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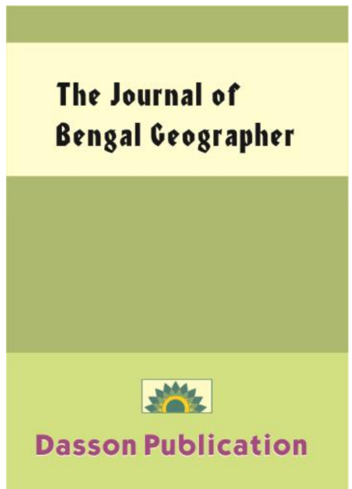


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# Evaluation of Ground Water Quality and Suitability for Irrigation Purposes in Nathusari Chopta block of Sirsa District (Haryana, India) using Geo-informatics

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***Abstract***

*Groundwater is a very important source of irrigation in most arid and semiarid regions of the country. Hence, there is a need to assess the quality and suitability of groundwater for irrigation and sustainable crop production in these regions. In order to evaluate the quality & suitability of groundwater in Nathusari Chopta block of Sirsa district, where total rural population exist and majority of them are farmers. The study area was fall under semiarid climatic condition where groundwater serves as the most consistent source of water for their domestic and agricultural activities. Seventy eight groundwater samples were collected and analysed for pH, electrical conductivity (EC), anions ($HCO_3^{-}$, $CO_3^{2-}$) and cations ($Ca^{2+}$, $Mg^{2+}$ and $Na^{+}$). From the results of the analyses and measurements, the suitability of the groundwater for irrigation were evaluated based on the EC, sodium adsorption ratio (SAR), permeability index (PI), residual sodium carbonate (RSC), and Kelly's ratio (KR). The interpolation technique of geospatial technology was also used to analyse and mapping of spatial changeability of EC, pH, SAR, RSC and groundwater quality, which provide first-hand information about the quality of groundwater. US salinity laboratory diagram were also applied for the present study. The EC results showed that the 60.25% and 25.64% of the samples fall under doubtful and unsuitable category respectively. The present study analyzed that groundwater in the study area falls within the high salinity-low sodium hazard and medium salinity-low sodium hazard classes. The importance of carrying out pre-treatment and monitoring of the studied samples if they were to be utilized for irrigation. One option is to beat this issue to grow salt tolerant crops. Regarding the remaining indices (RSC, SAR, PI & KR), the results showed that more than 90% of the samples were found to be within the safe limit and likely suitable for agricultural irrigation purposes.*

***Keywords:*** *Groundwater quality, Geospatial technology, Anions, Cations, SAR, KR, RSC.*

## Introduction

The realization that no life can be possible in the absence of water, but it is less; fact is that almost half of the total population of the world is deprived essential quality of water supply for various uses. The quality of water is as important as it has quantity. The availability of this essential natural resource has been taken for granted because of lack of awareness. Groundwater is the main source of water that meets the agricultural, industrial and household requirements. During the past few decades, the contest for economic development allied with the population growth and urbanization has led to the major changes in land use, thus resulting in more demand of water for these activities (Nag et. al, 2014). The usable water resource is not sufficient in India for irrigation in the cultivatable area. Due to this, efforts are required to enhance the source of water for irrigation in agriculture (Sharma, 2005; Ahamed *et al*., 2013). As per Agricultural Statistics of Haryana 2016-17, the irrigation facilities in the state mainly cover by canals (38.8%) and tube-well (61.2%). Thus, the groundwater is largely used in irrigation so the quality and suitability of groundwater is major requirement for sustainable crop production.

The groundwater quality for irrigation depends upon the mineral constituents present in the water (Etteieb *et al*., 2017). Groundwater is valuable only when its quality is suitable for a multiplicity of purposes. Therefore, Irrigation water of good quality is essential to maintain the soil crop productivity at a higher level. The excessive ground water draft from randomly distributed tube-wells for irrigation purposes has changed the ground water level, quantity and quality scenario making it difficult to study its behavior and movement. The basic feature controlling ground water quality is dissolved substances, which are generally called as the salts. The salts should contain small amounts of dissolved solids originating from dissolution or weathering of the rocks.

