Geochemical Assessment of Groundwater Quality for its Suitability for Drinking and Irrigation Purpose in Jabalpur, Madhya Pradesh, India

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***Abstract*: Hydro geochemical investigation of groundwater resources of the Jabalpur city has been carried out to assess the solute acquisition processes and water quality for domestic and irrigation use. Twenty one groundwater samples were collected from different locations and analyzed for pH, electrical conductivity (EC), total dissolved solid (TDS), hardness, major anions (Cl^-, HCO_3^-, SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^+, K^+). The results were compared to the WHO standards. All parameters were within the permissible limit. Piper plot indicate the groundwater belongs to Na-Cl water type. Durov specified the dominance of reverse dissolution. Durov and Chloroalkaline indices indicated the dominance of alkaline element were over alkaline earth elements. Granite along with feldspar and Na bearing silicates are common in the study area; ionic concentration in the groundwater is due to the dissolution of the rock that makes up the aquifer. SAR and CAI reveals that groundwater in the area is good for irrigation purpose.**

***Keywords*: Chloro-alkaline indices, Durov diagram, Groundwater, Jabalpur, Piper diagram, Water quality, Wilcox diagram.**

1. Introduction

Water resource has played a vital role throughout the history in the growth and development of human civilization. In modern times, water resources have critical importance in economic growth of contemporary societies. Therefore, water resources and assessment and sustainability consideration are of utmost importance, especially, in the developing countries like India where water is commonly of economical and social significance.

Geochemical processes occurring within the groundwater and reactions with aquifer minerals have significant impact on water quality. These geochemical processes are responsible for seasonal and spatial variations in groundwater chemistry. The geochemical properties of groundwater depend on the chemistry of water and also on the different geochemical processes that are taking place in the sub-surface (Back and Hanshaw, 1965; Hem, 1959; Cheboterev, 1955; Srinivasamoorthy, 2005; Gibbs, 1970). Groundwater contains minerals carried in the solution, the type and the concentration of which depends upon several factors. The chemical composition of groundwater depends upon the soluble products of weathering and decomposition of rocks in addition to external polluting agencies. As a result of interactions between groundwater and the geological material through which it flows, groundwater contains a wide variety of dissolved inorganic chemical constituents (Kinzelbach et.al.1989). In the current study an effort has been made to calculate the groundwater indices for the aptness of groundwater for drinking and agricultural purpose and to identify the influence of natural and anthropogenic actions on the groundwater chemistry. The study provides some basic hydro-geochemical data for utilization of groundwater resources that may also help in future water resources planning for the area.

Mahakoshal Super group are the oldest group which belongs to Palaeoproterogoic age found in south-western part of the area. The exposures are reported at Tiwaraghat, Lametaghat and Bheraghat. At some places, it has been intruded by the Madan Mahal granite of Palaeoproterozoic age. Jabalpur formation belongs to Gondwana Super group of Triassic to lower Cretaceous age, rest unconformably over this formation. Above Gondwana super group, the famous Lameta beds of Cretaceous age are present. Deccan trap of Palaeocene-Cretaceous age show a marked break in the succession. Unconformably above the Deccan traps various quaternary formations belonging to Upper and Lower Pleistocene, Holocene and Recent age are observed.

2. Study Area

District Jabalpur is located on 23° 10' N latitude and 79° 59' E longitude. Total area is 5,211 km² including 4,864.41 km² rural area and 346.59 km² urban area. The district is further divided into seven blocks for administrative purposes with 24, 63,289 peoples and 5,39,060 houses. Jabalpur has a humid subtropical climate. May is the hottest month; with the average temperature exceeding 45 °C (113 °F) January is the coldest month, with an average daily temperature near 15 °C (59 °F). Average annual precipitation is nearly 54.6 inches. Jabalpur district is located in the Mahakoshal region of Madhya Pradesh, on the divide between the watersheds of Narmada and the Son. The North and East belong to the basin of the Son River, a tributary of the Ganges and Yamuna, the South and West to the Narmada basin

Jabalpur is an important administrative, industrial, and business centre of Madhya Pradesh. It is a major education hub in India. The High Court of Madhya Pradesh and several departmental headquarters of the State Government are located here. The city has a major military base and has four major Indian Ordnance Factories for the production of arms and ammunition in India, which are the city's primary source of employment. It also has several other smaller industries. The city is a major trading centre and producer of forest products, experiencing fast growth in all sectors.

