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Irrigation Groundwater Quality for Agricultural Usability: A Case Study of Four Blocks of District Sangrur, Punjab, India.

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Abstract: *In agricultural settings, groundwater quality is of great significance in the district Sangrur, Punjab as it is the main source of regional irrigation. Overdependence on groundwater for irrigation has led to declining groundwater tables, salinization and sodification. For assessing groundwater quality for agricultural usability, a hydro chemical investigation was conducted in four blocks of district Sangrur by collecting 200 groundwater samples for premonsoon and postmonsoon season in year 2008. The analytical data was processed and interpreted as per standard laboratory methods by APHA. The water samples were characterized for various irrigation water quality parameters. According to U.S.S.L Classification 74.50% (premonsoon) and 97% (postmonsoon) of samples fell in the category of* $C_3 - S_1$ *(high salinity and low sodicity). 55% samples (premonsoon) and 86% samples (postmonsoon) were having value of Kelley's ratio above 1 which is unsuiTable for irrigation. High EC, Percent Sodium, Magnesium Hazards at a number of subareas clearly indicated the non-suitability of groundwater for irrigation except for a few locations and it may deteriorate in future, as is evident from the high percentage of samples falling beyond the desirable limits. Therefore, optimum management of irrigation groundwater has become absolutely necessary for sustainable agriculture.*

Keywords: *Agricultural usability, Irrigation Groundwater quality, Salinization, Sangrur.*

INTRODUCTION

Groundwater plays a significant role in Indian agriculture as it depends overwhelming on this source of water. It accounts for over 60 percent of the irrigated area in the country. As a result of increasing groundwater exploitation over the years there has been fall in the water levels. Depletion of water tables, groundwater pollution, water logging and salinity are major consequences of over exploitation and intensive irrigation [1]. The suitability of irrigation water significantly depends upon its chemical quality. Hence, a better understanding of the chemistry of groundwater is very essential to evaluate groundwater quality for agricultural usability.

THE STUDY AREA: DISTRICT SANGRUR

District Sangrur falls in the south-eastern part of the Punjab state (Fig.1) [2]. It has been declared industrially backward. The economy of this district is predominantly agriculture and irrigation has been the main stay of its economy and development. The area falls in the Survey of India toposheets no. 44N, 44O, 53B and a little area in 53C. It falls between North Latitude 29º 44′ 30′′ and 30º38′ 50′′, East Longitude 75º 16′ 30′′ and 76º 09′ 30′′ [3]. Major sources of irrigation are tube wells, wells, pumping sets and canals. Stage of groundwater development in district is 183% [4] indicating over-exploitation of the resource and declining groundwater tables. The study area is also suffering from various water quality problems like high sodicity and high salinity represented by high electrical conductivity.

METHODOLOGY

In the present study 4 blocks of the Sangrur district are selected: - Barnala, Lehragaga, Sehna and Sunam (Figure 1). A systematic random sampling of 200

