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Assessment of Groundwater Quality for Pre- and Post-Monsoon Variations in Molakalmur Taluk, Chitradurga District, Karnataka, India

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Abstract

Objectives: To ascertain whether the groundwater in Molakalmur Taluk is suitable for human consumption and it is anticipated that the study will assist regulators and policymakers in taking the proper actions to provide the study area's population with safe domestic water. The study's overall goal is to examine the suitability of groundwater for domestic purposes in accordance to WHO and BIS standards. **Methods:** The current study was carried out to analyze the water quality and spatial distribution of physicochemical parameters of groundwater in study area. A total of 92 groundwater samples were collected in the study region for study during both pre- and post-monsoon monsoon period, ArcGIS 10.1 was used to create a spatial distribution map based on a geographic information system. The concentrations of various ions like Ca^{+2}, K^{+1}, Cl^{-1}, Mg^{+2}, HCO_3^{-1}, Na^{+1}, CO_3^{-2}, and SO_4^{-2} were evaluated as per BIS 3025 (2014) and compared with BIS and WHO standards for drinking purpose. **Findings:** 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. Roughly 68% and 58% of the samples exceeded the permissible level of 500 mg/l for TDS. 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 $CaCl_2$ types, in that order of dominance. The plot shows that alkaline earths correspond to 75% of the samples. **Novelty:** The major ion chemistry of the groundwater in Molakalmur Taluk has never been studied, and there is no perennial river in the research area. The current investigation makes an effort to investigate if water is suitable for domestic purpose. 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 city planners in their efforts to restore and enhance groundwater quality.

Keywords: Groundwater; Physicochemical Parameters; Gibbs Diagram; Pre-Monsoon; Post-Monsoon Water Quality; Geographic Information System; Pipers Chart

1 Introduction

One of the five fundamental components that make up life on earth is classified as water in the mythological writings of India. Water is necessary for maintaining both the environment and life. 97% of the total amount of water on earth is found in the seas and oceans, and because of its high salt content, this water is not appropriate for human consumption or other uses in its natural state, two-thirds of the remaining 3% are covered by glaciers and polar ice caps[1,2]. In naturally occurring streams, rivers, lakes, reservoirs, ponds, and groundwater, only less than 1% of the water is pure enough for human use. Because of the ongoing population growth and accelerated industrialization, there is an enormous increase in the requirement for clean water. The quality of groundwater can be lowered by a variety of activities since it is a complicated resource that is recharged periodically by rainfall. Groundwater is used for about 60% of irrigation[3].

The main ion chemistry of the groundwater in Molakalmur Taluk has never been studied, and there is no perennial river in the study area. Groundwater is an important 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[4,5]. In the studied area, groundwater is the predominant source of agriculture and drinking purpose. The suitability of water for various purpose is determined by the water quality, the soil type, soil's drainage characteristics, the plants' ability to absorb salt and the atmosphere groundwater quality has deteriorated as a result of excessive use of groundwater for various purposes[6].

Water samples were obtained from 92 stations and analyzed for chemical characteristics during pre-monsoon and post-monsoon period and evaluated against BIS & WHO guidelines for domestic and drinking purpose. The groundwater plays a crucial part in classifying and determining water quality. The seven major constituents present in water quality are Ca+2, Mg+2, Cl-1, HCO3-1 Na+1, K+1, and SO4-2, 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[7,8].

1.1 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 represents the study area. Agriculture, horticulture, and animal husbandry are the main sources of employment, employing nearly 80% of the workforce. 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.

1.2 Significance of Study

In the study region, there is no perennial river and the main ion chemistry of Molakalmur Taluk's groundwater has never been investigated before. The present work attempts to study the suitability of water for domestic purpose. The findings of the study will aid in the collecting of crucial data on groundwater quality in Molakalmur Taluk. The findings of the study could also help groundwater managers and urban planners to restore and improve groundwater quality.

2 Methodology

In total, 92 groundwater samples were obtained from the study region for study during the pre-monsoon & post-monsoon period, the location map of study area and flow chart adopted for the study is as shown in Figures 1 and 2 respectively. 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) [9,10] andwith the help of standard instruments. Concentrations are stated in mg/l and then converted to mEq/L for computations except pH, TDS and EC [11] the maximum, minimum and mean concentrations of pre-monsoon and post-monsoon period are shown in Tables 1 and 2 respectively.

