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Hydrochemical evolution and quality assessment of groundwater in the watershed region of Devarakonda, Telangana State, India

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ABSTRACT

While groundwater is a critical supply of water for residential and agricultural activities in and around the Devarakonda region due to a scarcity of surface water resources, the quality of groundwater and its suitability for drinking and cultivation were assessed. Based on the analytical results, physical and chemical parameters of groundwater such as pH, Total Dissolved Solids (TDS), TH, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, CO_3^-, and SO_4^{2-}, as well as chemical index such as Percentage of Sodium (percent Na), Kelley's Ratio, Gibb's, and Permeability index were calculated. In a few situations, high total hardness and TDS indicate that groundwater is unfit for drinking and irrigation. Such locations require extra attention to provide appropriate drainage and the introduction of salt-tolerant agriculture.

Keywords: Hydrogeochemistry, Drinking and Irrigation, water quality, Devarakonda region.

INTRODUCTION

A clean and consistent supply of water is required to maintain a high standard of living and a healthy economy. Water use has increased in tandem with rapid development. As a result, urbanization places a significant strain on existing water supplies. Over-exploitation of groundwater can lead to both quantitative and qualitative degradation. As a result, if we are to ensure that the amount and quality of groundwater is preserved for our present and future needs, we must pay special attention to this resource. It is believed that about one-third of the world's population drinks groundwater. Physical, chemical, and biological qualities all have a role in groundwater quality. Industrial wastewater disposal, sanitary landfills, storage heaps, domestic septic tanks, incorrectly constructed wastewater disposal wells, and chemical application on agricultural areas all affect the natural composition of groundwater.

The availability of a vast amount of information about groundwater chemistry is frequently used to perform hydrochemical evaluations of groundwater systems (Aghazadeh, Mogadam, 2004 and Hossien, 2004). Because groundwater is suitable for a variety of applications, its quality is just as vital as its quantity (Schiavo, Havser, Gusimano, and Gatto, 2006 and Subramani, Elango, Damodarasamy, 2005). The chemistry of groundwater is influenced by a variety of factors, including general geology, the degree of chemical weathering of distinct rock types, the quality of recharge water, and inputs from sources other than water rock interaction. Groundwater quality is complicated as a result of these elements and their interactions (Domenico, Schwartz, 1990 and Guler, Thyne, 2004 and Vazquez Sunne, Sanchez Vila, and Carrera, 2005). In the study region, groundwater is a significant supply of water for drinking, agriculture, and industry. Physical, hydrogeological, and hydrochemical data from the groundwater system will be integrated and used in this study to discover the primary factors and mechanisms regulating groundwater chemistry in the area.

This prompted the author to conduct a study on water quality variations in and around Devarakonda. 45 water samples were taken from hand pumps and bore wells in the vicinity of cultivated agricultural land, with hand pumps in heavily inhabited areas being illustrated in Figure 1. In this study, an attempt is made to analyze groundwater quality indices in order to better understand the geochemical linkages of water quality and groundwater resource appropriateness.

Location of the Study Area

The study area covering about 380 km2 falls in and around of Devarakonda, Nalgonda district of Telangana State. Study area lies in between North Latitudes 16° 33' to 16° 48' and East Longitudes 78° 51' to 78° 59' **(Fig. 1)** and falls in the Survey of India toposheet No’s 56 L2, 56 L3, 56 L6 and 56 L7. The Study area receives rainfall (860 mm) both by northeast and southwest monsoons. It is entirely underlined by Pennisular gneissic complexes. The geology of the study area is grey and pink granites occupy dominant portion of the study area. These rocks are composed of quartz, feldspar, biotite and hornblende **(Fig. 2)**. The climate of the study area is generally hot. Average Temperature in summer is 44^0C, in winter is 14^0C.

