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Assessment of Drinking Water Quality in Palanpur Division

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KEYWORDS

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ABSTRACT:

Through the analysis of triplicate samples taken from boreholes in nine chosen villages in the Palanpur Division of Gujarat, this study evaluates the groundwater quality in those villages. pH, fluoride, total dissolved solids (TDS), electrical conductivity, turbidity, chloride, total hardness (TH), calcium, magnesium, total alkalinity, nitrate, sulfate, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) were among the important physicochemical and biological parameters that were assessed. The findings showed spatial variability, with multiple samples surpassing the WHO, TDS, and fluoride limits as well as the BIS (10500:2012) standards. Villages like Madana and Gadh had extremely hard water and TDS levels above 1000 mg/L. In several locations, fluoride levels were close to 1 mg/L, which could be harmful to health. Localized organic contamination was indicated by elevated BOD and COD levels. The results emphasize that in order to guarantee drinkable groundwater and long-term water security in the area, routine monitoring, defluoridation units, water softening, and community-level interventions are required.

1. Introduction

In Palanpur Division, Banaskantha, Gujarat, where there is little rainfall (600–700 mm per year), over 85% of the 3.1 million inhabitants rely on groundwater as their main resource for agriculture, drinking, and livestock (Census of India, 2011). Geochemical processes and anthropogenic inputs pose a threat to quality; the main contaminants are fluoride, nitrates, salts, and pollutants from industry, agriculture, and inadequate waste management (Adimalla & Venkatayogi, 2023; Shirke et al., 2020; Zhu et al., 2022). Fluorosis is caused by elevated fluoride (>1.5 mg/L) (Pradhan & Biswal, 2018; Shirke et al., 2020), and usability is restricted by high TDS and hardness (Jha et al., 2021; Vyas et al., 2019). High BOD and COD are indicators of organic pollution from both industrial and residential sources (CPCB, 2021; Kumar et al., 2022). There is still little monitoring (CGWB, 2022; UN-Water, 2023). In order to compare the results with the BIS (2023) and WHO (2022) standards, this study examined 27 samples from nine villages for the following parameters: pH, fluoride, TDS, EC, turbidity, chloride, TH, calcium, magnesium, alkalinity, nitrate, sulfate, DO, BOD, and COD. The results demonstrate spatial variability, with localized organic contamination (CPCB, 2021; Kumar et al., 2022) and multiple samples surpassing fluoride, TDS, and hardness limits (BIS, 2023; Jha et al., 2021). These findings point to areas of high contamination and demand focused treatment, public health initiatives, and sustainable groundwater management.

2. Scope of the Present Study

The majority of Gujarati groundwater studies are not village-specific, particularly in semi-arid areas like Palanpur Division and Banaskantha, and they frequently use district-wide averages, which obscures local variances that are essential for focused management. Biological indicators like BOD and COD are not fully integrated into previous research, which primarily focuses on physicochemical parameters (BIS, 10500:2023; WHO, 2022). Sources of contamination are often inferred without field-level validation, and comparisons against updated BIS and WHO standards are also scarce. This study fills these gaps by conducting a multi-parameter, village-level assessment at nine different locations. To identify hotspots and guide intervention strategies, triplicate borehole samples for pH, TDS, fluoride, total hardness, major ions, BOD, COD, and DO are analyzed and benchmarked against BIS (10500:2023) and WHO (2022) standards.

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3. Importance of the Study

In the semi-arid Palanpur Division, where communities rely significantly on groundwater for everyday needs, this study offers an essential, localized evaluation of groundwater quality. It closes a significant data gap that prevents focused intervention by examining village-level differences in physicochemical and biological parameters, such as BOD and COD. The results set a scientific foundation for sustainable groundwater monitoring and management while supporting rural water safety planning, policy creation, and the implementation of localized treatment solutions like defluoridation or RO systems.