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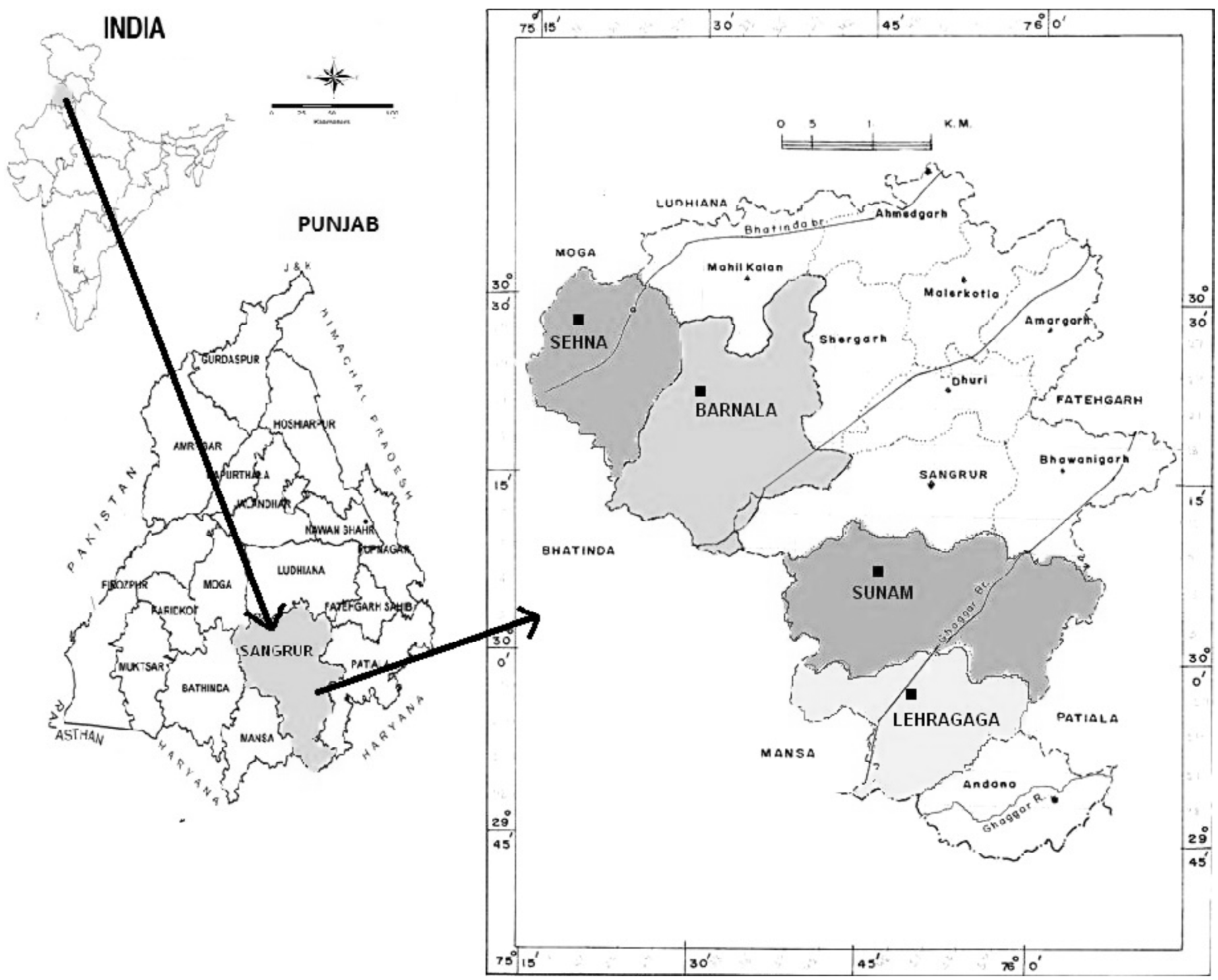

Figure 1: Location of district Sangrur, Punjab and the selected blocks as study area.

water samples (70 from Barnala, 35 from Sehna, 35 Sunam and 60 from Lehragaga respectively) was done from various functional hand pumps, tube wells and dug wells from the four selected blocks of the Sangrur district for premonsoon (May 2008) and postmonsoon (October 2008) season for their quality assessment. Analysis of water samples was carried out in the chemical laboratory of the Department of Geology, Punjab University.

The water samples were characterized for 16 parameters using APHA analytical methods [5] outlined in Table 1. Groundwater quality for agricultural usability was assessed by calculating EC, SAR, Percent Sodium, Residual Sodium Carbonate (RSC), Magnesium Hazard (MH) and Kelley's ratio (KR). Various classifications were also used for evaluating the status of Sangrur groundwater quality for agricultural use.

RESULT AND DISCUSSIONS

The statistical parameters like minimum, maximum, mean and the standard deviation values of groundwater samples are given in Table 2. Irrigation groundwater quality results of samples of the study area results are shown in Table 4. The pH values of groundwater samples in Sangrur indicated alkaline nature. Most of the groundwater samples fell in the category of Na–HCO_3-Cl type of water. Some water samples also represent mixed type (Ca, Mg, Na, K, CO_3, HCO_3 and Cl).

Existing paper discusses the suitability of groundwater quality for agricultural usability in the study area. There are three principal problems in relation to quality of irrigation water delivered to the agricultural fields:

Table 1
Analytical methods used for chemical analysis of the Groundwater samples

Parameters	*Analytical Method*
Temperature	Thermometer
EC and TDS	Soil and water analysis kit (potable)
pH	pH meter
Calcium and Magnesium	Titration with EDTA
Sodium and Potassium	Flame photometer
Carbonate and Bicarbonate	Titrimetric method using standard H_2SO_4 with phenolphthalein and methyl orange as an indicator
Chloride	Argentometric method using potassium dichromate as indicator
Sulphate and Phosphate	Spectrophotometer
Fluoride	Spectrophotometer DR4000
Nitrate	PDA Method

Table 2
Summary statistics of chemical constituents of groundwater in the study area for Various parameters
(*Units = mg/l except for EC and pH).

