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Groundwater quality assessment for drinking and irrigation in some villages of Sirsa district, Haryana India

Parul Kumar and Sushma Jain

Abstract
The present research work was carried out in some villages of Sirsa district of Haryana (India) to assess the ground water quality and also check its suitability for irrigation purpose. A total of 15 ground water samples were taken from different locations in both the pre and post monsoon period of 2017. On the basis of chemical analysis, the variation is the mean concentration of cations and that of the anions were observed as $Nat^{+}>Mg^{2+}>Ca^{2+}>K^{+}$ and $Cl^{-}>HCO_3^{-}>SO_4^{2-}>CO_3^{2-}$ respectively in both pre and post monsoon time. The results of the physico chemical study of ground water were compared with the Indian standards and WHO Standards. Several parameters like potential soil salinity (PSS), permeability index (PI), Sodium absorption ratio (SAR), Chloro alkaline Indices (CAI-I and CAI-II), Gibb's ratio (GR.I and G.R.II), Sodium percentage (%Na), Soluble Sodium percentage (SSP), Residual Sodium carbonate (RSC), meteoric genesis (Met. Gen.), Base exchange, Magnesium Hazard, Kelly's ration (KI) were measured to check the suitability for irrigation.

Keywords: Ground water, Sirsa, irrigation water quality, sodium absorption ration (sar), gibb's ratio, ground water chemistry.

Introduction

The rapid growth in human population is intensifying pressure on the natural resources like air, water and soil (Smil 1999) [1]. On the advent of the green revolution in India, the consumption of fertilizers is being increased many times for the increase in agriculture yield (FAO 1996) [2]. The demand of higher food supply can be achieved by intensive use of fertilizers and pesticides. This intensive use of agrochemicals is posing serious health and environmental problems. According to WHO report, the insufficient access to fresh, clean and potable water is a single main factor which affects the human life (Nash and McCall 1995) [3]. Almost one third of the world's population is completely dependent on groundwater for their daily requirement. This situation is getting more and more critical in the developing countries like India, where the ground water plays a significant role in rural areas for drinking and irrigation. Sirsa district of Haryana is such an area where the rural population mostly depends on ground water for their daily needs. The ground water is considered to be more safe as compare to the surface water because of the dilution of most of the pollutant or their chemical or biological degradation. But the over exploitation of ground water, annual rainfall, quality of recharge, geochemical processes are responsible to degrade the ground water quality(Zahedi 2017) [4]. So, it is of the great concern to understand and monitor the hydro chemical and physico chemical characteristics for the planning and management to ensure the safe use of ground water for drinking and irrigation. Keeping this in view, the present research work was carried out in some villages of Sirsa district to check the suitability of ground water for drinking and agricultural purposes.

Description of the study area

The Sirsa district is situated on the western part of Haryana state and falls in the coordinates $29^0 14'$ north extension and $74^0 29'$ to $75^0 18'$ east extension. It is surrounded by Punjab and

Rajasthan from three sides and its own state through one side. Nominal annual rainfall is observed in the district. A seasonal river Ghaggar flows through the district.

Materials and Methods

The groundwater samples were collected from different fifteen locations of the district during both pre and post monsoon seasons in 2017. Major cations and anions were estimated using standard methods as given by APHA (2005) [5].

Results and Discussion

Table 1 is showing the values of various parameters and their comparison with the Indian and WHO standards.

Table 1

	Pre monsoon				Post monsoon				Indian standards		WHO Standards
	Min.	Max.	Mean	St. Dev.	Min.	Max.	Mean	St. Dev.	Acceptable	Maximum	
pH	7.0	9.3	7.95	0.53	7.10	8.5	8.12	0.44	7-8.5	6.5-9.2	6.5-9.2
TDS	210	1050	582.6	244.61	295	1370	649	297.60	500	1500	500
TH	32	500	243.93	127.93	40	550	267.53	136.20	200	600	500
EC	330	1638	910	382.17	460	2140	1013.73	464.90	300	-	-
Ca^{2+}	06	64	32.46	15.77	08	60	37.57	16.02	75	200	75
Mg^{2+}	5.5	220	64.80	58.51	7.2	248	71.09	71.43	30	-	150
TA	43	135	95.33	24.98	50	160	114.2	31.43	200	600	-
Cl^-	72	490	175.46	106.77	80	550	198.93	119.63	200	1000	500
SO_4^{2-}	1.4	174	84.15	50.67	12	164	94.67	47.32	200	400	-
F^-	0.4	2.4	1.31	0.56	0.7	2.6	1.56	0.52	1.0	1.5	-
NO_3^-	0.0	40	5.26	10.22	0.0	42	6.54	10.94	-	-	-
Na^+	12	540	185.29	155.30	18	570	196.13	156.54	-	-	200
K^+	0.0	87	15.25	22.24	1.5	82	19.16	20.54	-	--	-
HCO_3^-	22	322	105.93	71.40	38	330	118.33	71.49	-	-	-
CO_3^{2-}	07	24	16.52	5.90	12	28	21.60	5.94	-	-	-

