Available online at www.elixirpublishers.com (Elixir International Journal)

Geoscience

Elixir Geoscience 75 (2014) 27862-27865

ISSN: 2229-712X

Interpretation of groundwater chemistry using piper and chadha´s diagrams: a comparative study from perambalur taluk

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ARTICLE INFO

Article history:

Received: 1 May 2012;

Received in revised form:

29 September 2014;

Accepted: 26 October 2014;

Keywords

Hyrogeochemistry,

Piper diagram,

Chadha´s diagram,

Perambalur,

South India.

ABSTRACT

Groundwater chemical behaviors in various locations are one of the most dynamic fields of research in the present world. In the present study, groundwater sampling was conducted with an aim to assess the groundwater chemistry and to compare the water types using piper and Chadha´s plots. Groundwater chemistry was assessed and natural processes are identified as the controlling factors of hydrochemistry. Piper and Chadha´s diagram was created for comparing the results of water types. Majority of the samples were behaved in more or less same way except few samples. The prominent type was Ca-Mg-Cl type of water in both methods. However, a slight variation was observed in the Na-Cl type of water. Easily accessible software's to plot is the Chadha´s diagram major advantage observed

Introduction

The chemistry of water is very dynamic, largely controlled and modified by its medium of contact. Since the chemistry of water directly hints the quality of water for various purposes, its monitoring and assessment gained substantial importance in the present century. A tremendous increase in the population increased the stress on both surface and the groundwater. It is believed at the beginning of the human civilization itself, groundwater was the most trusted form of drinking water because of the filtering effect of the aquifer. However, in the present world drinking the water directly from the source without proper treatment is a tough task.

Water type/ hydrochemical facies evaluation are extremely useful in providing a preliminary idea about the complex hydrochemical processes in the subsurface. Determination of hydrochemical facies was extensively used in the chemical assessment of groundwater and surface water for several decades. This method is able to provide sufficient information on the chemical quality of water, particularly the origin. However over the years the methods were undergone substantial modifications, without changing much on the basic theory behind it. The first attempt in this direction was made by Hill (1940) and which is modified by Piper (1944). Durov (1948) further improved the piper plot. However these plots could be drawn only by the specific software packages.

Piper diagram were made in such a way that the milliequivalents percentages of the major cations and anions are plotted in separate triangle. These plotted points in the triangular fields are projected further into the central diamond field, which provides the overall character of the water. In contrast, in Chadha´s diagram, the difference in milliequivalent percentage between alkaline earths (calcium plus magnesium) and alkali metals (sodium plus potassium), expressed as percentage reacting values, is plotted on the X axis, and the difference in milliequivalent percentage between weak acidic anions (carbonate plus bicarbonate) and strong acidic anions (chloride plus sulphate) is plotted on the Y axis. The resulting field of study is a square or rectangle, depending upon the size of the scales chosen for X and Y co-ordinates. The milliequivalent percentage differences between alkaline earths and alkali metals, and between weak acidic anions and strong acidic anions, would plot in one of the four possible sub-fields. The major advantage of this diagram is that it can be drawn in any spreadsheet software packages (Chadha 1999).

Groundwater types were used by many researchers in their studies to understand the controlling factors of the water chemistry (Aris et al. 2009; Martos et al. 2002; Mondal 2010; Rajesh et al. 2011; Ramesh and Elango 2011). In the present study along with groundwater chemistry, water types were assessed using Piper and Chadha´s diagrams.

Materials and methods

Study area

The present study area is located in the Tamil Nadu state in south India. It receives the rainfall under the influence of both southwest and northeast monsoon. There is a gradual decrease in precipitation from northeast to southwest. The normal rainfall for the period (1901-70) ranges from 843.5 to 1123.3 mm. Perambalur enjoys a typical semi arid climate with hot summers and moderately cool winters. The hottest season is from March to May. During the period the maximum temperature often exceeds 40°C. The winter season is spread over two months viz. January and February and the nights are cool and pleasant. The district generally has a high humidity. The district experiences strong winds during the southwest monsoon season. The wind speed during June to August is more than 25 km/hr. Thereafter there is a gradual decrease in speed reaching the lowest value 7.7 km/hr. In general, the study area has an undulating topography, characterized by low mounds and broad valleys. Hill ranges belonging to Pachaimalai Hills occupy the northwestern part of the district, where the terrain is rugged. The ground elevation ranges from 100 to 1015 m msl. The region slop is towards east. Denudational, structural and fluvial

