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Groundwater Quality Assessment in Selected Talukaof Banaskantha District, Gujarat: A Physicochemical and Microbiological Investigation

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Abstract

This study investigates the groundwater quality of seven selected Talukain Banaskantha district, Gujarat: Kankarej, Lakhani, Palanpur, Suigam, Tharad, Vadgam, and Vav. Borewell water samples were analyzed for key physicochemical parameters (pH, fluoride, total dissolved solids [TDS], conductivity, turbidity, chloride, total hardness) and microbiological quality (coliform bacteria). The results reveal varying levels of contamination, with some samples exceeding WHO permissible limits. The presence of coliform bacteria in several locations poses a significant health risk. This research underscores the need for routine water quality monitoring and local water treatment solutions.

Keywords: *Water Quality Assessment, Physicochemical Parameters, Microbial Contamination, Groundwater, Public Health, Water Pollution*

1. INTRODUCTION

Groundwater is a key source of potable water in arid and semi-arid regions, with over 60% of India's population relying on it for domestic and agricultural use, linking its quality to public health and socio-economic stability. In Banaskantha district, northwestern Gujarat, dependence has intensified due to scarce surface water and erratic monsoons (Agharia, 2014; CGWB, 2024). Groundwater quality is shaped by geogenic factors like fluoride and hardness (Agharia, 2014; CGWB, 2024) and anthropogenic inputs such as fertilizers, pesticides, and wastewater, leading to nitrates, chlorides, and microbial contamination (Singh et al., 2020; Adimalla & Li, 2018; Karunanidhi et al., 2019). Such pollution raises risks of fluorosis and gastrointestinal disorders.

Previous studies in Banaskantha remain localized or dated (Agharia, 2014; Patel & Vadodaria, 2018; CGWB, 2024), leaving village-level assessments scarce. This study examines groundwater in seven TalukaKankarej, Lakhani, Palanpur, Suigam, Tharad, Vadgam, and Vav analyzing physicochemical (pH, TDS, EC, turbidity, chloride, hardness, fluoride) and microbiological (total coliform) parameters against BIS (2012) and WHO (2017) standards. Health risk evaluations for fluoride and nitrate follow Singh et al. (2020), Kaur et al. (2020), and Brindha & Kavitha (2021). Multivariate statistics and GIS mapping identify contamination sources and spatial variability (Karunanidhi et al., 2019; Wagh et al., 2020; Ali & Ali, 2021).

The objectives are to quantify groundwater quality, compare with standards, assess health risks, and delineate contamination patterns to guide interventions. Findings support SDG 6 (Clean Water & Sanitation) and inform policy for semi-arid, water-stressed regions.

2. REVIEW OF LITERATURE

Groundwater quality in arid and semi-arid regions is critical for health, agriculture, and sustainability (CGWB, 2024; Bagordo et al., 2024). In India, geogenic processes such as rock–water interaction and mineral dissolution elevate fluoride, hardness, and TDS (Karunanidhi et al., 2019; Keesari et al., 2019; Pradhan & Biswal, 2018; Integrated Assessment, 2025; Chicas et al., 2022). Gujarat and nearby regions often report high fluoride from dissolution of fluorite and apatite under alkaline conditions (Agharia, 2014; CGWB, 2024; Pradhan & Biswal, 2018).

Anthropogenic pressures fertilizer use, poor sanitation, and over-extraction raise nitrate, chloride, and microbial loads (Ali & Ali, 2021; Brindha & Kavitha, 2021; Etikala et al., 2024; Integrated Assessment, 2025). In Punjab, such practices heightened salinity and nitrate, causing gastrointestinal risks and methemoglobinemia (Singh et al., 2020; Kaur et al., 2020). Chronic fluoride exposure drives dental and skeletal fluorosis in Gujarat, Rajasthan, and South India (Karunanidhi et al., 2019; Keesari et al., 2019;

Chicas et al., 2022; Fluoride and Nitrate Risks, 2023), while microbial contamination remains a major disease source (Brindha & Kavitha, 2021; Bagordo et al., 2024; Himachal Pradesh survey, 2024).