		Premonsoon				*Postmonsoon*			
S. N.	*Parameter*	*Min.*	*Max.*	*Mean*	*S.D.*	*Min.*	*Max.*	*Mean*	*S.D.*
1.	pH	7.02B*	9.55SU*	8.30	0.47	7.17L*	9.40L*	8.11	0.37
2.	EC(μS/cm)	523 L	3858 L	1777.55	762.87	810.00B	2176.00B	1202.49	276.54
3.	TDS	339.95 L	2507.70 L	1155.41	495.86	526.50B	1414.40 B	781.62	179.75
4.	Ca	4.81 B	72.95 L	33.82	20.04	2.89 SE	48.10 SU	18.59	8.32
5.	Mg	0.41 L	119.53L	41.56	19.38	4.20L	75.04B	34.54	12.86
6.	Na	3.50SU	722.00L	175.18	144.52	73.00SU	342.16 SE	147.91	55.00
7.	K	1.82B	9.90L	5.77	1.59	1.82B	9.90L	5.77	1.59
8.	Cl	14.20B	1150.00L	252.34	282.90	13.80SE	369.00SE	111.18	53.00
9.	F	0.30B	4.20SU	1.87	0.73	0.10L	5.77L	1.31	0.71
10.	SO_4	0.12SE	156.98SE	48.83	29.95	3.62SU	256.70B	74.81	31.15
11.	NO_3	0.05B	32.90B	8.12	6.96	0.05B	32.90B	8.12	6.96

B-Barnala Block, Se –Sehna Block, Su-sunam Block, L-lehragaga

1. Salinity hazard
2. Sodicity (alkali) hazard
3. Toxicity hazard

Salinity Hazard

EC is a good measurement of salinity hazard to crop as it reflects the TDS in groundwater. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil [6]. In the study area, the EC ranges from 523 μS/cm to 3858 μS/cm at 25°C in premonsoon season. 35 % samples were having EC value more than 2000 μS/cm. In post monsoon, EC ranges from 810.00 to 2176 μS/cm (Table 2). Table 3 is showing salinity hazard of irrigation water based upon EC [7]. Figure 2 shows suitability of groundwater for irrigation for the study area on the basis of EC.

Table 3
Salinity hazard of irrigation water based upon conductivity.

S.No.	*EC (iS/cm)*	*Categories*	*% Samples*	
			Premonsoon	*Postmonsoon*
1.	< 250	Excellent	–	–
2.	250–750	Good	2%	–
3.	750–2,250	Permissible	74.5%	100%
4.	2,250–5,000	Doubtful	23.5%	–
5.	> 5,000	Unsuitable	–	–

