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Interpretation on Groundwater Hydro-Chemistry in West Coastal Locations of Kanyakumari District, India

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In the present investigation, groundwater sampling and characteristics were carried out by collecting 19 samples from 19 different stations (S1-S19) of west coastal locations in between Kanyakumari to Thengapatnam, during the period August 2012 to August 2013 to decipher the hydro-geochemistry, hydro-chemical parameters with facies by using Chadha's plot and the analytical data were interpreted according to published guide line. The results illustrate that there is a great correlation between electrical conductivity and total dissolved solids. pH was within the maximum limit as per ALFA *i.e.*, 7.6 to 8.7. Further, all the study locations revealed that the area up to a distance of 224-273 m was found to be brackish to saline in nature. Mainstream of the samples exist in less same way with minor exceptions irrespective of type of weather and are within the limit approved by WHO.

Keywords: Hydro-geochemistry, Chadha's plot, Electrical conductivity, Total dissolved solids.

INTRODUCTION

Groundwater quality plays imperatively in groundwater protection and water quality conservation; consequently it is one of the principal concerns to evaluate the groundwater quality for future consumption. Groundwater chemical behaviors in the west coastal locations of Tamilnadu are of the most dynamic fields for the researchers to strengthen the regional and national water quality database. A number of studies on groundwater quality have been assessed with respect to drinking and irrigation points[1,2]. Water is crucial to health and it influences in socio-economic development of human being. At this instant, water pollution has become crisis immensely which depletes the potable water availability since increasing population, agricultural advancement, urbanization and industrialization[3]. So, the bore wells have to be made atleast 200-500 m deep for good quality water[4] which is due to decrease in water table. This provokes diffusion and percolation of water from coasts and makes the ground water saline due to sea water intrusion[5]. Furthermore, a number of chemical contaminants cause adverse health effects in humans for this reason. There is always a need and concern over the protection and management of water quality, for future generation[6]. It is known that 1 % of the groundwater table is threatened directly/ indirectly by pollution[7].

At present, groundwater chemical behaviors of coastal locations in India are of the most dynamic fields for researchers to strengthen the regional and national water quality database[8-14]. In the present study, an attempt has been made to evaluate groundwater hydro-geochemistry, hydro-chemical parameters with facies by using Chadha's diagram, in the west coast of Tamilnadu for 19 stations of Kanyakumari district namely Kovalam (S1), Dwarakapathi (S2), Naraiyanvilai (S3), Kovilvilai (S4), Manakudi (S5), Ambalapathi (S6), Sothavilai (S7), Puthenthurai (S8), Kesavanputhanthurai (S9), Pozhikarai (S10), Rajakamangalam (S11), Ammandivilai (S12), Murugavilai (S13), Muttom (S14), Kadiapatinam (S15), Kootumangalam (S16), Manavalakurichi (S17), Mandaikadu (S18) and Colachel (S19) during the period of August 2012 - August 2013.

EXPERIMENTAL

Water samples were collected from dug and bore wells for 19 stations of Kanyakumari district from Kanyakumari to Thengapatnam. The sampling guidelines adopted were based on the standard methods[17] for transportation to hydro-chemical and microbial studies further, all necessary precautions were taken accordingly[18]. The temperatures of the samples were measured in the field itself at the time of sampling as per standard methods[19] (APHA, 1989). Collected groundwater samples were analyzed by both classical and automated instrumental methods prescribed by the standard methods[19] (APHA 1989) and the mean value of analytical data parameters among the 19 stations were compared and tabulated.

Study area: Kanyakumari district, Tamin-Nadu (India) (longitude: 77°15′-77°36′ E, latitude: 8°03′-8°35′ N) is located in the Southernmost tip of the peninsular India. The boundary on north-east is Tirunelveli; north-west is Thiruvananthapuram; south-eastern is Gulf of Mannar (Bay of Bengal); south and west is Indian Ocean and Arabian Sea, respectively. It covers an area of about 1,675 square Km and it is a thickly populated district of south Tamil Nadu in India. It is administratively divided into 4 Taluks, 9 Blocks and 88 Villages. Normally, annual rainfall over this district varies from about 826 to 1456 mm under the influence of both south-west and north-east monsoons. The sampling stations (S1-S19), each lies at 77°32' 5.7", 77°32' 18.4", 77°24' 39.9", 77°29' 45.3", 77°28' 38.5", 77°32'18.4", 77°32'18.4", 77°25'9.4", 77°32'18.4", 77°24'6.9", 77°21'50.5", 77°19' 5.1",77°32'18.4", 77°19'10.3", 77°18'28.9", 77°32'18.4", 77°18' 8.2", 77°28'38.5",77°15' 22". East longitude and 8°6'26.4", 8°5'17.9", 8°6'42.8", 8°5'36", 8°5'28", 8°5'17.9", 8°5'17.9", 8°6'12", 8°5'17.9", 8°6'26.4", 8°7'44.5", 8°5' 17.9", 8°8'37.1", 8°7' 34.7", 8°7'52.6", 8°5'17.9", 8°8'49.7", 8°5'28", 8°10'43". North latitude, respectively (Fig. 1).

