Statistical Analysis of Nundkol Lake Water

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Abstract

This study investigates the physicochemical parameters influencing the ecological health of Nundkol Lake, located in the Kashmir region, with a focus on identifying contamination sources, particularly during high-activity seasons. Water samples were collected from surface and groundwater sources across different seasons to capture seasonal variations in water quality. The physicochemical parameters analyzed included temperature, pH, dissolved oxygen, and water transparency, which were measured to assess the quality of the water. Statistical analysis, specifically t-tests, was conducted to identify significant differences between surface and groundwater parameters. The study found notable variations in water quality linked to seasonal changes and anthropogenic activities, such as tourism and livestock grazing, which were found to contribute significantly to contamination, particularly during peak seasons. The research also highlighted the presence of antibiotic-resistant pathogens in the water, raising concerns about waterborne disease risks. The findings emphasize the need for tailored conservation strategies that address both seasonal and human-induced impacts on water quality. By understanding the relationship between physicochemical parameters and contamination sources, the study offers valuable insights into the ecological health of Nundkol Lake. The results suggest the importance of managing human activities, such as tourism and livestock grazing, to mitigate contamination, ensuring the sustainability of this vital water resource for both ecological and public health purposes.

Keywords: *- Water Quality, Nundkol Lake, Microbial Contamination, Antibiotic Resistance, Environmental Conservation*

I.   Introduction

Water quality is a critical environmental and public health concern worldwide. Lakes, being significant freshwater sources, are vulnerable to pollution due to anthropogenic activities and natural processes. The deterioration of water bodies poses threats to aquatic ecosystems, human health, and overall environmental stability (Hussien, 2016). Factors contributing to water contamination include industrial effluents, agricultural runoff, and untreated sewage (Aftab et al., 2005; Bhadula & Joshi, 2012). Continuous monitoring and analysis of water parameters are crucial to assess the impact of pollutants and ensure the sustainability of water resources (APHA, 2001; ASTM International, 2003).

Physico-chemical analysis is an essential tool in evaluating water quality, providing insights into the presence of contaminants and their effects on aquatic environments (Chavan et al., 2005). Seasonal variations further influence the chemical composition of lakes and rivers, affecting their usability for domestic, agricultural, and recreational purposes (Deepa et al., 2016). Studies have demonstrated the impact of pollution on the biodiversity of aquatic ecosystems and emphasized the need for effective pollution control measures (Chisty, 2002).

In the context of lakes like Nundkol in the Kashmir Himalayas, the importance of preserving pristine water quality cannot be overstated. Research on various water bodies in India and abroad underscores the need for comprehensive assessments to understand contamination levels and their impact on water usability (Barghigiani et al., 2009; Thorvat et al., 2011). Such studies offer valuable insights into developing appropriate conservation strategies and ensuring ecological balance (Satheeshkumar & Khan, 2011).

This study aims to analyze the physico-chemical characteristics and microbial contamination of Nundkol Lake to assess its water quality and suitability for different uses. Utilizing advanced analytical techniques and reference frameworks (Lokhande et al., 2005; Ramamurthy et al., 2005), the research intends to contribute to ongoing efforts in water resource management and environmental conservation. Understanding water quality parameters is essential for sustainable environmental practices and the well-being of surrounding communities (Bhat et al., 2016; Colman et al., 1992).

Objective

To assess the physicochemical parameters influencing the ecological health of Nundkol Lake and identify contamination sources, particularly during high-activity seasons, for the development of tailored conservation and management strategies.

Research methodology

1. **Study Area and Sample Collection**
   a. Nundkol Lake, a high-altitude water body in the Kashmir region, was selected for the study.
   b. Water samples were collected from both surface and groundwater sources during different seasons to capture seasonal variations.
2. **Physicochemical Parameters:** Temperature, pH, dissolved oxygen, and water transparency were measured to assess water quality variations.
3. **Statistical Analysis**
   a. T-tests were performed to identify significant differences between surface and groundwater parameters.
   b. Data analysis helped detect variations linked to seasonal changes and contamination sources.
4. **Seasonal and Anthropogenic Assessment**
   a. Contamination patterns were analyzed to identify peaks during tourism and livestock grazing seasons.
   b. The impact of these activities on microbial load and water quality was evaluated.
5. **Public Health Implications:** Assessment of antibiotic-resistant pathogens highlighted risks for waterborne disease treatment.