The interactions of water, soil, rock and source of various pollutants are responsible for the inequality of groundwater quality. Sequentially to excess withdrawal of groundwater can also change the natural quality of groundwater. Thus, the safety and management for improving the groundwater quality are necessary. For the sustainable development of society, the groundwater is playing a crucial role; consequently, the evaluation of groundwater quality is prerequisite at time to time of the country for its better supervision (Rao, 2018). Keeping in view the aforementioned facts, the present study was undertaken to evaluation and suitability of groundwater quality for irrigation purposes in Nathusari Chopta block of district Sirsa, Haryana.

## Materials and Methodology:

**Location of the study area:** The ‘Nathusari Chopta block’ of Sirsa district is situated on the border of Haryana and Rajasthan. It is located between 29°13’21” to 29°31’28” North latitude and 74°54’13” to 75°18’40 East longitude. The block is 20.3 kms far from district headquarter Sirsa. As per Censes, 2011 the block had 56 villages and total geographical area was 757.05 square km.

**Methodology:** In order to evolution of groundwater quality of the area, 78 groundwater samples were collected during 2019. The locations of groundwater sampling sites were also recorded in the field using Geographical Positioning System (GPS) and the location map is to be prepared. (Map-1). The samples were collected from private tube-well, hand-pump and wells in pre cleaned sterilized polyethylene plastic bottles of 1 L capacity. The ground water samples were analyzed for hydro- chemical parameters of Calcium (Ca), Magnesium (Mg) and Sodium (Na+). The physical parameters like Electrical Conductivity (EC) were also measured by conductivity meter and pH by pH meter. All chemical parameters are expressed in milli equivalent per liter except pH and EC. To find irrigation water quality based on EC, SAR and RSC, water samples were classified into different categories as per the classification of All India Coordinated Research Project (AICRP) on Management of Salt Affected Soils and Use of Saline Water in Agriculture (AICRP, 1989; Table 2). In order to find the suitability of groundwater in agricultural irrigation, several indices such as Sodium absorption ratio (SAR), Permeability index (PI), Residual sodium carbonate (RSC), Kelly`s ratio (KR) Electrical conductivity (EC) and US salinity laboratory diagram have been used. The concentrations of the ions were interpreted and calculated from standard equations as (Table-3)

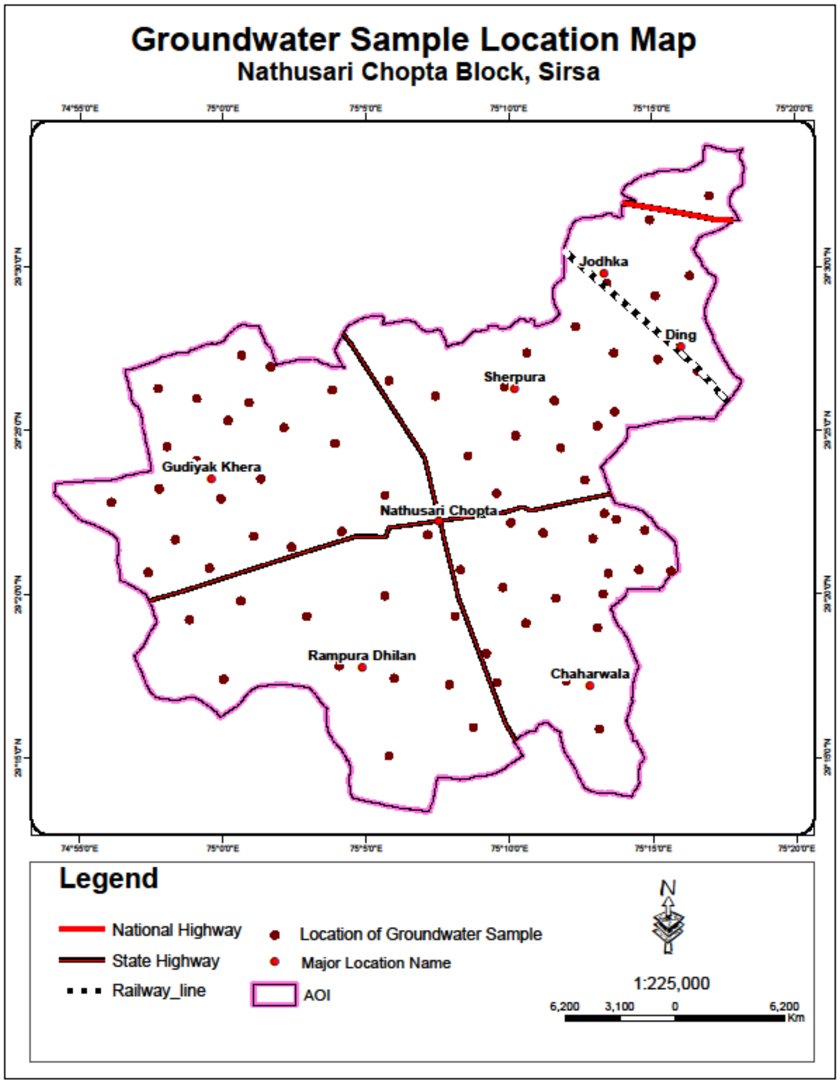
Table-2 Irrigation water quality classification