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.

$$1.0 < \frac{\text{Measured TDS}}{\text{Calculated TDS}} < 1.2 \tag{1}$$

$$\%\ \text{Difference} = 100 \times \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} < 5\% \tag{2}$$

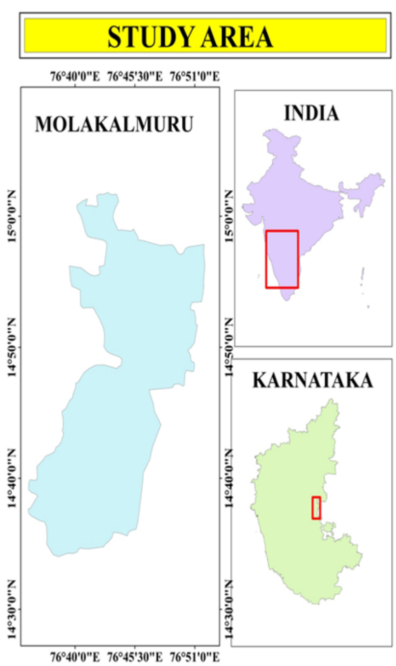

Fig 1. Location map of study area

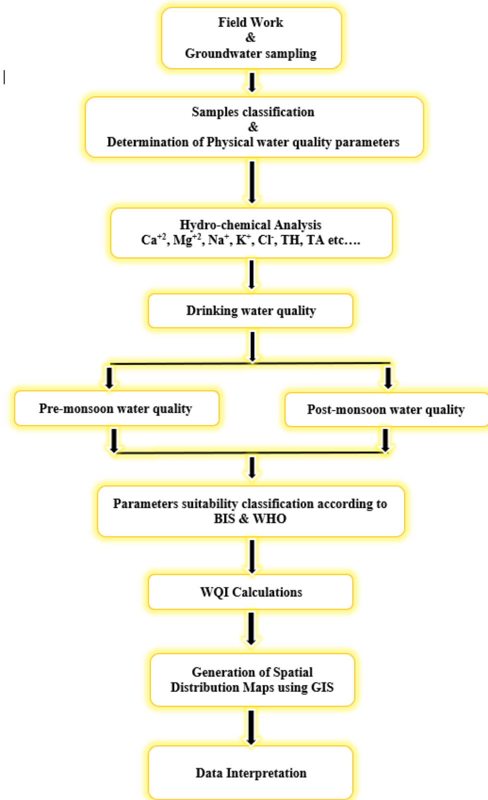

Fig 2. Flow Chart

3 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.

3.1 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 an inorganic salt 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. When TDS exceeds 1000 mg/l, household equipment, boilers, heaters, and water pipelines scale excessively, and the water's severe hardness becomes noticeably disagreeable. Although water with a greater TDS can be consumed when there are no other options or sources of fresh water, water with a TDS of more than 500 mg/l is not generally recommended for domestic purpose[(12)]. 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 spatial distribution and graphical map of TDS is shown in Figure 3 and Figure 5 respectively. 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[(13)]. The substantial TDS concentration of TDS and EC in the studied area is mostly due to decreased rainfall and increased borewell depths. In the current examination, the TDS in sub-surface water ranged from 337 to 2557 mg/l (EC 674 to 5114 μS/cm) and 245–2115 mg/l (mean 490-4230 μS/cm) both during the pre and post monsoon season indicating considerable mineralization in the area. The spatial distribution and graphical map of EC is shown in Figures 4 and 5 respectively.