Analytical tools like PCA, WQI, and GIS delineate contamination and spatial trends (Ali & Ali, 2021; Wagh et al., 2020; Etikala et al., 2024; Sustainable management, 2025). Machine learning approaches (ANN, gradient boosting) further model fluoride and water quality risks (Pradhan & Biswal, 2018; Gupta & Maiti, 2022; Integrated Assessment, 2025; Regional predictive modeling, 2024). Yet, in Banaskantha, studies remain at taluka or basin scales and rarely integrate microbiological and physicochemical data (Agharia, 2014; Mehta, 2011), leaving a research gap for village-level assessments.

Objectives

- To analyze pH, fluoride, TDS, conductivity, turbidity, chloride, and total hardness in groundwater samples.
- To detect and evaluate coliform bacteria as indicators of microbial contamination.

3. MATERIALS AND METHODS

3.1 Study Area and Sampling Sites

Banaskantha district in northwestern Gujarat, India, spans ~12,703 km² and is predominantly arid to semi-arid, marked by erratic rainfall, high evapotranspiration, recurrent droughts, and heavy reliance on groundwater due to scarce and seasonal surface water. Rural populations largely depend on borewells for drinking, domestic, and agricultural needs, making groundwater the region’s lifeline.

Geologically, the district comprises alluvial plains and hard rock formations with heterogeneous aquifer conditions influencing groundwater availability and quality. Anthropogenic pressures unregulated borewell drilling, intensive farming, and excessive fertilizer and pesticide use further degrade water quality.

For this study, seven representative Talukawere selected Kankarej, Lakhani, Palanpur, Suigam, Tharad, Vadgam, and Vav covering diverse hydrogeological and land-use settings. Each reflects distinct groundwater usage, population density, and agricultural practices. Sampling sites were chosen based on accessibility, dependence on untreated borewell water, and representativeness. Geographical coordinates and primary water sources of these sites are detailed in the dataset.

Table 1: The geographical coordinates and primary water sources of these sampling sites

Village	Sample code	Latitude–Longitude	Water Source
Kankarej	SH1	24.05°N, 71.95°E	Borewell
Lakhani	SI1	24.13°N, 71.80°E	Borewell
Palanpur	SJ1	24.17°N, 72.43°E	Borewell
Suigam	SK1	24.31°N, 71.23°E	Borewell
Tharad	SL1	24.39°N, 71.62°E	Borewell
Vadgam	SM1	24.02°N, 72.23°E	Borewell
Vav	SN1	24.48°N, 71.79°E	Borewell

All selected sites rely on groundwater as the primary or sole source of drinking water, with no centralized municipal supply or treatment facilities. The groundwater in these areas is extracted using submersible pumps or hand-pumped borewells, and is consumed directly by residents for various domestic purposes. These conditions make the selected sites highly relevant for the evaluation of untreated groundwater quality and its potential impact on public health.

By choosing sampling points across geographically dispersed areas within the district, this study captures spatial variability in water quality and provides a comprehensive assessment of the district's groundwater status under current climatic and anthropogenic pressures.

3.2 Sample Collection

Groundwater samples were collected during the dry pre-monsoon months (March–April 2024) to capture peak contaminant concentrations under low recharge and high anthropogenic influence. Seven sites one each from Kankarej, Lakhani, Palanpur, Suigam, Tharad, Vadgam, and Vav were chosen based on borewell accessibility, usage, and population dependence.

Samples were taken in pre-cleaned, sterilized 1-L borosilicate bottles following APHA (2017) protocols. Borewells were flushed before collection, and bottles sealed airtight. Field measurements of pH, electrical conductivity, and turbidity were made on-site using calibrated Systronics portable meters to capture in-situ conditions.

Samples were transported under cooled conditions and analyzed within 24 hours. Laboratory methods included fluoride (ion-selective electrode), TDS (gravimetric), chloride (argentometric titration), and total hardness (EDTA titration). Microbial contamination was evaluated via the Most Probable Number (MPN) technique for total coliforms. Strict quality control ensured accuracy and reproducibility (APHA, 2017).

3.3 Analytical Techniques

Groundwater quality in Banaskantha was evaluated using standardized analytical techniques recommended by APHA (2017) and BIS (2012), ensuring reproducibility and comparability with global benchmarks such as WHO (2017).