Major ions chemistry in ground water

The variation in the Concentration of cat ions follows the order $Na^+ > Mg^{2+} > K^+$ in both pre and post monsoon season. Ca^{2+}ions vary from 6 mg/l to 64mg/l in pre monsoon and 8mg/l to 60mg/l in post monsoon season. None the sample was found to exceed the acceptable limit of Ca^{2+} (75 mg/l). The Mg^{2+} ions varied from 5.5 mg/l to 220 mg/l in pre monsoon and 7.2 mg/l to 248 mg/l in post monsoon period. The maximum permissible limit per day for calcium is 2500 mg and that for magnesium it is 350 mg, above which they may be harmful for human health [6].

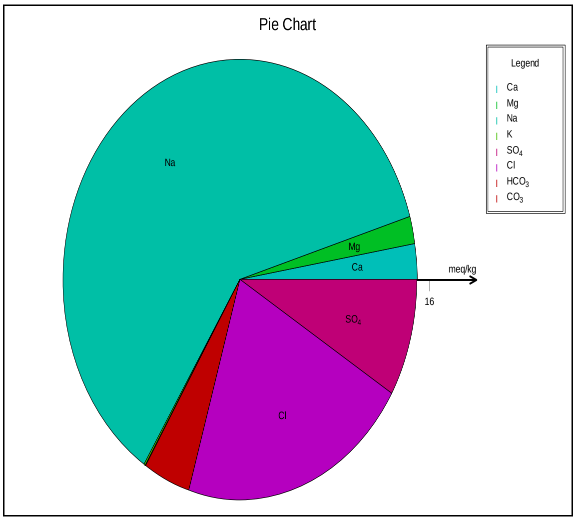
The variation in sodium in concentration observed is 12mg/l to 540mg/l in the pre monsoon and 18mg/l to 570mg/l in the post monsoon period respectively. 33% of the samples of the study area were found to have high concentration of sodium [7]. A high sodium content is responsible for heart problems, Kidney disease, hypertension [8].

The potassium ions variation was observed from Nil to 87mg/l is pre monsoon and 1.5mg/l to 8mg/l in the post monsoon period. There is no upper limit for K^+ in drinking water setup by any standard.

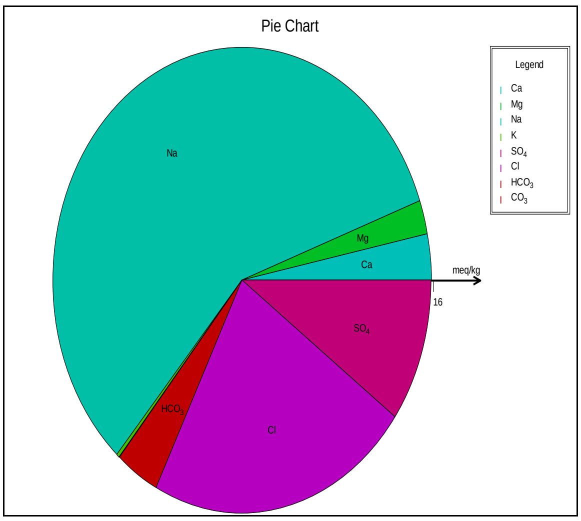
The variations in anions concentration was observed as $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-}$ for both the seasons. The chloride ions varied from 72mg/l to 490mg/l and 80mg/l to 550gm/l for both the pre and post monsoon periods respectively. A total of 13% sample and 33% samples exceeded the desirable limit for chloride ions (250mg/l) in pre and post monsoon seasons respectively. The Sulphate ions concentration varied in between 1.40mg/l to 174mg/l and 12mg/l to 160mg/l in both the seasons respectively. Sulphate doesn't pose any health risk when present in normal quantity but in higher quantities it deteriorates the water quality which may lead to health risk.