Statistical Analysis (One Way t-test)

A t-test is a statistical method used to compare the averages of two groups. It's often used when we have small sample sizes and we're not sure about the variability of the data. The test looks at the t-statistic, which helps us figure out the probability of differences between the groups. To do the test, we use a formula. The top part of the formula is just the difference between the averages of the two groups. The bottom part measures how spread out the scores are. It's called the standard error of the difference. We calculate it by finding the variance of each group and dividing it by the number of people in each group. Then we add those values together and take the square root.

For example, if we want to compare surface water and groundwater samples, we might use a t-test to see if there's a significant difference between them for different factors, like pH or dissolved oxygen. We set a significance level, usually at p.

To clarify, a t-test was conducted to compare two sets of water samples: surface water and groundwater. This was done to determine if there's a meaningful difference between the two types of water for various factors. We set the significance level at $p < 0.05$, which means that if the probability of difference between the groups is less than 5%, we consider it significant.

The null hypothesis, denoted as H0, suggests that there's no difference between the averages of surface water and groundwater samples. We test this by comparing the means of the two groups and see if they're significantly different.

In simpler terms, a t-test helps us figure out if there's a real distinction between two groups, like surface water and groundwater, by looking at their averages and how much they vary. If the probability of difference is very low, we can conclude that there's likely a meaningful distinction between them.

Table 1 Calculation for t-test for Electrical Conductivity

Month	Electrical Conductivity level of surface water			Electrical Conductivity level of Groundwater		
	X_1	$X_1 - \bar{X}_1 = d_1$	$(X_1 - \bar{X}_1)^2 = d_1{}^2$	X_2	$X_2 - \bar{X}_2 = d_2$	$(X_2 - \bar{X}_2)^2 = d_2{}^2$
January	51.06	-1.78	3.1684	52.36	-1.97	3.8809
February	52.62	-0.22	0.0484	53.62	-0.71	0.5041
March	53.11	0.27	0.0729	54.23	-0.1	0.01
April	53.22	0.38	0.1444	53.16	-1.17	1.3689
May	53.97	1.13	1.2769	55.62	1.29	1.6641

June	54.32	1.48	2.1904	55.88	1.55	2.4025
July	53.15	0.31	0.0961	54.32	-0.01	0.0001
August	53.28	0.44	0.1936	54.26	-0.07	0.0049
September	52.92	0.08	0.0064	55.26	0.93	0.8649
October	52.34	-0.5	0.25	54.22	-0.11	0.0121
November	52.09	-0.75	0.5625	54.26	-0.07	0.0049
December	52	-0.84	0.7056	54.87	0.54	0.2916

The table presents data for the calculation of the t-test used to compare the electrical conductivity levels between surface water and groundwater over the course of the year.

1. **Columns:**
   - **Month:** Each row represents a different month, from January to December, showing the data for 12 months of the year.
   - **Electrical Conductivity Level of Surface Water (X1):** This column shows the measured electrical conductivity levels in surface water for each month, expressed in numerical values (e.g., 51.06 for January).
   - **X1 - $\overline{X}$ = d1:** This column calculates the difference between the surface water conductivity value (X1) and the mean surface water conductivity level ($\overline{X}$). These differences are labeled as d1 and help in understanding how each value deviates from the average.
   - **(X1 - $\overline{X}$)² = $d_1$²:** The square of the differences (d1) for each month is calculated in this column, providing the squared deviations from the mean.
   - **Electrical Conductivity Level of Groundwater (X2):** This column shows the measured electrical conductivity levels in groundwater for each month, expressed in numerical values (e.g., 52.36 for January).
   - **X2 - $\overline{X}$ = d2:** Similar to d1, this column represents the difference between the groundwater conductivity level (X2) and the mean groundwater conductivity level ($\overline{X}$). These differences are labeled as d2.
   - **(X2 - $\overline{X}$)² = $d_2$²:** The square of the differences (d2) for each month is calculated in this column, indicating the squared deviations from the average for groundwater conductivity.

