Poll Res. 41 (4) : 1257-1260 (2022)

ISSN 0257–8050
DOI No.: http://doi.org/10.53550/PR.2022.v41i04.018

GEOCHEMICAL MODELING AND PRELIMINARY ASSESSMENT OF TRACE METALS CONTAMINATION IN GROUNDWATER AQUIFER OF GUNA DISTRICT, INDIA

SUNIL KUMAR SRIVASTAVA

Department of Chemistry, Jaypee University of Engineering & Technology, Guna 473 226, M.P., India

(Received 23 June, 2022; Accepted 11 August, 2022)

ABSTRACT

Water is the most precious natural resource, which gets contaminated in the recent past through various anthropogenic activities. The study reveals that Guna district subsurface water gets contaminated by leaching chemical fertilizers used in agriculture. Nitrate is the principal ion released in groundwater due to the excess utilization of urea as chemical fertilizer in agriculture. Fluoride is also reported in subsurface water through the chemical weathering of CaF_2 and other fluorite-rich minerals. Trace metals (Fe, Cu, Pb) are also reported in a few locations, affecting groundwater quality. A mathematical calculation has been performed to calculate the WQI value of the Guna district in this study. The interpretation of the WQI value for the study area indicates ~22.81% good water, ~71.14% poor water, and only ~5.37% very poor quality water.

KEY WORDS: Geochemical Modeling, Pollution, Water Quality Index (WQI), Guna

INTRODUCTION

In recent decades, groundwater resources have become increasingly threatened by the leaching of contaminants from agricultural fields and industrial and domestic effluent. Infiltration of pesticides and fertilizers from farming areas and leakage of a wide range of inorganic and organic pollutants from the fertilizer and sugar industries are some of the most severe problems for groundwater (Srivastava, 2019). In many circumstances, complex geochemical reactions, such as sorption, biodegradation, oxidation/reduction, and precipitation/dissolution occur when contaminants enter the groundwater system and mix with the ambient water.

Due to the ever-increasing population, increasing demand for groundwater has initiated the need to manage available groundwater resources effectively. Groundwater modeling is a powerful management tool that can serve multiple purposes, such as providing a framework for organizing hydrological data, quantifying the properties and behavior of the system, and allowing quantitative prediction of the response of those systems to externally applied stresses (Anderson, 2002; Srivastava and Ramanathan, 2012).

India is rich in water resources, but in the recent past, due to negligence of human civilization contamination of water resources have been reported (Ranjan *et al.*, 2017). In addition, the availability of contaminants (trace metals) in subsurface water has further deteriorated the water quality considering its practical use for domestic, industrial, and irrigation purposes. The sources of these contaminants in water varied geographically, both point and non-point sources. In their study, Srivastava and Ramanathan (2018a) reported groundwater contamination through leaching from anthropogenic and geogenic sources.

Guna is a city with ~98% of its population living in villages, whose principal activity is dependent on subsurface water. This study was planned to delineate the sources of contaminants, considering the importance of water and an increasing concern in the community. Further, a water quality index (WQI) has been calculated, and a graph for the spatial distribution has been created.

Study Area

Guna is located in the north-western part of Madhya

Pradesh. Geographically, it lies between latitude N 23º 53′ 2″ - N 25º 06′ 2″ and longitude E 76º 48′ 2″ - E 78º 16′ 2″. Guna is surrounded in the north by Shivpuri district, east by Ashoknagar district, south by the Rajgarh district, and west by the Rajasthan state. It is divided into six blocks (Kumbhraj, Chachoda, Raghogarh, Aron, Guna, and Bamori), which have 1260 villages with a total population of 1241519 (Census of Govt. of India, 2011).