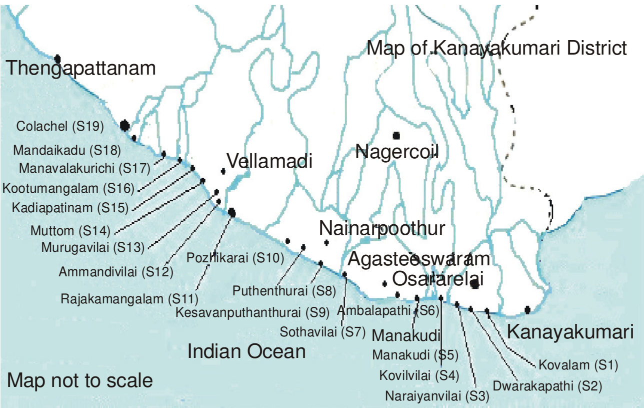

Fig. 1. Study area

Hydrogeology of study area: Hydrogeological provinces in India can be grouped into three main divisions; hard rock regions (nearly 65 % of India), alluvial regions of major river basins (mostly in the northern parts of India) and consolidated sedimentary formations (about 5 % of India). The soils of Kanyakumari district can be classified into (i) red soil, (ii) red lateritic soil, (iii) brown soil and (iv) coastal sand. The soils are mostly *in situ* in nature, lateritic, earthy and pale reddish in colour. They are derived from laterisation of gneisses are mostly brownish. The thickness of soils in the mounts is almost negligible whereas in the valleys it is around 2 m. Generally, the soils are acidic in nature due to massive rain fall and heavy leaching of basic rocks in hilly rocks. The coastal alluvium sand occurs in the western side of the district and is of high fertility. The district is part of the composite east flowing river basin between Pazhayar and Tamirabarani as per the irrigation Atlas of India. Valliyar, Pazhayar, Tamirabarani and Aralvaimozhi are the important sub-basins/watersheds.

At Present, the occurrence of groundwater is limited in Kanyakumari district, below the ground level are of 23-42 and 1842 m with respect to only of weathered mantle and weathered thickness range which is discontinuous both in space and depth, respectively[15]. In alluvial formation, the weathered thickness is of highly permeable, very shallow and porous, the groundwater occurs under water table conditions and so the recharging of water is influenced by the intensity of weathering. Rising and receding fluctuations for overall groundwater is observed during the months from October to December and from February to September. It is seen that a slight raising in the month of July, it is due to southwestern monsoon rain nevertheless; generally a decrease in water level is observed for the ten years[16].

RESULTS AND DISCUSSION

A total of 19 groundwater samples from 19 different stations (S1-S19) of Kanyakumari district were collected during the period, August 2012 to August 2013 in every month and the results were compared with the World Health Organization[20] (Table-1).

The water is alkaline with the pH ranging from 7.6 to 8.7. The seasonal variation shows the pH values fluctuating minimum in monsoon and maximum in post monsoon overall the stations. The electrical conductivity at 25 °C are higher than the permissible limit which varies between 110 to 945.3 µS/cm due to certain geochemical process *viz*., the ionic exchange, reverse exchange, evaporation, silicate weathering, rock water interaction, sulphate reduction and oxidation anthropogenic activities[21], it is used to indicate the total ionized constituents of water as it is directly related to sum of the cations and anions. The seasonal average conductivity shows maximum value in monsoon and minimum in post monsoon. The salinity concentration ranges from 67 to 2009 mg/L (Table-1), the wells which located at the fringe of coastal region showed very high salinity (S1, S5, S7, S11, S14, S18 and S19), overall there is a medium high salinity which is described by EC (750-2250 µS/cm).