4. Review of Literature

In India, groundwater quality is a major environmental and public health issue, especially in semi-arid areas like Banaskantha where contamination is influenced by both natural geogenic processes and human activities like waste discharge and agricultural runoff (Adimalla & Venkatayogi, 2023). Gujarat has a serious fluoride pollution problem, with levels above WHO guidelines associated with skeletal and dental fluorosis (Gupta et al., 2017; Saxena & Ahmed, 2003). In Gujarat borewells, high TDS is frequently reported to have an adverse effect on health and palatability (Jha et al., 2021; Shukla et al., 2020). BOD and COD, two indicators of organic pollution, are rising and are frequently associated with inadequate sanitation in the vicinity of agricultural areas (CPCB, 2021; Giri & Singh, 2014). Multivariate statistical tools aid in mapping hotspots and identifying the sources of contaminants (Kumar et al., 2020). Integrating local data into governance is emphasized by sustainable management frameworks (UN-Water, 2023; Singh et al., 2022). In semi-arid belts, seasonal fluctuations and overextraction deteriorate water quality (Rao et al., 2015; Rajmohan & Elango, 2005). While seasonal studies indicate post-monsoon dilution improves quality, geogenic elements contribute to hardness that affects infrastructure and health (Pathak & Vyas, 2019) (Yadav et al., 2021). For focused mitigation, village-level evaluations work better (Sharma et al., 2018). Micro-regional contamination patterns are revealed by sophisticated tools such as GIS (Singh & Bhatnagar, 2020). BIS (2023) and WHO (2022) offer crucial compliance benchmarks. According to Misra et al. (2022), socioeconomic factors also affect contamination, emphasizing the necessity of interdisciplinary approaches. Incorporating physicochemical, microbial, and heavy metal data into comprehensive water quality indices is also advised by reviews (Ghosh & Bhattacharya, 2021; Pandey & Singh, 2019).

5. Objectives of the Study

The primary aim of this study is to assess the groundwater quality in selected villages of the Palanpur Division, Banaskantha district, Gujarat, by analyzing a comprehensive set of physicochemical and biological parameters. The specific objectives are as follows:

1. To evaluate the physicochemical characteristics (such as pH, TDS, electrical conductivity, total hardness, calcium, magnesium, chloride, nitrate, sulfate, and alkalinity) of groundwater samples collected from nine selected villages.
2. To determine the levels of key biological parameters, including dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD), to assess organic pollution and potential anthropogenic impacts on water quality.
3. To identify spatial variations in groundwater quality across different villages and water sources (wells, boreholes, and hand pumps), highlighting areas with critical contamination issues.

6. Materials and Methods

6.1 Sampling Sites

The study was carried out in the semi-arid Palanpur Division of Banaskantha, Gujarat, which depends on groundwater for domestic, agricultural, and drinking purposes. Based on factors like population, reliance on groundwater, reported quality problems, and geographic distribution, nine villages were chosen. In order to represent actual exposure risks, sampling points included standposts, hand pumps, boreholes, and wells.

6.2 Sample Collection

In accordance with APHA (2017) and BIS guidelines, a total of 27 samples—three from each village—were taken from hand pumps, wells, or boreholes. Glass-stoppered BOD bottles were used for BOD/COD analyses, while HDPE bottles were used for physicochemical analyses. Samples were transported in

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ice-cooled boxes and preserved on-site using solutions such as sodium thiosulfate for chlorine and nitric acid for metals. Temperature, pH, turbidity, electrical conductivity, DO, and other field parameters were measured using calibrated portable meters, and laboratory analyses were finished in a day.

6.3 Analytical Methods

Biological and physicochemical parameters were examined in accordance with WHO (2017), BIS 10500:2012, and APHA (2017) guidelines. On-site measurements were made of pH, turbidity, TDS, and conductivity using a conductivity meter. UV-Vis spectrophotometry was used to quantify fluoride, chloride, nitrate, and sulfate. Titration techniques were used to measure alkalinity, calcium, magnesium, and hardness. Winkler's method was used to measure DO, dichromate reflux was used to measure COD, and a 5-day incubation at 20°C was used to measure BOD.

6.4 Methodology

Using triplicate samples taken during a single season in accordance with BIS (10500:2023) and APHA (2017) guidelines, the quality of the groundwater was evaluated. Fluoride, TDS, chloride, hardness, calcium, magnesium, alkalinity, nitrate, sulfate, BOD, and COD were all analyzed in the lab. To assess whether the results were suitable for drinking, they were compared to BIS and WHO standards.