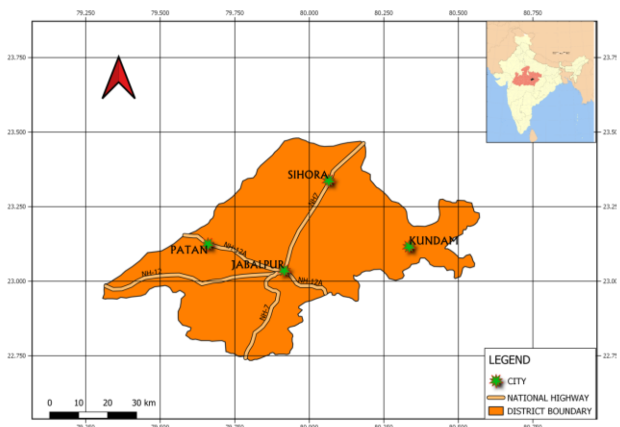

Fig. 1. Location of the study area

In this study, evaluation of groundwater quality was conducted using data obtained from samples collected from the tube wells. The location of study area and sampling wells which are recorded in Universal Transverse Mercator (UTM) coordinate system are shown in figure 1.

3. Materials and Methods

Chemical analyses of the water samples were carried out using the standard procedures (APHA-2005). Each of ground water samples were analyzed for pH, electrical conductivity (EC), major cations and major anions. Among variable parameters, pH and EC were measured immediately by using portable meters (Eutech, ECTestr11+). Total hardness and calcium were determined by ethylene diamine tetra acetic acid titrimetric method. Total alkalinity, carbonate and bicarbonate and chloride were estimated by using titrimetric method. Sodium and Potassium were estimated by using flame photometer. Sulphate was estimated by gravimetric method. Sodium Absorption Ratio (SAR) and Chloroalkaline Indices (CAI) were determined by calculation.

For the present study around 21 samples of groundwater were collected from the bore wells, tube wells of different localities shown in figure 2.

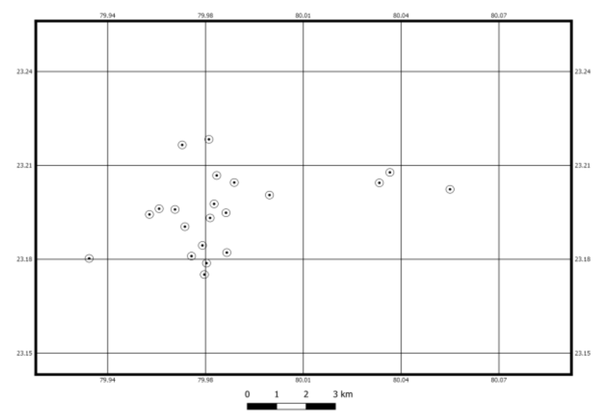

Fig. 2. Location the sample collection points of the study area

The water samples were collected in narrow mouthed, pre washed and sterilized polyethylene bottle of 1-2.5 litres capacity after flushing out the tube wells for minimum 10 minutes to get the fresh groundwater. The samples are collected up to the top, without leaving any space so as to prevent the premature release of dissolved gases during the transit period. Samples were prepared with and without preservatives as per norms. Some sensitive parameters like pH and TDS were determined on the spot using appropriate digital meters, for further analysis samples were transported to the well-recognized laboratory. The results obtained were elevated in accordance with the drinking water standards prescribed as WHO (table 1).