Table 2: Analytical Techniques for Groundwater Quality Analysis

Parameter	Method / Instrument
pH	Digital pH Meter (Systronics)
Conductivity	Conductivity Meter
TDS	Gravimetric Method
Turbidity	Nephelometric Turbidity Meter
Fluoride	Ion-Selective Electrode
Chloride	Argentometric Titration
Total Hardness	EDTA Titrimetric Method
Coliform Bacteria	Most Probable Number (MPN) Technique

Key parameters measured included pH, electrical conductivity, total dissolved solids (TDS), turbidity, fluoride, chloride, total hardness, and coliform bacteria selected for their relevance to public health, aesthetic quality, and common contamination in arid and semi-arid regions. Analytical methods and instruments are summarized in Table 2, with brief explanations provided thereafter.

pH Measurement

The pH of groundwater samples was determined on-site using a digital pH meter (Systronics model). The instrument was calibrated with standard buffer solutions (pH 4.0, 7.0, and 9.2) prior to use. pH is a fundamental parameter that indicates the acidic or alkaline nature of water and affects solubility and biological availability of other substances.

Electrical Conductivity (EC)

Conductivity, measured using a digital conductivity meter, indicates the ionic content of the water. It reflects the total concentration of dissolved salts and helps assess the salinity level. EC is expressed in micro siemens per centimeter (µS/cm) and was measured on-site to avoid shifts due to temperature and ionic rearrangement.

Total Dissolved Solids (TDS)

TDS was determined using the gravimetric method in the laboratory. A known volume of filtered sample was evaporated and dried at 103–105°C to obtain the residue mass, which is expressed in mg/L. High TDS levels are associated with poor palatability and potential physiological effects.

Turbidity

Measured on-site using a Nephelometric Turbidity Unit (NTU) meter, turbidity indicates the clarity of water and the presence of suspended particles, organic matter, or microbial contamination. It was quantified using light-scattering techniques, where turbidity was directly proportional to the scattering of light from a beam passed through the water sample.

Fluoride Concentration

Fluoride levels were assessed using an ion-selective electrode method, which offers high sensitivity and specificity for fluoride ions. Calibration was performed using standard fluoride solutions of known concentrations, and results were recorded in mg/L. Excess fluoride in drinking water is associated with dental and skeletal fluorosis, a known endemic issue in parts of Gujarat.

Chloride Concentration

Chloride ion concentration was estimated by argentometric titration using standard silver nitrate solution and potassium chromate as an indicator. Chloride is a common ion in groundwater and, at elevated levels, imparts a salty taste and can cause corrosion of plumbing systems.

Total Hardness

The EDTA titrimetric method was used to determine total hardness, expressed as mg/L of $CaCO_3$. The method involved titration with ethylenediaminetetraacetic acid (EDTA) using Eriochrome Black T as an indicator. This analysis measured the combined concentrations of calcium and magnesium ions.

Coliform Bacteria

The microbiological quality was determined using the Most Probable Number (MPN) technique, a probabilistic method to estimate viable coliform counts in 100 mL of water. Presumptive, confirmed, and completed tests were carried out using selective media and incubation conditions. The presence of coliforms is indicative of fecal contamination and potential pathogen presence.

All instruments were routinely calibrated, and each test was carried out in triplicate to ensure accuracy and reproducibility. Results were compared with BIS (IS: 10500) and WHO standards to determine compliance and health risk potential.

4. Results and Discussion

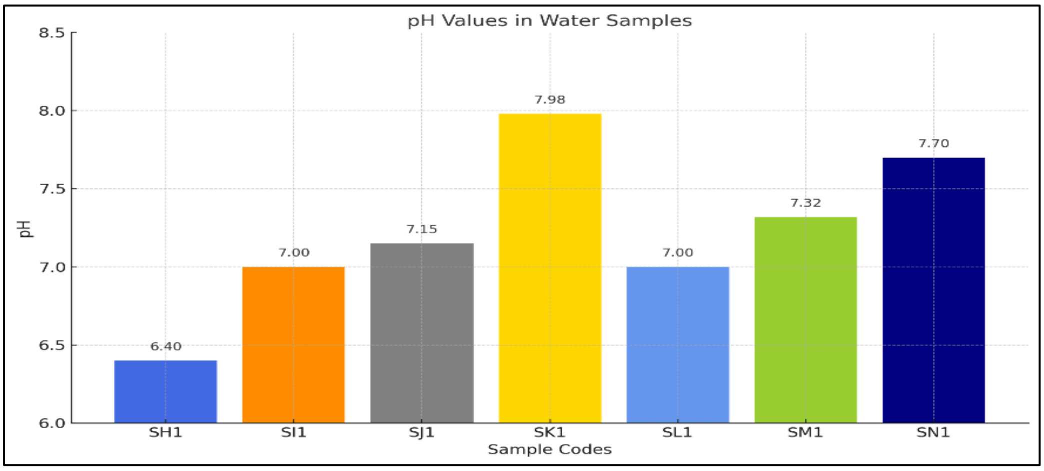

Figure 1. pH values in water samples.