6.5 Standards

The outcomes were contrasted with WHO (2022) drinking water standards and BIS 10500:2023. WHO offers globally accepted thresholds with updated TDS and fluoride limits (WHO, 2022; Adimalla & Venkatayogi, 2023), while BIS offers desirable and acceptable limits for physicochemical and biological parameters, such as fluoride and heavy metals (BIS, 2023; CGWB, 2022). The Palanpur Division's water management plans were guided by this comparison, which also assisted in identifying hazardous areas (Jha et al., 2021). (UN-Water, 2023).

7 Results and Discussion

Groundwater analysis from 27 samples across nine villages in Palanpur Division exhibited significant spatial variability in comparison to BIS (10500:2012) and WHO (2017) standards. The pH (7.0–8.26) and turbidity (0.3–1 NTU) were both fine. Fluoride levels often hit the upper limit of 1 mg/L, especially in Chadotar, Chandisar, Gadh, Madana, and Malan. This means that there was a risk of fluorosis. The total dissolved solids (TDS) levels were between 180 and 1270 mg/L. Madana, Gadh, and Khumbhasan all had levels higher than the recommended 500 mg/L. The hardness ranged from 100 to 560 mg/L, and the samples from Gadh and Madana were very hard. Nitrate levels were mostly low, but they were dangerously high at Madana (415 mg/L), which could be bad for babies' health. Sulfate levels stayed safe. Chloride (120–655 mg/L) was below the 1000 mg/L limit, but higher levels in Madana suggest salinity problems. DO levels were between 3.8 and 8.6 mg/L, BOD levels were between 1.2 and 7.8 mg/L, and COD levels were between 8 and 22.4 mg/L. This showed that there was organic pollution in certain areas. Madana and Gadh were found to be major contamination hotspots that needed actions like defluoridation, TDS and nitrate removal, and community-level water safety planning.

8. Conclusion

Groundwater quality showed marked variability across sites. pH (7.0–8.26) remained within WHO/BIS limits, though Jagana (8.26) indicated slight alkalinity. Fluoride (0.5–1 mg/L) was below the 1.5 mg/L threshold, with lower values in Malan, Sasam, and Takarwada. TDS ranged widely (180–2540 mg/L), with Madana (S18) far exceeding the 500 mg/L limit, while Malan (S20) was lowest. Conductivity followed the same trend, and turbidity (0.3–1 NTU) remained safe. DO varied from 3.8–10.8 mg/L, with low levels in Chadotar and Sasam, while BOD (up to 7.8 mg/L) and COD (up to 22.4 mg/L) peaked in Chandisar and Malan, reflecting organic pollution. Chloride exceeded 250 mg/L in Madana (654.79 mg/L) and Chandisar (364.88 mg/L), suggesting salinity or effluent impact. Hardness was high in Madana (560 mg/L) and Gadh (420 mg/L), linked to carbonate aquifers, while alkalinity (55–415 mg/L) and sulfate (55–81 mg/L) were within limits. Nitrate (20–38 mg/L) remained safe, indicating limited fertilizer intrusion.

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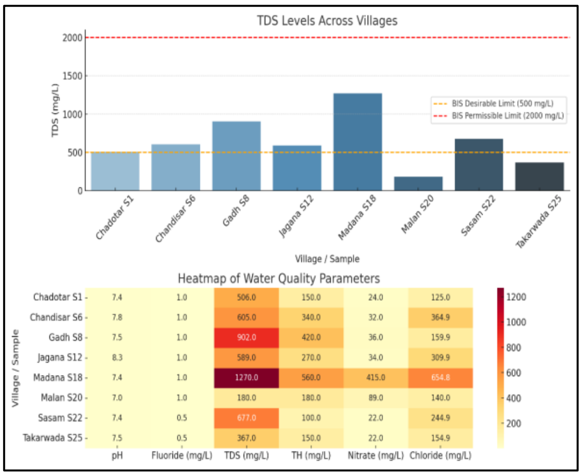