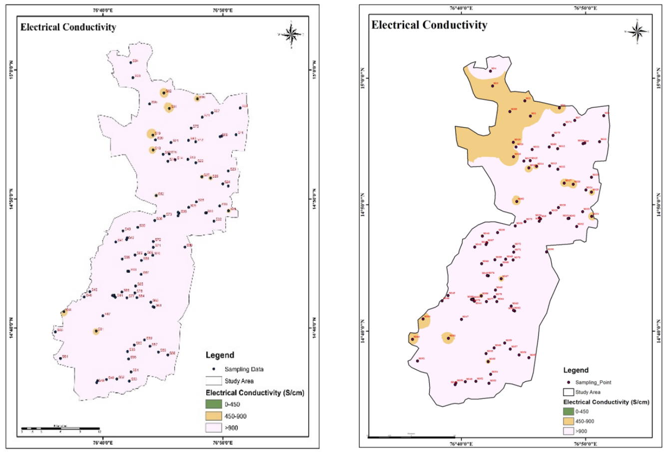

Fig 3. Geographic distribution of TDS during Pre-monsoon and post-monsoon period

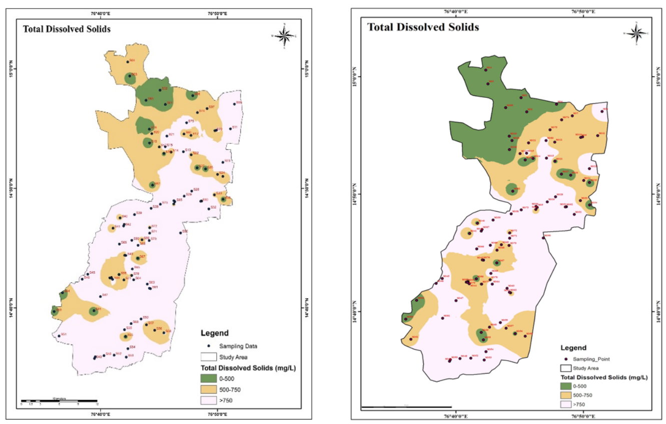

Fig 4. Geographic distribution of EC during Pre-monsoon and Post-monsoon period

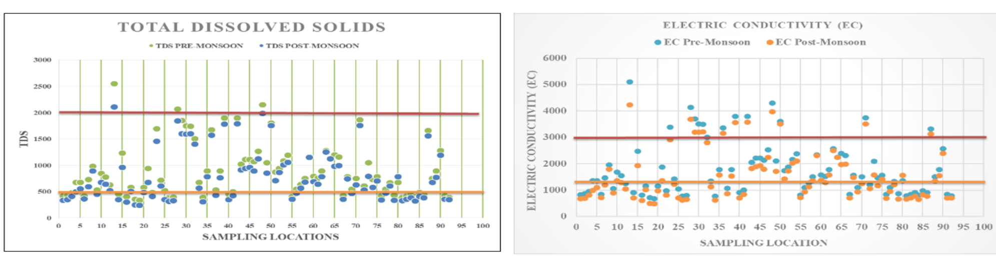

Fig 5. Graphical representation of TDS and EC

3.2 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 [14]. The concentration of hydrogen ions is quantified in terms of pH range and the pH of pure water is nearly neutral. In both Seasons, the pH values in the study area's subsurface water were largely constrained to a range between 6.5 and 8.8. The study area's geographical pH distribution for both types of samples revealed that, according to BIS and WHO standards, the entire region has acceptable groundwater quality. 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 with only few exceeding the limit, showing the alkaline character of groundwater.

3.3 Calcium (Ca2+ Magnesium Mg2+ And Total Hardness TH)

Total hardness is expressed as the sum of multivalent cations[15]. The Ca^{+2} and Mg^{+2} dissolves naturally when the water moves through calcium and magnesium bearing minerals present within the ground[16]. Pre-monsoon and post-monsoon total hardness in the research area were determined to be 136 to 836 mg/l and 125 to 760 mg/l, respectively.

Ca^{2+} in residential water is allowed to be no more than 200 mg/l. Pre- and post-monsoon seasons saw calcium levels in area fluctuate between 62 to 686 mg/l (mean 265 mg/l) and 76 to 636 mg/l (mean 293 mg/l), respectively. The fluctuations in Ca^{2+} content in the study area revealed that during the pre-monsoon and post-monsoon seasons, 59% and 51% of the water are above the allowed limit. Geographical distribution of calcium for both time periods revealed that areas with greater contents were dispersed throughout the majority of the study region.

Mg^{+2} is a moderately toxic component and typically has a lower value in aqua than Ca^{+2}, According to BIS, the permissible and tolerated limit of magnesium in household water is between 30 and 100 mg/l. For individuals, the maximum Mg^{+2} consumption shouldn't exceed 350 mg/l[17]. Magnesium levels in the study area were recorded at 44 to 268 mg/l and 87.55 to 258 mg/l, respectively, during the post- and pre-monsoon periods, The change in magnesium concentration in the research area revealed that, during the pre-monsoon and post-monsoon periods, roughly 27% and 24% of water exceeds the permitted level of BIS respectively.

In most areas of the investigation region as showed that larger quantities of Mg^{+2} were distributed during the pre-monsoon season, but not during the post-monsoon season. The samples' Mg^{+2} concentrations were higher than permitted levels, which could be attributed to the weathering of carbonates, silicates, salts from soil, significant human intervention, and semiarid environment. The spatial distribution of TH, Ca^{+2}, Mg^{+2} is shown in Figures 6, 7 and 8, respectively and graphical representation of Mg^{+2} and Ca^{+2} hardness is represented in Figure 9.

