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**Research Article**

# GROUNDWATER QUALITY AND ITS SUITABILITY FOR DRINKING AND AGRICULTURAL USE IN KALWAKURTHY AREA, NAGARKURNOOL DISTRICT, TELANGANA, INDIA

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**ABSTRACT**

Hydrochemistry of groundwater in Kalwakurthy area, Nagar kurnool District, Telangana, India was used to assess the quality of groundwater for determining its suitability for agricultural purposes. 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) and Kelley's Ratio and Magnesium hazard were calculated based on the analytical results. Concentrations of the chemical constituents in groundwater vary spatially and temporarily. Interpretation of analytical data shows that mixed Ca-Na-Mg-HCO3-Cl is the dominant hydrochemicalfacies in the study area. Alkali earths (Ca2+, Mg2+) and strong acids (Cl-, SO42-)) are slightly dominating over alkalis (Na+, K+) and weak acids (HCO3-, CO32-). High total hardness and TDS in a few places identify the unsuitability of groundwater for drinking and irrigation.



## INTRODUCTION

Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Water quality analysis is an important issue in groundwater studies. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. Groundwater is a vital natural resource. Depending on its usage and consumption it can be a renewable or a non renewable resource. It is estimated that approximately one third of the world's population use groundwater for drinking (R.T.Nickson, J.M. McArthur, B.Shrestha, T.O.Kyaw-Nyint and D. Lowry, 2005). Groundwater is the major source of water supply for domestic purposes in urban as well as rural parts of India. Among the various reasons, the most important are non-availability of potable surface water and a general belief that groundwater is purer and safer than surface water due to the protective qualities of the soil cover (P.C. Mishra, P.C.Behera and R.K. Patel, 2005). The water quality may yield information about the environments through which the water has circulated. Each groundwater system in the area has a unique chemistry, acquired as a result of chemical alteration of meteoric water recharging the system (W. BACK, 1966: J.I. DREVER, 1982)

The chemical alteration of the rain water depends on several factors such as soil-water interaction, dissolution of mineral species and anthropogenic activities (G. FAURE, 1998: N. SUBBA RAO, 2001: R. UMAR, and I. AHMED, 2007). The study of a relatively large number of groundwater samples from a given area, offer clues to various chemical alterations which the meteoric groundwater undergoes, before acquiring distinct chemical characteristics. Most of the inland areas of Indian sub-continent have Ca-Mg-HCO3 type of groundwater (S.K. BARTARYA, 1993: P.S. DATTA, and S.K. TYAGI, 1996). The quality of groundwater is the resultant of all the processes and reaction that act on the water from the moment it condenses in the atmosphere to the time it is discharged by a well. Therefore, determination of groundwater quality is important to observe the suitability of water for a particular use. The problems of ground water quality are more acute in areas that are densely populated and thickly industrialized and have shallow groundwater tube wells (H. S,Shivran Dinesh,D. Kumar, R.V. Singh, 2006).

### *Location of the Study Area*

The study area covering about 60 sq. km falls in Mahabubnagar district of Andhra Pradesh. It is located 80 km from Hyderabad, India on Srisailam highway. It is around 56 km from the District head quarter Mahabubnagar. Kalwakurthy lies in

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between North Latitudes 16° 34′ 30″ to 16° 42′ 00″ and East longitudes 78° 24′ 00″ to 78° 28′ 48″ (figure 1) and falls in the Toposheet No. 56 L/6 and 56 L/10. The climate of the study area is generally hot. Average Temperature in summer is $40.9^0$C, in winter is $25^0$C and rainfall is 604 mm.

### *Geology*

Grey granite occupies dominant portion of the area (Fig.2) these rocks are composed of quartz, feldspars, and biotite. These are medium to course grained and equigranular in texture. The typical grey colour is due to the presence of the plagioclase feldspars and quartz. The potash feldspars that are present in the rock are orthoclase and microcline but in less abundance. Biotite is the most predominant mineral in these rocks.

