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Original Research Article

EVALUATION OF GROUNDWATER QUALITY THROUGH IDENTIFICATION OF POTENTIAL CONTAMINANT

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Abstract

Groundwater, is crucial for human consumption and industrial purposes, demands continuous monitoring to assess quality standards. This study conducts a comprehensive evaluation of groundwater quality to assess its overall condition and identify potential contaminants. The research predicts the presence and levels of contaminants such as heavy metals, organic pollutants, and microbial agents using hydrogeological studies, chemical analysis, and statistical modelling. A covariance analysis identified places with low water quality. Analysis shows most samples satisfy drinking water requirements. A consolidated map illustrates a significant expanse suitable for domestic and drinking purposes, particularly in terms of drinking water quality. However, water quality in 2467.09 sq. km is deemed unacceptable. Further analysis, including correlation, ANOVA, and t-tests such as One Sample Test, Bayesian Statistics, and Power Analysis, identifies 836.87 sq. km under the category of maximum permissible water quality and 9.19 sq. km as highly desirable for drinking and domestic use.

Keywords: water quality evaluation, groundwater, water quality index, contaminants

1. INTRODUCTION

Clean water is a vital necessity for human survival, but in the Dharmapuri district of Tamil Nadu, India, the quality of groundwater has become a growing concern due to contamination from various sources. This article will evaluate the groundwater quality and water quality index in this region using hydro

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geochemical and physical-chemical parameters. The implications of these findings on public health will be discussed, along with recommendations for future monitoring and assessment measures to improve water quality in the region. The hydro geochemical analysis revealed high levels of total dissolved solids (TDS), which exceeded the permissible limit for drinking water set by the World Health Organization (WHO). The presence of heavy metals such as arsenic, iron, and manganese was also detected in some locations. The water quality index (WQI) further confirmed that groundwater in most areas of Dharmapuri district was unsuitable for consumption or agricultural use. The WQI values ranged from poor to very poor, indicating that the water was not fit for human consumption or irrigation [1]. The findings have serious implications for public health, especially since many people in this region rely heavily on groundwater for their daily needs. Therefore, it is crucial to implement regular monitoring and assessment measures to ensure that the water supply is safe and free from contamination. Furthermore, it is essential to raise awareness about safe drinking water practices among local communities to prevent health risks associated with contaminated water sources.

1.1 Analyzing Groundwater Quality in Dharmapuri District

The analysis of groundwater quality is a critical aspect of safeguarding public health and the environment. This assessment involves evaluating hydro geochemical parameters to determine the status of groundwater quality. Statistical methods are then utilized to assess the quality of groundwater resources, which have significant implications for water supply, human health, and agricultural practices. This comprehensive analysis takes into account several physical and chemical parameters, ensuring that water standards are maintained, and environmental quality is preserved [2]. The findings of this assessment are essential for both rural areas and developed regions as it contributes to understanding underground water. Moreover, it has implications for both surface and underground water bodies, affecting the general public's access to clean water for domestic purposes. Analyzing groundwater quality involves assessing various physical and chemical parameters to ensure the water meets the desired standards for safe consumption and environmental sustainability. Anthropogenic factors such as the use of fertilizers, manures, and chemicals, livestock farming practices, ineffective irrigation techniques, forest clearing, aquaculture, pollution from industrial effluents and domestic sewage, mining, and recreational activities all have a significant impact on water quality in rural areas. Industrialization, sewage discharge, and other residential activities significantly impact water quality in urban areas. Furthermore, changes in land use, particularly shifts in land cover, can negatively influence water flow and quality.

Groundwater resources are being depleted as a result of population increase, urbanization, industry, and agricultural activities. In various geological settings, such as deep marine crystalline, sedimentary, and igneous environments, the formation of naturally salinated groundwater can be attributed to the presence of connate fluid during the initial rock deposition. Groundwater quality is influenced by various factors such as connate saline fluid, seawater intrusion, evaporation, geothermal origin, dissolution of naturally occurring soluble salts, and membrane filtration process. These factors are observed in geological settings, including deep marine crystalline, sedimentary, and igneous environments.

Among the key parameters examined are pH, with an optimal range typically falling between 6.5 to 8.5, indicating the water's acidity or alkalinity. Temperature, which impacts the solubility of gases and minerals, generally hovers around 10-20 degrees Celsius. Total Dissolved Solids (TDS) measure the total amount of dissolved substances, and while acceptable levels vary, high TDS levels may signify contamination. Dissolved Oxygen (DO) levels above 5 mg/L are considered suitable for aquatic life, as oxygen is crucial for their survival. Turbidity, which measures water cloudiness, should ideally be low for drinking water. Nitrate (NO_3) and Nitrite (NO_2) levels, often indicators of agricultural or sewage contamination, should typically remain below 10 mg/L. Elevated Ammonium (NH_4^+) levels may indicate organic matter or pollution presence, requiring attention. High Chloride (Cl^-) levels may stem from road salt or industrial discharges, posing potential risks. Sulfate (SO_4^{2-}) concentrations, if high, may have a laxative effect and could be associated with industrial or natural sources.

1.2. Hydro Geochemical Parameters and Their Significance

Hydro geochemical characterization of groundwater involves an assessment of its mineral content, which is crucial in understanding its quality. This assessment includes evaluating the levels of dissolved oxygen, pH, and electrical conductivity, which provide essential insights into the water's properties [3]. Additionally, it is necessary to assess other factors such as water clarity, total phosphorus, and total organic carbon to gain a comprehensive understanding of the overall quality of groundwater resources. Hydro geochemical parameters are critical indicators in the study of water quality and the interaction between water and geological formations [4]. These parameters provide insights into the composition, origin, and behavior of groundwater. Here are some important hydro geochemical parameters and their significance:

Groundwater quality analysis encompasses the examination of various parameters to assess the purity and safety of groundwater, sustaining life and ecosystem health. Major ions, including calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), and chloride (Cl^-), influence water hardness, salinity, and overall chemistry. These ions' relative proportions aid in identifying water sources and geochemical processes. Trace elements such as iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and others, present in minimal amounts, can indicate natural or anthropogenic contamination when elevated. While some trace elements are essential nutrients, excessive levels can pose harm. pH, measuring water acidity or alkalinity, affects mineral solubility, contaminant mobility, and aquatic organism behavior. Hydro geochemical parameters help hydrogeologists, environmental scientists, and water resource managers assess groundwater quality, identify potential contamination sources, and make informed decisions regarding water use and management. Regular monitoring and analysis are essential to ensure the sustainable use of groundwater resources [4].

