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Groundwater Quality Assessment Using GIS for Drinking Propose in Molakalmur Taluk, Karnataka

S N Abhishek[1] and Dr. C Rangaraj[2]
[1]Research Scholar, Department of Civil Engineering, Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India
[2]Professor, Department of Civil Engineering, Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India

Abstract

In the hard rock terrain of Molakalmur Taluk in Karnataka, India, groundwater is an important source of drinking water supply. The goal of the current study was to appraise the groundwater's quality using WQI and the spatial distribution of its physicochemical properties. In order to build a spatial distribution map based on a GIS, ArcGIS 10.1 was used to analyse 92 groundwater samples that were collected in the study area during the pre-monsoon period. According to BIS 3025, the concentrations of several ions, including Ca^{+2}, HCO_3^{-1}, Na^{+1}, CO_3^{-2}, K^{+1}, Cl^{-1}, SO_4^{-2}, and Mg^{+2}, were assessed. In this work, an effort has been made to comprehend whether groundwater is suitable for consumption by humans. The WQI has been used to categorise the water quality into the following levels: excellent, good, poor, etc. This is pretty effective for inferring the water quality to the consumers and policy makers in the area of concern. In the research area, the WQI varies from 8.29 to 81.85 with a few exceptions at greater depths, the groundwater is safe and potable, according to the study area's overall WQI. According to the interpretation of Piper's trilinear diagram, the majority of the water samples fell into the categories of mixed $CaMgHCO_3$, $MgHCO_3$, and CaCl types, in that order of dominance. The plot shows that alkaline earths correspond to 75% of the samples. The correlation matrix has been created and its strength in influencing the assessment of groundwater quality has been investigated. The groundwater in the area with diminishing water quality needs to be treated before consumption and must also be safeguarded from the dangers of anthropogenic contamination, according to the current study.

Keywords: *Groundwater quality, Piper's trilinear diagram, Water Quality Index (WQI)*

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INTRODUCTION

Groundwater, as a complex resource that is recharged annually with the help of rainfall and is vulnerable to various activities which will degrade the quality of the water [1]. Groundwater is a vital source of water for domestic uses such as irrigation, drinking and manufacturing processes. One of the most critical aspects of groundwater research is water quality. The hydro chemical investigation shows weather the water quality that is ideal for drinking, change in the water quality will be mainly due to oxidation–reduction reactions and rock-water interaction [2,3]. Few soluble salts are always suspended in groundwater. The sources for groundwater recharge and the strata through which it travels determine the variety and quality of these salts. Groundwater quality has been tested and monitored on a regular basis in recent years using GIS technology and the IDW interpolation method, which has proven to be an excellent tool for assessing and analysing spatial data of water resources [4]. During the pre-monsoon period, water samples were obtained from 92 stations and analysed for chemical characteristics and evaluated against WHO guidelines for domestic and drinking water based on the WQI. Chemical characteristics of groundwater play a crucial part in classifying and determining water quality. The seven major constituents present in water quality are Ca^{+2}, Mg^{+2}, Cl^{-1}, HCO_3^{-1} Na^{+1}, K^{+1}, and SO_4^{-2}, A number of methodologies and approaches have been established to evaluate chemical data; chemical classification reveals the major cations, anions, and their interrelationships. Understanding water quality parameters is easier when they are represented graphically.

The WQI is a number that ranges from 0 to 100. WQI is a distinctive digital rating system that depicts the overall quality of the water at a specific location and time using a variety of water quality factors. As a result, the study's findings will assist in the gathering of critical data on groundwater quality in Molakalmur Taluk. The study's findings may be useful to groundwater managers and urban planners in their efforts to improve and replenish groundwater quality as well as choose an effective and financially viable treatment method to solve the quality challenges [5]. Therefore, the study objective is to use a GIS interpolation technique and a statistical approach (WQI) in the study area to determine whether it is suitable for human usage. According to the hydrochemistry of the examined samples, significant cations are present in greater amounts than major anions in the following order: Ca > Mg > Na > K, followed by HCO > Cl > SO > F. The study demonstrates that calcium and magnesium are the predominant alkaline earth metals leached in the aquafer due to rock water interaction impacting the quality of groundwater, while bicarbonate and chloride are the dominating alkali.

STUDY AREA

Molakalmur Taluk is situated in Chitradurga district of Karnataka, India, between 14º 30'00" to 15º 00' 00" North Latitude and 76º 40' 00" to 76º 51' 00" East Longitude. According to 2011 census, the taluk has an area of 739 km^2 including 695.94 km^2 rural area and 43.06 km^2 urban area, with a total population of 141,284 people. Figure 1 and Figure 2 represents the study area and groundwater collection points. Nearly 80% of the workforce is employed in agriculture, animal husbandry and horticulture, which are the preliminary sources of employment. In Molakalmur Taluk, Gneiss & Granites are the key water bearing formations. The thickness, and structure of rock formations influence the occurrence, transport, and storage of groundwater. Groundwater in the study area occurs in weathered and fractured granite, gneisses. The people in this region are frequently facing water shortage and poor water quality problems. Porosity is dependent on the degree of weathering and rock fracture, which is what causes the occurrence of groundwater.

