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Research Paper

Assessment of Groundwater Quality in parts of Jalna district of Maharashtra, India using Water Quality Index

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ABSTRACT

In the present study, fifty-five groundwater samples were collected from the parts of the Jalna district of Maharashtra, India. The water samples were analyzed to determine various physic-chemical parameters like pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, chloride, sulphate, calcium, magnesium, sodium and potassium. The groundwater's geochemical control and hydrogeochemistry were evaluated using the Piper plots and water quality index (WQI). The hydrochemical analysis reveals that the groundwater is predominantly of $CaNaHCO_3$ type, Water quality index (WQI) indicates that 33% and 2% of groundwater samples fall in poor and very poor categories for drinking purposes. This study reveals that groundwater quality is unfit for drinking purposes at a few places. The effective leaching, dissolution process and rock-water interaction process are the main sources for degrading the groundwater quality.

Keywords: Groundwater; Water quality index; Piper diagram; drinking purpose; Jalna.

INTRODUCTION

Groundwater is extremely important for the development of infrastructure, agriculture, and industrial activities. In semi-arid areas, it is the principal source of water (Bachmat, 1994; Keesari et al., 2014; Rahman et al, 2020). Groundwater quality is important as well as quantity. Poor quality of water adversely affects plant growth and human health (Todd, 1980; WHO, 1984; Hem, 1991; Milovanovic, 2007; Ahmad and Mazhar, 2020; Singh et al, 2020). Most of the rural and urban population depends on groundwater for their daily needs due to the continuous failure of monsoon and lack of surface water. Population growth, industrialization and fertilizer use in agriculture cause groundwater pollution (Dixit et al.,2005). Once contamination ensues in groundwater aquifers, it continues for a very long time because of the sluggish movement in aquifer's regime (Jerry,1986). The groundwater's suitability for drinking and irrigation purposes depends on the soluble salts present in it (Venkateswaran and Vediappan, 2013; Shah and Mistry, 2013). The amount of soluble salts depends upon the minerals present in the rock, soil composition, nature of the soil, climate condition, drainage characteristics of soil and the time of contact with these minerals in the region (Deshpande and Aher, 2012; Lakshmi, et al.2021). The assessment and classification of groundwater based on its quality can be obtained by analyzing its chemical characteristics. Variations in ion chemistry of groundwater are used to identify geochemical processes that control the groundwater quality (Varade et al, 2018). The chemical composition of water has evolved much interest during the last few decades because of several factors. The quality of groundwater is deteriorating mainly due to anthropogenic activity, irrigation return flow, excessive utilization of chemical fertilizers, municipal waste, unhygienic practices, septic tank effluent and landfills leachate (Srinivasmoorthy et. al, 2011; Golekar et al, 2017). The assessment of groundwater quality is much more important because it is directly connected with human health. Soil productivity and fertility have been affected by groundwater contamination, when wastewater is used in agriculture without any treatment (Aher and Deshpande, 2011; Golekar et al, 2013; Aher, 2017; Desai et al, 2020). In the study area, the main source for the availability of water for regular activity and agricultural purposes is groundwater. Though 90% of groundwater is used for irrigation purposes, about three-quarters of total groundwater is consumed for agricultural purposes (Harun, et al, 2015; Kale, et al, 2020). The present study focuses on the major ion chemistry of groundwater to understand the geochemical processes that regulate water quality. The results of the geochemical analysis of groundwater may help in the effective management of the groundwater resources and mitigate the mediocre groundwater quality.

MATERIALS AND METHODS

Study Area

The study area Jalna district forms the eastern part of Marathwada Region of Maharashtra and is bordered by Aurangabad district in the west, Jalgaon district in the north, Buldhana and Parbhani districts in the east and Beed district in the south. It is lies between longitudes: 75°36' to 76°45' E and latitudes: 19°15' to 20°32' N. It falls in Survey of India toposheet no 46P, 47 N, 55 D and 56 A. The climatic condition is semi-arid, because of peculiar diurnal contrasts of temperature and low, moderate precipitation. The average annual precipitation is 643 to 825 mm occurs between June to September due to the southwest monsoon. The entire area is underlain and surrounded mainly by basaltic lava flows belonging to the Deccan volcanic province. The Soils of the area are derived from the basaltic lava flows. The thickness of the soil cover is less in the northern and western regions where ground elevations are higher and consequently soil regur, gravels, murum are transported down to lower regions through gravity, water or winds. Soils ranging in depth from 1 to 2 m are black and rich in plant nutrients.

