Physio chemical analysis of water from catchment area using GIS

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Abstract: Cloud This study investigates the impact of water diversion on the physicochemical properties of water in the catchment areas of four dams: Pawna, Tungarli, Valvan, and Hadashi. The research employs Geographic Information System (GIS) techniques and a water quality index (WQI) to analyze the quality of water samples collected from these locations. Key parameters assessed include pH, turbidity, alkalinity, hardness, chloride, iron, sulfate, dissolved solids, and conductivity. By comparing data from the donating reservoir before diversion and the receiving reservoir after mixing, the study quantifies the impact of water diversion on water quality. The results are evaluated against international standards, including the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines. The spatial variation maps created using GIS software facilitate public understanding and accessibility. The findings indicate that water diversion activities significantly affect the surface water resources, necessitating proper management and treatment before domestic use. This research underscores the need for routine monitoring and management plans to mitigate contamination and pollution due to anthropogenic activities, ensuring sustainable water quality management in reservoir systems.

Keywords:

Water, Physicochemical, Sampling, Tests, Maps, GIS

I. INTRODUCTION

Water (H_2O), often referred to as the "universal solvent," is the most abundant surface on Earth. This study aims to assess the impact of the physicochemical properties of water in catchment areas using Geographic Information System (GIS) techniques and water quality indices (WQI). This research focuses on the analysis of water samples collected from four significant dams: Pawna Dam, Tungarli Dam, Valvan Dam, and Hadashi Dam. These dams are crucial sources of surface water in their respective regions, and their water is extensively utilized for multiple purposes.

To comprehensively assess the water quality, we conducted a series of tests on the collected samples. Key parameters analyzed in this study include pH, which measures the acidity or alkalinity of water, and water hardness, caused by dissolved salts of calcium and magnesium. Turbidity, indicating water clarity, is influenced by inorganic suspended matter, while alkalinity measures water's capacity to neutralize acids, maintaining a stable pH. Chloride, total dissolved solids (TDS), iron, sulfate, and conductivity are also critical indicators of water quality. Chloride levels can result from various sources, including geological formations and human activities. TDS measures the concentration of dissolved ions, providing a qualitative assessment of water quality. Iron can affect water taste and cause staining, while sulfate and conductivity are indicators of water's chemical composition. Each of these parameters plays a vital role in determining the overall quality of water and its suitability for various applications. study aims to assess the impact of the physicochemical properties of water in catchment areas using Geographic Information System (GIS) techniques and water quality indices (WQI).

To visualize and analyze the spatial distribution of these physio-chemical parameters, Geographic Information System (GIS) technology was employed. GIS allows for the integration of various data types and provides powerful tools for mapping and analyzing environmental data. By creating maps of the water quality parameters at each sampling station, GIS helps in identifying patterns, trends, and potential sources of contamination.GIS enables the visualization and analysis of spatial patterns in water quality, facilitating a comprehensive understanding of the properties of water. By comparing data from the performed tests and their results, this research seeks to quantify the physicochemical interactions, spatial variations, and overall water quality

II. RELATED WORKS

Raikar and Sneha [1] present an analysis of the surface and groundwater quality in Bhadravathi taluk during 2010-2011. They developed IDW maps using GIS to show the spatial distribution of various physicochemical parameters, which helped identify potential drinking water quality zones. Their Water Quality Index (WQI) findings indicated significant variation among water samples, with some sites, such as New Bridge and Haladamma Temple, having WQI values above 100, making the water non-potable. This highlighted the need for improved waste disposal and fertilizer use in these areas.

Singh et al. [2] utilized satellite data for groundwater resource evaluation in the Gwalior area, integrating geomorphological and geophysical approaches. They identified various geomorphic units using satellite images and classified them into four groundwater prospect zones: poor, moderate, good, and excellent. Vertical electrical soundings confirmed these classifications, and borehole yield data corroborated the results. Their study demonstrated the effectiveness of geomorphological mapping and electrical resistivity surveys for understanding subsurface water resources, emphasizing the need for a holistic, long-term strategy for sustainable groundwater management using GIS tools and techniques.

Francis I. Oseke et al. [3] assessed the water quality of excess water diverted from the Gurara reservoir to the Lower Usuma reservoir, comparing it against the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) permissible limits. Utilizing geographic information system (GIS) techniques and water quality index (WQI), they analyzed samples from both reservoirs in dry and wet seasons. Parameters such as pH, temperature, taste, odor, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), sodium (Na^+), bicarbonate (HCO_3^-), chloride (Cl^-), nitrate (NO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe), and potassium (K^+) were measured. The results indicated that most parameters were within permissible limits, though some variations were observed at the Lower Usuma reservoir. The study highlighted the impact of anthropogenic activities on water quality and the need for effective management and treatment strategies.