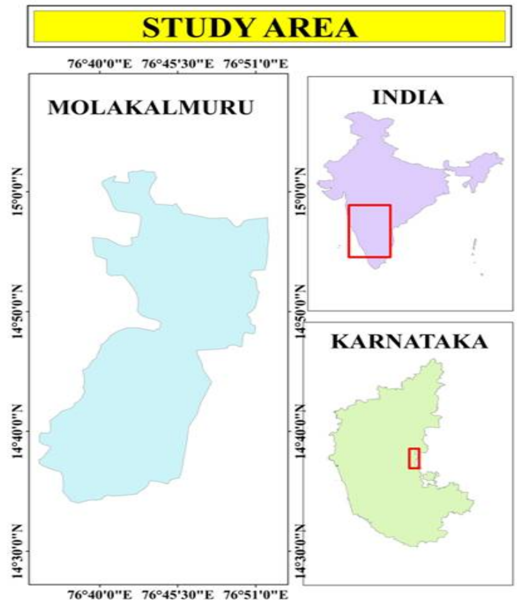

Figure 1: Study Area

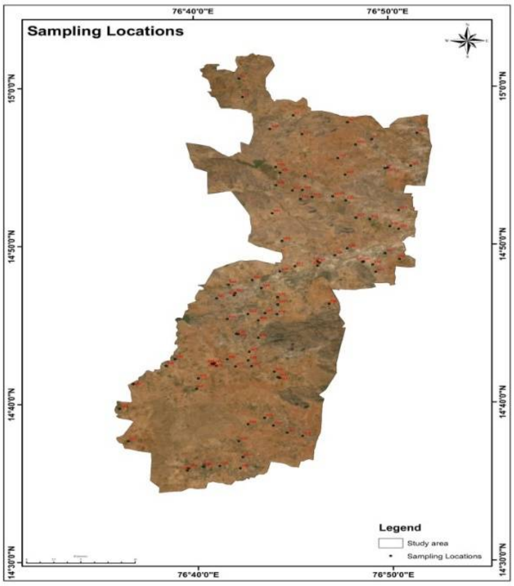

Figure 2: Groundwater sample collection points

NOVELTY

The major ion chemistry of the groundwater in Molakalmur Taluk has never been studied, and there is no perennial river in the study area. The current investigation makes an effort to investigate if water is suitable for drinking. The study's conclusions will help with the gathering of vital information on the condition of the groundwater in Molakalmur Taluk. The study's conclusions may also be useful to groundwater managers and planners in their efforts to restore and enhance groundwater quality.

MATERIALS AND METHOD

In total, 92 groundwater samples were obtained from the study region for study during the pre-monsoon period, the location of sample collection is as shown in Figure 2. They were gathered from their individual bore wells in cleaned 1L polyethylene bottles. Each bottle was cleaned with distilled water to prevent contamination. In the laboratory, the analysis was carried out as per BIS 3025 (2014) [14] and with the help of standard instruments. Concentrations are stated in mg/l and then converted to mEq/L for computations except pH, TDS and EC.

The hydrogen ion concentration, temperature, conductivity, and TDS in water samples were determined using a portable standard meter. For the analysis of sodium and potassium, a flame-photometer was utilized. Total Alkalinity (TA), Calcium Hardness (CH) and Total Hardness (TH) as $CaCO_3$ were assessed volumetrically. Sulphate by turbidity method and Fluoride, Copper, Iron was determined for drinking purpose using portable checkers from Hanna Equipment's India Pvt. Ltd. The correctness of analysis has been verified with the help of Equation 1 and 2. A spatial distribution image based on a GIS was created using ArcGIS 10.1. WQI is calculated with the help of index method.

$$1.0 < \frac{\text{Measured TDS}}{\text{Calculated TDS}} < 1.2 \qquad \textbf{Equation -1}$$

$$\%\ \text{Difference} = 100\ X \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} < 5\% \qquad \textbf{Equation -2}$$

COMPUTING OF WQI

The WQI was designed to assess the combined effect of distinct water quality parameters on overall water quality. The WQI is a mathematical formula that converts a significant amount of data on water quality into a single value in an easily accessible format [5]. The analysed samples' water quality data were compared to the BIS-2012 drinking water standard, as shown in Table 1. The WQI was calculated using the weighted arithmetic approach, which was invented by Horton in 1965 and modified by Brown et al. in 1972. The WQI is calculated with the help of following equations 3,4,5 and 6.

$$WQI = \sum_{i=1}^{n} W_i\ x\ Q_i \ / \sum_{i=1}^{n} W_i \qquad \textbf{Equation -3}$$

$$W_i = \frac{k}{S_i} \qquad \textbf{Equation -4}$$

$$k = \frac{1}{\sum \left(\frac{1}{S_i}\right)} \qquad \textbf{Equation -5}$$

$$Q_i = 100\ x\ \left[\frac{(V_n - V_o)}{(S_n - V_o)}\right] \qquad \textbf{Equation -6}$$

Where: **-**

n = no. of variables

W_i, Q_i & Si = unit weight, quality rating and standard value (i^{th} parameter)

K = proportional constant

Vn, Vo and **Sn** = observed, ideal and standard value of i^{th} parameter (with the exception of pH, which is 7, all typical values for potable water are assumed to be zero.)

