INVESTIGATION OF ROCK-WATER INTERACTION IN THATTAPARAI REGION OF THOOTHUKUDI DISTRICT USING GEOPHYSICAL AND GEOCHEMICAL TECHNIQUES

Abstract

The purpose of this study is to discuss the ideas and procedures underlying the Azimuthal square array electrical resistivity approach for the aquifer investigation in the Thattaparai region of Thoothukudi, Tamil Nadu. The physical properties of rocks and hydrochemical variations of groundwater were used to study rock-water interaction. The study region was covered with black and red soil, gravel, kankar, and hard rock composed of weathered gneiss and charnockite. Nine profiles were surveyed for electrical resistivity (DC) using an azimuthal square array. The surveys were conducted with the aid of the CRM-500 Aquameter, electrodes, and wire spools with accessories. The water-bearing zone occurs at depths of 10m, 30m, and 50m, with an apparent resistivity range of 100–120 Ohm.m in the hard rock region, as determined by the electrical resistivity research. This is an effective method for agricultural aquifer exploration. The hydrochemical approach is used to determine the interaction between rock and water, and the geochemical concentration of ions in groundwater has been determined using different factors. The chemical composition of groundwater reflects the interaction between rock and water and chemical processes. Therefore, groundwater geochemistry assists in determining the rock–water interaction and chemical processes of the various water types present.

Keywords: Rock-Water Interaction, Azimuthal Square array, Geochemistry, Aquifer.

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I. INTRODUCTION

Groundwater, which is found in aquifers and other underground water sources, is an essential part of the hydrological system. Both urban and rural areas rely heavily on groundwater for their drinking and household water needs. Several factors, such as the chemistry of the water being recharged, the distance that groundwater flows within the aquifer, the amount of time that it spends there, the number of soluble species present in the rock that it dissolves and mixes with, and the effects of human activity on the system, all contribute to the overall quality of the groundwater that is ultimately encountered (Balasubramanian, A., 2002). Chloride, iron, manganese, sodium, etc. are all naturally occurring compounds that, at certain amounts, do not pose a threat to public health but can reduce the desirability of drinking water. Subsurface chemical processes like weathering, dissolution, precipitation and associated phenomena are prevalent (Krishna Kumar, S., et al., 2014). Understanding the groundwater's nature in various aquifers throughout location and time has been shown to be a useful tool in resolving a variety of geochemical issues (Chebotarev, I. I, 1955; Hem, J. D. 1959; Back et al 1965; Gibbs, R. J. 1970; Srinivasamoorthy, 2008 and Dehnavi, A. G., et al, 2011).

The approach known as the Azimuthal Square Array Resistivity Survey involves rotating the entire electrode array over an angle of 180 degrees at predetermined intervals. HABBERJAM (1967) came up with the idea of employing a square array as a solution to the issue of inadequate sensitivity and orientation-dependent resistivity values that were produced by the commonly used collinear array (Wenner and Schlumberger). The identification of fractures in rocks beneath the subsurface can be accomplished with this approach with a high level of accuracy (Ramanujam, N., et al, 2006, Antony Ravindran, A. 2012, Obiadi, I. I., et al, 2013). Methods of Azimuthal Square Array Resistivity and groundwater geochemistry were utilized to study the interaction that occurs between rock and water.

II. STUDY AREA

The area chosen for study is the Thattaparai region of Thoothukudi district, situated on the North-Western side of Thoothukudi District, Tamil Nadu, India is shown in Fig.1. Black cotton soil dominates the western part of the district, although red soil can be found in a few outcroppings on higher land. Some of the district's streams have their headwaters in the region's hills and eventually empty into the sea after a distance of 10-20 kms. The district's main rivers include the Vaipar, the Thamirabarani, and the Karamaniar. The districts average annual rainfall ranges from roughly 570 to 740 mm, reflecting the region's hot, tropical environment. Alluvium from the Quaternary Period, Tertiary sediments and Teri Sands, eroded and cracked Pink Granites, Charnockite, and Gneisses are the main water-bearing rocks.

