Hydrochemical Assessment of Groundwater Quality in Kadur, Chikmagalur, Karnataka, India

Harish H.P, Abhilash M R *

Department of Studies in Environmental Science, University of Mysore, Manasagangotri, Mysuru 570006, India

*Corresponding Author: Abhilash M R

Abstract: **The hydro chemical study reveals the quality of water and its suitability for drinking, agriculture and industrial purposes. Presence of extreme quantities of salts in groundwater is one of the major constrains in agro-well farming and domestic use in Kadur, Chikmagalur. Irrigation with poor quality ground water in study area had many threats such as agricultural activities, over exploitation, rock interaction in aquifers and also persistence of continuous drought condition bringing uninvited rudiments to the soil in excessive quantities affecting its fertility and people health. This study mainly addresses Hydrogeochemical studies in the fourteen water samples of Kadur to understand the chemistry of water and to assess the suitability of water by using modern tools and secondary parameters. The results of all the findings are discussed in details which reflect the present status of the groundwater quality in the study area.**

I. INTRODUCTION

Hydrochemical studies of a groundwater provide a superior understanding of possible changes in quality as development progress for effective practice of individuals. It was estimated that approximately one third of the world's population use groundwater for drinking and agriculture. Hydrochemical study reveals the quality of water that is suitable for drinking, agriculture and industrial purposes and helps in understanding the change in quality due to rock–water interaction of anthropogenic influence (Kelley 1940; Wilcox 1948). The chemical parameters of groundwater play a significant role in classifying and assessing water quality. It was observed that the criteria used in the classification of waters for a particular purpose considering the individual concentration may not find its suitability for other purposes and better results can be obtained only by considering the combined chemistry of all the ions rather than individual characters (Handa 1964, 1965; Hem 1985). Chemical classification also throws light on the concentration of various predominant cations, anions and their interrelationships. Anthropogenic activities can alter the relative contributions of the natural causes of variations and also introduce the effects of pollution (Whittemore et al. 1989). Effective management of groundwater, there is a requirement for improved understanding of the controlling processes like natural, geologically controlled baseline chemistry. This is especially important if the impacts of contaminants on groundwater are to be clearly assessed. Consecutively to understand the pollution trends and impacts on an aquifer, it is essential to have knowledge of the natural baseline quality so that imposed environmental change can be measured with an acceptable degree of confidence (Edmunds et al. 2003).

II. MATERIALS AND TECHNIQUES EMPLOYED

Best quality available, commercial analytical grade reagents and chemicals were used as such while preparing desired concentration and grades as per the "standard Method for Examination of water and wastewater" prescribed in APHA-AWWA-WPCF (14th edition 1976), and "Methods For Chemical Analysis of Water and Waste" by Environmental Protection Agency (EPA), 1983, those described by the central pollution control board (CPCB) in "Guide Manual: Water and Wastewater Analysis". The major ion concentration data has been processed using the HYCY- Basic Computer program developed by Balasubramanian *et al.*, (1991). In the program, hydrochemical facies classification is attempted using the criteria of Handa (1964), Piper (1944), Stuyfund (1989), and USSL (1955) schemes. The Index of Base Exchange (IBE) and groundwater types are also computed using Scholler's procedure (1976). Scholler's also specified that, the first and foremost waters are expected to have $rCO_3^- > rSO_4^-$ (Type 1) as the total concentration increases it becomes $r\,SO_4^- > rCl^-$ (Type2) and $rCl^- > rSO_4^-$ (Type3) and $rNa^+ > rMg^{++} > rca^{++}$ (Type4). The water types of this area have been identified using this procedure. Ryzner (1944), proposed the corrosive tendencies of flowing water in a metallic pipe. Corrosivity ratio was calculated using the formula. Gibbs (1970) proposed plots using the chloroalkaline indices for inferring the mechanism controlling the chemistry of groundwater. Sodium adsorption ratio (SAR) was calculated using the formula, The output of HYCY-Basic Computer program contains information pertaining to the ionic strength, Index of Base Exchange (IBE), Non Carbonate Hardness (NCH), total hardness water types of Scholler and Stuyfund, Permeability Index of Donnen, Piper Hydrochemical Facies, USSL classes of water quality and the mechanism controlling water chemistry. A comprehensive picture of the water quality criterion is obtained using this software.

