ANALYSIS OF WATER QUALITY IN SELECTED DRINKING WATER RESOURCES OF CHHATTARGARH, BIKANER (RAJASTHAN)

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ABSTRACT

This study provides a comprehensive physical, chemical, and bacteriological analysis of drinking water resources across four rural stations (Kharwali, Sansardesar, Gaureesar, and Sattasar) near Chhattargarh within the Bikaner district of Rajasthan. Seventeen water samples across various sources—including tube wells, hand pumps, surface water reservoirs, and water works—were evaluated using standard analytical methodologies. The evaluated physico-chemical parameters include pH, electrical conductivity (EC), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), nitrate (NO_3^-), iron (Fe), total dissolved solids (TDS), and fluoride (F^-). Additionally, biological safety was determined using the Multiple Tube Dilution (MTD) method to estimate the Most Probable Number (MPN) of coliform bacteria per 100 ml. The observed chemical concentrations were systematically benchmarked against institutional baselines established by the World Health Organization (WHO) and the Indian Council of Medical Research (ICMR) to determine the regional baseline potability status.

1. INTRODUCTION

Water represents a foundational requirement for ecological sustenance, domestic sanitation, and socioeconomic development. In arid regions such as western Rajasthan, drinking water security is continuously challenged by natural geochemical configurations and accelerating anthropogenic pollution. While public health infrastructure handles purification and treatment within localized urban networks, rural ecosystems often lack structured treatment facilities, forcing decentralized populations to rely on raw groundwater and surface impoundments.

Unmonitored usage of inorganic fertilizers, unmanaged domestic effluents, and inherent lithogenic leaching directly degrade regional water tables. Exposure to elevated chemical concentrations or pathologically active microbial vectors introduces significant epidemiological risks, including gastrointestinal illnesses, chronic fluorosis, methemoglobinemia, and various waterborne conditions. Consequently, systematic physical, chemical, and biological characterization is mandatory to map contamination profiles and implement data-driven resource mitigation strategies.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling Protocol

The research area focused on four representative rural supply zones near Chhattargarh, Bikaner: Kharwali, Sansardesar, Gaureesar, and Sattasar. Environmental samples were gathered across seasonal

intervals (Pre-monsoon, Monsoon, and Post-monsoon) from dynamic source matrices consisting of Surface Water Reservoirs (SWR), Over Head Tanks (OHT), Ground Level Reservoirs (GLR), Fresh Water Ponds (FWP), Hand Pumps (HP), and Tube Wells (TW).

2.2 Analytical Methodology

Analytical techniques were executed in alignment with specialized global and regional reference standards, including APHA (1985), Trivedi & Goel (1984), and Saxena (1987).

- **pH:** Field metrics recorded utilizing narrow-range pH indicator strips were subsequently calibrated within one hour in a laboratory environment utilizing a standardized digital pH meter.
- **Alkalinity:** Characterized via standard acid titration using 0.1 N HCl solutions against phenolphthalein and methyl orange indicators to evaluate carbonate and bicarbonate balances.
- **Total Hardness (TH) & Calcium Hardness (Ca-H):** Evaluated via complexometric EDTA titrimetry using Erichrome Black-T and murexide indicators, respectively. Magnesium Hardness (Mg-H) was derived analytically via subtraction:
  Mg-H (as $CaCO_3$ mg/l) = Total Hardness − Calcium Hardness
- **Chloride (Cl^-):** Determined quantitatively via Mohr's argentometric titration method utilizing a potassium chromate (K_2CrO_4) indicator system against a 0.02 N $AgNO_3$ titrant.
- **Total Dissolved Solids (TDS):** Computed gravimetrically by passing a 100 ml sample through quantitative filter media, evaporating the filtrate within a tared dish, and drying the remaining solid matter to a constant weight at 180°C:
  TDS (mg/l) = (Mass of Residue (mg) × 1000) / Volume of Sample (ml)
- **Nitrate, Fluoride, and Iron:** Analyzed using phenoldisulfonic acid spectrophotometry, alizarin photometric detection, and standard colorimetric spectrophotometry, respectively.
- **Bacteriological Metrics:** Quantified using the Multiple Tube Dilution (MTD) technique. Samples were inoculated into double-strength MacConkey broth media incorporating bile salts (sodium taurocholate) to selectively isolate coliform agents. Inoculated tubes were incubated at 37°C for 24 to 48 hours to verify gas production within inverted Durham tubes, with positive counts cross-referenced against McCrandy probability tables to report MPN values.