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processes mainly control the geomorphic evolution of the area. Mainly the varying resistance of geological formations to those processes has governed the evolution of various landforms. Various land forms occurring in the area such as structural hills, erosional plains, residual hills rolling uplands and pediments of different facies belonging to the denudational and structural land forms. Fluvial landforms caused by the activity of Cauvery, Marudayar and Vellar river systems, include younger flood plains, older flood plains and buried pediments. The major aquifer systems in the study are constituted by Basal crystalline rocks consisting mainly of Charnockites, Granites and Gneisses of Archean age (CGWB 2009)

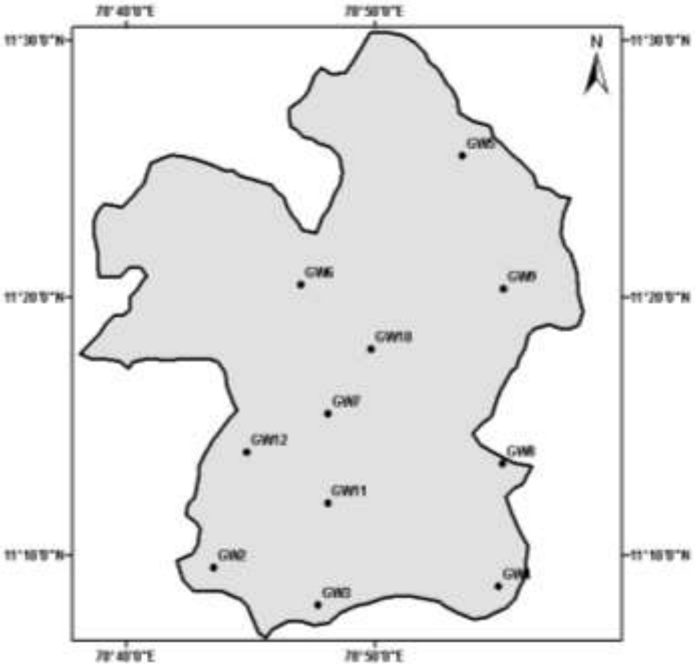

Fig. 1 Location map of the study area with sampling points

Methods

Extensive groundwater sampling was conducted at point calimere during August 2011. One Sample was collected from the meeting point of Bay of Bengal and Palk Strait (Popularly known as Pint Calimere. One sample form the salt pans area also collected. Wells were pumped for 5minutes prior to the collection of samples. Polythene bottles, which were cleaned with detergents, were used as containers. Each bottle was rinsed with distilled water before pouring the sample water. Proper labeling including the sample number, location were done. The bottles were labeled and air-tight. Two sets of samples were collected from each location. The geographical location of each well was determined with a handheld GPS (Gramin 76CSX). Physical and chemical parameters were analyzed using the standard method suggested by APHA (1985). EC and pH were analysed as insitu using field kit. TDS was calculated from EC by an empirical formula TDS= 0.64*EC. Chloride, hardness, calcium, magnesium, carbonate and bicarbonate were determined by titration. Flame photometer was used to measure the sodium and potassium. Sulphate was determined by spectrophotometer. Analytical precision was maintained throughout the experiments. Aquachem 4.0 software package was used to plot the piper diagram and the Chadha´s diagram was created using MS Excel spreadsheet.