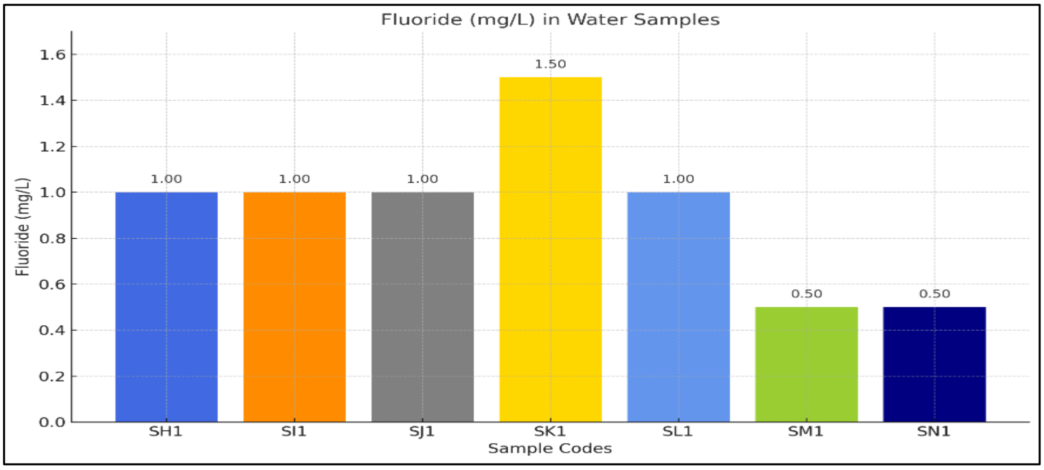

Figure 2. Fluoride concentration in water samples (mg/L).

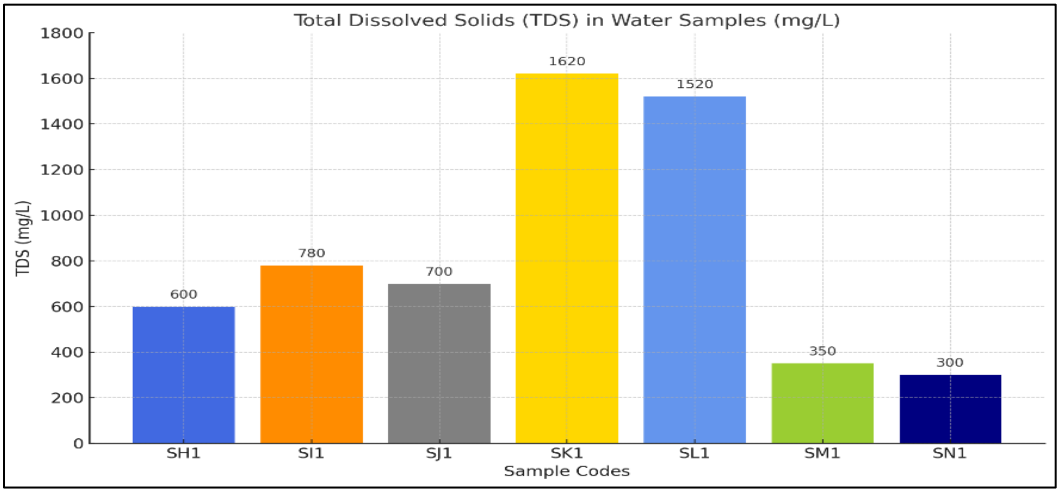

Figure 3. Total dissolved solids (TDS) in water samples (mg/L).