If, Qi = 0 denotes the absence of impurities, whereas Qi = 0 to 100 denotes the presence of contaminants that are within the permitted limits. That suggests that the pollutants are over the standards when Qi > 100.

RESULT AND DISCUSSION

Groundwater quality maps were created with the use of ArcGIS software based on the selected parameters as stated. The drinking water standards from BIS 2012 and WHO 2017 were used as a reference in this investigation.

TOTAL DISSOLVED SOLIDS (TDS) AND ELECTRICAL CONDUCTIVITY (EC)

"Dissolved solids" refers to any minerals, salts, elements, cations, or anions that are dissolved within water. TDS generally is a inorganic salts dissolved in water, mostly Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-1}, SO_4^{-2}, and Cl^{-1}, as well as some minor quantity of organic materials. The groundwater sample's high percentage of dissolved solids is caused by salt leaching from the soil and rocks, as well as the possibility of residential sewage and agricultural runoff percolating into the groundwater, causing a rise in TDS levels. The ability of a solution to conduct electricity is measured by its electrical conductivity, and it is proportional to TDS. According to standards, the amount of TDS and EC must be between 500–2000 mg/l and 750 and 3000 µS/cm respectively. The high concentration of TDS and EC in the studied area is mostly due to decreased rainfall and increased borewell depths. The TDS and EC in the studied area ranges from 337 to 2557 mg/l and 674 to 5114 µS/cm.

HYDROGEN ION CONCENTRATION (pH)

pH and other chemical components are closely related and it is a useful indicator for measuring the quality and pollution of any system [6]. The concentration of hydrogen ions is quantified in terms of pH range and the pH of pure water is nearly neutral. The pH range in this study area varies from 6.3 to 8.24, which is within the permissible range of 6.5–8.5, showing the alkaline character of groundwater. The spatial distribution of pH is shown in Figure 5.

CALCIUM (Ca^{2+}) MAGNESIUM (Mg^{2+}) AND TOTAL HARDNESS (TH),

Total hardness is expressed as the sum of multivalent cations [7]. The Ca^{+2} and Mg^{+2} dissolves naturally when the water moves through calcium and magnesium bearing minerals present within the ground. The TH, Ca^{+2} and Mg^{+2} in the study region varies from 136 to 864 mg/l, 62 to 686 mg/l and 10 to 378 mg/l respectively. As per the standards the Ca^{+2} in the water should be within 75 to 200 mg/l and Mg^{+2} should not be greater than 100 mg/l. The spatial distribution of TH, Ca^{2+} and Mg^{2+} is represented in Figure 6,7 and Figure 8 respectively.

