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Evaluating the Potability of Groundwater for Irrigation in Jammu and Kashmir: A quality Assessment.

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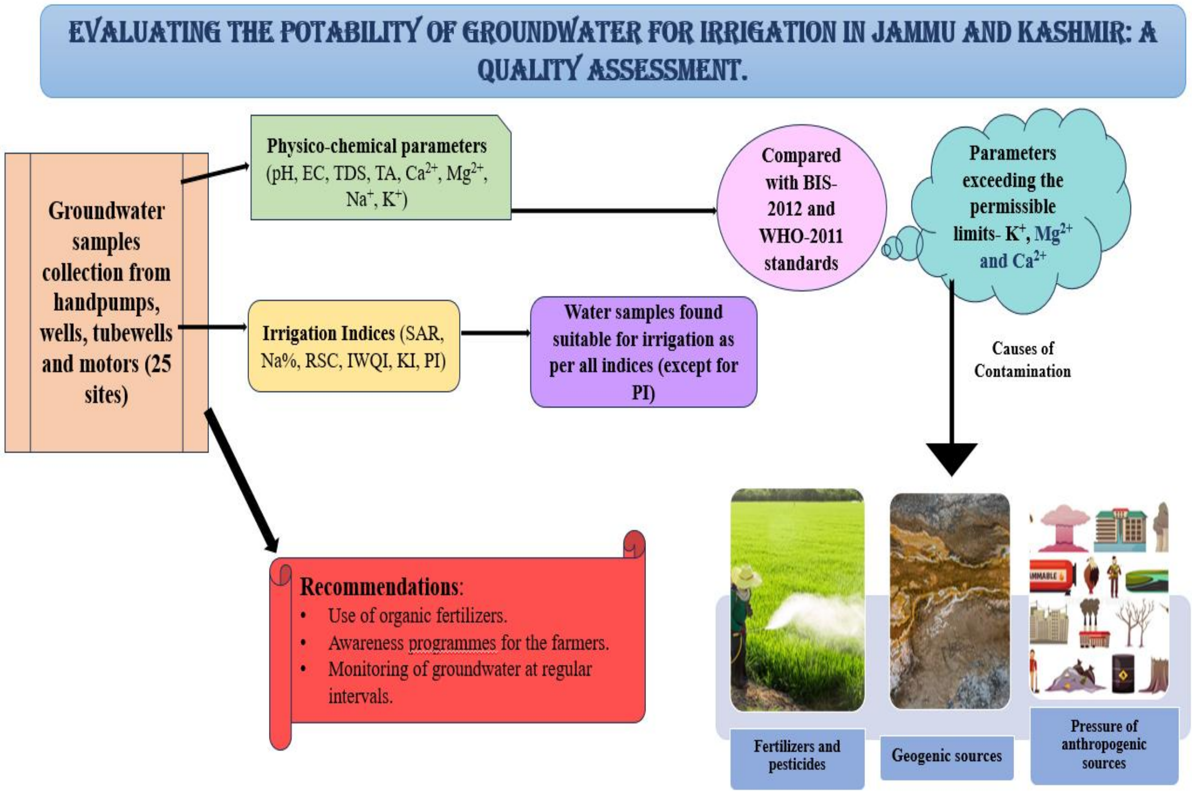
GRAPHICAL ABSTRACT



Abstract: *Groundwater is the only source available for drinking in the study area. Apart from drinking usage, it is used for irrigation and domestic purpose. Study area is having agricultural importance so present work has been carried out to assess irrigation groundwater suitability. 25 sampling sites were selected and were assessed for various physico-chemical parameters including pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total alkalinity (TA), Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}). To assess the irrigation water suitability of study region, various irrigation indices such as Irrigation Water Quality Index (IWQI), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Percent Sodium (Na%), Kelly's Index (KI), Permeability Index (PI) have been calculated. Results of present study reported the groundwater of the study area to be fit for irrigation usage according to Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Sodium Percent (Na%), Kelly's Index (KI) but 60% and 32% unsuitable during Post-monsoon (POM) and Pre-monsoon (PRM) season respectively as per Permeability Index (PI). According to IWQI, nearly 60% water samples for PRM and 40% samples for POM season were classified under 'moderate to high restriction' category. Piper trilinear plot revealed that Mg-CO_3 is the dominant hydro-chemical facies followed by Mg-SO_4-Cl type facies. Groundwater of the sampling site S-14 (Satowali) reported to have unsuitable water for irrigation as per PI and IWQI. Thus, present study recommends regular monitoring of groundwater of study area.*

Keywords: *groundwater, irrigation water quality index, sodium absorption ratio, pre-monsoon, piper-trilinear plots.*

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I. INTRODUCTION

Groundwater pollution is a serious problem in India as well as in the world. Various factors such as urbanization, excess use of pesticides and fertilizers in agricultural fields, population explosion, pollution, heavy metals etc. are leading to the degradation of groundwater quality [1-6]. The above- mentioned factors are adversely affecting the plant growth, soil fertility, and human health [7]. Globally, groundwater satisfies 40% and 30% needs for food production and for drinking respectively. In the entire world, groundwater consumption is highest in India i.e.~230 Km^3 [8-9] i.e., 65%, 20% and 15% for drinking purpose, agriculture and for industry and mining purposes respectively [4-5, 9-11].

Due to increase in demand of groundwater, it is under great stress. Salinity, sodium, Electrical conductivity etc. have the ability to affect the soil quality. In excessive concentration, they can deteriorate groundwater quality by hampering soil fertility and crop growth. Generally, sodium-enriched soil does not support plant growth. Thus, suitability for irrigation waters needs to be assessed as it may contain some undesirable dissolved constituents in it. The evaluation of groundwater suitability for irrigation has been studied by many researchers and reported that various indices are helpful in assessing the suitability of water for irrigation such as Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Sodium Percent (Na%), Kelley's Index (KI), Permeability Index (PI) etc. [3, 12-16]. This will give an overview of chemical nature of groundwater and is helpful in assessing whether the groundwater is suitable for the agricultural usage. Various studies reported irrigation water quality to be good with respect to few parameters whereas to be poor with respect to the others. [1,3, 12-14]. Study area is having high population and locals are dependent on groundwater as it is the major source of water for irrigation and drinking purpose. Despite having agricultural importance, very less or no work has been done on the groundwater quality assessment of this area so far. So, present study will focus on the groundwater quality assessment for irrigation purpose in the study area.

II. MATERIALS AND METHODS

1.1. Study area: Ranbir Singh Pura (R. S. Pura) is situated in Jammu district of Jammu and Kashmir Union territory of India and is located at 32.63°N 74.73°E. Study area is selected because of its agricultural importance and is Basmati rice producer and exporter area. Locals are entirely dependent on farming practices. Study area includes 25 sampling Sites- R.S.Pura, Agra chak, Khana chak, Rangpur Sadrey, Mottey, Seer, Suchetgarh, Purana Pind, Kotli gala bana, Satraiyan, Satowali, Bhadyal qazian, Khamb, Musa chak, Abdulliyan, Dablehar, Chohala, Kotli Arjan singh, Biaspur, Gagian, Nari, Sunderpur, Kheper, Gharana and Jassore and are shown in Fig. 1.