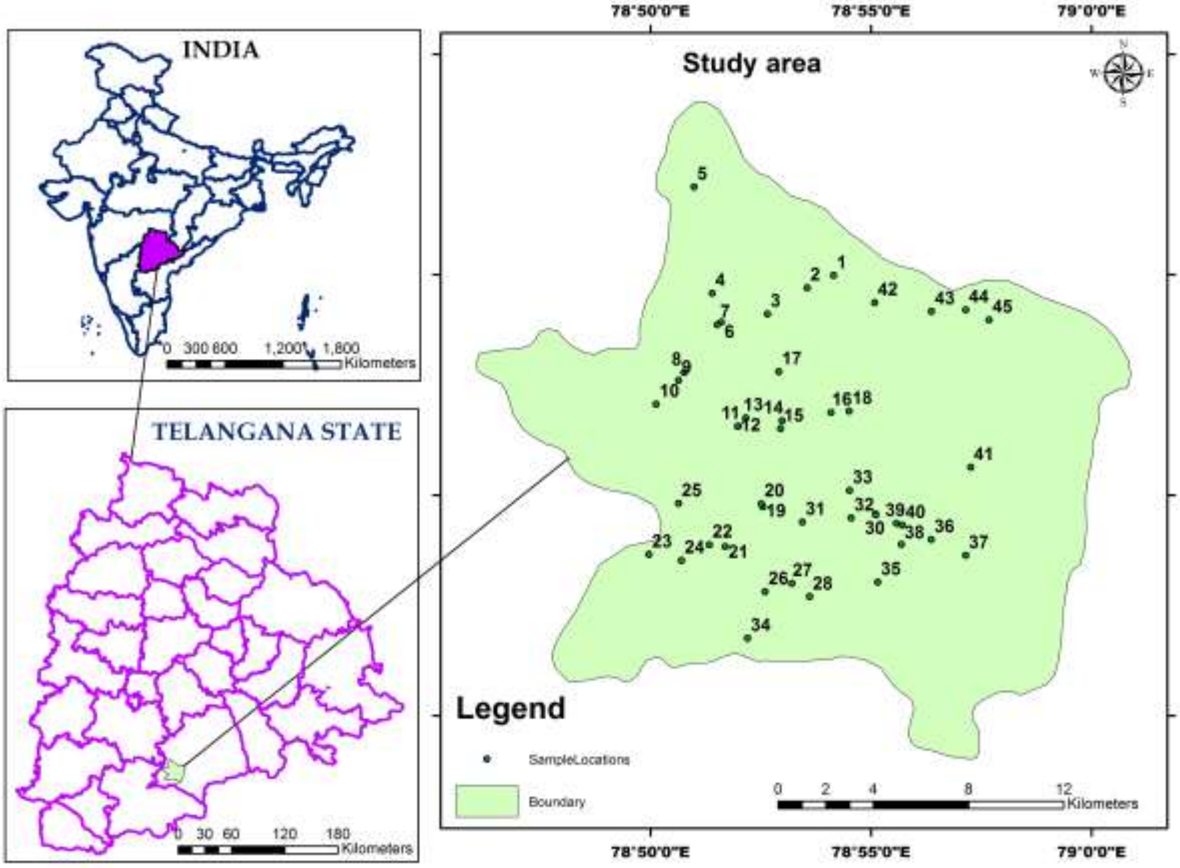

Fig. 1 sampling location map of the study area

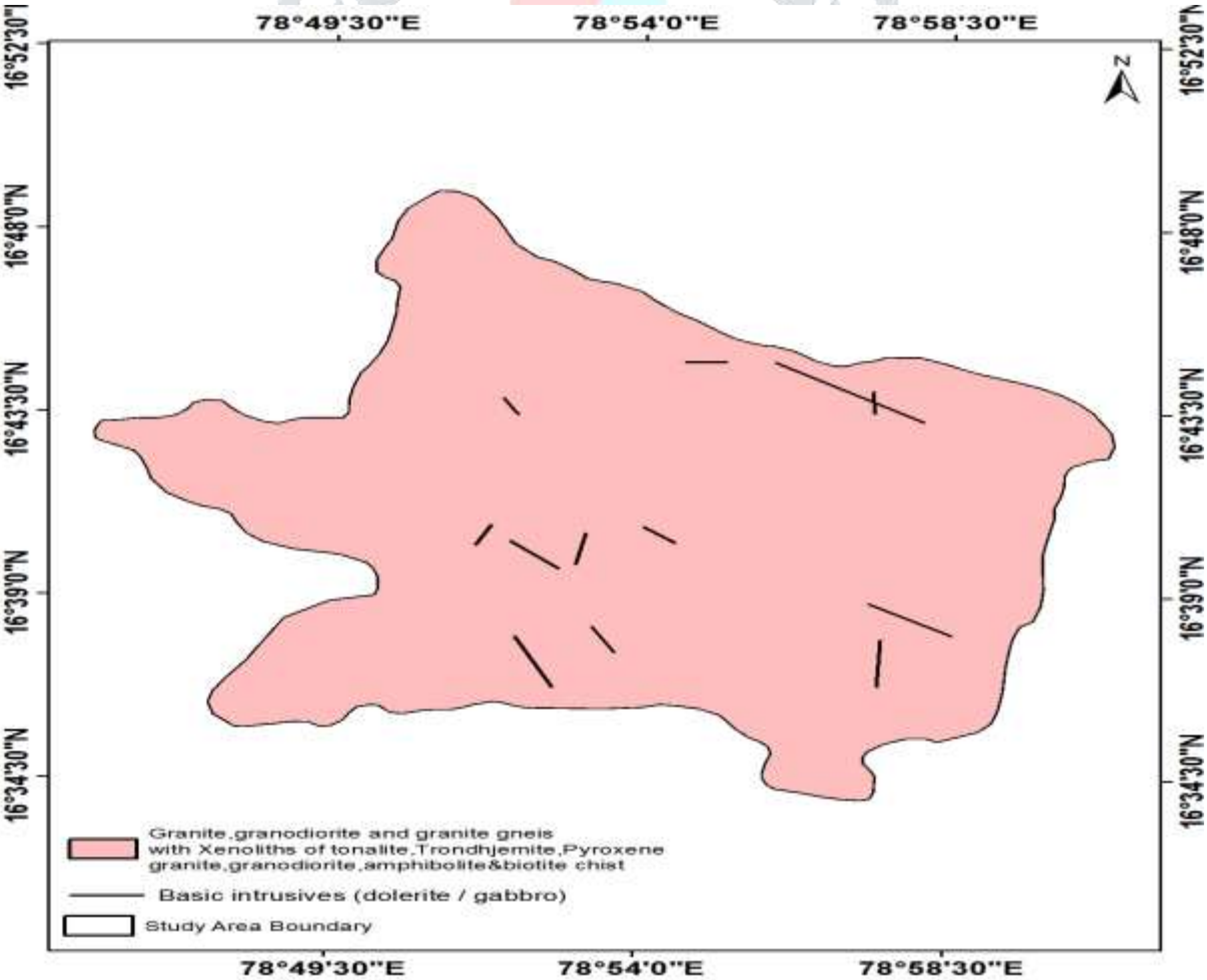

Fig. 2 Geology map of the study area

Materials and Methods

In order to assess the groundwater quality, 45 groundwater samples have been collected. The water samples collected in the field were analyzed for electrical conductivity (EC), pH, total dissolved solids (TDS), Total Hardness (TH), major cations like calcium, magnesium, sodium, potassium and anions like bicarbonate, carbonate, chloride, nitrate and sulphate, trace element like fluoride in the laboratory using the standard methods (APHA, 1995). Sampling was carried out using pre-cleaned polyethylene containers. The results were evaluated in accordance with the drinking water quality standards (WHO, 2004 and BIS, 2009).

The pH was measured with Digital pH Meter (Model 802 Systronics) and EC was measured with Conductivity Meter (Model 304 Systronics), Sodium and Potassium was measured with Flame photometer (Model Systronics 130). Total Dissolved Solids were estimated by calculation method.Sulphates and Nitrates were measured with Spectronics 21 (Model BAUSCH & LOMB), Carbonate, Bicarbonate, Calcium, Magnesium, Total Hardness, and Chloride by titrimetric methods, Fluoride concentration was measured with Orion ion analyzer with fluoride ion selective electrode. The concentration of EC is expressed in microsiemens/cm at 25ºC and TDS, TH, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, $C1^{-}$, SO_4^{-}, NO_3^{-}, CO_3^{-}, HCO_3^{-} and F^{-} are expressed in mg /l. Location map of the water sample is shown in the (Fig 1).

