Evaluation of quality of underground irrigation water of Nagaur District with salinity, Sodicity and alkalinity contamination

Prabhoo Singh, KK Sharma, BL Yadav, Rajhans Varma and Ramesh Chand Bana

Abstract
In this study, some important chemical parameters of underground water of the area were evaluated for the criteria of irrigation water quality. Higher values of pH, EC, SAR and RSC make the underground water unfit for irrigation purposes. One hundred fifty underground irrigation water samples were collected from various tehsils of Nagaur district during 2018-19. Based on salinity the classes of irrigation water were recorded normal water (0.66%), Low salinity water (39.34%), Medium salinity water (60%) and based on sodicity the classes of irrigation water were recorded normal water (2%), Low sodicity water (74.66%), medium sodicity water (23.34%) and based on alkalinity the classes of irrigation water were recorded non alkaline water (30%), Normal water (2%), Low alkalinity water (44.66%), medium alkalinity water (16%), high alkalinity water (7.34%). Majority of the water samples are fall under low to medium suitable category of water for irrigation purposes.

Keywords: Irrigation water quality, Ph, electrical conductivity, sodium absorption ratio and residual sodium carbonate

Introduction
Quality of underground water is one of the major factors to be considered in irrigation purpose. The soil properties viz. physical, chemical and biological properties are generally associated with use of underground water which can alter soil properties as well as plant characteristics (Khan et al., 2014) [9]. The arid and semi arid zone of Rajasthan is characterized with deep and generally saline ground water (Khan and Sharma 2007) [6], ranging from 2.1 to 9.1 dS m⁻¹ salinity in underground irrigation water of Rajasthan (Agrawal et al., 2002) [1]. In the arid and semi-arid regions, irrigation is essential for successful agriculture and in some areas, particularly in the arid zone, the main source of irrigation is underground irrigation water which is usually saline with varying degree of salt concentration. Such saline waters have been in the use since decades with adverse effects on physical, chemical and biological properties of irrigated soils and ultimately the crop growth (Chopra et al., 2014) [8].

Sodium content is another limiting factor of underground irrigation water under arid and semi arid condition. The use of high-SAR irrigation water was found to reduce the efficiency of the irrigations (Emdad et al., 2006) [1]. Excess sodium in underground water causes soil particles to repel each other, preventing the formation of soil aggregates (Batarseh 2017) [5]. High carbonate and bicarbonate concentration in irrigation water leads to precipitation of calcium and magnesium as carbonate and bicarbonate in the soil solution. This result in loss of Ca²⁺ and Mg²⁺ ions and increase of Na⁺ ions on the exchange complex. These soils become highly sodic (Naga et al., 2017) [11]. The literature showed that no studies had been undertaken within the study area with regard to chemical properties of water yet. So the aim of this study turns out to be to analyze the satisfactory of underground water with special connection with the awareness of sodicity and salinity.

Materials and Methods

Study area and its location
The area studied lied in the Agro climatic zone IIA (Internal drainage dry zone) of Rajasthan.

Received: 01-01-2020
Accepted: 05-02-2020

Prabhoo Singh
Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

KK Sharma
Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

BL Yadav
Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

Rajhans Varma
Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

Ramesh Chand Bana
Department of Agronomy, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

Corresponding Author:
Prabhoo Singh
Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India

DOI: https://doi.org/10.22271/chemi.2020.v8.i2y.8990
The present district of Nagaur finds a place in the heart of the Rajasthan state at 26° 25' & 27° 40' North latitude and 73° 10' & 75° 15' East longitude, comprising of five tehsils, viz. Nagaur, Jayal, Didwana, Ladnu, Nawa.

Collection of ground water samples
Georeferenced 150 water samples of tube well/open well were collected where the waters are being used for irrigation for last few years. Water samples were collected in various tehsils of Nagaur district. In order to get representative samples, pump was kept in operation before collecting the sample. Collected samples were stored in cleaned, rinsed and properly label bottles. Before the bottles were corked, few drops of toluene were also added to check the microbial growth.