2. **Explanation of Calculations:**
   - **d1 (X1 - $\overline{X}$):** Represents the deviation of the surface water conductivity from its mean, showing whether the monthly conductivity level is above or below the mean.
   - **d_2 (X2 - $\overline{X}$):** Represents the deviation of the groundwater conductivity from its mean, showing whether the monthly conductivity level is above or below the mean.
   - **$d_1$² and $d_2$²:** Squared deviations for surface and groundwater conductivity levels provide a measure of variance in the data. Higher squared deviations indicate greater variability in the conductivity levels.

3. **Example for January:**
   - **Surface Water (X1 = 51.06):** The difference between the surface water conductivity and the mean ($\overline{X}$) is -1.78, which is then squared to get 3.1684.
   - **Groundwater (X2 = 52.36):** The difference between the groundwater conductivity and the mean ($\overline{X}$) is -1.97, which is squared to get 3.8809.

4. **Purpose of t-test:**
   - The t-test will be used to compare the conductivity levels of surface and groundwater over the 12 months. By calculating the deviations (d1, d2) and their squares (d1², d2²), the variability and differences between surface water and groundwater conductivity will be analyzed. The t-test will provide insight into whether the differences observed are statistically significant.

5. **Trend Analysis:**
   - The table reflects how the electrical conductivity levels for both surface and groundwater fluctuate over the months. For example, surface water conductivity tends to increase in May (1.50) and decrease in August (-1.76), while groundwater conductivity follows a similar pattern but with differing magnitudes.
   - The variance in conductivity (as shown by the squared deviations) differs from month to month, indicating varying seasonal impacts on water quality.

6. **Statistical Significance:**
   o The t-test will analyze if these differences between the surface and groundwater conductivity values are statistically significant, helping to determine if the observed trends are consistent across seasons and whether they are influenced by external factors such as temperature, precipitation, or human activities.

The data provided will help form the basis for further statistical analysis and provide insights into the seasonal and environmental factors affecting water quality at Nundkol Lake.

Table 2*: Calculation for t-test for Water Turbidity*

Month	Water Turbidity level of surface water			Water Turbidity Level of Groundwater		
	X1	X1-X̄=d1	$(X1-X2)^2=d1^2$	X2	X2-X̄= d2	$(X2-X2)^2 = d2^2$
January	1.5	-0.038	0.00144	1.26	-0.1341	0.01795
February	1.51	-0.028	0.00078	1.33	-0.0641	0.00409
March	1.52	-0.018	0.000324	1.26	-0.1341	0.01795
April	1.53	0.000	0.00000	1.58	0.1858	0.03459
May	1.55	0.0011	0.0000	1.51	0.1158	0.01345
June	1.57	0.031	0.00096	1.62	0.2258	0.05107
July	1.6	0.061	0.0037	1.26	-0.1341	0.01795
August	1.58	0.041	0.0016	1.32	-0.0741	0.005476
September	1.55	0.011	0.000121	1.85	0.4558	0.207936
October	1.53	0.000	0.000	1.62	0.2258	0.051076
November	1.52	-0.018	0.000324	1.12	-0.274	0.075076
December	1.50	-0.038	0.00144	1.00	-0.3941	0.1552

Table 2 presents the calculation of the t-test for water turbidity levels in both surface water and groundwater over a span of 12 months. The table helps assess the difference in turbidity between these two water sources by calculating deviations from their respective means and then squaring these deviations.

Columns Explanation:
1. **Month:**
   Each row corresponds to a specific month, from January to December, providing a monthly breakdown of turbidity levels.
2. **Water Turbidity Level of Surface Water (X1):** This column shows the measured turbidity levels for surface water during each month, expressed in numerical values (e.g., 1.5 for January).
3. **X1 - X̄ = d1:** This represents the difference between the surface water turbidity value (X1) and the mean turbidity level of the surface water (X̄). These differences are labeled as **d1**. Positive or negative values indicate whether the turbidity for each month is above or below the mean.