Figure 02: Hydrogeological Map of Chikmagalur District

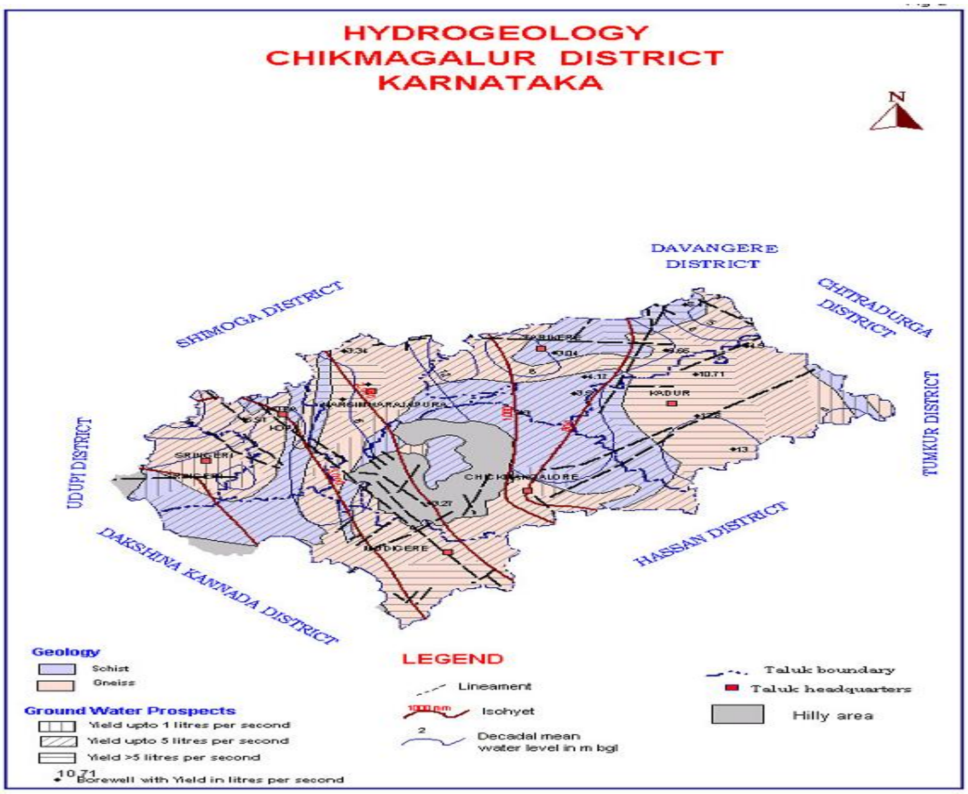


Table 01: Sample locations and Sample code.

Sl.No.	Sample Code	Location
1	KDR-01	Keresanthe
2	KDR-02	Singitagere
3	KDR-03	Panchanahalli
4	KDR-04	Chowlhiriyur
5	KDR-05	Antaragatte
6	KDR-06	Giriyapura
7	KDR-07	Ballekere
8	KDR-08	Hochihalli
9	KDR-09	Machagondanahalli
10	KDR-10	Bommenahalli
11	KDR-11	Nidagatta
12	KDR-12	Sakkarayanapatna
13	KDR-13	Patnigere
14	KDR-14	Devanur

III. RESULTS AND DISCUSSIONS

Hydrogeochemical Studies: The soil zone has unique and powerful capacities to alter the water chemistry, as infiltration occurs through areas, the soil zone undergo a net loss of mineral matter to flowing water. As groundwater moves along flow lines from recharge to discharge areas, its chemistry is altered by the effect of variety of geochemical processes (Freeze et al., 1979).

Sodium Adsorption Ratio (SAR): The expression of the equilibrium between exchangeable positive ions (Cations) in the soil and cations in the irrigation water is known as Sodium Adsorption. It gives a measure of suiltability of water for irrigation with respect to the sodium (alkali) hazards High SAR values may cause damage to soil. The SAR may be determined by the formula (epm).