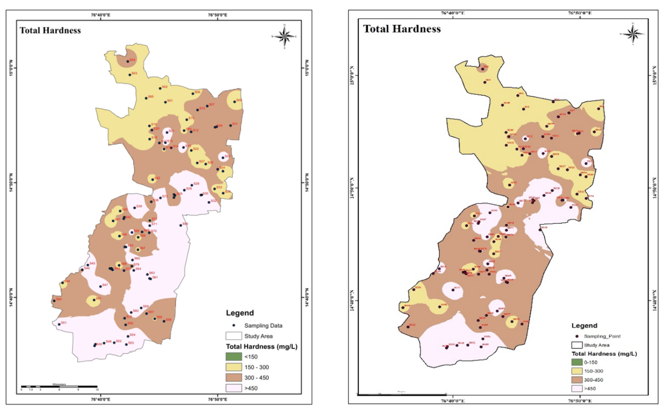

Fig 6. Geographic distribution of TDS during Pre-monsoon and post-monsoon period

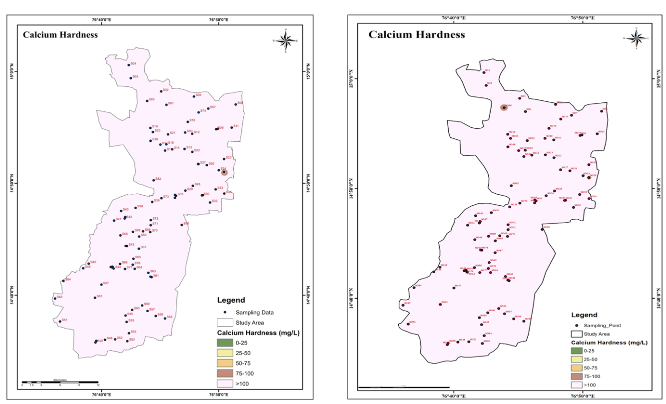

Fig 7. Geographic distribution of Ca^{+2} during Pre-monsoon and post-monsoon period

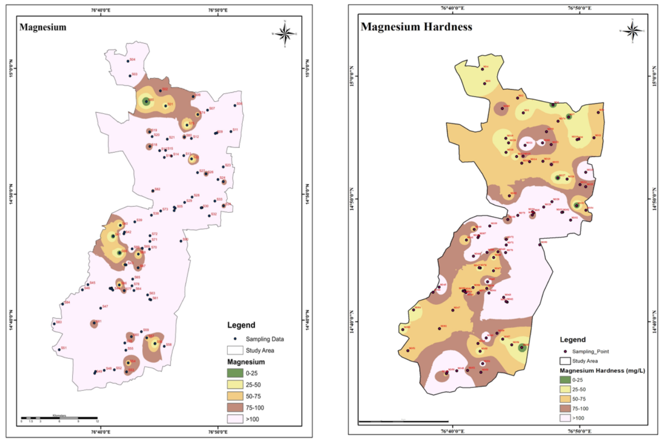

Fig 8. Geographic distribution of Mg^{+2} during Pre-monsoon and post-monsoon period

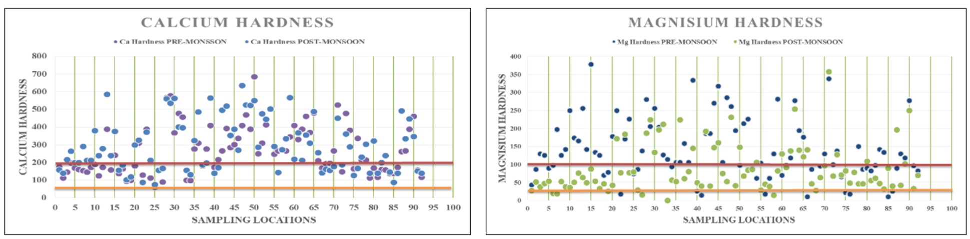

Fig 9. Graphical representation of TDS and EC

3.4 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, Although Na^+ is generally accepted to be beneficial to human life, the WHO has not set any minimum or maximum daily requirements, However, at concentrations higher than 200 mg/l, Na^+ may influence the taste of household water[18]. Sodium 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[18]. 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. Na^+ levels in the study area were recorded between 44 to 268 mg/l and 87.55 to 258 mg/l, respectively, during the post- and pre-monsoon periods. The spatial and graphical distribution of Na^+ is shown in Figures 10 and 11.

K^+ is a cofactor for numerous enzymes and is necessary for the synthesis of proteins, insulin secretion, and glucose metabolism. Although the potassium in residential water is often low and does not pose a health risk, it is nonetheless necessary[19]. Neither the WHO nor the BIS have set any limitations for domestic water potassium levels. K^+ levels in the study area were recorded between 8 to 154 mg/l and 2 to 114 mg/l, respectively, during the post- and pre-monsoon periods. There is no minimum daily need set by the WHO or BIS because it is commonly agreed that Na^+ is consumed in the form of NaCl in everyday life. The graphical and spatial distribution of K^+ is shown in Figures 11 and 12.

