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RESEARCH ARTICLE

CHARACTERIZATION AND MAPPING OF GROUND WATER QUALITY IN THE BARWALA BLOCK OF THE INDIAN STATE OF HARYANA

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Abstract: A survey was conducted to assess the groundwater quality for irrigation purposes in different villages of the Barwala block in Panchkula district, Haryana, from 2022 to 2023. A total of 23 water samples were collected and analyzed for various hydrochemical parameters including pH, EC (electrical conductivity), and concentrations of cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, and SO_4^{2-}), using standard procedures. Irrigation indices such as SAR (sodium adsorption ratio) and RSC (residual sodium carbonate) were calculated for these samples. The pH, EC, SAR, and RSC values in the groundwater ranged from 6.75 to 7.85, 0.54 to 1.12 dSm^{-1}, 2.88 to 5.95 (mmol L^{-1})1/2, and 0.00 to 3.01 (me L^{-1}), respectively. The average ionic concentration of cations and anions showed the following trend: $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$ for cations, and $Cl^{-} > SO_4^{2-} > HCO_3^{-} > CO_3^{2-}$ for anions. According to the guidelines provided by the All India Coordinated Research Project (AICRP) in 1989, 95.7% of the samples were classified as good quality, while 4.3% fell into the marginally alkali or alkali categories in the Barwala block of Panchkula district, Haryana. Spatial variability maps depicting the EC, SAR, and RSC values of groundwater used for irrigation were also prepared for the district.

Keywords: Anions, Barwala block, Cations, Saline water

INTRODUCTION

Groundwater serves as a critical source of water for irrigation purposes, playing a vital role in sustaining agricultural activities worldwide. With the increasing demands of modern agriculture, groundwater has become an essential resource to meet irrigation needs. Unlike surface water, which is directly influenced by weather patterns and seasonal variations, groundwater offers a more stable and reliable supply throughout the year. It provides a consistent source of water for crop cultivation, particularly in areas where surface water availability is limited or unpredictable (Wood and Cherry, 2021, Dhingra and Shah, 2021). However, ensuring the suitability and quality of groundwater for irrigation is crucial, as it directly impacts crop productivity, soil health, and long-term sustainability. Therefore, assessing and monitoring the groundwater quality and understanding its characteristics are essential for effective irrigation management and sustainable agricultural practices. India, with 2.2% of global land and 4% of world water resources, supports 16% of the world's population. The country's water resources face significant challenges due to high population density and agricultural reliance. Groundwater provides around 60% of irrigation water in India, but unsustainable practices have led to overexploitation and declining water tables (Prajapati *et al*., 2022, Chhimwal *et al*., 2022). Efforts such as the National Water Policy and technological advancements are promoting sustainable management. Conservation practices and efficient irrigation techniques are crucial to ensure long-term availability and quality of groundwater for irrigation. Presently groundwater is the most important source of irrigation in India, thus deserving considerable attention for use in a sustainable way quantitatively and qualitatively (Toumi *et al*., 2015). The total groundwater potential in India is estimated as 43.1 M ha-m and the utilizable groundwater for irrigation is assessed as 32.47 M ha-m. It is likely to increase to 35 M ha-m by 2025. In Haryana, during the year 1966-67, about 1.3 million ha out of the total cultivated area of 3.6 million ha was being irrigated (22% from groundwater and 78% from surface water). By the year 2010-11, the irrigation facilities with groundwater were developed for about 2.9 million ha area, the share is more than 57 % of the net irrigated area. This shows that groundwater utilization has increased considerably over the years. The average groundwater table in the districts of the state of Haryana has decreased as a result of this indiscriminate exploitation. As per the research, the