III. MATERIALS AND METHODS

To investigate the rock-water interaction in the area under study, a surface geophysical survey, as well as the collection of water samples, were carried out. Methods adopted include

1. Azimuthal Square Array Resistivity
2. Geochemistry.

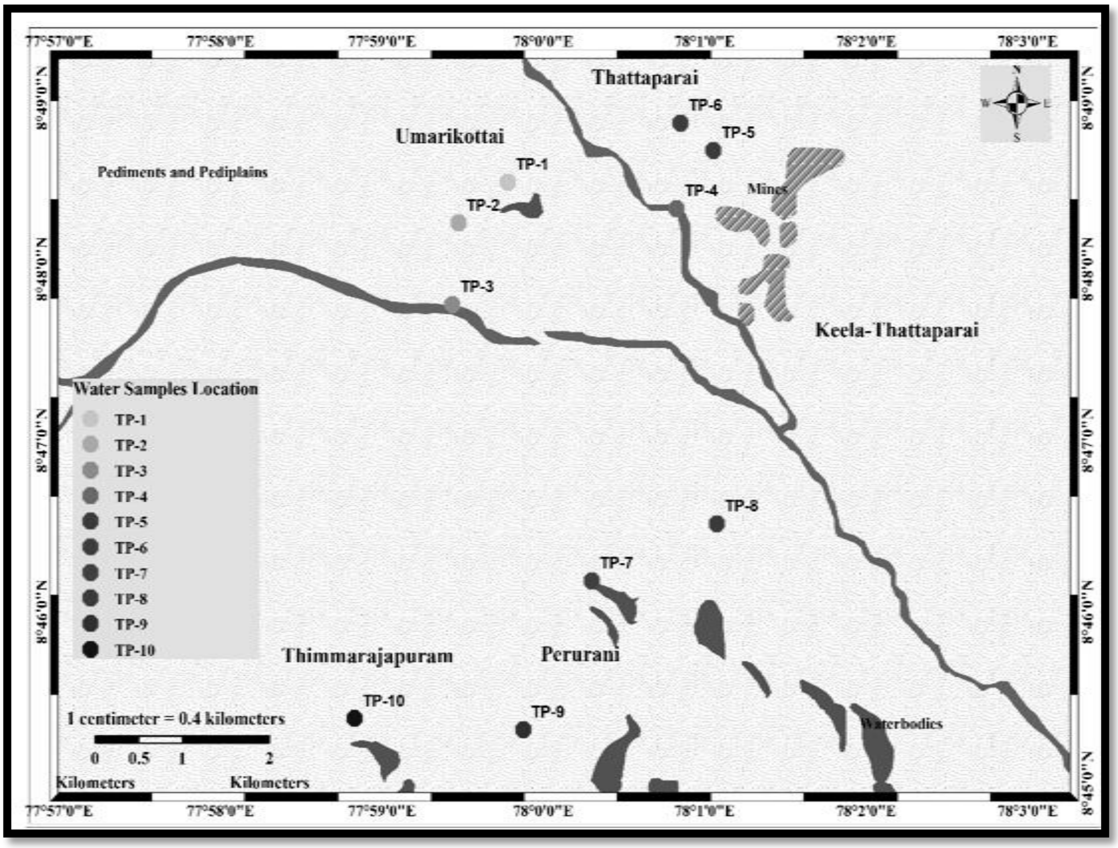


Figure 1: Study area Map Displaying Geomorphology and Water sample location.

1. **Azimuthal square array resistivity:** By using an electrical geophysical approach, we may create a qualitative map of the fracture orientations beneath precise locations. The apparent resistivity changes with azimuth were measured during resistivity surveys using a square-array electrode configuration. The relationship between the applied current and the potential difference measured between a set of electrodes is known as the apparent resistivity, and it is defined as the resistivity of an electrically homogenous and isotropic half-space. After rotating an electrode array along its central axis, its apparent resistivity is measured in a multitude of orientations (Habberjam 1975). The square-array direct current resistivity sounding technique involves inserting four electrodes into the ground in a square formation. Three measurements were taken for each square by Lane et al. (1995): two perpendiculars (α and β) to determine apparent resistivity(ρa), and one diagonal (γ)) to verify the measurements (i.e., in a homogeneous isotropic material, $\rho a\gamma = 0$, and in a homogeneous anisotropic material, ($\rho a\gamma = \rho a\alpha - \rho a\beta$). Habberjam and Watkins (1967) provided the formula for determining apparent resistivity:

$$\rho a = K(\Delta V/I),$$

Where, $K = 2\pi a/(2 - \sqrt{2})$, where "a" is the length of side of a square array. The measurement location is determined using the center of the square. Azimuthal apparent resistivity measurements are obtained by rotating the square array about its central axis (Habberjam and Watkins 1967). Each electrode spacing is increased by a factor of $a\sqrt{2}$, in every direction of the compass, where a is the length of the first square array reading. The data was gathered with the use of an Aquameter CRM-500 Auto-C, an electrode rod, an external battery, and a spool of wire is displayed in Fig.2.

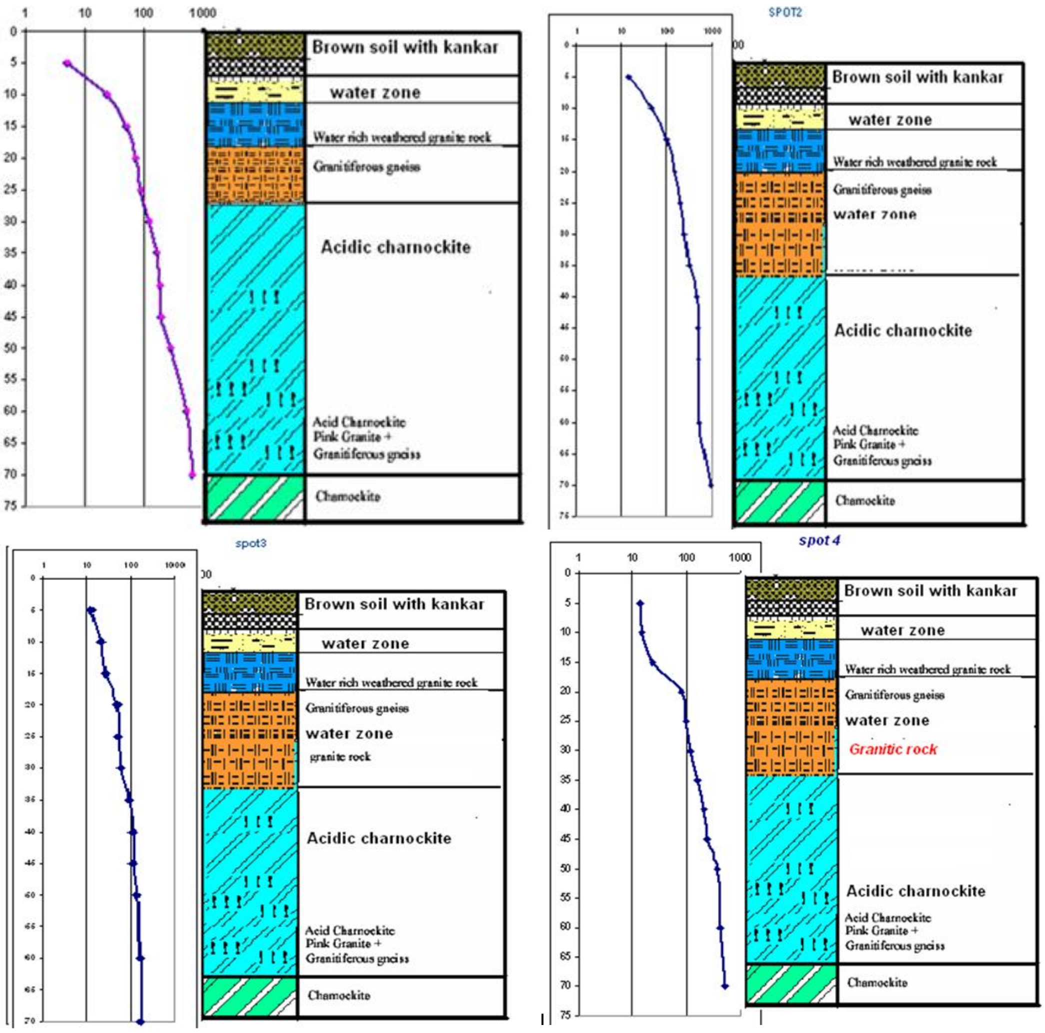
Figure 2: Resistivity Data Collection on the Field.