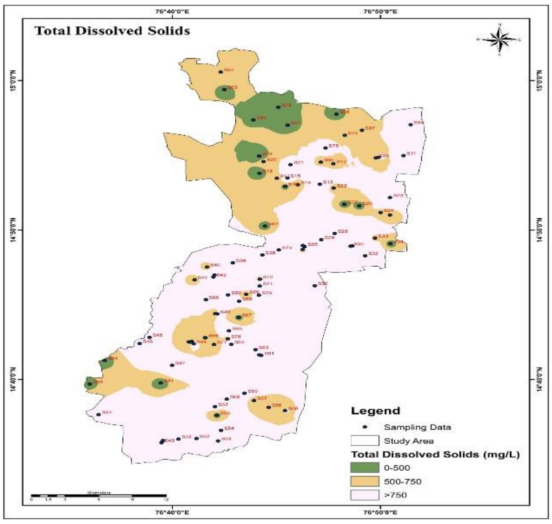

Figure 3: Spatial distribution of TDS

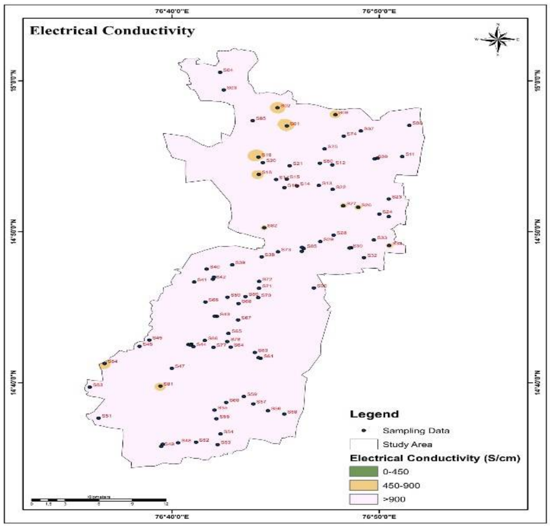

Figure 4: Spatial distribution of EC

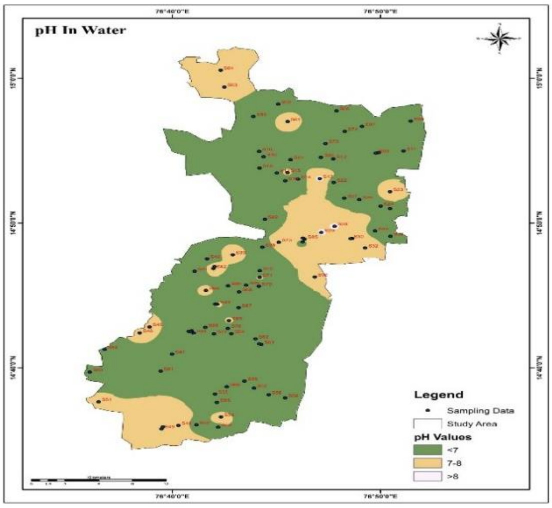

Figure 5: Spatial distribution of pH

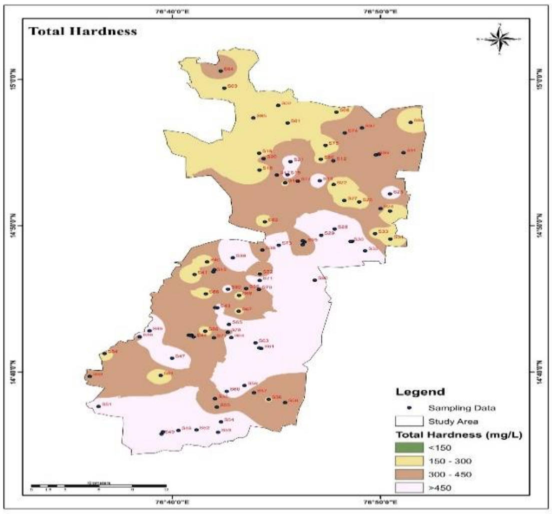

Figure 6: Spatial distribution of TH

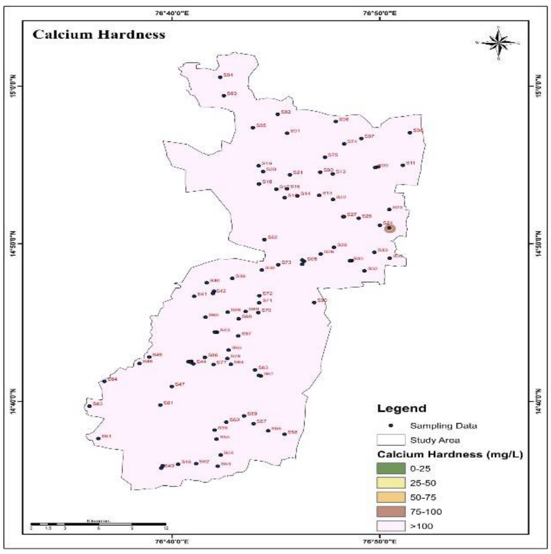

Figure 7: Spatial distribution of Ca^{+2}

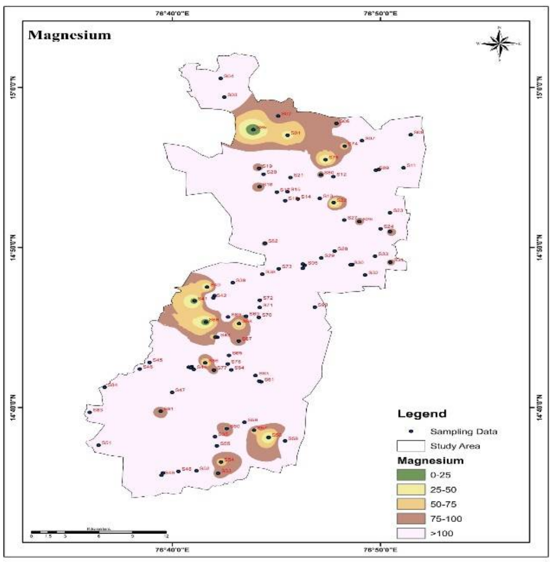

Figure 8: Spatial distribution of Mg^{+2}

SODIUM (Na^+) and POTASSIUM (K^+)

These are the alkali metal with a high reactivity and can be found in the majority of groundwater. Most of the rocks and soils contain Na^+ and K^+ ions, which dissolve quickly in groundwater to discharge sodium. This is one of the most significant criteria in determining groundwater for irrigation, higher sodium levels affect soil permeability and add to overall water salinity, which can be hazardous to sensitive crops [8]. The high level of Na^+ and K^+ suggests weathering of rock-forming minerals, such as silicate minerals and dissolution of soil salts driven by evaporation. The Na^+ and K^+ ions in the research area is ranging from 14.8 to 376 mg/l and 2.2 to 114.6 mg/l respectively.

BICARBONATE (HCO_3^{-1}), SULPHATE (SO_4^{-2}), CHLORIDE (Cl^{-1})

HCO_3^{-1} is produced when carbon dioxide reacts with water in carbonate rocks like limestone and dolomite. The presence of bicarbonate is caused by CO_2 in the soil reacting with rock-forming minerals, resulting in an alkaline environment in the groundwater [9]. Sulphate is disintegrated and leached from gypsum, iron sulphides, and other sulphur-bearing materials. Similarly, several things can contribute to groundwater containing chloride, including soil weathering, salt-bearing rock structures, salt spray deposits, and salt used for road de-icing. HCO_3^{-1}, SO_4^{-2} and Cl^{-1} in the study region varies from 52 to 412 mg/l, 12 to 164 mg/l, 15 to 388 mg/l respectively.