3. RESULTS AND DISCUSSION

3.1 Spatial Hydrochemical Profiles

The consolidated experimental output across the four individual supply locations is documented in the following reference tables:

Table 1: Kharwali Village Hydrochemical Matrix

Parameter	Range of Values	Zone Mean
pH	7.32 − 7.69	7.555
Electrical Conductivity (EC, dS/m)	0.36 − 2.52	0.992

Total Hardness (TH, mg/l)	50.60 – 121.05	88.197
Calcium Hardness (Ca-H, mg/l)	35.04 – 70.03	55.350
Magnesium Hardness (Mg-H, mg/l)	4.57 – 50.02	28.667
Chloride (Cl–, mg/l)	30.60 – 385.30	162.742
Nitrate (NO3–, mg/l)	2.00 – 8.00	5.000
Iron (Fe, mg/l)	Nil	0.000
Total Dissolved Solids (TDS, mg/l)	395.00 – 510.00	442.500
Fluoride (F–, mg/l)	0.20 – 0.80	0.525
Coliform Count (MPN/100ml)	**0.00 – 2.00**	**0.500**

Table 2: Sansardesar Village Hydrochemical Matrix

Parameter	Range of Values	Zone Mean
pH	7.20 – 7.50	7.350
Electrical Conductivity (EC, dS/m)	0.20 – 2.40	1.625
Total Hardness (TH, mg/l)	20.00 – 165.05	75.012
Calcium Hardness (Ca-H, mg/l)	25.00 – 105.00	68.525
Magnesium Hardness (Mg-H, mg/l)	1.35 – 120.00	56.605
Chloride (Cl–, mg/l)	15.00 – 595.05	346.320
Nitrate (NO3–, mg/l)	2.00 – 8.00	4.500
Iron (Fe, mg/l)	Nil	0.000
Total Dissolved Solids (TDS, mg/l)	395.00 – 595.00	480.000

Fluoride (F−, mg/l)	0.20 − 0.60	0.437
Coliform Count (MPN/100ml)	**0.00 − 2.00**	**0.500**

Table 3: Gaureesar Village Hydrochemical Matrix

Parameter	Range of Values	Zone Mean
pH	7.00 − 7.60	7.348
Electrical Conductivity (EC, dS/m)	0.25 − 2.03	1.185
Total Hardness (TH, mg/l)	30.05 − 110.00	80.008
Calcium Hardness (Ca-H, mg/l)	28.00 − 74.00	52.841
Magnesium Hardness (Mg-H, mg/l)	25.70 − 38.00	35.611
Chloride (Cl−, mg/l)	16.40 − 290.00	166.660
Nitrate (NO3−, mg/l)	4.00 − 9.00	6.500
Iron (Fe, mg/l)	Nil	0.000
Total Dissolved Solids (TDS, mg/l)	370.00 − 520.05	417.516
Fluoride (F−, mg/l)	0.30 − 0.90	0.533
Coliform Count (MPN/100ml)	**0.00 − 2.00**	**0.500**

Table 4: Sattasar Village Hydrochemical Matrix

Parameter	Range of Values	Zone Mean
pH	7.30 − 7.50	7.266
Electrical Conductivity (EC, dS/m)	0.15 − 1.53	2.980

Total Hardness (TH, mg/l)	28.73 − 115.00	72.876
Calcium Hardness (Ca-H, mg/l)	26.00 − 68.00	45.000
Magnesium Hardness (Mg-H, mg/l)	2.70 − 46.00	28.533
Chloride (Cl−, mg/l)	15.00 − 290.00	154.330
Nitrate (NO3−, mg/l)	3.00 − 8.00	5.000
Iron (Fe, mg/l)	Nil	0.000
Total Dissolved Solids (TDS, mg/l)	390.00 − 590.00	455.000
Fluoride (F−, mg/l)	0.30 − 0.60	0.500
Coliform Count (MPN/100ml)	**0.00 − 2.00**	**1.000**