## MATERIALS AND METHODS

In order to assess the groundwater quality, 56 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, and sulphate in the laboratory using the standard methods given by the American Public Health Association (American Public Health Association (APHA), 1995). Sampling was carried out using pre-cleaned polyethylene containers. The results were evaluated in accordance with the drinking water quality standards given by the WHO and Bureau of Indian Standards (BIS (Bureau of Indian Standards), 2003)

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). Sulphates and Nitrates were measured with Spectronics 21 (Model BAUSCH & LOMB), Carbonate, Bicarbonate, Calcium, Magnesium, Total Dissolved Solids, Total Hardness, and Chloride by titrimetric methods, Fluoride concentration was measured with Orion ion analyzer with fluoride ion selective electrode. Nitrate was determined by spectrophotometer. 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).Physical and chemical parameters including statistical measures such as minimum, maximum, mean, Median, Std.Dev are summarized in Table 1. Classification of groundwater on the basis of TDS, %Na, KI, is shown in Table 2.

## RESULTS AND DISCUSSION

### *Groundwater Chemistry*

pH is varying between7.42 to 8.8 with an average value is 8.04 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 78.44 to 1568.8micromhos/ cm at $25^0$C(average 402.86 micromhos/cm). The acceptable limit of EC in drinking water is less than 1500 micromhos/cm (WHO, 2004. BIS, 2009). 4% of samples show values higher than the prescribed limit. Higher concentrations indicate that the ionic concentrations are more in the groundwater. The chemical data of groundwater samples are plotted in the Gibbs diagram (see Fig. 3a and b). The Gibbs plot of data from study area indicates that rock is the dominant processes controlling the major ion composition of groundwater.

### *Hydrogeo chemical Facies of Groundwater*

The hydrochemical evolution of groundwater can be understood by the plotting the major cations and anions in Piper triliner diagram (A. M. A. Piper, 1944**),** (figure 4). A- Calcium type, B- No Dominant type, C- Magnesium type, D- Sodium and potassium type, E- Bicarbonate type, F- Sulphate type, G- Chloride type 1-Magnesium bicarbonate type, 2- Calcium-chloride type, 3- Sodium-chloride type 4- Sodium-Bicarbonate type, 5- Mixed type (No cation-anion exceed 50%) This diagram reveals similarities and dissimilarities among groundwater samples because those with similar qualities will tend to plot together as groups(D.K. Todd**, 2001)** This diagram is very useful in bringing out chemical relationships among groundwater in more definite terms(W.C. Walton, 1970)**.** The geochemical evolution can be understood from the Piper plot, which has been divided into six sub categories viz. Type-I- ( $Ca^{2+}$ - $Mg^{2+}$ - $HCO_3^-$ type), Type-II- ( $Na^+$ - $Cl^-$ type), Type-III- (Mixed $Ca^{2+}$ - $Na^+$ - $HCO_3^-$ type), Type-IV- (Mixed $Ca^{2+}$ - $Na^+$ - $Cl^-$ type), Type-V- ( $Ca^{2+}$ - $Mg^{2+}$ - $Cl^-$ type) and Type-VI- ( $Na^+$ - $HCO_3^-$ type). As per the classification of Piper diagram, the groundwater samples from the study area are classified into the hydrochemicalfacies which are arranged in the decreasing order of abundance as Type-I-**(** $Ca^{2+}$ - $Mg^{2+}$ - $HCO_3^-$ type), and Type-V-( $Ca^{2+}$ - $Mg^{2+}$ - $HCO_3^-$ ).

From another point of view 100% of the plots clustered in Type I (Ca-Na-Mg-HCO3-Cl) facies of the Piper's diagram (figure 5). In this study, the dominant ions are Cl, Na with Ca and $HCO_3$ ions following. Generally, within the evolutionary trend, groundwater tends to acquire chemical compositions similar to that of seawater (that is more dissolved and relative increase in chloride ion) the longer it remains underground and the further it travels. The plot shows that majority of the groundwater samples fall under the subdivision of alkaline earths exceeds alkali metals and weak acidic anions exceed strong acidic anions.