1.3. Physical and Chemical Parameter Examination

In order to gauge water quality, it is imperative to consider several parameters. The presence of harmful pollutants such as pesticides or heavy metals can have a devastating impact on the environment and human health. Therefore, it is necessary to monitor the water supply regularly to ensure that it is free from contaminants [5,6]. Water treatment plants use various methods like filtration and disinfection to remove impurities from the water before it reaches our homes. Water quality plays a crucial role in maintaining public health and ensuring that our aquatic ecosystems remain healthy. The World Health Organization (WHO) has set guidelines for drinking water quality which outline specific criteria for various parameters such as pH balance, bacterial contamination levels, chlorine content, etc[7-9]. By adhering to these standards and conducting regular assessments of water quality parameters, we can ensure that our drinking water is safe for human consumption and that our natural resources are protected for future generations

1.4. Quality of Ground Water by Water Quality Index: Pre and Post-Monsoon Climate Change

Assessing the water quality index post-monsoon can yield valuable insights into seasonal variations and provide a comprehensive understanding of the fluctuating quality of ground and surface water. The derivation of individual index values for water quality parameters is critical in facilitating in-depth analysis and interpretation of overall water quality status[10]. The post-monsoon season is particularly important because it determines how much rainwater has percolated into the groundwater table and how much surface runoff occurs [11]. This information is crucial because groundwater provides drinking water to millions of people worldwide, and surface runoff can contribute to flooding events. Therefore, monitoring and assessing water quality during this time can help identify potential sources of contamination before they become more severe. It is also worth noting that different regions may have varying standards for what constitutes good or bad water quality. Thus, having a standard measure like the water quality index allows for better communication between stakeholders and enables them to compare results across different regions[12].

2. METHODOLOGY

2.1 General

To compare groundwater quality to World Health Organization (WHO) standards, it's important to refer to the specific guidelines and permissible limits set by the WHO for various water quality parameters. The WHO provides guidelines for drinking water quality, which can be used as a reference for assessing whether groundwater meets acceptable standards for human consumption. Here are some key parameters and their WHO standards mentioned in Table 1.

Table 1. WHO Standards and Significance of Water Quality Parameters

Parameter	WHO Standard	Significance

pH	6.5 to 8.5	Ensures that water is not too acidic or too alkaline for human consumption.
Total Dissolved Solids (TDS)	Guideline value not specified, but higher TDS may affect taste	TDS reflects the concentration of dissolved minerals in water.
Nitrate (NO_3)	50 mg/L (as NO3)	Elevated nitrate levels may indicate contamination from fertilizers or human waste.
Fluoride (F)	1.5 mg/L	Fluoride levels are critical for dental health, but excessive concentrations can lead to fluorosis.
Arsenic (As)	0.01 mg/L	Arsenic is a toxic element; elevated levels can pose health risks.
Iron (Fe)	0.3 mg/L	Elevated iron levels can affect taste and cause staining, but high concentrations may be a health concern.
Manganese (Mn)	0.4 mg/L	Elevated manganese levels may impact taste and can be associated with health issues.
Chloride (Cl)	250 mg/L	High chloride levels may indicate contamination and affect taste.
Sulfate (SO_4)	400 mg/L	Elevated sulfate levels may have a laxative effect.
Bacterial Contamination	Zero fecal coliforms per 100 mL for drinking water	Presence of bacteria may indicate contamination from sewage or other sources.

It's crucial to note that these standards are general guidelines, and regional or national standards may vary. Table 2 shows the mean value of the taluk-wise water quality data in Dharmapuri district. The interpretation of water quality data should consider the cumulative impact of multiple parameters. Routine monitoring and testing are essential to ensure that groundwater quality remains within acceptable limits and to identify any trends or issues that may require corrective action. Figure 1 shows the graph of Mean values of water quality parameters data as per village-wise data calculation. When comparing groundwater quality to WHO standards, it's recommended to work with local environmental agencies or authorities to ensure compliance with specific regional regulations and standards.

Table 2. Mean Value of the collected Taluk wise water quality data in Dharmapuri district

		TDS	NO_2+ NO_3	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	Na%
		Mean										
Taluk	Dharmapuri	1139	26	88	64	200	26	324	154	27	322	43

	Harur	1124	24	93	80	185	11	292	160	47	372	40
	Karimangalam	843	15	70	57	146	33	208	114	39	322	40
	Nallampalli	1756	24	58	63	439	66	369	257	20	451	67
	Palacode	1593	54	128	56	330	21	319	384	40	272	57
	Pappireddipatti	1091	18	76	66	213	12	276	176	28	361	47
	Pennagaram	880	21	75	60	145	16	210	123	45	320	40
	Uthangarai	1212	31	97	77	201	25	288	199	35	352	41