Methodology

A total of 55 numbers groundwater samples were collected from various locations of the study area as per the standard protocol prescribed by APHA (1995). In this study, the physicochemical properties such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness(TH), major cation like calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and major anions such as total alkalinity (TA), and sulphate (SO4) were analyzed using the standard method prescribed by APHA (1995). The EC and pH were measured immediately after sampling. The flame photometry method was used to assess the concentration of alkali metals (Na and K). The concentrations of alkaline earth metals (Ca and Mg)and total hardness were measured volumetrically with standard EDTA. The HCO3 and total alkalinity were assessed by alkalinity titration. The Cl content in samples was determined by using the silver nitrate titration method. The concentrations of SO4 were evaluated using a UV-visible spectrophotometer. The geochemical results are plotted on Piper trilinear plot using

AquaChem 4.0 software. The physicochemical parameters of the groundwater were compared with standard values recommended by the Bureau of Indian Standards (BIS, 2012).

RESULTS AND DISCUSSION

Hydrochemical Facies

Hydrochemical properties of groundwater vary depending on lithology, regional flow patterns of water and resident time (Domenico, 1972). The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations and anions on Piper's trilinear diagram (Piper, 1953). The plot shows that 34% (n = 19) of the groundwater samples fall in the field of CaHCO3 type of water, 2 % (n=1) fall in the field of NaCl type of water, 55% (n = 30) fall in the field of mixed CaNaHCO3 type of water and remaining 9% (n = 9) falls in the field of CaCl type of water (Fig.1). Higher values for calcium (Ca), sodium (Na) and bicarbonate (HCO3) in the groundwater indicate recharge, mixed, weathering and leached from sewage as well as the presence of chloride-type water indicates its withdrawal from very deep strata of discharge zone in groundwater (Aher et al, 2019, Deshpande et al, 2020; Kale et al, 2021).

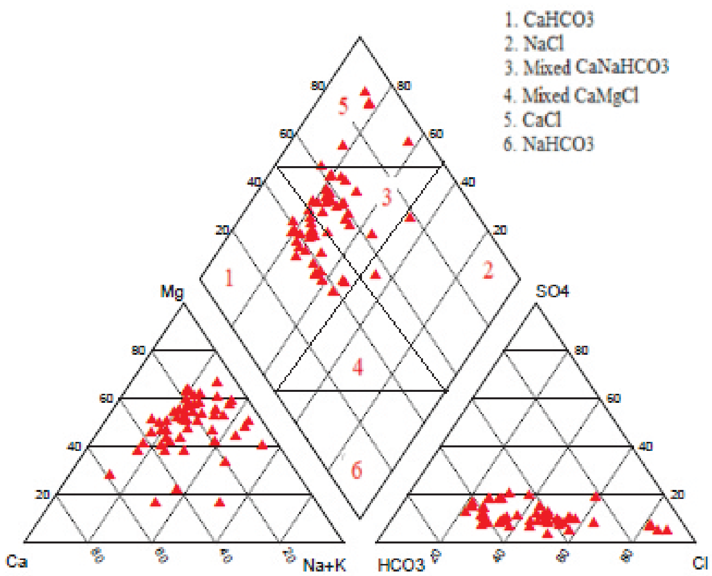

Fig.1. Distribution of groundwater samples on Piper trilinear diagram.