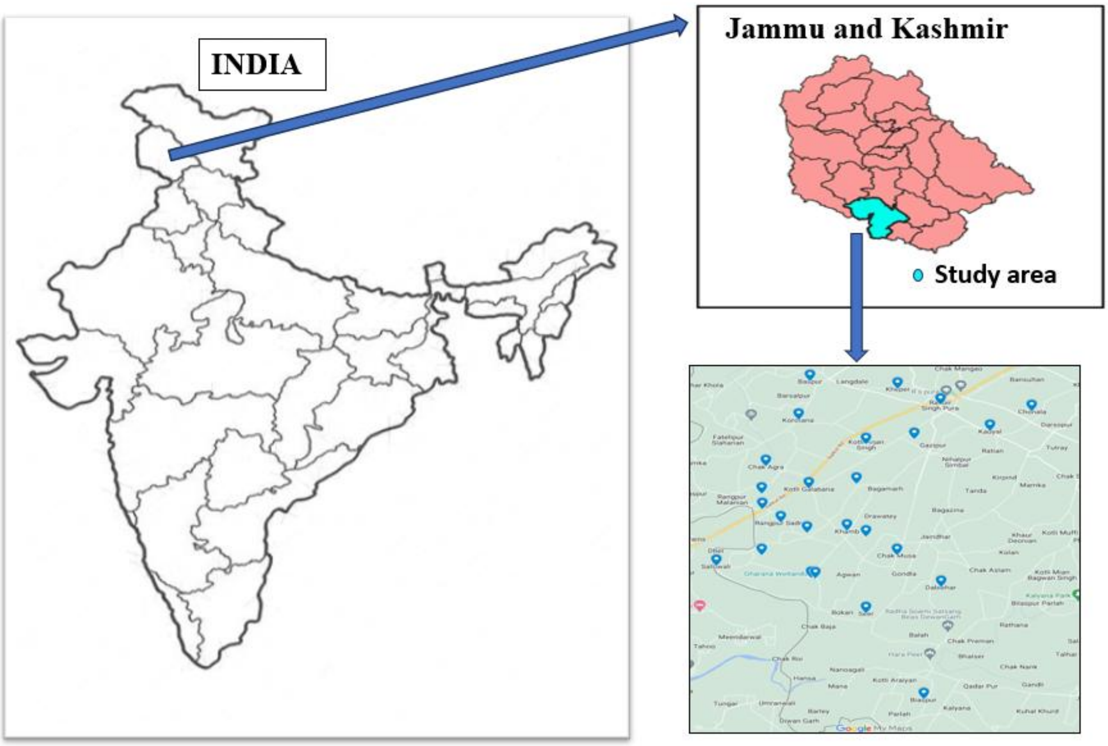

Fig. 1. Study area map with sampling Sites.

1.2. Sample Collection and analytical methods: Groundwater samples (n=25) were collected during pre-monsoon (PRM) and post monsoon (POM) season of 2022 from motors, bore wells, tube wells and hand-pumps. Parameters such as pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Temperature were recorded on site. After collection, the samples were transported to laboratory for other parameters analysis within 12-24 hours**.** Analytical methods used to determine the parameters are mentioned in Table 1 and Indices applied are mentioned in Fig. 2.

Table 1: Analytical methodology used for Physico-chemical parameters.

S. no.	Parameter	Analytical methods
1.	Ph	pH meter (Ionix imported pH meter)
2.	Electrical Conductivity (EC)	Electrical Conductivity Meter (Ampereus EC meter)
3.	Total Dissolved Solids (TDS)	TDS meter (Ampereus TDS meter)
4.	Sodium (Na^+) and Potassium (K^+)	Flame Photometer
5.	Total Alkalinity (as $CaCO_3$)	Titrimetric Method
6.	Calcium (Ca^{2+}) and Magnesium (Mg^{2+})	Titration Method

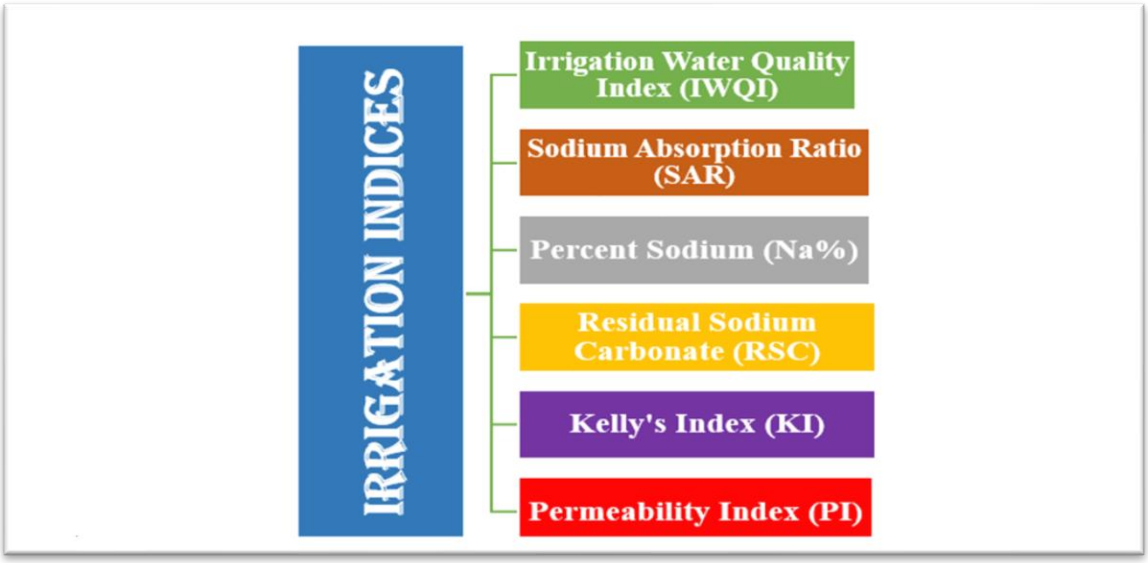

Fig. 2. Indices used to assess the irrigation water suitability.

1.3. Irrigation Indices: In order to evaluate the negative impacts on crop production as well as on the health of soil, irrigation water quality assessment is carried out [14, 17-19, 20]. Important indices which assess the suitability of groundwater for irrigation purposes includes Sodium Absorption Ratio (SAR), Sodium Percent (Na%), Residual Sodium Carbonate (RSC), Kelly's Index (KI), Permeability Index (PI) [1, 21-22]. Methodology used to determine the indices are given in detail as follows:

1.3.1. Irrigation Water Quality Index (IWQI): IWQI is used to calculate the suitability of water for the irrigation usage. The IWQI is assessed using parameters such as EC, SAR, Na^+, Cl^- and HCO_3^- and is calculated by equations [20, 22-23]. After applying the equations, we will get a single value and based on that value water is then classified according to the standard values [20, 22-23]. IWQI classifies water into categories- 'No Restriction', 'Low Restriction', 'Moderate Restriction', 'High Restriction' and 'Severe Restriction' category and their respective IWQI value ranges include 85-100, 70-85, 55-70, 40-55, 0-40 [20, 22-23].