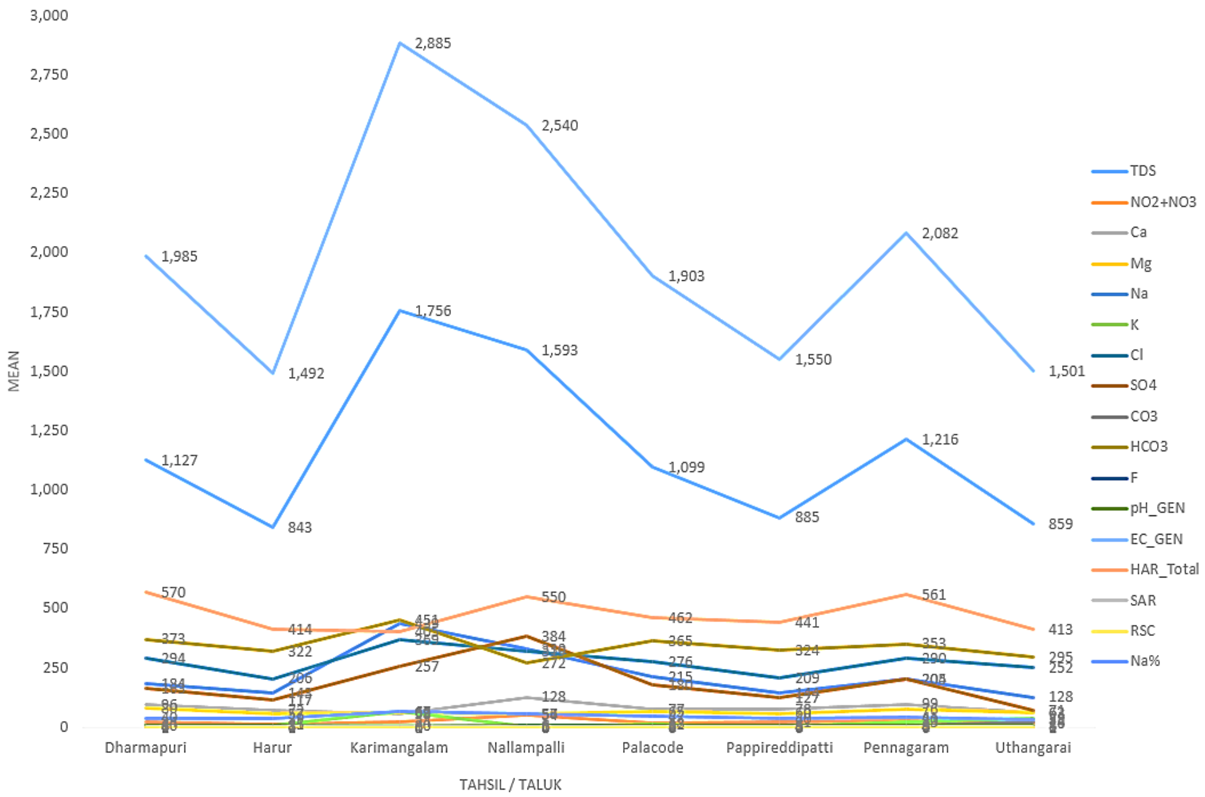

Fig. 1. Taluk wise Mean Chart for water quality parameters derived from SPSS software v29

2.2 Ground Water Quality Index (WQI)

The monsoon season is a critical period for assessing the groundwater quality index, as it provides a comprehensive understanding of the overall water quality. The classification of groundwater quality using statistical methods and deriving single value representations that reflect its intended use are vital in interpreting the data collected. The water quality index values provide valuable insights into the impact of climate change on groundwater, which can contribute to environmental protection and public health safety [13]. This analysis is essential for identifying potential risks associated with consuming water from ground and surface water bodies in rural areas. It also ensures compliance with water standards set by environmental protection agencies and safeguards human health. Furthermore, this assessment supports the evaluation of water suitability for different purposes such as domestic use, irrigation, and overall environmental quality.

Thus, monitoring the water quality index during the monsoon season is crucial in maintaining safe and healthy groundwater resources for various purposes. In India, the Central Pollution Control Board (CPCB) has developed a specific Water Quality Index (WQI) formula to assess the overall quality of water based on several water quality parameters. The Indian WQI is calculated using the following formula:

The US EPA's formula 2.1 for calculating the Aggregate Water Quality Index is as follows:

$$WQI = \sum_{i=1}^{n} \quad (W_i x\, I_i)]/\sum_{i=1}^{n} \quad W_i \tag{2.1}$$

Where:
WQI - is the Water Quality Index.
n - is the number of parameters.
W_i - is the weight assigned to the i-th parameter.
I_i - is the sub-index for the i-th parameter.
Here's a breakdown of the steps:

i. **Weight Assignment W_i:**
   a. Assign a weight to each water quality parameter based on its relative importance. Weights are usually determined through expert judgment or stakeholder consultation.

ii. Calculation of Sub-Indices I_i:

a. Calculate a sub-index for each water quality parameter using the following formula 3.2:

$$I_i = \frac{Q_i - L_i}{U_i - L_i} \tag{2.2}$$

Where R_i is the measured concentration of the parameter, L_i is the minimum desirable concentration, and U_i is the maximum desirable concentration.

iii. Calculation of WQI:

a. Multiply each sub-index I_i by its corresponding weight W_i and sum the products.

b. Divide the sum by the sum of the weights.

iv. Interpretation:

a. The resulting Water Quality Index value can be interpreted based on predefined categories. These categories typically range from "excellent" to "unsatisfactory," helping to communicate the overall water quality to the public or relevant stakeholders.

It's important to note that specific guidelines and standards for water quality parameters, as well as the assignment of weights, may vary based on regional or national regulations. Users should adapt the formula and parameters to suit the specific goals and context of their water quality assessment. Additionally, local authorities or environmental agencies may provide guidelines for calculating a Water Quality Index that align with regional priorities and standards.

2.2 Classification of Groundwater Quality

Groundwater quality index-based categorization supports effective management practices by guiding decision-making in environmental protection. Hierarchical cluster analysis can aid in establishing the status of groundwater quality, and thus identifying areas with significant impact. Categorizing groundwater quality also creates targeted strategies for suitable and sustainable water resource management, which includes implementing specific measures to improve water quality. This classification serves as a guide for decision-making, facilitating the implementation of measures that address specific issues and promote better water resource management practices.

The method of categorizing groundwater based on the quality index is an effective way to measure water quality. The hierarchical cluster analysis provides an overview of the status of groundwater quality for different areas, thus enabling the identification of critical zones that require attention. With this information at hand, authorities can take appropriate measures to reduce contamination sources, prevent over-exploitation of aquifers, promote conservation measures and implement sustainable practices. By creating targeted strategies for improving water quality, one can ensure that groundwater resources meet current and future demands while maintaining their ecological balance [14].

2.3 Examination of Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) evaluation is a critical aspect of comprehending water quality parameters. Managing groundwater quality requires a clear understanding of SAR values as excessive levels can have adverse effects on soil quality, water clarity, and agricultural productivity. By monitoring SAR levels, you can effectively mitigate issues related to water quality and agricultural use. High SAR values can result in soil degradation, decreased crop yield, and damage to the environment. Therefore, it is imperative to prioritize regular monitoring of SAR levels to ensure that the water used for agricultural purposes is suitable for farming activities. Agricultural professionals must pay attention to SAR levels before irrigating crops as high sodium content can cause soil dispersion leading to poor soil structure. This results in poor drainage and reduced soil fertility. Additionally, high salt content in irrigation water can also lead to plant root damage and stunt growth [14,3].