Sodium Adsorption Ratio	Water types
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Table 02: Sodium Adsorption Ratio

From the experimental results obtained, it was found that, all the samples from the study area have found to be excellent type with respect to SAR values. KDR-02 found to have maximum epm of 7.686 among all the samples.

Residual sodium carbonate (RSC): In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influence the inappropriateness of groundwater for irrigation. This is termed as residual sodium carbonate (RSC) (Richard L.A). The RSC is calculated using the formula given below:

Corrossivity Ratio: Corrosion is an electrolytic process that takes place on the surface of the metals, which severely attacks and corrodes away the metal surfaces. Most of the corrosion problems are associated with salinity and encrustation associated with alkalinity. Badrinath *et al.*, (1984) used the corrossivity ratio to evaluate the corrosive tendencies of river waters.

Water having corrosivity ratio less than 1 is considered to be non- corrosive, while the value above 1 is considered as corrosive. From the analysis of all ground water samples, the corrosivity ratio was found to be greater than 1 epm, except, samples from KDR-10, KDR-12 and KDR-13 which were found to have values less than 1 epm. KDR-14 sample found to have very high corrosivity ratio of 11.9432 epm. The results indicate that, 80% of the samples from the study area found to have corrosivity ratio greater than 1 epm.

USSL Classification: According to a method formulated by the US Salinity Laboratory (1954), water used for irrigation can be rated based on salinity hazards and sodium or alkali hazards and sodium or alkali hazard. When the sodium hazard ratio and Electrical conductivity of water are known, classification of water for irrigation can be done by plotting these on the diagram. Low salinity water ($C1^-$ <250i-250mho/cm) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop.

Table 03: USSL Diagram

Salinity Hazard	Sodium Hazard
S1 - Low	C1 - Low
S2 - Medium	C2 - Medium
S3 - High	C3 - High
S4 - Very High	C4 - Very High
S5 - Extreamly High	C5 - Extremely High

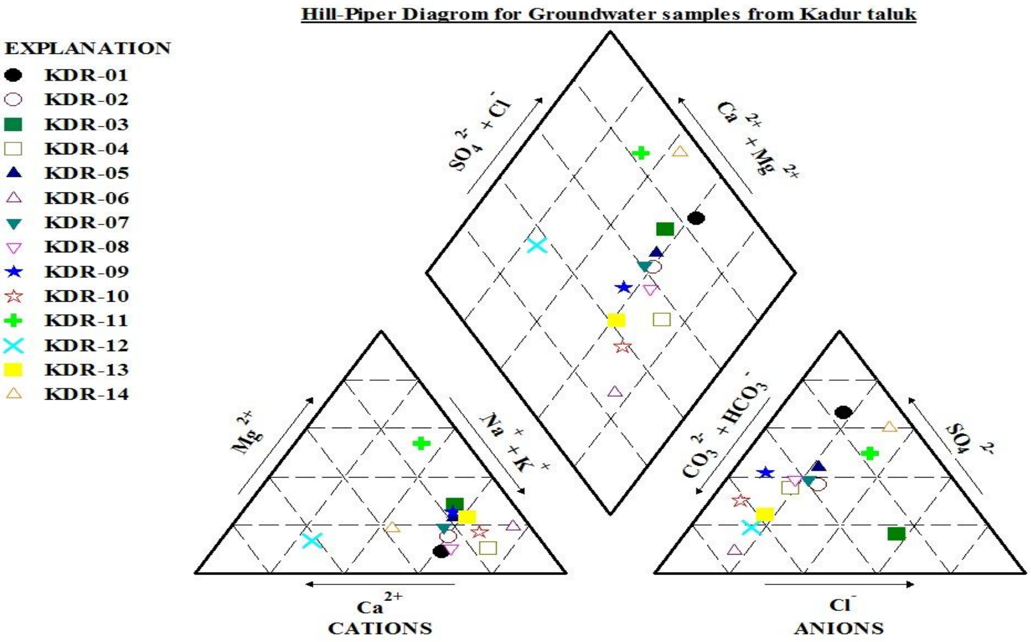
From the study, it was observed that, most of the samples from the study area are found to be C3S2, C4S2, and C2S1 type. Samples from KDR-01, KDR-04, KDR-05, KDR-06, KDR-07 and KSR-08 are found to have Medium Salinity with High Sodium hazard (C3S2) and KDR-03, KDR-11 and KDR-14 are found to have Very high salinity with Medium sodium (C4S2). And sample from KDR-09 have found to have low salinity with low Sodium hazard (C1S1).