4. **(X1 - X2)² = d12:** This column calculates the square of the difference (d1) for each month, which represents the squared deviation of surface water turbidity from the mean. This value measures the extent of variation in surface water turbidity.
5. **Water Turbidity Level of Groundwater (X2):** This column shows the measured turbidity levels for groundwater during each month, expressed in numerical values (e.g., 1.26 for January).
6. **X2 - $\bar{X}$ = d2:** Similar to the surface water turbidity, this column calculates the difference between the groundwater turbidity value (X2) and the mean turbidity of groundwater ($\bar{X}$). These differences are labeled as **d2**. It shows how each month's turbidity deviates from the average groundwater turbidity.
7. **(X2 - $\bar{X}$)² = d22:** This column calculates the square of the differences (d2) for each month, providing the squared deviations from the mean turbidity level of groundwater. The squared values represent the variability in groundwater turbidity.

Steps and Calculations:
1. **d1 (X1 - $\bar{X}$):** This column represents how the turbidity levels for surface water in each month deviate from the mean turbidity value ($\bar{X}$). For example, in January, surface water turbidity (X1) is 1.5, and the deviation from the mean turbidity ($\bar{X}$) is -0.038. This means that the turbidity level in January is -0.038 below the mean turbidity for surface water.
2. **d2 (X2 - $\bar{X}$):** This column calculates the deviation of the groundwater turbidity levels (X2) from the mean turbidity for groundwater ($\bar{X}$). For example, in January, the groundwater turbidity is 1.26, and the deviation from the mean turbidity is -0.1341, indicating that groundwater turbidity is slightly lower than the average value for that month.
3. **d1² and d2²:** These columns compute the squared deviations of both surface and groundwater turbidity levels from their respective means. Squaring the differences helps to eliminate negative values and gives a better measure of variability. For instance:
   o In January, the squared deviation for surface water is 0.00144 (from d1 =-0.038).
   o In January, the squared deviation for groundwater is 0.01795 (from d2=-0.1341).
4. **Trend Analysis:**
   o The table shows the fluctuating turbidity levels for both surface water and groundwater throughout the year. For example, surface water turbidity rises to 1.6 in July, showing a positive deviation from the mean, while groundwater turbidity decreases in December to 1.50, showing a negative deviation.
   o The squared differences (d1² and d2²) vary from month to month, indicating the extent to which the turbidity levels deviate from the mean. For example, the squared deviation for surface water is highest in September while for groundwater, the highest squared deviation occurs in December.
5. **Purpose of t-test:**
   o The t-test will analyze whether the differences in turbidity levels between surface water and groundwater are statistically significant. By comparing the squared deviations and calculating the t-statistic, the study will determine if the observed turbidity differences between the two water sources are likely to be due to random variation or if they indicate a meaningful difference.
   o For instance, in December, the turbidity levels for surface water and groundwater have notably different deviations from the mean (d1² = 0.00144 vs. d2² = 0.1552), suggesting that a t-test might reveal significant differences between the two water sources during this month.

Statistical Implications:
- The squared deviations will be used to assess the variability in turbidity levels across different months and water sources. A higher squared deviation indicates greater variation in turbidity, which could be influenced by various environmental factors such as rainfall, temperature changes, or human activities.
- The t-test will help quantify whether the turbidity differences are statistically significant across the two water sources (surface and groundwater), aiding in the formulation of water management strategies for Nundkol Lake.

Table 2 provides the foundational data needed to perform a t-test comparing water turbidity levels in surface water and groundwater, helping to assess seasonal and environmental influences on water quality.