The variation in bicarbonate ions observed was 22 to 322 and 38 to 338 mg/l for both the seasons respectively. It is the dissolution of carbonates and silicates by carbonic acid which is responsible for the presence of bicarbonates in soil.

Pie charts showing the ionic contribution in ground water



Pre monsoon



Post monsoon

Table 2: Showing the irrigation water quality parameters in pre monsoon time

	PSS	PI	SAR	CAI 2	CAI 1	GR 1	GR 2	% Na	SSP	RSC	Met. Gen.	Base Ex.	Mg Hz.	KR
1	4.73	99.2	19.10	-2.95	-1.92	0.841	0.96	92.95	92.93	0.07	11.56	4.63	43.39	13.16
2	11.87	41.8	3.50	-0.54	-0.32	0.845	0.82	39.21	37.29	-15.23	8.12	0.64	86.95	0.59
3	1.68	68.5	1.88	-0.14	-0.20	0.007	0.77	52.48	47.24	-1.04	1.21	-0.03	72.72	0.89
4	2.23	26.1	0.33	0.65	0.78	0.748	0.34	9.90	9.42	-3.74	-0.87	-1.13	80.0	0.10
5	15.80	80.5	13.11	-3.45	-0.73	0.974	0.94	78.82	78.58	-5.72	17.8	4.22	78.12	3.66
6	1.40	77.5	5.32	-1.12	-1.25	0.610	0.84	64.98	64.98	-1.14	7.37	5.09	68.85	1.85
7	1.90	10.5	0.21	0.86	0.82	0.663	0.68	3.52	3.37	-16.04	-2.90	-3.02	98.38	0.03
8	6.43	63.2	5.88	-1.71	-1.12	0.787	0.84	58.07	57.48	-7.49	10.15	3.18	74.68	1.35
9	8.44	36.1	1.04	0.57	0.61	0.802	0.37	23.62	22.61	-4.35	0.45	-0.96	50.0	0.29
10	8.42	43.1	1.30	0.41	0.45	0.834	0.50	33.95	29.31	-3.40	1.24	-0.72	59.34	0.41
11	0.0	62.3	4.09	-1.41	-1.83	0.559	0.79	53.20	52.21	-3.99	5.15	1.58	71.42	1.09
12	0.0	64.7	4.32	-0.76	-0.37	0.737	0.76	54.70	54.70	-3.77	2.10	0.15	62.5	1.21
13	1.29	70.5	3.15	-0.67	-1.29	0.459	0.74	54.94	52.09	-1.13	3.20	2.05	62.26	1.09
14	1.86	68.6	4.74	-1.36	-2.47	0.598	0.85	59.43	59.21	-3.02	6.40	3.32	75.04	1.45
15	1.20	82.6	9.98	-2.60	-5.60	0.369	0.92	75.55	73.35	-0.72	14.2	19.38	75.75	2.75