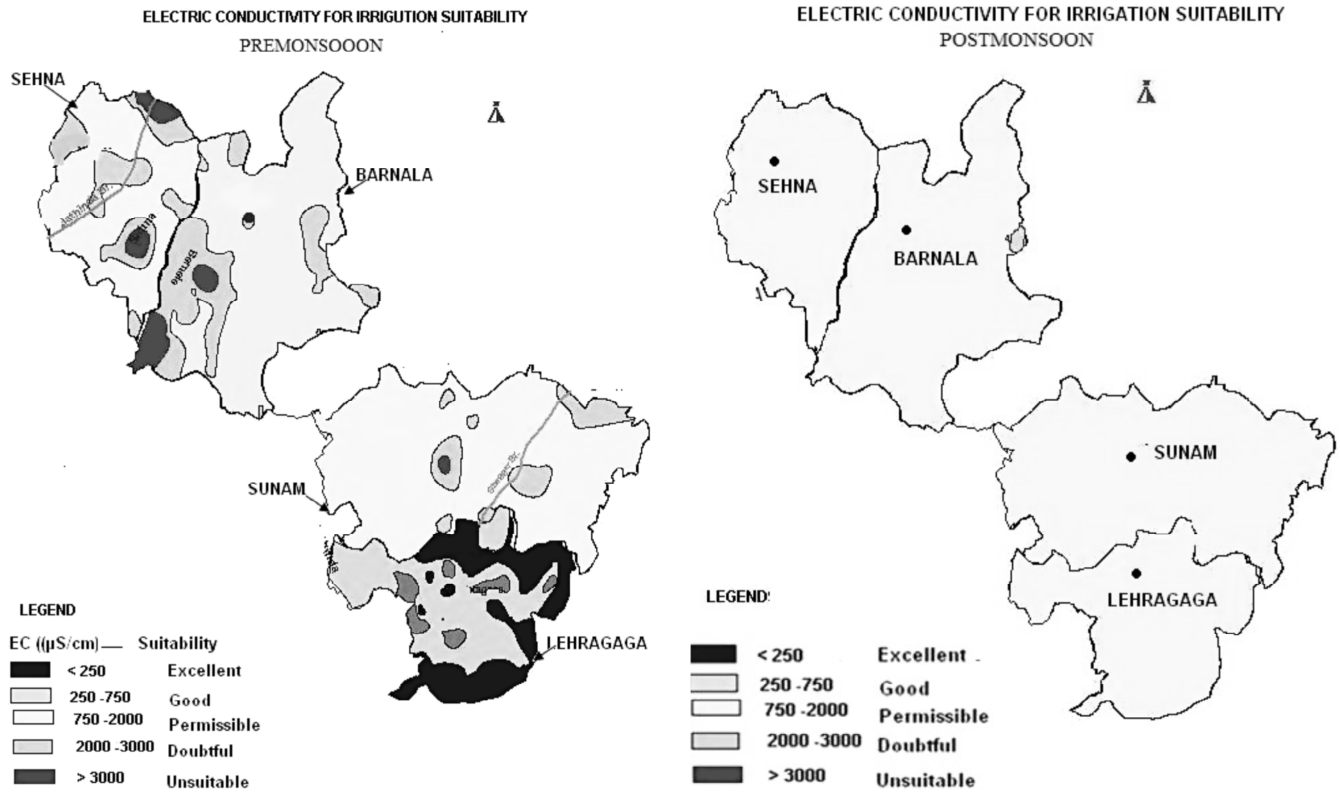

Fig.2: Suitability of groundwater quality for irrigation based on EC values in the study area.

Table 4
Summary statistics of chemical constituents of groundwater in the study area for agriculture use for various parameters.

		Premonsoon				*Postmonsoon*			
S. N.	*Parameter*	*Min.*	*Max.*	*Mean*	*S.D.*	*Min.*	*Max.*	*Mean*	*S.D.*
1.	SAR (meq/l)	0.08SU	20.03SU	5.04	4.40	2.12SU	13.14SE	4.85	2.06
2.	RSC (meq/l)	–11.08L	11.44SE	–0.31	4.70	2.74B	9.52SE	1.55	1.81
3.	%Na	3.68 SU	92.02SU	54.02	18.79	40.28BA	86.74SE	62.58	9.89
4.	PI (%)	14.03SU	107.45L	70.73	18.89	58.28B	107.86LE	83.20	9.82
5.	Magnesium ratio	2.61L	95.16B	66.78	16.26	20.72L	96.54SE	74.43	12.51
6.	Kelly's ratio	0.02SU	11.33SU	1.76	1.91	0.66B	6.43SE	1.88	1.04

Alkali Hazard: Sodium Absorption Ratio (Sar)

High concentration of sodium is undesirable for irrigation because sodium cause permeability problems. Table 5 is showing the suitability of groundwater quality for irrigation based on SAR in the study area. The sodium/alkali hazard is expressed as [8]:

$$SAR = [Na^+]/\{([Ca^{2+}] + [Mg^{2+}])/2\}^{1/2}$$

(where ions are in meq. /l)

Table 5
Suitability of groundwater quality for irrigation based on SAR values in the study area.

S. No.	*After Richards (1954)*		*% Samples*		*International Standard [9]*	*% Samples*	
	SAR	*Categories*	*Premonsoon*	*Post monsoon*	*SAR values*	*Premonsoon*	*Postmonsoon*
1	0-10	Excellent	84%	97.5%	< 3 : suitable	46%	13.5%
2	10-18	Good	13.5%	2.5%	3–9 : use may be restricted	37%	82.5%
3	18-26	Fair	2.5%	–	> 9 :unsuitable for irrigation	17%	4%
4	> 26	Poor	–	–			