Table 1
Ranges of chemical parameters and their comparison with World Health Organisation (1997) standards for drinking water

Parameter	Min	Max	Average	WHO(1997) Permissible limit	Sample No. Exceeding Permissible limit
pH	6.23	7.9	7.4	9.2	0
EC(µS/cm)	578	993	753.8	-	0
TDS(mg/l)	157	501	569.8	1500	0
Ca^{2+} (mg/l)	20	78	56.1	200	0
Mg^{2+} (mg/l)	10.2	19	13.8	150	0
Na^{+}(mg/l)	43	91	68.7	200	0
K^{-}(mg/l)	1.8	8.4	3.5	12	0
SO_4^{2}- (mg/l)	8	33	16.5	600	0
Cl^{-}(mg/l)	17	67	45.1	600	0
HCO_3(mg/l)	132	298	202.7	600	0
NO_3^{-}(mg/l)	23	43	30.0	50	0

4. Results and Discussion

A. Piper and Durov Diagram

Piper classification (piper 1953) is used to express similarity and dissimilarity in the chemistry of different water samples based on the dominant cations and anions (Fig. 3). This diagram is an effective tool in segregating analysis with respect to sources of the dissolved constituents in the groundwater, in the character of water as it passes through an area and related geological problems. The results obtained after the analysis were plotted on the Piper plots as shown in Fig. 4.

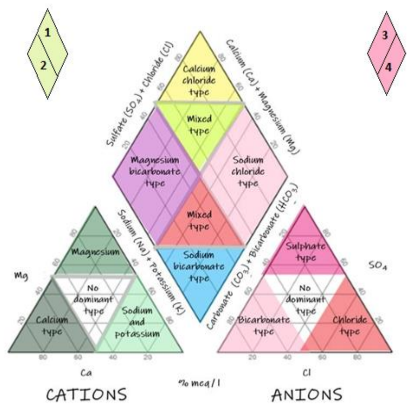

Fig. 3. Classification diagram for anion and cation facies (Piper 1953, Back and Hanshaw1965)
(1-strong acid exceed week acid; 2- week acid exceed strong acid; 3- alkalies earth exceed alkalies; 4-alkalies exceed alkalies earth)

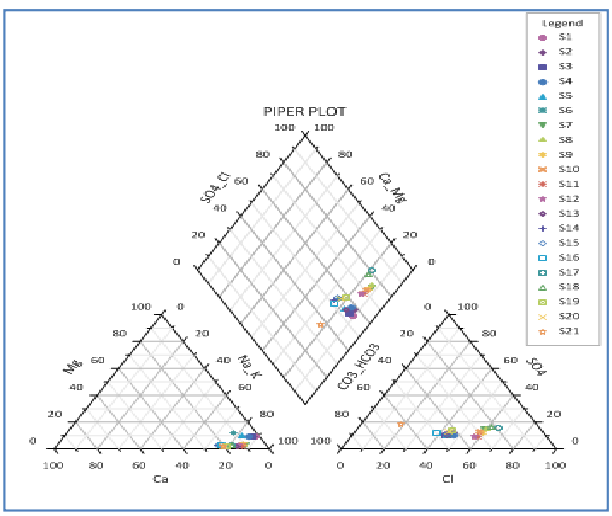

Fig. 4. Piper trilinear diagram of the collected samples

Majority of the samples in study area fall in NaCl water type. Groundwater is grouped into facies depending on the dominant ions present. Figure 4 shows the pipers trilinear plot of groundwater in the study area, reflects the dominance of NaCl water type. The percentage of samples falling under NaCl –type were 95% and only 5% of sample number S16 and S21 falls in mixed water type. Results depict that alkalise exceed alkalise earth metals and the strong acid exceeds weak acid (figure 3).

