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# Hydrochemical Characteristics and Groundwater Quality Assessment in Southeastern part of Ranga Reddy District, Andhra Pradesh, India.

KEYWORDS: Hydrogeochemistry, Drinking and Irrigation, water quality, Southeastern part of Ranga Reddy district

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**ABSTRACT** *As groundwater is a vital source of water for domestic and agricultural activities in Southeastern part of Ranga Reddy district due to lack of surface water resources groundwater quality and its suitability for drinking and agriculture usage were evaluated. Physical and chemical parameters of groundwater such as pH, Electrical Conductivity, Total Dissolved Solids (TDS), TH, Na+, K+, Ca2+, Mg2+, Cl-, HCO3-, CO3-, and, SO4- and Chemical index like Percentage of Sodium (%Na), Chloro Alkaline Indices (CAI), Kelley's Ratio, Gibb's and Magnesium hazard were calculated based on the analytical results. The chemical relationships in Piper diagram identify Ca-Na-HCO3 and mixed Ca-Na-Mg-HCO3 as most prevent water types. Alkaline earths exceed alkalies and strong acids exceed weak acids. High total hardness and TDS in a few places identify the unsuitability of groundwater for drinking and irrigation. Such areas require special care to provide adequate drainage and introduce alternative salt tolerance cropping.*

## INTRODUCTION

A clean and dependable supply of water is necessary to ensure a high quality of life and strong economy. In conjunction with the fast development, water use has also increased. As a result, urbanization severely stresses available water resources. Groundwater over-exploitation can ultimately result in quantitative and qualitative deterioration. So it is important that we pay extra attention to this resource, if we are to ensure the quantity and quality of groundwater is maintained for our current and future needs. It is estimated that approximately one-third of world's population use groundwater for drinking. Groundwater quality comprises physical, chemical and biological qualities. Human activities alter the natural composition of groundwater through disposal of industrial wastewater, sanitary landfills, storage piles, household septic tanks, improperly constructed wastewater disposal wells and application of chemicals on agricultural lands.

Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry (Aghazadeh, Mogadam, 2004 and Hossien, 2004). Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes (Schiavo, Havser, Gusimano, and Gatto, 2006 and Subramani, Elango, Damodarasamy, 2005). Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interaction. Such factors and their interactions result in a complex groundwater quality (Domenico, Schwartz, 1990 and Guler, Thyne, 2004 and Vazquez Sunne, Sanchez Vila, and Carrera, 2005). Groundwater is an important water resource for drinking, agriculture and industrial uses in study area. In this study, physical, hydrogeological, and hydrochemical data from the groundwater system will be integrated and used to determine the main factors and mechanisms controlling the chemistry of groundwater in the area.

This has prompted author to take study related to the quality variations in Southeastern part of Ranga Reddy district, 37 water samples were collected from hand pumps and bore wells in the vicinity of cultivated agricultural land, hand pumps in densely populated area in March 2014 shown in (Fig 1). In this paper, an attempt is made to evaluate the quality indices of groundwater to understand the geochemical relationships of water quality for the suitability of groundwater resources. In view of this, an extensive survey has been conducted in order to know the quality of water for domestic, irrigation and industrial use.

### Location of the Study Area

The study area covering about 240 sq. km falls in Ranga Reddy district of Andhra Pradesh. It is located 35 km from Hyderabad, India on Srisailam highway. Study area lies in between North Latitudes 17° 04' to 17° 24' and East Longitudes 78° 30' to 78° 55' (Fig 2) and falls in the Survey of India toposheet No. E44 M/8 and E44 M/12. Grey granites occupy dominant portion of the study area. These rocks are composed of quartz, feldspar, biotite and hornblende (Fig 3). The climate of the study area is generally hot. Average Temperature in summer is 40$^0$C, in winter is 14$^0$C and rainfall is 738 mm.

### Materials and Methods

In order to assess the groundwater quality, 37 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

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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 25°C 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 6.70 to 8.60 with an average value is 7.27 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 260 to 1830 micromhos/ cm at $25^0$C (average 1115 micromhos/cm). The acceptable limit of EC in drinking water is less than 1500 micromhos/cm. 8% of samples show values higher than the prescribed limit. Higher concentrations indicate that the ionic concentrations are more in the groundwater.