1.3.2. Sodium Adsorption Ratio (SAR): SAR determines the sodium concentration in irrigation waters. Excessive amount of sodium in groundwater effects the soil and is harmful for crop production [5, 43]. It evaluates the impact of Na^+ on soil which is expressed in terms of alkalinity. SAR concentration inversely proportional to soil permeability, which further adversely effects the plant growth [6, 18, 44] and can calculated by formula, where ionic concentrations are expressed in milliequivalent per liter (meq/L):

$$\text{SAR} = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

To classify the water for agricultural purposes, a classification has been given by US Salinity Laboratory, Department of agriculture, USA [3, 14, 17, 24-26] and classify irrigation waters as 'poor' if SAR value is >26, 'Fair' if SAR value is 18-26, 'Good' if SAR value is 10-18 and 'Excellent' if SAR value is <10.

1.3.3. Sodium Percentage (Na%): High sodium concentration in irrigation waters may lead to exchange of Na^+ in water and can displace Mg^{2+} and Ca^{2+} from soil [1, 7, 12-14, 17, 27]. Thus, tend to change the soil properties, increases infiltration problem and effects the soil permeability [6, 18, 44-45]. It is determined by using formula:

$$\text{Na\%} = \frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} * 100$$

where ionic concentrations are expressed in milliequivalents per litre (meq/l). Na% classification for irrigation waters has been given by Wilcox (1955) and classified irrigation water as 'Unsuitable', 'Doubtful', 'Permissible', 'Good' and 'Excellent' if Na% values are >80, 60-80, 40-60, 20-40 and <20 respectively [12, 14, 18, 21, 28-29].

1.3.4. Residual Sodium Carbonate (RSC): RSC is also known to be Residual Alkalinity (RA). Increase in total concentration of carbonates & bicarbonates ions in the water can lead to precipitation of calcium and magnesium ions [12, 14, 26, 30-32, 47]. High concentration of carbonates and bicarbonates in irrigation waters can lead calcium and magnesium to precipitate due to the concentrated water in the soil, resulting in formation of sodium carbonate in soil, which effects the soil structure as well as crop production [25, 46]. RSC is determined using equation as follows:

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

Where ionic concentrations are in meq/L. The RSC classification given by US Salinity classification (1954), which classifies irrigation waters as 'not appropriate' (if RSC value > 2.5 meq/l) is of 'marginal quality' (if RSC value = 2.5 meq/l) and is 'Safe' (if RSC value < 2.5 meq/l) [12, 14, 26-27, 30-32].

1.3.5. Permeability Index (PI): Permeability index is applied to assess the irrigation water suitability. Permeability of soil is proportionally related to excessive concentrations of Mg^{2+}, Na^{+}, HCO_3^{-} and Ca^{2+} due to long term exposure by irrigation water [3,14]**.** An equation was developed by Doneen (1964) to measure the permeability index and then classify the irrigation water into classes- 'Unsuitable' (PI values < 25), 'Moderately Suitable' (PI values 25-75), and 'Suitable' (PI value >75) [3, 14, 17-18, 30, 33-35].

$$\mathbf{PI} = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{(Na^{+}+K^{+}+Mg^{2+}+Ca^{2+})} * \mathbf{100}$$

where the ionic concentrations are expressed in meq/L.

1.3.6. Kelly's Index (KI): Kelly's Index categorize the water used for irrigation purpose [12, 26, 30] as 'Acceptable for irrigation' (if KI Values <1); 'Excess sodium in water' (if KI Values >1) and 'Sodium deficiency in water' (if KI Values <2) [12, 26, 30, 34, 36]. It is determined using equation:

$$\mathrm{KI} = \frac{Na^{+}}{(Ca^{2+} + Mg^{2+})}$$

Where these ionic concentrations are in meq/L.

1.3.7. Piper-Trilinear plots/diagrams: Piper plots are applied to study the composition of waters in terms of ions and to classify the waters into different classes. These plots help to understand the hydrochemistry of the groundwater. In piper diagram hydrogeochemical facies and water types is determine by major anions and cations [37-38]. These diagrams include two triangles, one for plotting anions and other for plotting cations. One diamond shaped field which represents the hydro-geochemical facies concept [25, 39]. These anionic and cationic concentrations are expressed in meq/L. These plots are also helpful in evaluating the relationship among various groundwater samples and the groundwater types [20, 40]. 'Diagrammes Software version 8.44' was used to plot the Piper-Trilinear diagrams for Pre-monsoon and Post monsoon season of the study area.

1.3.8. Wilcox Diagram: The Wilcox's Diagram shows appropriateness of groundwater quality for irrigation purposes by plotting graph between Salinity Hazard [represented as Electrical Conductivity (EC)] and Sodium content in water [represented as Sodium Percentage (Na%)] [25, 28-29]. This diagram is basically a plot in which irrigation water is classified into five categories- unsuitable category, doubtful to unsuitable category, permissible to doubtful category, good to permissible category and excellent to good category [1, 13, 26, 31,41]. Wilcox diagrams for both the seasons were prepared by Diagrammes Software version 8.44.

III. RESULTS AND DISCUSSIONS

The above-mentioned parameters were evaluated and their results are discussed below:

3.1. Irrigation Water Quality Index (IWQI): IWQI assesses the groundwater quality of the study area and its classification is given in Table 2 [5, 20, 22, 28, 42]. In present study, IWQI for Pre-monsoon season ranged from 42.36- 89.77 with a mean of 70.14. Maximum samples were reported under 'Moderate restriction' category (52%) and rest under 'No restriction' (12%), 'Low restriction' (32%), 'High restriction' (4%) whereas no sample was found under 'Severe restriction' category (0%) of IWQI classification. Only 1 sample was found under 'High restriction' category i.e., S-14 (Satowali) for Pre-monsoon season. For Post-monsoon season, IWQI value ranged from 48.48- 87.65 with a mean of 71.06. 12% of samples were found under 'No restriction' category, 28% of samples under 'Low restriction' category, 48% of samples under 'Moderate restriction' category, 12% of samples under 'High restriction' category and no sample under 'Severe restriction' category of IWQI classification. S-9 (R. S. Pura), S-14 (Satowali) and S-25 (Kheper) were reported under high restriction category of IWQI for Post-monsoon season. Comparison of IWQI for both seasons is presented graphically in Fig. 3. Similar findings were reported in Gunabay watershed of upper Blue Nile basin of Ethiopia where groundwater was classified into no restriction, low restriction, moderate and high restriction category of IWQI classification [5, 42]. Thus, can be concluded that the maximum water samples can be used for irrigation without any prior treatment.

Table 2. Classification of groundwater samples of study area as per IWQI.

