Evaluation of chemical composition and appraisal of groundwater appropriateness for drinking and agricultural practice in rural areas near Rania city of Haryana state, India

Parul Kumar and Sushma Jain
Government Dungar College, Bikaner, Rajasthan, India
Corresponding author: parulsardana3@gmail.com

Abstract: Haryana being the green land of the nation is highly cultivated state with a huge consumption of agrochemicals. The present study area Rania is the agricultural dominated area where the economy mainly depends upon agriculture. The present work emphasizes on the evolution of the hydro chemistry of the groundwater. For this, 30 representative groundwater samples have been collected in the month of May 2017 and analyzed for a number of quality parameters. Based upon the results of the quality analysis, a number of parameters such as Kelly’s index (KI), Sodium absorption ratio (SAR), residual sodium carbonate (RSC) and magnesium ratio (MR) have been considered to evaluate the aptness of groundwater for irrigation. Chloro-alkaline indices and Gibb’s ratios were calculated to understand the hydrochemistry of groundwater. A comparison of the results of the quality analysis has been made with the WHO standards to check the fitness for consumption. Pearson’s correlation coefficient has been used to establish the connection among various parameters.

Keywords: Drinking water quality, Groundwater samples, Haryana, Irrigation, Physico-chemical analysis.

1. Introduction

Water is nature’s gift to man-kind which is necessary for all life aspects. Sustainable development is not possible without the fresh and clean water supply. The supply of fresh and clean water ensures the high quality of crop yield, better health and therefore a strong economy. In typical dry and semi-arid areas, the groundwater is one of the chief sources of water for various uses (1). The population explosion, urban development and intensive cultivation have put a great demand of groundwater in these particular areas across the world and in India. The evaluation of groundwater quality is important for ensuring the correctness for a number of purposes (2). In a particular area, the groundwater quality depends upon physico-chemical parameters which are largely affected by anthropogenic as well as by geological formations. These parameters show remarkable changes due to groundwater extraction, pollution and seasonal variations (3). The use of polluted water may cause serious health issues. So, in order to manage the groundwater quality and to ensure its safe use to humans, a time to time understanding of the groundwater quality is necessary. Several researchers have been proposed in this regard (2,4,5). The proposed area is a semi-arid agricultural land of Haryana state of India which is irrigated by tube wells.
The disproportionate use of groundwater, excessive use of fertilizers and pesticide, unprocessed sewage release yielded the degradation of its quality. In the light of above facts, the current work has been carried out with the objectives to evaluate the quality of groundwater and for the understanding of the hydrochemical processes taking place in Rania area.

2. Study area

Rania is a small town in Sirsa district of Haryana (India) having the biggest grain market of the district. It is located on 29.53° N latitude and 74.83° E longitudes at an altitude of 190 m (figure 1) from ocean level. Rania forms the far west corner of Haryana state. The key profession of the citizens of the study part is agriculture. Here wheat, rice, cotton and vegetables are the main crops.

![Figure 1. showing the study area.](image-url)
3. Sample collection and analysis

The samples have been collected after running out the tube-well for about 15 minutes in order to take the representative samples in a pre cleaned plastic bottle and labeled. The pH, EC and TDS have been recorded at the sampling site using potable instruments. The samples have been freezed, taken to the laboratory and analyzes using standard methods. The maximum, minimum, standard deviation and correlation coefficient (r) have been evaluated using SPSS-16.0. The irrigation quality parameters can be calculated by using the relations as $\text{SAR} = \frac{\text{Na}^+}{\{(\text{Ca}^{2+} + \text{Mg}^{2+})/2\}^{1/2}}$ (12), $\text{RSC} = (\text{HCO}_3^- + \text{CO}_3^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$ (13),

$\text{MR} = \frac{\text{Mg}^{2+}}{\{(\text{Ca}^{2+} + \text{Mg}^{2+})\} \times 100}$ (14), $\text{KI} = \frac{\text{Na}^+}{\text{Ca}^{2+} + \text{Mg}^{2+}}$ (15).