Permeability Index: The soil permeability is influenced by long term used of irrigation water containing and Bicarbonates. Permeability Index is calculated using the formula (Donean, 1966)

Ground Water Facies: Back (1961, 1966), Morgan and Winner (1962), and Seaber (1962) introduced the concept of Hydrochemical facies (Freeze and Cherry, 1979). The facies represent district zones with definite cation and anion concentrations and it depicts the diagnostic chemical character of water in various parts of the system. Flow patterns modify the hydrochemical facies and control their distribution. Hydrochemical facies of groundwater for the study region have been analysed using the following approaches.

1. Modified hill-piper Diagrom
2. Indices of Base exchange
3. Schoeller's water type
4. Gibb's plot of determining the Mechanisms controlling ground water Chemistry
5. Stuyzfzand's Classification and
6. $CaCO_3$ Saturation Indices.

Modified Hill Piper Diagram: The modification of Hill-piper method as proposed by Handa (1964) has been reported in the present works for the classification of groundwater in regard to their suitability for not only domestic purpose but particularly for irrigation purposes. He has combined the trilinear plot of piper and the U.S salinity Research Lab Diagram with some modifications. Instead of SAR, the percent sodium concentration is plotted against salinity. Hence water could be classified into A1, A2, A3 or B1, B2, B3 classes (based on salinity and other ionic relation), C1, C2, C3, C4 and C5 classes (based on salinity) and S1, S2, and S3 classes (based on sodium hazards).



igure 02: Modified Hill-Piper diagram for groundwater samples from Kadur.

Table 04: Basic Criteria used in Handa's Classification

Type	Ca^{2+} $+Mg^{2+}$	Ca^{2+} + Mg^{2+}	$Cl^{-}+SO_4^{2-}$	Charecterstics
A1	$>HCO_3^-$	$>Na^+K^+ +$	$<HCO_3^-$	Non-Carbonate Hardness
A2	$>HCO_3^-$	$>Na^+K^+ +$	$>HCO_3^-$	Non-Carbonate Hardness
A3	$>HCO_3^-$	$<Na^+K^+ +$	$>HCO_3^-$	Non-Carbonate Hardness
B1	$<HCO_3^-$	$>Na^+K^+ +$	$<HCO_3^-$	Carbonate Hardness
B2	$<HCO_3^-$	$<Na^+K^+ +$	$<HCO_3^-$	Carbonate Hardness
B3	$<HCO_3^-$	$>Na^+K^+ +$	$>HCO_3^-$	Carbonate Hardness

Table 05: Salinity TSC/TSA (epm)

C1	Low	<2.5
C2	Low to medium	2.5-7.5
C3	Medium to high	7.5-22.5
C4	High to very high	22.5-37.5
C5	Extremely high	>37.5

Table 06: Sodium Hazard

S1	Low sodium water	0-30
S2	Low to medium sodium water	30-57.5
S3	Medium to high sodium water	57.5-100

The study area characterized by both water having temporary and permanent hardness. But 64% of the water samples are in permanent hardness (A1, A2 and A3) remaining samples are in temporary hardness (B1, B2 and B3).

Indices of Base Exchange

Schoeller (1965 and 1967) suggested two chloroalkaline indices CAI 1 and CAI 2 to indicate the exchange of ions between the groundwater and its host environment. The exchange of ions Na^+ and K^+ from the water with the Mg^{++} and Ca^{++} in the rock is designated as direct exchange. If the exchange is reversing, it is known as reverse exchange, this may be represented as a reversible chemical reaction. Based on Schoellers (1965, 1967) water type classifications, all the samples are falling under Type II except sample KDR-03 where it is fall under Type IV.

