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RESEARCH ARTICLE

STUDIES ON THE HYDROGEOCHEMISTRY OF GROUNDWATER IN KUSHAIGUDA AREA RANGE, REDDY DISTRICT (ANDHRA PRADESH)

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ABSTRACT

Hydrogeochemistry of Groundwaters in Kushaiguda region, Reddy district, Andhra Pradesh, India has been analyzed to evaluate its aptness for domestic and agricultural uses. Sixteen samples of groundwater were collected and evaluated the different physico chemical parameters namely, pH, Total hardness (TH), Electrical conductivity (EC), Total dissolved solids (TDS), cations such as Ca²⁺, Mg²⁺, Na⁺ and K⁺ and anions such as CO₃²⁻, HCO₃⁻, Cl⁻ and SO₄²⁻. Different irrigation water quality parameters and diagrams such as, Permeability index (PI), Kelley's ratio (KR) and Wilcox plot revealed that most of the water samples are suitable for irrigation. Gibbs plot suggests that the qualities of most of the samples are influencing the chemical weathering of rock forming minerals. Piper plot and Durov plot indicates the chemical composition of water, chiefly controlled by dissolution and mixing.

INTRODUCTION

The water is a chief natural resource that is indispensable for all forms of life.¹ It is also essential for maintenance and sustenance of life and hence is required for domestic, agricultural and industrial uses.² Since water bodies are in contact with rocks, different kinds of soils, so many solutes may be present in ground and surface water. The quality of water differs because of different phylogeny sources (such as fertilizers, sanitary landfills, septic sewage etc.), atmospheric assertion and rock weathering process. There are major (>5ppm), minor (0.01 -10 ppm), and trace solutes (<0.01 ppm) in ground water.³ The major inorganic materials include Na, Ca, Mg, bicarbonate, sulphate, chloride, Silica while minor inorganic materials may be B, Fe, NO₃, NO₂, K, Sr, Mn, Br, F, NH₄, CO₂, O₂; rest may be present in traces. Common organic constituents may include carbohydrates, humic acid, amino acids, fulvic acid, lignins, tannins, hydrocarbons, acetates, propionates; however, their concentrations are very low.⁴ A wide range of chemical reaction may also occur between solids, gases and solutes present in water. The chemical reactions include acid-base, complexation, hydrolysis, redox reactions. Presence of solute in water may be due to different physical processes including solubility-precipitation and adsorption process. Atmospheric carbon dioxide dissolves in water to form carbonic acid, bicarbonate, and carbonate, whereas atmospheric oxygen dissolves unchanged.

Different standards have been prescribed for water for a particular use. For drinking water standards prescribed by W.H.O. and B.I.S. are most commonly used.⁵ The quality and quantity of water in an aquifer need to be known for its proper use. This is known by studying the hydro geochemistry.⁶ The hydrogeochemical evaluation of groundwater provides knowledge about time and origin of ground recharge, time period of water in aquifer, composition of minerals, interaction and mixing of water from different sources and (bio) geochemical processes occurring during journey of water through the system.⁷ Therefore, the study of hydrogeochemistry creates extensive management and conservation of groundwater and surface water.⁸ In this paper a case has been studied on the Hydrogeochemistry of Groundwater in Kushaiguda region, Reddy District, Andhra Pradesh, which is not traceable in literature.

MATERIALS AND METHODS

The data for the evaluation of Hydrogeochemistry of groundwaters of the study region is taken from the paper which has been already published.⁹ The analysis of Hydrogeochemistry of waters of the investigative area is carried by Using Aqua Chem Software and MS- EXCEL.