RESULTS AND DISCUSSION

Groundwater Chemistry:

pH is varying between 6.72 to 8.86 and 6.48 to 8.15 with an average value is 8.15 and 7.57 in pre and post-monsoon seasons respectively. The pH of groundwater in the study area is moderately alkaline (pH more than 7) in nature. Electrical Conductivity of the groundwater varies from 1032 to 3645 µS/cm and 700 to 3490 µS/cm at 25^{0}C (average 2252 and 2023 µS/cm).

Hydrogeochemical Facies of Groundwater:

The trilinear diagrams of Piper are very useful in determining chemical relationships in groundwater in more definite terms than is possible with other plotting methods (Piper, 1944). Piper's trilinear diagram method is used to classify the groundwater, based on basic geochemical characters of the constituent ionic concentrations. The chemical data of the groundwater samples collected from the study area are plotted in the Piper's diagram (Fig. 4). The chemical subdivisions 1, 2, 3, 4, 5, 6, 7, 8 and 9 indicate that the alkaline (Ca+ and Mg+) and strong acids mainly dominate the chemical characteristic of the groundwater (Table 3).

Gibbs Diagram

The component of water-rock collaboration monitoring the groundwater chemistry can be concentrated by plotting TDS vs. $Na^{+}/(Na^{+}+Cl^{-})$ and TDS vs. $Cl^{-}/(Cl^{-}+HCO_3^{-})$ using Gibb's diagram (Gibbs 1970). As per Gibbs diagram majorly three categories, that is, precipitation dominance, rock dominance, and evaporation dominance. Gibb's estimation is meq/L.

$$\text{Gibb's ratio I (for anion)} = Cl^{-} / (Cl^{-} + HCO_3^{-})$$

$$\text{Gibb's ratio II (for cation)} = (Na^{+} + K^{+}) / (Na^{+} + K^{+} + Ca^{+2})$$

Gibbs proportion I of the consider region esteems extend of pre, post-monsoons and average from 0.60 – 0.78, 0.71 meq/L and 0.68 – 0.78, and 0.71 meq/L (Table 1). Gibbs proportion II for the study region regards extend from pre, post-monsoons and an average 0.36 – 0.51, 0.44 meq/L and 0.36 – 0.57, 0.48 meq/L (Table 1). The Gibbs chart illustrated that the examination region mostly rock dominance field (**Fig. 3**). The present investigation uncovers that the groundwater chemistry is significantly affected by rock dominance, which shows that the foremost mechanism of weathering of rock-forming minerals because of the whole territory of involved by granitic gneisses (Satyanarayana et al. 2017).