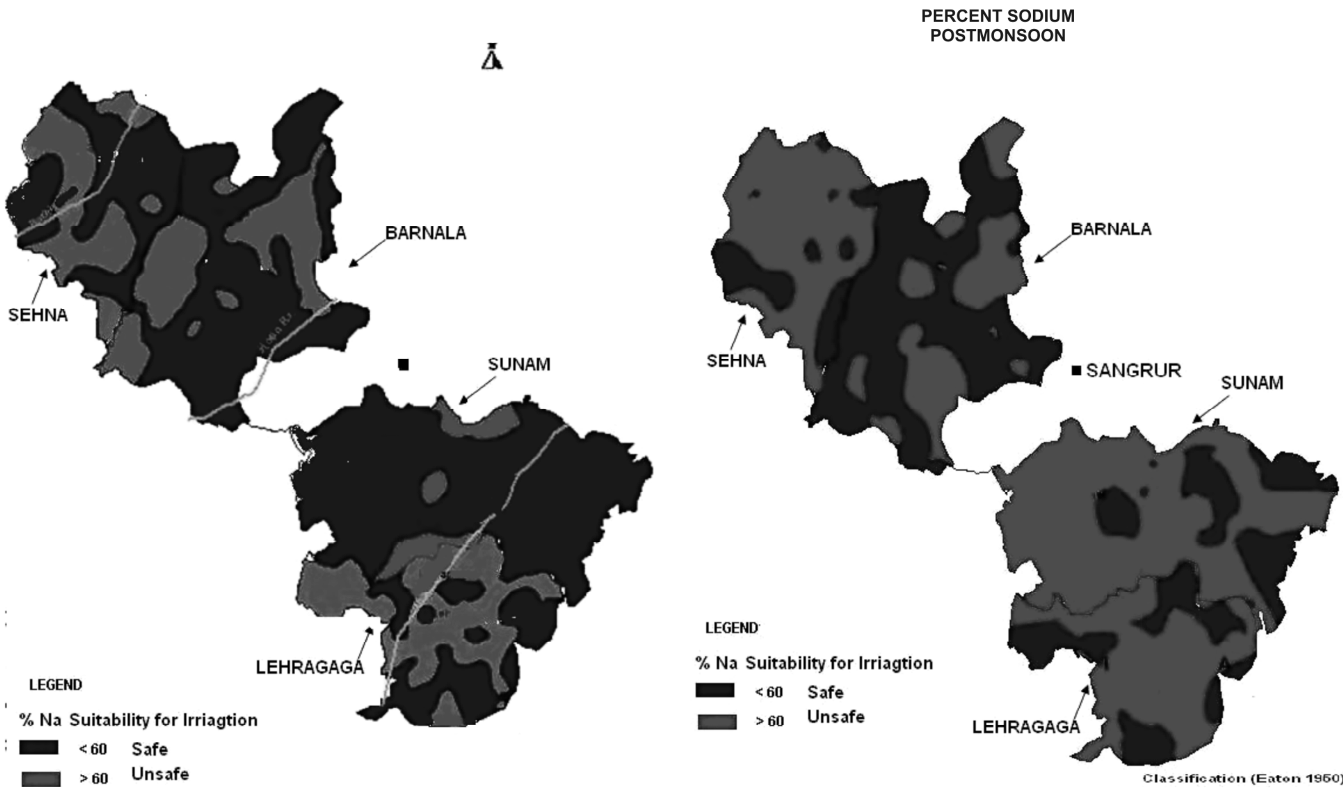

Fig.3: Suitability of groundwater quality for irrigation based on %Na values in the study area.

Percent Sodium

Irrigation water with a Na % greater than 60% may result in sodium accumulations that will cause a breakdown in the soil's physical properties [10]. Table 6 and Figure 3 are showing the suitability of groundwater quality for irrigation based on % sodium in the study area. Na % is (where all ions are expressed [11] in meq/l):

$$(\text{Na}\,\%) = \frac{(\text{Na}^+ \left| \text{K}^+ \right.)X100}{(\text{Ca}^2 + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+)}$$

Table 6
Suitability of groundwater quality for irrigation based on %Na values in the study area.

S. No.	*Na%*	*Categories*	*% Samples*	
			Premonsoon	*Postmonsoon*
1	< 60	Safe	64%	41.5%
2	> 60	Unsafe	36%	58.5%

Residual Sodium Carbonate (Rsc): *Black Alkali Bicarbonate Hazard*

RSC (scorching and leaf burning at the early seedling development stage of crops) is caused by RSC. It can be expressed as (where all ions are expressed in meq/l) [12]:

$$RSC(\text{meq/l}) = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

In premonsoon season RSC ranging from –11.08 meq/l to 11.44 meq/l whereas in post-monsoon the concentration of RSC varies between –2.74 meq/l to 9.52 meq/l. Figure 4 is showing the suitability of groundwater quality for irrigation based on RSC in the study area.

Kelley's Ratio (KR)

Kelley's ratio of more than 1 indicates an excess level of Na^+ in water, therefore unsuiTable for irrigation.

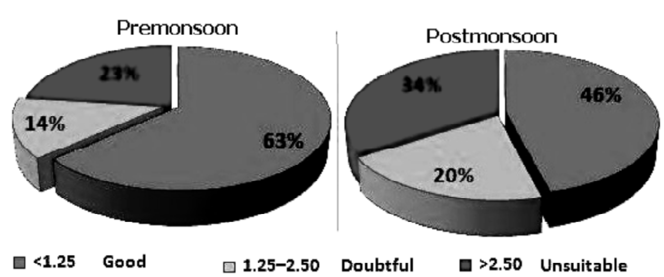

Figure 4: Suitability of groundwater quality for irrigation based on RSC values in the study area.

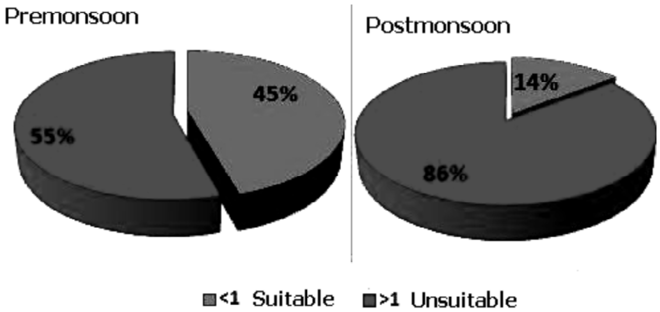

Figure 5: Suitability of groundwater quality for irrigation based on Kelley's ratio in the study area.