Mechanism of controlling groundwater chemistry: Gibb's (1970) discussed the relationship between water composition and aquifers lithology. Vishwanathaiah *et al.*, (1978) have studies the mechanisms controlling the groundwater composition of Karnataka. Gibb's plots distinguish the interaction of groundwater due to precipitation or rock interaction or evaporation by demarcating these folds. This helps in understanding the factors that control the chemistry of groundwater. According to Gibb's plot, all the samples in the study area are under the category of Rock interaction, except the sample KDR-02 and KDR-09 are found to have the category of Evaporation.

Table 07: Gibb's plots

Category		No.of samples
Evaporation	Longer residence time	02
Rock Interaction	Dissolution mixing of mineral matter	12
Precipitation	Recent recharge water	00

Stuyfzand Classification: Stuyfzand (1986, 1989) proposed a hydrochemical classification system for the determination of water type that helps in successive identification of main types, such types and class of water sample.

Main types: The Chloride content determines the main types, as indicated in Table. The boundaries are based upon criteria discussed in Stuyfzand, 1986.

Table 08: Division of main types based on chloride concentrations.

Main Type	Code	Cl^- (mg/L)
Very Oligohaline	G	<5
Oligohaline	g	5-30
Fresh	F	30-150
Fresh brackish	f	150-300
Brackish	B	$300\text{-}10^3$
Brackish salt	b	$10^{3}\text{-}10^4$
Salt	S	$10^4 – 2.\ 10^4$
Hyperhaline	H	$>2.\ 10^4$

Boundaries in mg/L: 5, 30, 150, 300, 1000, 10000, 20000

From this classification, 7 water samples are characterized by Fresh. Both Fresh Brackish and Brackish characterized by 3 samples each. KDR-09 is the only sample found characterized by Oigohaline.

Types: Each main type is further subdivided into a maximum of 11 types according to alkalinity, Table The upper boundary of each type except no. 9, is defined by: Upper boundary type $X= 2^x$ in meq/L**.** Where X is an integer between -1 and 9.

Table 09: subdivision of main types into types according to alkalinity

Type/ no. name	Alkalinity(meq/L)	Code
-1 Very low	<1/2	*
0 Low	½-1	0
1 Moderate low	1-2	1
2 Moderate	2-4	2
3 Moderate high	4-8	3
4 High	8-16	4
5 Very high	16-32	5
6 Extremely	32-64	6
7 Extremely high	64-128	7
8 Extremely high	128-256	8
9 Extremely high	>256	9

From this classification, 9 water samples are under Alkalinity moderately high and remaing 5 samples are under Alkalinity high and Moderate Alkalinity. Sample KDR-02, KDR-09 and KDR-10 are under Alkalinity High.

Calcium Carbonate Saturation Indices: The percolating water is assumed to equilibrate rapidly with soil carbon dioxide and calcite in an open system (Wallick, 1976) becomes weakly acidic as a powerful weathering cum-dissolution agent and disintegrate, decompose the country rocks and leach away the soluble salt, while passing through calcium bearing rocks. Calcium is dissolved as $Ca\ (HCO_3)_2$ due to the influence of carbon dioxide, temperature, pH, Ionic strength of solutions and the organic content of groundwater.

Groundwater passes through unsaturated, saturated and over saturated stages of $CaCO^3$ saturation indices of groundwater for the present study area are calculated using,

1. The equilibrium pH method (Hem 1961; Handa 1964)
2. The equlibrium Ca^{++} method (Back 1961, 1963, Rebertson 1964, Bhandari et al., 1975).

