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# Lithological controls on hydrogeochemical parameters: a case study from parts of Vaigai River basin, Madurai, India

**K. K. Sharma and S. Jayashree**
*Department of Applied Geology, University of Madras, Guindy Campus, Chennai - 600 025, India*

## ABSTRACT

Water being a universal solvent carries minerals in solution which though present in small quantities determine its suitability for various purposes. The suitability of a well is determined more by the quality of water and not by the quantity of water which it can yield. Geochemical studies provide complete knowledge of the water resources of a hydrological region.

The influence of mineralogical composition upon the filtering properties and the water quality can be analysed form the point of view of the mineral properties. Quality of ground water varies from place to place and from stratum to stratum, it also varies from season to season. There are various techniques to analyse the groundwater quality. However, not much work has been carried out to study the variations in water quality as a result of lithological and structural controls. In the present paper, an attempt has been made in this direction. It is found that the first step for any groundwater quality data analysis should be its correlation with the lithological variations. This paper presents the details of the work carried out in the Vaigai River basin of Tamilnadu.

## INTRODUCTION

Water is most essential for all activities of man. Quantity as well as the quality of water is an important factor in the determination of its use. The term quality as applied to groundwater embraces the combined physical chemical and biological character of the most abundant compound in nature. The quality of water may be altered due to over dosage of fertilser, the chemistry of host rock through which groundwater permeates and flows subsurface and the total time of residence of the water with the host material.

Increasing awareness of water quality has forced many agencies to become more active in monitoring groundwater quality. Parameters, such as permeability Index (PI), Sodium Absorption Ratio (SAR), Corrosivity Ratio (CR), and Salt Index (SI), can be successfully used to identify groundwater recharge and discharge areas, to determine residence time of groundwater in an aquifer, to determine suitability of water for domestic or industrial use, to identify optimum areas for groundwater exploitation and to study many other similar problems. In this paper, the importance of these parameters is highlighted as well as the use of lithological and structural controls to study the hydrogeochemical behaviour of parts of the Vaigai River basin are presented.

The Vaigai River basin lies in the southern portion of Tamilnadu between the longitudes 77°10' E and 79°00' E and the latitudes 9°00' N and 10°25' N. It covers an area of 7,741 $km^2$ (Fig. 1). The total length of the Vaigai River from its origin up to its fall into Ramnad big tank is 230 km. This basin is spread over Madurai, Ramanathapuram, and Dindigul- Quaid E-Millat Districts.

## GEOLOGY AND HYDROGEOLOGY

The geology of the area is highly complex. Archeans comprising of charnockties, gneisses, granites, schists and calcareous gneisses; the upper Gondwanas comprising of shales, clays, grits and micaceous sandstones; the Quaternary alluvial sands