Figure 1: Heatmap of Water Quality Parameters

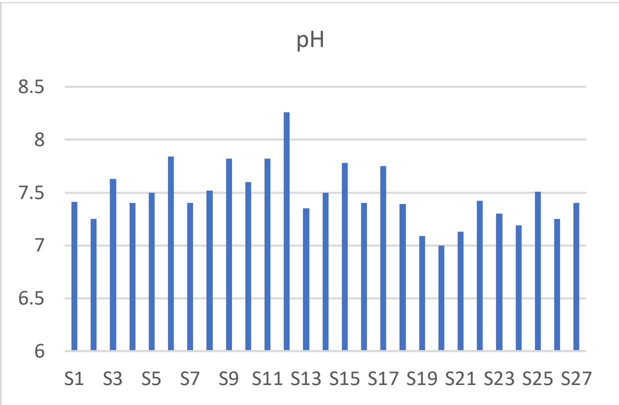

Figure: 2 Bar chart showing pH levels

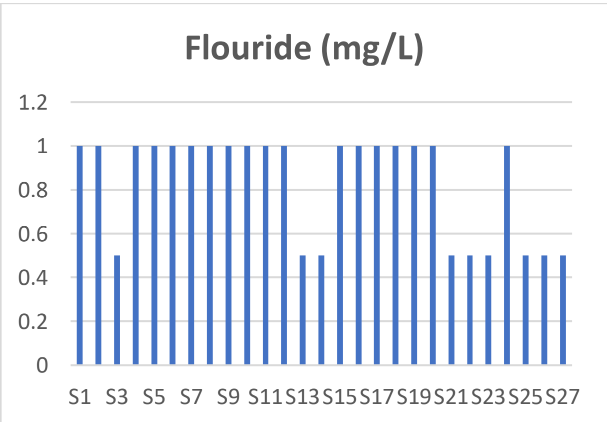

Figure: 3 Bar chart illustrating fluoride concentrations (mg/L)

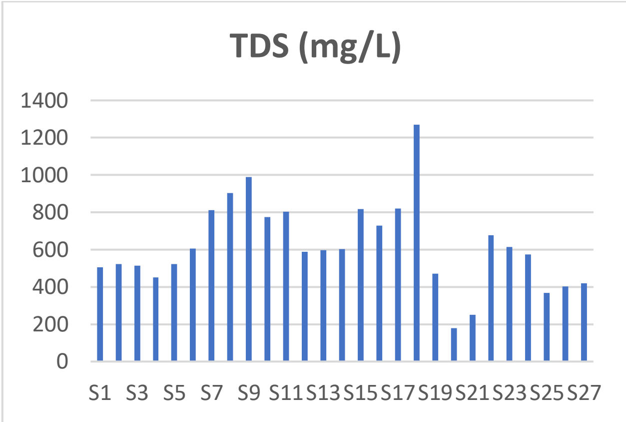

Figure: 4 Bar chart TDS (mg/L)