| Water quality | Class | Quality parameter | | |
|---|---|---|---|---|
| | | EC (dS m-1) | SAR | RSC (meq L-1) |
| Good | A | < 2 | <10 | < 2.5 |
| Saline | B | | | |
| Marginally saline | $B_1$ | 2-4 | <10 | < 2.5 |
| Saline | $B_2$ | > 4 | <10 | < 2.5 |
| High SAR saline | $B_3$ | > 4 | >10 | < 2.5 |
| Alkai water | C | | | |
| Marginally alkali | $C_1$ | < 2 | <10 | 2.5-4 |
| Alkali | $C_2$ | < 2 | <10 | > 4 |
| Highly alkali | $C_3$ | Variale | >10 | > 4 |

Table-3

The equations used to calculate the irrigation induces

| **Index** | **Equation** | **Reference** |
|---|---|---|
| Sodium adsorption ratio | $\mathrm{SAR} = \frac{\mathrm{Na}^+}{[(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})/2]^{1/2}}$ | Raghunath,1987 |
| Kelly`s ratio | $KR = \frac{\mathrm{Na}^+}{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}$ | Kelly,1963 |
| Permeability Index | $\mathrm{PI} = \frac{(\mathrm{Na} + \sqrt{\mathrm{HCO_3}}) \times 100}{\mathrm{Ca} + \mathrm{Mg} + \mathrm{Na}}$ | Doneen, 1964 |
| Residual Sodium Carbonate | $RSC = (\mathrm{CO_3} + \mathrm{HCO_3} - (\mathrm{Ca} + \mathrm{Mg}))$ | Eaton,1950 |




Map-1

## Result and Discussion

The concentration and composition of dissolved constituents in groundwater determine its quality for irrigation use. The ground water samples were analysed for various chemical parameters, viz., pH, EC, anions ($CO_3^{-2,}$ & $HCO3^{-)}$ and cations ($Ca^{2+}$, $Mg^{2+}$ and $Na^{+)}$. Subsequently, SAR, PI, KR and RSC were calculated for these samples. The range and mean of different water quality parameters are given in table 4.

Table-4
Minimum-maximum and mean values of different water quality parameters in Nathusari Chopta block