### *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 (WHO 2004, BIS 2009) for drinking and public health purposes (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 (D. Carroll, 1962), which are presented in Table 2. 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 75 to 560 mg/L, the classification of groundwater (Table 2) based on total hardness (TH) shows that a majority of the most desirable limit is 200 mg/l as per the WHO international standard. 21 samples out of 56 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 ( N. Subba Rao, 2006). Hence, the assessment of sodium percentage is necessary while considering the suitability for irrigation, which is computed by Eq. 1.

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

Where all the ion concentrations are expressed in meq/L. The %Na values varied from 17.64 to 57.8 meq/L (Table 2). The Wilcox (L. V. Wilcox, 1955) diagram (Figure 6) relating sodium percentage and total concentration shows that % 07 of the groundwater samples fall in the field of good to permissible for irrigation purposesand 93% 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 (J. C. V. Aastri, 1994)**.** The Chloro-alkaline indices CAI 1, 2 are suggested by Schoeller (H. Schoeller, 1977) 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

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

2) Chloro Alkaline Indices

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

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's (W.P. Kelley, 1940)

$$KR = \frac{Na}{Ca + Mg} \qquad (4)$$

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 (S. K. Sundaray, 2009). In the present study area KI values varied from 0.17 to 1.24 (Table 2). According to Kelley's index 89% groundwater locations are suitable for irrigation and11% 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 (I. Szaboles and C.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.

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

Forty eight percent waters show magnesium ratio above 50. The magnesium ratio water varies from 6.24 to 82.60.

## CONCLUSIONS

Interpretation of hydrochemical analysis reveals that the groundwater in Kalwakurthy is hard, fresh to brackish and alkaline in nature. The Piper plot shows that majority of the groundwater samples fall under the subdivision of alkaline earths exceeds alkali metals and weak acidic anions exceed strong acidic anions. In the study area, the dominant hydrochemical facieses of groundwater is Ca-Na-Mg-$HCO_3$-Cl.TH 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. Thus the study suggests appropriate remedial measures to improve the groundwater quality.

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**Table 1** Statistical Summary of the Chemical Composition ofGroundwater

| Parameter | Minimum | Maximum | Mean | Median | Std.Dev | Acceptable Limit(WHO,2004) (BIS, 2009) | % of samples exceeding the limit |
|---|---|---|---|---|---|---|---|
| pH | 7.42 | 8.8 | 8.04 | 8.1 | 0.29 | 6.5-8.5 | 5 |
| EC | 78.44 | 1569 | 387.88 | 314 | 272.86 | 1500 | 4 |
| TDS | 50.2 | 1004.03 | 248.2 | 201 | 174.57 | 500 | 5 |
| $CO_3^-$ | 0 | 15 | 7.411 | 6 | 3.46 | 10 | 89 |
| $HCO_3^-$ | 48.8 | 219.6 | 122.35 | 122 | 38.81 | 500 | Nil |
| $Cl^-$ | 21.3 | 678.05 | 123.75 | 56.85 | 135.62 | 250 | 7 |
| TH | 75 | 560 | 206 | 172 | 104.28 | 200 | 39 |
| $Ca^{++}$ | 16.03 | 154.03 | 41.232 | 32.000 | 26.535 | 75 | 5 |
| $Mg^{++}$ | 2.91 | 83.83 | 26.326 | 23.000 | 17.107 | 30 | 29 |
| $Na^+$ | 17 | 182 | 55.589 | 44.500 | 35.608 | 250 | Nil |
| $K^+$ | 10 | 47 | 15.161 | 14.000 | 6.771 | 10 | 89 |
| $SO_4^-$ | 4 | 180 | 29.705 | 20.000 | 33.83 | 200 | Nil |

**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 | 96 |
| Brackish water | 1,000 – 10,000 | 04 |
| Saline water | 10,000 – 1,,00000 | 00 |
| Brine | >1,00,000 | 00 |
| **Based on Soluble Sodium Percentage after Wilcox(1955)** | | |
| Good to permissible | <20 | 07 |
| Excellent to good | 20–40 | 93 |
| Doubtful to unsuitable | 40–60 | 00 |
| Unsuitable | 60–80 | 00 |
| Permissible to doubtful | >80 | 00 |
| **Kelley's Ratio(Kelley1951)** | | |
| Good | ≤1 | 89 |
| Not good | >1 | 11 |