RESULTS AND DISCUSSION

The investigative results of the physiochemical indices⁹ are given in Table-1. From the above data, the evaluated hydrogeochemistry of underground waters of the study area is discussed below:

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Table 1. Physicochemical indices of Water Quality Parameters

Sample ID	Station ID	pH	Cond.	TDS	TH	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	SO ₄ ²⁻	HCO ₃ ⁻	CO ₃ ²⁻	Cl ⁻
1	KW-1	6.48	1730	1107	500	152	29	51	8	39	305	12	213
2	KW-2	6.98	2530	1619	115	248	29	89	16	91	549	54	845
3	KW-3	6.61	1556	995	250	712	372	127	12	78	354	48	533
4	KW-4	7.1	2858	1140	650	240	12	64	12	39	329	48	369
5	KW-5	7.07	1960	1254	218	112	462	62	9	36	476	60	206
6	KW-6	6.55	1265	809	102	244	508	89.7	13	91	403	36	497
7	KW-7	7.06	2380	1523	480	104	54	63	5	32	476	60	198
8	KW-8	6.77	2120	1356	430	196	15	47	5	36	378	48	256
9	KW-9	6.78	2130	1363	630	200	32	33	7	39	354	36	263
10	KW-10	6.64	2240	1433	640	204	32	33	5	41	329	54	312
11	KW-11	6.75	2525	1616	500	244	27	43	6	45	354	60	533
12	KW-12	7.18	1364	872	310	184	36	46	4	28	464	30	185
13	KW-13	6.85	2250	1440	290	80	22	43	6	23	244	66	128
14	KW-14	6.66	2881	1843	480	164	17	60	5	32	354	30	249
15	KW-15	6.82	2470	1580	490	180	10	43.7	6	32	464	48	334
16	KW-16	6.65	1860	1190	660	16	15	38	3	28	561	36	277

Hydrogeochemical facies: Hydrogeochemical facies evaluation provides important information about groundwater type which reflects the chemical reaction occurs when water passes through pores of soil and rock fractures (Kehew, 2001). Different categories of plots reveal the nature of the minerals with water which is in contact. Some of the important plots are:

area as listed below (Table-2). The sample points plotted in triangle of piper plot again classified into six fields (indicated by a to f). From this classification, the waters of the study area were classified into five categories indicated by a, b, c, d and f (Table-3).

Durov Plot: The Tri-linear Durov Plot is plotted by following the prescribed procedure (Young, 1985) in which the percentages of major ions are expressed in milliequivalents.

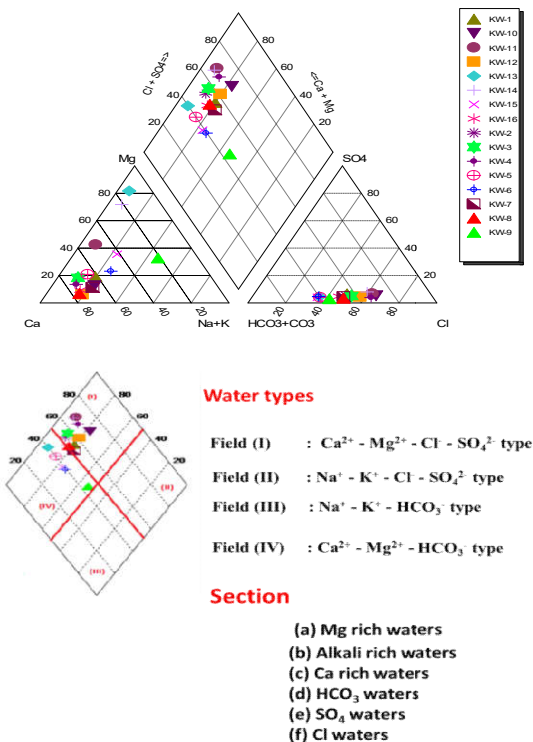


Figure 1: Piper Trilinear diagram showing hydro geochemical facies of groundwater

Piper Plot: Piper plot separates the corresponding qualities as groups, therefore it is important for recognition of resemblance and variation of groundwater (Piper, 1944). The Piper plot is convenient for presenting the trends of major ions of multiple samples. The percentage of major cations and anions in meq/L are plotted in two separate triangles. The overall cations and anions in meq/L are calibrated to 100% and then data points of its two triangles projected over diamond grid. This diamond grid discloses certain important relationship of the total ions. All samples are projected by three data points, i.e., one in each triangle and one in the diamond grid. From the above Piper Diagram, the following types of waters are found in the study