Total dissolved solids (TDS) is in the range of 400-604.96 mg/L, it confirms that the ground water from S2-S4, S12, S13 and S16 only falls in fresh water category which is prescribed for drinking and irrigation pupose while others are brackish. The higher range during monsoon maybe due to leaching of surrounding rain water. The declivity of DO can be attributed to the intrusion of effluents containing oxidisable organic matter, biodegradative and decayed matter.

Total hardness of the study area varies between 170.98 to 777.3 mg/L reveals carbonate hardness[22,23] for the study area except S2, S3 and S16 and wells located near to the coastal area showed higher hardness. The higher value maybe due to abundant availability of limestone rocks in the surrounding area consequently more solubility of salts under anaerobic conditions[24]. Long-term uses of water with high hardness lead to certain health problems are urolithiasis, anencephaly, prenatal mortality, some type of cancer and cardiovascular disorders[25].

Comparatively less plenty of the carbonate ions in the study areas specify that the major source of Ca and Mg is silicate weathering. The concentrations of calcium and magnesium ion are responsible for the total hardness and ranges between 24 to 157 mg/L 41.6 to 187.9 mg/L, respectively. The maximum desirable limit in drinking water is 75 mg/L and the maximum permissible limit is 200 mg/L. While for magnesium, it is 30 to 150 mg/L (Fig. 2). Due to silicate weathering, at station S15, the concentration of Mg^{2+} observed is high in the month of Sept 2012 and Sept 2013 which ranges from 151 to 199 mg/L. Calcium is essential for human and the low content in drinking water causes rickets and defective teeth. In addition, it is essential for nervous system, cardiac function and coagulation of blood. Chemical softening, reverse osmosis, electro dialysis or ion exchange reduces the magnesium and associated hardness to acceptable levels.

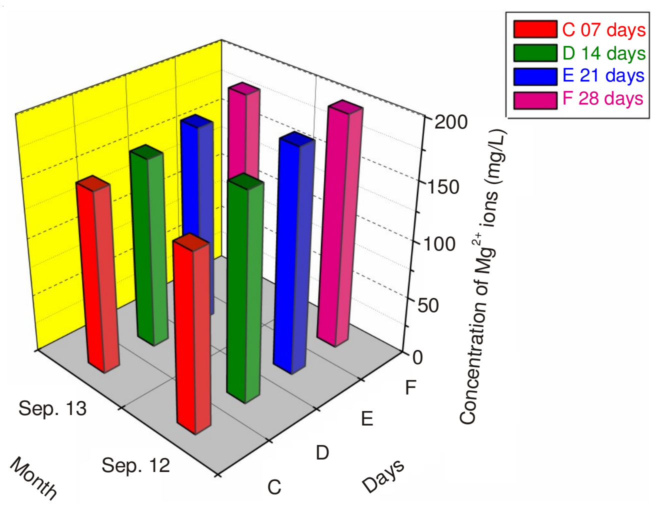

Fig. 2. Concentration of magnesium ion of water sample S15 in the period of september 2012 to september 2013

The concentrations of sodium ions is largely controlled by the saline intrusions, evaporates and silicate minerals and are exceeding the permissible limit (142.2 to 198.98 mg/L) which may lead to hypertension, congenial heart disease and kidney problems[26]. Concentration of sodium ions are shown in Table-2. The potassium is crossing the permissible limit (6.57 to 12.89) which is due to mixing of silicate mineral from the igneous and metamorphic rock layers. Sodium and potassium ions in this study area are derived from silicate weathering of the hard rocks. The lower concentration of sodium than calcium shows the effect of cation exchange between these two. The seasonal average of sodium and potassium ions show maximum in monsoon and minimum in post monsoon in most of the locations. The limit for domestic purpose, concentration of chloride ion does not exceed 250 mg/L, the major sources are igneous rocks, high concentration of Cl^- ions produce hypertension, effect of metabolic activity and increase in conductivity of water[27].

Chlorides in excess make the water salty[28]. The seasonal average shows maximum in monsoon and minimum in post monsoon in most of the locations. The other anions, sulphate, phosphate, nitrite, nitrate and bicarbonate ions exceed the recommended limit. The higher concentration of sulphate may cause respiratory problems[29], catharsis, dehydration and gastrointestinal irritation. It may also contribute to the corrosion of distribution systems. The concentration of nitrite ion is normally low but can reach high levels as a result of leaching/runoff from agricultural land and contamination from living beings as a consequence of ammonia and similar sources. Moreover, anaerobic conditions may result in the formation and persistence of nitrite.