Secondary Parameters	**KDR-01**	**KDR-02**	**KDR-03**	**KDR-04**	**KDR-05**	**KDR-06**	**KDR-07**
Sodium Adsorption Ratio (SAR)	6.915411	7.686306	6.042814	7.350513	6.242573	9.658638	6.207446
Residual Sodium Carbonate (RSC)	-5.05615	-6.590176	-3.915956	2.514733	-1.539674	3.160745	-1.232147
Non-carbonate Hardness.	252.8075	3.295088	195.7978	-125.7366	76.98369	-158.0373	61.60736
Permeability Index(Doneen)	70.66415	73.98258	67.80105	93.85648	71.60629	90.70007	75.12495
Ionic Strength	0.0351	0.0387	0.0308	0.0159	0.0320	0.0258	0.0277
Corrosivity Ratio (CR)	4.3992	1.3619	2.3146	1.0105	1.6015	1.2396	1.2794
Indices of Base Exchange (IBE)	-2.5304 -0.5411	-1.4193 -0.4972	0.0116 0.0158	-2.8639 -0.6826	-1.6520 -0.4732	-7.1928 -0.7378	-1.7709 -0.4992
CaCO$_3$ SATURATION INDICES							
Equilibrium Ca method	-0.8109	0.3653	0.8075	0.5375	-0.4205	-6.3373	-0.3152
Equilibrium pH method	0.4820	0.8372	1.1556	0.9749	0.7875	0.2745	0.7209
GIBB'S PLOT							
Mechanism Controlling the Chemistry	Rock Interaction	Evaporation	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction
HANDA'S CLASSIFICATION							
Hardness	A3 Permanent	A3 Permanent	A3 Permanent	B3 Temporary	A3 Permanent	B3 Temporary	A3 Permanent
Salinity	C4 High	C5 V.High	C4 High	C3 Moderate	C3 Moderate	C3 Moderate	C3 Moderate
Sodium hazard	S3 High	S3 High	S2 Moderate	S2 Moderate	S2 Moderate	S3 High	S2 Moderate
SCHOELLER'S WATER TYPE (r=epm)	II Since rSO4 > rCl	II Since rSO4 > rCl	IV Since rCl > rSO4 > rCO3 and rNa > rMg > rCa	II Since rSO4 > rCl	II Since rSO4 > rCl	II Since rSO$_4$ > rCl	II Since rSO$_4$ > rCl
PIPER'S HYDROGEOCHEMICAL FACIES							
Cations	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg
Anions	Cl+SO4	Cl+SO4, HCO3+CO3	Cl+SO4, HCO3+CO3	Cl+SO4, HCO3+CO3	Cl+SO4, HCO3+CO3	Cl+SO$_4$, HCO$_3$+CO$_3$	Cl+SO$_4$, HCO$_3$+CO$_3$
Significant Environment	Water Contaminated with Gypsum	Static and Disco-Ordinated Regimes	Water Contaminated with Gypsum	Dissolution and Mixing	Static and Disco-Ordinated Regimes	Dissolution and Mixing	Static and Disco-Ordinated Regimes
STUYFZAND'S CLASSIFICATION							
Water Type (Based on Cl-)	F-Fresh	F-Fresh-brackish	B-Brackish	F-Fresh	F-Fresh-brackish	F-Fresh	F-Fresh-brackish
Sub-Type (Based on Alk)	ALK-MODERATE	ALK-High	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH
Facies	NA+K SO4	Na+K Mixed	Na+K Cl	Na+K Mixed	NA+K Mixed	Na+K SO$_4$	Na+K Mixed
Significant Environment	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere
USSL CLASSIFICATION							
Salinity	C3	C4	C4	C2	C3	C3	C3
Sodium hazard	S2	S2	S2	S2	S2	S2	S2