The Kelley's ratio of the ground waters is given as $\{Na^+/(Ca^+ + Mg^+)\}$, where ions are in meq/l [13]. 55% samples (premonsoon) and 86% samples (postmonsoon) were having value of Kelley's ratio above 1 which is unsuitable for irrigation (Figure 5).

Magnesium Hazard

High magnesium absorption by soils affects their physical properties as it may associate with soil aggregation and friability. Magnesium hazard (MH) value for irrigation water as given below [14]:

$MH = Mg^{2+}/(Ca^{2+} + Mg^{2+}) *100$: $MH > 50$ harmful and unsuiTable for irrigation use 84.5 % in premonsoon and 94 % samples in postmonsoon were having value of magnesium ratio above to 50 (Figure 6).

PERMEABILITY INDEX (PI)

PI indicates that the soil permeability is affected by long-term use of irrigation water as influenced by Na^+, Ca^{2+}, Mg^{2+}, and HCO_3^- contents of the soil and also indicate the suitability of groundwater for irrigation. It is defined as [15]:

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

Water can be classified as Class I, II and III. Class I and II water are categorized as good for irrigation with 25%-75% or more of maximum permeability. Class III water is unsuiTable with 25% of maximum permeability. In premonsoon, 97.5% of samples fall in class II and 2.5% under class III while in postmonsoon all the samples represent class II category.

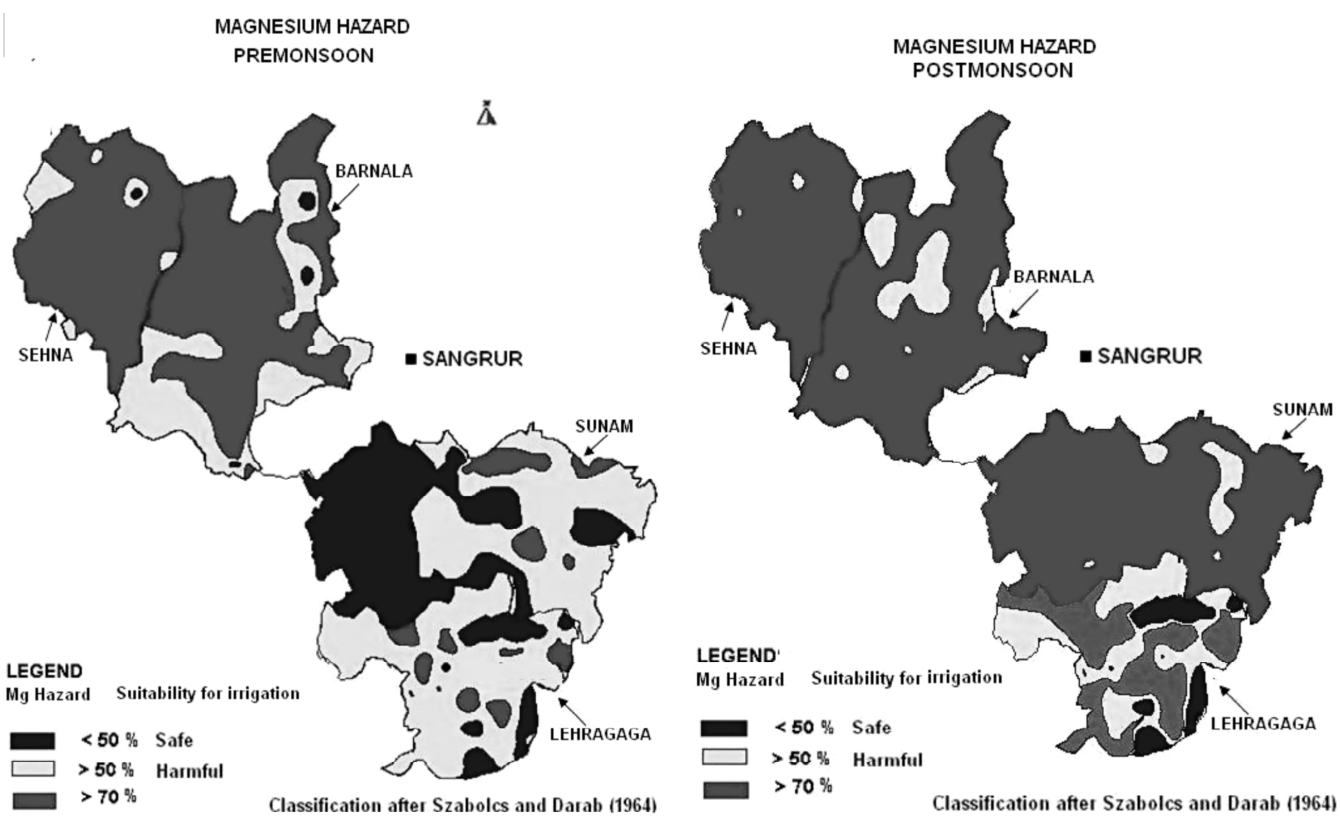

Figure 6: Suitability of groundwater quality for irrigation based on Magnesium hazard in the study area.