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TABLE-1
MEAN VALUE AND STANDARD DEVIATION OF THE HYDRO-CHEMICAL PARAMETERS FOR THE STUDY AREA (S1-S19)

Parameters	Units	WHO (1997) values	Sampling Stations (S1–S19)				(%)
			Min	Max	Mean	Standard deviation	
pH	—	7.0—9.20	7.6	8.7	8.15	0.55	—
EC	μS/cm	500—1500	110	945.26	527.63	417.63	—
TDS	mg/L	500—2000	400.4	604.96	502.68	102.28	5.1
DO	mg/L	—	6.67	7.34	7.005	0.335	0.07
TH	mg/L	100—500	170.98	777.3	474.14	303.16	4.74
Cl^-	mg/L	250—600	101.23	200.6	150.915	49.685	1.51
HCO_3^-	mg/L	300—600	36	696	366	330	3.66
SO_4^{2-}	mg/L	200—600	0.9	74	37.45	36.55	0. 37
Na^+	mg/L	50—200	142.2	198.98	170.43	28.39	1.7
K^+	mg/L	10—12	6.57	12.89	9.62	3.16	0. 96
Ca^{2+}	mg/L	75—200	24	157	90.5	66.5	0. 905
Mg^{2+}	mg/L	30—150	41.6	187.9	114.75	73.15	1.14
PO_4^{2-}	mg/L	0.1	0.094	0.129	0.108	0.0178	0.001
NO_3^-	mg/L	45	2.19	5.24	3.68	0.44	0.037
NO_2^-	mg/L	0.001	0.006	0.013	0.0065	0.0046	0.00006

haemoglobin to methhemoglobin which is unable to transport oxygen to the tissues (blue baby disease), causes cyanosis and causes asphyxia at higher concentrations[30].

The phosphate concentration increases towards the coastal region which is due to saline water intrusion. The higher concentration of phosphate might be due to use of detergents for washing clothes and utensil activities by the villagers around the dug wells. The major origin is the sewage system. The maximum seasonal value in monsoon is observed for sulphate and phosphate ions. The bicarbonate concentration exceeds the permissible limit for the samples S1, S5, S11, S17 and S19 and is not harmful to humans. It is the dominant ion with the average concentration of 366 mg/L.

Hydrogeochemical evaluation: The hydro-chemical processes suggested by Chadha[31] are indicated in each of the four quadrants of the graph. These are broadly summarized as: field-5 (recharging water): when water enters in to the ground from the surface it carries dissolved carbonates in the form of HCO_3^- and the geochemically mobile Ca. Field-6 (reverse ion-exchange): waters are less easily defined and less common, but represent groundwater where Ca^{2+} + Mg^{2+} is in excess to Na^+ + K^+ either due to the preferential release of Ca^{2+} and Mg^{2+} from mineral weathering of exposed bed rock or possibly reverse base cation-exchange reactions of Ca^{2+} + Mg^{2+} into solution and subsequent adsorption of Na^+ on mineral surfaces. Field 7 (Na^+- Cl^-): waters are typical sea water mixing and are mostly constrained to the coastal areas. Field 8 (Na^+-HCO_3^-): waters possibly represent base exchange reactions or an evolutionary path of groundwater from Ca-HCO_3 type fresh water to Na-Cl mixed sea water, where Na^+-HCO_3^- is produced by ion exchange processes. The resultant diagram is exhibited in (Fig. 5). In this presentation, the cationic and anionic concentrations of all the analysed samples (S1, S5, S7, S9, S11, S14, S15 and S17-S19) are confined to 5, 6, 7 and 8 fields respectively. The majority of the samples (42 %) are plotted in the seventh field, representing (Na^+-Cl^-) type of water. Field 5 represents the Ca-HCO_3 type, percentage of

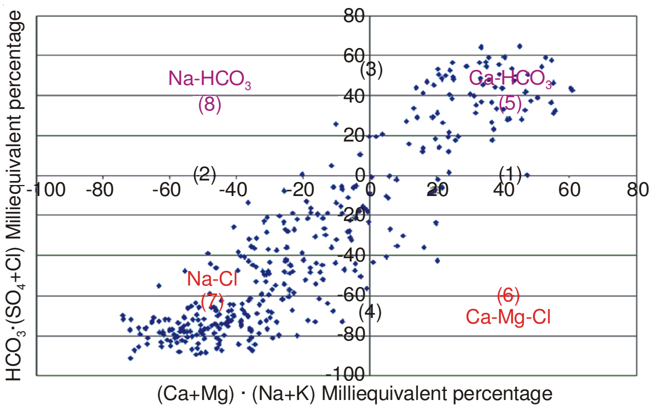

Fig. 5. Chadha's plot of water samples (S1 to S19) during the period of July 2012 to July 2013