### 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

Gibbs (Walton, 1970) demonstrated that if TDS is plotted against Na/ (Na + Ca), this would provide information on the mechanism controlling chemistry of waters. (Fig 5) displays that groundwater samples were plotted mostly in the rock-water interaction zone and few samples in the evaporation zone. This observation suggests that dissolution of carbonate and silicate minerals are mostly controlled the groundwater chemistry in the study region. However, few samples plotted in the evaporation zone reveal that surface contamination sources, for example irrigation return flow, seem to be affected the groundwater quality in the study region. Both Piper and Gibbs plots suggest that water chemistry is regulated by mixing of salinity water, caused by surface contamination sources, with existing water, ion exchange reactions, mineral dissolution, and possibly evaporation process will give a positive value (Cl > Na + K). During this process, the host rocks are the primary sources for dissolved solids in the water. Indices indicate that all samples in the study region have positive values except a few samples and explain that reverse ion exchange reaction is dominant in the study region. But in a few sites where the values are negative, this suggests the influences of normal ion exchange reactions.

### 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.

### 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 30 to 880 mg/L, the classification of groundwater based on total hardness (TH) shows that a majority of the most desirable limit is 200 mg/l as per the WHO international standard. 28 samples out of 37 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.

$$\%N = \frac{(Na+K)}{Ca+Mg+Na+K} x100 \text{ -------------------- } (1).$$

Where all the ion concentrations are expressed in meq/L. The %Na values varied from 13.55 to 76.47 meq/L (Table 2). The Wilcox, 1955 diagram (Fig 7) relating sodium percentage and total concentration shows that % 97 of the groundwater samples fall in the field of good to permissible for irrigation purposes and 3% of the groundwater samples fall in the field of excellent to good for irrigation.

### Chloro Alkaline Indices (CAI)

It is essential to know the changes in chemical composition of groundwater during its travel in the sub-surface (Aastri, 1994). The Chloro-alkaline indices CAI 1, 2 are suggested by (Schoeller, 1940) which indicate the ion exchange between the groundwater and its host environment. The Chloro-alkaline indices used in the evaluation of Base Exchange are calculated using the Equations (2, 3).

**1) Chloro Alkaline Indices**

$$CAI1 = \frac{Cl-(Na+K)}{Cl} \text{ -------------------------- } (2)$$

**2) Chloro Alkaline Indices**

$$CAI2 = \frac{Cl-(Na+K)}{So4+HCo3+Co3+No3} \text{ -------------- } (3)$$

If there is ion exchange of Na and K from water with magnesium and calcium in the rock, the exchange is known as direct when the indices are positive. If the exchange is reverse then the exchange is indirect and the indices are found to be negative. The CAI 1, 2 are calculated for the waters of the study area. Chloro Alkaline Indices 1, 2 calculations shows that 61% of the groundwater sample is negative and 39% positive ratios.

**Kelley's Ratio**
Sodium measured against $Ca^{2+}$ and $Mg^{2+}$ is used to calculated by (Eq.) (Kelley, 1940).

$$KR = \frac{Na}{Ca + Mg} \quad \text{..............................} \quad (4)$$

Where all the ion concentrations are expressed in meq/L. A 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 0.56 to 5.86 (Table 2). According to Kelley's index 16% groundwater locations are suitable for irrigation and 84% groundwater locations are unsuitable for irrigation.

**Magnesium Hazard (MH):**
Generally, alkaline earths are in equilibrium state in groundwater. If soils have more alkaline earths, they reduce a crop yield. (Szaboles and Darab, 1964) have proposed a magnesium hazard in relation to the alkaline earths for irrigation. This hazard is expressed in terms of Magnesium Hazard (MH), which is computed by (Eq. 5), using the values of ions in meq/L.

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad \text{---------------------} (5)$$

Forty eight percent waters show magnesium ratio above 50. The magnesium ratio water varies from 4.71 to 20.45.

**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

$$PI = \frac{(Na + K) + \sqrt{HCO_3}}{Ca + Mg + Na + K} x100 \quad \text{-----------------} (6)$$

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 24.59 to 89.13 and the average value is 50.55. According to PI values, 22% groundwater samples had fallen in class I, 67% in class II and 11% in class III of the Doneen's chart which is shown in (Figure 6).