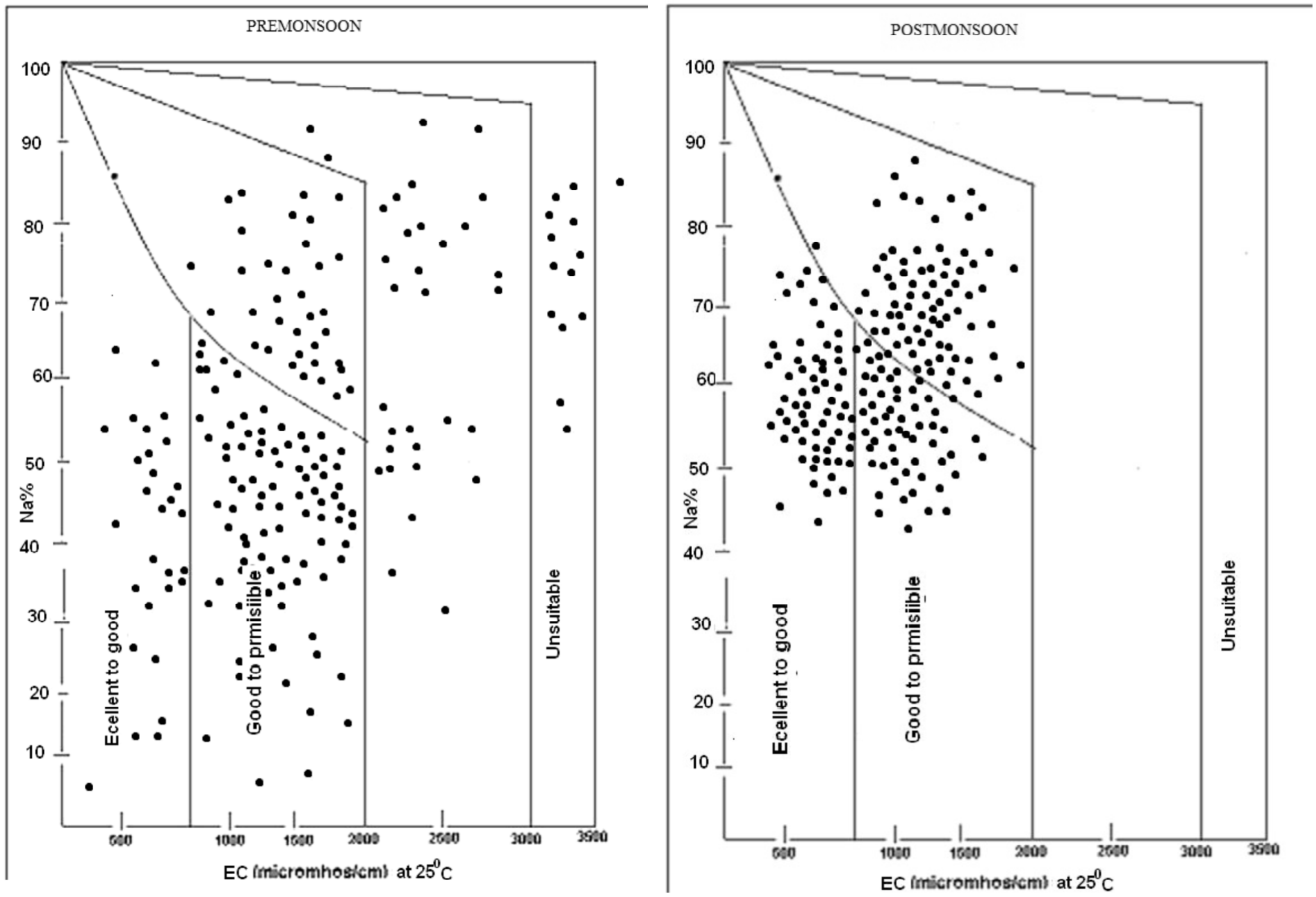

Figure 7: Classification of Water Quality of the study area for Irrigation on Wilcox classifications.

IRRIGATION WATER QUALITY BASED ON VARIOUS CLASSIFICATIONS

US Salinity Laboratory Procedure [16]

74.50% groundwater samples fall in the field of (C_3 – S_1) which can be used for irrigation on almost all types of soil with little danger of exchangeable Sodium. 13.50% samples fall in the field of (C_4 – S_2), which is normally not suiTable for irrigation on salinity basis but can be used on organic soils with good permeability. 2.5% samples fall in the field of (C_4 – S_3) which is unsuitable for irrigation (Table 7).