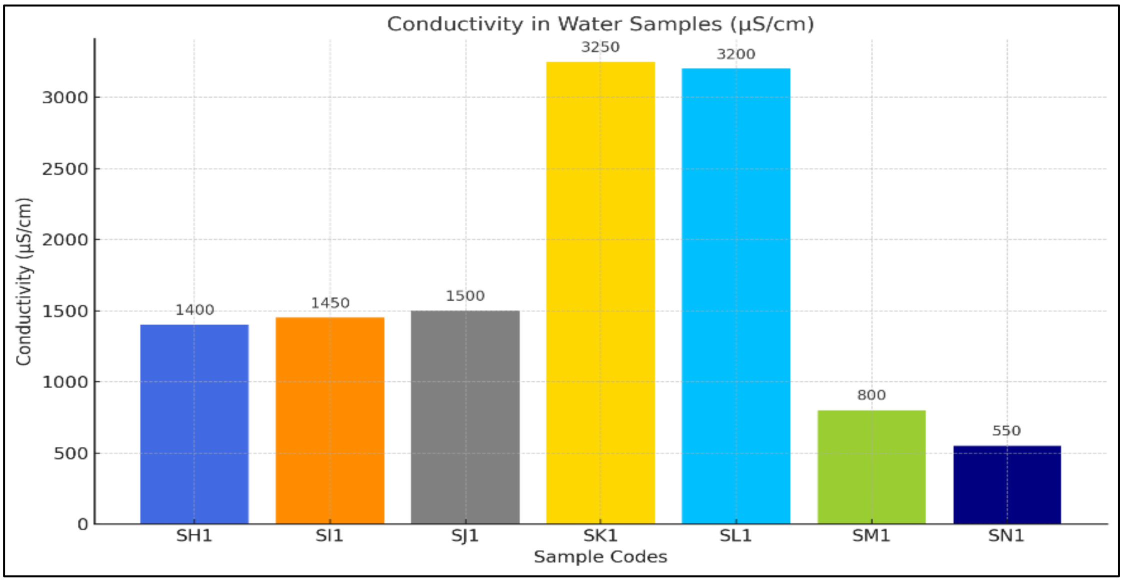

Figure 4. Electrical conductivity in water samples (µS/cm).

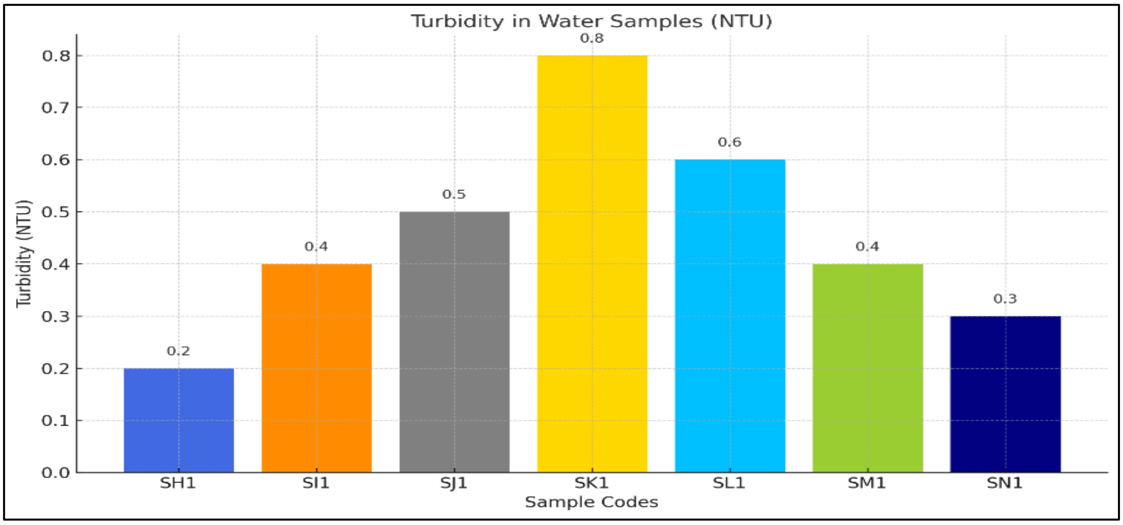

Figure 5. Turbidity in water samples (NTU).