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present trend of declining groundwater depth could reduce India's total food grain production by around 25% or more by 2050.Water quality is a key concern due to rising demand these days. Quality aspects decide whether groundwater is suitable for specific use or not (Prakash *et al*., 2021). The quality of water used for various purposes, including irrigation, is subject to alteration due to agricultural, industrial, and human activities. These activities can modify the physical, chemical, and biological characteristics of water, leading to variations in its quality across different sources and over time. Any deviation from the natural quality of water can disrupt the balance within the ecosystem and render it unsuitable for its intended applications. When it comes to irrigation water quality, the key factors influencing it are the type of water source and the concentrations of dissolved solids and salts present. Evaluating these parameters is crucial to ensure that water is suitable for irrigation, as improper water quality can have detrimental effects on soil fertility, crop growth, and overall agricultural productivity. By understanding and monitoring these characteristics, appropriate measures can be taken to maintain water quality standards and promote sustainable irrigation practices. The assessment of irrigation water quality relies on several key factors, including the total concentration of soluble salts (which indicates salinity hazards), the relative proportion of sodium, calcium, and magnesium, the sodium absorption ratio (SAR, indicating sodium hazards), the residual sodium carbonate (RSC), and the presence of toxic elements. The salts present in irrigation water stem from the dissolution or weathering of rocks, as well as the dissolution of minerals such as lime and gypsum (Lal *et al*., 2022). These factors play a crucial role in determining the suitability of water for irrigation, as they directly impact soil health and crop productivity. In Haryana state, 37% of water is of good quality, 8% normal and 55% is of poor quality. Out of this poor-quality water, 11% is saline, 18% is alkali, and 26% is saline-alkali (Manchanda, 1976). The sustainable development of society relies heavily on the availability and quality of groundwater. Therefore, it is essential to conduct surveys and characterize groundwater quality in every region of the country. This serves as a prerequisite for effective monitoring and supervision of groundwater resources (Rao *et al.*, 2018). Understanding the specific characteristics of groundwater enables informed decision-making for sustainable utilization and protection of this invaluable resource. By keeping the above facts, an investigation was carried out to access groundwater quality of Barwala block of Panchkula District, Haryana, used for irrigation purposes by accessing different water quality parameters. Limited information exists regarding groundwater quality for irrigation in the Panchkula district region, and significant variations in water quality parameters have been observed. Therefore, a comprehensive investigation is essential to understand the nature, properties, and quality of irrigation water in order to assess the potential for secondary salinization or sodification in this area. To achieve a holistic understanding of groundwater quality for irrigation purposes in a specific region or block, a substantial number of samples from various locations within the area must be examined. In light of these considerations, this research collected 23 water samples from the Barwala block of Panchkula district to assess the water quality status for irrigation purposes.

MATERIALS AND METHODS

Study area

Panchkula district of Haryana is located in Northern part of Haryana State and lies between 30^{o} 26': 30^{o} 55' North latitudes and 76^{o} 46': 77^{o} 10' East longitudes. Himachal Pradesh bound the district, in North in the east by Uttar Pradesh, in west by Ambala district, in south by Karnal and Kurukshetra districts. Total geographical area of the district is 898 Km^2. Panchkula district is divided into two tehsils and four development blocks viz. Pinjore, Barwala, Raipur Rani and Morni. Panchkula is thickly populated district and density of population is 522 persons per Km^2, which is higher than State average of 478 persons per Km^2. As per 2001 census the population of the district is 468411. The climate of Panchkula can be classified as subtropical monsoon, mild &dry winter, hot summer and sub-humid which is mainly dry with hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrates into the district. There are four seasons in a year. The hot weather season starts from mid March to last week of the June followed by the southwest monsoon, which lasts up to September. The transition period from September to November forms the post monsoon season. The winter season starts late in November and remains up to first week of March. The normal annual rainfall of the district is 1057 mm, which is unevenly distributed over the area in 49 days. The southwest monsoon sets in from last week of June and withdraws in end of September, contributed about 86% of annual rainfall. July and August are the wettest months. Rest 14% rainfall is received during non-monsoon period.

Barwala block of Panchkula, district during 2022-2023 to evaluate the quality of groundwater for irrigation for different crops and the location map is prepared (Fig. 1). The samples were collected in thoroughly cleaned, properly labeled and carefully corked plastic bottles. Before collection of water in a particular bottle, the bottle is rinsed thoroughly with the respective samples of groundwater and immediately after collection samples were transferred laboratory for chemical analysis. The chemical analysis was accomplished at CCS Haryana Agricultural University, Hisar, India as per the standard methods relevant to analysis of groundwater. Electrical Conductivity (EC) was measured by conductivity meter and pH by digital pH meter. Sodium (Na^+) and potassium were measured by flame photometer. Calcium and magnesium were determined with standard EDTA solution titrimetrically. Carbonate and bicarbonate were estimated by titration with H_2SO_4, Chloride by titrating against standard silver nitrate ($AgNO_3$) solution. The colorimetric analysis of sulphate was done by spectrophometer. Measurements were done in triplicate to ensure reliability and good quality control. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are calculated as:

a) Sodium adsorption ratio (SAR) {Richards 1954}:

$$\text{SAR (mmol l}^{-1})^{1/2} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

b) Residual sodium carbonate (RSC) (Eaton 1950):

$$\text{RSC (me l}^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Water samples were classified into different categories as per the classification of All India Coordinated Research Project (AICRP, 1989) on Management of Salt Affected Soils and Use of Saline Water in Agriculture.