METHODOLOGY

A well-planned survey of the Guna district was carried out in May 2016 to understand the hydrogeochemistry of groundwater. A Garmin Global Positioning System (GPS) was used to fix suitable sampling locations in the district.One hundred fifty groundwater samples were collected in post-monsoon (Sept-Oct 2016), winter (Jan-Feb 2017), and pre-monsoon (May-June 2017) through preferably bore well. The parameters [pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), oxidation-reduction potential (ORP), total dissolved solids (TDS)] were measured in the field at the time of sampling by using a water-analyzer kit. Further, these measurements were cross-checked in the laboratory on the same day. For analysis of cations, 100 ml samples were filtered using 0.45µm filter paper and on-site preserve with ultra-pure nitric acid (boric acid was used as a preservative for nitrate) and stored at 4 ºC to avoid chemical alteration to samples during transport and holding (APHA, 1995). Acidification stops most bacterial growth, blocks oxidation reactions, and prevents adsorption or precipitation of cations. Sodium and potassium were analyzed by an AIMIL, PE I Flame Photometer following the standard method (APHA, 1995). An atomic absorption spectrophotometer (Shimadzu-AA-6800) was used for the analysis of heavy metals (Fe, Cu, and Pb) and alkaline earth metals (Mg and Ca). Anions (SO_4^{2-}, NO_3^-, PO_4^{3-} and silicate) were analyzed using a JENWAY 6505 UV/Vis Spectrophotometer, using the standard method detailed in APHA (1995). Fluoride was analyzed by using a fluoride sensor electrode. Bicarbonate and chloride were analyzed by titration using the standard procedure given in APHA (1995).

RESULTS AND DISCUSSION

A summary of analyzed parameters with the details of minimum, maximum, mean, and standard deviation has given in Table 1. Assessment of the analyzed physicochemical parameters like EC, temperature, ORP, DO, and pH helped us understand the hydrogeochemical processes occurring in groundwater aquifer systems. In addition, it helps to understand the role of geology on the hydrochemistry of groundwater. For example, the hydrogeochemical parameters with the high standard deviation indicate anthropogenic input in groundwater since geogenic input is almost similar in an aquifer (Prasad *et al.*, 2006; Srivastava and Ramanathan, 2008 and Drever, 1997).

CGWB assesses Ground Water quality in the Guna district based on water samples collected from twenty-five hydrograph stations. Groundwater is generally medium to high saline as electric conductivity values vary between 353 to 2443 micromhos/cm. High EC of more than 1500 micromhos/cm was found in three dug well of Barod (1704 micromhos/cm), Panchi (1709 micromhos/cm), and Khakariya (2643 micromhos/cm) villages. Constituents like Fluoride, Sulphate, calcium, and Magnesium were within the safe limit for drinking water as per BIS standards. Nitrate in the ground water varies from 6.4 to 332mg/l. Nitrate of more than 100 mg/l was found at Husainpur (332 mg/l) and Mau (313 mg/l) villages. High nitrate in groundwater appears due to the use of chemical fertilizers in agriculture fields. The total hardness of groundwater is under the safe limit of BIS standards. High chloride of more than 250 mg/l was found at Barod, Panchiand Khakariya villages.

The salinity diagram also shows that ~49.66 % of samples fall under the C_3S_1 classification, indicating groundwater can be used for irrigation based on SAR but cannot be used on soil with restricted drainage based on salinity (Fig. 1). Similarly, ~3.36 % of groundwater samples fall under the C_4S_1 category, while ~0.67 % of water falls under C_2S_2, C_3S_3, C_4S_3,

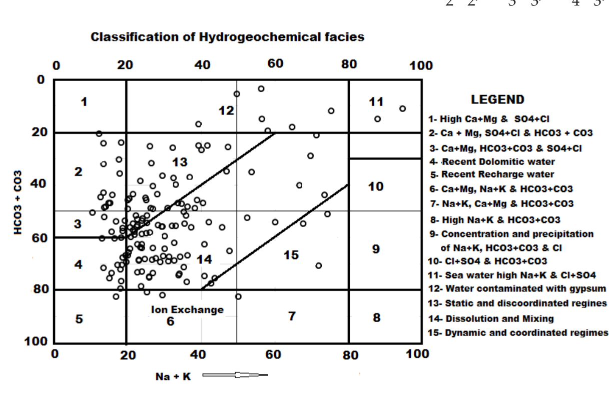

Fig. 1. Classification of Hydrogeochemical facies

Table 1. Summary of analyzed hydrogeochemical parameters and trace metals.