Table 3: Showing the irrigation water quality parameters in post monsoon

	PSS	PI	SAR	CAI 1	CAI 2	GR 1	GR 2	% Na	SSP	RSC	Met. Gen.	Base Ex.	Mg Hz.	KR
1	7.04	97.2	17.22	-1.58	-2.29	0.85	0.96	91.21	91.17	-0.05	3.56	3.54	42.85	10.33
2	13.96	37.6	3.35	-0.34	-0.05	0.83	0.79	35.44	33.55	-19.61	0.99	0.68	86.93	0.50
3	2.23	58.8	1.49	-0.05	-0.03	0.69	0.64	44.23	37.75	-1.39	0.06	-0.22	66.66	0.61
4	3.05	26.1	0.45	0.69	0.57	0.74	0.39	12.91	11.50	-4.55	-0.98	-1.03	80.0	0.13
5	19.36	77.9	8.75	-0.62	-2.45	0.96	0.93	75.91	75.59	-6.58	3.89	3.72	80.0	3.10
6	2.11	72.7	3.49	-0.86	-0.86	0.64	0.83	61.12	60.99	-1.73	3.64	3.60	68.0	1.56
7	2.40	12.0	0.38	0.69	0.69	0.50	0.75	5.74	5.47	-18.0	-2.58	-2.63	98.10	0.06
8	8.27	61.0	5.85	-0.99	-1.51	0.79	0.82	56.08	55.44	-8.73	2.98	2.83	72.72	1.24
9	7.93	42.5	1.23	0.52	0.42	0.57	0.42	28.57	27.05	-3.22	-0.71	-0.76	49.0	0.37
10	6.56	57.0	2.42	0.05	-0.04	0.78	0.66	47.42	42.17	-2.71	0.06	-0.08	58.69	0.80
11	1.54	67.8	4.76	-1.92	-1.45	0.55	0.80	58.78	57.22	-2.94	1.78	1.61	68.40	1.34
12	3.80	68.8	4.89	-0.09	-0.21	0.76	0.77	58.47	58.06	-2.88	0.21	0.17	59.32	1.38
13	2.99	69.6	3.20	-0.65	-0.40	0.53	0.75	54.85	51.42	-1.09	1.24	0.84	65.21	1.06
14	8.20	71.5	4.88	-0.16	-0.22	0.79	0.71	62.68	60.83	-2.17	0.51	0.24	67.34	1.55
15	1.76	84.4	10.05	-4.51	-2.56	0.39	0.91	76.58	74.47	0.23	6.81	5.91	73.0	2.92

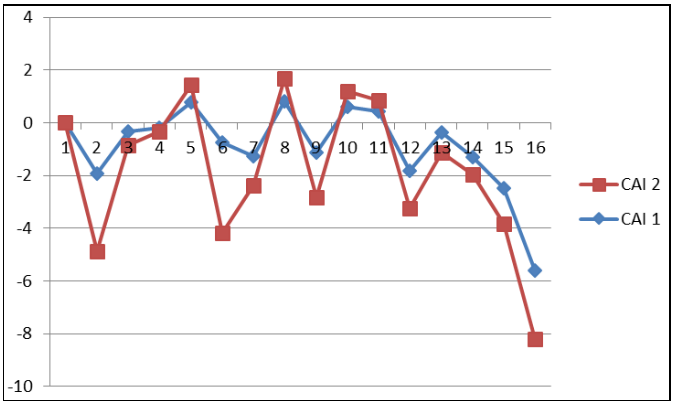


Fig 1: Chloroalkaline index of the study area during pre-monsoon

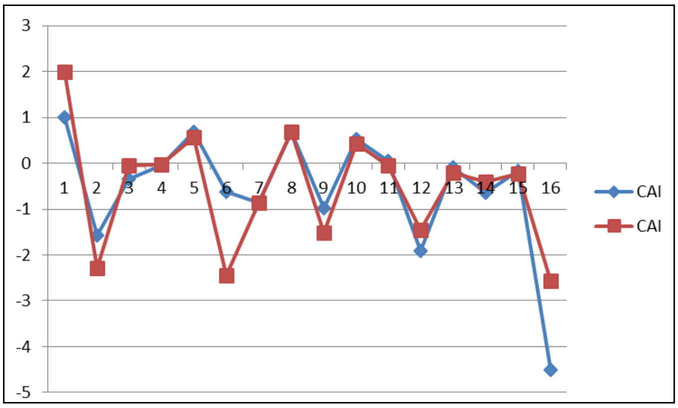


Fig 2: Chloroalkaline index of the study area during post monsoon:

Gibbs Diagram

To understand the mechanism that controls the groundwater hydrochemistry, Gibbs diagram is of major importance. Gibbs diagram explains the hydrochemistry by explaining three major factors, namely precipitation dominance, rock water interactions and evaporation dominance [24]. Fig 3 and 4 represents the Gibbs diagram for the pre monsoon period and Fig 5 and 6 for the post monsoon period respectively. In our study, most of the samples were found to belong to rock water interactions category.