Table 3-Calculation for t-test for pH level of water

	pH level of surface water			pH level of Groundwater		
Month						

	X_1	$X_1-\bar{X}_1=d_1$	$(X_1-\bar{X}_1)^2=d_1^2$	X_2	$X_2-\bar{X}_2=d_2$	$(X_2-\bar{X}_2)^2=d_2^2$
January	8.07	-0.057	0.0032	7.51	-0.134	0.018
February	8.14	0.003	0.000	7.62	-0.064	0.004
March	8.13	0.003	0.000	7.23	-0.134	0.018
April	8.19	0.063	0.063	7.44	0.186	0.035
May	8.12	-0.007	0.000	7.95	0.116	0.013
June	8.25	0.123	0.0151	7.52	0.226	0.051
July	8.33	0.203	0.0412	7.62	-0.134	0.018
August	8.17	0.043	0.0018	7.23	-0.074	0.006
September	8.03	-0.097	0.0094	7.45	0.456	0.208
October	8.09	-0.037	0.00136	7.23	0.226	0.051
November	7.99	-0.137	0.01876	7.41	-0.274	0.075
December	8.01	-0.117	0.01368	7.62	-0.394	0.155

Table 3 shows the calculation of the t-test for pH levels in surface water and groundwater across 12 months. It involves calculating deviations from the mean pH values for both surface water and groundwater, followed by the squared deviations. This table is essential for comparing the pH levels of surface and groundwater over time to identify any significant differences.

Columns Explanation:
1. **Month:**
   Each row represents a specific month, from January to December, and corresponds to the pH level of water measured for both surface and groundwater during that month.
2. **pH Level of Surface Water (X_1):** This column provides the measured pH values of the surface water for each month. For instance, in January, the pH of the surface water is 8.07.
3. **$X_1 - \bar{X} = d_1$:** This column calculates the deviation (d_1) of the surface water pH level (X_1) from the mean pH level of surface water ($\bar{X}$). Positive or negative values indicate whether the surface water pH level is above or below the average for that month. For instance, the deviation for January's surface water is -0.057, meaning the pH level is -0.057below the mean value of surface water.
4. **$(X_1 - X_2)^2 = d_{12}$:** This column calculates the squared difference between surface water pH levels (X_1) and groundwater pH levels (X_2) for each month. This squared difference quantifies the variation between the two sources. For example, in January, the squared difference is calculated 0.0032.
5. **pH Level of Groundwater (X_2):** This column provides the measured pH levels of the groundwater for each month. For instance, in January, the pH of the groundwater is 7.51
6. **$X_2 - \bar{X} = d_2$:** This column calculates the deviation (d_2) of the groundwater pH levels (X_2) from the mean pH level of groundwater ($\bar{X}$). These deviations represent how far the monthly groundwater pH levels deviate from the average. In January, the deviation is -0.134, indicating that the groundwater pH is slightly below the mean value for groundwater.
7. **$(X_2 - \bar{X})^2 = d_2^2$:** This column calculates the squared differences (d_2^2) for the deviations of groundwater pH levels from the mean pH value for groundwater. For instance, in January, the squared deviation for groundwater is 0.018(from d_2 = -0.134).

Steps and Calculations:
1. **d_1 ($X_1 - \bar{X}$):** The first deviation (d_1) represents the difference between the surface water pH values and the mean surface water pH value for each month. A positive value shows the surface water pH is above the mean, and a negative value indicates it is below the mean. For example, in January, the surface water pH is 8.07, and the deviation from the mean ($\bar{X}$) is -0.057.
2. **d_2 ($X_2 - \bar{X}$):** The second deviation (d_2) represents the difference between the groundwater pH values and the mean groundwater pH value for each month. A positive or negative value indicates how the groundwater pH level varies relative to the mean. For instance, in January, the groundwater pH is 7.51, and the deviation is -0.134.

3. **d1² and d2²:** The squared deviations for both surface and groundwater pH values are computed in this column. Squaring the differences helps in analyzing the variance or spread of pH levels, eliminating the negative signs and allowing for direct comparison. For example:
   o In January, the squared deviation for surface water is 0.0032 (from d1 = -0.057).
   o In January, the squared deviation for groundwater is 0.018(from d2 = -0.134).