To manage SAR effectively, treatment options such as reverse osmosis or ion exchange can be considered. Implementing these treatments will reduce the concentration of dissolved salts and improve water quality. By taking a proactive approach towards monitoring and managing SAR levels, farmers can ensure optimal crop growth and maintain sustainable agriculture practices for years to come.

A. **SAR Calculation:**

- The SAR is calculated using the formula:

$$SAR = (Na^+)/\sqrt{((Ca^{2+}+Mg^{2+})/2)} \tag{2.3}$$

- Where Na^+, Ca^{2+}, and Mg^{2+} are the concentrations of sodium, calcium, and magnesium ions, respectively, in milliequivalents per liter (meq/L).

B. **Interpretation:**

- SAR values are interpreted as follows:
    - SAR < 6: Low sodium hazard (suitable for most crops)

- $6 \leq SAR < 12$: Medium sodium hazard (suitable for tolerant crops)
- $SAR \geq 12$: High sodium hazard (may cause problems, especially in fine-textured soils)

C. **Impact on Soil Structure:**

- High SAR values can lead to the dispersion of clay particles in the soil, causing a breakdown of soil structure. This can result in reduced water infiltration, increased soil erosion, and poor aeration.

D. **Cation Exchange Capacity (CEC):**

- SAR is related to the Cation Exchange Capacity of the soil. Soils with low CEC are more susceptible to the negative effects of high SAR water.

E. **Alkali Soils:**

- High SAR water can contribute to the development of alkali soils, where the concentration of sodium in the soil exceeds acceptable levels, affecting plant growth.

F. **Mitigation Strategies:**

- If water with a high SAR is to be used for irrigation, appropriate amendments such as the application of gypsum (calcium sulfate) may be recommended to counteract the effects of sodium on soil structure.

G. **Irrigation Management:**

- Understanding the SAR of irrigation water helps in planning and managing irrigation practices. It's especially crucial in arid and semi-arid regions where water scarcity is a concern.

2.4 Evaluation of Water Suitability

An accurate assessment of hydro geochemical characterization is essential to ensure that the water meets necessary standards for its intended use. This detailed analysis guides decision-making processes for environmental protection and management of water bodies, addressing concerns related to domestic, agricultural, and industrial use. As a result, it has a significant impact on environmental quality.

The groundwater quality index (WQI) is used as an indicator of the overall water quality and can be calculated by considering various parameters such as pH, electrical conductivity, total dissolved solids, hardness, chloride content, and nitrate concentration. By using this WQI formula, one can assess the suitability of groundwater for irrigation purposes or drinking water supply. In addition to this, it is also important to monitor the presence of contaminants like heavy metals and pesticides in groundwater. These pollutants can affect human health and damage ecosystems if they reach unsafe levels. Regular monitoring and effective management strategies are critical to ensure that groundwater remains safe for various uses. Evaluating water suitability for different purposes involves assessing various water quality parameters and comparing them against established standards or guidelines. Different uses require different water quality criteria, and regulatory bodies often define these criteria based on health, environmental, and industrial considerations. Here's a general guide for evaluating water suitability for different purposes:

1. **Drinking Water:**

    - Parameters to Evaluate: pH, turbidity, total dissolved solids (TDS), microbial contaminants (coliform bacteria), chemical contaminants (nutrients, heavy metals), disinfection byproducts.

    - Standards: Refer to drinking water standards set by relevant authorities such as the World Health Organization (WHO) or national drinking water standards.

2. **Agricultural Irrigation:**

    - Parameters to Evaluate: Electrical conductivity (EC), sodium adsorption ratio (SAR), pH, nutrients (nitrogen, phosphorus, potassium), salinity.

    - Standards: SAR and EC are critical for assessing the suitability of water for irrigation. Guidelines may vary based on crop type and soil characteristics.

3. **Industrial Use:**

    - Parameters to Evaluate: Total dissolved solids (TDS), pH, specific ions (chlorides, sulfates), heavy metals (cadmium, chromium, lead), temperature.

    - Standards: Standards can vary widely depending on the industry. Consult industry-specific guidelines or regulations.

4. **Ecosystem Health:**

   - Parameters to Evaluate: Biotic indices (presence of indicator species), dissolved oxygen, nutrients (nitrogen, phosphorus), pH.

   - Standards: Ecosystem health is often assessed by examining the diversity and abundance of aquatic organisms. Nutrient levels and pH can impact the overall health of the ecosystem.

5. **Groundwater Quality:**

   - Parameters to Evaluate: pH, total dissolved solids (TDS), contaminants (nitrates, heavy metals).

   - Standards: May vary based on regional or national guidelines. Groundwater quality is critical for drinking water and agricultural use.

When evaluating water suitability, it's essential to consider the specific guidelines or standards provided by relevant regulatory agencies or organizations. Regular monitoring and testing are crucial to ensuring that water quality remains within acceptable limits for the intended use and to identify any potential issues promptly. Integrated water resource management involves considering the interconnectedness of different water uses and implementing sustainable practices to maintain water quality across various sectors.

3. RESULTS

Collect new data or use existing data on the identified water quality parameters. Enumerate the specific water quality parameters analyzed, such as pH, dissolved oxygen, total dissolved solids, nitrate, sulfate, chloride, heavy metals (e.g., lead, arsenic), and microbial indicators. Clearly state the units of measurement for each parameter (e.g., milligrams per liter, micrograms per liter, parts per million). Specify the locations where groundwater samples were collected. This might include information about the depth of the groundwater samples. Compare the results against relevant water quality standards or guidelines. Figure 2, Figure 3, Figure 4 and Figure 5 shows the Bayesian statistics report derived from SPSS for TDS, NO_2 + NO_3, Ca, and SAR parameter of water quality.

This could involve regulatory standards set by environmental agencies or international organizations like the World Health Organization (WHO) for drinking water. Indicate the frequency of sampling (e.g., quarterly, annually) to provide context for the temporal aspects of the data. To compare the water quality parameters for well water with standard water quality parameters, it's essential to refer to establishedguidelines or standards set by regulatory bodies such as the World Health Organization (WHO) for drinking water, environmental agencies, or other relevant authorities.