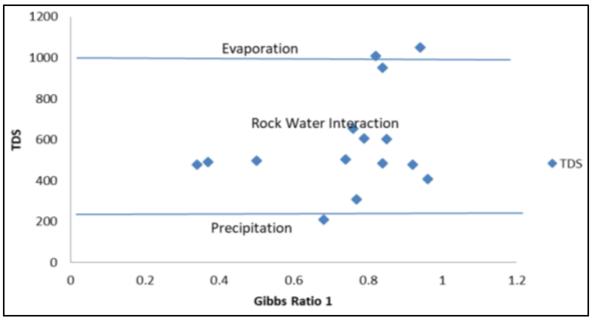


Fig 3

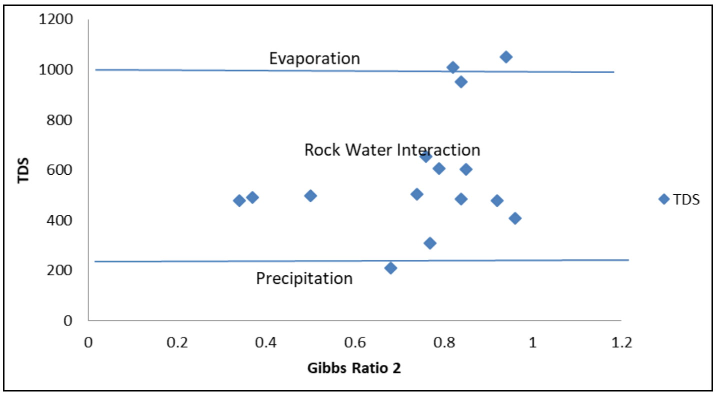


Fig 4

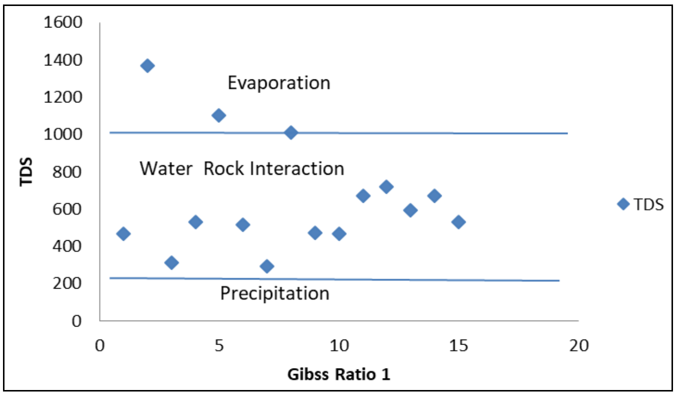


Fig 5

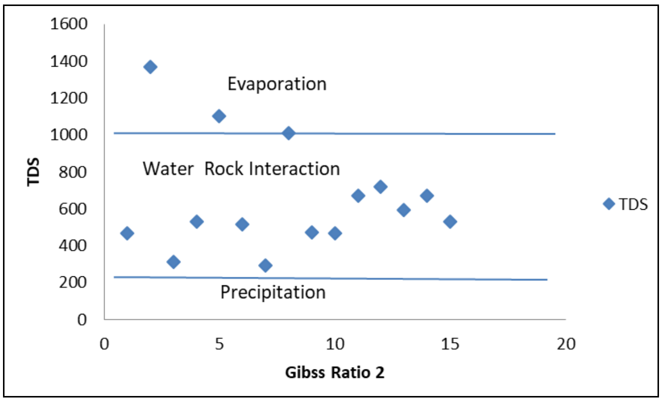


Fig 6

Classification of ground water on the basis of TDS[9] and TH[10]-

	Total hardness	**Samples %**	**Samples Number**
i)	Soft TH< 75	13	1,2
ii)	Moderately hard 75-150	13	3,7
iii)	Hard 150-300	33	4,6,10,13,14
iv)	Very hard >300	41	5,8,9,11,12,15

	Total dissolved solids	**Samples %**	**Samples Number**
i)	Freshwater<1000	87	1,3,4,6,7,8,9,10,11,12,13,14,15
ii)	Slightly saline 1000-3000	13	2,5
iii)	Moderately saline 3000-10000		Nil
iv)	Very saline 10000-30000		Nil
v)	Brine > 30000		Nil

Sodium percentage (Na %)

Sodium ions react with soul and reduces its permeability. Therefore, sodium is the main ion used to classify the irrigation water (Wilcox 1955) [11]. % Na was be calculated by using the equation:-

$\% Na^+ = [(Na^+ + K^+) / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)] \times 100$ (1)

As per the classification given by Wilcox (1955), 13% samples are in excellent category, 20% in good category, 40% are in permissible category where as the remaining samples are in non-permissible category.