- pH = pH meter
- EC = Conductivity meter
- Sodium Adsorption Ratio (SAR) =
  \[ \text{SAR} = \frac{\text{Na}^+}{\sqrt{\text{Ca}^{2+} + \text{Mg}^{2+}}} \]
- Residual Sodium Carbonate (RSC) = RSC = (CO$_3^{2-}$ + HCO$_3^-$) – (Ca$^{2+}$ + Mg$^{2+}$)

Classification of irrigation water on the basis of salinity (EC), sodicity (SAR) and alkalinity (RSC) (Gupta, 1986) [7]

Salinity
The classification of irrigation water on the basis of EC is based primarily on the development of salinity in the soil to the extent that yields of crops are adversely affected. On the basis of electrical conductivity, the irrigation water may be classified into six salinity classes as proposed by Gupta (1986) [7].

C-0 non-saline waters (EC <0.2 dS m$^{-1}$) may create severe permeability problem in the soil because infiltration rate into the soil is adversely affected due to lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced.

C-1 normal water (EC 0.2-1.5 dS m$^{-1}$) can be used for irrigation for most crops on most soils with little likelihood that soil salinity will develop.

C-2 Low salinity water (EC 1.5-3.0 dS m$^{-1}$) can be used if a moderate amount of leaching occurs under the current irrigation practices. Most of the crops except sensitive ones can be grown on all soils except very heavy textured soils with impeded drainage.

Sodicity
The classification of irrigation water with respect to sodic hazard on the basis of SAR is based primarily on the increase of exchangeable sodium and its effect on the physical condition of the soil. On the basis of SAR, the irrigation waters may be classified in six classes as proposed by Gupta (1986) [7].

S-0 Non-sodic water (SAR < 5) can be used for irrigation on almost all soils for all crops even those sensitive to sodium.

S-1 Normal water (SAR 5-10) can be used for irrigation on almost all soils with little danger of the development of harmful level of exchangeable sodium for growing all crops except sensitive to sodium.

S-2 Low sodicity water (SAR 10-20) can be used for crops which are semi-tolerant or tolerant to sodium on almost all soils such that leaching fraction is around 0.3. If there is a presence of gypsum or calcium carbonate in the soil, these waters can be used more successfully.

Alkalinity
The alkalinity hazard is based on RSC and primarily caused by the precipitation of Ca$^{2+}$ or Mg$^{2+}$ and pairing of residual CO$_3^{2-}$ or HCO$_3^-$ with sodium and formation of Na$_2$CO$_3$ in the soil and increasing SAR/ESP, characterizing it as alkali soil. On the basis of RSC, the irrigation water may be classified in six classes as proposed by Gupta (1986) [7].

A-0 Non-alkaline water (RSC negative) can be used for irrigation on almost all soils for all crops for indefinitely long periods without any problem.

A-1 Normal water (RSC 0 me L$^{-1}$) can be used for irrigation on almost all soils for all crops even those were sensitive to carbonates or bicarbonates.

A-2 Low alkalinity water (RSC < 2.5 me L$^{-1}$) can be used for irrigation on almost all soils for all crops.

A-3 Medium alkalinity water (RSC 2.5-5.0 me L$^{-1}$) can be used for irrigation on almost all soils with little danger of the development of harmful levels of alkali for growing all crops except sensitive to carbonates or bicarbonates.

A-4 High alkalinity water (RSC 5.0-10.0 me L$^{-1}$) can be used for irrigation on soils provided with good drainage such that leaching fractions (L.F.) is not less than 0.3 for growing semi tolerant and tolerant crops to sodium. EC should be < 3.0 dS m$^{-1}$ and < 10 SAR.

Results and Discussion
One hundred fifty irrigation water samples were taken from five tehsils of Nagaur District. The irrigation water samples were analyzed for their chemical properties and the results obtained have been presented and discussed in the light of past findings and that of present investigation.