Range	Water Category	% of Water samples	
		Pre-monsoon	Post-monsoon
85-100	No Restriction	12%	12%
70-85	Low Restriction	32%	48%
55-70	Moderate Restriction	52%	28%
40-55	High Restriction	4%	12%
0-40	Severe Restriction	-	-

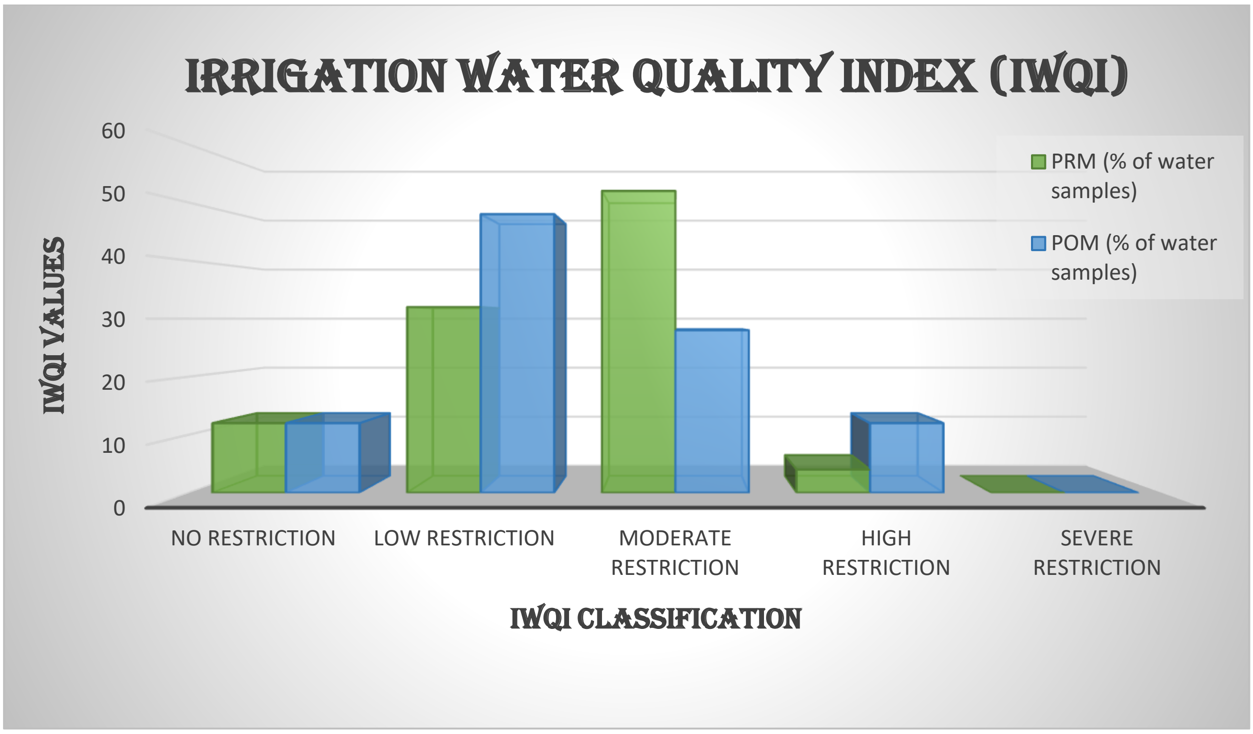

Fig. 3. Classification of water samples of study area as per IWQI for PRM & POM season.

3.2. Sodium Absorption Ratio (SAR): During the analysis of SAR index, S-22 (Gharana) and S-5 (Dablehar) sampling sites were reported to have best quality irrigation water in the study area. SAR value for Pre-monsoon season ranged from 0.19-0.51 with a mean of 0.36 while it ranged from 0.18-1.06 with an average of 0.44 for post-monsoon season. All the samples (100%) of the study area were found under the excellent category of SAR irrigation water classification in both the seasons. As sodium concentration was reported within the desired limits, hence, no alkali hazards were found. Also, high concentration of calcium and magnesium was reported in the groundwater of study area, which indicates low sodium hazards in groundwater of study region. Several studies conducted in different parts of India and across the world published similar reports where 100% of water samples fall under excellent category of SAR classification in both Pre-monsoon and post-monsoon seasons [8, 10, 19, 35, 45-46]. SAR classification for both seasons is presented in Fig. 4 and values are represented in Table 4.

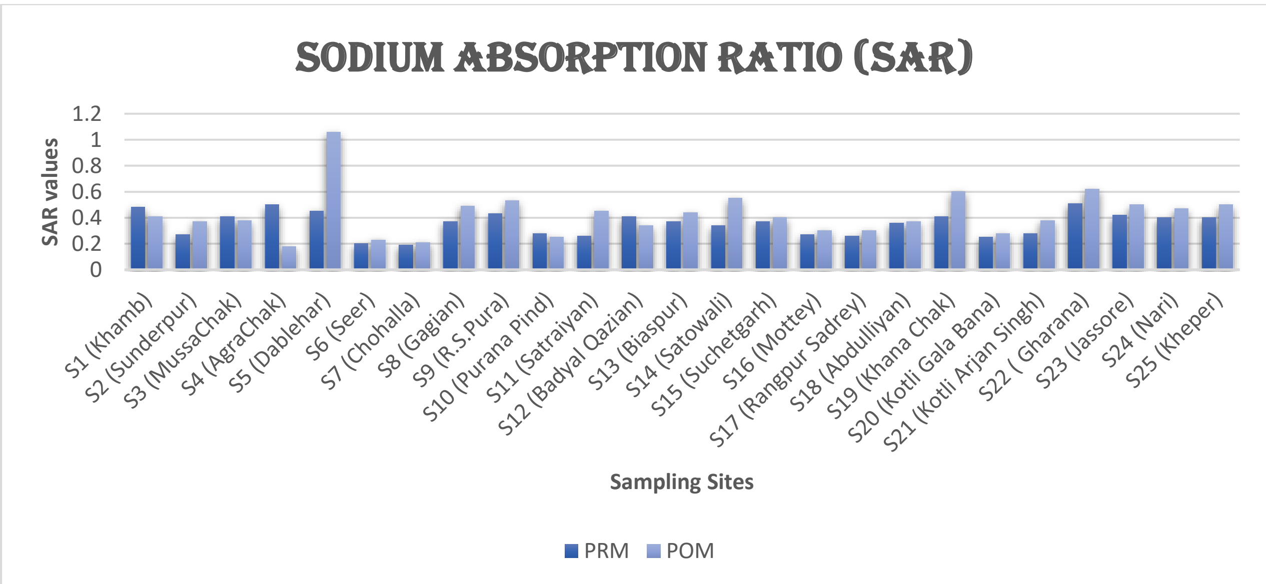

Fig. 4. Water samples classification of study area as per SAR classification for PRM & POM season.

3.3. Percent Sodium (Na%): Na% for Pre-monsoon season ranged from 4.16-13.05 with a mean of 8.37 while it ranged from 2.69-13.33 with an average of 6.68 for post-monsoon season. All the sampling sites of the study area were reported under the 'safe category' of Na% irrigation water classification for both the seasons. Since, the sodium ions concentration is within the desired limits, thus sodium ions are unable to replace ions of magnesium and calcium ions in the soil, which implies that no sodium hazards and sodicity hazards in the groundwater of the study area and hence groundwater can be safely applied to the crops for irrigation usage. Similar results have been reported by studies where all the groundwater samples were reported under the safe category of irrigation according to Na% [35, 45]. Na% classification for Pre-monsoon and post-monsoon seasons is presented in Fig. 5 and values are represented in Table 4.