FLUORIDE (F^-)

Fluoride is an electronegative element and which cannot be removed by boiling or cooling of water. It can be found in small amounts or in high concentrations as a significant ion. Majority of fluoride is distributed as fluorite (CaF_2) and found deep inside the earth. The study area is composed of granite, granitic gneiss etc. and occurrence of fluoride in groundwater is commonly due to presence of CaF_2 which plays a substantial role in contribution [10].

Table 1: Minimum, Maximum, and Mean ion concentrations for the research area's drinking water in relation to WHO and BIS standards

	Standards for drinking water		Observed value			
Parameters	BIS (2015)	WHO (2017)	Min	Max	Mean	SD (σ)
pH	6.5–8.5	7—8	6.88	8.24	6.89	0.46
EC (μS/cm)	750–3000	---	674.00	5114.00	1778.09	999.02
TDS (mg/l)	500–2000	600–1000	337.00	2557.00	889.04	499.51
Alkalinity (mg/l)	200–600	---				
TH as $CaCO_3$ (mg/l)	200–600	200	136.00	864.00	405.21	188.66
Ca^{2+} (mg/l)	75–200	100–300	62.00	686.00	264.58	135.22
Mg^{2+} (mg/l)	30–100	---	10	378	139.54	84.02
Na^+ (mg/l)	---	50–200	14.8	376	130.18	74.32
K^+ (mg/l)	---	---	2.2	114.6	38.018	23.93
HCO_3^-(mg/l)	300–600	---	52	412	141.52	54.92
SO_2^- (mg/l)	200–400	250	12	164	50.09	32.28
Cl^- (mg/l)	250–1000	250	14.89	387.22	97.95	80.32
F^- (mg/l)	1–1.5	1.5	0	3.3	0.15	0.57
Fe^{+2} (mg/l)	0.3-1.0	0.3	0	0	0	0

CORRELATION MATRIX AND STATISTICAL ANALYSIS

The simple correlation coefficient, which shows whether one variable is sufficient to predict the other, is a widely used correlation criterion between two variables [3]. Tables 2, contain the overall statistical analysis and correlation matrix of the parameters affecting groundwater quality. MS Excel 2019 was used to generate and analyse the correlation matrix. Eight of these parameters—TDS, EC, Na^+, TA, TH, Ca^{2+}, Mg^{2+}, and HCO_3—are significantly associated, with a correlation value of greater than 0.50. The vast majority of quality indicators, however, have a positive correlation with one another.

WATER QUALITY INDEX

Using ArcGIS 10.1, the WQI map has been created to distinguish between the many quality classifications, including excellent, good, poor, extremely poor, and inappropriate for each groundwater stations. the WQI values vary from 8.29 to 81.85 during pre-monsoon period. The majority of groundwater are in excellent to good condition with very few in unsuitable condition. In most of the research area, the groundwater's quality falls into the excellent category and is fit for human consumption, The spatial distribution map of WQI is shown in Figure 12.