Weathering and dissolution of water bearing rocks like granite and other rock forming minerals like feldspar and Na bearing silicates are common in the study area are the source of Na-Cl water type.

The Durov Diagram is an alternative to the Piper diagram. In the two triangles, it plots the major ions as percentages of milliequivalents. The totals of both the cations and anions are set to 100% and the data points in the two triangles are projected onto a square grid which lies perpendicular to the third axis in each triangle (figure-5). From the above discussion it reveals that NaCl type of water prevail in the study area was supported by data plotted on Durov diagram, the samples falls in the field 'F' of Durov plot along reverse ion exchange field.

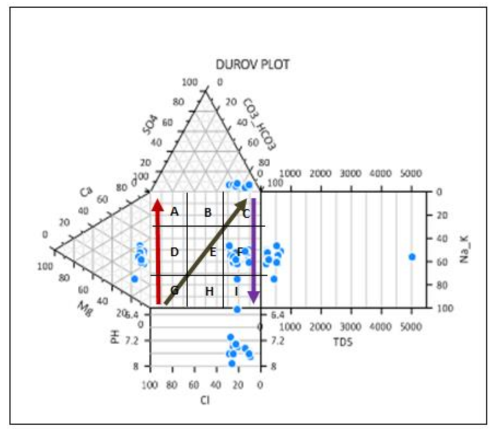

Fig. 5. Durov plot portray hydrochemical processes involved in the area, where arrow indicates ↑ = Ion exchange; ↑ = Simple dissolution or mixing; ↓ = Reverse ion exchange

B. Chloro Alkaline Index

The ion exchange between the groundwater and its host environment during residence or travel can be understood by studying chloro- alkaline indices. To know the direction of exchange during the path of groundwater through the aquifer Schoeller (1965) suggested two Chloro Alkaline Indices CAI 1 and CAI 2 to indicate the exchange of ions between groundwater and its host environment. The ion exchange and reverse ion exchange were confirmed by using Chloro Alkaline Indices following equation 1 and 2.

$$CAI\ 1 = CL^{-} - (Na^{+} + K^{+}) / Cl^{-} \quad (1)$$
$$CAI\ 2 = CL^{-} - (Na^{+} + K^{+}) / (SO_4^{2-} + HCO_3^{-} + CO_3^{2-} + NO_3^{-}) \quad (2)$$

Among chloro alkaline indices, CAI 1 varied from +11.71 to +65.80 meq/l and CAI 2 ranged from -0.00 to -0.25 meq/l. Majority of the samples were positive, suggesting inverse/ reverse ions exchange processes causing exchange of Mg^{+} + Ca^{+} from water with Na^{+} + K^{+} from rocks (figure 6). Thus, the findings clearly indicated that exchangeable cations can also be used to indicate the chemical composition of groundwater of the study area.

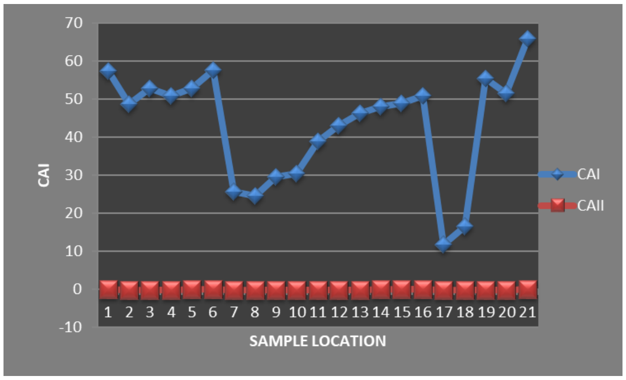

Fig. 6. Line chart represents CAI I and CAII in groundwater samples

C. *Wilcox Diagram*

Wilcox (1948) projected a scheme to categorize groundwater for agricultural use based on percent sodium and electric conductivity in the form of a diagram. Following are classification of groundwater in four distinct degree of suitability for irrigation (Table 2).

