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Hydrogeochemistry and Groundwater Quality Assessment in and around Pandalgudi Region, Viruthunagar District, Tamilnadu, India

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Abstract : Twenty four representative groundwater samples collected during pre-monsoon and post monsoon seasons during 2014, were analyzed for various physico-chemical parameters such as pH, TDS, EC, Cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Anions HCO_3^-, SO_4^-, Cl^-, F^- and NO_3^-. The GIS based, thematic iso-quality geospatial contour maps for the integrated parameters of cations Ca^{2+}- Mg^{2+}, Na^{+}-K^{+} and anions HCO_3^- - SO_4^- - Cl^-, were generated by the software Arc GIS 10.1, to find out the distribution concentration. Further, the water quality parameters were illustrated with Gibbs and Back facies method. Finally, water qualities of the study area are compared with BIS and WHO standards of drinking water and other standards such as livestock and irrigation purposes.

Keywords:Physico-Chemical Parameters, Arc GIS 10.1, Gibbs, BIS, WHO, Drinking water, Livestock, Irrigation

Introduction

Groundwater is more absolutely essential resources in the earth. Utilization and requirement of groundwater for agriculture, industries and domestic purposes are being increased in developing countries. Further, due to overgrowth of population, socio-economic development, rapid growth of urbanization and environmental degradation, water stress in the world has been emerged as a real threat for human lives (Kaliammal and Udayanapillai, 2016). The quality of groundwater is highly affected spatially and temporally by various factors such as lithology, aquifer chemistry, rock-water interaction and its circulation, microbial action, pollution and seawater intrusion (Udayanapillai et al., 2012). These complex processes which make various hydro geochemical characterization, occurring in wide range of lithology from the age of Archaean crystalline rock to recent alluvium. Different lithological condition in India makes tremendous changes in the hydro geochemicalcharacterization of groundwater (Chadha and Chakaraborty, 2001). Many villages centered on Pandalgudi region of Viruthunagar district are being utilized groundwater long time for domestic and irrigation purposes. Except one or two minor reports, no much research work has been concentrated previously in the above study area pertaining to geochemistry of groundwater. Due to the welfare of

the society of the study area, an attempt has been made in this paper to evaluate the geochemical characterization of groundwater utilizing GIS based techniques.

Study area

The study area is located above the Vaippar river basin. It is bounded with an aerial distance of 90 sq.km, centered on Pandalgudi town, whichfalls in the survey of India toposheet no 58/K3, prepared in the scale of 1:63360. The area encompasses between the latitude from N 9° 15' to N 9° 30' and longitudes from E 78° 0' to E 78° 15' (Figure. 1).It has been well connected with national and state highway road network. The topography of the study area is generally flat and plain with devoid of any hill outcrop. It has the maximum elevation of 82m from the MSL. Drainage patterns are dendritic and the drainage slope directions is generally facing towards south and south east direction and merge into the Vaippar river basin located at the south. The area generally experiences tropical climate and receives an average rainfall of 700 mm per annum whichare influenced by south west and north east monsoons. The cultivation is generally practiced by lake and well irrigations.

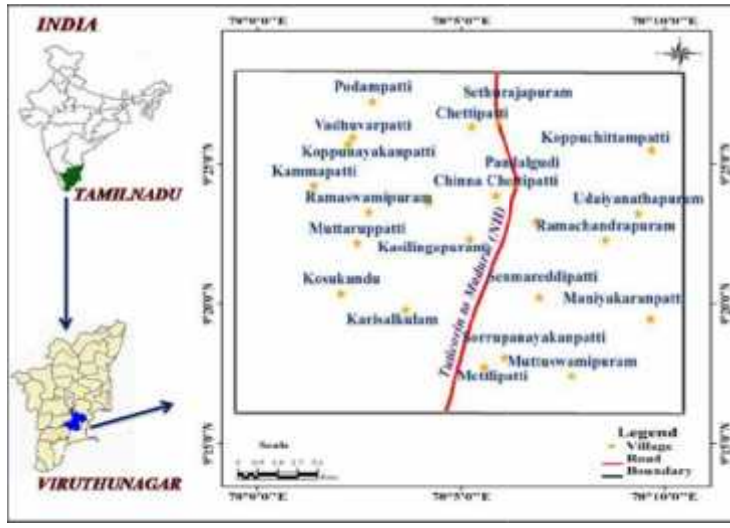


Figure 1. The Location map of the study area.