2. **Geochemistry:** The geochemical analysis is performed in the study region to determine the water quality and rock-water interaction of the study area. In the study region, 10 water samples were taken from Open wells and Bore wells. The gathered samples were analyzed in the research laboratory at V.O.C. College. Based on the results of the geochemical analysis, Wilcox plots and Piper Diagrams were created. The Wilcox plot compares salt concentration to electrical conductivity (EC), as a high concentration of either is detrimental to irrigation. A Piper diagram is a graphical representation of water sample chemistry. The Piper diagram can be used to compare the ionic composition of a

series of water samples, but it is not suited for spatial comparisons. Using Aquachem software, these plots were created.

IV. RESULT AND DISCUSSION

1. **Azimuthal square array resistivity:** The N-S orientation is the default for a square array. In each of the three experimental sites, alpha, beta, and gamma azimuthal square array soundings were conducted to quantify apparent resistivity from perpendicular sides. Using a spacing range of 10–170 m at intervals of 3.5 m and 10 m, we were able to gather apparent resistivity data in 20 equiangular azimuthal grids for all possible orientations. The identical steps are carried out once again for the alpha', beta', and gamma' arrangements. Thus, measurements of apparent resistivity are taken at each of the three experimental sites, with a 10 m spacing between measurements.



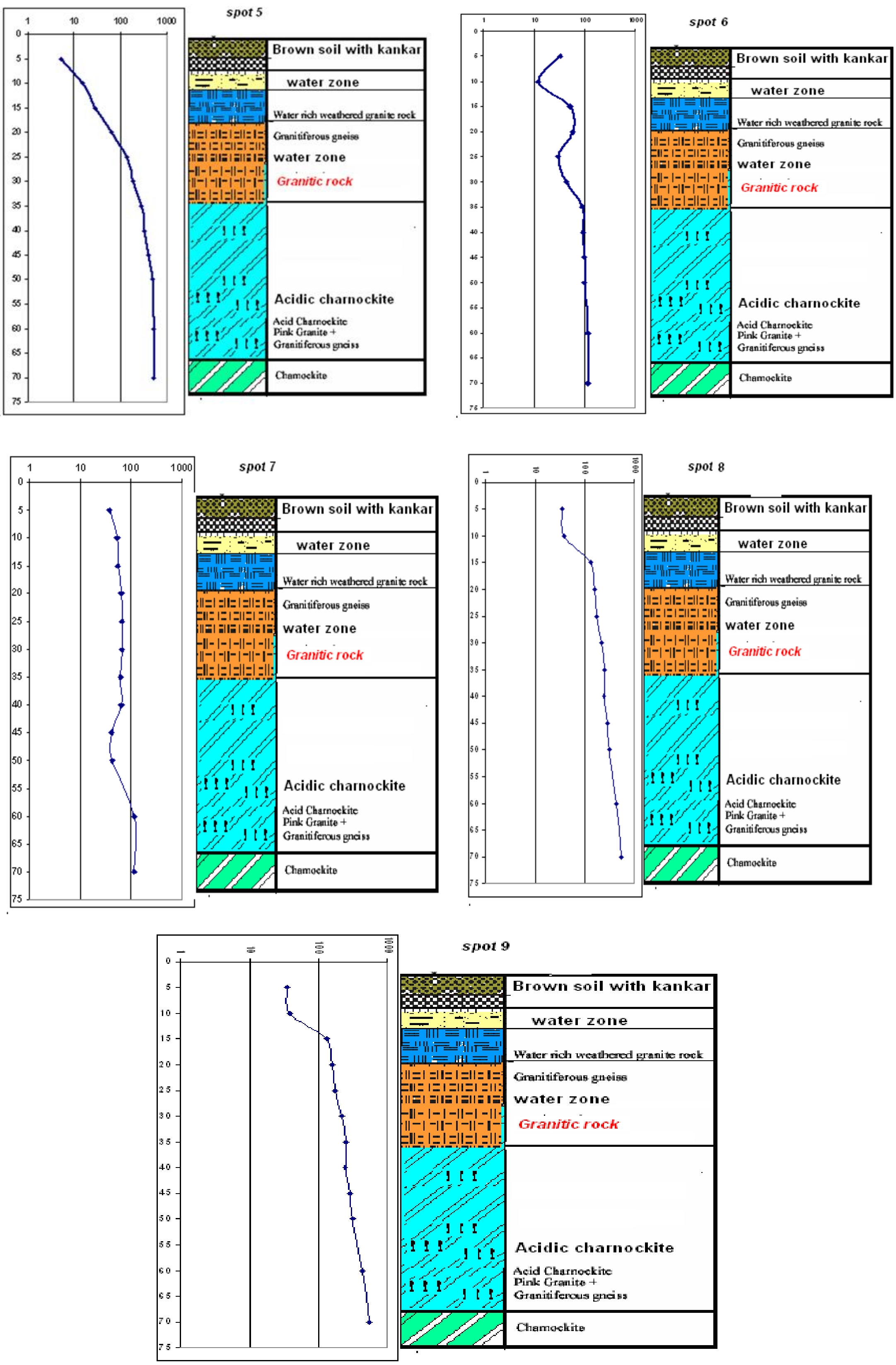


Figure 3: Apparent Resistivity VS Depth plot and Lithology.

The apparent resistivity and the 'A' spacing are plotted to produce the depth-sounding curve. The 'A' spacing was plotted against the apparent resistivity values that were acquired from the square array resistivity zones. The highest resistance that can be found in this region is 1200-ohm m. At a depth of 30 meters, all geological profiles that contained groundwater had a resistivity reading in the range of 120 Ohm.m. The presence of Charnockite rock in the research area can be deduced from its high resistivity of 1196 Ohm.m which is displayed in Fig.3. The contour charting will provide