The classification of underground irrigation water on the basis of combind effect of salinity (EC), sodicity (SAR) and alkalinity (RSC) of the irrigation water as the characteristics proposed by Gupta (1986) [7].

| S. No. | Water quality     | Symbol | EC (dS m$^{-1}$) | No. of water sample | Percent of water sample |
|-------|------------------|--------|----------------|---------------------|------------------------|
| A.    | Salinity         |        |                |                     |                        |
| 1.    | Non saline water | C-0    | <0.2           | 1                   | 0.66%                  |
| 2.    | Normal water     | C-1    | 0.2-1.5        | 59                  | 39.34%                 |
| 3.    | Low salinity water| C-2    | 1.5-3.0        | 90                  | 60%                    |
| B.    | Sodicity         | SAR    |                |                     |                        |
| 1.    | Non sodicity water| S-0    | ≤5             | 3                   | 2%                     |
| 2.    | Normal water     | S-1    | 5-10           | 112                 | 74.66%                 |
| 3.    | Low sodicity water| S-2    | 10-20          | 35                  | 23.34%                 |
| C.    | Alkalinity       | RSC (me L$^{-1}$) |            |                     |                        |
| 1.    | Non-alkaline water| A-0    | Negative       | 45                  | 30%                    |
| 2.    | Normal water     | A-1    | 0              | 3                   | 2%                     |
| 3.    | Low alkalinity water| A-2    | ≤2.5           | 67                  | 44.66%                 |
Table 2: Chemical properties of irrigation water of various tehsils of Nagaur district

| Tehsils | Ph     | EC (dS m⁻¹) | SAR   | RSC (me L⁻¹) |
|---------|--------|-------------|-------|--------------|
| Nagaur  | Max    | 8.70        | 4.60  | 22.78        | 3.70         |
|         | Min    | 7.20        | 1.20  | 8.50         | -3.30        |
|         | Mean   | 8.00        | 3.10  | 15.05        | 0.40         |
| Jayal   | Max    | 8.80        | 4.70  | 24.35        | 6.60         |
|         | Min    | 7.20        | 2.20  | 10.88        | -1.90        |
|         | Mean   | 8.10        | 3.60  | 18.15        | 1.40         |
| Didwana | Max    | 8.90        | 5.00  | 26.51        | 6.40         |
|         | Min    | 7.40        | 2.20  | 9.53         | -1.80        |
|         | Mean   | 8.10        | 3.40  | 17.71        | 2.00         |
| Ladnu   | Max    | 8.70        | 4.70  | 23.89        | 5.90         |
|         | Min    | 7.30        | 1.70  | 9.21         | -2.00        |
|         | Mean   | 8.10        | 3.30  | 16.77        | 1.00         |
| Nawa    | Max    | 8.90        | 4.90  | 28.40        | 5.80         |
|         | Min    | 7.20        | 1.90  | 10.35        | -1.80        |
|         | Mean   | 8.10        | 3.40  | 18.50        | 1.60         |

1. **pH**
The pH of underground irrigation water of various tehsils was recorded from 7.20 to 8.70 with the average value of 8.00 in Nagaur, 7.20 to 8.80 with the average value of 8.10 in Jayal, 7.40 to 8.90 with the average value of 8.10 in Didwana, 7.30 to 8.70 with the average value of 8.10 in Ladnu, 7.20 to 8.90 with the average value of 8.10 in Nawa, respectively. Similar result was also reported by Pradeep and Singh (2016) [16], Singh et al., (2018) [17]. According to Ayers and Westcot (1976) [3] the quality of underground irrigation water regarded 6.5 to 8.4 as a normal range of pH for safe irrigation.