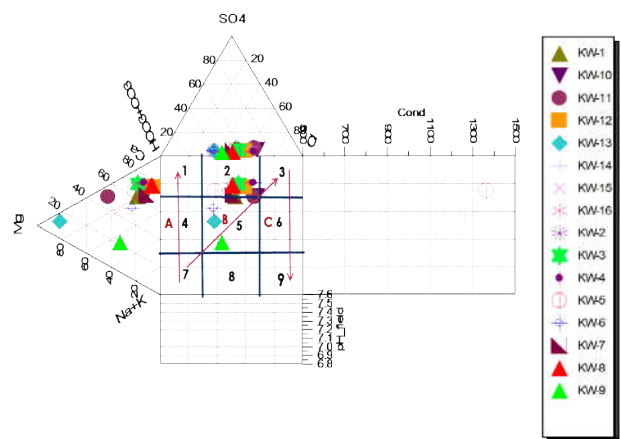


Figure 2: Durov plot showing hydro geochemical facies of groundwater

From this plot we can evaluate the following classes of water type:

- (i) Bicarbonate and calcium dominant, which indicates that the water is recharging in lime stone, sand stone, and many other aquifers,
- (ii) Association with dolomite or ion exchange clay,
- (iii) Bicarbonate and sodium dominant means the water belongs from ion exchange, however at the depth, the formation of CO₂ can produce bicarbonate under certain circumstances when sodium is dominant,
- (iv) Calcium and sulfate dominant indicates the lava or gypsiferous deposits recharge water,
- (v) No dominant cation and anion reveals that the water is exhibiting simple dissolution or mixing,
- (vi) Sulphate and sodium dominant water type indicates the probable mixing or uncommon dissolution influences,
- (vii) Chlorine and sodium dominant water is only when there is presence of cement, otherwise the waters are reversed ion exchange of Na-Cl type,
- (viii) Cl ions and Na ions dominant indicates that the groundwaters may corresponds to reverse ion

Table 2. Classification of water based on Piper diagram

S.No.	Water Type	No. of Samples	%
A	Normal earth alkaline water with prevailing bicarbonate	....	....
B	Normal earth alkaline water with prevailing bicarbonate and sulphate or chloride	6	37.5
C	Normal earth alkaline water with prevailing sulphate or chloride	4	25
D	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate	3	18.75
E	Earth alkaline water with increased portions of alkalis with prevailing sulphate or chloride	3	18.75
F	Alkaline water with prevailing bicarbonate	....	....
G	Alkaline water with prevailing sulphate or chloride	....	....

Table 3. Classification of water based on Piper diagram

S.No.	Water Type	No. of Samples	%
A	Mg rich waters	2	12.5
B	Alkali rich waters	1	6.25
C	Ca rich waters	13	81.25
D	HCO ₃ waters	10	62.5
E	SO ₄ waters	....	....
F	Cl waters	6	37.5

Table 4. Classification of waters on the basis of Durov plot

S.No.	Water Type	No. of Samples	%
1	Bicarbonate and calcium dominant, which indicates that the water is recharging in lime stone, sand stone, and many other aquifers	....	....
2	Association with dolomite or ion exchange clay	4	25
3	Bicarbonate and sodium dominant means the water belongs from ion exchange, however at the depth, the formation of CO ₂ can produce bicarbonate under certain circumstances when sodium is dominant	....	....
4	Calcium and sulfate dominant indicates the lava or gypsiferous deposits recharge water	....	....
5	No dominant cation and anion reveals that the water is exhibiting simple dissolution or mixing	12	75
6	Sulphate and sodium dominant water type indicates the probable mixing or uncommon dissolution influences	....	....
7	Chlorine and sodium dominant water is only when there is presence of cement, otherwise the waters are reversed ion exchange of Na-Cl type	....	....
8	Cl ions and Na ions dominant indicates that the groundwaters may corresponds to reverse ion exchange of Na-Cl type water	....	....
9	Cl ions and Na ions dominant simply indicates that the resultant down gradient waters through dissolution.	....	....

exchange of Na-Cl type water, (ix) Cl ions and Na ions dominant simply indicates that the resultant down gradient waters through dissolution. In the by Ca²⁺ and HCO₃⁻ ions and 75% water samples of theinvestigative area shows that there is no dominance of anion and cation which shows that they are exhibiting direct dissolution and mixing (table-4). study area, 25% of the water samples are dominated.