Block	Number of Samples	Statistics	pH	Eh (mV)	EC (µS/cm)	DO (mg/l)	TDS (mg/l)	Na (mg/l)	K (mg/l)	Mg (mg/l)	Ca (mg/l)	Cu (mg/l)	Pb (mg/l)	Fe (mg/l)
Kumbharaj	12	Min.	7.05	370	550	9.1	385	44	3	14	24	0.22	0.01	0.01
		Max.	7.89	410	2700	12.6	1890	154	133	126	204	1.52	0.24	1.03
		Mean	7.36	392.92	1075.8	11.28	753.08	79.04	20.91	54.46	88.43	0.98	0.04	0.25
		Std.	0.31	12.5	632.65	0.96	442.85	35.81	37.62	31.12	62.72	0.38	0.06	0.3
Raghogarh	59	Min.	6.79	311	400	8.7	280	25	0.01	1.2	1.6	0.26	0.001	0.02
		Max.	7.81	415	4100	13.5	2865	730	510	245.2	328.8	7.04	0.9	6.99
		Mean	7.21	367.93	1163.7	10.59	816.27	104.9	26.51	68.8	86.55	1.14	0.27	0.54
		Std.	0.21	18.26	747.45	0.9	523.01	126.5	83.92	45.27	57.81	0.87	0.13	1.01
Aron	22	Min.	6.71	322	350	8.8	245	20	0.01	14	16	0.11	0.001	0.03
		Max.	7.24	395	1820	11.8	1274	112	29	103.6	206.4	1.52	0.018	1.98
		Mean	7.08	366.13	804.54	10.36	554	67.27	5.41	50.04	65.81	0.74	0.01	0.93
		Std.	0.18	21.66	339.54	0.79	237.68	24.98	7.18	23.06	41.19	0.53	0.004	0.43
Guna	17	Min.	6.71	247	470	8.8	330	34	1	26.8	44.8	0.33	0.006	0.02
		Max.	7.27	388	1560	11.8	1090	91	170	84.4	144	2.33	0.016	5.23
		Mean	7.04	352.7	806.47	10.15	560	63.24	22.46	54.68	78.78	1	0.014	1.04
		Std.	0.15	32.36	249.65	0.94	170	17.58	43	13.88	28.28	0.54	0.002	1.14
Bamori	29	Min.	6.6	297	300	8.7	204	15	1	6	30.4	0.22	0.003	0.02
		Max.	7.32	425	1020	11.5	693.6	70	189	66.8	121.6	2.22	0.015	3.73
		Mean	6.96	380.86	549.31	9.81	373.53	39.48	23.48	37.13	57.23	1.1	0.012	0.75
		Std.	0.18	23.96	167.95	0.71	114.2	13.92	43.87	17.5	19.89	0.46	0.003	0.91
Chachoda	11	Min.	6.91	305	520	10.4	525	55	1	23.6	3.2	0.37	0.01	0.03
		Max.	8.78	388	3300	12.2	2310	176	27	231.4	304.8	1.81	0.86	2.31
		Mean	7.39	355.5	1615	11.11	1130.5	109.6	5.5	84.99	133.8	0.99	0.09	0.43
		Std.	0.66	24.06	962.06	0.51	673.82	41.59	7.56	74.08	98.18	0.48	0.27	0.73

and C_4S_2 each category. Therefore, these groundwater samples (~2.68 %) are not suitable for irrigation based on the salinity diagram due to high salinity or sodium hazard.

The water quality index (WQI) is utilized in this study to understand the influence of various geochemical parameters on groundwater quality. The different hydrogeochemical data were used to generate a unitless sub-index value. The summation of all these sub-index values gives the WQI of the groundwater. It can be calculated by applying the simple formulae recommended by various researchers (Batabyal and Chakraborty, 2015 and Srivastava and Ramanathan, 2018b).

$$I = \sum_{i=0}^{n} SIi\ Wi$$

Where n= number of samples, SI_i = Subindex I, W_i = Weight given to Subindex.

In this study, WQI was calculated by utilizing all the 15 analyzed hydro-geochemical parameters (pH, TDS, Alkalinity, Total hardness, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, F^-, Ca^{2+}, Mg^{2+}, Fe^{2+}, Cu^{2+}, Pb^{2+}, Hg^{2+}). The weight (Wi) assigned for each hydro-geochemical parameter according to its relative importance in the overall quality of water. The maximum weight of 5 was given for Hg^{2+}, NO_3^- and F^- and the minimum assigned 2 to Ca^{2+} and Mg^{2+}. The relative weight of the geochemical parameter was calculated by applying the following formulae

$$\text{Relative Weight} = \frac{Wi}{\sum_{i=0}^{n} Wi}$$

The quality rating scale (Qi) for each parameter was assigned by dividing its concentration in each water sample concerning a standard value according to guidelines (BIS, 2012). The result is multiplied by 100. Hence quality rating scale is defined as-

$$Qi = \frac{\text{Ci}}{\text{Si}} \times 100$$

Qi is the quality rating, and Ci is the groundwater samples' concentration (mg/l) of each geochemical parameter. Si is the Indian drinking water standard (mg/l) for each geochemical parameter. Sub Index (SIi) can be calculated by applying the formulae-