RESULTS AND DISCUSSION

In the Barwala block, the water samples exhibited a range of electrical conductivity (EC) values from 0.54 to 1.12 $dSm.^{-1}$, with a mean of 0.71 dSm^{-1} (Table 1 and Fig. 2). To assess the spatial distribution of EC across the entire block, a spatial variability map was created using ArcGIS by interpolating the data collected from 23 sampling points (Fig. 1).The pH of the water samples in the area ranged from 6.75 to 7.85, with a mean value of 7.27. The sodium adsorption ratio (SAR) of the groundwater samples ranged from 2.88 to 5.95 (mmol $l^{-1})^{1/2}$, with a mean value of 4.13 (mmol $l^{-1})^{1/2}$. Furthermore, the RSC (Residual Sodium Carbonate) in the study area varied from 0.00 to 3.01 mel-1, with an average of 0.13 mel^{-1} (Table 1). Spatial variability of RSC and SAR of groundwater used for irrigation is presented in (Fig.3 & 4 respectively). Similar findings were reported by Patel and Desai (2005) in certain villages of Surat District, Gujarat, India. The low electrical conductivity and pH levels of the water samples indicate their relative purity. On the other hand, the sodium adsorption ratio and RSC values suggest that the water has a relatively low sodium content and contains lower levels of carbonates and bicarbonates, respectively. Water with high concentrations of carbonate and bicarbonate ions tends to precipitate calcium and magnesium as their carbonates. Consequently, the relative proportion of sodium increases and becomes fixed in the soil, resulting in reduced soil permeability (Reddy *et al.*, 2019). When it comes to anions, chloride was the dominant anion with the maximum value of 4.85mel^{-1} being recorded and the minimum value of 2.36 mel^{-1} being recorded as the predominant anion. There were a wide range of values for bicarbonate ranging from 0.21 to 5.20 mel^{-1}, with an average value of 0.77 mel^{-1}. Table 1 gives the mean values for CO_3^{2-}, HCO_3^-, Cl^-, and SO_4^{2-}, respectively, which have been found to be 0.44, 0.77, 3.64, and 2.33 mel^{-1}, respectively. Among cations, Na^+ was highest and also varied widely from 3.10 to 6.82 me/l (Table 2), followed by magnesium (0.21–2.11 mel^{-1}) and calcium (0.20-3.00 mel^{-1}). Average values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 4.22, 1.53, 0.65 and 0.23 mel^{-1}, respectively (Table 1). The mean cationic composition was observed in order of $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ likewise the anionic composition was observed in order of $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}$.

In Barwala block of Panchkula district 95.7 and 4.3 per cent samples were found in good, and marginally alkali categories, respectively (Fig. 5). This is due to higher concentration of tubewells in that area and accordingly more samples were collected from that area. Maximum area of the block having EC < 2 can come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 will come under marginally alkali and alkali. There is a little problem of alkalinity in groundwater of the Barwala block because marginally alkali and alkali categories were observed very scattered with small polygons. This is due to higher concentration of tubewells in that area and accordingly more samples were collected from that area. Maximum area of the block having EC < 2 can come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 will come under marginally alkali and alkali. There is a little problem of alkalinity in groundwater of the Barwala block because marginally alkali and alkali categories were observed very scattered with small polygons.

CONCLUSION

This study provided data about water quality occurring in Barwala block for farmers, researcher and planner. The dominance of major ions were in the order of $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and anions were $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}$ for cations and anions, respectively. Therefore, the chemical composition of the groundwater was characterized by the Na–Cl water type. The spatial distribution maps generated for various physico-chemical parameters using GIS techniques could be valuable for policy makers for initiating groundwater quality monitoring in the area.