Geology

The Proterozoic basement rocks consists of quartzite, crystalline limestone, calc-granulite, hornblende – biotite gneiss, charnockite or pyroxene granulite, granite and pegmatite in the study area. Weathered, fissured cracks, shear zones and joints in the basement rock act as a good groundwater potential zone in the study area. Proterozoic formation is overlain by a thick calcrete with a thickness of 1.20m

which is believed to be the age of Holocene to Pleistocene deposits. The calcrete is overlain by the Recent alluvium of black soil and detached batches of red sandy loamy soil. The general stratigraphy of the study area is shown (Table 1).

Table 1 Stratigraphical Succession in and around Pandalgudi area.

Age	Thickness	Strata	Depth
Recent	1.25m	Black soil	0 – 1.25m
Holocene-Pleistocene	1.20m	Calcrete layers	1.25 – 2.45m
Proterozoic	Infinitive	Sap rock or Basement rock	Below 2.45m

Materials and methods

Twenty four representative groundwater samples from both open wells and dug wells collected for both pre monsoon and post monsoon periods during 2014 were analyzed by adopting the standard analytical procedure (APHA, 1998). Moreover, well inventory details such as location, geology, well shape and dimensions and depth of water table were also observed while collecting the samples.Physical parameters pH, TDS and EC, cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, anions HCO_3^-, SO_4^-, Cl^-, F^- and NO_3^- of the groundwater samples were analyzed. The GIS based geospatial iso quality contour maps by using Arc GIS 10.1 software, for the integrated parameters of cations $Ca^{2+} – Mg^{2+}$, $Na^{+} – K^{+}$ and anions $HCO_3^- – SO_4^- – Cl^-$ are prepared by IDW interpolation technique and overlay analysis. A computer programme Aqua chem. 4.0 was used for calculation and graphical representation of Gibbs diagrams. The characterization of groundwater qualities of the study area are compared with BIS (2012) and WHO (2011) drinking water standard and other standards of livestock use and irrigation purposes.

Result and discussion

The average values of the analytical result of 12 parameters of 24 water samples for both pre-monsoon and post-monsoon are given in (Table. 2). The integrated parameters of $Ca^{2+} – Mg^{2+}$ and $Na^{+} – K^{+}$, and HCO_3^-, SO_4^- and Cl^- are taken into consideration for the GIS based evaluation, for knowing the distribution concentration. Since, the other parameters such as F-, NO_3^- are in smaller values, they are not considered for drawing iso-spatial maps.

Table 2. Average water quality parameters of all values for two season in mg/l, except EC in µS/Cm

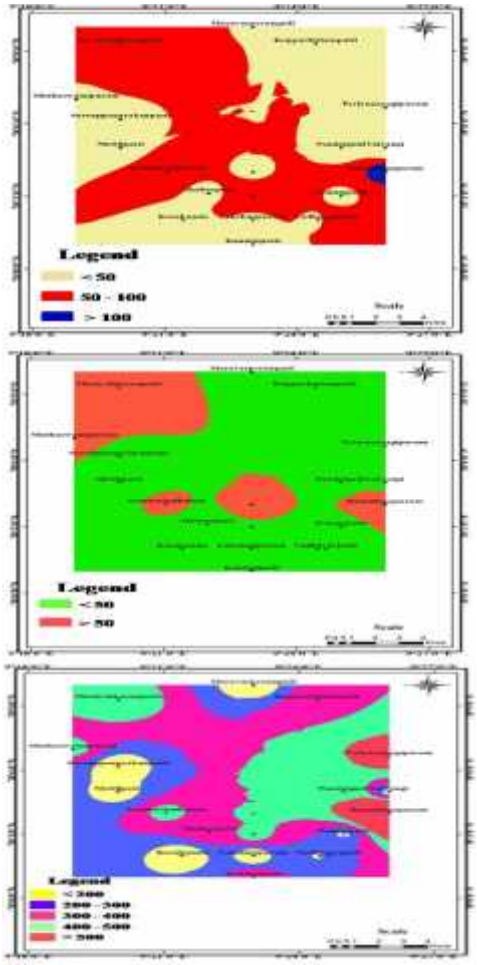
S.No	Village	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	F^{-}	Cl^{-}	SO_4^{-}	HCO_3	CO_3^{-}	NO_3^{-}	pH	EC	TDS
1	Podampatti	22	16	15	4	0.16	43	49	659	48	1.2	8.5	736	471
2	Ramalingapuram	139	457	83	30	0.19	545	736	98	0	1.1	8	3185	2038
3	Chidambarapuram	82	17	23	21	0.17	150	56	342	12	0.3	8	807	516
4	Chettikurchi	54	27	58	24	0.21	128	72	342	12	0	8.1	828	530
5	Valvangi	98	32	67	88	0.24	113	163	403	24	0.1	8.2	1185	759
6	Periyanayagipuram	82	51	165	13	0.19	255	125	500	24	2.4	8.1	1461	935
7	Ayankarisalkulam	354	97	400	60	0.13	454	952	281	24	1.2	8	3835	2454
8	Kosukundu	51	36	65	11	0.21	85	90	207	24	2	8.2	687	440
9	Mutharpatti	325	97	188	26	0.21	808	216	183	12	0.3	8.2	2734	1750
10	Ramaswamipuram	112	46	68	21	0.21	142	120	479	0	0.1	7.8	1159	742
11	Chinnathummakundu	40	65	585	5	0.23	440	537	671	12	3.2	8.1	3125	2000
12	Lakshmipuram	107	58	19	17	0.12	85	63	293	12	1.2	8.1	771	494
13	Kanmaipatti	168	98	284	36	0.13	283	724	427	12	2.8	8.1	2816	1802
14	Koppunayanpatti	48	42	112	80	0.15	255	114	305	24	0.4	8.3	1250	800
15	Vadhuvarpatti	259	132	120	6	0.17	440	441	480	12	2.5	8	2552	1633
16	Sethurajapuram	66	42	33	8	0.31	43	168	183	24	0.1	8.3	701	449
17	Pandalgudi	220	70	103	27	0.23	421	990	320	24	0.2	8.3	3106	1982
18	Koppuchittampatti	66	80	620	5	0.21	780	872	634	36	3.1	8.2	4270	2732
19	Maniyakkaranpatti	312	275	350	20	0.23	113	355	415	12	2.3	8.1	2545	1629
20	Surruppanayakanpatt	226	92	59	30	0.12	64	72	305	12	3	8	1083	693
21	Maravarperungudi	30	10	134	3	0.19	113	72	366	48	1.8	8.4	847	542
22	Pungamarathupatti	59	23	92	2	0.2	142	183	171	24	0.4	8.2	914	585
23	Mettlipatti	80	78	49	9	0.15	142	178	366	12	2.4	8	1203	770
24	Muthuswamipuram	38	15	135	110	0.24	28	39	244	24	0.1	8.1	758	485