TABLE-2
CONCENTRATION OF SALINITY (mg/L) DURING JULY2012 TO JULY 2013

Period	S-1	S-5	S-7	S-9	S-11	S-14	S-15	S-17	S-18	S-19
July 2012	1062	1309	2003	1199	1239	1395	1458	1152	1705	1700
August 2012	1056	1315	2002	1195	1238	1392	1434	1151	1679	1692
September 2012	1069	1334	2006	1195	1236	1388	1446	1150	1678	1678
October 2012	1107	1405	2009	1247	1252	1404	1504	1153	1711	1731
November 2012	1114	1411	2006	1276	1259	1403	1581	1161	1748	1776
December 2012	1114	1427	2007	1297	1267	1403	1608	1164	1792	1819
Period	S-1	S-5	S-7	S-9	S-11	S-14	S-15	S-17	S-18	S-19
January 2013	1087	1397	2009	1264	1257	1404	1556	1160	1783	1799
February 2013	1071	1352	2007	1227	1250	1402	1495	1155	1756	1764
March 2013	1060	1317	2007	1190	1242	1400	1486	1154	1724	1725
April 2013	1057	1314	2022	1201	1240	1405	1533	1154	1710	1704
May 2013	1055	1312	2008	1198	1241	1404	1458	1153	1703	1705
June 2013	1057	1301	2000	1203	1240	1402	1461	1154	1710	1707

TABLE 3
CONCENTRATION OF SODIUM (mg/L) PRESENT IN THE GROUND WATER DURING JAN 2012 TO JAN 2013

Period	S1	S5	S7	S9	S11	S14	S15	S17	S18	S19
July 2012	175	172	173	177	176	156	175	171	172	170
August 2012	175	165	158	149	191	161	168	179	190	166
September 2012	1740	155	148	151	181	191	148	156	185	194
October 2012	147	146.5	144.8	144.9	142.1	151.4	144.7	144.4	142.7	151.3
November 2012	143	142.5	141.8	149.4	143.1	146.0	143	142.5	141.8	149.4
December 2012	150.4	141.9	151.2	149.8	144.5	145.5	151.4	144.1	143.2	147.8
Period	S1	S5	S7	S9	S11	S14	S15	S17	S18	S19
January 2013	150.9	142.4	161.7	151.2	145.0	146.0	152.9	143.4	162.7	141.9
February 2013	147	142	143	145	144	145	143	144	143	146
March 2013	146.8	147.2	147.1	146.4	147.4	147.7	145	144	147	142
April 2013	147	142	143	145	144	145	143	144	143	146
May 2013	146.8	147.2	147.1	146.4	147.4	147.7	145	144	147	142
June 2013	147.1	142.3	143.2	145.1	144.3	145.1	143.2	144	143	146
July 2013	146.1	147.1	147.6	146.1	147.4	147.5	145.3	144.2	147.5	142.3

samples in this field falls is of 17 %. Field 5 represents the Ca-HCO_3 type, percentage of samples in this field falls is of 17 %.

Evaluation of water types using piper plots suggests that there is a clear indication of the contribution from silicate weathering. Though a slight variation was observed in both water facies which was shifted to Ca-Mg-Cl in Chadha's plot. The dominance of Mg^{2+} and Ca^{2+} ions in suggested there is an inverse ion exchange process during which Ca^{2+} from the Aquifer matrix will be exchanged by Na^+ from the groundwater. The dominance of Na^+ and Cl^- ions suggests that there is a sluggish flow which enables the occurrences of sufficient rock-water.

Conclusion

Results of the hydrochemistry suggest that the water samples of 77 % (S1, S5, S7, S9, S11, S14, S15 and S17-S19) are alkaline in nature. It is suggested that the major process to control water quality is the silicate weathering, cationic exchange, mineral dissolution and inverse cationic exchange process which is more observed in station S15. Groundwater types were assessed by Chadha's plot and the dominating water facie is Na-Mg-Ca-Cl-HCO3. 32 % of the samples (S2-S4, S12, S13 and S16) are within the permissible limits which are suitable for drinking and irrigation purpose. Others are unfit, because the interaction of ground water with sewage, sea water intrusion and agricultural activities. All the study locations revealed that the area up to a distance of 224-273 m was found to be brackish to saline in nature. Mainstream of the samples exist in less same way with minor exceptions irrespective of type of weather and are within the limit approved by WHO.