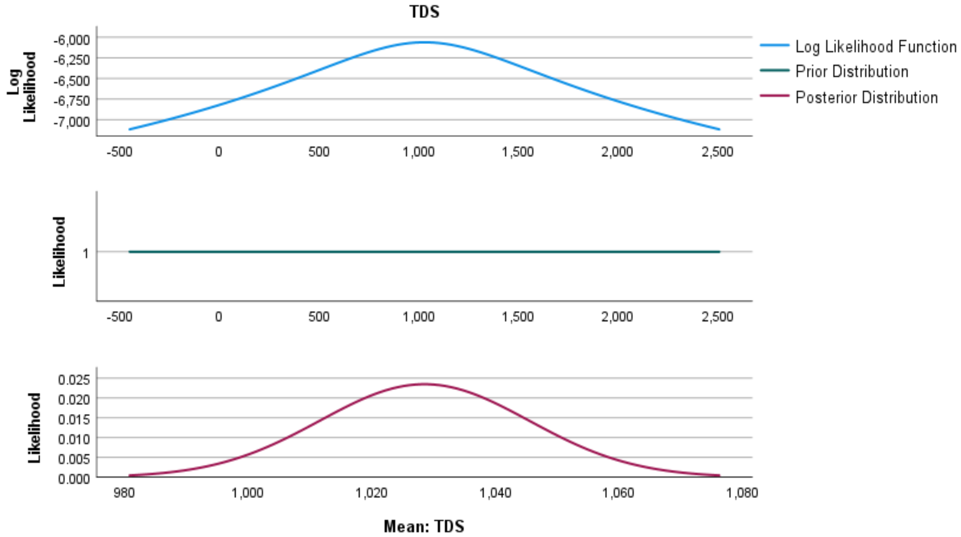

Fig. 2. Bayesian statistics report derived from SPSS for TDS parameter of water quality

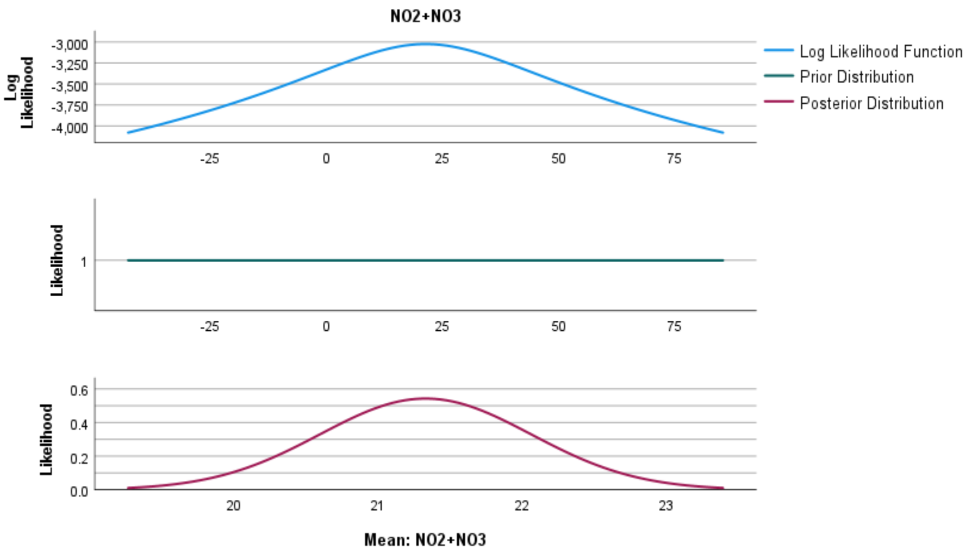

Fig. 3. Bayesian statistics report derived from SPSS for $NO_2 + NO_3$ parameter of water quality

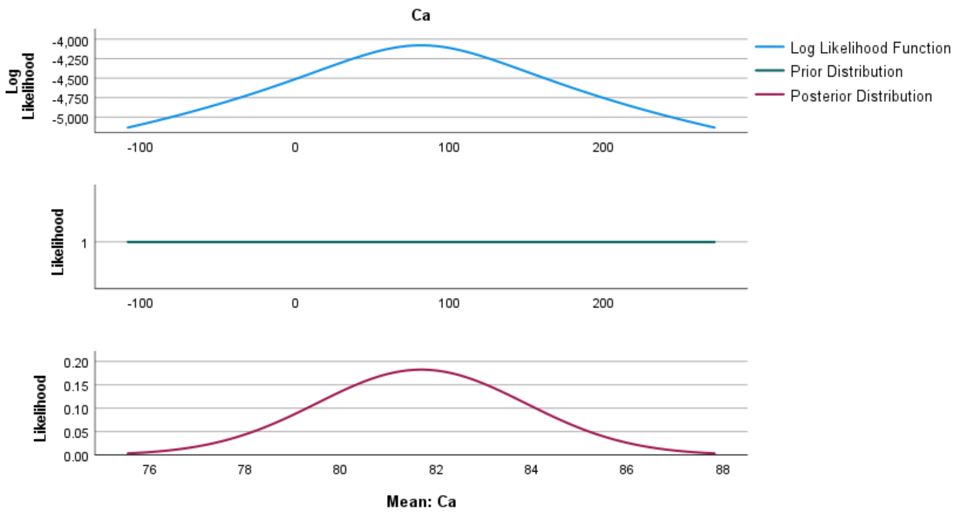

Fig. 4. Bayesian statistics report derived from SPSS for Ca parameter of water quality