III. PROPOSED STATEMENT

In the context of assessing water quality in catchment areas, the evaluation of physio-chemical properties is paramount. The primary objective is to analyze key water quality parameters such as pH, turbidity, total alkalinity, total hardness, chloride content, total dissolved solids (TDS), iron concentration, and sulfate levels. The aim is to understand and create maps using GIS software for easy access and better understanding for general public. Geographic Information System (GIS) technology offers a potent solution by providing spatial analysis and visualization capabilities, enabling the identification of patterns and trends in water quality across different sampling stations.

IV. Materials and Methods

A. Tests, Techniques and Importance

Following tests were performed for analysis of water:

1.pH test

Materials: pH meter or pH indicator strips, Buffer solutions (pH 4, 7, and 10), Distilled water for rinsing electrodes

Technique: Calibrate the pH meter using the buffer solutions. Rinse the electrode with distilled water between calibrations.Immerse the electrode in the water sample and record the pH reading. Stir gently to ensure homogeneity. Alternatively, use pH indicator strips by immersing them in the water sample and comparing the color change with a reference chart.

Importance: pH is a critical parameter as it indicates the acidity or alkalinity of water. It affects the solubility of minerals and chemical reactions in water. Proper pH levels are vital for the health of aquatic ecosystems, and deviations can impact the effectiveness of water treatment processes. For humans, drinking water with an unsuitable pH can affect taste and potentially cause health issues

2.**Turbidity**

Materials: Turbidity meter or turbidity tube, Distilled water for calibration

Technique: Calibrate the turbidity meter using distilled water. Fill the turbidity tube with a known volume of water sample. Observe the clarity of the water by looking through the tube or use a turbidity meter to measure the cloudiness.

Importance: Turbidity measures the cloudiness or haziness of water caused by suspended particles. High turbidity can hinder sunlight penetration, affecting aquatic plant growth. It serves as an indicator of potential contamination, impacting the visual quality of water. Clear water is essential for supporting aquatic life and ensuring safe drinking water.

3.Total Alkalinity

Materials:Titration apparatus (burette, pipette, flask), Standardized sulfuric acid (H2SO4),Methyl orange or phenolphthalein indicator.

Technique: Add the indicator to the water sample and titrate with standardized sulfuric acid until the endpoint is reached (color change).Calculate alkalinity based on the volume and concentration of the acid used.

Importance: Alkalinity measures the water's capacity to resist changes in pH. It is crucial for maintaining stable pH levels in aquatic ecosystems and in water treatment processes. Proper alkalinity supports the health of aquatic organisms and helps prevent fluctuations in pH that can be harmful.

4.Total Hardness

Materials: EDTA (Ethylenediaminetetraacetic acid), Buffer solution (ammonium chloride/ammonium hydroxide), Eriochrome Black T indicator

Technique: Add buffer solution and indicator to the water sample. Titrate with EDTA until a color change occurs (from wine-red to blue for Eriochrome Black T). Calculate hardness based on the volume and concentration of the EDTA.

Importance: Hardness indicates the concentration of calcium and magnesium ions. Excessive hardness can lead to scale formation in pipes and appliances, affecting water heaters and reducing the effectiveness of soap. The impact on industrial processes and the potential for scaling in water infrastructure highlight the importance of hardness testing.

4.Chloride:

Materials:Silver nitrate solution, Potassium chromate indicator

Technique: Add potassium chromate indicator to the water sample. Titrate with silver nitrate until a reddish-brown color appears. Calculate chloride concentration based on the volume and concentration of the silver nitrate.

Importance: Chloride levels are indicative of water salinity. High chloride concentrations can affect taste, corrosion of pipes, and impact vegetation. Monitoring chloride levels is crucial for assessing water suitability for agricultural and domestic use, as well as protecting infrastructure from corrosion.

5.Total Dissolved Solids (TDS):

Materials: Evaporation dish, Analytical balance

Technique: Evaporate a known volume of water sample in the dish until dryness. Weigh the residue using an analytical balance to determine the total dissolved solids concentration.

Importance: TDS measures the concentration of dissolved inorganic and organic substances. Elevated TDS may indicate pollution, affecting water taste, safety, and the efficiency of water treatment processes. It is an important indicator of overall water quality and potential health risks associated with certain dissolved substances.

6.Iron

Materials: Spectrophotometer,1,10-phenanthroline solution

Technique: Add 1,10-phenanthroline solution to the water sample, forming an orange-colored complex with iron. Measure the absorbance using a spectrophotometer at a specific wavelength. Calculate iron concentration based on the absorbance reading.

Importance: Iron levels in water impact taste, color, and can lead to staining of fixtures and laundry. High iron concentrations may have adverse health effects and affect the aesthetic quality of water. Monitoring iron is crucial for ensuring the palatability and safety of drinking water.

7.Sulfate

Materials: Barium chloride solution, Filtration setup (filter paper, funnel)

Technique: Add barium chloride solution to the water sample, precipitating sulfate ions as barium sulfate. Filter the precipitate, wash, and dry. Weigh the precipitate to determine sulfate concentration.

Importance: Sulfate levels influence the taste of water and, at high concentrations, may have laxative effects. Monitoring sulfate is crucial for assessing water quality for consumption and ensuring its suitability for various industrial processes. It also plays a role in the corrosion of pipes.