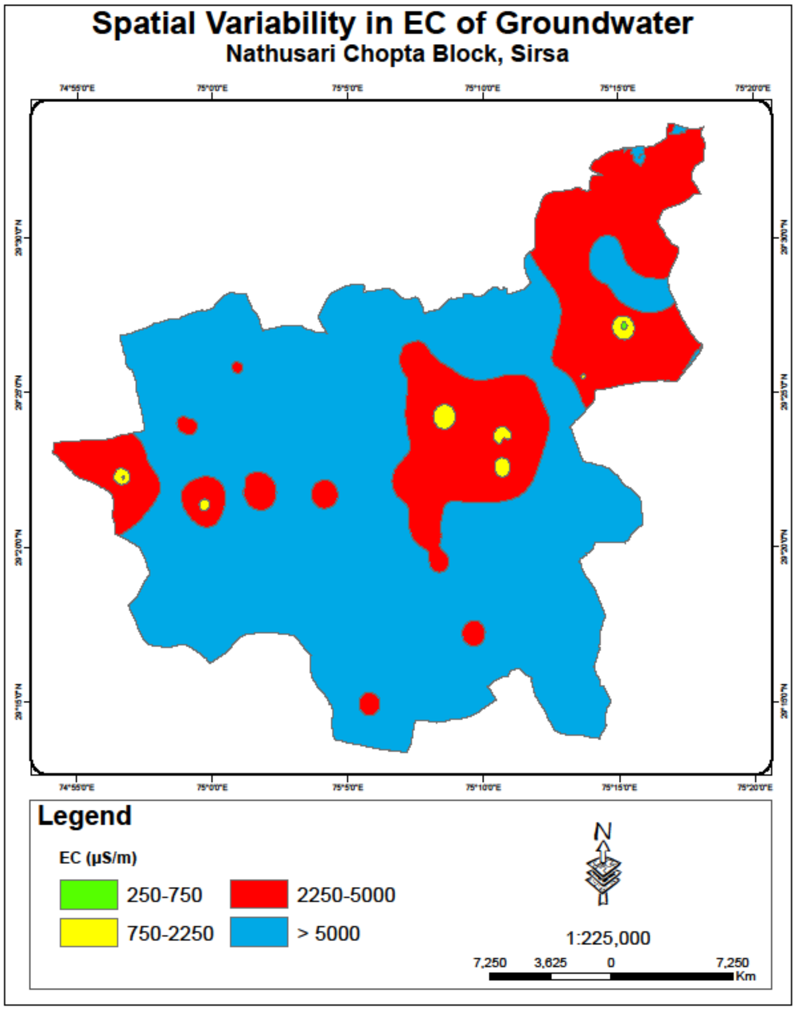
| Index | Minimum | Average | Maximum |
|---|---|---|---|
| KR(meq/l) | -0.86 | 0.53 | 2.26 |
| SAR(meq/l) | -3.43 | 2.13 | 9.04 |
| PI(meq/l) | -557.89 | 32.57 | 89.64 |
| RSC(meq/l) | -96 | -36.87 | -1.96 |
| EC(µs/cm) | 450 | 5990.71 | 16300 |
| pH | 6.7 | 7.31 | 8.4 |

**Electrical Conductivity (E.C.):**

Electrical Conductivity (EC) is a measure of the degree of the mineralization of the water, which is dependent on rock water interaction, and thereby the residence time of the water in the rock (Eaton, 1950). EC of the irrigation water becomes one of the important parameters to evaluate the overall chemical quality of groundwater. It is also a powerful criterion to measure the salinity hazard to the crops. It conveys information about the soluble salts in the water samples and potential risk to the productivity of the crops. The higher values of the electrical conductivity the less the amount of water that is available to the crops. In the present study irrigation water quality based on electrical conductivity values (Richards, 1954) were adopted (Table-5). The EC values in this study indicated that 61.04 % (47 samples) fall within the unsuitable category; while 20 samples (25.97%) and 8 samples (10.39 %) fall within the doubtful and permissible categories, respectively. Only 2 samples (2.60%) fall within the good categories as showed in table-5 and spatial variability in EC of groundwater in the study area as showed map-2

Table-5
Groundwater quality based on EC

| Criteria | Parameter | Category | Range | No of Sample | % of Samples |
|---|---|---|---|---|---|
| USSL Classification after Richards (1954) | E.C. (µS/m) | Excellent | < 250 | Nil | Nil |
| | | Good | 250-750 | 2 | 2.60 |
| | | Permissible | 750-2250 | 8 | 10.39 |
| | | Doubtful | 2250-5000 | 20 | 25.97 |
| | | Unsuitable | >5000 | 47 | 61.04 |




Map-2

## Residual Sodium Carbonate (RSC):

The quantity of bicarbonate and carbonate in excess of alkaline soil (Ca +Mg) also influences the suitability of water for irrigation purposes. Residual sodium carbonate (RSC) is frequently used to assess the water quality for irrigation purpose, was not applied in present day. The RSC value is computed, where ions are expressed in meq/l using the formula (Table-2).

As per criteria of EEC Classification in Lloyd and Heathcote, 1985 (Table-6) all samples of study area are within the safe quality categories for irrigation this indicates that water is suitable for irrigation. The RSC values varied from -91.3 to 0.78 meq $L^{-1}$ (Table 4).Most samples (95%) showed negative values which indicated that dissolved calcium and magnesium contents were higher than carbonate and bicarbonate contents. It indicates that 100 % of the samples have a good water quality where RSC values are less than 1.25 meq $L^{-1}$. (Table-6)