Residual sodium carbonate (RSC)

RSC index assess the suitability of ground water for irrigation in those types of soils having high cation exchange capacity. When the concentration of Na^+ ions becomes more than that of the Ca^{2+} and Mg^{2+} ions, the soil undergoes dispersion and this reduces the infiltration capacity of the soil [12]. In such type of soil, the plant roots can't penetrate deeper due to lesser moisture content.

The RSC Can be calculated by using the formula given by Regunath (1987) [13].

$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$ (2)

As per Eaton (1950) [14], the ground water containing RSC<1.25mg/l is suitable. In our study, all the samples lie in suitable range in both pre and post monsoon seasons.

Sodium Absorption Ratio (SAR)

SAR is an important factor to determine the ground water quality for irrigation. The Na^+ and K^+ ions promote the dispersion of soil particles where as the Ca^{2+} and Mg^{2+} ions promote their coagulation. This aggregation of soil clay particles affects the soil structure and the water in filtration rate. Higher is the value of SAR, the lesser is the suitability of ground water for irrigation. The use of such type of water having high SAR for long time may require soil amendment [15].

In our study, 87% samples are in excellent range and 13% are in good.

Meteoric genesis (met.gen.)

The met.gen. can be calculated by using equation,

$Met.Gen. = [(K^+ + Na^+) - Cl^-] / SO_4^{2-}$ (4)

According to meteoric genesis, the ground water can be classified into two types. If the value of met.gen. is greater than 1, water is shallow meteoric type and if the value of meteoric genesis is less than 1, it is deep meteoric type. In our study, 53% water samples have met.gen.>l and rest 47% samples have met.gen.< l. Therefore, 53% samples were found to belong to shallow meteoric and 47% to the deep meteoric type in both the seasons respectively.

Permeability index

The presence of ions like Na^+, K^+, Ca^{2+} and Mg^{2+} influences the permeability [16]. Doneen (1964)[17]developed a diagram for the classification of water for irrigation. PI was calculated using the equation:

$PI= Na^+ + (HCO_3^-)^{1/2} / Na^+ + Ca^{2+} + Mg^{2+}$ (5)

Magnesium Hazard

Mg Hazard can be calculated using the equation[6],

$Mg\ Hz. = [(Mg^{2+}) / (Ca^{2+}+Mg^{2+})] \times 100$ (6)

If Mg Hz. >50 water is unfit for irrigation and such water increases the basic nature of soil and there fore affect adversely the crop yield [19]. In our study 87% water samples have Mg Hz > 50 and there fore unfit for irrigation where as 13% samples have Mg Hz <50 and can be taken as suitable for irrigation.

Kelly Ratio (KR)

KR> 1 indicates excess of sodium and KR<l indicates deficiency of Sodium. (Kelly 1951)[20] Also if KR<l water is considered to be suitable for irrigation, If KR lies in between 1-2, water is marginally suitable and if KR>2 water is unfit to use for irrigation [21]. KR was calculated using the equation:

$KI= [Na^+] / [Ca^{+2}Mg^{+2}]$ (7)

In our study, 40% samples have KR<1, 40% have KR in between 1-2 and 20% have KR>1 in both pre and post monsoon periods.

Chloroalkaline Index

Schoeller (1977) [22] proposed chloro alkali Indices (CAIs) to understand the change in the chemical composition of ground water through its way of flow. The CAI-1 and CAI-2 values in temperate the ion exchange behavior between the ground water and its prevailing environment.

$CAI\text{-}1 = [Cl^- - (Na^+ + K^+)] / Cl^-$ (8)

$CAI\text{-}2 = [Cl^- - (Na^+ + K^+)] / (SO_4^{2-} + HCO_3^- + CO_3^{2-})$ (9)

The positive values of CAIs indicate the direct ion exchange between Mg^{2+} and Ca^{2+} from the rocks and Na^+ and K^+ ions from the water where as the negative values indicate the exchange of Na^+ and K^+ ions from the rocks with Mg^{2+} and Ca^{2+} ions from the water. In our study 11 out 15 (73.3%) of ground water samples have negative values of CAI-1 and CAI-2 4 out of 15 (26.7%) Samples have positive value of CAI-2 in both the pre monsoon and post monsoon time respectively. This finding clearly show that there is and ion exchange of Na^+ and K^+ from the rocks and Ca^{2+} and Mg^{2+} from water from for most of the samples.