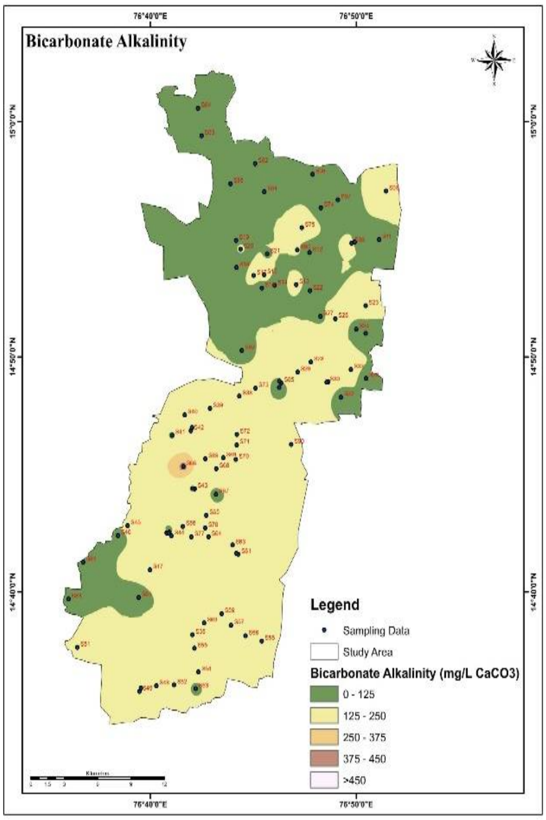

Figure 9: Spatial distribution of HCO_3^-

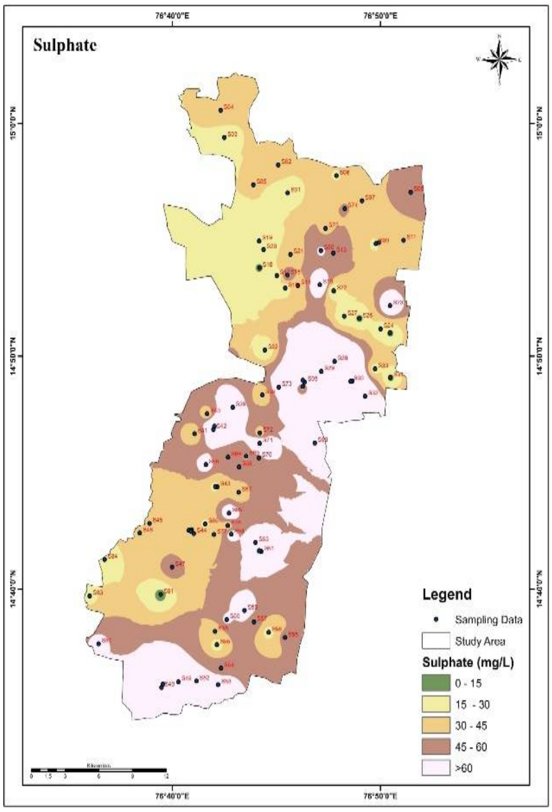

Figure 10: Spatial distribution of SO_4^{-2}

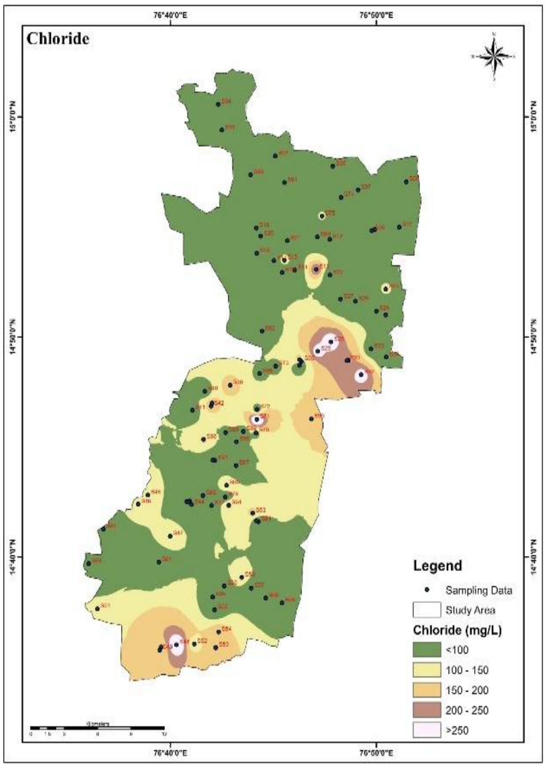

Figure 11: Spatial distribution of Cl^-

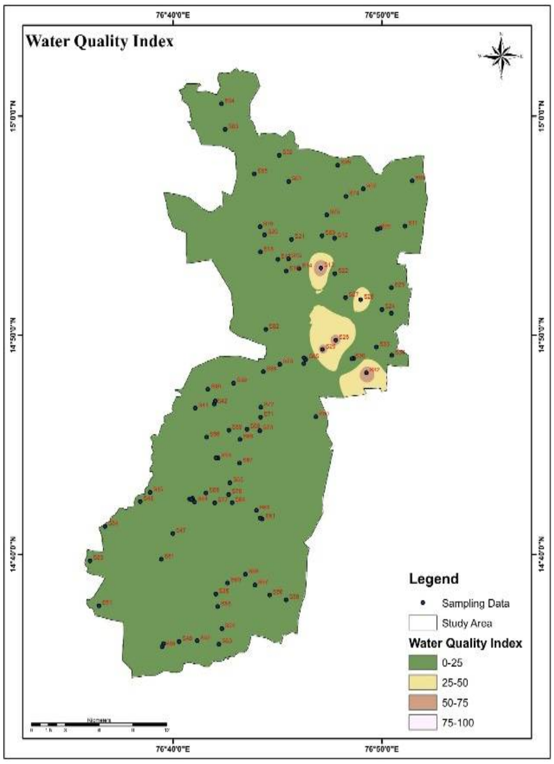

Figure 12: Spatial distribution of WQI

Table 2: Major cations and anion correlation coefficient matrix (R2) for the studied area

	pH	EC	TDS	TH	Ca	Mg	F	Cl	TA	SO_4	Na	HCO_3
pH	1.000											
EC	0.805	1.000										
TDS	0.805	1.000	1.000									
TH	0.684	0.817	0.817	1.000								
Ca	0.638	0.768	0.768	0.914	1.000							
Mg	0.501	0.591	0.591	0.750	0.422	1.000						
F	0.506	0.477	0.477	0.319	0.328	0.193	1.000					
Cl	0.727	0.905	0.905	0.806	0.779	0.547	0.472	1.000				
TA	0.442	0.564	0.564	0.409	0.396	0.282	0.185	0.444	1.000			
SO4	0.696	0.857	0.857	0.730	0.740	0.433	0.464	0.828	0.445	1.000		
Na	0.473	0.721	0.721	0.554	0.573	0.329	0.156	0.645	0.485	0.678	1.000	
HCO_3	0.358	0.504	0.504	0.40	0.434	0.193	0.074	0.441	0.934	0.437	0.487	1

GIBBS DIAGRAM

The Gibbs diagram is frequently used to determine the connection between the lithological properties of an aquifer and its water composition. The Gibbs diagram illustrates three separate fields, including areas where precipitation, evaporation, and rock-water interaction are dominant [11,12]. The Gibbs diagram represents rock-water interaction and evaporation contain the samples that are most prevalent. The rock-water interaction dominant field determines the link between the chemistry of the rocks and percolated water. This phenomenon shows that the primary regulating factor affecting the groundwater chemistry of the studied area is the dissolution of carbonate and silicate minerals. Additional surface contamination sources including irrigation runoff and anthropogenic effects may degrade groundwater quality by raising Na and Cl concentrations. According to the Gibbs diagrams in Figure 13, evaporation and chemical weathering of the minerals that form rocks are the key processes that add ions to water. Anthropogenic activities can also raise the TDS value.