2. **Electrical conductivity (EC)**
The EC of underground irrigation water of various tehsils was varied from 1.20 to 4.60 dS m⁻¹ with the average value of 3.10 dS m⁻¹ in Nagaur, 2.20 to 4.70 dS m⁻¹ with the average value of 3.60 dS m⁻¹ in Jayal, 2.20 to 5.00 dS m⁻¹ with the average value of 3.40 dS m⁻¹ in Didwana, 1.70 to 4.70 dS m⁻¹ with the average value of 3.30 dS m⁻¹ in Ladnu, 1.90 to 4.90 dS m⁻¹ with the average value of 3.40 dS m⁻¹ in Nawa, respectively. Similar result was also reported by Arora et al., (2012), Riaz et al., (2018) [2, 15].

3. **Sodium adsorption ratio (SAR)**
The sodium adsorption ratio of underground irrigation water of various tehsils was recorded from 8.50 to 22.78 with the average value of 15.05 in Nagaur, 10.88 to 24.35 with the average value of 18.15 in Jayal, 9.53 to 26.51 with the average value of 17.71 in Didwana, 9.21 to 23.89 with the average value of 16.77 in Ladnu, 10.35 to 28.40 with the average value of 18.50 in Nawa, respectively. Similar results
were also obtained by Chopra et al., (2014) [5], Singh et al., (2016) [16].

4. Residual sodium carbonate (RSC)
The RSC values of underground irrigation water of various tehsils was recorded from -3.30 to 3.70 me L⁻¹ with the mean value of 0.40 me L⁻¹ in Nagaur, -1.90 to 6.60 me L⁻¹ with the mean value of 1.40 me L⁻¹ in Jayal, -1.80 to 6.40 me L⁻¹ with the mean value of 2.00 me L⁻¹ in Didwana, -2.00 to 5.90 me L⁻¹ with the mean value of 1.00 me L⁻¹ in Ladnu, -1.80 to 5.80 me L⁻¹ with the mean value of 1.60 me L⁻¹ in Nawa, respectively. Similar results also reported by Singh et al., (2016) [16], More et al., (2017) [10].

5. Soluble cations
The cations viz., Na⁺, Ca²⁺, Mg²⁺, and K⁺ of underground irrigation water varied from 9.12 to 38.80, 1.10 to 4.40, 1.20 to 4.20 and 0.10 to 0.48 me L⁻¹ with the mean value 24.84, 2.63, 2.89 and 0.24 me L⁻¹ in Nagaur, 17.20 to 38.86, 1.40 to 3.80, 1.40 to 4.20 and 0.10 to 0.50 me L⁻¹ with the mean value 30.19, 2.86, 2.74 and 0.26 me L⁻¹ in Jayal, 15.80 to 42.50, 1.60 to 4.40, 1.40 to 4.20 and 0.10 to 0.41 me L⁻¹ with the mean value 28.82, 2.63, 2.66 and 0.25 me L⁻¹ in Didwana, 14.20 to 40.10, 1.10 to 4.10, 1.50 to 4.50 and 0.10 to 0.40 me L⁻¹ with the mean value 27.36, 2.78, 2.61 and 0.24 me L⁻¹ in Ladnu, 16.20 to 42.50, 1.40 to 4.20, 0.60 to 3.80 and 0.10 to 0.45 me L⁻¹ with the mean value 29.04, 2.59, 2.50 and 0.24 me L⁻¹ in Nawa, respectively. The results of the present investigation are in accordance with the findings of Reddy (2013) [14] and Singh et al., (2018) [17]. In general Na⁺ was found dominant cation in these underground irrigation waters followed by Mg²⁺, Ca²⁺ and K⁺.

