coliform levels rose markedly during the monsoon season relative to other periods, a pattern that points to surface runoff as the principal route by which microbial contamination enters the canal.

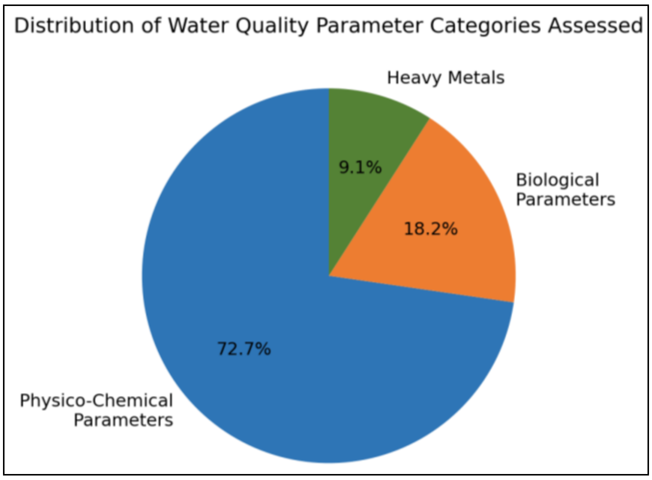

Fig 1: Relative share of the major water-quality parameter groups examined in this study.

The chart above summarises how the analytical effort was distributed across parameter categories. Physico-chemical measures make up the bulk of the assessment, reflecting the central role that chemical composition plays in determining whether canal water is fit for irrigation, domestic use and ecological maintenance. Biological indicators - chiefly the coliform counts used to flag sanitary risk - form a smaller but still essential share of the work, and heavy-metal testing, while the smallest category numerically, carries outsized importance because of the toxicity and bioaccumulation risk these substances present. The spread illustrated here reinforces the case for an integrated evaluation strategy: chemical, microbiological and toxicological data each contribute something the others cannot.

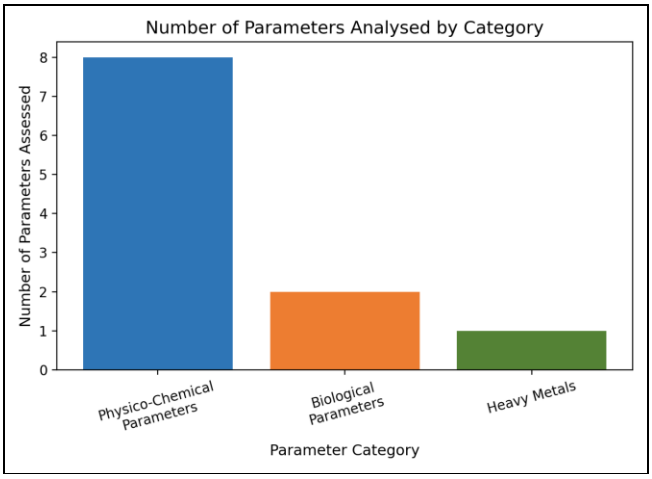

Fig 2: Number of individual parameters analysed within each category.

The bar chart conveys the same distribution in absolute terms. Physico-chemical parameters account for the tallest bar, underscoring their weight in the overall testing regime and their role in shaping conclusions about irrigation and domestic suitability. Biological indicators occupy a smaller but analytically important middle position, while the heavy-metals category, though represented by the shortest bar, remains critical given how persistent and toxic these substances can be once introduced into the aquatic system. As with the pie chart, the pattern here supports the broader argument that a comprehensive water-quality assessment cannot rest on any single parameter group alone.