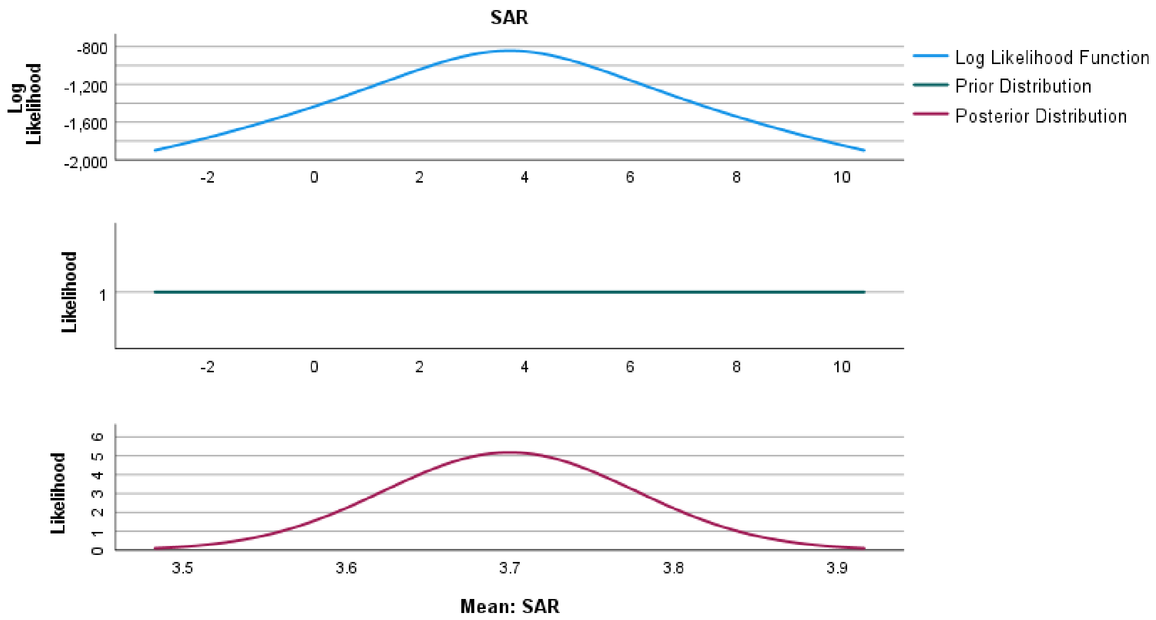

Fig. 5. Bayesian statistics report derived from SPSS for SAR parameter of water quality

3.1 Statistical Analysis

The SPSS software v29 was used for analysis the field data of water quality parameters in Dharmapuri, Tamil Nadu, India. The mean, standard error, standard variance were analysed through the one sample statistics and Bayesian statistics. Table 2 shows the Compare Means of one sample statistics test report for the water quality parameters by the analysis for significance data. The p values less than the 0.05, than there is no statistically significance difference. Table 3 shows the comparison of means of one sample effect size of statistics test report for the water quality parameters by the analysis for significance data with Cohen’s and Hedges correction for 95% confidence interval.

The following is a general comparison, and actual standards may vary based on specific regulations and regional considerations: TDS (Total Dissolved Solids): WHO guidelines for drinking water is < 500 mg/L. Compare TDS levels in well water to the WHO guidelines

Table 3. Compare Means of one sample statistics test report for the water quality parameters by the analysis for significance data. The p value less than the 0.05, than there is no statistically significance difference

One-Sample Test							
	Test Value = 0						
	t	d_f	Significance One-Sided p	Significance Two-Sided p	Mean Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
TDS	60.64	966.00	0.00	0.00	1028.47	995.19	1061.76
NO_2+NO_3	29.07	966.00	0.00	0.00	21.33	19.89	22.77
Ca	37.43	966.00	0.00	0.00	81.69	77.40	85.97
Mg	50.69	966.00	0.00	0.00	66.98	64.39	69.58
Na	46.48	965.00	0.00	0.00	178.89	171.34	186.44
K	13.23	965.00	0.00	0.00	14.08	12.00	16.17
Cl	37.48	966.00	0.00	0.00	257.75	244.26	271.25
SO_4	32.72	966.00	0.00	0.00	152.33	143.19	161.46
CO_3	12.84	966.00	0.00	0.00	7.64	6.47	8.81
HCO_3	72.72	966.00	0.00	0.00	343.32	334.06	352.59
F	26.68	963.00	0.00	0.00	0.91	0.85	0.98
pH_GEN	803.48	966.00	0.00	0.00	8.01	7.99	8.03
EC_GEN	63.01	966.00	0.00	0.00	1789.22	1733.50	1844.95
HAR_Total	55.10	966.00	0.00	0.00	479.86	462.77	496.95
SAR	48.10	966.00	0.00	0.00	3.70	3.55	3.85
RSC	8.90	899.00	0.00	0.00	0.36	0.28	0.44
Na%	74.83	966.00	0.00	0.00	41.69	40.60	42.78

Elevated TDS may impact the taste and palatability of water. NO_2 + NO_3 (Nitrite + Nitrate): WHO guideline for nitrate is < 50 mg/L as NO_3. Check nitrite and nitrate levels against WHO standards. Elevated levels may indicate contamination from agricultural or other sources. Ca (Calcium) and Mg (Magnesium): No specific WHO guideline, but levels are considered as part of water hardness. Assess calcium and magnesium levels in relation to water hardness standards, which may vary by region. Na (Sodium): WHO guideline for sodium is < 200 mg/L. Compare sodium levels in well water to the WHO guideline. Elevated sodium may be a concern for those on sodium-restricted diets. K (Potassium), Cl (Chloride), SO_4 (Sulfate): No specific WHO guidelines, but local standards may apply. Assess these parameters based on local water quality standards or guidelines. CP_3 (Chemical Oxygen Demand): No specific WHO guideline, but higher values may indicate organic pollution. Compare CP_3 levels to local environmental standards. HCO_3 (Bicarbonate): No specific WHO guideline, but levels influence water alkalinity. Assess bicarbonate levels based on local water quality standards. F (Fluoride): WHO guideline for fluoride is < 1.5 mg/L. Compare fluoride levels in well water to the WHO guideline. Excessive fluoride may lead to dental fluorosis. pH-Gen (General pH) and EC GEN (General Electrical Conductivity): WHO guideline for pH is 6.5–8.5; no specific EC guideline. Check pH and electrical conductivity against WHO guidelines for drinking water. HAR Total (Total Hardness): No specific WHO guideline; levels may impact water hardness. Assess total hardness in relation to local water quality standards. SAR (Sodium Adsorption Ratio), RSC (Residual Sodium Carbonate), Na% (Sodium Percentage): No specific WHO guidelines; local agricultural standards may apply. Evaluate these parameters based on regional or local guidelines for irrigation water quality. Figure 6 illustrate the Simple Bar Chart for Mean of TDS by Village Wise parameters. The Maximum TDS availed in Taluk Office in Dharmapuri District.