Secondary Parameters	**KDR-08**	**KDR-09**	**KDR-10**	**KDR-11**	**KDR-12**	**KDR-13**	**KDR-14**
Sodium Adsorption Ratio (SAR)	6.131539	6.991805	6.847847	4.011085	1.264575	5.486616	5.706529
Residual Sodium Carbonate (RSC)	1.16388	3.536049	4.557175	-20.2453	-0.8635483	2.436136	-21.89644
Non-carbonate Hardness.	-58.19402	76.8024	-227.8588	1012.265	43.17741	-121.8068	1094.822
Permeability Index(Doneen)	80.96371	68.40434	89.89976	41.48616	51.36013	91.68141	48.55449
Ionic Strength	0.0213	0.0431	0.0188	0.0662	0.0134	0.0124	0.0708
Corrosivity Ratio (CR)	1.1845	1.5107	0.5419	4.0309	0.4827	0.7045	11.9432
Indices of Base Exchange (IBE)	-2.5200 -0.5702	-1.4566 -0.5838	-7.7507 -0.6741	-0.0514 -0.0258	-0.4974 -0.1016	-2.4249 -0.6146	-0.3303 -0.1671
$CaCO_3$ SATURATION INDICES							
Equilibrium Ca method	-1.0420	1.0000	-2.1359	0.8812	-0.5167	-8.4791	0.0945
Equilibrium pH method	0.4299	-6.599	0.6436	1.5650	0.6590	0.0633	1.0830
GIBB'S PLOT							
Mechanism Controlling the Chemistry	Rock Interaction	Evaporation	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction
HANDA'S CLASSIFICATION							
Hardness	B3 Temporary	A3 Permanent	B2 Temporary	A2 Permanent	A1 Permanent	B2 Temporary	A2 Permanent
Salinity	C3 Moderate	C5 V.High	C3 Moderate	C5 V.High	C3 Moderate	C3 Moderate	C5 V.High
Sodium hazard	S2 Moderate	S3 High	S2 Moderate	S3 High	S1 Low	S1 Low	S3 High
SCHOELLER'S WATER TYPE (r=epm)	II Since $rSO_4 > rCl$	II Since $rSO_4 > rCl$	II Since $rSO_4 > rCl$	II Since $rSO_4 > rCl$	II Since $rSO_4 > rCl$	II Since $rSO_4 > rCl$	II Since rSO4 > rCl
PIPER'S HYDROGEOCHEMICAL FACIES							
Cations	Na+K, Ca+Mg	Na+K, Ca+Mg	Na+K, Ca+Mg	Ca+Mg, Na+K	Ca+Mg, Na+K	Na+K, Ca+Mg	Ca+Mg, Na+K
Anions	$Cl+SO_4$, HCO_3+CO_3	$Cl+SO_4$, HCO_3+CO_3	HCO_3+CO_3, $Cl+SO_4$	$Cl+SO_4$	HCO_3+CO_3, $Cl+SO_4$	HCO_3+CO_3, $Cl+SO_4$	Cl+SO4
Significant Environment	Dissolution and Mixing	Water Contaminated with Gypsum	Static and Disco-Ordinated Regimes	Water Contaminated with Gypsum	Static and Disco-Ordinated Regimes	Dissolution and Mixing	Water Contaminated with Gypsum
STUYFZAND'S CLASSIFICATION							
Water Type (Based on Cl-)	F-Fresh	G-Oligohaline	F-Fresh	B-Brackish	F-Fresh	F-Fresh	B-Brackish
Sub-Type (Based on Alk)	ALK-MOD-HIGH	ALK-HIGH	ALK-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MODERATE
Facies	Na+K Mixed	NA+K $_{SO4}$	Na+K HCO_3	Mg Mixed	Ca HCO_3	NA+K HCO_3	Ca SO4
Significant Environment	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere	(+) Na+Mg Surplus Indicates Freshwater Intrusion-Anytime Anywhere
USSL CLASSIFICATION							
Salinity	C3	C1	C3	C4	C2	C2	C4
Sodium hazard	S2	S1	S2	S2	S1	S1	S2

IV. CONCLUSION

Irrigation water quality was clearly determined based on hydrochemical facies. Out of tested ground water sample Nidagatta (KDR-11) and Devanur (KDR-14) was not good quality to inappropriate irrigation and domestic usage to comparative to other samples. Present study suggested that, Local administration authorities can manage the poor irrigation water by increasing salt tolerance of plants and recuperating irrigation management technologies. The physical, economic, social and institutional costs and feasibility requirements for salt disposal will have to be met as part of the necessary and sufficient conditions for a prosperous long-term anthropogenic use.

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