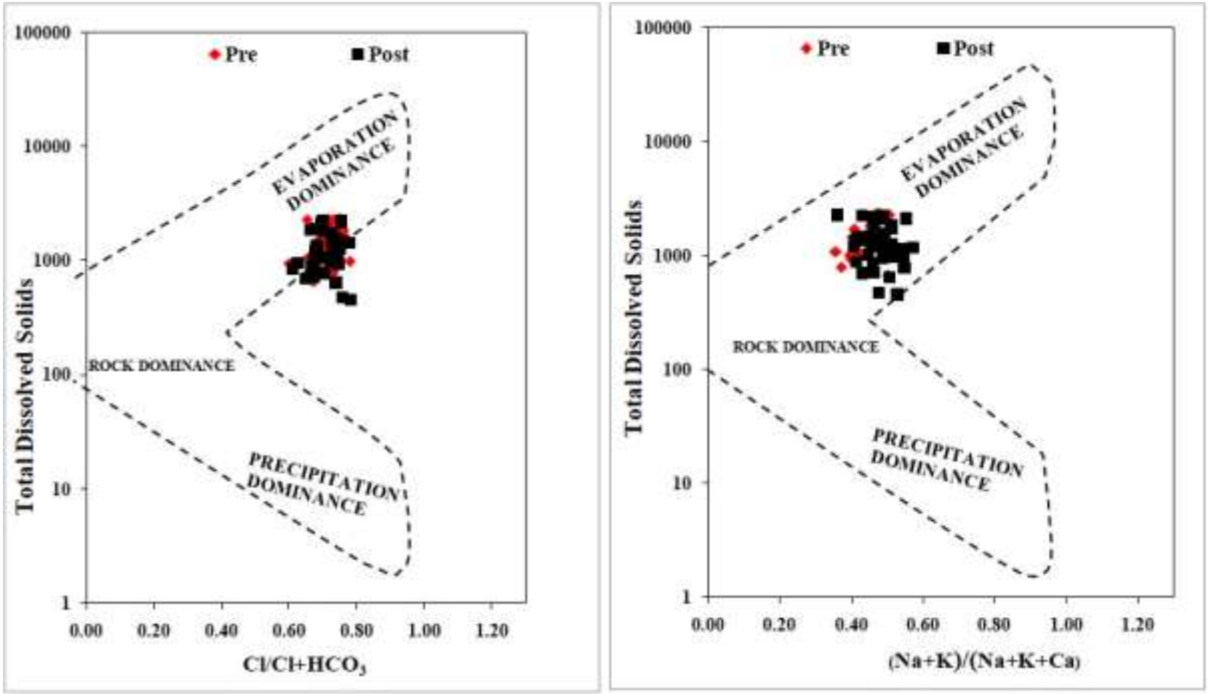

Fig. 3 Gibb's plot of the study area

Drinking water quality

Drinking water quality the analytical results of physical and chemical parameters of groundwater were compared with the standard guideline values as recommended by the World Health Organization for drinking and public health purposes (WHO, 2009) (Table 1). The table shows the most desirable limits and maximum allowable limits of various parameters. The concentrations of cations, such as Na^+, Ca^{2+}, and Mg^{2+}, K^+ and anions such as HCO_3^-, CO_3^{2-}, Cl^- and SO_4^- are within the maximum allowable limits for drinking except a few samples.

Table 1: Statistical Summary of the Chemical Composition of Groundwater

Variables	Pre-monsoon season				Post-monsoon season				BIS (2012)
	Minimum	Maximum	Mean	% of samples exceeded the limits	Minimum	Maximum	Mean	% of samples exceeded the limits	
pH	6.72	8.86	8.15	2	6.48	8.15	7.57	-	**6.5 - 8.5**
EC (µS/cm)	1032	3645	2252	-	700	3490	2023	-	**-**
TDS (mg/l)	660	2333	1441	100	448	2234	1295	96	**500**
TH as CaCO3	350	1460	804	91	280	1360	707	89	**500**
Ca^{2+} (mg/l)	56	198	127	96	36	168	87	62	**75**
Mg^{2+} (mg/l)	32	105	62	100	20	92	48	91	**30**
Na^{+} (mg/l)	94	360	207	51	64	334	181	36	**-**
K^{+} (mg/l)	2	12	7	7	2	18	6	2	**-**
Cl^{-} (mg/l)	198	960	480	93	152	710	407	80	**250**
CO_3^{-} (mg/l)	0	68	19	-	0	0	0	-	
HCO_3^{-} (mg/l)	118	460	243	-	65	388	205	-	**-**
SO_4^{2-} (mg/l)	41	262	150	22	28	228	123	9	**200**
F^{-} (mg/l)	0.36	3.44	1.53	51	0.25	2.56	1.35	36	**1.5**
NO_3^{-} (mg/l)	25	122	62	58	22	99	44	40	**45**
Gibb's I	0.60	0.78	0.71	-	0.68	0.78	0.71	-	**-**
Gibb's II	0.36	0.51	0.44	-	0.36	0.57	0.48	-	**-**

Table 2: Classification of groundwater for drinking, irrigation suitability and % of samples falling in various categories

Category	**Ranges**	**Percent of the samples (Pre-season)**	**Percent of the samples (Post-season)**
Based on TDS(mg/L)			
Fresh water	0 – 1,000	16	27
Brackish water	1,000 – 10,000	84	73
Saline water	10,000 – 1,,00000	Nil	Nil
Brine	>1,00,000	Nil	Nil