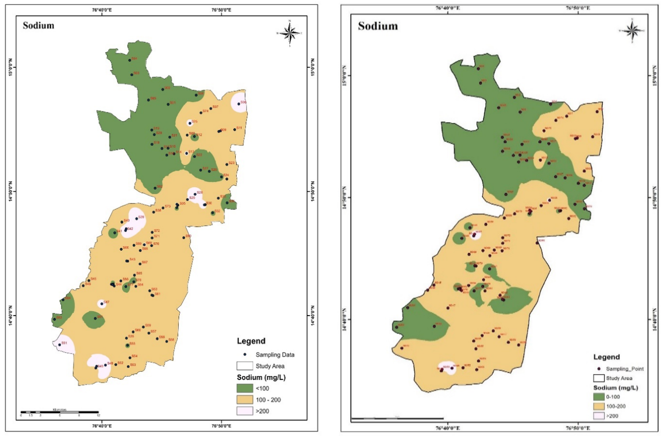

Fig 10. Geographic distribution of Na^{+} during Pre-monsoon and post-monsoon period

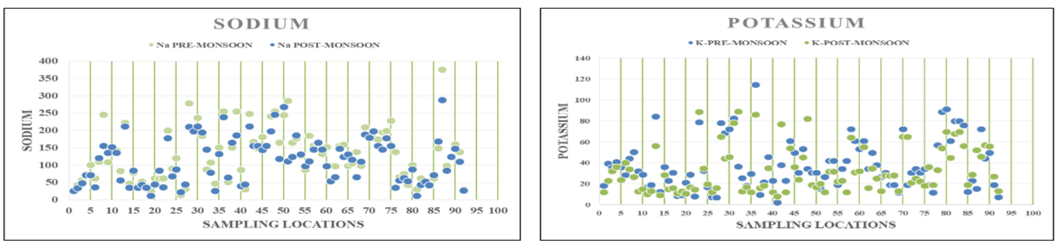

Fig 11. Graphical representation of Na^{+} and K^{+}

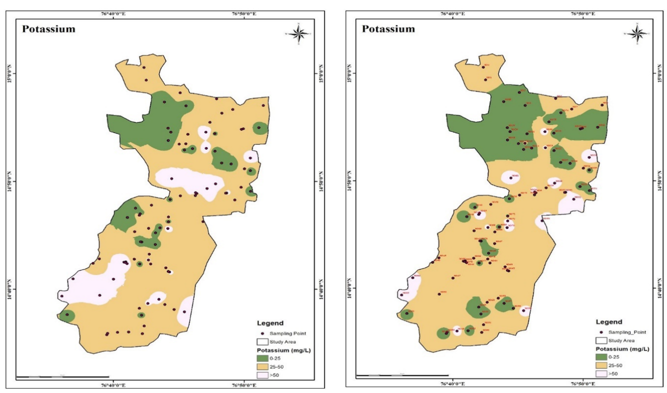

Fig 12. Geographic distribution of K^{+} during Pre-monsoon and post-monsoon period

3.5 Bicarbonate (HCO3-1, Sulphate (SO4-2, 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 [20]. HCO_3^{-1} has no limits specified by BIS or WHO, however total alkalinity does have limits between 300-600 mg/l. Total Alkalinity levels in the study area were recorded between 76 to 278 mg/l and 108 to 312 mg/l, respectively, during the pre-monsoon and post-monsoon periods. The spatial and graphical distribution of HCO_3^{-1} is shown in Figures 13 and 15 , Sulphate is disintegrated and leached from gypsum, iron sulphides, and other sulphur-bearing materials, The dissoluble salts of Mg^{2+}, Na^{+}, and Ca^{2+} are the most common form in which SO_2 is present in subsurface water [21]. The recommended value as per BIS is 200–400 mg/l. SO_2^{-4} levels in the study area were recorded between 17 to 115 mg/l and 23 to 164 mg/l, respectively, during the pre-monsoon and post-monsoon periods. The spatial and graphical distribution of SO_4^{-2} is shown in Figures 14 and 15.

Cl^- can come from a variety of sources, including soil weathering, salt-bearing rock structures, salt spray deposits, and salt used for road de-icing and seawater intrusion, etc. It produces a salty taste within the range of 250-500 mg/l, however as per BIS and WHO the permissible limit for chloride is between 250-1000 mg/l[22]. Cl^- levels in the study area were recorded between 15 to 388 mg/l and 10 to 260 mg/l, respectively, during the pre-monsoon and post-monsoon periods. The spatial and graphical distribution of Cl^{-1} is shown in Figures 16 and 17.

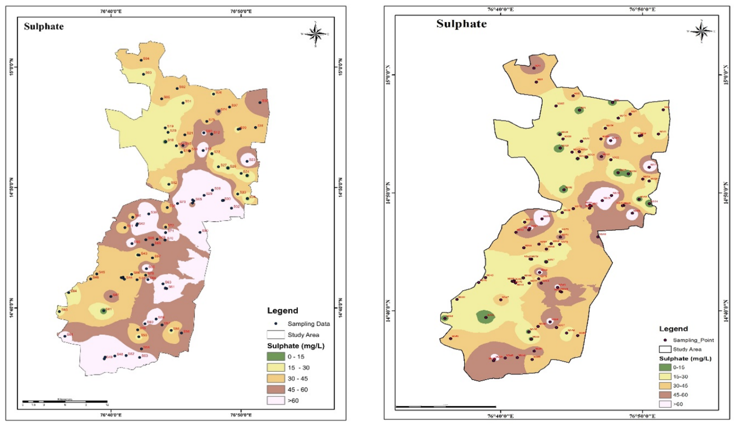

Fig 13. Geographic distribution of HCO_3^{-1} during Pre-monsoon and post-monsoon period