Geochemical Process: The evaluation of causes for changes in quality of groundwater and planning for protection of groundwater, the following hydrogeochemical processes are used for identification the mechanism that controlling the chemistry of groundwater of the study area.

The Gibbs Diagram: From the Gibbs diagram the mechanism of quality control and dominated hydro geochemical facies can be evaluated (Gibbs, 1970). From the Gibbs diagram three distinct fields can be characterize such as the dominance of rock–Water interaction, Precipitation dominance, and Evaporation dominance (all the ions are expressed in meq/L).

$$\text{Gibbs ratio (for cation)} = \frac{Na^+ + K^+}{Na^+ + K^+ + Ca^{2+}}$$

$$\text{Gibbs ratio (for anion)} = \frac{Cl^-}{Cl^- + HCO_3^-}$$

The Gibbs ratio (for cations and anions) verses total dissolved solid concentration (TDS) of the water samples is plotted and calculated Gibbs equation values (fig.-3). From the Gibbs Equation we can infer whether the water source belongs to evaporation dominance field or Precipitation dominance or rock–water dominance field.

The distribution of groundwater samples of the study area suggests that the qualities of most of the samples are influencing the chemical weathering of rock-forming minerals. It is obvious that most of the cations and anions of water samples are derived from the rock weathering and not evaporation, precipitation and crystallization which suggest that the mechanism controlling groundwater chemistry is mainly water-rock interactions. Therefore, the rock-water interactions incorporate the dissolution or weathering of these minerals forming aquifer and the cation-exchange reaction taking place on the clay minerals.

Source rock deduction: The Rock Source Deduction report helps in gaining information about the possible origin of water samples (Thilagavathi, 2012). According to the Gibbs diagram, mostly ions are derived from the rock weathering of crystalline dolomite, limestone and Ca-Mg carbonates. If TDS values are more than 600mg/L the formation of calcite and dolomite is easy (Brindha, 2014). If the average TDS value in the study area is greater than 600mg/L, then it is possible that calcite and dolomite containing rocks are present in equilibrium with water. The plot between (Ca²⁺ + Mg²⁺) and (HCO₃⁻ + SO₄²⁻); fig. (4a) indicates that mostly data point of the samples is above 1:1 equiline which indicates that the cations present may have originating by weathering of carbonate rocks. The plot between (Ca²⁺ + Mg²⁺) and (HCO₃⁻); fig. (4b) indicates that mostly data points of the samples are above 1:1 equiline which suggests that a part of the carbonate alkalinity is stabilized by alkali (Na⁺ and K⁺). The ratio of Na⁺/ (Na⁺ + Cl⁻) when less than 0.5 and TDS is greater than 500 suggest the reverse softening of water.