4. Results and discussion

Statistics of various physico-chemical parameters has been set in table 1. pH ranged from 6.8 to 8.0 which is within the limits of WHO (7). The variation in EC was observed between 578-1155 µS/cm. The desirable limit of EC in water for drinking is 2000 µS/cm (7). All the 30 samples were found to be suitable for drinking. TDS indicates the nature and amount of salts that are present in water. Total dissolved salts (TDS) ranged from 370-820 mg/l. For irrigation purpose, TDS of water should be in the range of 450-2000 mg/l (8). None of the sample was found to exceed the desirable limit of TDS. The total hardness (TH) varied between 88 to 290 mg/l. The calcium concentration ranged from 40-215 mg/l. For irrigation, the calcium content should be less than 400 mg/l (8). The magnesium ions concentration ranged from 45-93 mg/l. The enviable limit for Mg in drinking water is 50 mg/l (7). In the present study, 23 samples go beyond the enviable limit for drinking. The sodium ions concentration ranged from 1080 – 1195 mg/l. Generally water having less than 920 mg/l of sodium ions is taken to be fit for soil and crops (8). All the 30 samples were found to be unfit for irrigation. There is no upper limit for sodium ions in drinking water however excess of sodium in water imparts salty nature in water. The potassium content ranged from 8-24 mg/l. The bicarbonate concentration ranged from 185- 525 mg/l. There is no higher limit set for bicarbonate ions in ingestion water. The chloride concentration varied between 100-318 mg/l. The upper limit for chloride ions in drinking water is 200 mg/l (7). In the present study, 14 samples exceed the upper limit for drinking. The sulphate concentration ranged from 50-320 mg/l. The permissible limit for sulphate in drinking water is 500 mg/l (7). In our study, all the samples have been found to be suitable for drinking. The nitrate content varied between 2.8-58 mg/l. The upper limit for nitrate in drinking water is 50 mg/l (7) and for irrigation it is 10 mg/l (8). 03 samples out of 30 exceed the desirable limit for drinking and 20 samples exceeded the upper limit for irrigation. The higher concentration of nitrate in groundwater is mainly due to the unwarranted use of fertilizers. The fluoride content ranged from 0.6 to 1.6 mg/l. The tolerable limit for fluoride in consumption water is 1.5 mg/l (7). 03 samples out of 30 exceed the upper limit for drinking.
Table 1. Showing the descriptive statistics

| Parameter    | Minimum   | Maximum | Std. Deviation | WHO Standard | % of samples exceeding the limit |
|--------------|-----------|---------|----------------|---------------|----------------------------------|
| TDS (mg/l)   | 370.00    | 820.00  | 111.92         | 500 – 1500    | /                                |
| EC (µS/cm)   | 578.00    | 1281.00 | 171.14         | 2000          | /                                |
| TH (mg/l)    | 188.00    | 320.00  | 30.11          | 100 – 500     | /                                |
| TA (mg/l)    | 50.00     | 190.00  | 28.29          | /             | /                                |
| Ca (mg/l)    | 40.00     | 215.00  | 36.99          | 75 – 200      | 3.33                             |
| Mg (mg/l)    | 32.00     | 98.00   | 18.17          | 50 – 150      | /                                |
| HCO3 (mg/l)  | 185.00    | 720.00  | 117.65         | /             | /                                |
| Chloride (mg/l) | 100.00 | 370.00  | 70.96          | 200 – 600     | /                                |
| Fluoride (mg/l) | .60    | 1.60    | .30            | 0.5 – 1.5     | 13.33                           |
| pH           | 6.80      | 8.00    | .28            | 6.5 – 8.5     | /                                |
| Nitrate (mg/l) | 3.20    | 58.00   | 17.20          | 50            | 10                               |
| Na (mg/l)    | 1080.00   | 1192.00 | 38.39          | ./ - 200      | 100                              |
| K (mg/l)     | 8.00      | 24.00   | 4.87           | ./ - 12       | 83.33                            |
| SO4 (mg/l)   | 50.00     | 320.00  | 57.89          | 200 – 400     | /                                |

4.1 Irrigation water quality. The quality with respect to irrigation has been made by using a number of parameters like electrical conductivity (EC), sodium absorption ratio (SAR), residual sodium carbonate (RSC), magnesium ratio (MR) and Kelly’s Index (KI) as given in table 2.

Table 2. Table showing the suitability of the samples with respect to irrigation-

| Name of Parameter | Water type | Water Quality | % of samples |
|-------------------|------------|---------------|--------------|
| KI                | >1         | Unsuitable    | 100          |
|                   | <1         | Suitable      | /            |
| MR                | >50        | Unsuitable    | 43           |
|                   | <50        | Suitable      | 57           |
| RSC               | <1.25      | Good          | 100          |
|                   | 1.25-2.5   | Doubtful      | /            |
|                   | >2.5       | Unsuitable    | /            |
| SAR               | <10        | Excellent     | /            |
|                   | 10-18      | Good          | 6.67         |
|                   | 18-26      | Doubtful      | 80           |
|                   | >26        | Unsuitable    | 13.33        |
From table 2 it is clear that all the samples have been unfit for irrigation with respect to KI, most of the samples with respect to MR and SAR. With respect to RSC all the samples have been found to be fit for irrigation.