3.4.

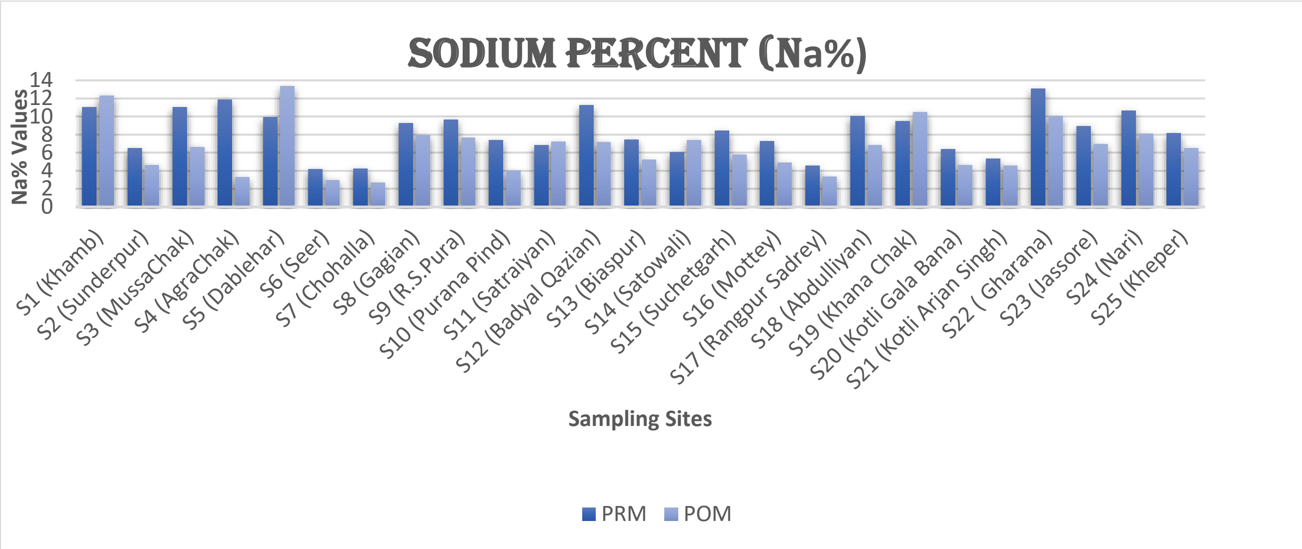

Fig. 5. Water samples classification of study area as per Na% classification for PRM & POM season.

3.5. Residual Sodium Carbonate (RSC): RSC values in the groundwater of study area ranged from -39.2 to -12.13 and -38.48 to -11.1 for Pre-monsoon and post-monsoon season respectively. Groundwater of the study area was reported to be safe for irrigation as per this index because all the groundwater samples fall under the safe category of RSC classification for irrigation waters. Since irrigation waters of the study region was reported with absence of carbonate ions, and high content of calcium and magnesium ions in the water, which results in the increase of bicarbonate ions and thus effects the soil structure and crop production. Similar results are quoted by studies [26, 35, 48] for both Pre-monsoon and post-monsoon seasons. Results of study for RSC classification is presented in Fig. 6 and values are represented in Table 4.

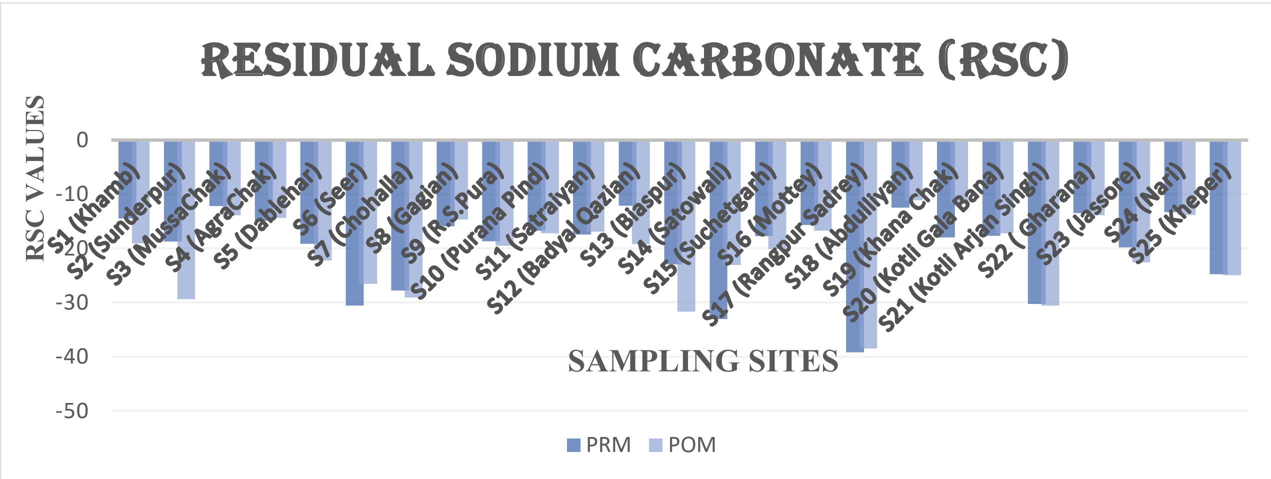

Fig. 6. Classification of groundwater samples of study area according to RSC classification for PRM & POM season.

3.6. Permeability Index (PI): PI values in the groundwater of study area ranged from 8.04-18.51 having average of 13.75 for Pre-monsoon season while for post-monsoon season, it ranged from 1.23-39.44 with a mean of 23.93. The permeability of the soil is directly proportional to increased values of Ca^{2+}, Na^{+}, Mg^{2+} and HCO_3^- ions due to continuous exposure by irrigation water. But for the present study, only Ca^{2+} and Mg^{2+} ions were exceeding the desirable limits of set standards, thus affecting the permeability of the soil and limiting its use for irrigation. Classification of groundwater samples of the study area for Pre-monsoon season and post-monsoon seasons on the basis of PI is given in Table 3 and graphically presented in Fig. 7.

Table 3: Classification of groundwater samples of study area based on PI.