**Conclusions**
Interpretation of hydrochemical analysis reveals that the groundwater in Maheshwaram area is hard, fresh to brackish and alkaline in nature. The chemical relationships in Piper diagram identify Ca-Na-HCO3 and mixed Ca-Na-Mg-HCO3 as most prevent water types. Alkaline earths exceed alkalies and strong acids exceed weak acids. Total Hardness is generally high in the groundwater thereby, causing the groundwater in one fourth of the study area to be unsuitable for drinking. Groundwater in one third of the study area exceeded the recommended limits of TDS as per the international drinking water standard. The concentrations of major ions in groundwater are within the permissible limits for drinking except in some places. Based on Wilcox classification ninety three percent of the waters belong to excellent to good which is indicate that groundwater suitable for irrigation, Chloro Alkaline Indices, Kelley's index and magnesium hazard suggest that the groundwater is not safe in 61%, 11% and 48% of groundwater respectively. According to PI values the groundwater in study area is suitable for irrigation purposes. Thus the study suggests appropriate remedial measures to improve the groundwater quality.

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**Table 1: Statistical Summary of the Chemical Composition of Groundwater**

| Parameter | Minimum | Maximum | Mean | Acceptable Limit (WHO,2004) (BIS, 2009) | % of samples exceeding the limit |
|---|---|---|---|---|---|
| pH | 6.70 | 8.60 | 7.27 | 6.5-8.5 | 3 |
| EC | 260 | 1830 | 1115 | 1500 | 8 |
| TDS | 166 | 1171 | 714 | 500 | 92 |
| $CO_3^-$ | 0 | 30 | 3 | 10 | 3 |
| $HCO_3^-$ | 55 | 555 | 272 | 500 | 3 |
| $Cl^-$ | 36 | 667 | 200 | 250 | 24 |
| TH | 30 | 880 | 311 | 200 | 76 |
| $Ca^{++}$ | 25 | 260 | 92 | 75 | 62 |
| $Mg^{++}$ | 1 | 67 | 21 | 30 | 22 |
| $Na^+$ | 16 | 189 | 70 | 250 | Nil |
| $K^+$ | 1 | 147 | 6 | 10 | 3 |
| $SO_4^-$ | 16 | 100 | 39 | 200 | Nil |
| $NO_3^-$ | 3 | 70 | 25 | 45 | 24 |
| $F^-$ | 0.28 | 2.10 | 0.85 | 1 | 32 |

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

| Category | Ranges | Percent of the samples |
|---|---|---|
| Based on TDS(mg/L) | | |
| Fresh water | 0 – 1,000 | 92 |
| Brackish water | 1,000 – 10,000 | 08 |
| Saline water | 10,000 – 1,,00000 | 00 |
| Brine | >1,00,000 | 00 |
| Based on Soluble Sodium Percentage after Wilcox(1955) | | |
| Excellent to good | <20 | 97 |
| Good to permissible | 20–40 | 03 |
| Permissible to doubtful | 40–60 | 00 |
| Doubtful to unsuitable | 60–80 | 00 |
| Unsuitable | >80 | 00 |
| Kelley's Ratio(Kelley1951) | | |
| Good | ≤1 | 16 |
| Not good | >1 | 84 |

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**Table 3: Distribution of Groundwater samples (%) in the subdivisions of Piper diagram (Piper 1953)**

| Area | Subdivisions | Percentage (%) |
|---|---|---|
| 1 | Alkaline earths exceeds alkalies | 84 |
| 2 | Alkalies exceeds alkaline earths | 16 |
| 3 | Weak acids exceed strong acids | 30 |
| 4 | Strong acids exceed weak acids | 70 |
| 5 | Carbonate hardness (secondary alkalinity) exceeds 50% | 24 |
| 6 | Non carbonate hardness (secondary salinity) exceeds 50% | 8 |
| 7 | Non carbonate alkali (primary salinity) exceeds 50% | 8 |
| 8 | Carbonate alkalies (primary alkalinity) exceeds 50% | 0 |
| 9 | No one cation – anion pair exceeds 50% | 59 |