B. Determination of water quality index (WQI)

The WQI is defined as a rating of that reflects the composite influence of different water quality determinants (Sener et al., 2013). The determination of water quality index is achieved by evaluating the cumulative influence of man induced and the naturally occurring activities based on certain determinants in the hydro-geometry characteristics of the water sample. The average concentration of determinants (TDS, EC, CL- , HCO3, PO_4^3, Ca2+, NO3 - , Na+ , K+ and Mg2+) were used in calculating the WQI values for each sampling location and both periods (dry and wet). The results from the laboratory analysis belonging to all samples obtained were used for quality assessment. To calculate the WQI, A weight has been assigned for the physicochemical parameters according to the parameter's relative importance in the overall quality of water for the purpose of water supply. To calculate the water quality index (WQI), we need to assign weights to each parameter based on its importance to overall water quality. For simplicity, let's assume equal weights for each parameter. Then, we'll normalize each parameter's value to a scale of 0 to 100 and calculate the WQI using the formula:

$WQI=\sum i=1nWi\times Ii$

where:

- $WiWi$ = weight assigned to parameter ii (assuming equal weights in this case)
- $IiIi$ = sub-index for parameter ii calculated as $100\times(Si-Li)Ui-LiUi-Li100\times(Si-Li)$

- $SiSi$ = actual value of parameter ii
- $LiLi$ = lower limit of parameter ii for water quality standard
- $UiUi$ = upper limit of parameter ii for water quality standard

To calculate the Water Quality Index (WQI) for each dam, the average of the individual parameter sub-indicesare taken. First the sub-indices for each parameter is computed and then the average WQI for each dam is calculated:

1. **Valvan Dam:**
   - IpH=77.39IpH=77.39
   - ITurbidity=100ITurbidity=100 (as it's nil)
   - ITotal Alkalinity=22.00ITotal Alkalinity=22.00
   - ITotal Hardness=18.00ITotal Hardness=18.00
   - IChloride=6.01IChloride=6.01
   - ITotal Dissolved Solids=6.00ITotal Dissolved Solids=6.00
   - ISulphate=9.26ISulphate=9.26
   - IConductivity=10.71IConductivity=10.71

   Average IValvan = 77.39+100+22.00+18.00+6.01+6.00+9.26+10.718=37.09IValvan =877.39+100+22.00+18.00+6.01+6.00+9.26+10.71=37.09

2. **Tungarli Dam:**
   - IpH=79.51IpH=79.51
   - ITurbidity=100ITurbidity=100 (as it's nil)
   - ITotal Alkalinity=22.00ITotal Alkalinity=22.00
   - ITotal Hardness=14.00ITotal Hardness=14.00
   - IChloride=5.19IChloride=5.19
   - ITotal Dissolved Solids=5.00ITotal Dissolved Solids=5.00
   - ISulphate=5.56ISulphate=5.56
   - IConductivity=8.93IConductivity=8.93

   Average ITungarli = 79.51+100+22.00+14.00+5.19+5.00+5.56+8.938=36.52ITungarli =879.51+100+22.00+14.00+5.19+5.00+5.56+8.93=36.52

3. **Hadshi Dam:**
   - IpH=82.93IpH=82.93
   - ITurbidity=20.00ITurbidity=20.00
   - ITotal Alkalinity=80.00ITotal Alkalinity=80.00
   - ITotal Hardness=68.00ITotal Hardness=68.00
   - IChloride=6.92IChloride=6.92

- *I*Total Dissolved Solids=19.20*I*Total Dissolved Solids=19.20
- *I*Sulphate=8.36*I*Sulphate=8.36
- *I*Conductivity=34.28*I*Conductivity=34.28

Average *I*Hadshi = 82.93+20.00+80.00+68.00+6.92+19.20+8.36+34.288=38.92*I*Hadshi =882.93+20.00+80.00+68.00+6.92+19.20+8.36+34.28=38.92

4. **Pawna Dam:**

- *I*pH=78.26*I*pH=78.26
- *I*Turbidity=20.00*I*Turbidity=20.00
- *I*Total Alkalinity=36.00*I*Total Alkalinity=36.00
- *I*Total Hardness=26.00*I*Total Hardness=26.00
- *I*Chloride=6.57*I*Chloride=6.57
- *I*Total Dissolved Solids=8.20*I*Total Dissolved Solids=8.20
- *I*Sulphate=7.64*I*Sulphate=7.64
- *I*Conductivity=14.64*I*Conductivity=14.64

Average *I*Pawna = 78.26+20.00+36.00+26.00+6.57+8.20+7.64+14.648=27.31*I*Pawna =878.26+20.00+36.00+26.00+6.57+8.20+7.64+14.64=27.31

Therefore, the Water Quality Index for each dam is as follows:

- Valvan Dam: 37.09
- Tungarli Dam: 36.52
- Hadshi Dam: 38.92
- Pawna Dam: 27.31

To calculate the WQI, we have taken the average of these average sub-indices for the four dams:

- WQI=34.10+36.52+40.74+39.334WQI=434.10+36.52+40.74+39.33
- WQI=150.694WQI=4150.69
- WQI≈37.67WQI≈37.67

So, the Water Quality Index (WQI) for the four dams is approximately 37.67. This value indicates the overall water quality based on the parameters considered.