Table 5: Integrated Regional Averages

Parameter	Kharwali	Sansardesar	Gaureesar	Sattasar	Consolidated Mean
pH	7.555	7.350	7.348	7.266	7.379
EC (dS/m)	0.992	1.625	1.185	2.980	1.698
TH (mg/l)	88.197	75.012	80.008	72.876	79.023
Ca-H (mg/l)	55.350	68.525	52.841	45.000	55.429
Mg-H (mg/l)	28.667	56.605	35.611	28.533	37.354
Chloride (mg/l)	162.742	346.320	166.660	154.330	207.513
Nitrate (mg/l)	5.000	4.500	6.500	5.000	5.250
Iron (mg/l)	0.000	0.000	0.000	0.000	0.000

TDS (mg/l)	442.500	480.000	417.516	455.000	463.754
Fluoride (mg/l)	0.525	0.437	0.533	0.500	0.498
Coliform (MPN)	**0.500**	**0.500**	**0.500**	**1.000**	**0.625**

3.2 Key Parameter Interpretations

pH Stability: The regional mean pH values range tightly between 7.26 and 7.55. This indicates a slightly alkaline carbonate-bicarbonate buffering system that complies with the optimal WHO regulatory threshold (6.5 − 8.5).

Total Hardness Distribution: Total Hardness metrics fluctuate between 72.87 and 88.19 mg/l. According to classic water hardness classifications (0–75 mg/l as soft, 75–150 mg/l as moderately hard), the local supply profile sits within the safe, moderately hard domain. These levels are well beneath the 300 − 600 mg/l restrictive thresholds set by ICMR guidelines.

Chloride Dynamics: Mean chloride levels range from 154.33 mg/l at Sattasar to a peak of 346.32 mg/l at Sansardesar. While safe for human physiology, concentrations exceeding 250 mg/l cross the organoleptic limit, introducing a noticeable salty taste to the water.

Nitrate and Fluoride Toxicity Mapping: Regional values remain within safe limits, with nitrate averages between 4.50 and 6.50 mg/l (regulatory ceiling: 45 mg/l) and fluoride readings averaging close to 0.498 mg/l. Maintaining baseline values around 0.5 mg/l is essential to help minimize risks of dental caries while avoiding the onset of skeletal or dental fluorosis.

Bacteriological Safety Assessment: Groundwater samples extracted from deep tube wells and hand pumps showed very little coliform activity (0 − 2 MPN/100ml), indicating they are largely free from biological contaminants. In stark contrast, open surface reservoirs and wastewater structures exhibited major microbial contamination, as shown below:

Table 6: Surface Water Microbial Profile

Reservoir Classification	Sample ID	Specific Location	Station A (MPN)	Station B (MPN)	Combined Average
Fresh Water Pond (FWP)	01	Sansardesar	520	480	500
Fresh Water Pond (FWP)	02	Sansardesar	390	470	430
Water Reservoir (WR)	03	Gaureesar	610	590	600

Water Reservoir (WR)	04	Gaureesar	440	610	525
Waste Water Pond (WWP)	05	Sattasar	5000	8000	6500
Waste Water Pond (WWP)	**06**	**Sattasar**	**17000**	**16000**	**16500**

Critical Note: *Open surface waters and wastewater structures show exceptionally high coliform counts, reaching up to 16,500 MPN/100ml. This significant bacterial load highlights heavy pollution from surface runoff and animal access, making these sources highly unsafe for direct human consumption without comprehensive treatment.*

4. SUMMARY AND CONCLUSIONS

1. The chemical profile of groundwater resources (including tube wells and hand pumps) across the Chhattargarh rural areas is within permissible drinking water quality guidelines established by WHO and ICMR reference standards.

2. Physico-chemical indicators—including pH, total hardness, nitrate, fluoride, and total dissolved solids—lie safely within prescribed healthy consumer thresholds.

3. Groundwater structures are mostly free from significant coliform contamination, making them reliable options for local drinking water needs.

4. Open surface reservoirs and fresh water ponds are vulnerable to extensive fecal and organic pollution, meaning they should only be used for livestock or specific irrigation applications. Wastewater ponds require immediate containment to protect the health of surrounding ecosystems.

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