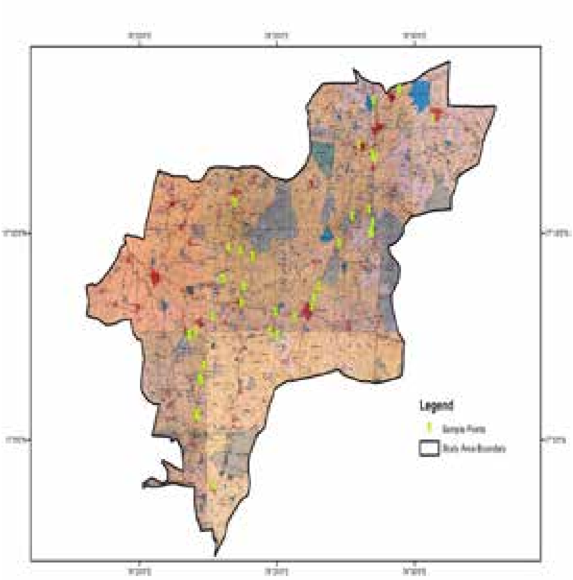


**Fig. 1: Sampling points with the toposheet**

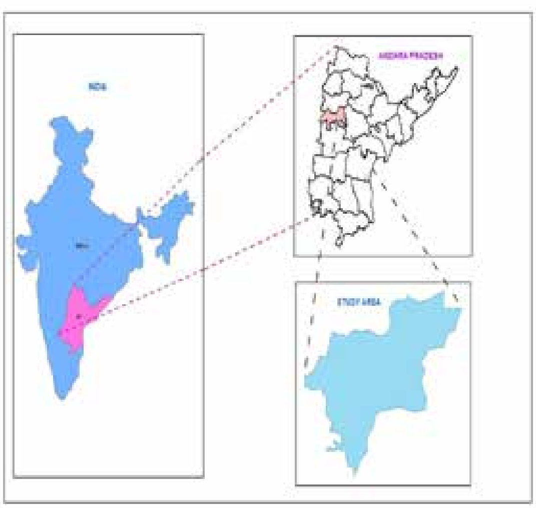


**Fig. 2: Location Map of the Study Area**

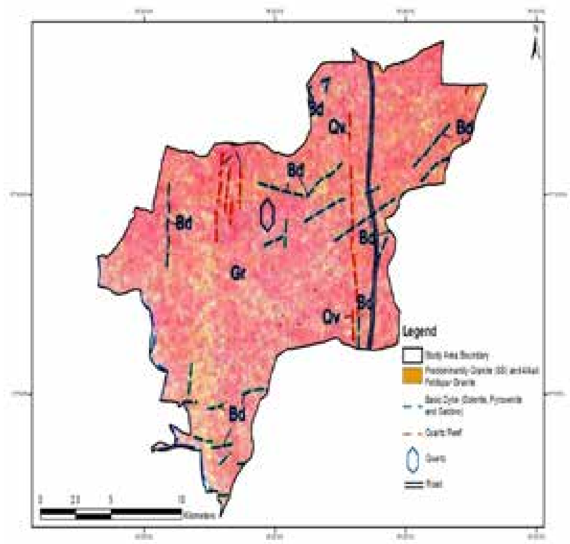


**Fig. 3: Geological map of the study area**

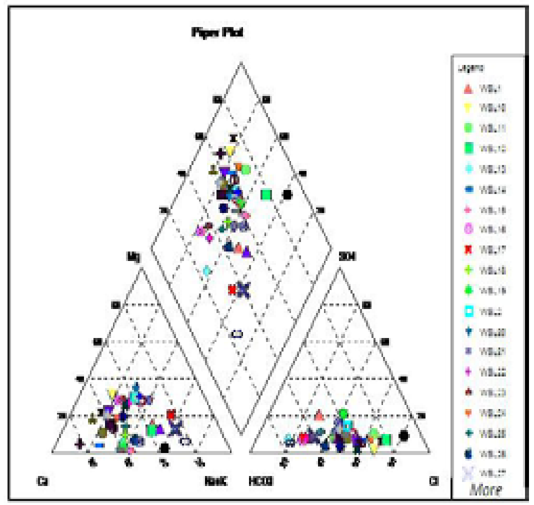


**Fig. 4: Piper Trilinear Diagram Representing the Chemical Analysis of the Study Area**

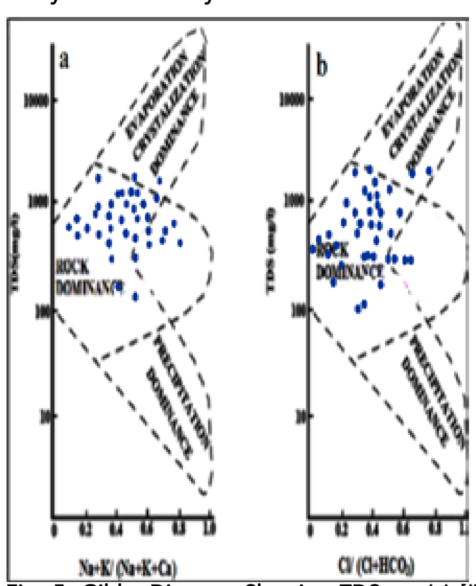