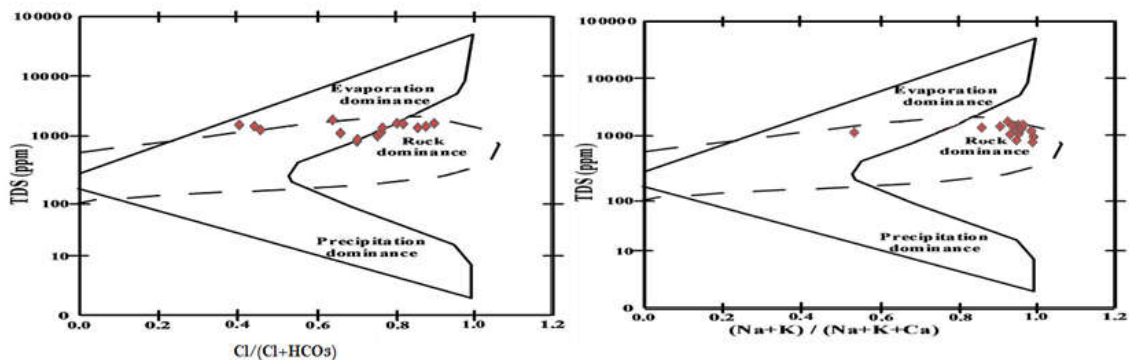


Figure 3. Gibbs diagram for groundwater of the investigative area

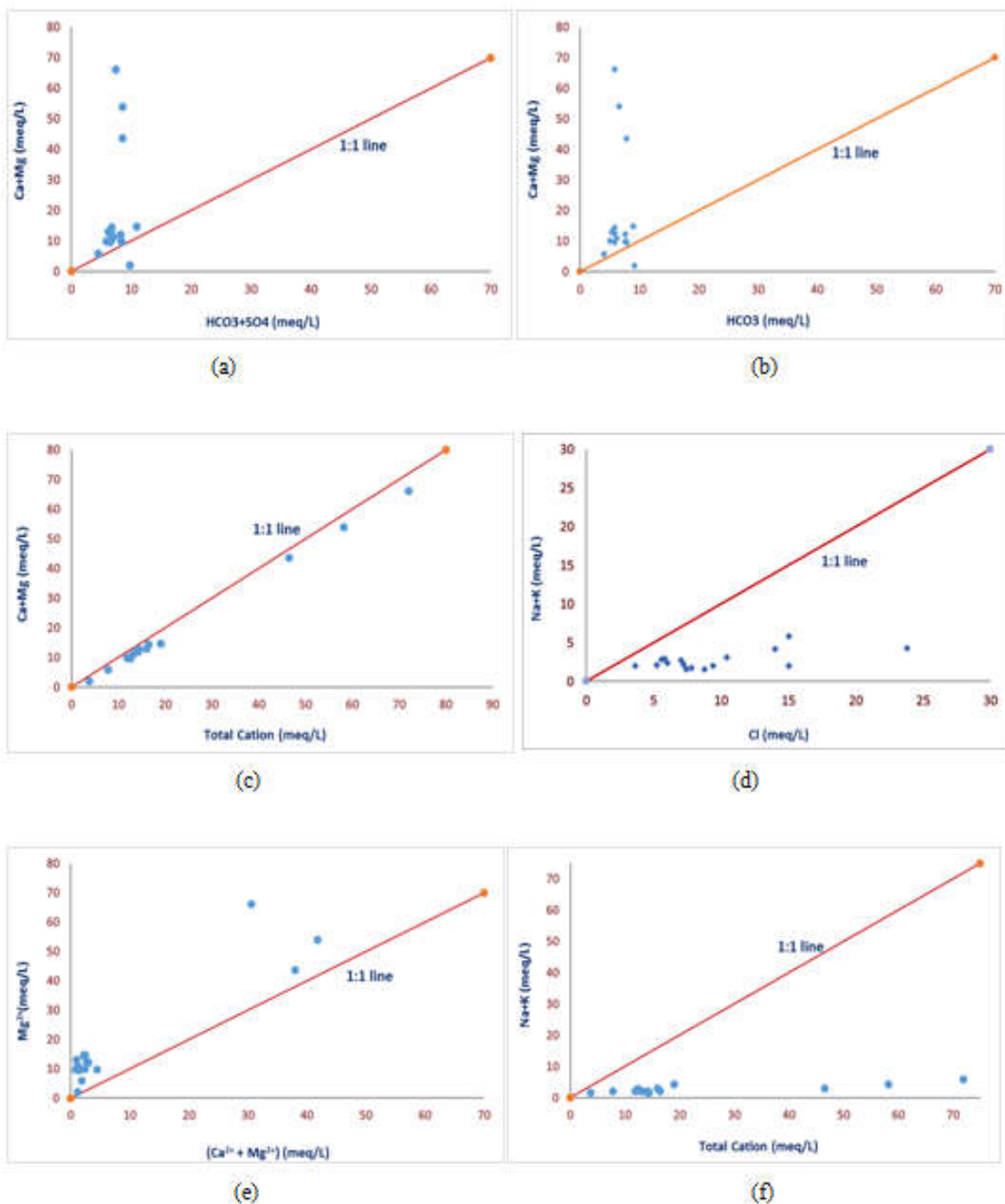


Figure 4. Different Bivariate plots

Moreover, the excess of $Ca^{2+} + Mg^{2+}$ is however leveled by Cl^- and SO_4^{2-} ions (Wen, 2005). The plot between $(Ca^{2+} + Mg^{2+})$ and total cations; fig. (4c) reveals that the mostly data point is just on the 1:1 equiline which indicates the constant contribution of Na^+ and K^+ . in fig. (4d), the plot against $(Na^+ + K^+)$ and Cl^- shows that the lack of $(Na^+ + K^+)$ over Cl^- in the water, this indicates the carbonate weathering.¹⁷ Additionally the Average molar ratio of $Mg^{2+} / (Ca^{2+} + Mg^{2+}) < 0.5$; fig. (4e) reveals that the origin of Ca and Mg is carbonate weathering, particularly calcite-dolomite weathering. However, the ratio of $(Na^+ + K^+)$ verses total cations (less than 0.2), fig (4f)., of groundwater samples of the study area indicates that cations in the water samples originated via carbonate weathering to some extent.¹⁸⁻¹⁹

Cation-Exchange Reaction: One of the important geochemical reactions is Cation exchange reactions. This reaction controls the origin and distribution of ions in the groundwater. These can be recognized by using the correlation between the sodium and Chloride ions. The cation exchange reaction is evident as the Concentration of Na^+ ion is high with respect to Cl^- ion (Jha, 2016). In the typical cation exchange reaction, Ca^{2+} ion can be remained as in the aquifer materials and Na^+ ion is liberated to the water which is not leveled by Cl^- ions, however can be balanced by alkalinity or SO_4^{2-} ions. In the reverse cation exchange reaction Na^+ ion is remained as in the aquifer and Ca^{2+} ion is liberated to the water. In the study area, Excess concentration of Cl^- ions over Na^+ ions (fig.