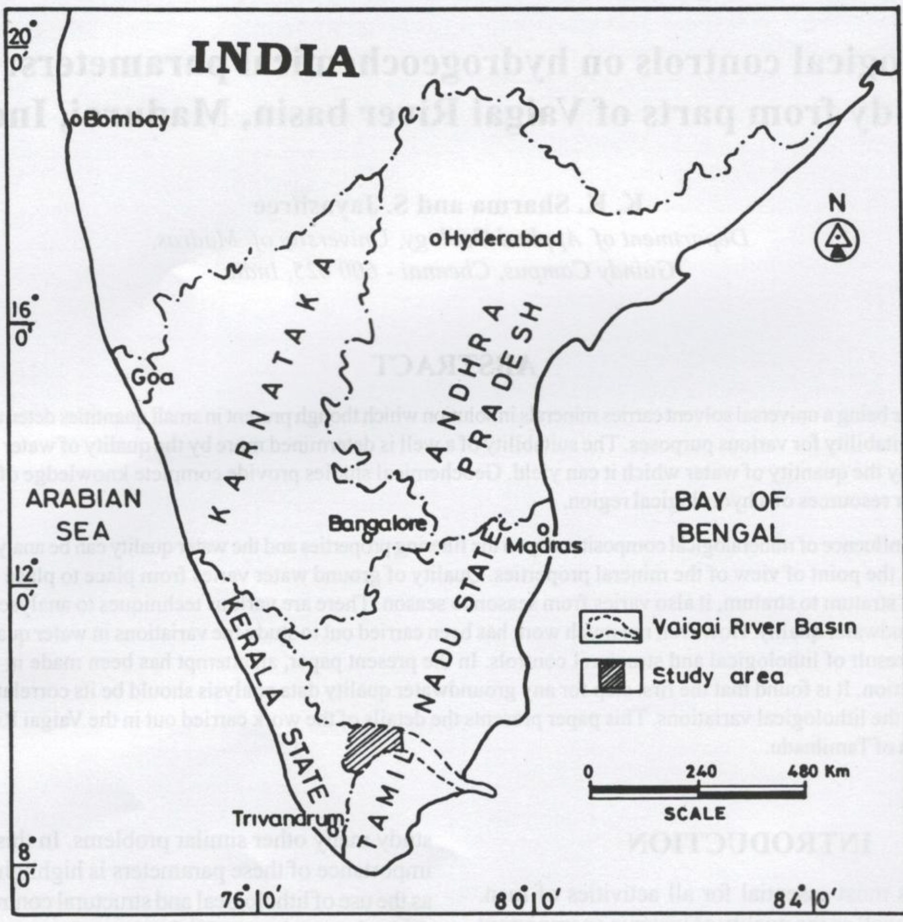


**Fig. 1: Location map of the study area**

and clays occur in this basin (Fig. 2). In the Archean formations, groundwater occurs in the weathered zones, fissured, fractured, jointed and faulted zones. In the Tertiary formations, the sandstone and clayey sandstone form the aquifer zones and are overlain by clay and the groundwater occurs under semi-confined conditions. Water level fluctuation varies from 0.1 m. to 11.8 m. Generally, towest water level is observed during the month of December. The area has a major lineament in NE-SW and NW-SE directions.

## LITHOLOGICAL CONTROLS ON HYDROGEOCHEMICAL PARAMETERS

Water quality depends on the presence or absence of various ions. However, the suitability of groundwater for a particular purpose depends upon the relative quantities of various ions. For example, water having higher concentrations of Ca and Mg than Na can be used for irrigation purposes without adversely affecting either the crop or the soil. Derived parameters use this relative concentration of ions, e.g., waters with high SAR and PI values. Similarly, high CR values are obtained alkalinity, i.e., low $CO_3$ and $HCO_3$ concentration.

Most of the concentration changes of major ions in groundwater can be attributed to the presence of feldspars, amphiboles, pyroxens, clay minerals, ferro-magnesium minerals and other readily soluble minerals. Rocks rich in such minerals lead to "poor" quality of groundwater and also for variations in terms of deterioration of quality with time. For example, feldspar, which