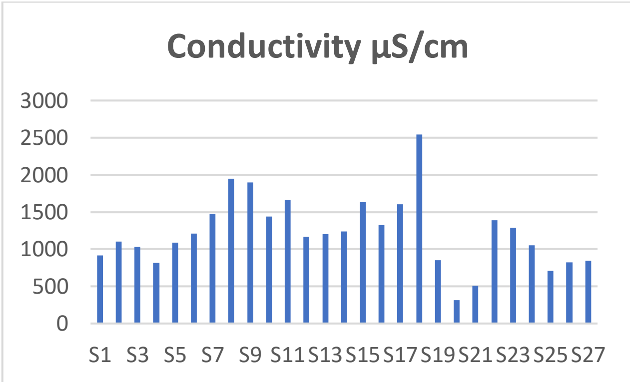

Figure: 5 Bar chart Conductivity µS/cm

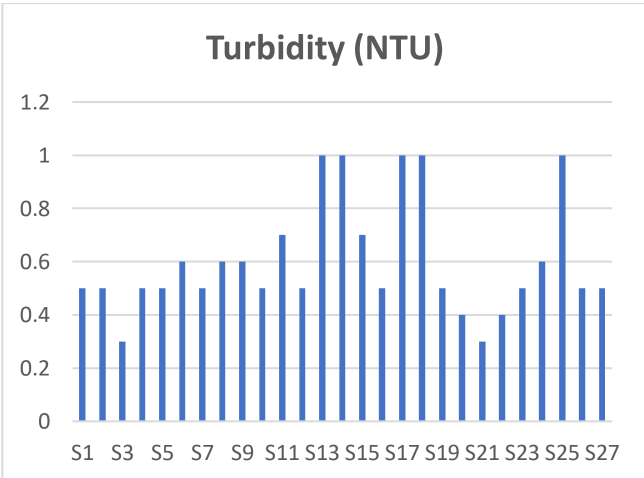

Figure: 6 Bar chart Turbidity (NTU)

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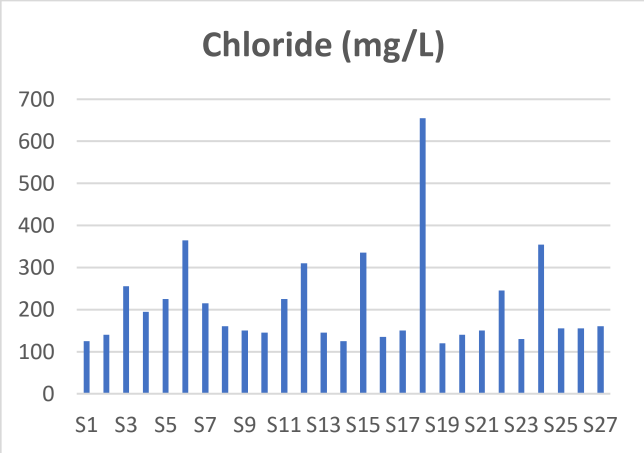

Figure: 7 Bar chart Chloride (mg/L)

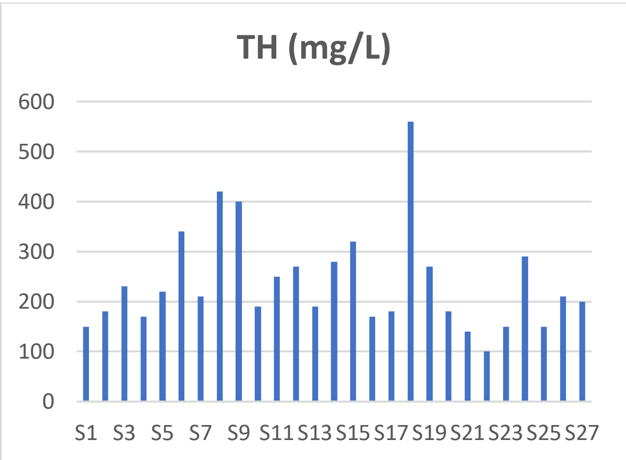

Figure: 8 Bar chart TH (mg/L)

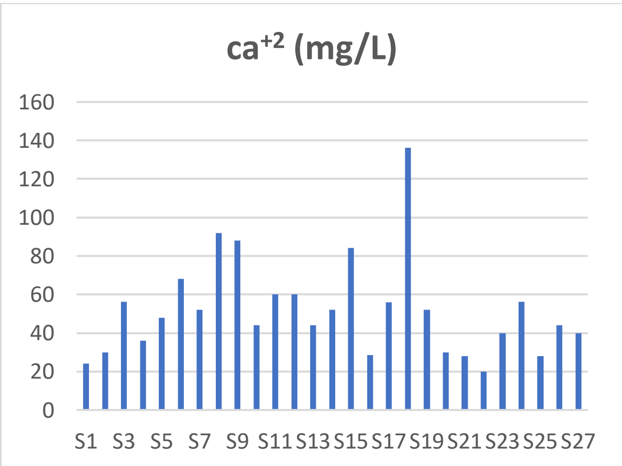

Figure: 9 Bar chart ca^{+2} (mg/L)