Table -6
Suitability of irrigation water based on RSC

| Criteria | Parameter | Value range | Suitability for Irrigation | Area in Sq. km | Percent of Study area |
|---|---|---|---|---|---|
| EEC Classification in Lloyd and Heathcote(1985) | RSC(meq/l) | < 1.25 | Suitable | 756.44 | 100 |
| | | 1.25–2.5 | Marginal | 0 | 0 |
| | | > 2.5 | Unsuitable | 0 | 0 |

## Sodium adsorption ratio (SAR):

The SAR is used to estimate the sodicity hazard of the water, the sodium adsorption ratio (SAR) is used to predict the danger of sodium accumulation in soil. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability and soil structure (Kelly, 1957). Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The sodium or alkali hazard in irrigation water is recommended by USSL which takes into account of the relative activity in the exchange reaction with soil as expressed in terms of ratio known as SAR (Sodium Adsorption Ratio) and SAR is calculated by the formula (Table-2).

While high salt content (EC) in waters leads to development of saline soil, high sodium content (SAR) leads to development of an alkaline soil. SAR can indicate the degree to which irrigation water tends to enter cation-exchange reaction in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and develops permeability problems. This will support little or no plant growth. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd, 1980).

The groundwater of the study area was classified with respect to SAR values (Richard 1954) (Table 7). According to the above classification, the SAR values in the study area range from - 3.43 to 9.04 meq/l and the samples of the study area have been classified as there is no danger of sodium consideration in soil as per SAR. The higher the SAR values in the water, the greater the risk of sodium.

Table -7

Suitability of irrigation water based on SAR

| **Criteria** | **Parameter** | **Value range** | **Suitability for Irrigation** | **Area in Sq. km** | **Percent of Study area** |
|---|---|---|---|---|---|
| USSL Classification after Richards (1954) | SAR | <10 | Excellent | 756.44 | 100 |
| | | 10–18 | Good | 0 | 0 |
| | | 18–26 | Doubtful | 0 | 0 |
| | | > 26 | Unsuitable | 0 | 0 |

A plot of groundwater data on the US salinity diagram (Richards 1968), in which the EC is taken as salinity hazard and SAR as alkalinity hazard (Fig.-1), shows 19.48 %(Table-8) of the samples fall within the meduim salinity-low sodium type of water (C2-S1) and 40.26 % fall under medium salinity-low sodium class (C3-S1). More over 45 % of the samples fall within the high-salinity hazard-medium sodium hazard class (C3-S2). Groundwater that fall within the C1-S1 and C2-S1 can be used for irrigation on all types of soil with little danger of the development of harmful levels of exchangeable sodium. However, C3- S2 and C3-S4 types of water could only be used to irrigate certain semi-tolerant crops (Ahamed et al. 2013).

Table-8

| Water quality | Class | Number of Sample | % of Sample |
|---|---|---|---|
| Very Good | C1- S1 | 2 | 2.60 |
| Good | C2-S1 | 15 | 19.48 |
| | C2-S2 | | |
| Medium | C2-S3 | 31 | 40.26 |
| | C3-S1 | | |
| Bad | C2 - S4 | 17 | 22.08 |
| | C3-S2 | | |
| Very Bad | C3 - S3 | 12 | 15.58 |
| | C3 - S4 | | |