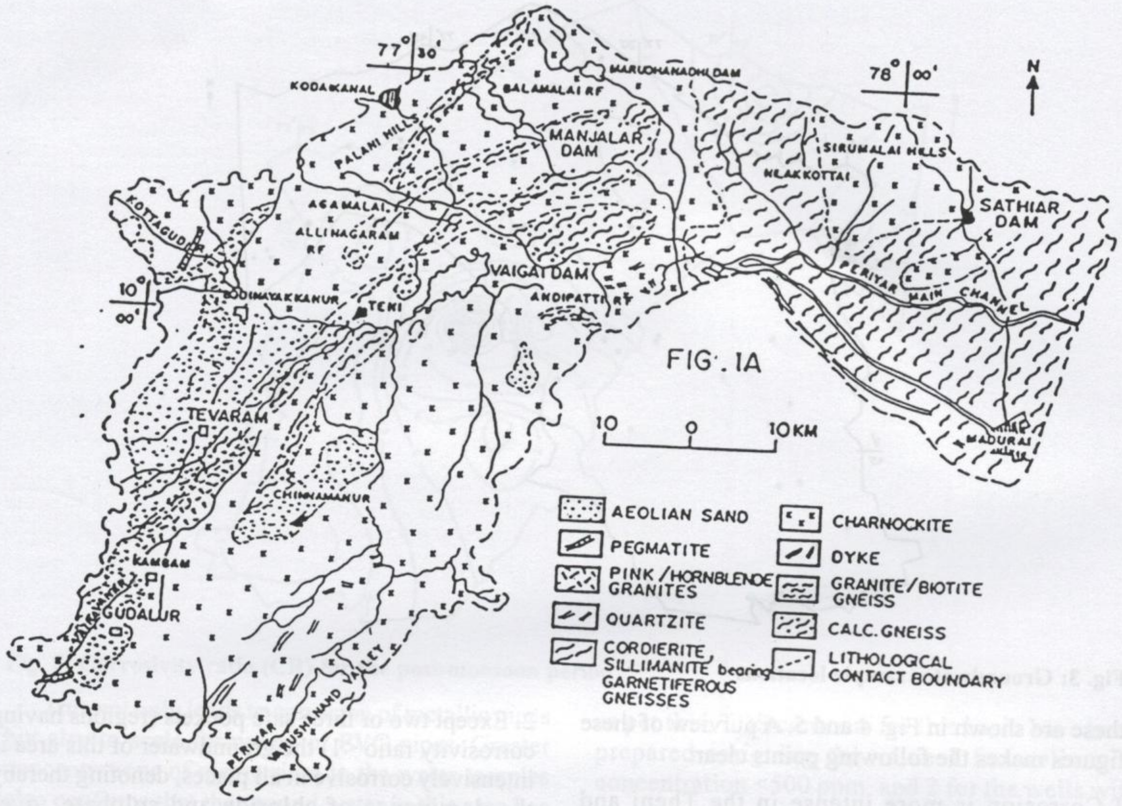


**Fig. 2: Geological map of the study area.**

is a common constituent in igneous rocks has the elements Ca, Na and K. Hence, in an area occupied by these rocks, a high SI and high CR values can be expected since calculation of these parameters takes into consideration of the elements like Ca, Na, K, etc. that are present in feldspar

## Methods of Analysis

Major ion characteristics of water samples from 40 open wells collected during pre and post-monsoon periods for one year have been used for the present study. Location of water samples are shown in Fig.3. Derived parameters including PI, SAR, CR and SI have been computed. Contours maps prepared using PI, SAR, CR and TDS values have been interpreted to evaluate lithological controls on these variations.

## RESULTS AND DISCUSSIONS

### Corrsivity Ratio (CR)

Corrosion is basically an electrolytic process which severely attacks a metal surface. Physical factors like temperature, pressure and velocity of flow and a variety of chemical equilibrium reactions control the rate at which corrosion proceeds (Ayers and Westcot, 1985). The absence of carbonate minerals increases the concentration of chlorides and sulphates of minerals and in turn increases the corrosion rate (Raman, 1983).

The corrosivity ratio (CR) proposed by Ryzner (1944) is of the following form:

$$CR = \frac{0.28\ Cl + 0.021\ SO_4}{0.02\ (HCO_3 + CO_3)}$$

The corrosivity ratio of groundwater collected from this study areas have been evaluated using this equation, and contours have been drawn and interpreted for the pre and post monsoon periods,