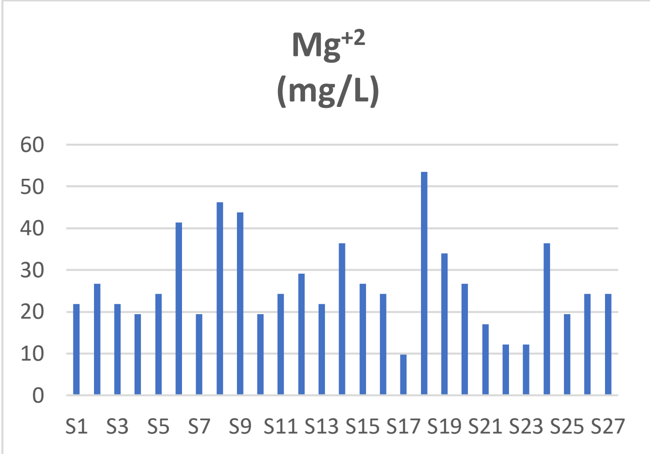

Figure: 10 Bar chart Mg^{+2} (mg/L)

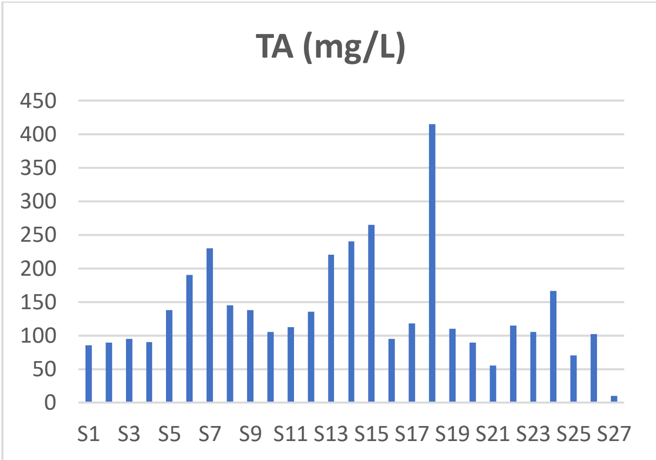

Figure: 11 Bar chart TA (mg/L)

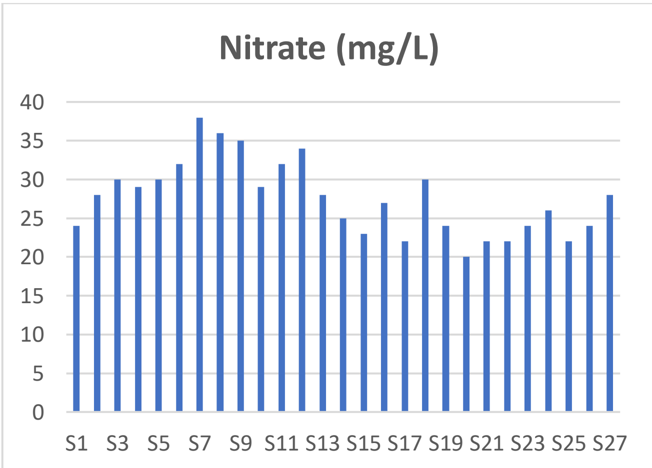

Figure: 12 Bar chart Nitrate (mg/L)

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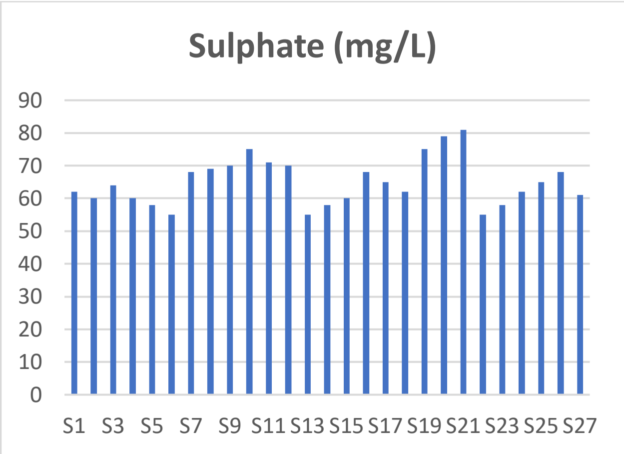