6. Soluble anions
The anions viz., Cl⁻, CO₃²⁻, HCO₃⁻ and SO₄²⁻ of underground irrigation water ranged from 8.40 to 32.80, 0.30 to 2.00, 2.10 to 8.40 and 0.60 to 6.50 me L⁻¹ with the mean value 21.01, 0.86, 5.01 and 3.74 me L⁻¹ in Nagaur, 11.20 to 36.20, 0.40 to 2.00, 3.20 to 9.80 and 1.20 to 7.96 me L⁻¹ with the mean value 24.86, 1.00, 5.97 and 4.16 me L⁻¹ in Jayal, 8.80 to 32.80, 0.20 to 2.00, 3.20 to 9.20 and 1.10 to 9.56 me L⁻¹ with the mean value 22.89, 1.20, 6.13 and 4.19 me L⁻¹ in Didwana, 9.80 to 37.80, 0.20 to 1.60, 2.20 to 8.60 and 0.60 to 9.15 me L⁻¹ with the mean value 22.85, 0.85, 5.58, 3.82 me L⁻¹ in Ladnu, 16.60 to 40.60, 0.40 to 2.00, 2.50 to 8.80 and 0.58 to 8.20 me L⁻¹ with the mean value 23.74, 1.00, 5.71 and 3.95 me L⁻¹ in Nawa, respectively. In general chloride was found dominant anion in these irrigation water samples followed by HCO₃⁻, SO₄²⁻ and CO₃²⁻. Similar results were also reported by Ramkumar et al., (2010), Singh et al., (2018) [13, 17].

Table 3: Ionic composition of irrigation water of various tehsils of Nagaur district

| Tehsils | Cations (me L⁻¹) | Anions (me L⁻¹) |
|---------|-----------------|-----------------|
|         | Na⁺ | Ca²⁺ | Mg²⁺ | K⁺ | Cl⁻ | CO₃²⁻ | HCO₃⁻ | SO₄²⁻ |
| Nagaur  | Max  | 38.80 | 4.40 | 4.20 | 0.48 | 32.80 | 2.00 | 8.40 | 6.50 |
|         | Min  | 9.12  | 1.10 | 1.20 | 0.10 | 8.40  | 0.30 | 2.10 | 0.60 |
|         | Mean | 24.84 | 2.63 | 2.89 | 0.24 | 21.01 | 0.86 | 5.01 | 3.74 |
| Jayal   | Max  | 38.86 | 3.80 | 4.20 | 0.50 | 36.20 | 2.00 | 9.80 | 7.96 |
|         | Min  | 17.20 | 1.40 | 1.40 | 0.10 | 11.20 | 0.40 | 3.20 | 1.20 |
|         | Mean | 30.19 | 2.86 | 2.74 | 0.26 | 24.86 | 1.00 | 5.97 | 4.16 |
| Didwana | Max  | 42.50 | 4.40 | 4.20 | 0.41 | 38.20 | 2.00 | 9.20 | 9.56 |
|         | Min  | 15.80 | 1.60 | 1.40 | 0.10 | 8.80  | 0.40 | 3.20 | 1.10 |
|         | Mean | 28.82 | 2.63 | 2.66 | 0.25 | 22.89 | 1.20 | 6.13 | 4.19 |
| Ladnu   | Max  | 40.10 | 4.10 | 4.50 | 0.40 | 37.80 | 1.60 | 8.60 | 9.15 |
|         | Min  | 14.20 | 1.10 | 1.50 | 0.10 | 9.80  | 0.20 | 2.20 | 0.60 |
|         | Mean | 27.36 | 2.78 | 2.61 | 0.24 | 22.85 | 0.85 | 5.58 | 3.82 |
| Nawa    | Max  | 42.50 | 4.20 | 3.80 | 0.45 | 40.60 | 2.00 | 8.80 | 8.20 |
|         | Min  | 16.20 | 1.40 | 0.60 | 0.00 | 10.60 | 0.40 | 2.50 | 0.58 |
|         | Mean | 29.04 | 2.59 | 2.50 | 0.24 | 23.74 | 1.00 | 5.71 | 3.95 |

Conclusion
Monitoring of the quality of underground irrigation water is done by collecting representative water samples and analysis of physico-chemical characteristics of water samples at different locations of Nagaur district. The majority of irrigation water samples were low to medium in salinity (EC), sodicity (SAR) and alkalinity (RSC).