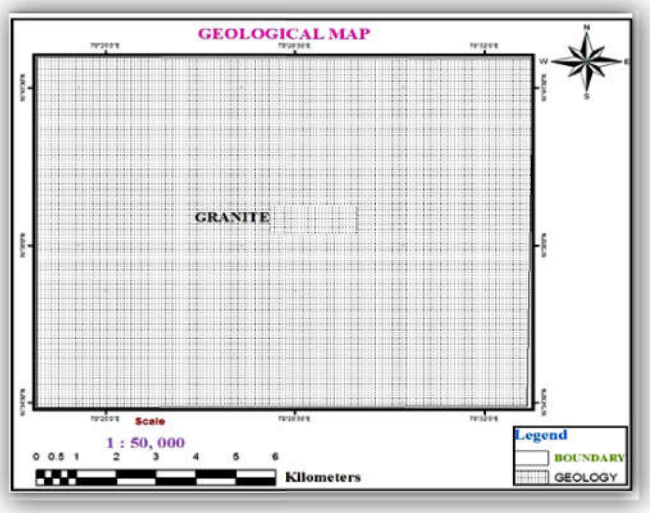


**Figure 2** Geological map of the study area

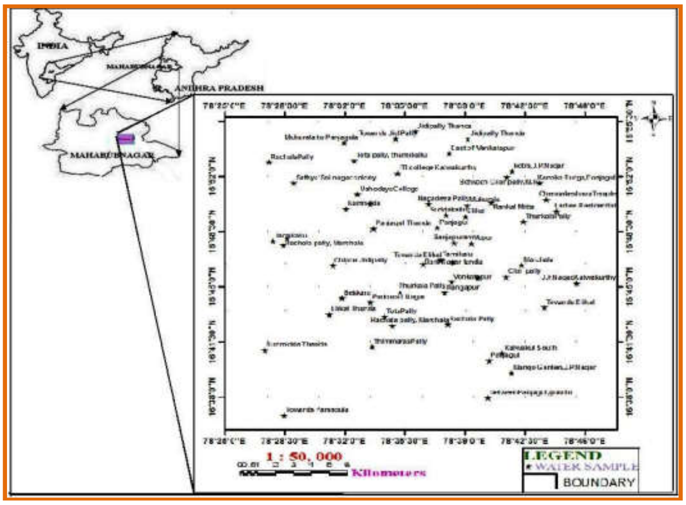


**Fig 1** Location map of the study area with water samples

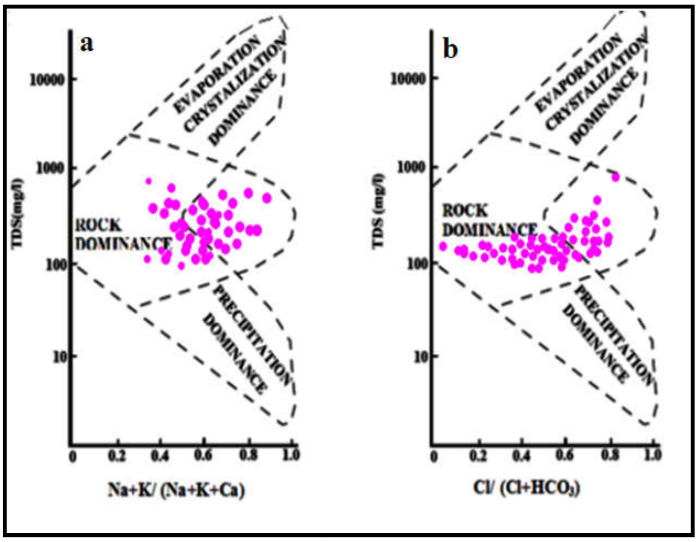


**Fig 3** Gibbs Diagram Showing TDS vs. (a) $[(Na^+ + K^+)/ (Na^+ + K^+ + Ca^{2+})]$, and (b) $[Cl^-/ (Cl^- + HCO_3)]$

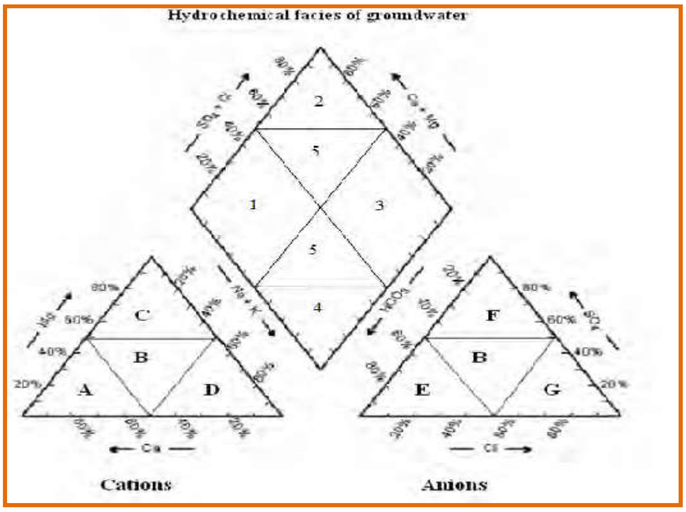