Groundwater Quality

In the present study, the hydrochemical characteristics of groundwater were assessed in parts of the Jalna district of Maharashtra. The water quality has been assessed for drinking purposes. The detailed observations show that pH value ranges from 7.15 to 8.97 with an average of 7.7, Hardness values range from 240 to 2380 mg/L with an average value of 770.72 mg/L, Electrical conductivity ranges from 50 to 450 µS/cm with an average value of 770.72 µS/cm and TDS concentration is 32.50 to 292.50 mg/L having an average value of 117.47 mg/L. Ca concentration is 20.04 to 637.27 mg/L with an average of 103.34 mg/L whereas, the Mg concentration ranges from 20.95 to247.06 mg/L with an average of 124.96 mg/L. Na concentration ranges from 39 mg/l to 320 mg/L have an average value of is 115.18 mg/L. Whereas, K concentration ranges from 0.00 to 133 mg/l and the average value is 17.85 mg/L. HCO3 having a range of 155 to 1315 mg/L with an average of 483.45 mg/L. The concentration of SO4 shows a minimum value of 53.79 up to 135.59 mg/L with an average of 93.01 mg/L. Cl is having 63.90 to 1505 mg/L with an average value of 342.32 mg/L. Among anions, the average abundance trend found was in the order of HCO > Cl > SO4, on the other hand, the dominant cations were in the order of Mg >Ca > Na > K.

Table 1. Physico-chemical parameters of groundwater of the study area.

Parameter	Minimum	Maximum	Mean	Std. Deviation
pH	7.15	8.97	7.75	0.38
EC	50.00	450.00	180.73	102.41
TDS	32.50	292.50	117.47	66.57
TH	240.00	2380.00	770.73	417.40
Ca	20.04	637.27	103.35	106.25
Mg	20.95	247.06	124.96	58.37
Na	39.00	320.00	115.18	56.39
K	0.00	133.00	17.85	26.97
TA	155.00	1315.00	483.45	207.32
Cl	63.90	1505.20	342.32	320.14
SO4	53.79	135.59	93.01	21.02
WQI	38.16	184.55	77.77	30.53

Water Quality Index (WQI)

Water Quality Index Provides a single number (like a grade) that expresses over water quality of a certain groundwater sample (location and time-specific) for several water quality parameters. The objective of developing an index is to simplify the complex water quality parametric data into comprehensive information for easy understanding. A simple indicator of water quality and a general idea of the possible problems with water in the region. In 1970, the National Sanitation Foundation, USA developed the Water Quality Index (NSFWQI), a standardized method for comparing the water quality of various water bodies. NSFWQI is one of the most respected and utilized water quality indexes in the united states. Nine water quality parameters were selected for calculating the index included. In 1970, with the support of the US National Institutes of Health, Brown et al. (−1970) presented a qualitative index based on a survey of many professionals in this field with different types of expertise. NSFWQI formula is as follows,

$$NSFWQI=\sum_{i=1}^{n} w_i \qquad (1)$$

where,
i = sub-index for ith water quality parameter,
w_i = weight associated with water quality parameter
n = number of water quality parameters

Groundwater Quality for parameters like pH, total hardness, Calcium, Magnesium, Chloride, Total Dissolved Solids, and Sulphate is analysed, based on stringency of the parameter and its relative importance in the overall quality of water for drinking purposes each parameter has been assigned specific weightage. Relative weights of the same have been determined for the parameters. These weights indicate relative harmfulness present in water. The maximum assigned is 5 and a minimum 2.

Relative weight is then computed from the following equation

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

where w_i is the relative weight, w_i is the weight of each parameter and (n) is the number of parameters Table 1. In the third step, quality rating scale calculation (Qi) for each parameter is computed by dividing its concentration for each groundwater sample with drinking water quality standards and then multiplied by 100 using Equ. (3).

$$Q_i = (C_i / S_i) \times 100 \tag{3}$$

where,

Q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in milligrams per litre (mg/L) and S_i is the drinking water standard guidelines for each chemical parameter. Eventuality, water quality sub-index (SIi) for each chemical parameter was computed by Equ. (5), and whole the WQI was determined by Equ. (4).

$$SI_i = W_i \times Q_i \tag{4}$$

$$WQI = \sum SI_{i-n} \tag{5}$$

Where,
SI_i = is the sub-index of the ith parameter,

Q_i is the rating based on the concentration of ith parameter, and n is the total number of parameters. The assigned weight and relative weight of physicochemical parameters for calculation of WQI are presented in Table 2., based on the assigned value of the index determined from the calculations, groundwater quality is classified as presented in Table 3.