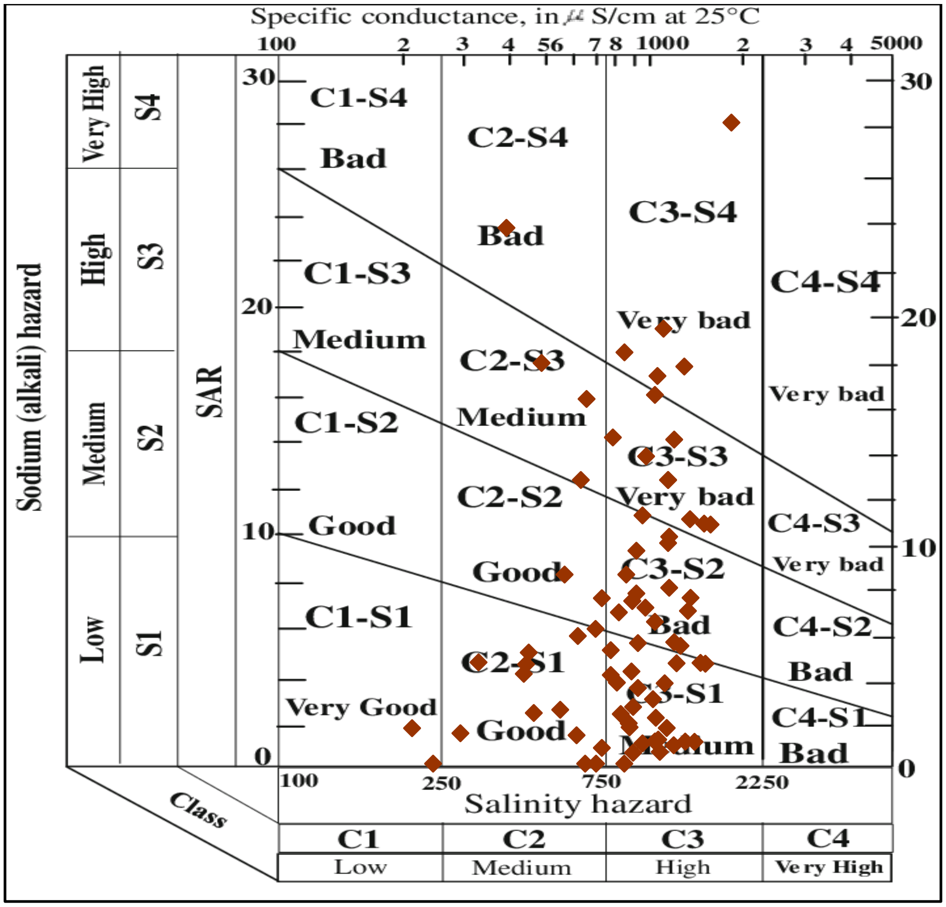



Fig-1

**pH:**

The pH is the concentration of hydrogen ions (H+) and hydroxyl ions (OH-) in the water. It is important parameter for determining acidity, neutrality or alkalinity of water. In the present study, the pH of groundwater samples ranged from 6.7 to 8.4 with a mean value of 7.31 (Table-2) indicating that the water is neutral to alkaline in nature. The lowest pH was observed in Jogiwala village and highest in Mochiwali village. The variations in pH are relatively small and the results also show that the alkaline pH is particularly due to bicarbonate and not due to carbonate alkalinity (Ahmad et.al, 2011). The higher pH of most of the groundwater samples may be due to considerable sodium, calcium, magnesium, carbonate and bicarbonate concentration (Al-Tabbal *et al*, 2012) as carbonates and bicarbonates are hydroxyl generating ions (Bhat *et al*., 2018). The spatial variability of pH of groundwater the block is showed in map-

**Permeability Index (PI):** Permeability index of the soils can be affected by the long term use of the irrigation water when it contains high concentrations of salts. It is a crucial parameter for assessing the suitability of irrigation water. In accordance with PI, water can be classified as Class I, II and III. The PI values of the groundwater samples varied from-557.89 to 89.64 with an average of 32.57%, while as 68.83 % (53 samples) of groundwater fall within II class and 27.27% (21Samples) with in III class categories respectively. (Table-9)

Table-9

Classification of irrigation water based on permeability index

| PI% | Class | No of Sample | % of Sample |
|---|---|---|---|
| > 75 | I | 3 | 3.90 |
| 25-75 | II | 53 | 68.83 |
| < 25 | III | 21 | 27.27 |

**Kelly's Ratio (KR):** Waters with a KR value <1 are regarded suitable for irrigation, while those with higher values are considered unsuitable (Table-10). KR values of groundwater varied from -0.86 to 2.26 while as the majority (80.52%) of the collected samples fall within the permissible limit of < 1 and thus are considered suitable for the agricultural irrigation. Only 19.48 % (15 Samples) of collected groundwater fall within unsuitable class as per KR index.