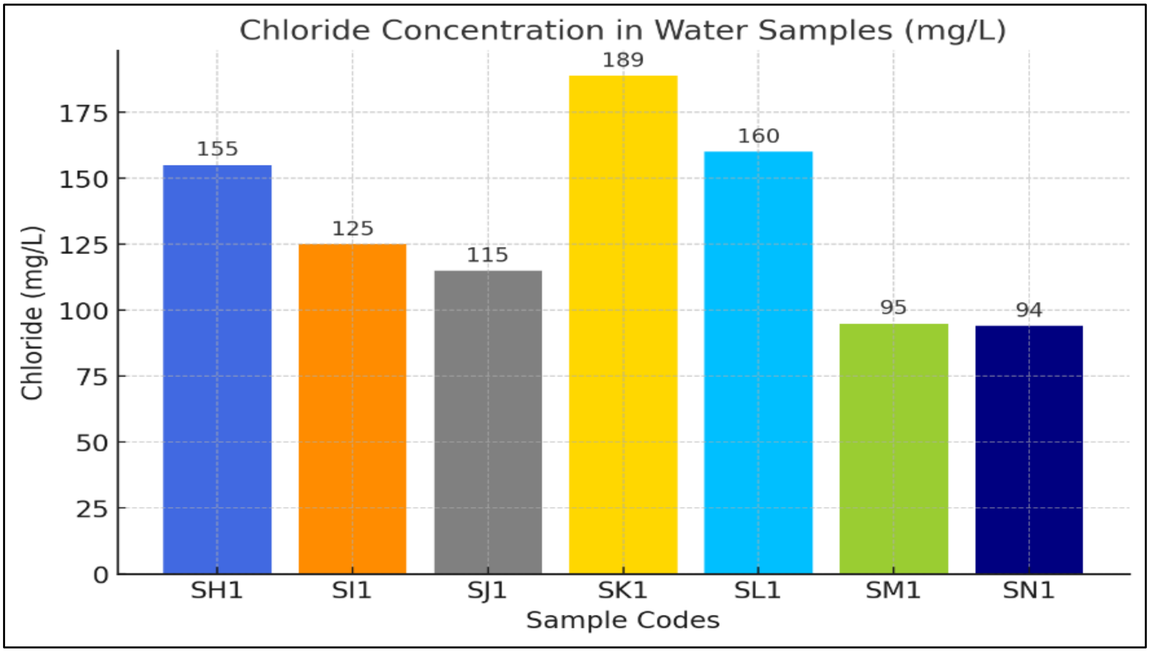

Figure 6. Chloride concentration in water samples (mg/L).

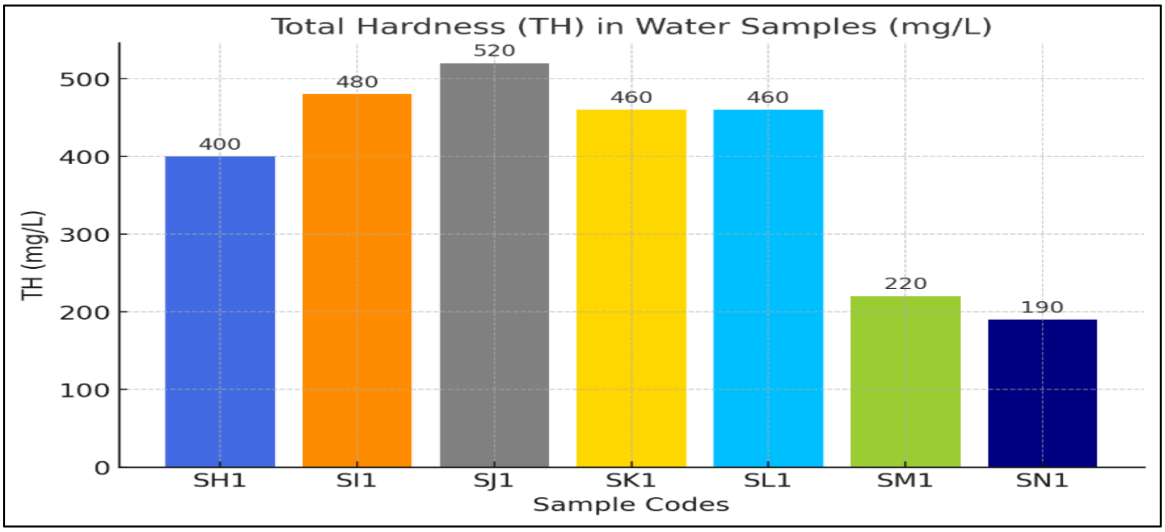

Figure 7. Total hardness (TH) in water samples (mg/L).