Based on Sodium Percentage after Wilcox(1955)			
Excellent to good	<20	Nil	Nil
Good to permissible	20–40	16	7
Permissible to doubtful	40–60	82	89
Doubtful to unsuitable	60–80	2	4
Unsuitable	>80	Nil	Nil
Kelley's Ratio(Kelley1951)			
Good	<1	93	62
Not good	>1	7	38

Total dissolved Solids and Total hardness

To ascertain the suitability of groundwater for any purposes, it is essential to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Carroll, 1962), which are presented in (Table 3). The groundwater of the area is fresh water except a few samples representing brackish water. Most of the groundwater samples are within the maximum permissible limit for drinking as per the WHO international standard. The hardness values ranged from 350 to 1460 mg/L and 280 to 1360 mg/L the classification of groundwater based on total hardness (TH) shows that a majority of the most desirable limit is 500 mg/l as per the WHO international standard. 91 and 89 samples out of 45 exceed the maximum allowable limits (Table 1).

IRRIGATION WATER QUALITY

Percentage of Sodium (% Na)

Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on soil and poses a sodium hazards. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability (Subba Rao, 2006). Hence, the assessment of sodium percentage is necessary while considering the suitability for irrigation, which is computed by Eq. 1.

$$\%N = \frac{(Na + K)}{Ca + Mg + Na + K} x100$$

The %Na values varied from 36 to 62 meq/L and 38 to 66 meg/L (Table 2). The Wilcox, 1955 relating sodium percentage and total concentration shows that 16% and 7% of the groundwater samples fall in the field of good to permissible, 82% and 89% of the groundwater samples are fall in the field of permissible to doubtful and 2% and 4% of the samples are fall in Doubtful to unsuitable for irrigation purposes in pre and post-monsoon seasons respectively.

Kelley's Ratio

Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate by (Eq.) (Kelley, 1940).

$$KR = \frac{Na}{Ca + Mg}$$

Kelley's index (KI) of more than one indicates an excess level of sodium in waters. Therefore, water with a KI (<1) is suitable for irrigation, while those with a KI (>1) unsuitable (Sundaray, Nayak and Bhatta, 2009). In the present study area KI values varied from 0.57 to 1.58 meq/L and 0.60 to 1.89 meq/L in pre and post-monsoon seasons (Table 2). According to Kelley's index 93% and 62 % groundwater locations are suitable for irrigation and 7% and 38% in pre and post-monsoon season groundwater locations are unsuitable for irrigation.

Permeability Index (PI)

The Permeability Index (PI) values also depicts suitability of groundwater for irrigation purposes, since long-term use of irrigation water can affect the soil permeability, influenced by the Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents of the soil. The PI can be expressed as

$$PI = \frac{(Na + K) + \sqrt{HCO_3}}{Ca + Mg + Na + K} x100$$

The concentrations are reported in meq/l. (Doneen, 1964) developed a criterion for assessing the suitability of water for irrigation based on PI, where waters can be classified as classes I, II, and III. The PI of the area varied from 45.47 to 72.52 meq/L and 47.92 to 78.62 meq/L in pre and post-seasons and the average value is 53.75 and 60.24 meq/L. According to PI values, all of the groundwater samples had fallen in class I in pre-monsoon, In post-monsoon season except three samples are fall in class II, remaining samples are fall in class I of the Doneen's chart which is shown in (Figure 5).