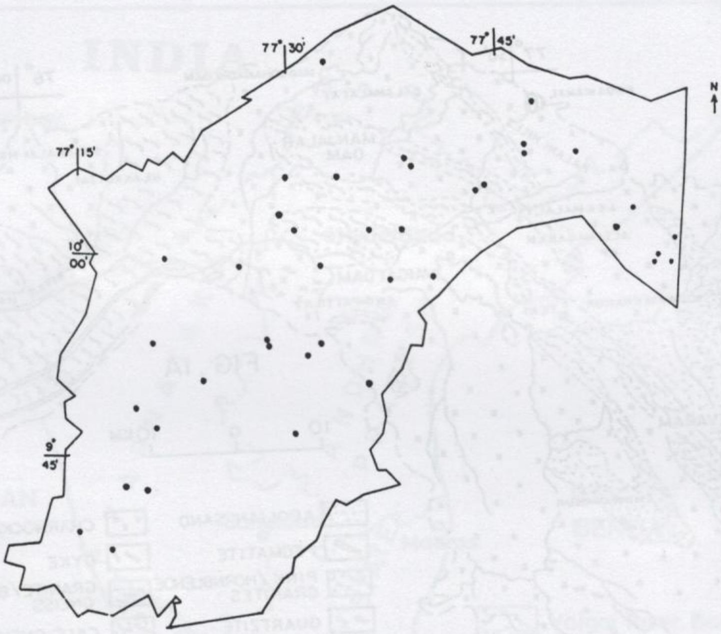


**Fig. 3: Groundwater sample locations**

these are shown in Fig. 4 and 5. A purview of these figures makes the following points clear:

1.Corrosion is more intense in the Theni and Nilkottain blocks, where CR is up to 12.

2. Except two or three safe pockets (regions having corrosivity ratio <1) the groundwater of this area is intensively corrosive in all places, denoting thereby the dominance of chloride and sulphate over carbonate ions in the groundwater.

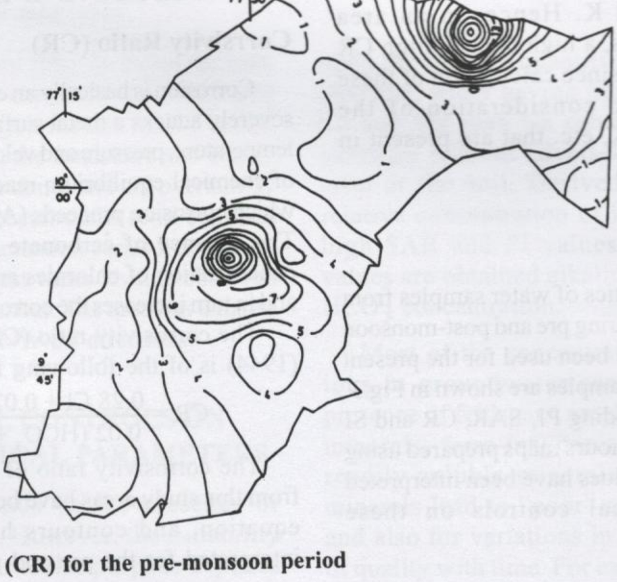


**Fig 4: Corrosivity ratio (CR) for the pre-monsoon period**

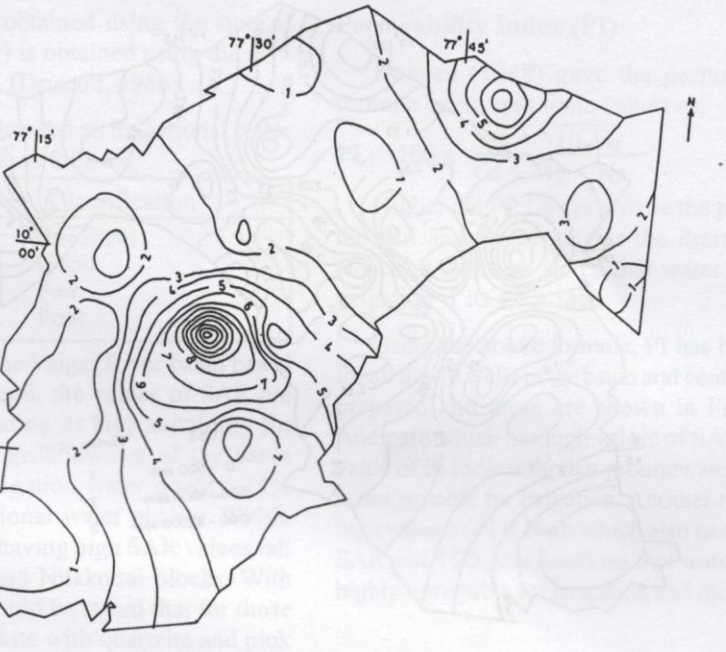


**Fig. 5: Corrosivity ratio (CR) for the post-monsoon period**

This not only leads to corrosion of metallic pipes but also to scale formation of PVC pipes. Greater concentrations of magnesium in the water samples also confirms that the ground water in this area has more incrustation formation characteristics.