PI Value	Classification	% of water samples	
		Pre-monsoon	Post monsoon
>75	Suitable	-	-
25-75	Moderately Suitable	68%	40%
<25	Unsuitable	32%	60%

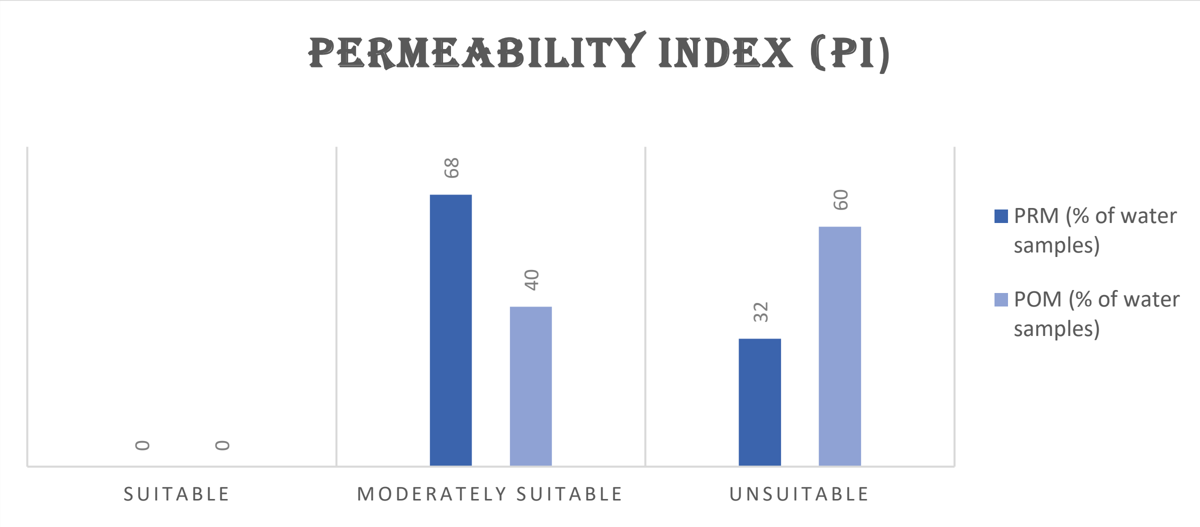

Fig. 7. Water samples classification of study area as per PI classification for PRM & POM season.

3.7. Kelly's Index (KI): KI values in the groundwater of study area ranged from 0.03-0.13 and 0.03-0.15 for Pre-monsoon and post-monsoon season respectively. Values of KI for both the season implies that the samples of the study region are fit for irrigation usage. Similar results have also been reported by various studies, conducted in different parts of India and world, where KI values for both Pre-monsoon and post-monsoon seasons are less than 1 and reported the groundwater of the study area well suitable for irrigation purpose [14, 35, 49-50]. Values of KI are listed in Table 4 and water classification based on KI for both seasons are presented in Fig. 8.

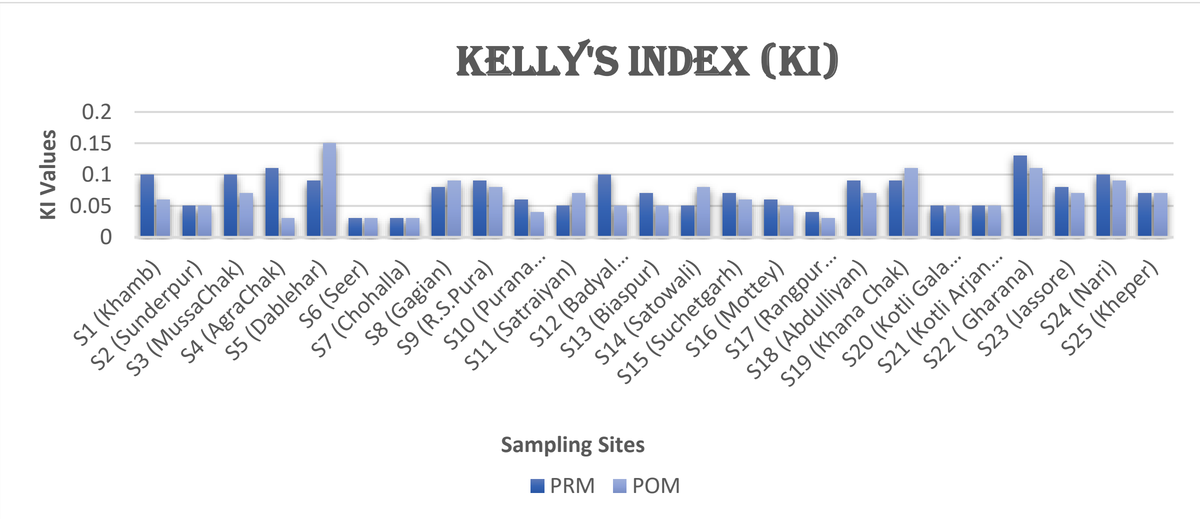

Fig. 8. Water samples classification of study area as per KI classification for PRM & POM season.

Table 4. Water classification of water samples of study area and comparison of Pre-monsoon (PRM) and post-moonsoon (POM) values based on various irrigation indices.

S. No.	Irrigation Index	Water Classification	Classification of irrigation water of study area	
			(PRM value range)	(POM value range)
1.	Sodium Absorption Ratio (SAR)	>26- Poor 18-26- Fair 10-18- Good <10- Excellent	Excellent (0.25-0.69)	Excellent (0.18- 1.06)
2.	Percent Sodium (%Na)	>80- Unsuitable 60-80- Doubtful 40-60-Permissible 20-40- Good <20- Excellent	Excellent (4.14-13.05)	Excellent (2.69-13.33)
3.	Residual Sodium Carbonate (RSC)	<2.5- is safe =2.5- is of marginal quality >2.5- is not appropriate	Is safe [-39.18-(12.11)]	Is safe [-38.48- (-11.1)]
4.	Kelly's Index (KI)	>2- sodium deficiency in water >1- excess sodium in water <1- acceptable for irrigation	Acceptable for irrigation (0.03-0.13)	Acceptable for irrigation (0.03-0.15)

3.8. Piper Trilinear Plots: Piper plots are generally used to study the composition of waters in terms of ions and to classify the waters into different classes. These plots are used to understand the hydrochemistry of the groundwater. These diagrams determine major anions and cations in the study region [37-38]. Fig. 9 and Fig. 10 shows the Piper plots of 25 groundwater samples of study area during Pre-monsoon (PRM) and Post- monsoon (POM) respectively. Anionic triangle highlights the dominance of carbonate ions and absence of bicarbonates ions in the groundwater of study area. Cationic triangle shows the abundance of Magnesium ions while sodium and potassium ions were scarcely available in the groundwater of study area. Piper trilinear plot revealed that Mg-CO_3 is the dominant hydro-chemical facies followed by Mg-SO_4-Cl type facies. This indicate that the strong acids (SO_4^{2-} and Cl^-) and alkaline earth (Mg^{2+} and Ca^{2+}) dominated over the alkalis (Na^+ and K^+). For the post-monsoon season, Mg^{2+} was reported as dominant cation while SO_4^{2-} followed by HCO_3^- found to be the dominant anions. $MgSO_4$ is the dominant hydro-chemical facies followed by Magnesium sulphated chlorides (Mg-SO_4-Cl) type facies for the post-monsoon season. Fig. 9 and Fig. 10 shows the Piper plots of 25 groundwater samples of study area during Pre-monsoon season (PRM) and Post-monsoon (POM) respectively. Similar findings have been reported by [51] where it was found that the alkaline earth metals exceed the alkalis in the groundwater of Western Doon valley of Uttarakhand, India.