Calcium and Magnesium

The analytical data of the study area show the Ca^{2+} and Mg^{2+} contents which varies from 22mg/l to 10mg/l and 354mg/l to 457mg/l respectively. The concentration of calcium in groundwater depends on the solubility of $CaCO_3$, SO_4^{-} and rarely Chloride (Biswajeet Pradhan and Saied Pirasteh, 2011). Magnesium is known to occur naturally through magnesium bearing minerals in the rocks (Gnana Chandra swamy et al., 2014). The spatial distribution of integrated Ca^{2+}-Mg^{2+} maps (Fig.2a) a indicate that Ramalingapuram, Ramaswamipuram, Koppuchittampatti, Ayankarisalkulam and Maniyakaranpatti wells show higher concentration (above 100ppm) of Ca^{2+} – Mg^{2+} level in the study area. Dissolution of calc-granulite, crystalline limestone and weathering of other calc-alkaline metamorphic rocks such as gneiss, charnockite, granite and black soil causes for Ca^{2+} – Mg^{2+} sources in the groundwater.

Sodium and Potassium : The analytical result of Na^+ and K^+ contents of the samples varies from 15mg/l to 2mg/l and 620mg/l to 110mg/l respectively. Sources of Na^+ are generally from halite, sea spray, hot spring, brine and some silicates or rare minerals such as (Nahcolite) (Kaliammal and Udayanapillai, 2016). But Na^+ and K^+ sources in the study area is due to from the weathering of Na^+ and K^+ rich feldspar, hornblende, aegirine-augite and clay minerals montmorillonite and Illite derived from the source rocks such as Hornblende-Biotite gneiss charnockite, granite and black soil. The spatial distribution integration map of Na^+ and K^+ (Fig.2b) illustrate Ayankarisalkulam, Ramalingapuram, Sorruppanayakanpatti, Muthuswamipuram, Maniyakaranpatti and Chinnathummakundu villages which show higher concentration $Na^+ – K^+$ content (> 50) level in the study area.