## Total Dissolved Solids

TDS concentration happens to be a main factor which determines the groundwater suitability for different purpose. As the residence time of water in the water bearing formations increases, there is a general increase in TDS due to rock water interactions and base exchange characteristics. Freeze and Cherry (1979) noticed that shallow groundwater in the recharge area have lower TDS concentration than the groundwater in the discharge areas.

TDS in groundwater ranges from about 25 ppm to 300,000 ppm. The former represents the natural waters in high rainfall areas while the latter value goes with the brines. Davis and De Wiest (1996) proposed the three fold separation <500 ppm; 500-1000 ppm and >1000 ppm to decipher the suitable groundwater horizons for domestic, irrigation and industrial utility. Hence, as per this, TDS contours for this basin have been prepared assigning the value 1 for wells with concentration <500 ppm. and 2 for the wells with concentration > 500 ppm. and <1000 ppm. and 3 for wells with concentration >100 ppm.

It could be seen from the maps (Fig. 6 and 7) that major portion of the basin is occupied by 500-1000 ppm (contours with values in between 1 and 2), thus supporting the point noticed by Freeze and cherry. With respect to lithology it could be stated that TDS value, in general, is in between 500-1000 ppm. in charnockites with very high values existing near Utthamapalayam and Bodi and Nilakottai, where calcareous gneiss and aeolian sand are dominant. Even the corrosivity ratio is higher in these two zones indicating that these high values of TDS and CR are attributable to the lithology and geology of the area.

## Sodium Adsorption Ratio (SAR)

Richards (1954) defined SAR as Na/(Ca+Mg)/2 where all the ionic concentrations are expressed in epm. This has direct relation to the adsorption of Na by soil. Driscoll (1986) modified this and defined another parameter called Adjusted SAR as,

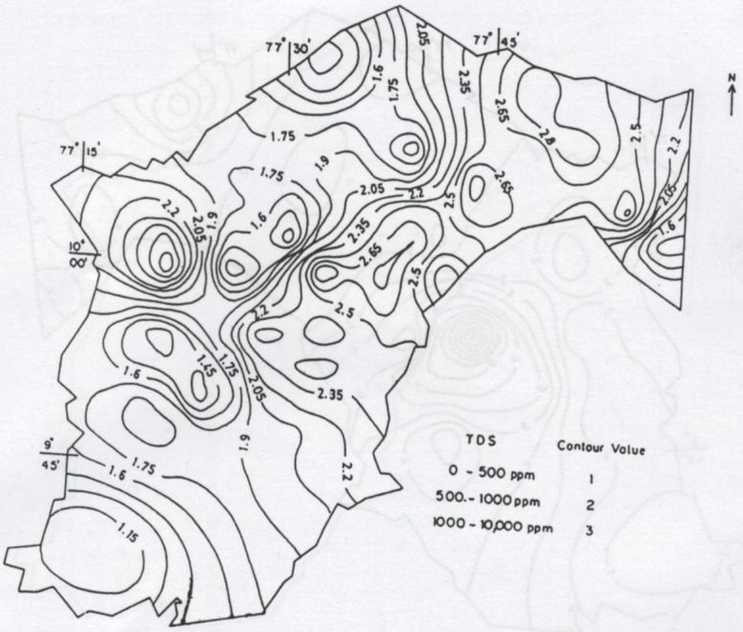


**Fig. 6: Total dissolved solids (TDS) for the pre-mosoon period.**

$$\textbf{Adjusted SAR} = \frac{Na}{\sqrt{(Ca+Mg)}}(1+8.4-pHc)$$

where Na, Mg Ca are in meq/1 from the water analysis. The value for pHc (which is theoretically calculated pH of the irrigation water in contact with lime and in equilibrium with soil $CO_2$ is calculated using the following relationship:

$$pHc + (pK2'-pKc') + p(Ca+Mg) + p(alk)$$

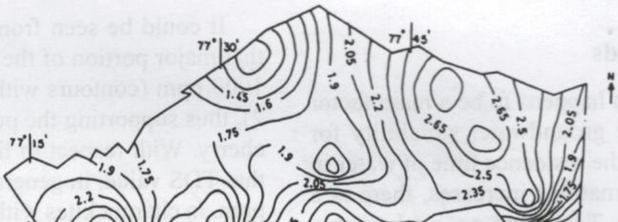

**Fig. 7: Total dissolved solids (TDS) for the post-monsoon period.**

where, (pK2'–pKc') is obtained using the sum of Ca+Mg in meq/1; p)alk) is obtained using the sum of $CO_3$+$HCO_3$ is meq/1 (Driscoll, 1986).