Results and discussion

A) Water quality

Water quality parameters of the Perambalur Taluk are presented in Table 1. All the samples were alkaline in nature, with a rage of 77- 8.8. The permissible limit of TDS in the drinking water is 1000 mg/L (WHO 1993). However in this study, the TDS values were varied between 225 – 1344 mg/L, with n average of 899 mg/L. Among the 12 samples, 5 of them exceeded the permissible limit. Calcium and magnesium in the study area ranged between 20-60 mg/L and 29.2 – 102.1 mg/L respectively. In the normal groundwater systems, the principal origin of these ions is carbonate minerals and their dissolution and depositional processes. Weathering of silicate minerals are also contributing towards the enrichment of these minerals. Relatively less abundance of the carbonate minerals in the study area indicate that the major origin of Ca and Mg is silicate weathering. Na and K concentrations were varied between 14-321 mg/L and 0.1- 113 mg/L. Sodium in the groundwater is largely controlled by the saline intrusions, evaporates and silicate minerals. However, Na and K in the study area is derived from the weathering of the hard rocks, especially silicate weathering. A relative lower concentration of Ca than Na shows the effect of cation exchange between these minerals. Bicarbonate was the dominant anion in the study area, with an average concentration of 321.9 mg/L. Apart from the dissolution of carbonated the major origin of bicarbonates are the sewage systems. However there is no prescribed permissible limit of for this ion. Bicarbonate was absent in most of the samples. Chloride ion is generally used in delineating the saline intrusions. The peculiar characteristics is that this ion has high mobility and hardly undergone for sorption. In Perumablur are the concentration of Cl in the groundwater was 21-371 mg/L, with an average of 205.6 mg/L. sulphate in the study area varied between 6- 194. The major origin of sulphate is the dissolution of Gypsum ad anthropogenic activities.

B) Water types

A Piper diagram (see Fig. 2) was created for the Perambalur area using the analytical data obtained from the hydrochemical analysis. In general, we can classify the sample points in the piper diagram into 6 fields. They are 1. Ca-HCO_3 type 2. Na-Cl type 3. Ca-Mg-Cl type, 4.Ca-Na-HCO_3 type 5. Ca-Cl type 6. Na-HCO_3 type. However, in the present study water types were confined to the first four types. Majority of the samples (42%) are plotted in the Ca-Mg-Cl field. 25 % of the samples showed Na-Cl type. Rest of them was fall in the Ca-HCO_3 and Na-HCO_3 types. Evaluation of the water types using piper plot suggests that there is a clear indication of the contribution from the weathering of pyroxenes and amphibole in the hard rocks. The study was conducted during the post-monsoon season and in this period dissolution of the minerals are the major processes occurring in the groundwater environment. Since the flow is high there will not be much time for precipitation. Dominance of Ca and Mg in the groundwater samples collected from the high topography suggested an inverse ion exchange process. During this process Ca from the Aquifer matrix will be exchanged by Na from the groundwater. However in the lower topographic region water is dominated by the Na and Cl ions, which is represented by the discharge zone. Sluggish flow in these relatively flat regions enables sufficient rock-water interactions.

For the better understanding the hydrochemistry and comparing the water types Chadha´s diagram was plotted (Fig. 3). The six fields are mentioned by Chadha (1999) is given in below. 1. Alkaline earths exceed alkali metals. 2. Alkali metals exceed alkaline earths. 3. Weak acidic anions exceed strong acidic anions. 4. Strong acidic anions exceed weak acidic anions. 5. Alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, respectively. 6.

Table 1. Results of hydrochemical parameters

S. No	pH	TDS	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3
GW1	8.1	1000	40	36	258	4	188	132	0	336
GW2	8.1	906	38	53	161	86	138	12	0	573
GW3	8.0	987	60	100	115	18	284	194	0	165
GW4	8.1	1052	40	86	182	0	273	187	0	110
GW5	8.5	1186	34	102	161	113	372	29	24	329
GW6	8.6	752	22	80	133	3	184	14	24	311
GW7	8.2	876	50	52	145	26	213	78	0	140
GW8	8.6	485	32	32	113	6	53	6	14	361
GW9	8.0	758	36	74	107	10	142	52	0	348
GW10	7.7	1344	28	87	322	34	369	58	0	580
GW11	8.1	225	30	29	14	2	21	7	2	183
GW12	8.8	1104	20	77	271	4	230	91	42	427
Min.	7.7	225.0	20.0	29.2	14.0	0.1	21.0	6.0	0.0	109.8
Max.	8.8	1344.0	60.0	102.1	322.0	113.0	372.0	194.0	42.0	579.5
Avg.	8.2	889.6	35.8	67.4	165.2	25.5	205.6	71.7	8.8	321.9

Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. 7. Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. 8. Alkali metals exceed alkaline earths and weak acidic anions exceed strong acidic anions.