Potential Soil Salinity (PSS)

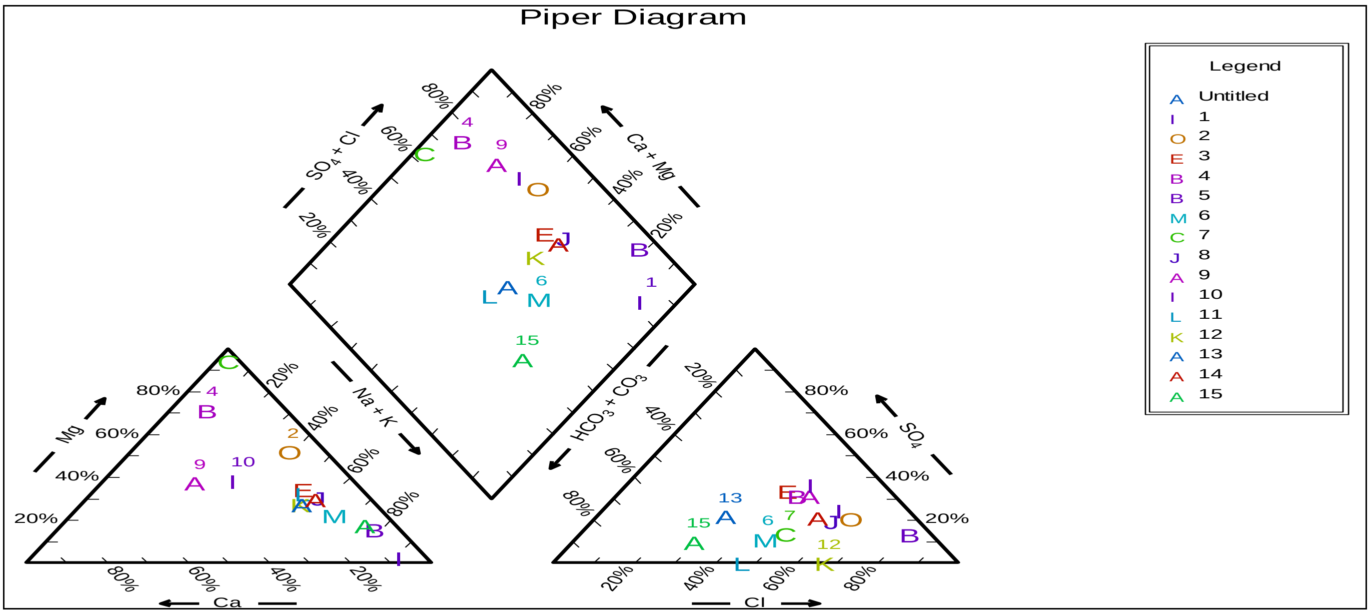
According to the potential of soil salinity index the irrigation water can be classified into three categories. PSS<5 suitable, PSS 5-15 moderate and if PSS>15 it is unsuitable water for irrigation. In our study, we found ten samples in suitable range, 4 Samples in moderate range and 1 samples in unsuitable range in pre monsoon season where as 8 samples in suitable range, Six in moderate and one in unsuitable range in post monsoon season. The high concentration of chlorine and sulphate is responsible for high value of PSS. In the present study area the PSS has been affected by an increase in concentration of chlorine or sulphate (due to anthropogenic or geological sources.)

Total dissolved solids (TDS):- The salinity hazard can be assessed by measuring the total dissolved salts in a water samples. Irrigation water can be classified into five groups [23].