Todd (1959) recommended an irrigational water classification using SAR as follows:

| SAR | Water Classification |
|---|---|
| <10 | Excellent |
| 10-18 | Good |
| 18-26 | Fair |
| >26 | Poor |

Fig. 8 and 9 depict the Vaigai River basin based on SAR values. In general, the values of SAR are low for this basin indicating its high suitability for irrigation. 68% of the groundwater of the basin belongs to excellent irrigation water quality. 15% belongs to good irrigational water quality. Within the basin, three regions having high SAR values fall in the Bodi, Andipati and Nilakottai blocks. With respect to lithology it could be stated that for those regions having charnockite with quartzite and pink granite and calcareous gneisses there is an over all increase in SAR from pre to post monsoon. Nilakottai area shows high values of CR, TDS, and SAR. The high value is associated with its lithology, i.e. cordierite sillimanite bearing garnetiferous gneisses.

**Permeability Index (PI)**

Doneen (1948) gave the permeability index formula using epm ionic values as,

$$\textbf{PI} = 100 \times \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na}$$

Higher the PI, Lower will be the permeability of the soil and hence greater the drainage problem. Hence, it could be stated that water is suitable for irrigation if its PI is low.

Using the above formula, PI has been calculated for all the 40 wells in the basin and contours have been prepared and these are shown in Fig. 10 and 11. Andipatti which has high values of SAR also has high value of PI indicating that groundwater of this region is not suitable for irrigation. Another region showing high value of PI is Bodi which also has high values of SAR and TDS; this confirms that water in this area is highly unsuitable for irrigation and drinking purpose.

**Salt Index (SI)**

SI = Total Na - 24.5 - 4.85 (total Can - Ca in $CaCO_3$)

where all the quantities are expressed in ppm. Salt index in negative for waters suitable for irrigation and positive for those that are unsuitable.