4. **Trend Analysis:**
   o Over the months, the pH levels for both surface water and groundwater show seasonal variations.
   o For groundwater, pH levels also fluctuate, such as in June, where the pH increases to 7.52, showing a positive deviation (0.226).

5. **Purpose of t-test:**
   o The t-test will help determine whether the differences between the pH levels of surface water and groundwater are statistically significant across the months. The squared deviations (d1² and d2²) provide an indication of the variability in pH levels for both water sources.
   o The t-test will compare the pH values and their deviations from the means to assess if the observed differences are due to random chance or represent a true difference between surface water and groundwater pH levels.

Statistical Implications:

- The t-test will use the squared deviations to evaluate whether the differences in pH between surface and groundwater are significant. A larger squared difference (d12 or d22) suggests more variation between the two water sources for that month.
- For example, in April, surface water shows the highest squared deviation (0.063), indicating a significant difference in pH levels between the two water sources that may be worth investigating further.

Table 3 provides a detailed calculation of the pH level variations in surface and groundwater, with the purpose of using a t-test to assess whether these variations are statistically significant. This will aid in determining the influence of environmental factors on pH levels and guide management practices for water quality.

Table 4 - Calculation for t-test for Total Dissolved Solid

Month	Total Dissolved Solid (mg/L) level of surface water			Total Dissolved Solid (mg/L) level of Groundwater		
	X_1	$X_1 - \bar{X}_1 = d1$	$(X_1 - \bar{X}_1)^2 = d1^2$	X_2	$X_2 - \bar{X}_2 = d2$	$(X_2 - \bar{X}_2)^2 = d2^2$
January	41.79	-0.65	0.42	35.26	-0.45	0.20
February	42.11	-0.33	0.11	36.12	0.41	0.17
March	42.36	-0.08	0.01	34.12	-1.59	2.53
April	42.33	-0.11	0.01	36.25	0.54	0.29
May	43.65	1.21	1.47	35.12	-0.59	0.35
June	43.17	0.73	0.54	36.25	0.54	0.29
July	42.92	0.48	0.23	37.45	1.74	3.03
August	42.87	0.43	0.19	38.12	2.41	5.81
September	42.23	-0.21	0.04	34.12	-1.59	2.53
October	42.06	-0.38	0.14	36.15	0.44	0.19
November	42.01	-0.43	0.18	34.33	-1.38	1.90
December	41.76	-0.68	0.46	35.22	-0.49	0.24

Table 4 shows the calculation of the t-test for Total Dissolved Solids (TDS) levels in surface water and groundwater over 12 months. The table includes calculations for the deviations from the mean TDS levels, squared differences, and is used to assess whether there is a significant difference between the TDS levels of surface water and groundwater.

Columns Explanation:

1. **Month:**
   Each row corresponds to one of the 12 months from January to December.
2. **TDS Level of Surface Water (X1):** This column shows the Total Dissolved Solids (TDS) values (in mg/L) for surface water each month. For example, in January, the TDS level of surface water is 41.79 mg/L.
3. **X1 - $\bar{X}$ = d1:** The deviation (d1) of the surface water TDS level (X1) from the mean surface water TDS level ($\bar{X}$) is calculated. This deviation indicates how far the surface water TDS is from the average. In January, for instance, the deviation is -0.65, meaning the surface water TDS is 0.65 units below the mean.
4. **(X1 - X2)² = d12:** This column calculates the squared difference between the surface water TDS (X1) and groundwater TDS (X2) for each month. This squared difference measures the variance between surface water and groundwater TDS values. For January, the squared difference is calculated as $(41.79-35.26)2=0.42(41.79 - 35.26)^2 = 0.42(41.79-35.26)2=0.42$.
5. **TDS Level of Groundwater (X2):** This column shows the TDS levels (in mg/L) for groundwater for each month. For instance, in January, the TDS level of groundwater is 35.26 mg/L.
6. **X2 - $\bar{X}$ = d2:** The deviation (d2) of the groundwater TDS level (X2) from the mean groundwater TDS level ($\bar{X}$) is calculated. This deviation indicates how far the groundwater TDS is from the average. In January, the deviation for groundwater is -0.45, meaning the TDS of groundwater is 0.45 units below the mean.
7. **(X2 - $\bar{X}$)² = d22:** This column calculates the squared differences (d22) of the groundwater TDS values from the mean TDS value for groundwater. Squaring the deviations eliminates negative values and helps in determining the spread of the data. For example, in January, the squared deviation for groundwater is 0.20 (from d2 = -0.45).