-5) is balanced by Ca^{2+} ions and Mg^{2+} ions and is a good indication of cation exchange reaction (Senthil, 2013).

Irrigation Water Quality: There are mainly four types of problem when using poor quality of water: (i) Toxicity (ii) Salinity (iii) Water infiltration rate and (iv) Miscellaneous (Ayers, 1985). The parameters EC, TDS, SAR, MAR, SSP, RSBC, PI, KR, sodium percentage etc (Michael, 1987; Raghunath, 1987) are determined and collated with national and international grades to estimate the water quality for irrigation purposes in which EC, TDS, SAR, MAR, SSP, RSBC have already been discussed in relevant paper^[9]. For current evaluation of the irrigation water quality in the investigative region, the following parameters have been considered:

Permeability Index: The permeability index (PI) provides significant information for improvement of the quality of water for irrigation (Thilagavathi, 2012; Thivya, 2013). The Permeability Index in the groundwater sample evaluates the overall concentrations of sodium and bicarbonate to total cations (Doneen, 1964).

Table 5. PI and KR values of Water samples

Sample ID	Station ID	PI	KR
1	KW-1	18.35	0.22
2	KW-2	16.1	0.26
3	KW-3	3.36	0.08
4	KW-4	14.75	0.21
5	KW-5	6.03	0.06
6	KW-6	4.44	0.07
7	KW-7	22.58	0.28
8	KW-8	19.06	0.18
9	KW-9	17.15	0.11
10	KW-10	16.3	0.11
11	KW-11	14.81	0.13
12	KW-12	19.5	0.16
13	KW-13	26.07	0.32
14	KW-14	19.76	0.27
15	KW-15	23.56	0.19
16	KW-16	82.29	0.81