more information about the apparent variations in resistivity in the area under study. The use of geochemical modelling to conduct an evaluation of the groundwater quality at the Thattaparai location enables the provision of potable water and water suitable for agricultural use to the local farming community. The distribution of various chemical constituents at the lake site can be used as a variation in the alluvium, concrete, and gneiss rock.

2. **Geochemistry:** The pH levels of different samples of groundwater range from 7.2 to 8, which can be described as being slightly alkaline. The electrical conductivity (EC) of the groundwater that was obtained from the research site ranged from 290 to 890 μS/cm. The TDS in the sample can range anywhere from 177 to 5603 parts per million. A small number of the groundwater samples located along the calcrete sample contain a high quantity of Cl. The content of SO4 is quite low, and it varies anywhere from 37 to 2050 mg/l. This region makes use of groundwater for a variety of purposes, including irrigation, drinking water production, and domestic and industrial use. As a result, establishing the appropriateness of the water for consumption and usage in irrigation is an absolute necessity before putting it to those uses. The results of the analyses were compared to those of the WHO (1984). The findings of the hydrochemical analysis indicate that the Groundwater in the area under study can be safely used for drinking (samples 1,2 and 9) and other household activities. According to the USSL classification, eight of the samples fit into categories C1S1 and C2S1, which respectively suggest safe and marginal types. In addition to being useful for irrigation, the groundwater has low alkalinity and a risk ranging from mild to high salinity. The parameters and values obtained is displayed in Table.1.

   Ions of sodium, calcium, and hydrogen carbonate predominate in the groundwater beneath the research region, which encompasses a portion of the Thattaparai. The area's groundwater that comes from the eroded rocks has a comparatively high percentage of sodium, whereas the groundwater that comes from the alluvial formations has a high concentration of calcium.