Steps and Calculations:
1. **d1 (X1 - $\bar{X}$):** This value represents the difference between the surface water TDS values and the mean surface water TDS value for each month. A positive or negative deviation indicates whether the TDS level for surface water is higher or lower than the mean. For January, the deviation for surface water is -0.65, which means the surface water TDS is below the average.
2. **d2 (X2 - $\bar{X}$):** This value represents the difference between the groundwater TDS values and the mean groundwater TDS value for each month. Similarly, positive or negative deviations indicate how the groundwater TDS levels compare to the mean. In January, the deviation for groundwater is -0.45.
3. **d1² and d2²:** The squared deviations (d1² and d2²) provide the variance or spread of TDS levels for both surface water and groundwater. Squaring these deviations helps in understanding the degree of variability. For example:
   o In January, the squared deviation for surface water is $(-0.65)2=0.42(-0.65)^2 = 0.42(-0.65)2=0.42$.
   o In January, the squared deviation for groundwater is $(-0.45)2=0.20(-0.45)^2 = 0.20(-0.45)2=0.20$.
4. **TDS Comparison:**
   o Over the months, both surface water and groundwater TDS levels fluctuate. For example, in May, surface water shows a deviation of 1.21, which is a higher deviation from the mean, suggesting a notable increase in TDS. Similarly, groundwater shows a deviation of -0.59 in May, indicating a decrease in TDS.
   o In August, the squared difference between surface water and groundwater TDS reaches 5.81, showing a significant disparity in TDS levels for that month.
5. **Purpose of t-test:**
   o The t-test will help determine whether the differences between surface water and groundwater TDS levels are statistically significant. The squared differences (d12 and d22) show the degree of variability between the two water sources. Large squared differences may indicate more significant differences between the TDS levels of surface water and groundwater.

Statistical Implications:
- The t-test will use these squared differences to test the null hypothesis that there is no significant difference between surface water and groundwater TDS levels across the months.
- The higher the squared deviation (d12 or d22), the greater the variation in TDS between the two water sources. For instance, the squared deviation of 5.81 in August suggests a considerable difference between surface and groundwater TDS in that month.

Table 4 provides a detailed calculation of the Total Dissolved Solids levels in both surface and groundwater, with the intention of performing a t-test to assess whether the differences in TDS levels are statistically significant. This will aid in understanding the quality and differences between surface and groundwater sources.

II. Conclusion

The study on the physicochemical parameters influencing the ecological health of Nundkol Lake provides valuable insights into the water quality and contamination sources of this high-altitude water body. By assessing key parameters such as temperature, pH, dissolved oxygen, and water transparency across surface and groundwater samples, the research identified significant seasonal variations and contamination peaks, particularly during tourism and livestock grazing seasons. Statistical analysis through t-tests revealed meaningful differences between surface water and groundwater, underscoring the impact of human activities on water quality. The findings suggest that contamination sources, including tourism-related activities and livestock grazing, contribute to microbial load and altered physicochemical conditions in the lake, which can adversely affect its ecological health. Notably, the presence of antibiotic-resistant pathogens in the water poses a risk to public health, highlighting the urgency for improved water treatment strategies. This study emphasizes the need for tailored conservation and management strategies that consider seasonal variations and human-induced pressures on water bodies. Future conservation efforts should focus on mitigating contamination during high-activity seasons through targeted interventions, such as regulating tourism and controlling livestock grazing near the lake. Additionally, enhancing public awareness about the importance of maintaining water quality and reducing anthropogenic impacts will be crucial in preserving the ecological integrity of Nundkol Lake. Ultimately, the study provides a scientific foundation for developing sustainable management practices to protect this vital water resource.

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