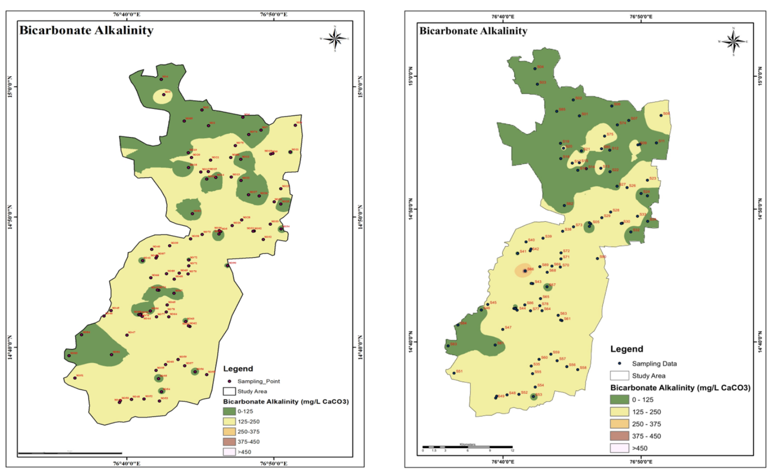

Fig 14. Geographic distribution of SO_4^{-2} during Pre-monsoon and post-monsoon period

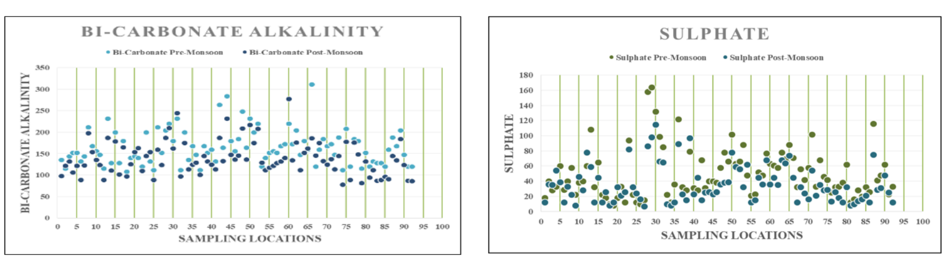

Fig 15. Graphical representation of HCO_3^{-1} and Sulphate SO_4^{-2}

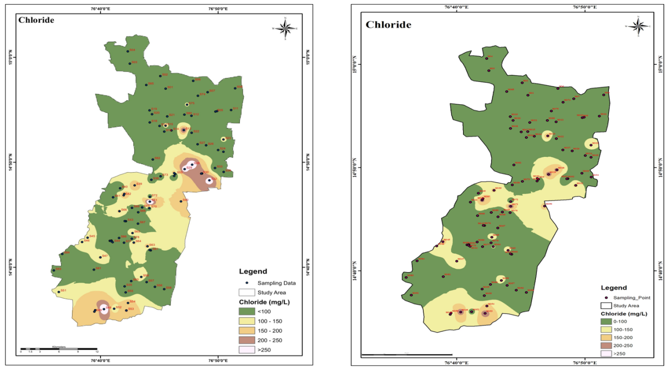

Fig 16. Geographic distribution of Cl^{-1} during Pre-monsoon and post-monsoon period

3.6 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 [23]. The recommended value as per WHO and BIS is 1-1.5 mg/l. in very few borewell with depths more than 1500 ft. the occurrence of fluoride was dominant i.e maximum value of fluoride in the study area was found to be 5 mg/l in both pre-monsoon and post-monsoon periods.

Table 1. Minimum, Maximum, and Mean ion concentrations of area's drinking water in relation to WHO and BIS standards for Pre-monsoon period

Parameters	Standards for drinking water		Observed value			
	BIS (2015)	WHO (2017)	Min	Max	Mean	SD (σ)
pH	6.5–8.5	7-8	6.88	8.8	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	5	0.15	0.57
Fe^{+2} (mg/l)	0.3-1.0	0.3	0	0	0	0

Table 2. Minimum, Maximum, and Mean ion concentrations of area's drinking water in relation to WHO and BIS standards for post-monsoon period

Parameters	Standards for drinking water		Observed value			
	BIS (2015)	WHO (2017)	Min	Max	Mean	SD (σ)
pH	6.5–8.5	7-8	6.78	8.56	6.87	0.47
TDS (mg/l)	500–2000	600–1000	245.00	2115.00	467.78	777.97