5. Discussion

The results point to considerable spatial and seasonal variability across the parameters examined. Much of this variability tracks known seasonal drivers - monsoon inflow, reduced summer flow and the rhythm of the agricultural calendar - all of which leave a measurable imprint on both the chemical and biological character of the canal water. The combination of lower dissolved oxygen and higher BOD observed in certain periods hints at eutrophic tendencies that could, over time, place aquatic life under stress. These patterns broadly echo findings from other Indian surface-water studies, where heavy nutrient input and elevated microbial presence are similarly implicated in quality decline. The monsoon-season rise in coliform counts is most plausibly linked to surface runoff carrying animal and human waste into the canal, while the summer rise in TDS and conductivity fits the expected pattern of evaporative concentration during low-flow conditions. Set against canal studies from Central and Western India, the trends recorded here are consistent with the broader picture seen across agriculturally dominated watersheds in the country, suggesting that Hanumangarh's experience is not an isolated case but part of a wider regional pattern.

6. Implications

The findings carry practical weight for several groups with a stake in the canal's condition. For public-health planning, the monsoon-season spike in coliform counts is the most pressing signal: it implies that drinking-water treatment along the canal command area needs to be seasonally responsive rather than fixed, with disinfection capacity scaled up ahead of and during the monsoon rather than applied uniformly across the year. For agricultural water management, the summer rise in TDS, conductivity and nutrient concentrations suggests that irrigation scheduling and fertiliser application timing could be adjusted to reduce the concentration effect that low flow and high evaporation currently produce, and that farmers drawing water for irrigation during peak summer months should be aware of the elevated salinity load.

From a regulatory and policy standpoint, the periodic exceedance of permissible limits for BOD, nutrients and microbial load points to gaps in the current oversight of wastewater discharge and agricultural runoff within the canal command area. Strengthening enforcement of effluent standards, expanding decentralised wastewater treatment in settlements along the canal, and building seasonal water-quality monitoring into routine CPCB and state pollution-control-board schedules would together close much of this gap. For the scientific community, the seasonal patterns documented here reinforce the value of multi-season sampling designs over single-point assessments, since a one-time survey conducted outside the monsoon window would likely have understated the canal's microbial contamination risk substantially. Finally, for the communities that depend on the canal for drinking water, livestock use and irrigation, the results underline the importance of household-level precautions - such as basic water treatment before consumption during monsoon months - until systemic improvements in wastewater management and monitoring take fuller effect.

7. Conclusion

This study set out to characterise the physico-chemical and biological condition of the Indira Gandhi Canal as it flows through Hanumangarh District, and the evidence gathered confirms that water quality here is far from static. Both parameter groups showed clear seasonal movement, and at several sites and time points the readings crossed the thresholds recommended for drinking and irrigation use. These shifts trace back to a combination of hydrological change, agricultural practice and localised human pressure operating within the canal's command area, and the interaction between rising nutrient concentrations, higher dissolved-solids loads and intermittent microbial contamination shows that the canal's condition is sensitive to natural cycles and human activity in roughly equal measure.

Addressing this sensitivity calls for a management approach that treats water quality as an ongoing concern rather than a periodic checkbox. Practical measures - tighter control of agricultural runoff, better wastewater handling in settlements along the canal, regular desiltation and a sustained monitoring programme - can collectively bring pollutant loads down and stabilise conditions over time. None of this works in isolation from the people who depend on the canal, so public awareness campaigns and genuine community participation deserve equal billing alongside technical interventions; a monitoring programme that the surrounding population understands and trusts is far more likely to translate into behavioural change than one imposed from outside. Regulatory bodies, for their part, have a role in tying scientific monitoring data more closely to policy decisions, so that evidence of seasonal risk - such as the monsoon coliform spike documented here - feeds directly into treatment and enforcement schedules rather than sitting in a report. Looking ahead, extending this kind of assessment to cover a longer time series, a wider set of trace contaminants and the socio-economic dimensions of water use would sharpen understanding of how the canal's condition is likely to evolve as agricultural intensity and settlement along its banks continue to grow. Ultimately, the canal's long-term value to Hanumangarh District rests on treating these findings as a starting point for sustained, proactive intervention rather than a one-off diagnosis, so that water quality, public health and ecological stability can all be protected together over the years ahead.

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