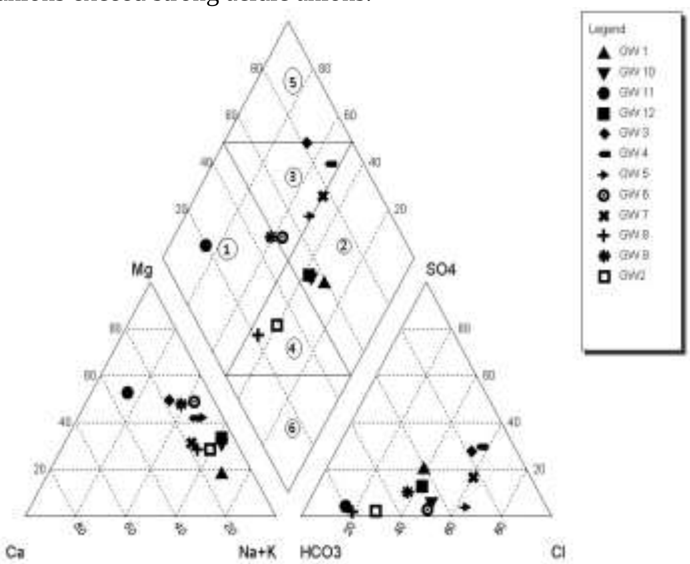

Fig. 2 Piper plot

In the present study all the samples are confined to 5, 6, 7 and 8 fields respectively. A majority of the samples (42%) are plotted in the 6th field, representing Ca–Mg–Cl type, Ca–Mg dominant Cl type, or Cl-dominant Ca–Mg type waters. This is exactly similar to the results obtained from the piper plot. Field 7 represents the Na-Cl type of water, the percentage of samples in this category is reduced to 17%, which was 25% in the piper plot. Rest of the samples was behaved exactly similar to the piper plot.

Conclusions

Results of the hydrochemistry suggest that all the water samples are alkaline in nature. Major process controlling the water quality is the silicate weathering, mineral dissolution, Cation exchange and inverse cation exchange processes. Topographical undulations and the groundwater flow were identified as the other supporting factors for the hydrochemical processes. Groundwater types were assessed and compared with Piper and Chadha´s diagrams. 42% of the water samples were Ca-Mg-Cl types, in both methods. However, a slight variation was observed in the second highest water type which was Na-Cl in the piper plot, which was shifted to Ca-Mg-CO_3 in Chadha´s plot. Other types were similar in both methods.

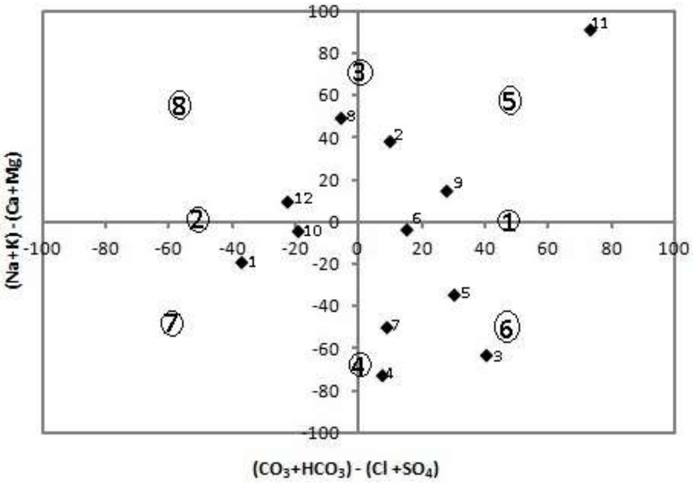

Fig. 3 Chadha´s diagram

This discrepancy may be due to the small data set used in this study. Since Chadha´s plot can be plotted in simple spreadsheets, this method will be more suitable for small budget studies and for academic purposes.

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