Table-10

Classification of irrigation water based on Kelly's ratio

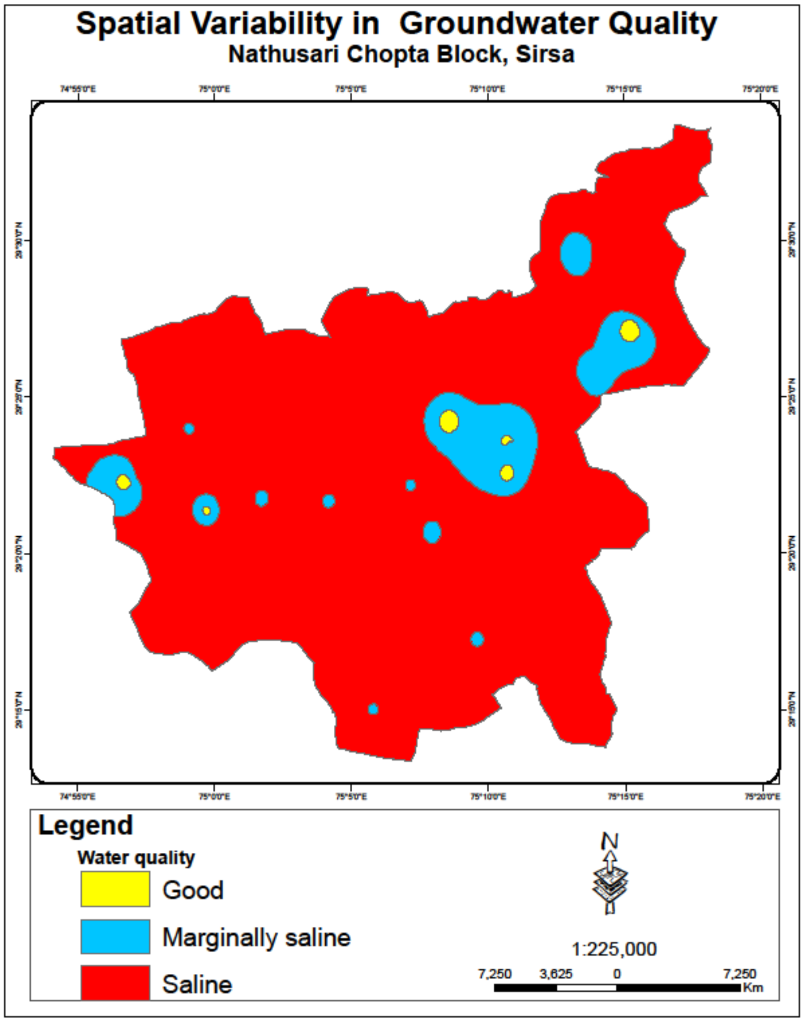
| KR(me/I) | Class | No of samples | % of samples |
|---|---|---|---|
| <1 | Safe | 62 | 80.52 |
| > 1 | Unsuitable | 15 | 19.48 |

**Groundwater quality as per AICRP Criteria:** According to AICRP, (1989) on Management of Salt Affected Soils and Use of Saline Water in Agriculture classification, in the present study area out of 77 groundwater samples indicated that 72.73% (56 samples) fall within saline category; while as 10 samples (12.99%) and 11 samples (14.29%) fall within the good and marginally saline categories, respectively as showed in table-11 and map-4.

Table-11

Groundwater quality classification of Nathusari Chopta block

| Water quality | Class | Number of Sample | % of Sample |
|---|---|---|---|
| Good | A | 10 | 12.99 |
| Saline | B | Nil | Nil |
| Marginally saline | $B_1$ | 11 | 14.29 |
| Saline | $B_2$ | 56 | 72.73 |
| High SAR saline | $B_3$ | Nil | Nil |
| Alkai water | C | Nil | Nil |
| Marginally alkali | $C_1$ | Nil | Nil |
| Alkali | $C_2$ | Nil | Nil |
| Highly alkali | $C_3$ | Nil | Nil |




Map-4

## Conclusion

The evolution of groundwater quality and suitability for agricultural irrigation in Nathusari Chopta block was conducted based on different indices like RSC, PI, SAR, KR and EC. These indices were complied with the recommended to national and internationally accepted standards. Moreover, the groundwater was suitable for irrigation at most sites by using RSC, SAR, and KR approaches. However, 87% of the samples were doubtful and unsuitable for irrigation, because of the high salinity in water. More attention should be paid on groundwater salinity variations in future management for sustainable utilization. The PI values based analysis shows that 72.73 % groundwater samples falls under Class I and II, making the groundwater suitable for irrigation. The US Salinity diagram also reveals that majority of the groundwater fall within the medium salinity-low sodium hazard and high salinity-medium sodium hazard class. This groundwater could therefore be used limitedly and carefully to irrigate only semi-tolerant crops. The spatial variability maps generated for various physicochemical parameters using geospatial technology could be valuable for policy makers for initiating groundwater quality monitoring in the study area.

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