Figure: 13 Bar chart Sulphate (mg/L)

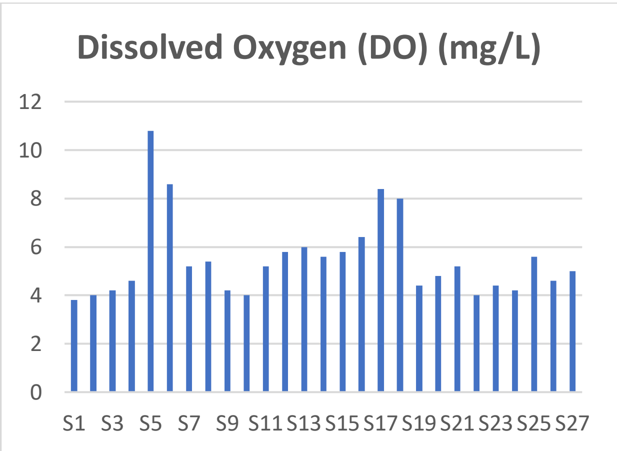

Figure: 14 Bar chart DO (mg/L)

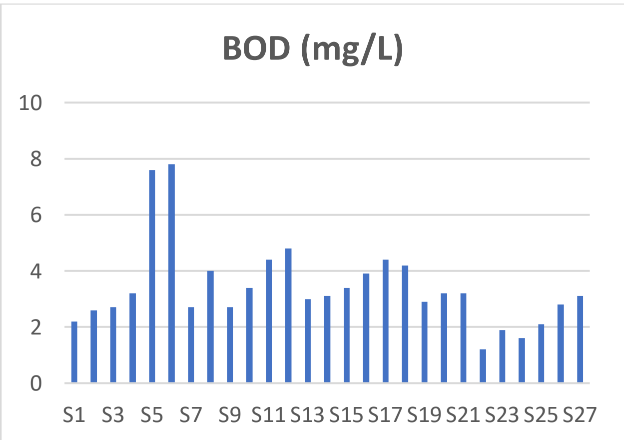

Figure: 15 Bar chart BOD (mg/L)

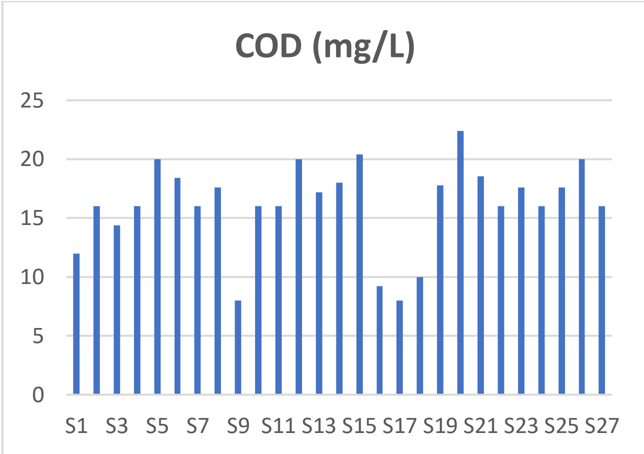

Figure: 16 Bar chart COD (mg/L)

Key Findings

1. All of the villages had safe pH levels (7.0–8.26).

2. High fluoride levels (about 1.0 mg/L) in Chadotar, Chandisar, Gadh, Madana, and Malan put people at risk for fluorosis.

3. TDS levels in Madana (1270–2540 mg/L) were too high, which means there were too many minerals.

4. Because there is a lot of Ca and Mg in Gadh and Madana, the water is very hard.

5. The level of nitrate in Madana (415 mg/L) was much higher than what is safe, which could be bad for your health.

6. The high levels of chloride (654.79 mg/L) and alkalinity (415 mg/L) in Madana suggest that saltwater or wastewater is getting in.

7. There was not much turbidity, but the high BOD (7.8 mg/L) and COD (22.4 mg/L) levels show that some places were polluted with organic matter.

8. Madana and Gadh were found to be pollution hotspots that need to be cleaned up.

9. It's very important to keep an eye on things, be aware, and have safety plans for each village.

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