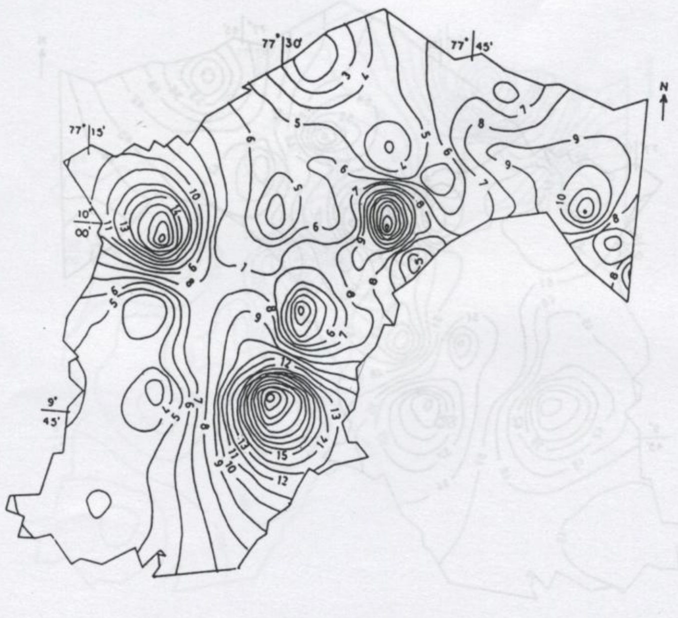


**Fig. 8: Solution absorption ratio (SAR) for the pre-monsoon period.**

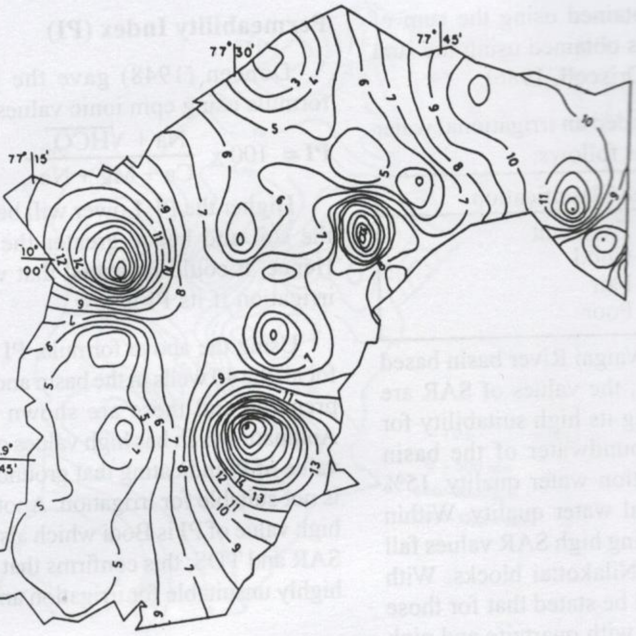


**Fig. 9: Solution absorption ratio (SAR) for the post-monsoon period.**

Fig. 12 and 13 show the SI of the Vaigai River basin. 60% of the groundwater of the basin has negative SI values indicating its suitability for irrigation. Prominent zones showing high positive values of SI fall in Bodi, Andipati and Vadipatti blocks once again confirm the earliest results.