**Fig. 5: Gibbs Diagram Showing TDS vs. (a) [($Na^+$ + $K^+$)/ ($Na^+$ + $K^+$ + $Ca^{2+}$)], and (b) [$Cl^-$/ ($Cl^-$+ $HCO_3$)]**

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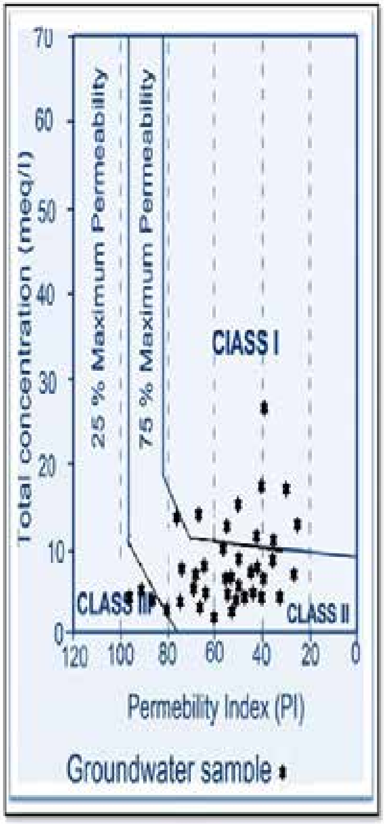


Fig. 6: Doneen Classification (1964) of Irrigation Water Based on The Permeability Index of Study Area.

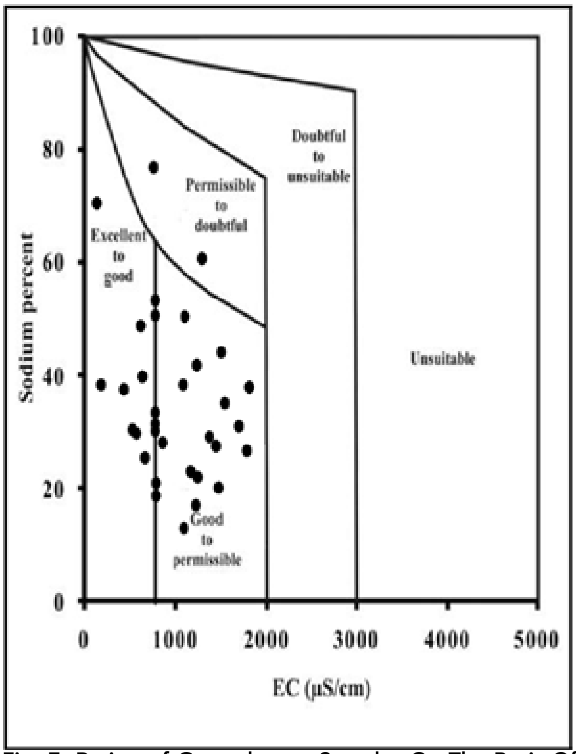


Fig. 7: Rating of Groundwater Samples On The Basis Of Electrical Conductivity and Percent Sodium (After Wilcox, 1955)

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