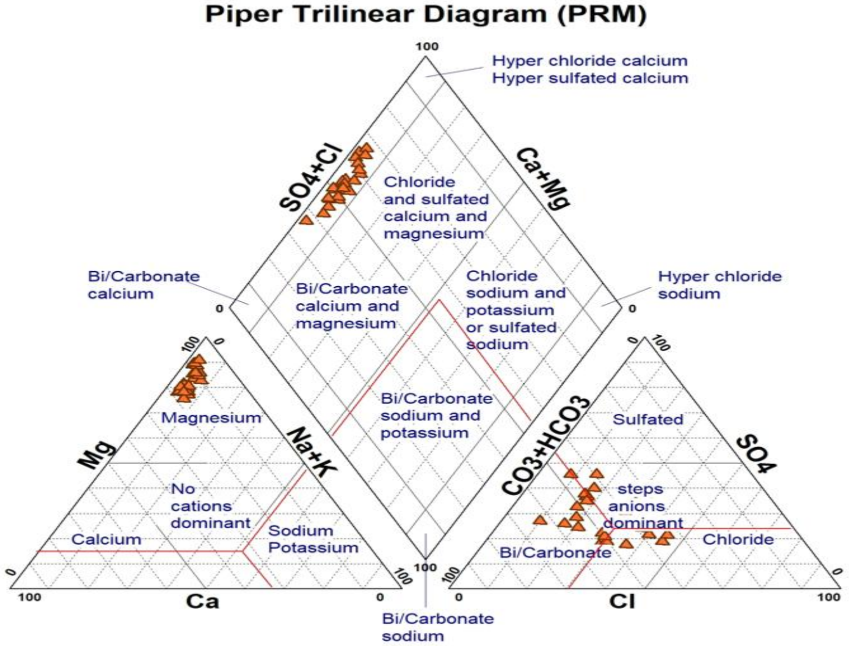

Fig. 9. Piper Trilinear plot for groundwater samples of study area for PRM season.

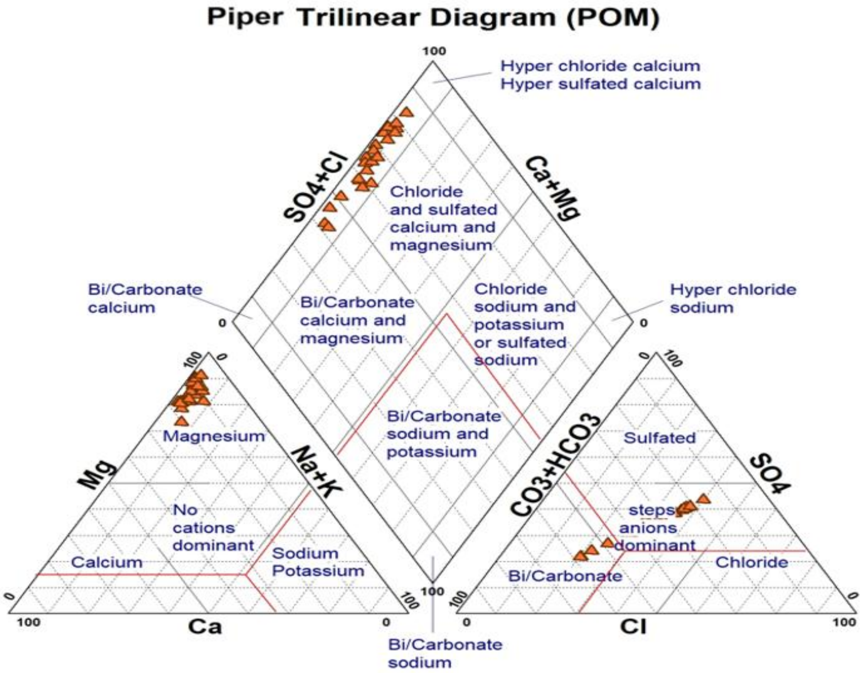

Fig. 10. Piper Trilinear plot for groundwater samples of study area for POM season.

3.9. Wilcox Diagrams: Wilcox classified the groundwater for irrigation usage based on sodium percent (Na%) and Electrical Conductivity (EC) and are classified as 'unsuitable' category, 'doubtful to unsuitable' category, 'permissible to doubtful' category, 'good to permissible' category and 'excellent to good' category [25-26]. It depicts that the quality of groundwater for irrigation decreases with the increase in the concentration of EC and Na% [10' 52-53]. During Pre-monsoon season, 80% of groundwater samples of the study area was found under 'Excellent to Good' and 20% under 'Good to Permissible' category of Wilcox classification (Fig. 11) while in post-monsoon season, maximum water samples (84%) were fall under the 'Excellent to Good' category and rest (16%) under "Good to Permissible' category of Wilcox classification (Fig. 12). Thus, according to these diagrams, groundwater of study area was found suitable for irrigation usage. Similar results have been reported by a study conducted in Kathua region of Jammu and Kashmir, India where the groundwater samples for both seasons were classified under only two categories i.e., 'excellent to good' category and 'good to permissible' category [10].

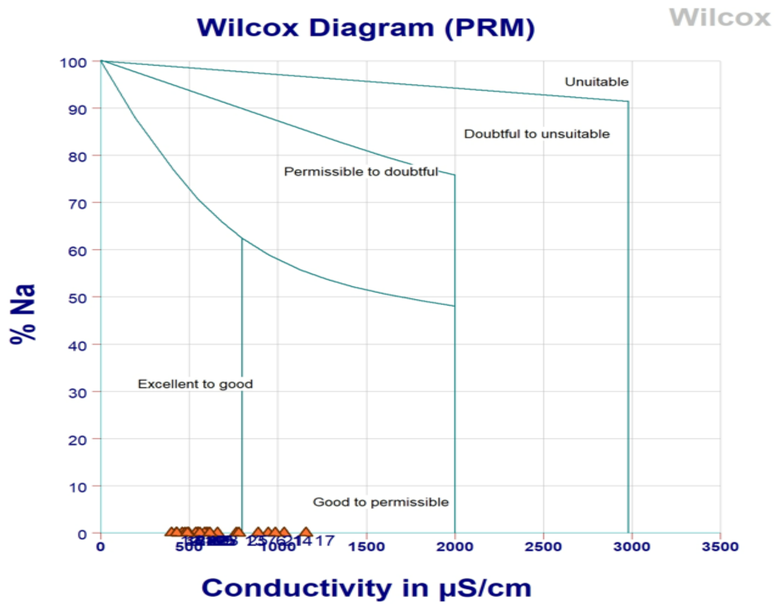

Fig. 11. Wilcox classification of groundwater of study area for Pre-monsoon season (PRM).