Table 1: Water Samples Collected With Parameter Values.

Sample ID	Station ID	Latitude	Longitude	Elevation	pH	Temp	Cond	TDS	Na	K	Mg	Ca	Cl	SO4	HCO3	CO3
1	TP-1	8.80841	77.9963	23	7.3	27.8	290	177	41	13	29	22	28	37	171	12
2	TP-2	8.80444	77.9912	23	7.5	28.2	890	4797	97	30	266	267	1064	2053	305	24
3	TP-3	8.79651	77.9906	43	7.2	27.9	651	543	85	29	40	43	71	171	305	NILL
4	TP-4	8.80584	78.0137	20	7.9	29	862	4232	93	20	202	179	922	1856	305	24
5	TP-5	8.8115	78.0176	21	7.5	27	648	5603	90	10	343	400	2482	1073	390	12
6	TP-6	8.81416	78.0141	21	7.8	25	236	3953	74	10	200	366	1276	1560	268	24
7	TP-7	8.76965	78.005	24	7.6	29.2	279	1440	134	29	51	118	85	754	342	12
8	TP-8	8.77519	78.0179	16	8	29.1	154	1702	220	14	86	168	284	854	232	24
9	TP-9	8.75514	77.9979	37	7.6	29.7	378	939	98	20	60	173	85	525	256	NILL
10	TP-10	8.75624	77.9805	31	7.7	28	255	1206	68	18	53	116	98	160	246	10

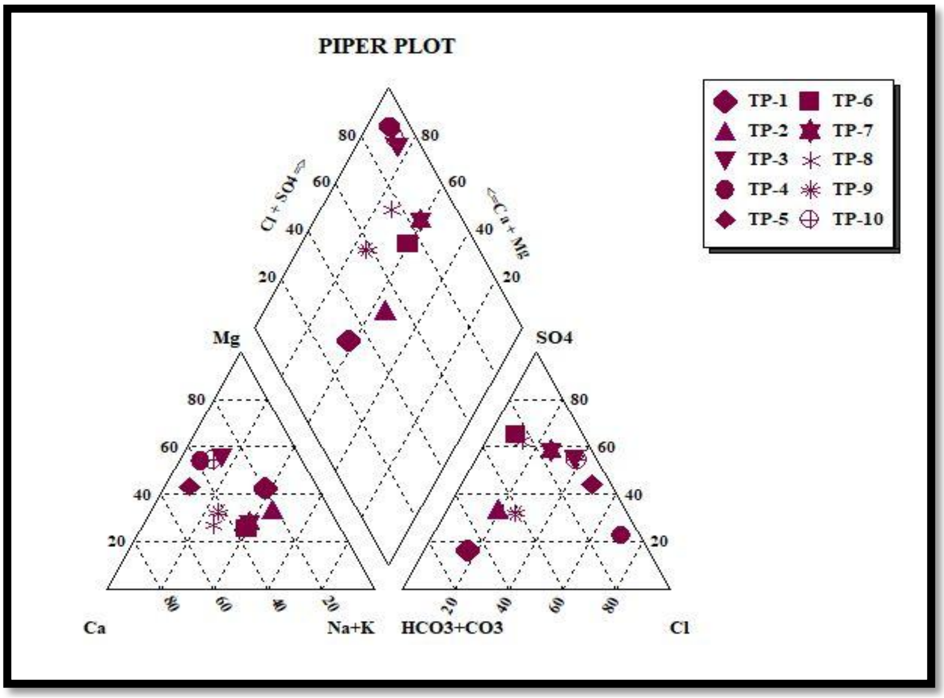


Figure 4: Piper Plot

The chemistry of the groundwater in this region is controlled by a process called cation exchange as well as silicate weathering. Along the journey that groundwater takes, geochemical reaction modelling predicts that ion exchange reactions will result in the release of calcium and the absorption of magnesium and sodium. The dissolution of minerals and their subsequent precipitation are two additional significant processes. The majority of the region's groundwater is adequate for domestic use, although there are a few spots where it is harmful to drink due to excessive concentrations of electrical conductivity, pH, and other dissolved ions.