SIi = Relative Weight × Q_i

Hence,

WQI = $\sum_{i=0}^{n} SIi - n$

The calculated WQI values were utilized in this study to classify the water into five categories (Batabyal and Chakraborty, 2015). These five categories are i) Excellent Water (WQI < 50); ii) Good Water (WQI=50-100); iii) Poor Water (WQI=100-200); iv) Very Poor Water (WQI=200-300) and v) Water unsuitable for drinking purpose (WQI> 300). The interpretation of the WQI value for the study area indicates ~22.81% good water, ~71.14% poor water, and only ~5.37% very poor water. The graph of the WQI value shows water quality decreases with depth, indicating saline water intrusion in depth. The quality of water that remains better in the top layer may be due to dilution by rainwater. The other reason may be the presence of a scared aquifer in the study area.

CONCLUSION

Guna is a district that depends primarily on groundwater for its basic needs like irrigation, domestic, drinking, and industrial requirement. This study reveals contamination of water through various anthropogenic and geogenic sources. The few significant outputs have listed as given below-

1. Nitrate was reported in groundwater through the leaching of chemical fertilizer from agriculture fields.
2. Fluoride was reported in subsurface water through the chemical weathering of fluorite available in the geology of the study area.
3. The analysis of WQI of the study area indicates ~22.81% good water, ~71.14% poor water, and only ~5.37% very poor water.
4. The salinity diagram shows that ~44.30% of groundwater samples fall in the C_2S_1 category, ~49.66% fall under the C_3S_1 classification, and only 3.36% of groundwater samples fall under the C_4S_1 category. In comparison, in each category, ~0.67% of water falls under C_2S_2, C_3S_3, C_4S_3, and C_4S_2.

REFERENCES

Anderson, M.P. 2002. Groundwater in the new millennium. *Groundwater.* 40: 1.

APHA 1995. *Standard Methods for the Examination of Water and Wastewater*, 19thedn. American Public Health Association, Washington DC.

Batabyal, A.K. and Chakraborty, S. 2015. Hydrogeochemistry and water quality index in assessing groundwater quality for drinking use. *Water Environ. Res*. 87(7): 607-617.

BIS, 2012. Indian Standard specifications for drinking water IS:10500, Bureau of Indian Standards, New Delhi.

Census of Govt. of India, 2011. Census report published by the government of India.

Drever, J.I. 1997. The Geochemistry of Natural water (second edition), Prentice-Hall, Englewood Cliffs, 3rd ed. New Jersey.

Prasad, M.B.K., Ramanathan, AL., Srivastava, S.K., Anshumali and Saxena, R. 2006. Metal fractionation studies in Surfacial and Core sediments in the Achankovil River basin, India. *Environmental Monitoring Assessment*. 121: 77-102.https://doi.org/10.1007/s10661-005-9108-2.

Ranjan, R., Srivastava, S.K. and Ramanathan, AL. 2017. An assessment of hydrogeochemistry of two wetlands located in Bihar State in the subtropical climatic zone of India. *Environmental Earth Science.* 76 : 16 (1-19). https://doi:10.1007/s12665-016-6330-x.

Srivastava, S.K. 2019. Assessment of groundwater quality for irrigation suitability and its impacts on crop yields in the Guna district, India. *Agricultural Water Management*. 216 : 224-241. https://doi.org/10.1016/j.agwat.2019.02.005

Srivastava, S.K. and Ramanathan, A.L. 2008. Geochemical assessment of groundwater quality in the vicinity of Bhalswa Landfill, Delhi, India using graphical and multivariate statistical methods. *Environmental Geology*. 53 : 1509-1528.https://doi.org/10.1007/s00254-007-0762-2.

Srivastava, S.K. and Ramanathan, A.L. 2018a. Geochemical assessment of fluoride enrichment and nitrate contamination in groundwater in hard rock aquifer by using graphical and statistical methods. *Journal of Earth System Science.* 127(7): 104. https://doi.org/10.1007/s12040-018-1006-4.

Srivastava, S.K. and Ramanathan, A.L. 2012. Groundwater in the vicinity of the landfill. Application of the graphical and multivariate statistical method for hydrogeochemical characterization of groundwater. Lambert Publication, Germany, ISBN-10:3847328859, 1-380.