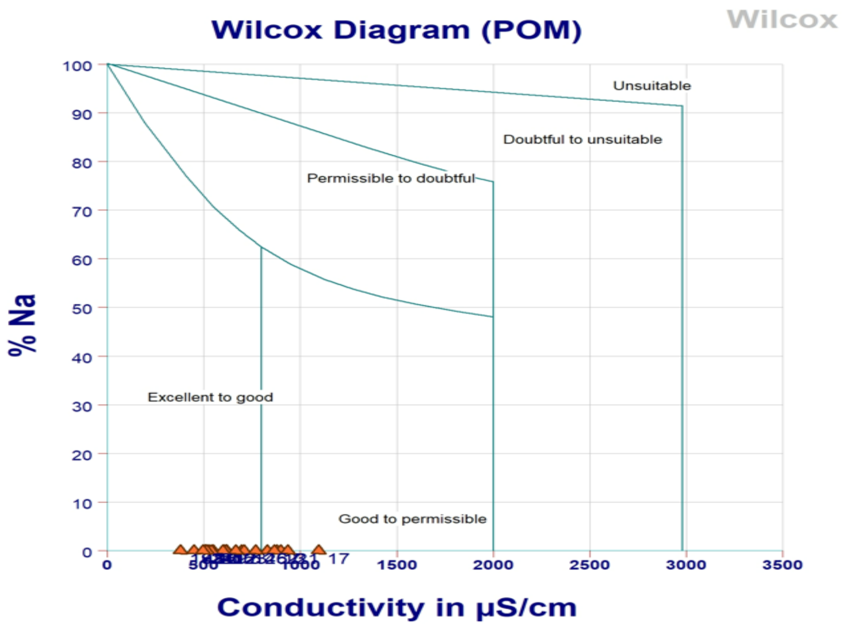

Fig. 12. Wilcox classification of groundwater of study area for post-monsoon season (POM).

IV. STATISTICAL ANALYSIS

4.1. Descriptive Statistics: Statistics such as Mean, Minimum, Maximum, Standard Deviation (S.D) and Standard Error Mean (SEM) have been applied on the parameters for Pre-monsoon (PRM) and Post-monsoon (POM) season and all the values are mentioned in Table 5.

Table 5: Descriptive statistics applied on various parameters for Pre-monsoon (PRM) and Post-monsoon (POM) season.

Parameter	Pre-monsoon Values					Post-monsoon Values				
	Min.	Max.	Mean	S.D.	SEM	Min.	Max.	Mean	S. D.	SEM
pH	6.00	6.87	6.43	0.052	0.03	6.12	7.13	6.57	0.05	0.03
EC	356	1172	676.84	2.1	1.22	394	1037	622.37	4.88	2.82
TDS	208	596	330.72	2.28	1.32	197	814	346.85	4.08	2.36
CO_3^{2-}	100	250	162.88	4.27	2.46	65	185	104.11	4.04	2.33
K^+	12.21	15.01	13.74	0.59	0.34	0.19	4.29	1.37	0.04	0.02
Na^+	23.02	46.71	35.56	4.30	2.48	11.63	45.21	29.82	2.08	1.20
Ca^{2+}	47.09	117.75	88.01	4.29	2.47	42.13	117.74	81.39	2.05	1.18
Mg^{2+}	120.94	448.98	217.81	5.28	3.05	112.8	416.8	221.3	4.86	2.81
SAR	0.19	0.51	0.36	0.5	0.21	0.18	1.06	0.44	0.24	0.13
Na%	4.16	13.05	8.37	3.4	1.65	2.69	13.33	6.68	1.15	0.76
RSC	-39.2	-12.13	-20.31	-	-	-38.48	-11.1	-20.71	-	-
KI	0.03	0.13	0.08	0.05	0.03	0.03	0.15	0.07	0.4	0.25
PI	8.04	18.51	13.75	2.1	1.11	12.3	39.44	23.93	4.56	2.24

4.2. Pearson's Correlation: Correlation matrix is used to explain the relationship among different parameters. Statistically, it helps us to understand how two variables are closely associated [15, 38]. For Pre-monsoon season, strong positive correlation was found for EC with TDS, CO_3^- and Mg^{2+}; for TDS with CO_3^- and Mg^{2+} and for CO_3^- with Mg^{2+} while strong negative correlation was reported for pH with EC, TDS, CO_3^- and Mg^{2+}, which indicates that the increase in one variable tends to decrease in the other variable. Fig. 13 depicts the correlation matrix for different variables in Pre-monsoon (PRM) season. For Post-monsoon (POM) season, strong positive correlation was found for EC with TDS while strong negative correlation was reported for pH with EC and TDS. Fig. 14 depicts the correlation matrix for different variables in post-monsoon season.

	pH	*EC*	*TDS*	*CO3*	*Ca*	*Mg*	*Na*	*K*
pH	1							
EC	-0,81428	1						
TDS	-0,80165	0,889735	1					
CO3	-0,6173	0,784923	0,722279	1				
Ca	-0,1215	0,289973	0,286233	0,522513	1			
Mg	-0,68867	0,783097	0,842749	0,716102	0,200491	1		
Na	0,061374	0,02277	0,047591	0,164986	-0,07696	0,125253	1	
K	-0,21543	0,151811	0,177226	0,048005	0,173506	0,238594	0,275896	1

Negative Correlation   Moderate Correlation   Positive Correlation

Fig. 13: Pearson correlation matrix of physico-chemical parameters for PRM season.

	pH	*EC*	*TDS*	*CO3*	*Ca*	*Mg*	*Na*	*K*
pH	1							
EC	-0,6511	1						
TDS	-0,60873	0,8006	1					
CO3	-0,32771	0,332727	0,396814	1				
Ca	-0,14707	0,465793	0,298047	0,380907	1			
Mg	-0,39375	0,60955	0,59885	0,045209	0,293968	1		
Na	-0,17959	0,21664	-0,02494	0,221257	0,06152	0,253947	1	
K	0,047951	0,100492	0,053106	0,551051	0,335989	-0,07972	0,27314	1

Negative Correlation   Moderate Correlation   Positive Correlation

Fig. 14: Pearson correlation matrix of physico-chemical parameters POM season.

V. CONCLUSION

Irrigation indices were implied to assess the irrigation water suitability for Pre-monsoon (PRM) and post-monsoon (POM) seasons. Groundwater of the study area was found suitable for irrigation according to SAR, RSC, Na% and KI for both the seasons. No salinity hazards were reported in the study area according to Wilcox and Piper trilinear diagrams. According to PI, for PRM season, maximum samples were found under moderately suitable category (68%) and 32% under unsuitable category of PI classification while during POM season, maximum samples were reported under unsuitable category of irrigation (60%) and rest 40% under moderately suitable category of PI classification. 12% samples were reported under 'no restriction' category, 32% under 'low restriction', 52% under 'moderate restriction' and 4% under 'high restriction' category of IWQI classification for PRM season while for POM season, 12% under 'no restriction' category, 48% under 'low restriction', 28% under 'moderate restriction' and 12% under 'high restriction' category of IWQI classification. No sample was reported under 'severe category' of IWQI classification for both the seasons. Sampling site S-14 (Satowali) was reported to have unsuitable water for irrigation as per IWQI classification as well as PI index classification. Probable causes for the contamination of water in this area may include lack of awareness regarding the usage of fertilizers and pesticide as residents of this site are not literate and second reason may be internet connectivity in this area as this area is less than three kilometers from the Indo-Pak border. Some geogenic and anthropogenic sources may also contribute in the release of calcium and magnesium ions in the groundwater of study area. So, present study will help locals to make them aware regarding the contamination in their respective area. Use of organic fertilizers and pesticides as well as continuous monitoring of the groundwater of the study area are recommended by the author. Awareness campaign for the farmers of the locality must be organized by the government or by private institutions so that locals may gain information regarding use of chemical fertilizers and alternate ways to these chemicals.

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