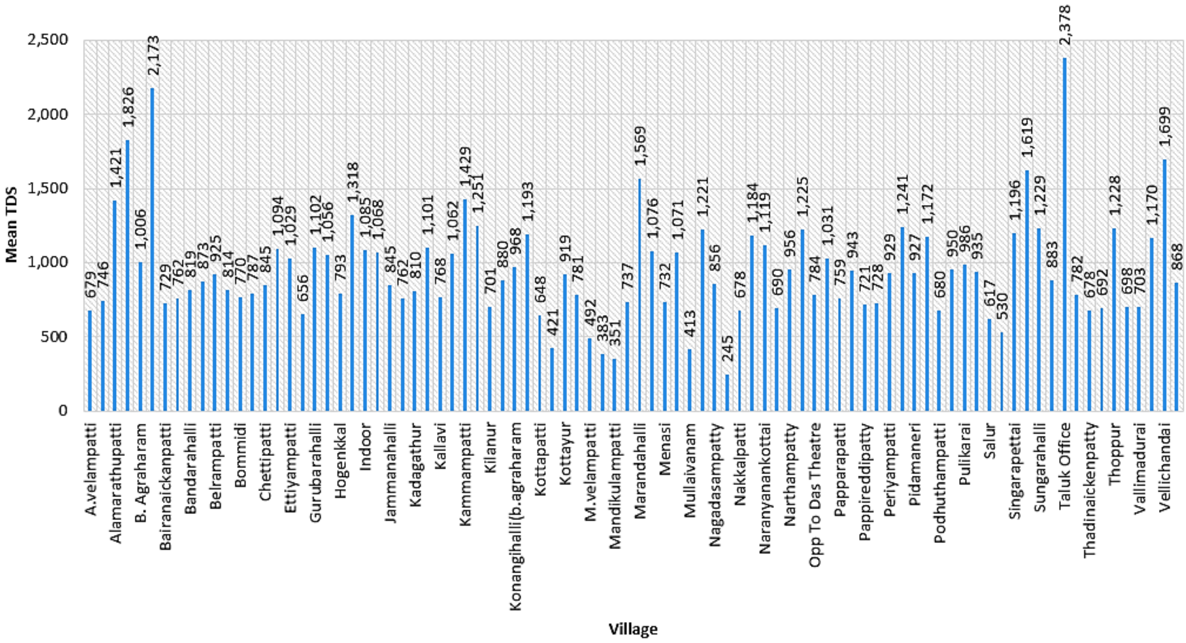

Fig. 6. Simple Bar Chart for Mean of TDS by Village Wise parameters. The Maximum TDS availed in Taluk Office in Dharmapuri District

Utilize charts, graphs, or maps to visually represent the groundwater quality data. This can aid in conveying information more effectively. The model should incorporate prior beliefs about the relationships and update them with observed data and analysis through the prior distributions, likelihood function, posterior inference, uncertainty assessment and statistical analysis. Figure 7 give you an idea about the Correlation Power analysis: Power Estimation versus sample size of 967 on x-axis and the difference between hypothesized values on y-axis. And power estimation versus null hypothesis value on y-axis. Figure 8 illustrate Bar Chart of statistical data: Compare means of SAR and pH Generation by Taluk wise field data of Dharmapuri Distrirct. X- Axis: Group data of water quality parameters such as SAR and pH. Y-Axis: Mean Value. Standard Error taken as 95% confidence interval. This statistical analysis done by using SPSS V29, the p value less than 0.05 that indicate there is no significant difference.

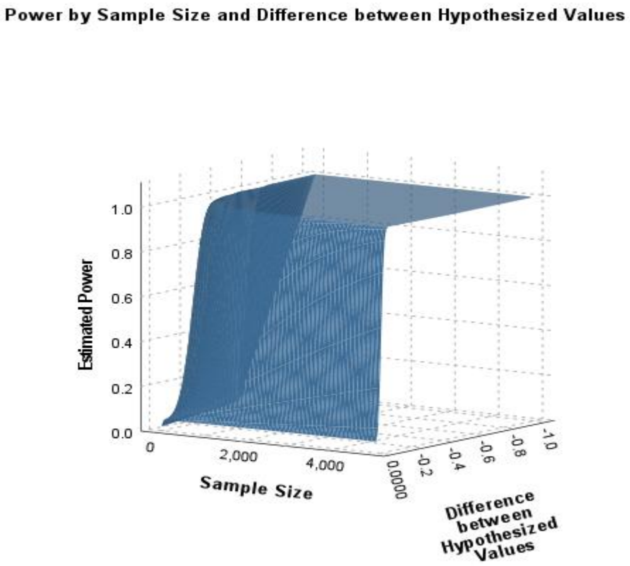

Fig. 7. Correlation Power analysis: Power Estimation versus sample size of 967 on x-axis and the difference between hypothesized values on y-axis. And power estimation versus null hypothesis value on y-axis

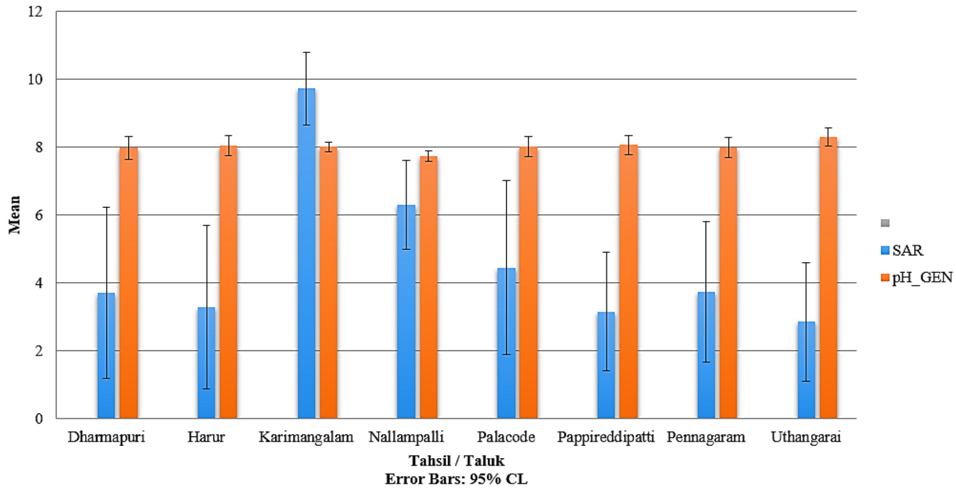

Fig. 8. Bar Chart of statistical data: Compare means of SAR and pH Generation by Taluk wise field data of Dharmapuri Distrirct. X- Axis: Group data of water quality parameters such as SAR and pH. Y-Axis: Mean Value. Standard Error taken as 95% confidence interval

4. DISCUSSION

4.1 Suitability for Drinking Purpose

One of the most critical aspects of public health is ensuring that groundwater is safe for drinking purposes. To assess its quality, several key water quality parameters need to be considered, such as dissolved oxygen and chemical oxygen demand. It is essential to adhere to the guidelines established by the World Health Organization (WHO) to ensure a safe and reliable supply of drinking water [15].