Continued on next page

Table 2 continued

EC (μS/cm)	750–3000		490.00	4230.00	1555.93	935.55
Alkalinity (mg/l)	200–600	—	72.00	256.00	139.28	41.65
TH as $CaCO_3$ (mg/l)	200–600	200	125	760	381.92	189.46
Ca^{2+} (mg/l)	75–200	100–300	76	636	293.28	145.90
Mg^{2+} (mg/l)	30–100	—	14.00	258.00	87.95	62.28
Na^{+} (mg/l)	—	50–200	12.00	288.00	113.86	65.11
K^{+} (mg/l)	—	—	8.00	89.00	32.88	21.51
HCO_3^{-} (mg/l)	300–600	—	72.00	256.00	139.28	41.65
SO_2^{-} (mg/l)	200–400	250	7.00	115.00	36.15	24.65
Cl^{-} (mg/l)	250–1000	250	10.00	260.00	80.90	65.07
F^{-} (mg/l)	1–1.5	1.5	0	5	0.17	0.43
Fe^{+2} (mg/l)	0.3-1.0	0.3	0	0	0	0

3.7 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[24,25]. Tables 3 and 4, contain the overall statistical analysis and correlation matrix of the parameters affecting groundwater quality for both pre-monsoon and post-monsoon periods. MS Excel 2019 was used to generate and analyses 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 in both pre-monsoon and post-monsoon period.

3.8 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 using pre-monsoon data. 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 18.

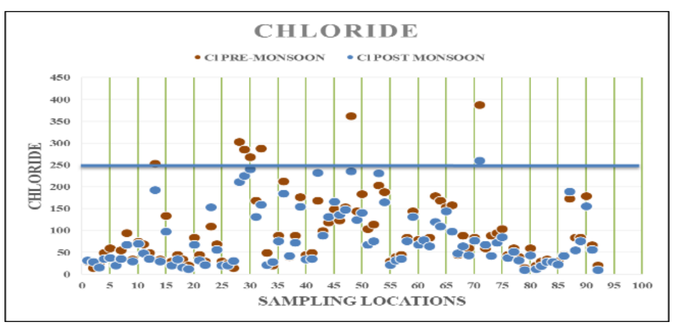

Fig 17. Graphical representation of Cl^{-1}

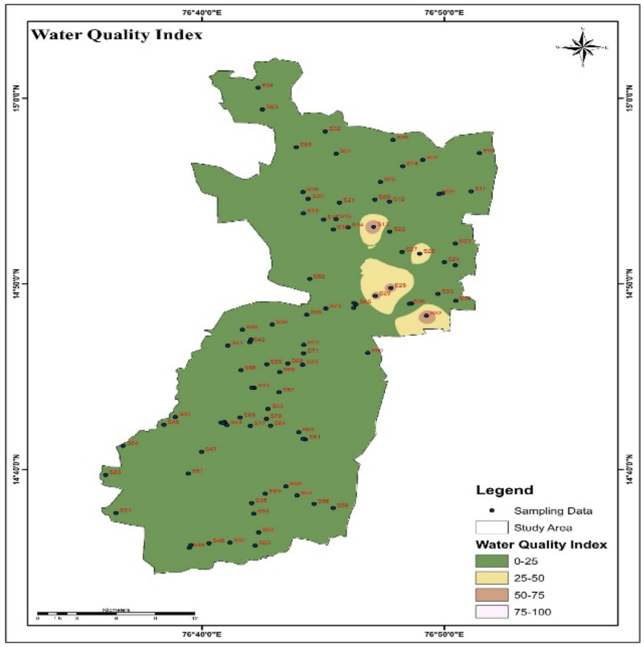

Fig 18. Spatial distribution of WQI

Table 3. Major cations and anion correlation coefficient matrix (R2) for the studied area during Pre-monsoon period

	pH	**EC**	**TDS**	**TH**	**Ca^{2+}**	**Mg^{2+}**	**F^-**	**Cl^-**	**TA**	**SO_4^{-2}**	**Na^+**	**HCO_3^{-1}**
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^{2+}	0.638	0.768	0.768	0.914	1.000							
Mg^{2+}	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			
SO_4^{-2}	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^{-1}	0.358	0.504	0.504	0.40	0.434	0.193	0.074	0.441	0.934	0.437	0.487	1.000

3.9 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 [24]. 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 19, 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.