Table 2. The assigned weight and relative weight of physicochemical parameters

Sl.No.	Chemical Parameter	Indian Standards	Weight (wi)	Relative weight (Wi)
1	pH	6.5-8.5	4	0.14286
2	TDS	500-2000	4	0.14286
3	TH	200-600	2	0.07143
4	HCO_3^-	200-600	3	0.10714
5	Cl^-	250-1000	3	0.10714
6	SO_4^{2-}	200-400	4	0.14286
7	Ca^{2+}	75-200	2	0.07143
8	Mg^{2+}	30-100	2	0.07143
9	Na^+	200	2	0.07143
10	K^+	12	2	0.07143
		Sum	$\Sigma wi = 28$	Σ Wi = 1.00

* All parameters are in (mg/L) except pH

Table 3. Water quality classification based on WQI value

Sr.No.	WQI value	Water quality	No of water samples	% of water samples
1	< 50	Excellent	4	7
2	50-100	Good water	32	58
3	100-200	Poor water	18	33
4	200-300	Very poor water	1	2
5	>300	Unsuitable	0	0
		Total	55	100

Table 4. Water quality index value for individual groundwater sample

Well no.	WQI	Classification	Well no.	WQI	Classification
1	125.25	Poor	29	72.50	Good
2	128.88	Poor	30	54.20	Good
3	49.05	Excellent	31	48.71	Excellent
4	55.12	Good	32	88.90	Good
5	155.61	Poor	33	56.53	Good
6	175.86	Poor	34	43.41	Excellent
7	168.96	Poor	35	66.11	Good
8	232.63	Very poor	36	65.84	Good
9	52.94	Good	37	66.07	Good
10	54.34	Good	38	114.74	Poor
11	54.95	Good	39	95.22	Good
12	51.57	Good	40	132.13	Poor
13	89.97	Good	41	69.85	Good

14	135.88	Poor	42	76.77	Good
15	59.99	Good	43	80.14	Good
16	51.74	Good	44	76.74	Good
17	91.36	Good	45	96.55	Good
18	105.92	Poor	46	52.23	Good
19	112.48	Poor	47	77.97	Good
20	125.09	Poor	48	71.05	Good
21	139.58	Poor	49	99.70	Good
22	121.62	Poor	50	92.92	Good
23	89.55	Good	51	139.80	Poor
24	133.54	Poor	52	49.85	Excellent
25	99.99	Good	53	105.62	Poor
26	92.53	Good	54	70.19	Good
27	119.80	Poor	55	92.99	Good
28	102.85	Poor	Mean	93.41	Good

Water quality index calculation (WQI)

Groundwater samples (n = 55) and their WQI values are presented in Table 4. Therefore, the groundwater quality status can be categorized into five types based on WQI values, namely excellent water (<50), good water (50–100), poor water (100–200), very poor water (200–300) and water unsuitable for drinking (>300) (Table 5). The computed WQI values for the 55 groundwater samples in the study area ranged from 43.41 to 232.63 with a mean value of 93.34 (Table 4), among these, 7% (4 wells) of the samples fall under the excellent category, 58 % of samples (32wells) fell under good water category and 33 % (18 wells) of the samples showed poor water category, and 2 (1 well) fall under very poor water category for drinking purposes. The well having poor and very poor water, indicating effective leaching, dissolution process and the rock–water interaction process is the main source for degrading the groundwater quality (Aher, 2012; Deshpande et al, 2014; Aher and Deshpande, 2015).

CONCLUSIONS

Groundwater suitability has been evaluated through processed-based hydrogeochemical signatures and is compared with the BIS (2012) concerning drinking uses. The results show that the quality of groundwater is mainly alkaline. The interpretation of the hydrochemical analysis reveals that the groundwater is predominantly of CaNaHCO3 type of water. The order of abundance trend found was in the order of HCO3>Cl> Mg >Ca > Na > SO4 > K. The water quality index (WQI) shows that 7% of samples fall under the excellent category, 58 % has good water and 33 % of the samples showed poor water and 2 % fall under very poor water category for drinking purposes. The 19 wells having polluted water indicate effective leaching, dissolution process and the rock-water interaction process is the main source for degrading the groundwater quality. The study concludes that the groundwater quality is weakened by man-made activities and a suitable managing strategy is needed to protect valuable groundwater resources.

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