References
1. Agrawal PB, Sinha AK, Yadav BR. Influence of saline water irrigation and varying soil moisture regimes on soil properties, crop water use and yield of wheat inter-crop. Journal of the Indian Society of Soil Science. 2002; 50:287-293.
2. Arora NK, Chaudhary SK, Farooqui JA, Basak N. Effect of poor quality water on the chemical properties of the salt affected soils and performance of rice. Journal of Soil Salinity and Water Quality, 2012; 4:114-121.
3. Ayers RS, Westcot DW. Water quality for agriculture, irrigation and drainage. Paper 29.FAO, Rome, 1976, 97p.
4. Batarseh M. Sustainable Management of Calcareous saline-Sodic Soil in Arid Environments: The Leaching Process in the Jordan Valley. Applied and Environmental Soil Science, Article ID 1092838, 9 pages, 2017.
5. Chopra R, Kumawat BL, Singh A, Sharma DK. Evaluation of underground irrigation water quality and its associated effects on irrigated soils of Sri Madhopur Panchayat Samiti of district Sikar (Rajasthan). Annals of Agri Bio Research, 2014; 19:268-275.
6. Emdad MR, Raine SR, Smith RJ, Hossein F. Effect of water quality on soil structure and infiltration under

“1622”
7. Gupta IC. Quality of irrigation water—recent criteria and classification. Current Agriculture. 1986; 10:1-42.
8. Khan GD, Akbar F, Khan T, Ullah W, Naseebullah, Bismillah. Assesment of Salinity and Alkalinity of Groundwater and It Relation to the Geochemical Propersties of Soil in a Specific Site of Lasbela Region, Chemistry and Materials Research. 2014; 6(4):93-96.
9. Khan MA, Sharma M. Assessment of Ground Water Quality in Churu District, Rajasthan, Annals of Arid Zone. 2007; 46(2):145-149.
10. More NB, Kadam BS, Getthe RM, Mahalashi DM. Assessment of quality of irrigation water used for grape gardens in western Maharashtra. Contemporary Research in India. 2017; 7:96-99.
11. Naga SR, Yadav BL, Sharma SR. Effect of different levels of RSC in irrigation waters, zinc and iron on soil properties and yield of wheat on loamy sand soil. Green Farming. 2013; 4:330-333.
12. Pradeep T, Ananda SK. Assessment of groundwater quality for agricultural purposes in lower part of Noyyal sub-basin, Cauvery river, Tamil Nadu, India. Asian Journal of Research in Social Sciences and Humanities. 2016; 6:961-968.
13. Ramkumar T, Venkatramanan S, Mary IA, Tamilselvi M, Ramesh G. Hydro geochemical quality of groundwater in Vedaraniyam town, Tamil Nadu, India. Research Journal of Environmental and Earth Sciences. 2010; 2:44-48.
14. Reddy KS. Assessment of groundwater quality for irrigation of Bhaskar Rao Kunta watershed, Nalgonda District, India, International Journal of Water Resources and Environmental Engineering. 2013; 5:418-425.
15. Riaz U, Abbas Z, Zaman Q, Mubashir M, Jabeen M, Zulqadar SA et al. Evaluation of Ground Water Quality for Irrigation Purposes and Effect on Crop Yields: A GIS Based Study of Bahawalpur. Pakistan Journal of Agricultural Research. 2018; 31:29-34.
16. Singh B, Sharma PK, Parmar AB, Choudhary MK. Groundwater quality and its suitability for irrigation in Matar Tehsil of Kheda district, Gujarat. International Journal of Farm Sciences. 2016; 6:119-123.
17. Singh VK, Prakash R, Bhat MA, Gagandeep, Kumar S. Evaluation of groundwater quality for irrigation in Kaithal block (Kaithal District) Haryana. International Journal of Chemical Studies. 2018; 6(2):667-672.