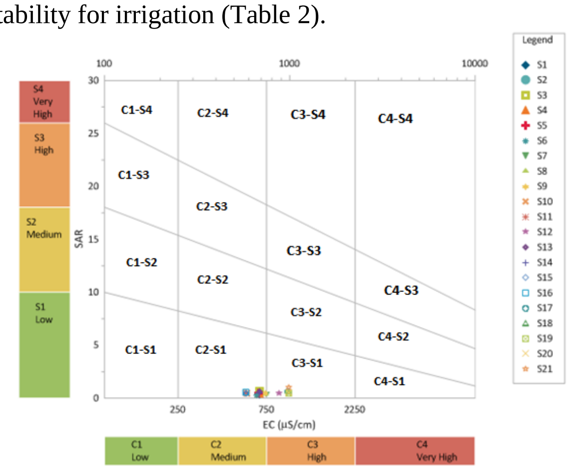

Fig. 7. Classification of groundwater samples in relation to salinity hazard and sodium hazard (after US salinity laboratory diagram 1954)

Table 2
Some parameter indices for rating the sustainability of groundwater quality for irrigation (Wilcox 1948; Ayers and Westcot 1985)

S. No.	Class	SAR	Suitability for Irrigation	Observed Value of SAR
1	I	<10	Excellent	1.38
2	II	10-18	Good	-
3	III	18-26	Fair	-
4	IV	>26	Poor	-

The classification of water sample (Richards, 1954) from the study with respect to SAR value against EC reveals that 66.6% of groundwater samples lies in the field of C2S1 (suited for all plants but drainage should be good) and 33% falls in C3S1 (required drainage or dangerous to soil) categories (Figure 7 and Table 3).

5. Conclusion

In this evaluation of groundwater, conventional hydrochemical techniques were used to find out the status of groundwater for its utilization to drinking and irrigation purpose. From the study it is concluded that the geochemistry of the study area is controlled by geogenic factors. All the water quality parameters of water samples are within permissible limit set by WHO (1997) and suitable for drinking. Groundwater of study area is slightly alkaline in nature which is due to reverse ion exchange as supported by the Durov plot. Data plot of Piper diagram show 95% of the water samples belong to NaCl water type. Result depict that alkalise exceed alkalise earth metals and strong acid exceeds weak acid.

Study of Wilcox diagram suggested that 66% of data falls in C2S1 which indicates good quality; this type of water suited for all plants, rest of the data of water samples are classed as C3S1 which is an indicator of water with moderate quality and can be used in irrigation of coarse lands with good drainage.

Table 3
Water quality for agriculture of the Wilcox method

Sample no.	SAR	Electric-conductivity	Water class	Water quality for agriculture
S1	0.3851	683	S1C2	usable for agriculture
S2	0.4189	688	S1C2	usable for agriculture
S3	0.6	684	S1C2	usable for agriculture
S4	0.478	687	S1C2	usable for agriculture
S5	0.4523	675	S1C2	usable for agriculture
S6	0.2977	664	S1C2	usable for agriculture
S7	0.3875	747	S1C2	usable for agriculture
S8	0.3888	751	S1C3	usable for agriculture
S9	0.4512	742	S1C2	usable for agriculture
S10	0.481	589	S1C2	usable for agriculture
S11	0.4712	590	S1C2	usable for agriculture
S12	0.4444	872	S1C3	usable for agriculture
S13	0.6818	685	S1C2	usable for agriculture
S14	0.4416	689	S1C2	usable for agriculture
S15	0.425	582	S1C2	usable for agriculture
S16	0.5327	578	S1C2	usable for agriculture
S17	0.6041	981	S1C3	usable for agriculture
S18	0.6148	979	S1C3	usable for agriculture
S19	0.5	984	S1C3	usable for agriculture
S20	0.5588	993	S1C3	usable for agriculture
S21	1	987	S1C3	usable for agriculture

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