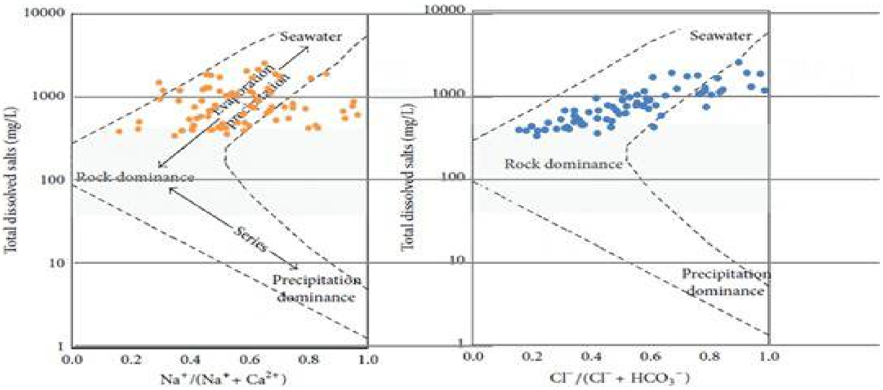

Figure 13: Gibbs Diagram

PIPER-TRILINEAR PLOT

Table 1 shows the max and min concentrations of the main ions that were found in the groundwater from the research area. To comprehend and distinguish the water composition in various classes, the concept of hydro-chemical facies was established [13]. Hydro-geochemical facies are inferred using the Piper-Hill diagram. The categorisation of water samples from diverse lithological environments is displayed on the Piper-trilinear plot, to draw attention to the variations and resemblances among the groundwater samples. It also analyses the predominant cation and anion to show how the water samples are composed. These findings demonstrate that the chemical composition varies from region to region, indicating various sources of mineralization. These tri-linear diagram is also beneficial in highlighting chemical correlations among groundwater samples in more precise terms. Figure 15 of Piper trilinear diagram illustrates a hydrogeochemical facies with mixed $CaMgHCO_3$ type dominance. Additionally, it is proposed that the dominance of silicate weathering and the interaction between rocks and water are the main causes of the groundwater's rising major ion concentration.

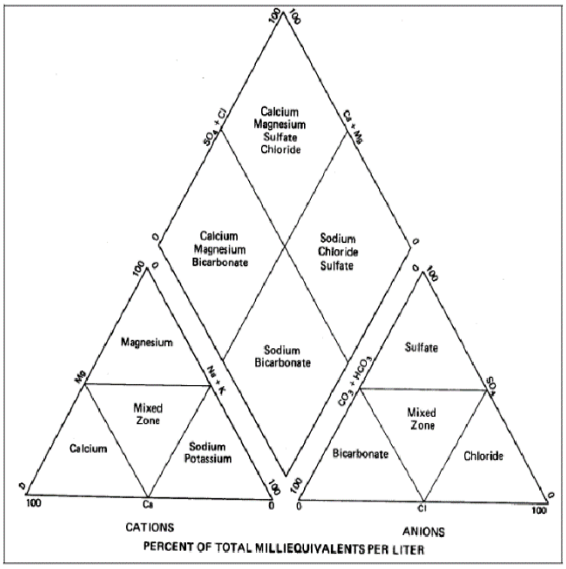

Figure 14: Piper's chart

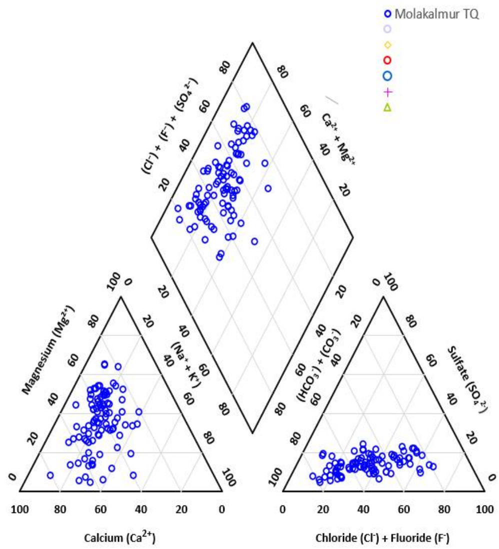

Figure 15: Piper's chart for Molakalmur Taluk

CONCLUSION

The goal of the current investigation is to determine whether the groundwater in Molakalmur Taluk is suitable for human consumption. After collecting water samples from 92 stations during the pre-monsoon season and analysing them for chemical characteristics, a spatial distribution map was produced using ArcGIS 10.1 based on GIS. According to the interpretation of Piper's trilinear diagram, the majority of the water samples fell into the categories of mixed $CaMgHCO_3$, $MgHCO_3$, and CaCl types, in that order of dominance. The plot shows that alkaline earths correspond to 75% of the samples. The Gibbs diagram shows that the two main elements that affect the chemical composition of groundwater are evaporation and rock-water interaction. Weathering of silicate minerals and carbonate minerals are the principal sources of carbonate and bicarbonates. It has been proposed that the primary processes which contribute the ions to the water are chemical weathering of the rock-forming minerals. A constant monitoring programme of water quality is necessary to verify that the water is fit for drinking. The majority of borewells are privately held by farmers, so it is necessary to advise all private bore well users to utilise proper groundwater recharge techniques, limit their groundwater usage, take precautions to prevent groundwater pollution, and be aware of the significance of water quality.