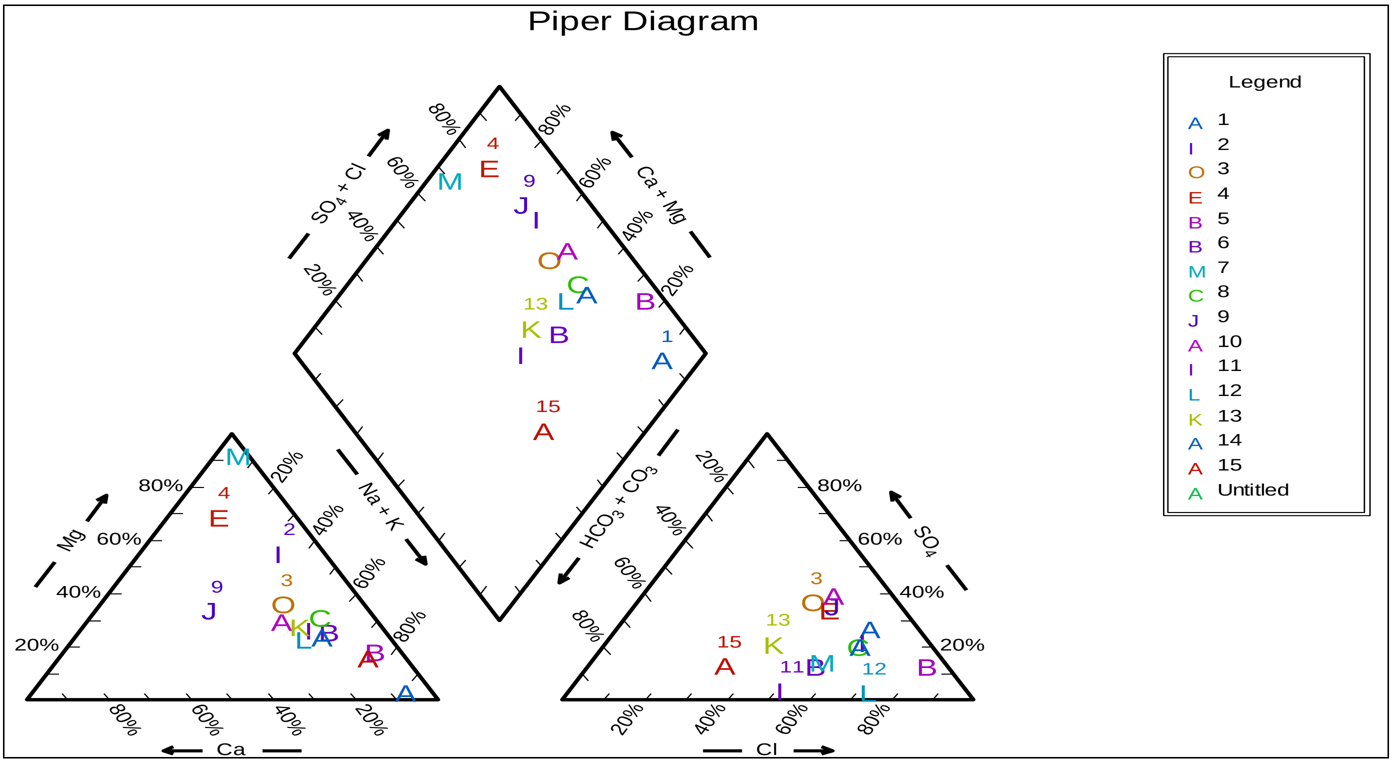
TDS Salinity Hazard % of samples
0-160 Very low 0.00 (both seasons)
160-480 Low 33 (both seasons)
480-1280 Medium 67 (pre), 60 (post)
1280-1920 Medium high 6.6 (post)
1280-1920 High 0.00 (both)

Piper diagrams showing the hydro chemical facies for the groundwater

To understand the connection between the important dissolved ions of the ground water, Piper diagram is used[25]. The Na and Cl ions dominance were observed in our study.



Pre monsoon season



For post monsoon period

Conclusion

The Gibbs diagram shows the rock water interactions in the study area. Chloroalkaline indices show the ion exchange mechanism is responsible to control the hydrochemistry of ground water. 53 % samples are shallow meteoric and 47 % are deep meteoric type. SAR and RSC show that most of the samples are suitable for irrigation. The Na and Cl ions are the dominating ions in the study area. TDS criteria shows that most of the samples are having low to medium high salinity hazard and therefore taken as fit for irrigation. The results will be helpful in future for the sustainable development of the ground resources in the study area.

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