Table 1. Range and mean of different water quality parameters in Barwala block

Sr. No.	Quality Parameter	Range	Mean
1	pH	6.75-7.85	7.27
2	EC (dSm^{-1})	0.54-1.12	0.71
3	RSC (me l^{-1})	0.00-3.01	0.13
4	SAR (mmol $l^{-1})^{1/2}$	2.88-5.95	4.13
5	Ca^{2+} (me l^{-1})	0.20-3.00	0.65
6	Mg^{2+} (me l^{-1})	0.21-2.11	1.53
7	Na^{+} (me l^{-1})	3.10-6.82	4.22
8	K^{+} (me l^{-1})	0.09-0.74	0.23
9	CO_3^{2-} (me l^{-1})	0.00-1.02	0.44
10	HCO_3^{-} (me l^{-1})	0.21-5.20	0.77
11	Cl^{-} (me l^{-1})	2.36-4.85	3.64
12	SO_4^{2-} (me l^{-1})	1.10-3.26	2.33

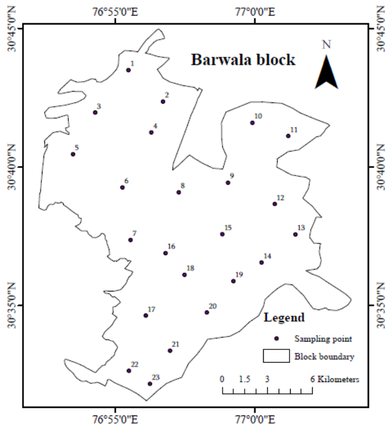

Fig.1: Location map of sampling points in Barwala

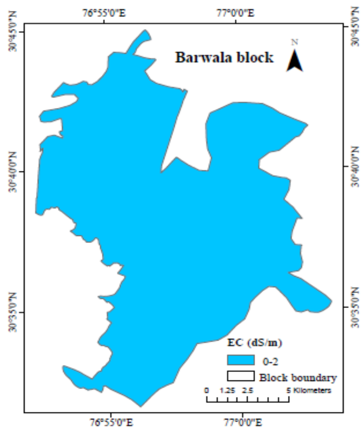

Fig.2: Spatial variable map for EC of groundwater in Barwala

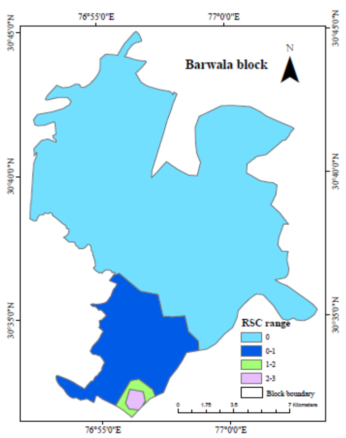

Fig.3: Spatial variable map of RSC of groundwater in Barwala

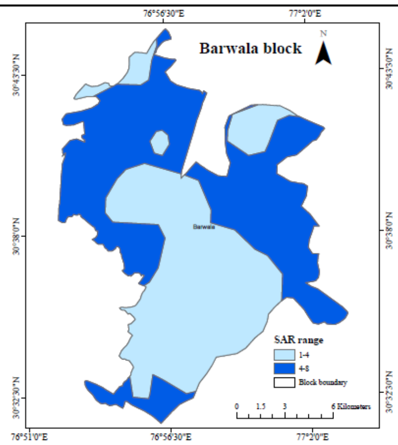

Fig.4: Spatial variable map of SAR of groundwater in Barwala

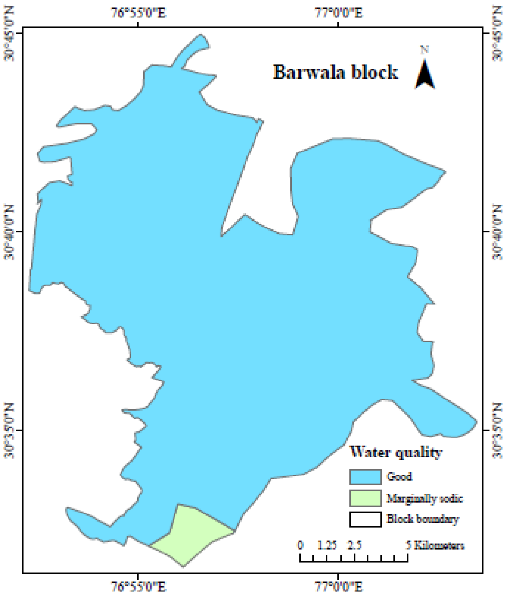

Fig.5: Spatial variable map of groundwater quality in Barwala block of Panchkula district

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