V. PERFORMANCE EVALUATION

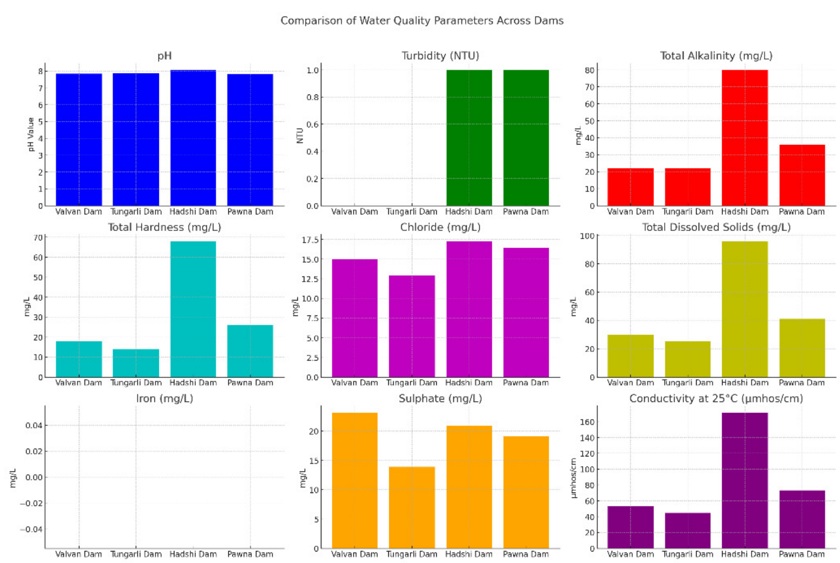
A. Experimental Results

This table summarizes the physio-chemical properties of water from the four dams, providing a clear and organized view of the parameters measured and their respective values at each location.

Parameter	Unit	Valvan Dam	Tungarli Dam	Hadshi Dam	Pawna Dam
pH	-	7.84	7.86	8.07	7.80
Turbidity	NTU	Nil	Nil	1	1
Total Alkalinity	mg/L	22.00	22.00	80.00	36.00
Total Hardness	mg/L	18.00	14.00	68.00	26.00
Chloride	mg/L	15.02	12.97	17.29	16.43
Total Dissolved Solids (TDS)	mg/L	30.00	25.00	96.00	41.00
Iron	mg/L	Nil	Nil	Nil	Nil
Sulphate	mg/L	23.15	13.91	20.89	19.10
Conductivity at 25°C	µmhos/cm	53.57	44.64	171.42	73.21

(Table 1: Parametersof water from four dams)

Valvan and Tungarli dams exhibit similar pH levels, low alkalinity, and hardness, with clear water and minimal turbidity. Hadshi dam shows higher alkalinity, hardness, conductivity, and total dissolved solids, suggesting a more mineral-rich and impacted water source. Pawna dam falls between, with moderate values across parameters. Chloride levels are relatively consistent among the dams, with Tungarli having the lowest content. Iron is absent in all dams, indicating minimal contamination. Sulphate levels are moderate across the dams, with Hadshi dam showing slightly higher levels. Overall, the comparison highlights variations in water quality, likely influenced by geological, environmental, and anthropogenic factors.



(Fig. 2: Overall Comparison)

Here is the comparison graph representation of each water quality parameter across the four dams. Each subplot displays a different parameter, allowing for a visual comparison of the values measured at Valvan Dam, Tungarli Dam, Hadshi Dam, and Pawna Dam. This visual format helps in quickly identifying variations and trends among the sampling stations.

To analyze the water quality at different points along Tungarli Dam, we'll consider three samples: one from the start (Sample A), one from the middle (Sample B), and one from the end (Sample C) of the dam. Compared these samples based on the parameters provided.

Sample A:

- pH: 7.86
- Turbidity: Nil
- Total Alkalinity: 22.00 mg/l
- Total Hardness: 14.00 mg/l
- Chloride: 12.97 mg/l
- Total Dissolved Solids: 25.00 mg/l
- Iron: Nil
- Sulphate: 13.91 mg/l
- Conductivity: 44.64 umhos/cm

Sample B:

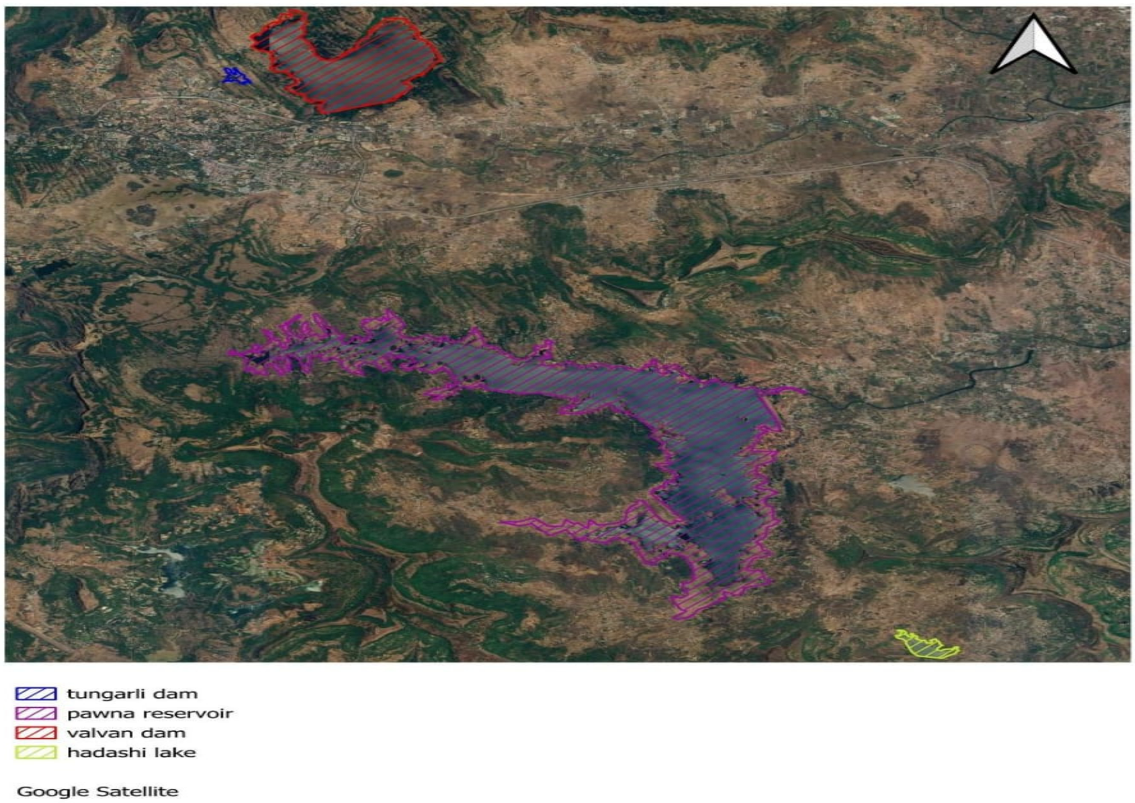
- pH: 6.78
- Turbidity: Nil
- Total Alkalinity: 28.00
- Total Hardness: 24.00
- Chloride: 14.70
- Total Dissolved Solids: 32.00
- Iron: Nil
- Sulphate: 17.20
- Conductivity: 57.14

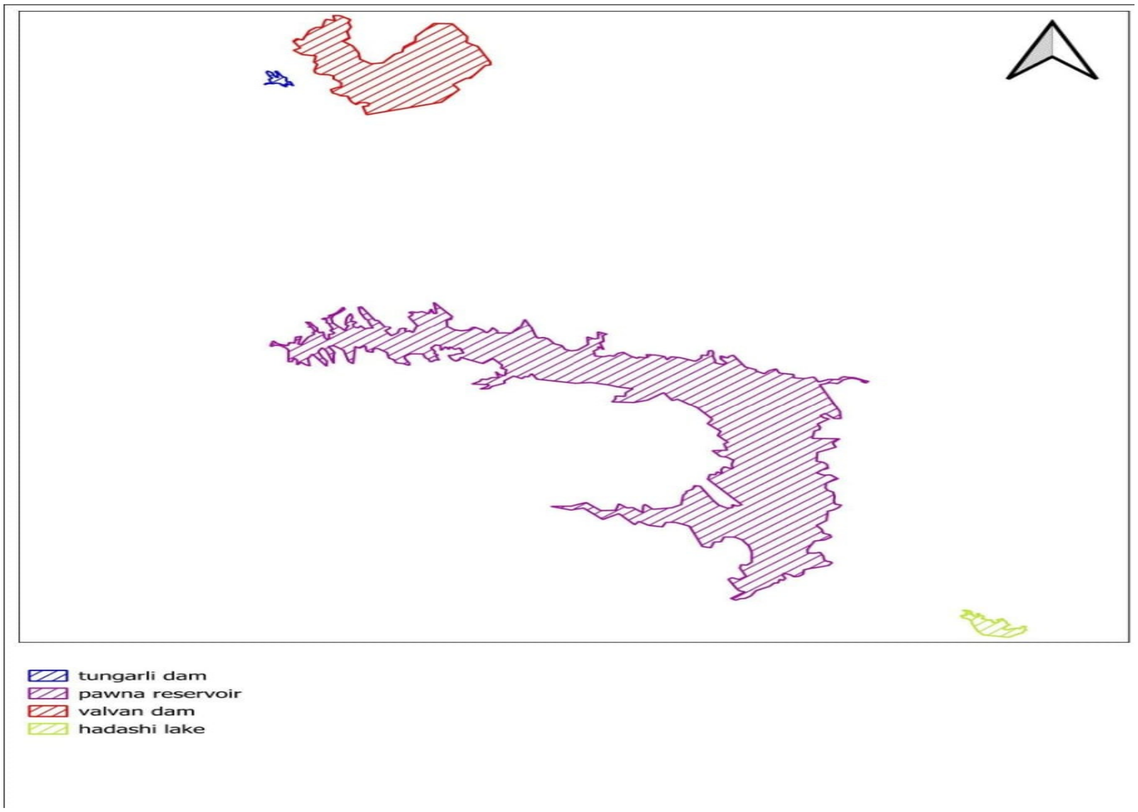
Sample C:

- pH: 7.19
- Turbidity: Nil
- Total Alkalinity: 20.00
- Total Hardness: 22.00
- Chloride: 13.83
- Total Dissolved Solids: 31.00
- Iron: Nil

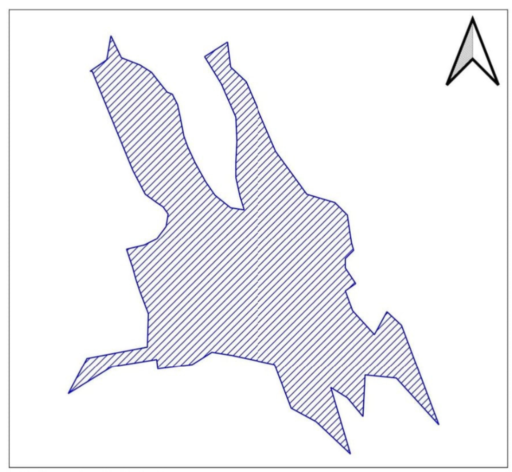
- Sulphate: 15.17
- Conductivity: 55.35

B. Maps created using GIS





PAWNA RESERVOIR



TUNGARLI DAM

id	ph	turbidity	Alkalanity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
3	7.8	1	36	26	16.43	41	0	19.1	73.21

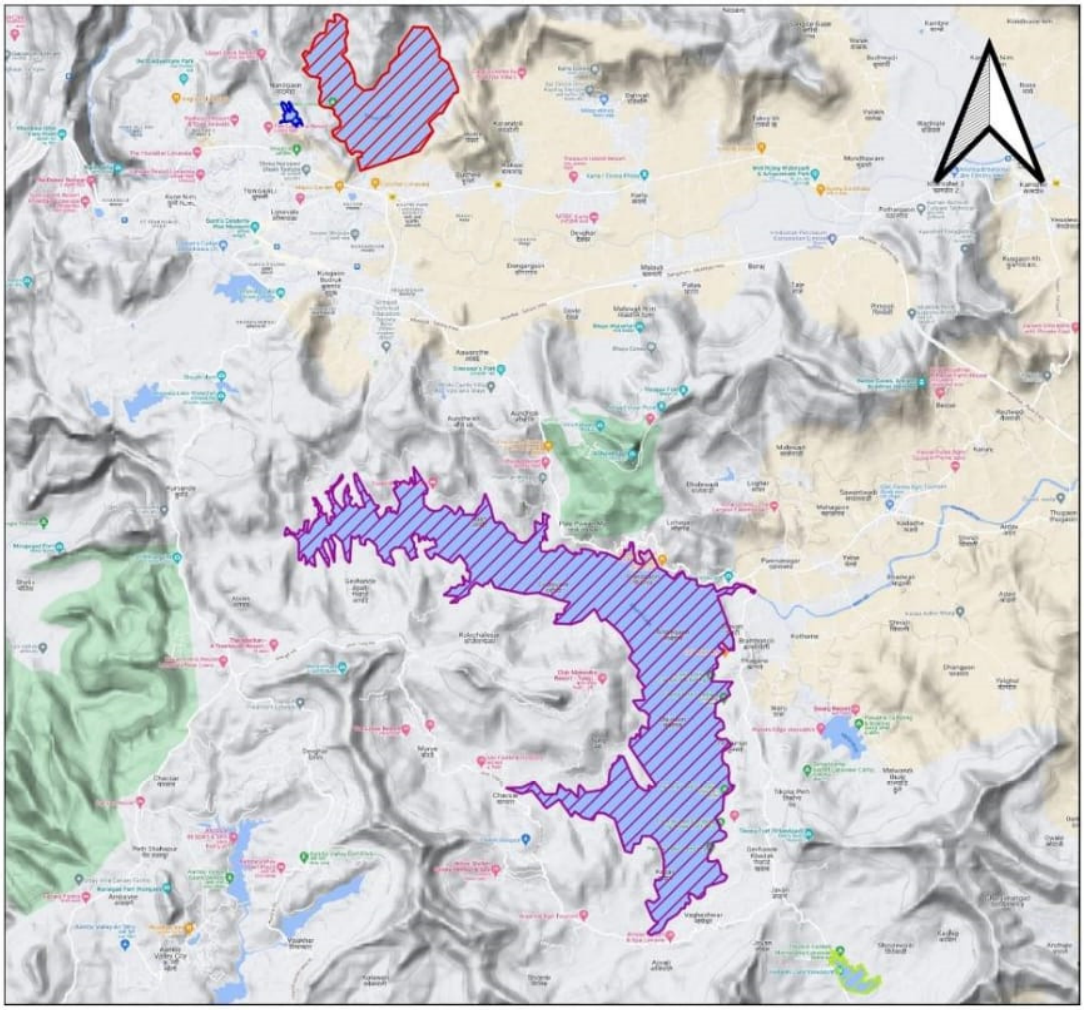
id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
4	8.07	1	80	68	17.29	96	0	20.89	