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REFERENCES

1. Alice Makonjo Wekesa and Calford Otieno. (2022). Assessment of Groundwater Quality Using Water Quality Index from Selected Springs in Manga Subcounty, Nyamira County, Kenya. The Scientific World Journal, 1-7. https://doi.org/10.1155/2022/3498394.
2. Soumaia Mnassri, Asma El Amri, Nesrine Nasri and Rajouene Majdoub. (2022). Estimation Of Irrigation Water Quality Index in a Semi-Arid Environment Using Data-Driven Approach. Water Supply. 22 (5): 5161–5175. https://doi.org/10.2166/ws.2022.157.
3. B. Guerra Tamara, A. C. Torregroza-Espinosa, D. Pinto Osorio, M. Moreno Pallares, A. (2022). Corrales Paternina and A. Echeverría Gonzalez. Implications of irrigation water quality in tropical farms. Golbal Journal of Environmental Science and Management. 8(1): 75-86. https://dx.doi.org/10.22034/GJESM.2022.01.06.
4. K. Praveen and L. B. Roy. (2022). Assessment of Groundwater Quality Using Water Quality Indices: A Case Study of Paliganj Distributary, Bihar, India. Engineering, Technology & Applied Science Research.;12(1) 8199-8203. http://dx.doi.org/10.48084/etasr.4696.
5. V. Sunitha and B. Muralidhara Reddy. (2022). Geochemical characterization, deciphering groundwater quality using pollution index of groundwater (PIG), water quality index (WQI) and geographical information system

(GIS) in hard rock aquifer, South India. Applied Water Science. 12 (41): 1-40. https://doi.org/10.1007/s13201-021-01527-w.
6. Xiaogang Fu,Zihan Dong, Shuang Gan, Zhe Wang , and Aihua Wei. (2021). Groundwater Quality Evaluation for Potable Use and Associated Human Health Risk in Gaobeidian City, North China Plain. Journal of Chemistry.: 1-15. https://doi.org/10.1155/2021/3008567.
7. Faiza Hallouz, Mohamed Meddi and Salaheddine Ali Rahmani.(2021). Multivariate Analysis to Assess the Quality of Irrigation Water in a Semi-Arid Region of North West of Algeria: Case of Ghrib Dam. Environmental Earth Science. 1-20 https://doi.org/10.21203/rs.3.rs-206444/v1.
8. Abdel-Fatteh M., Abd-Elmabod S., Aldosari A., Elrys A. & Mohamed E. (2020). Multivariate Analysis for Assessing Irrigation Water Quality: A Case Study of The Bahr Mouise Canal, Eastern Nile Delta. Journal of Waste ; 12(9). https://doi.org/10.3390/w12092537.
9. Esmaeil Asadi,Mohammad Isazadeh, Saeed Samadianfard, Mohammad Firuz Ramli, Amir Mosavi, Narjes Nabipour, Shahaboddin Shamshirb, Eva Hajnal and Kwok-Wing Chau. (2020). Groundwater Quality Assessment for Sustainable Drinking and Irrigation. 12(177):1-13. http://dx.doi.org/10.3390/su12010177.
10. AliEl Bilali and AbdeslamTaleb. Prediction Of Irrigation Water Quality Parameters Using Machine Learning Models in A Semi-Arid Environment. Journal of the Saudi Society of Agricultural Sciences. 2020; 19(7): 439-451. https://doi.org/10.1016/j.jssas.2020.08.001.
11. Salah Elsayed, Hend Hussein, Farahat S. Moghanm, Khaled M. Khedher, Ebrahem M. Eid and Mohamed Gad. (2020). Application of Irrigation Water Quality Indices and Multivariate Statistical Techniques for Surface Water Quality Assessments in the Northern Nil Delta, Egypt. Water. 2020; 12(3300). 1-26. http://dx.doi.org/10.3390 /w12123300.
12. S.K Mondal, S. Kole Dutta, Sanjit Pramanik and Ramen Kumar Kole. Assessment of River Water Quality for Agricultural Irrigation. International journal of Environmental Science and Technology. 2019; 16(1):451-462. http://dx.doi.org/10.1007/s13762-018-1657-3.
13. Arindam Malakar, Daniel D.(2019). Snow and Chittaranjan Ray. Irrigation Water Quality—A Contemporary Perspective. 11(7): https://doi.org/10.3390/w11071482.
14. IS 3025,(2000). Methods of sampling and test (physical and chemical) for water and wastewater.

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