Table 7
Classification of irrigation water of the study area based on "U.S.S.L staff Classification of irrigation waters".

S. No.	*Class*	*Hazard*	*% Samples Pre*	*Post*
1.	(C_1 – S_2)	Low salinity-Low sodicity	–	
2.	(C_2 – S_1)	Medium salinity-Low sodicity	2%	–
3.	(C_3 – S_1)	High salinity-Low sodicity	74.5%	97%
4.	(C_4 – S_1)	Very High salinity-Low sodicity	7.5%	–
5.	(C_3 – S_2)	High salinity-Medium sodicity	–	3%
6.	(C_3 – S_3)	High salinity-High sodicity	–	–
7.	(C_4 – S_2)	Very High salinity-Medium sodicity	13.5%	–
8.	(C_4 – S_3)	Very High salinity - High sodicity	2.5%	–

WILCOX CLASSIFICATION

Another method for determination of suitability for agricultural use in groundwater is by calculating Na+ percentage [17], because Na+ concentration reacts with soil to reduce its permeability [18].

Where all soluble cations are expressed in meq/l

$$\%Na = \frac{Na + K}{Ca + Mg + Na + K} \times 100$$

The classification of water for irrigation purposes on the basis of sodium concentration is shown in Table 8. Figure 7 is showing the classification of the water quality of the study area for irrigation after Wilcox (1955) for premonsoon and postmonsoon respectively.

Table 8
Classifications of water quality of the study area for irrigation waters on Wilcox classifications.

S. No.	Percent Sodium	Water Class	Premonsoon	Postmonsoon
1.	< 20	Excellent	5%	–
2.	20-40	Good	17%	–
3.	40-60	Permissible	42%	41%
4.	60-80	Doubtful	25%	54%
5.	> 80	Unsuitable	11%	5%

Table 9
Permissible limits for classes of irrigation water

S.No.	Classes of water		%Na	Cl^{-1}(meq/l)	SO_4^{-2}(meq/l)
1.	Class 1	Excellent	<20	<4	<4
2.	Class 2	Good	20-40	4-7	4-7
3.	Class 3	Permissible	40-60	7-12	7-12
4.	Class 4	Doubtful	60-80	12-20	12-20
5.	Class 5	Unsuitable	>80	>20	>20

Scofield Classification

Scofield (1935) published a Table (Table 9.) of permissible limits for irrigation waters which included consideration of chlorides and sulfates in addition to total salinity and sodium percentage [19]. Classification of the irrigation water quality of the study area based on Scofield Table is given in Table 10.

CONCLUSION

The results revealed that the status of groundwater in Sangrur was not so good for irrigation except for a few locations and it may deteriorate in future, as was evident from the very high percentage of water samples falling beyond the desirable limits. High EC, percent sodium, Kelley's ratio and magnesium hazards at a number of subareas clearly indicate the non-suitability of groundwater for irrigation purposes. 13.50% samples fall in the field of (C_4 – S_2), which is normally not suiTable for irrigation on salinity basis but can be used on organic soils with good permeability. 2.5 % samples fall in the field of (C_4 – S_3) which is unsuiTable for irrigation. The quality of groundwater for few samples was better in premonsoon than postmonsoon.

Table 10
Classification of the groundwater quality of the study area

Water Class		Na%		Cl^{-1} (meq/l)		SO_4^{-2}(meq/l)	
		Pre	Post	Pre	Post	Pre	Post
Class 1	Very Good	5%	---	52.5%	81.5%	100%	99%
Class 2	Good	17%	---	13%	16%	---	1%
Class 3	Can be used	42%	41.4%	16%	2.5%	---	---
Class 4	Use with Caution	5%	53.5%	10%	---	---	---
Class 5	Harmful	17%	5%	8.5%	---	---	---

*Figure are in sample % in the particular categories of degree of problem

This may be due to contribution from anthropogenic and agricultural sources, which leached to groundwater in postmonsoon. On an average, the groundwater of study area is fine for irrigation except in some parts of Sehana and Lehragaga blocks where high salinity and sodicity have been observed. For such areas, adequate drainage and the introduction of alternative salt tolerant crops are required. Undoubtedly, the overstretched use of natural resources has been done to meet the growing food. Therefore, efficient use and management of agriculture resources, especially groundwater has become absolutely necessary to sustain intensive agriculture and income of farmers in the state.

SUGGESTIONS

Public awareness program for the farmers on the consequences of inferior water quality on agricultural fields shall be made mandatory which is a key factor for successful water quality management for sustainable development. Proper salinity control programmes should be adopted throughout the whole district to reduce salts content in soils and their seepage to groundwater sources. Change in cropping pattern is recommended to reduce the heavy pumping of groundwater. The construction of roof top rainwater harvesting and artificial recharge to groundwater structure should be made mandatory for urban area.

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