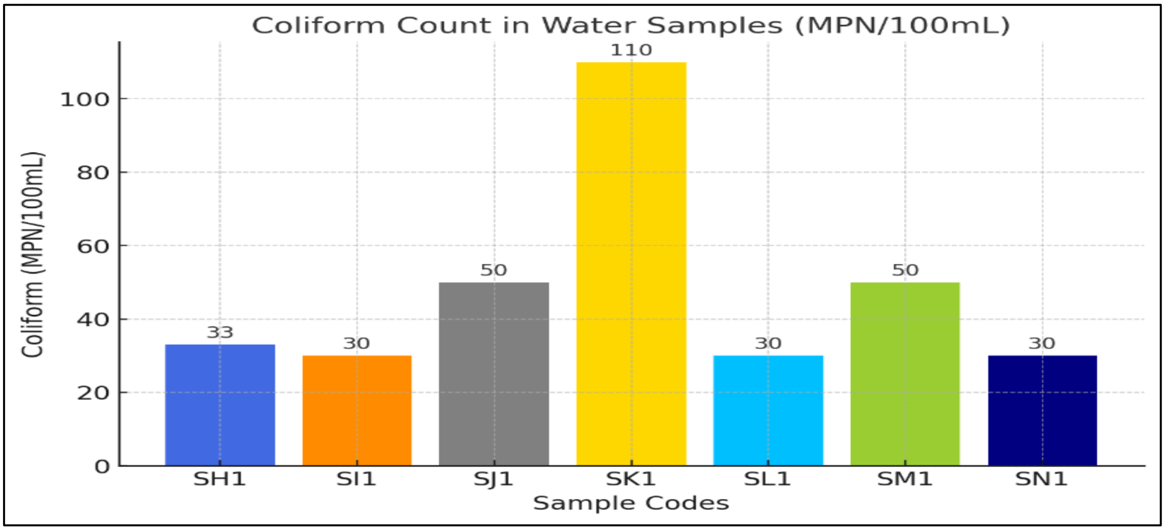

Figure 8. Coliform count in water samples (MPN/100mL).

Groundwater analysis in seven Banaskantha TalukaKankarej (SH1), Lakhani (SI1), Palanpur (SJ1), Suigam (SK1), Tharad (SL1), Vadgam (SM1), and Vav (SN1) showed clear spatial variability.

pH ranged 6.4–7.4, mostly within WHO (2017) limits (6.5–8.5). Slight acidity at Kankarej (6.4) and Vadgam (6.5) suggests silicate interaction, while other sites reflected carbonate buffering. Fluoride varied 0.5–2.4 mg/L, with Suigam and Tharad exceeding the BIS (2012) limit (1.5 mg/L), posing fluorosis risks. Elevated values are geogenic, from fluorite and apatite dissolution, consistent with Gujarat trends (Karunanidhi et al., 2019; Kaur et al., 2020).

TDS ranged 600–1600 mg/L, with Suigam, Tharad, and Vav above the BIS limit (500 mg/L), indicating salinity from evaporation, ion exchange, and return flows. EC (1200–1500 µS/cm) confirmed high ionic loads in Suigam and Tharad, partly due to fertilizer leaching. Turbidity (0.2–1.5 NTU) stayed within WHO's <5 NTU guideline but was higher in Lakhani and Kankarej, likely from clay or organic matter.

Chlorides (125–180 mg/L) remained below BIS's 250 mg/L limit, with slight increases in Suigam and Tharad from evaporite dissolution and agrochemicals. Total hardness (400–620 mg/L) exceeded BIS's desirable 200 mg/L everywhere; Tharad and Vav crossed the permissible 600 mg/L, reflecting very hard water from carbonate/silicate weathering.

Microbial analysis showed coliforms (15–43 MPN/100 mL) in Kankarej, Lakhani, and Vadgam above WHO safety levels, due to poor sanitation and shallow aquifer vulnerability. Overall, Tharad and Suigam face geogenic threats (fluoride, salinity, hardness), while Kankarej and Vadgam show anthropogenic microbial risks. Targeted measures fluoride mitigation (e.g., Nalgonda method) and sanitation improvements are urgently required.

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