Table 4. Major cations and anion correlation coefficient matrix (R2) for the studied area during post-monsoon period

	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	F^-	Cl^-	TA	SO_4^{-2}	Na^+	HCO_3^{-1}
pH	1.000											
EC	0.770	1.000										
TDS	0.770	1.000	1.000									
TH	0.719	0.909	0.909	1.000								
Ca^{2+}	0.687	0.836	0.836	0.954	1.000							
Mg^{2+}	0.563	0.766	0.766	0.761	0.538	1.000						
F^-	0.506	0.444	0.444	0.333	0.320	0.258	1.000					
Cl^-	0.709	0.913	0.913	0.886	0.813	0.737	0.373	1.000				
TA	0.586	0.731	0.731	0.647	0.592	0.545	0.250	0.657	1.000			
SO_4^{-2}	0.678	0.795	0.795	0.789	0.731	0.663	0.361	0.731	0.501	1.000		
Na^+	0.541	0.816	0.816	0.743	0.703	0.584	0.232	0.791	0.597	0.605	1.000	
HCO_3^{-1}	0.586	0.731	0.731	0.647	0.592	0.545	0.250	0.657	1.000	0.501	0.597	1.000

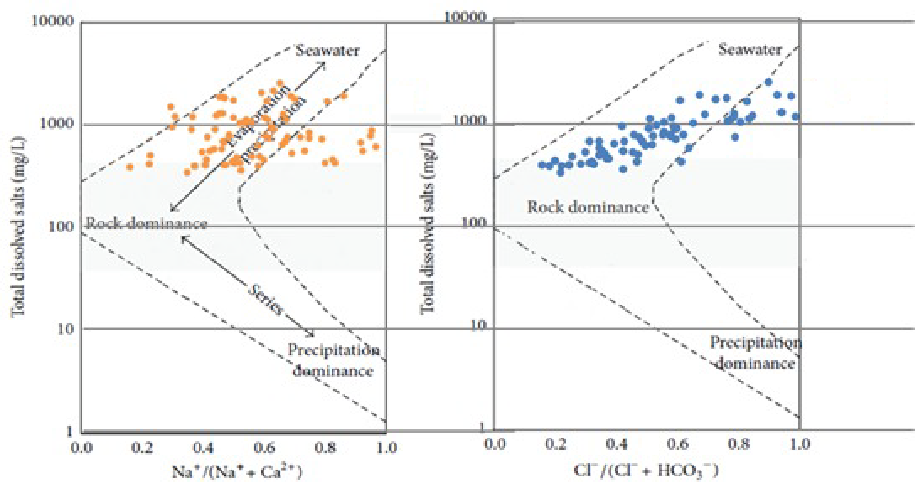

Fig 19. Gibbs Diagram

3.10 Piper-Trilinear Plot

Tables 1 and 2 shows the max and min concentrations of the main ions that were found in the groundwater from the research area during both the monsoons. 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 categorization 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 20 of Piper trilinear diagram illustrates a hydrogeochemical facies of both the seasons 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.

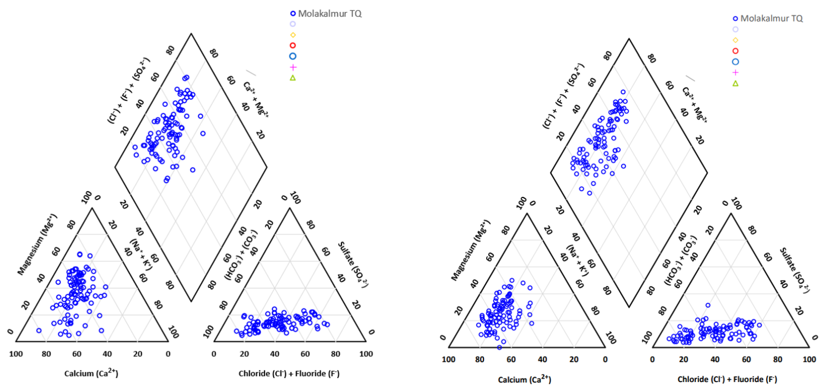

Fig 20. Piper's chart for Molakalmur Taluk both during pre-monsoon and post-monsoon period

4 Conclusion

The current study investigated the groundwater for its potability in Molakalmur Taluk. After collecting water samples from 92 stations during the pre- and post-monsoon seasons and analyzing them for chemical characteristics, a spatial distribution map was produced using ArcGIS 10.1. All of the water samples in the basic zone were with pH values ranging from 7.0 to 8.8. Roughly 68% and 58% of the samples exceeded the permissible level of 500 mg/l for TDS. Nearly 35% and 22% of the samples had total alkalinity (TA) values that above the maximum desirable limit of 200 mg/l, but these values were still under the maximum tolerated limit of 600 mg/l with the exception of nearly 12% and 15% of the samples during pre- and post-monsoon period. 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 $CaCl_2$ 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 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.The majority of borewells are privately held by farmers, so it is necessary to advise all private bore well users to utilize proper groundwater recharge techniques, limit their groundwater usage, take precautions to prevent groundwater pollution, and be aware of the significance of water quality. It is anticipated that the study will assist regulators and policymakers in taking the proper actions to provide the study area's population with safe domestic water.

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