Apart from these parameters, assessing the water quality index can provide valuable insights into the overall quality of groundwater. It offers a comprehensive understanding of its suitability for drinking purposes. To evaluate groundwater's safety for consumption, it is necessary to monitor factors such as water clarity, oxygen demand, and the presence of heavy metals. By doing so, we can make sure that the water meets the necessary safety and health standards for public consumption. Regular monitoring and testing are crucial in ensuring that groundwater remains safe for drinking purposes. Any deviation from acceptable levels should be promptly addressed through proper treatment or other corrective measures. It is also important to promote awareness among communities regarding the significance of safeguarding their local groundwater sources and how they can play an active role in protecting them [16].

4.2 Suitability for Irrigation Purpose

Assessing the quality of groundwater for agricultural irrigation is essential for ensuring optimal crop production. Evaluating water quality parameters such as total nitrogen and electrical conductivity plays a key role in determining the suitability of groundwater for irrigation purposes. It is crucial to understand the impact of industrial processes on groundwater quality, as this directly influences its suitability for irrigation. Additionally, employing water quality index evaluation techniques aids in accurately assessing the groundwater's appropriateness for agricultural irrigation, thus providing valuable insights for sustainable farming practices. Monitoring these parameters enables farmers to make informed decisions regarding water usage and irrigation methods, contributing to the overall efficiency and environmental sustainability of agricultural activities [17].

4.3 Implication of Findings on Public Health

Assessing groundwater quality parameters is crucial for safeguarding public health, as the findings have a direct impact on public health and environmental conditions. Understanding water quality issues and their implications is imperative for public health protection, considering the significant role that groundwater quality assessment plays in protecting human health and aquatic life. It aids in identifying potential health risks associated with water use, and evaluating the groundwater quality status is essential for recognizing these risks. The implications of the findings are far-reaching and underscore the importance of continuous monitoring and assessment to mitigate potential health hazards and protect public health [18,19].

4.4 Direct Impacts on Human Consumption

The assessment of groundwater quality directly impacts human consumption and the protection of public health. It is crucial to assess water quality parameters for domestic use in order to safeguard human health. Moreover, the monitoring of water quality parameters such as total phosphorus and seawater intrusion has a direct impact on human consumption. The evaluation of water quality parameters for human consumption is essential for ensuring the safety of drinking water. By understanding and monitoring these parameters, potential health risks associated with water use can be identified and mitigated, thus protecting the general public from potential hazards [20].

4.5 Indirect Impacts through Domestic and Industrial Use

Evaluating groundwater quality for residential and industrial use is crucial for preserving the environment. Understanding the influence of farming practices on groundwater quality is vital for both domestic and industrial purposes. The assessment of groundwater quality parameters plays a significant role in safeguarding water sources for residential and industrial uses. Additionally, the evaluation of the water quality index provides valuable insights into the suitability of groundwater for domestic and industrial purposes. Furthermore, the monitoring of water quality parameters, such as total organic carbon and the impact of water treatment, has a direct effect on both residential and industrial utilization.

4.6 Recommendations for Future Monitoring and Assessment

Enhancing water quality monitoring practices is an essential step towards ensuring public health protection and environmental quality. Advanced statistical methods can significantly improve the accuracy of groundwater quality assessment, making it easier to monitor changes over time in Dharmapuri district. Comprehensive analysis of water quality data is vital for informed decision-making concerning future monitoring efforts. Remote sensing used to analyze surface characteristics can provide useful insights into underlying geological systems. This method is useful for faster groundwater monitoring in large and isolated locations. Combining remote sensing and GIS tools with other academic investigations, such as VES and geochemical studies, is typical to identify several pathways for seawater intrusion.

Continuous assessment of water quality parameters can provide valuable insights into groundwater quality changes over time, allowing authorities to address emerging water quality issues proactively. Hierarchical cluster analysis can be utilized to identify spatial patterns and sources of contamination accurately. This, in turn, helps prioritize remedial actions and optimize limited resources.Overall, implementing advanced statistical methods and improving monitoring capabilities are critical steps towards safeguarding public health and preserving environmental quality in Southern Tamilnadu and other regions.

By adopting a proactive approach to water quality management, we can ensure that our natural resources remain safe and accessible for generations to come. To improve water quality, it is crucial to implement measures that reduce significant impacts on groundwater. Promoting scientific research aids in developing effective management strategies. Evaluating individual index values helps identify areas for improvement. Developing strategies to mitigate pollution is imperative for overall water quality. Understanding the intended use of groundwater is essential for implementing improvements.

5. CONCLUSION

The assessment of groundwater quality and the water quality index in the Dharmapuri district of Tamil Nadu, India, underscores the critical importance of monitoring and preserving water sources. By analyzing hydrogeochemical parameters and comparing them to WHO standards, we can determine the suitability of groundwater for various purposes, including drinking and irrigation. The study emphasizes the necessity of calculating the Water Quality Index (WQI) to gauge the groundwater's fitness for potable use. Notably, a WQI value exceeding 75 indicates unsuitability for consumption.

According to the Water Grade Index (WQI) categorization, the majority of samples were rated as excellent to good-grade water, making them suitable for drinking. However, areas of concern were identified, particularly in taluks where certain parameters exceeded WHO standards. For example, elevated fluoride levels in Palacode and Nallampalli taluks surpassed the WHO standard of 1.5 mg/L, highlighting the urgency of targeted interventions to mitigate potential health risks from water contamination. It's worth noting that approximately 30% of the analyzed samples exhibited a total dissolved solids (TDS) value exceeding the maximum allowable limit of greater than 1,000 milligrams per liter. Statistical analysis revealed a significance value of $p<0.05$, indicating no significant difference.

The one-sample t-test and Bayesian statistics were derived from the field data, while a simple bar chart displayed key parameter values village and taluk-wise, with a standard error of +/- 1 and a 95% confidence interval.

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