Bicarbonate, Sulphate and Chloride: The concentration HCO_3^-, SO_4^- and Cl^- contents in the samples varies from 98mg/l, 39mg/l and 28 mg/l to 671mg/l and 990mg/l to 808mg/l respectively. Sources of bicarbonate are obtained from the minerals calcite, dolomite and aragonite etc and the prime contributing rocks are crystalline limestone, calc granulite and calcrete. The dissolving Ca^{2+} and HCO_3^- ion from groundwater derived from the sources rocks of calc-alkaline igneous rocks form calcrete by evapotranspiration process (Udayanapillai et al., 2014). So, the occurrence of more calcrete deposit indicate the evidence that groundwater is generally more alkaline in nature.The sources of SO_4^- are generally obtained from the sulphur, sulphides, sulphates of heavy metals, gypsum, anhydrite and pyrite. Sulphate content in the study area is mainly obtained from rock sources. The higher Cl^- content in groundwater may be attributed by soluble chloride from rock, sea water ingress (Sridher et al., 2013) and black soil (Lakshmanan



et al., 2003). The Cl^- content in the study area is mainly obtained from rock sources and black soil. The integrated iso-quality geospatial maps of HCO_3^-, SO_4^- and Cl^- illustrate Ramalingapuram and Periyanayakipuram villages which show higher HCO_3^-, SO_4^- and Cl^- content (> 500) levels in the study area (Fig.2c).

Fig2 (a-c). The integrated distribution concentration map. a- Calcium and Magnesium.b- Sodium and Potassium.c- Chloride, Sulphate and Bicarbonate.

Back Facies Diagram

The quality of groundwater is evaluated by plotting cations and anions in the back facies diagram. It is a derived form of Piper's diagram. Back (1969) prepared two diamond shaped field diagrams. Each diamond field is plotted separately. One diamond shaped field consists of the percentage of epm values of cations $Na^+ + K^+$ and $Ca^{2+} + Mg^{2+}$. The another diamond shaped field diagram consists of anions HCO_3 and SO_4^2 + Cl-. Each anion and cation facies are sub dived into four parts. The cation facies diamond diagram consists of the following subdivision of facies; Calcium – Magnesium; Calcium – Sodium; Sodium – Calcium and Sodium – Potassium. The anion facies diamond diagram is subdivided into four facies as follows; Chloride – Sulphate; Chloride – Sulphate – Bicarbonate; Bicarbonate – Chloride – Sulphate and Bicarbonate. The data plots of the study area in the back facies diagram reveal that it falls on the cation facies such as; Calcium – Magnesium – 4%; Calcium – Sodium – 71% and Sodium – Calcium – 21% where as in the anion facies of Chloride – Sulphate – 21%, Chloride – Sulphate – Bicarbonate – 42% and Bicarbonate – Chloride – Sulphate – 29% and Bicarbonate – 8%.

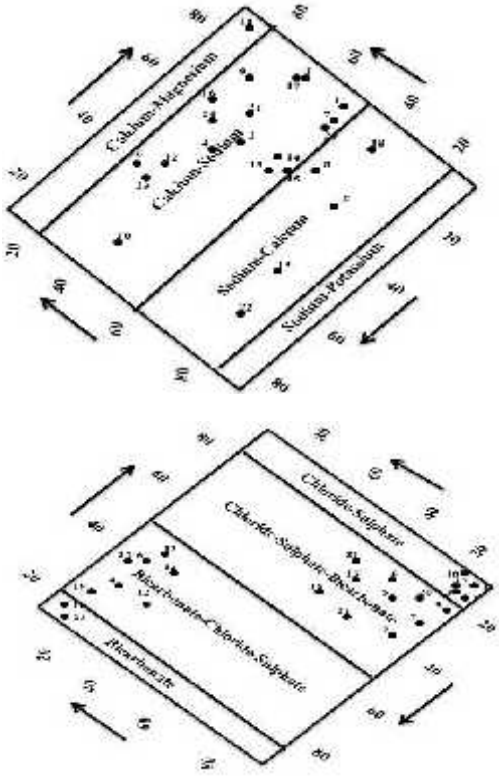


Figure 3. Back Facies Diagram.

Groundwater quality assessment

Many researches on the chemical quality of the study area is discussed related to the drinking water qualities standard (WHO, 2011; BIS, 2012) livestock standard (Ramakrishna 1998) and irrigation standard (USDA,1954 and Wilcox, 1995). Drinking water qualities of groundwater of the study area generally shows within permissible limit of BIS and WHO, except serial number (1, 3, 4, 5, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22 and 23) which show higher concentration than the permissible limit of WHO standard. Livestock use of water quality based on TDS (Ramakrishna 1998) is given as follows, Below 2500mg/l TDS – Fair; Below 3500 mg/L TDS – Poor; Above 4500 mg/L TDS – Not satisfactory, As per the above classification, 75% of the study area is having low TDS which shows more suitable for livestock uses.

Conclusion

The integrated spatial distribution maps indicate the higher and lower composition al area of water quality parameters.Back facies diagrams of the study area indicate that area has the predominance water quality characterization of calcium-sodium cations (71%) and chloride –sulphate-Bicarbonate facies (42 %).All water quality parameters of the study area is generally within the BIS and WHO and Ramakrishnan standard.

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