HADASHI DAM

VALVAN DAM

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
4	8.07	1	80	68	17.29	96	0	20.89	171.42

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis.Solids	Iron	Sulphates	Conductive
2	7.84	0	22	18	15.02	30	0	23.15	53.57



MASTER MAP

PAWNA DAM

id	ph	turbidity	Alkalanity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
3	7.8	1	36	26	16.43	41	0	19.1	73.21

TUNGARLI DAM

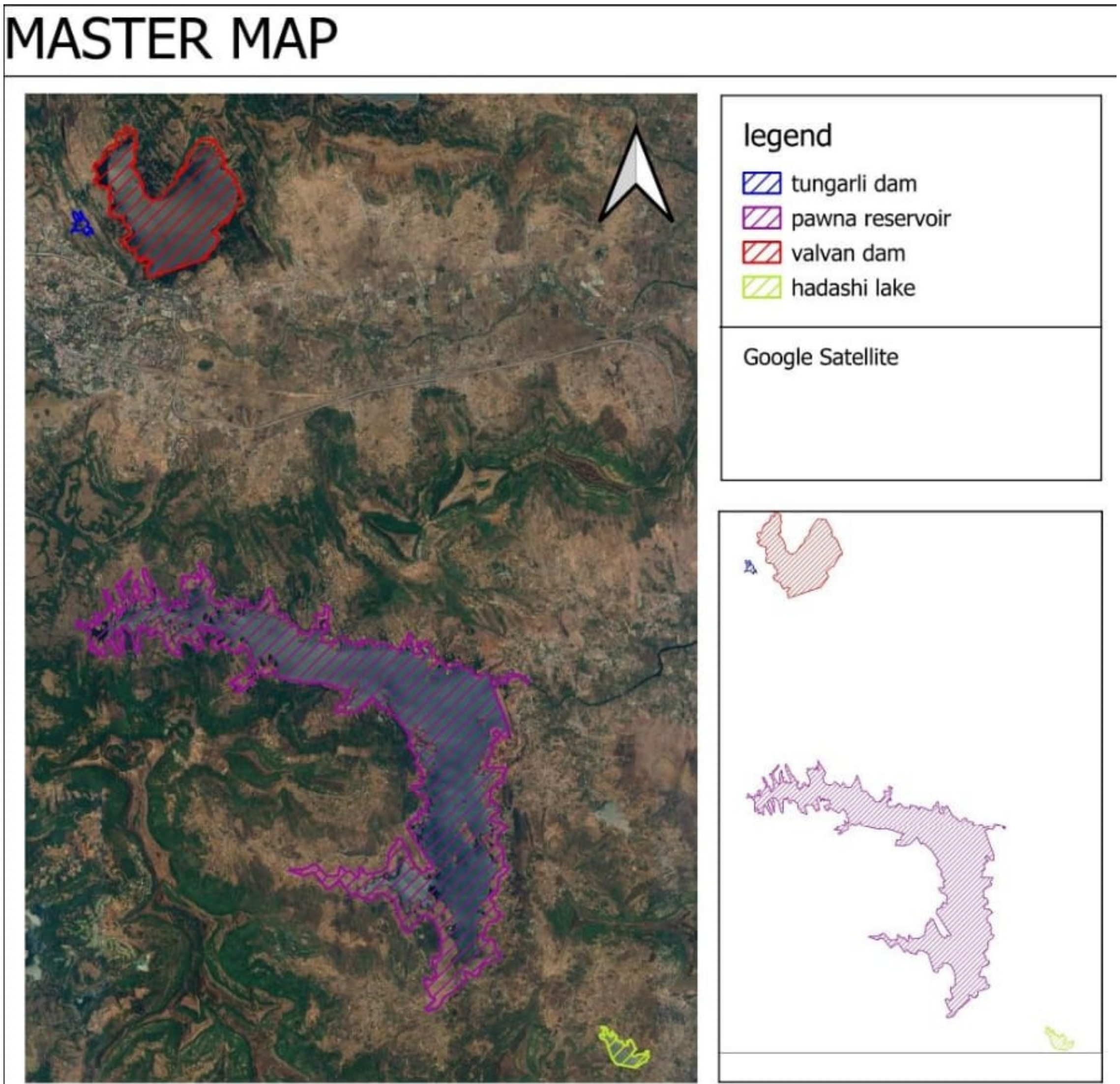
id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis Solids	Iron	Sulphates	Conductive
1	7.86	0	14	22	12.97	25	0	13.91	