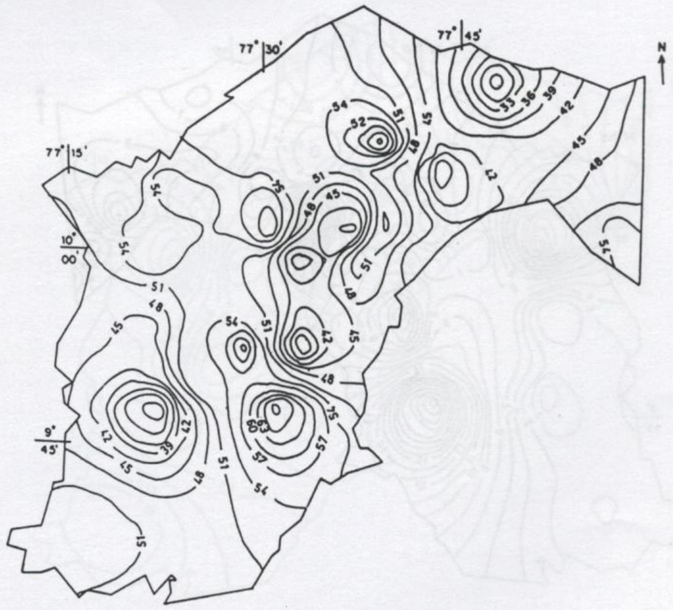


**Fig. 10: Permeability index (PI) for the pre-monsoon period.**

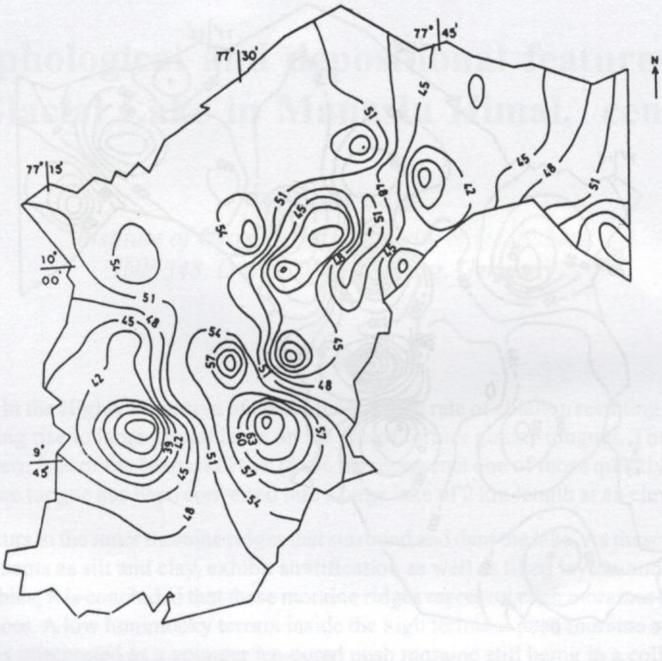


**Fig. 11: Permeability index (PI) for the post-monsoon period.**

## CONCLUSIONS

On the basis of the study discussed above it can be seen that cordierite sillimanite bearing garnetiferous gneiss areas are generally having high CR and SAR values. Also the SAR increases with time and is associated with areas underlain by pink granite and charnockites. Most of the area

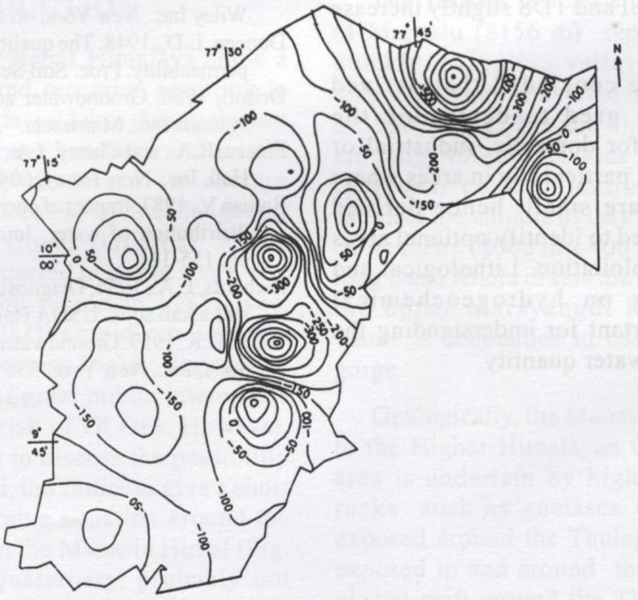


**Fig. 12: Salt index (SI) for the pre-monsoon period.**

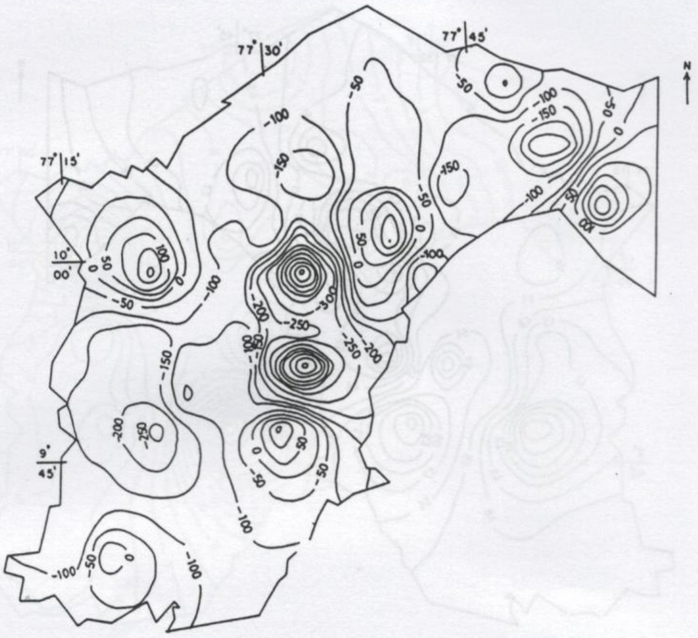


**Fig. 13: Salt index (SI) for the post-monsoon period.**

is suitable for irrigation as seen by negative SI in more than half of the study area. In the transition zone between charnockties surrounded by quartzites and pink granite and those surrounded by calcareous gneiss and alluvium, SAR and PI remain constant, but SI and TDS slightly increase temporarily.

Hence, it can be concluded that derived parameters can be used to determine the suitability of water for domestic, industrial or irrigational purposes, particularly in areas where variations in TDS are small, hence derived parameters can be used to identify optional areas for ground water exploitation. Lithological and structural controls on hydrogeochemical parameters are important for understanding the behaviour of groundwater quantity.

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