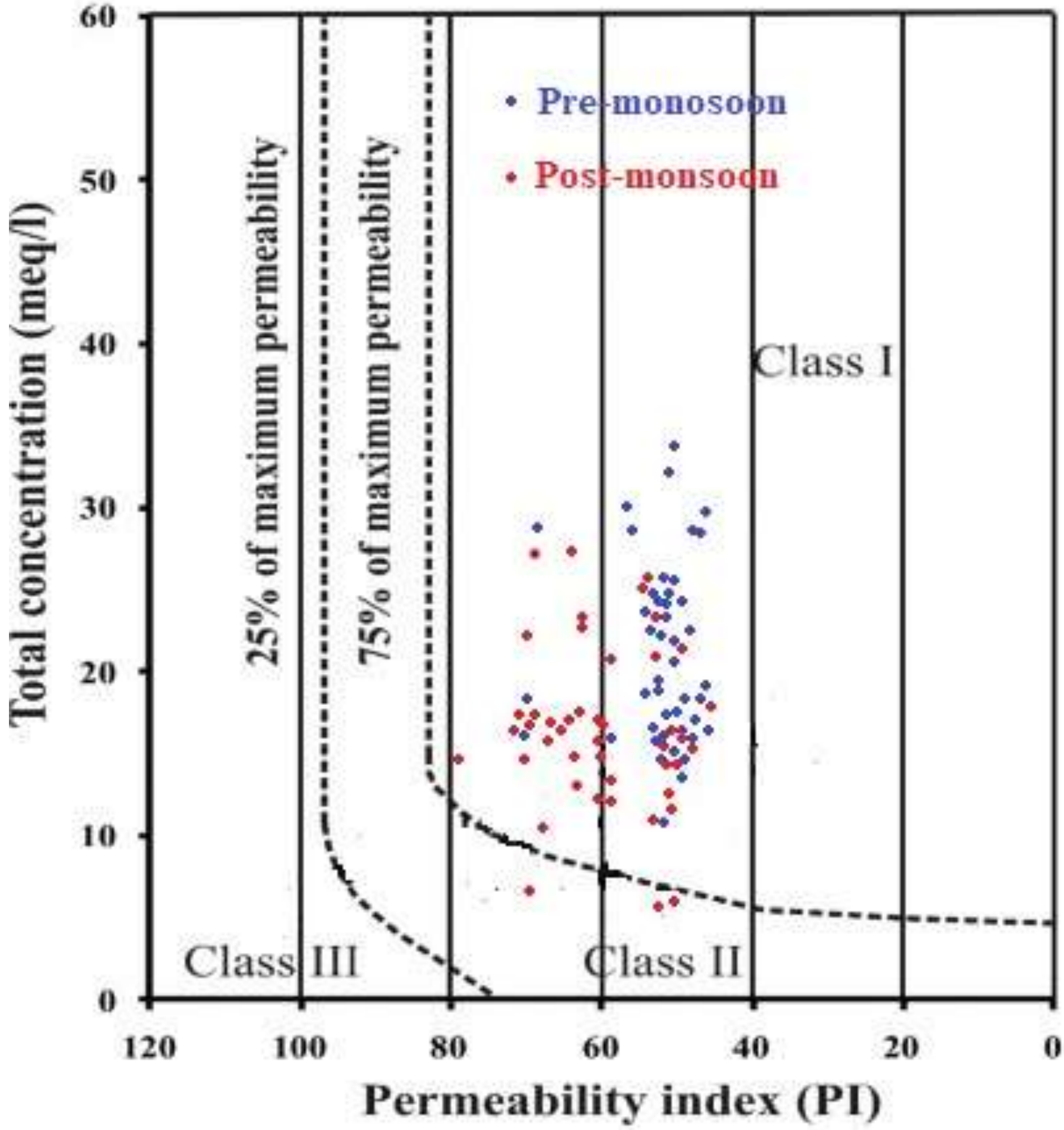

Fig. 5 Permeability index of the study area

Conclusions

The groundwater in and around the Devarakonda area is hard, fresh to brackish, and alkaline in character, according to hydrochemical study. Ca-Na-HCO3 and mixed Ca-Na-Mg-HCO3 are the most prevalent water kinds, according to the chemical connections in the Piper diagram. Strong acids outnumber weak acids, while alkaline earths outnumber alkalis. Because total hardness levels in the groundwater are often high, one-fourth of the research area's groundwater is unfit for drinking. One-third of the research area's groundwater had TDS levels that exceeded the international drinking water standard. Except in a few spots, main ion concentrations in groundwater are within permissible drinking levels. According to Wilcox categorization, 93% of the waters are excellent to good, indicating that groundwater is acceptable for irrigation. Kelley's index indicates that groundwater is safe in 93 percent and 62 percent of cases, respectively. The groundwater in the studied region is acceptable for irrigation purposes, according to PI readings. As a result, the study recommends appropriate remedial actions to improve groundwater quality.

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