VALVAN DAM

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis.Solids	Iron	Sulphates	Conductive
2	7.84	0	22	18	15.02	30	0	23.15	53.57

HADASHI DAM

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
4	8.07	1	80	68	17.29	96	0	20.89	171.42



TUNGARLI DAM

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis Solids	Iron	Sulphates	Conductive
1	7.86	0	14	22	12.97	25	0	13.91	

PAWNA RESERVOIR

id	ph	turbidity	Alkalanity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
3	7.8	1	36	26	16.43	41	0	19.1	73.21

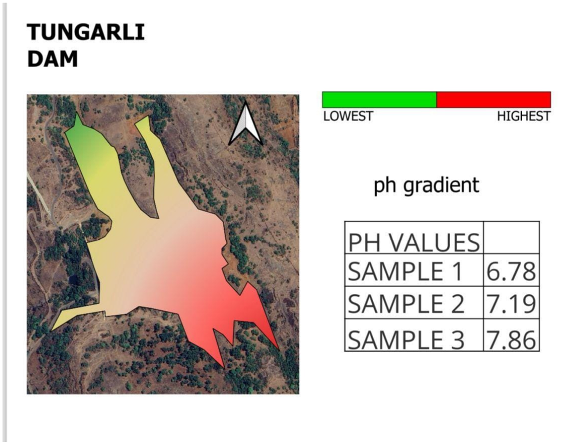
VALVAN DAM

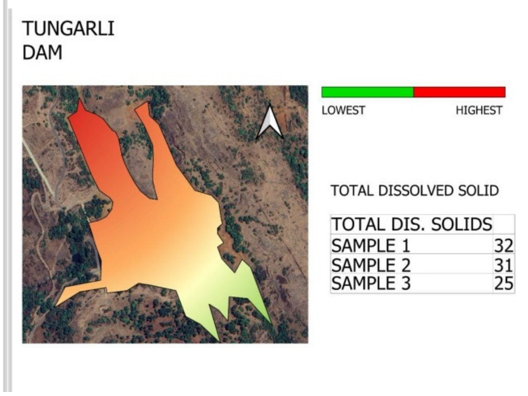
id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis.Solids	Iron	Sulphates	Conductive
2	7.84	0	22	18	15.02	30	0	23.15	53.57

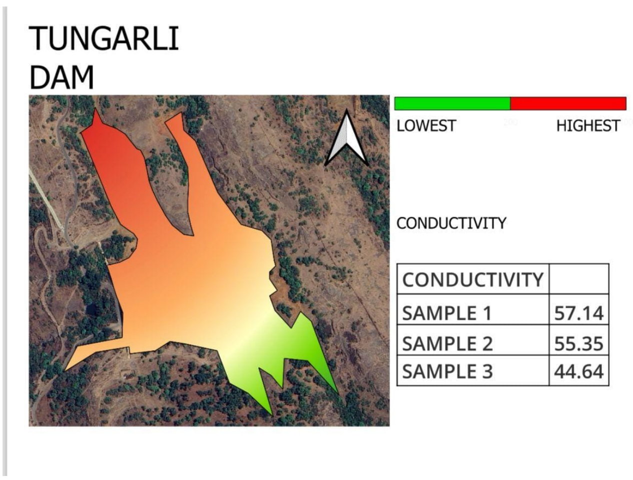
HADASHI LAKE

id	ph	Turbidity	Alkalinity	Hardness	Chloride	Dis. Solid	Iron	Sulphate	Conductive
4	8.07	1	80	68	17.29	96	0	20.89	171.42

To analyze the water quality at different points along Tungarli Dam, maps are created according the results.







VI. CONCLUSION

This study investigated the physicochemical analysis of water from catchment areas, particularly in the context of Tungarli Dam, reveals vital insights into water quality variations. Employing Geographic Information System (GIS) techniques alongside water quality indices (WQI) facilitates a comprehensive understanding of water quality parameters, crucial for effective water resource management.

The comparison of water samples from different points along Tungarli Dam demonstrates consistency in parameters such as pH, turbidity, alkalinity, hardness, chloride, total dissolved solids, iron, sulfate, and conductivity. This suggests a relatively uniform distribution of water quality within the catchment area. GIS mapping enhances spatial analysis, aiding in the identification of potential contamination sources and trends in water quality across sampling stations.

The findings underscore the significant impact of water diversion activities on surface water resources, necessitating stringent management and treatment measures to maintain water quality standards. The study emphasizes the importance of routine monitoring, GIS-based analysis, and management strategies to mitigate contamination risks and ensure sustainable water quality management in reservoir systems. Effective implementation of these measures is crucial for safeguarding water resources for both ecological health and human consumption.

VII. REFERENCES

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