REFERENCES

1. N. Subba Rao and D. John Devadas, *J. Appl. Geochem.*, **7**, 9 (2005).
2. A.M. Piper, *Trans. Am. Geophys. Union*, **25**, 914 (1944).
3. D. Ray, R. Ravindar Rao, A.V. Bhoi, A.K. Biswas, A.K. Ganguly and P.B. Sanyal, *Environ. Monit. Assess.*, **61**, 387 (2000).
4. L. Giridharan, T. Venugopal and M. Jayaprakash, *Arch. Environ. Contam. Toxicol.*, **56**, 654 (2009).
5. A. Abdollahi-Nasab, M.C. Boufadel, H. Li and J.W. Weaver, *J. Hydrol.*, **386**, 1 (2010).
6. P.R. Patil, S.R. Badgujar and A.M. Warke, *Oriental J. Chem.*, **17**, 283 (2001).
7. M.L. Davis and D.A. Cornwell, Introduction to Environmental Engineering, McGraw Hill, edn. 3, PWS, Publishers, New York, p. 93 (1991).
8. S. Bhagavathi Perumal and P. Thamarai, *Int. J. Appl. Environ. Sci.*, **3**, 37 (2008).
9. S. Bhagavathi Perumal and P. Thamarai, *Int. J. Appl. Environ. Sci.*, **3**, 139 (2008).
10. C. Palpandi, *Int. J. Biodiv. Conserv.*, **3**, 121 (2011).
11. R.K. Ranjan, J. Routh and A.L. Ramanathan, *Appl. Geochem.*, **25**, 1176 (2010).
12. P. Swarna Latha and K. Nageswara Rao, *J. Environ. Earth Sci.*, **66**, 2143 (2012).
13. S.V. Sarath Prasanth, N.S. Magesh, K.V. Jitheshlal, N. Chandrasekar and K. Gangadhar, *Appl. Water Sci.*, **2**, 165 (2012).
14. Y. Srinivas, D.H. Oliver, A.S. Raj and N. Chandrasekar, *Appl. Water Sci.*, **3**, 631 (2013).
15. CGWB, Technical Report, Central Ground Water Board (2008).
16. PWD, Groundwater Perspectives: A Profile of Kanyakumari District, Tamil Nadu, Tamil Nadu Public Works Department, India (2005).
17. A.D. Eaton, L.S. Clescri, E.W. Rice, A.E. Greenberg and M.A.H. Franson, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association, Water Environment Federation, USA, edn 21 (2005).
18. E. Brown, M.W. Skougsted and M.J. Fishman, Methods for Collection and Analysis of Water Sample for Dissolved Minerals and Gases, US Department of Interior, Book No. 5 (1974).
19. APHA, Standard Methods for the Examination of Water and Waste Water, American Public Health Association, Washington, DC, edn. 19 (1989).
20. WHO, Guidelines for Drinking-Water Quality,World Health Organization, Geneva, Switzerland, edn. 2, 3 and 4 (1993, 2004, 2011).
21. R. Ramesh, K. Shiv Kumar, S. Eswaramoorthi and G.R. Purvaja, *Environ. Geol.*, **25**, 126 (1995).
22. D.K. Todd, Groundwater Hydrology, John Wiley & Sons, New York, p. 535 (1980).
23. C.H. Sawyer, Chemistry for Sanitary Engineers, McGraw-Hill Book Co., Inc., New York (1960).
24. P.N. Palanisamy, A. Geetha, M. Sujatha, P. Sivakumar and K. Karunakaran, *E-J. Chem.*, **4**, 434 (2007).
25. V.S. Durvey, L.L. Sharma, V.P. Sainim and B.K. Sharma, Handbook on the Methodology of Water Quality Assessment Rajasthan, Agriculture University, India (1991).
26. N. Janardhana Raju, U.K. Shukla and P. Ram, *Environ. Monit. Assess.*, **173**, 279 (2011).
27. K.V. Paliwal, *Ann. Arid Zone*, **10**, 266 (1971).
28. H. Manjunatha, H.B. Arvinda and E.T. Puttaih, *Indian J. Environ. Prot.*, **31**, 511 (2011).
29. T.C. Maiti, *Sci. Report*, **9**, 360 (1982).
30. S.C. Gupta, *Curr. Agric.*, **24**, 37 (2000).
31. D.K. Chadha, *Hydrogeol. J.*, **7**, 431 (1999).