4.2 Hydro-chemical evaluation. Hydro-chemical characterization was made using graphical interpretation via Gibb’s diagrams (11) and Chloro-alkaline indices. The analysis provides the information about the chemical composition and evolution of groundwater. Further, the ion exchange behavior is very important phenomenon that governs the geo-chemical processes. For this, chloro-alkaline indices (CAIs) have been calculated (10). The groundwater chemistry gets changed seasonally, regionally and also during percolation due to ion exchange (16). The CAIs can be calculated as CAI-1 = [Cl⁻ – (Na⁺ + K⁺)] / Cl and CAI-2 = [Cl⁻ – (Na⁺ + K⁺)] / [SO₄²⁻ + HCO₃⁻ + CO₃²⁻ + NO₃⁻] (10). Further the groundwater chemistry can be decided mainly by three mechanisms namely evaporation, rock – water interactions and precipitation (17). Gibb’s (11) proposed a scatter diagram to determine the role of these natural mechanisms to control the groundwater chemistry. Gibb’s ratios (G.R.s) can be calculated as G.R.-I = Cl⁻ / (Cl⁻ + HCO₃⁻) and G.R.-II = Na⁺ / (Na⁺ + Ca²⁺) (11). A plot of TDS v/s G.R.s individually (Graph 2 and 3) gives the dominance of any of these three natural mechanisms. In the current study, the groundwater has been of mainly rock-water dominated.

Graph 1. showing the variation of CAIs in the study area

There negative value indicates the exchange of calcium (Ca²⁺) and magnesium (Mg²⁺) ions from water with the sodium (Na⁺) and potassium (K⁺) ions of the rocks whereas the positive value gives the reverse ion exchange. In our analysis, the values of CAIs have been found to be negative. So, it can be clearly said that there is an exchange of alkaline earth ions from water with that of the alkali ions from rocks.
The groundwater in the present study area is mainly dominated by rock water interactions.

**Graph 2.** showing the variation of Gibb’s ratio I with respect to TDS.

**Graph 3.** showing the variation of Gibb’s ratio II with respect to TDS.
From graph 3 it is clear that the groundwater chemistry is mainly rock water dominated.

4.3 Piper Diagram. A piper diagram (9) is a helpful way to segregate the data to recognize the presence of dissolved chemical substances in water. The basic principal behind the diagram is that the cations and anions are present in natural waters in equilibrium. The major cations and anions are shown by different plots known as the ternary plots. The major cations are the sodium (Na$^+$), potassium (K$^+$), calcium (Ca$^{2+}$) and magnesium (Mg$^{2+}$) ions whereas the major anions include chloride (Cl$^-$), sulphate (SO$_4^{2-}$), carbonate (CO$_3^{2-}$) and bicarbonate (HCO$_3^-$) ions. The regions on the graph include the dominant cations, dominant anions and their combinations on diamond shaped part as shown in the diagrams given below. The water samples can be classified as 1) Calcium chloride, 2) magnesium bicarbonate, 3) sodium chloride, 4) sodium bicarbonate, 5) magnesium, 6) calcium, 7) sodium and potassium, 8) no dominance, 9) sulphate, 10) bicarbonate, 11) chloride and 12) No dominance type.

![Figure 2 showing the Piper diagram](image)

The groundwater of the investigated part is of largely sodium chloride type. The alkali ions dominate strongly over the alkaline earth ions. Sulphate is not the dominant ion but some of the samples belong to bicarbonate, chloride and also of no anion dominance type.
4.4 Correlation Matrix:

|     | pH  | TDS | EC   | TH  | TA  | Ca  | Mg  | SO4 | NO3 | Cl  | F   | HCO3 | Na  | K   |
|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|
| pH  | 1   |     |      |     |     |     |     |     |     |     |     |      |     |     |
| TDS | -.030| 1   |      |     |     |     |     |     |     |     |     |      |     |     |
| EC  | .028 | 1   | 1.00 | 1   |     |     |     |     |     |     |     |      |     |     |
| TH  | .262 | .216| .216 | 1   |     |     |     |     |     |     |     |      |     |     |
| TA  | -.086| -.303| -.237| .036| 1   |     |     |     |     |     |     |      |     |     |
| Ca  | .294 | .434| .434 | .635| -.085| 1   |     |     |     |     |     |      |     |     |
| Mg  | -.046| .709| .746 | .154| -.239| .091| 1   |     |     |     |     |      |     |     |
| SO4 | .277 | -.197| -.205| -.145| .151| -.110| -.259| 1   |     |     |     |      |     |     |
| NO3 | .323 | -.061| -.066| -.334| .101| .311| -.126| -.123| 1   |     |     |      |     |     |
| Cl  | -.210| .561| .490 | .102| -.220| .312| .051| .093| .018| 1   |     |      |     |     |
| F   | .218 | .006| .012| .203| -.133| .476| .016| .094| .088| -.036| 1   |      |     |     |
| HCO3| .562 | .036| .064| .202| .087| .078| .006| .291| .050| .025| -.001| 1   |     |     |
| Na  | -.223| -.332| -.332| -.172| .099| -.221| -.233| -.381| .019| -.135| -.115| -.426| 1   |     |
| K   | .158 | .126| .117| -.055| -.104| .007| -.031| -.125| .231| .389| .097| .166| -.228| 1   |

It is evident from the correlation table that there is a strong positive correlation exists between TDS and EC \( r = 1.00 \), TDS and Mg \( r = 0.709 \), Mg and EC \( r = 0.746 \) showing the significant contribution of Mg in the salinity of the groundwater of the study area. A moderate positive correlation exists between TH and Ca \( r = 0.635 \), TDS and Cl \( r = 0.561 \), Cl and EC \( r = 0.490 \), pH and HCO3 \( r = 0.562 \) and between Ca and F \( r = 0.476 \).

5. Conclusions

The analysis reveals that the samples from the study area belong to sodium chloride (Na-Cl) type with the rock-water dominance.

References

[1]. Al-Shaibani A.M. 2008 Hydrogeol. J. 16: 155-165
[2]. Subramani T., Elango L. and Damodarasamy S.R. 2005 Environ. Geol. 47: 1099-1110
[3]. Venugopal T., Giridharan L., Jayaprakash M. and Periakali P. 2009 Environ. Monit. Assess. 149: 81-97
[4]. Haritash A.K., Kaushik C.P., Kaushik A., Kansak A. and Yadav A.K. 2008 Environ. Monit. Assess. 145: 397-406
[5]. Hosseinfard S.J. and Aminiyan M.M. 2015 Water Qual. Exposure Health 7:531-544
[6]. Aastri J.C.V. 1994 Groundwater chemical quality in river basins, hydrogeochemical facies and hydrogeochemical modeling. Bharathidasan University, Thiruchirapalli, Tamil Nadu, India
[7]. WHO 2011 Guidelines for drinking water quality. 4th edition, World Health Organization, Geneva, Switzerland, ISBN: 9789241548151
[8]. Doneen L.D. 1964 Notes on water quality in agriculture, published as water science and engineering. Paper number 4001, Department of Water Science and Engineering, University of California, Davis
[9]. Piper A.M. 1944 A graphic procedure in the geochemical interpretation of water analysis. EOS Trans. Am. Geophys. Union, 25:914-928
[10]. Schoeller H. 1977 *Geochemistry of groundwater*. In: Groundwater studies an international guide for research and practice, UNESCO, Paris, pp-1-18

[11]. Gibbs R.J. 1970 Mechanism controlling the world water chemistry *J. Sci.* 17 1088-1090

[12]. Richards L.A. 1954 Diagnosis and improvement of saline and alkaline soils. *In: agricultural handbook* 60 IBH Pub. Co. Ltd., pp.98-99

[13]. Eaton E.M. 1950 Significance of carbonates in irrigation waters. *Soil Sci.* 69 123-133

[14]. Wilcox L.V. 1955 Classification and use of irrigation waters. USDA, *Washington DC circular* pp-969

[15]. Kelley W.P. 1963 Use of saline irrigation waters *Soil Sci.* 95 385-39

[16]. Aghazadeh N., Mogaddam A.A. 2010 *J. Environ. Prot.* 1: 30-40

[17]. Gupta S., Mahato A., Roy P., Datta J.K., Saha R.N., 2008 *Environ. Geol.* 53: 1271-1282