Table 6. Limits of some important parameters for irrigation water quality^{7, 22, 29}

S.No.	Parameters	Range	Suitable for irrigation
1	SAR	<10	Excellent
		10-18	Good
		18-26	Doubtful
		>26	Unsuitable
2	SSP	<20	Excellent
		20-40	Good
		40-80	Fair
3	PI	>80	Poor
		>75	Good
		25-75	Moderate
4	KR	<25	Poor
		<1	Good
5	RSBC	>1	Unsuitable
		<5	Safe
		5-10	Marginal
6	MAR	>10	Unsatisfactory
		<50	Good
		>50	Unsuitable

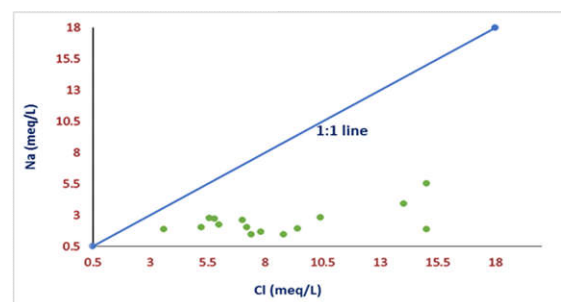


Figure 5. Plot of Na+ (meq/L) vs. Cl- (meq/L)

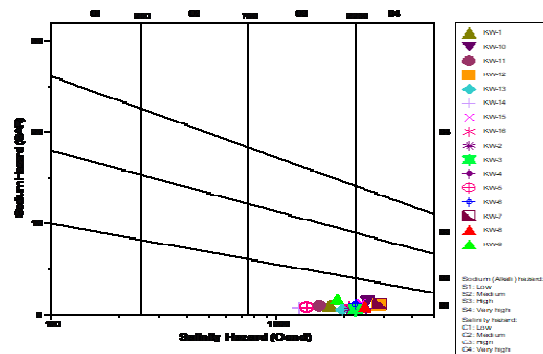


Figure 6. Wilcox diagram for groundwater of the investigative area

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

The PI values of the groundwater samples of the investigative area are given in the above table. This PI values indicates that only sample no. 16 belongs to class-I (PI >75%) and sample no. 13 belongs to class-II (25–75 %) and rest belongs to class-III (PI <25 %) types of water indicated good, poor and very poor respectively for irrigation purpose in the study region.

Kelley's ratio: Kelley's ratio (KR) is an index of the suitability of waters for the irrigation in agriculture. Sodium is measured with respect to calcium and magnesium for calculation of KR parameter. The acceptable limit of the Kelly's ratio is less than one (<1) of waters for irrigation (Kelly, 1940). In the study region, the KR ratio of all the samples are below such standards, i.e., <1 which shows that all the waters are suitable for irrigation.

$$\text{Kelley's ratio (KR)} = \frac{\text{Na}^+}{\text{Ca}^{2+} + \text{Mg}^{2+}}$$

Wilcox Plot: The Wilcox plot is usually used for the evaluation of the viability of water for irrigation (Wilcox, 1955). The other name of Wilcox plot is the U.S. Department of Agriculture diagram. According to Wilcox diagram (fig.-6) all water samples of the study region shows low sodium hazards and high and very high salinity hazards.

Conclusion

The mean trend of anions and cations in the groundwater of the Kushaiguda region, Reddy District is $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$ and $\text{Ca} > \text{Mg} > \text{Na}$ respectively. Considering hydrogeochemical facies, 25% of the water samples are dominated by Ca^{2+} and HCO_3^- ions and 75% water samples of the investigative area shows that there is no dominant of anion and cation which indicates that they are exhibiting direct dissolution and mixing. From the Gibbs diagram the quality of groundwaters of the investigative area is influenced by rock forming minerals of carbonate - weathering minerals rather than precipitation, crystallization and evaporation. Different irrigation water quality parameters and diagrams such as, Permeability index (PI), Kelley's ratio (KR) and Wilcox plot revealed that mostly water samples are satisfactory for irrigation.

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