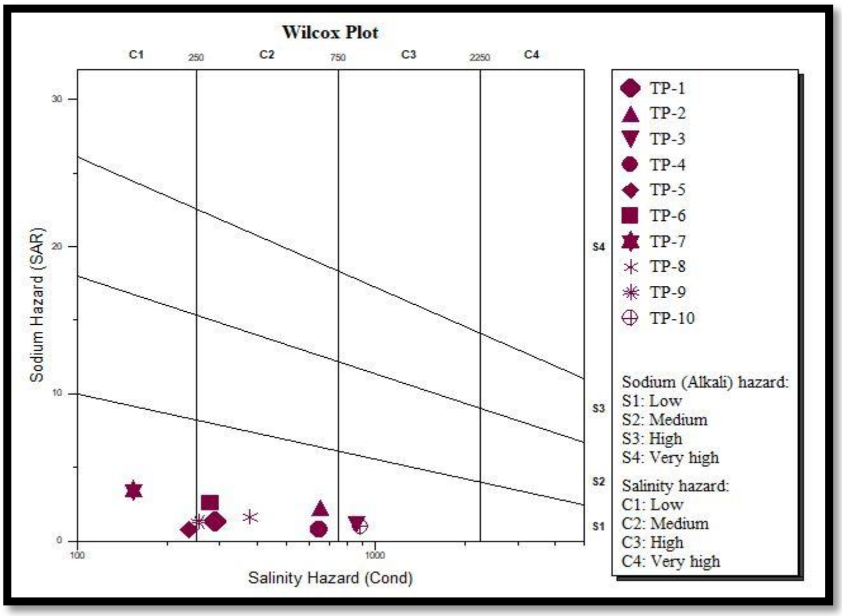


Figure 5: Wilcox Plot.

V. CONCLUSION

To learn more about the subsurface fracture zone and the groundwater level at Thattaparai Village, Thoothukudi, studies utilized the Azimuthal Square Array (DC) Resistivity method. Anisotropic distribution is caused by the fact that both the horizontal fracture/permeability and the contribution from vertical or steep fracture sets change with azimuth. It has been determined that the water table in the Study area is at a depth of between 10 and 30 and 70 metres. At depths between 10 and 30 metres, both shallow and deep aquifers have been discovered. Research area borewell logging was compared to electrical resistivity lithographs. This survey found that Azimuthal square array electrical resistivity was an effective technique for determining the physical parameters of rock and aquifer zone in the hard rock environment.

Table 2: Water Type of the Studyare

Sample no.	Water type
1	Mg-Ca-HCO3
2	Na-Mg-SO4-Cl
3	Na-Mg-Ca-HCO3-SO4
4	Na-Mg -SO4-Cl
5	Na-Mg-Ca-Cl-SO4
6	Na-Ca-Mg-Cl-SO4
7	Ca-Na-Mg-SO4-HCO3
8	Na-Ca-Mg-SO4-Cl
9	Ca-Mg-Na-SO4-HCO3
10	Na-Mg-Ca-HCO3-SO4

Depending on its source, its journey, and the lithology of its host, groundwater can acquire new chemical components and transform into various forms of water. Ten samples were analysed, and their water compositions were determined to vary as follows: Mg-Ca-HCO3, Na-Mg-SO4-Cl, Na-Mg-Ca-HCO3-SO4, Na-Mg-SO4-Cl, Na-Mg-Cl-SO4, Na-Ca-Mg-Cl-SO4, Na-Mg-Cl-SO4, Ca-Na-Mg-SO4-Cl, Ca-Mg-Na-SO4-HCO3. There were four major water evolutions, and they are categorized as Mg-Ca-HCO3, Na-Mg-SO4-Cl, Na-Mg-Cl-SO4, Na-Ca-Mg-Cl-SO4, and Ca-Na-Mg-SO4-HCO3 is shown in **Table II**. Different congruent dissolution of carbonate lithology, silicate, and multi-complex systems of Khondalite and granulitic topography resulted in the following water types. This research is applicable to the processes of rock water intrusion and stream flow.

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