**Fig 4** Subdivisions of the Trilinear Diagram (Sadashivaiah *Et Al*., 2008)

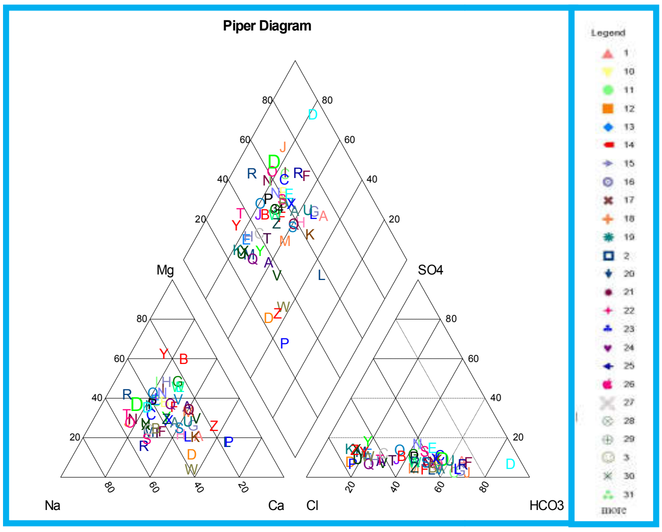


**Fig 5** Piper Trilinear Diagram Representing the Chemical Analysis of the Study Area

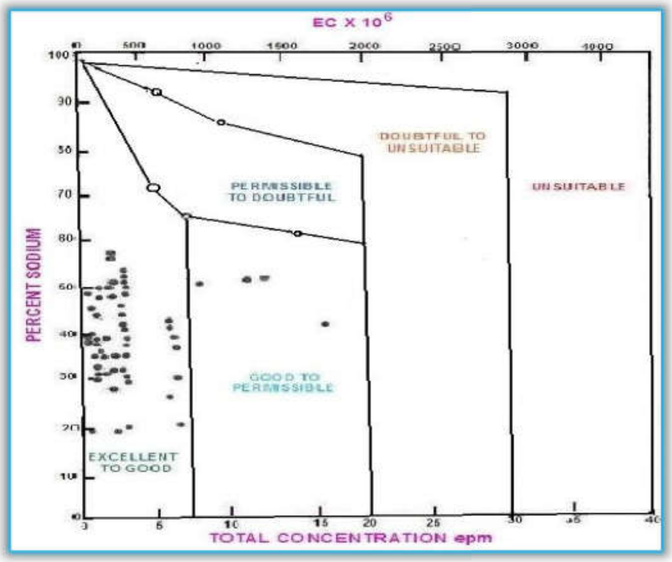


**Fig 6** Rating of Groundwater Samples On The Basis Of Electrical Conductivity and Percent Sodium (After Wilcox, 1955)

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