Integrated Study on Groundwater Quality for Drinking and Irrigation Utilities in Tirupur Taluk, Tamil Nadu, India

S.Pichaiah, G.R. Senthil kumar, K.Srinivasamoorthy

Abstract— **An attempt has been made to assess the quality of groundwater in Tirupur Taluk of Tirupur District, Tamil Nadu, India for drinking and irrigation purposes. In the study area forty five groundwater samples have been collected from bore wells and dug wells. The groundwater samples were chemically analyzed by standard procedure. From the analytical results pH, EC, TDS, TH, CaCO3, Ca2+,Mg2+,Na+, K+, Cl−, CO32−, HCO3− and SO42− were determined. The obtained groundwater quality parameters were compared with Bureau of Indian Standards (BIS), 1991. The Ca2+ and Cl− ion concentration are within the permissible limits, whereas TDS, Na++, Mg++, SO42− and TH exceed the limit of BIS. A SAR values reveal that majority of the groundwater samples falls in excellent (S1) and good (S2) categories. USSL, diagram illustrates that the groundwater samples fall in the field of C3S1, C2S1, C3S2, C4S2, C4S3 and C3S3 indicating medium to high salinity and low to high alkalinity hazard. The Soluble sodium percent (SSP) exhibits majority of the samples are within the maximum allowable limit. Based on RSC values, almost fifty percentage of samples fall as safe and doughtful categories. Anthropogenic pollutants and the nature of geological formations can be the factors for exceeding the permissible limits in certain locations of the study area. From the overall groundwater quality studies majority of the groundwater sample locations are fit for domestic and irrigation purposes.**

Index Terms— **Tirupur Taluk, physico chemical parameters, water quality standard, anthropogenic pollutants.**

I. INTRODUCTION

Water is the bloodstream of the biosphere (Falkenmark and Rockstrom, 2004). It is an economic asset and also a critical environmental factor. Groundwater is a vital source of clean drinking and irrigation water. This is increasingly the case due to the effects of population growth and climate change, which are causing severe stress to surface water supplies in these areas (Edmunds, 2003; Shanmugam and Ambujam, 2011). Due to these reasons and increasing in different utilities of water consumption the groundwater condition in Tamil Nadu State has fallen to alarming stage. Modern industries, urban development and population growth are the main reasons for gradual deterioration in water quality in the study area. WHO (1996) has reported that about 80% of diseases in world population are due to consumption of polluted water. This condition is more worsened in the present study area. The study area Tirupur Taluk consists of hard rocks and cotton hosiery units. At present, around 9000 knitting, processing, manufacturing and other textile units are running in Tirupur Town. Due to a large quantity of water utilized for bleaching and dyeing purposes, groundwater scarcity increased vigorously. Most of the water used by hosiery units are discharged its effluents containing a variety of dyes and chemicals (acids, salts, wetting agents, soaps, oil, etc.) (UNIDO, 2004; Blomqvist, 1996). Unused fertilizers, pesticides, effluents discharged from industries and sewage water are the main contaminants of the groundwater (Venugopal and Giridharan, 2009). Hence it is essential to understand the complex hydrogeochemical process and evaluate relationship between litho units, space and time along with quality aspects. The chemical composition of groundwater is controlled by several factors that include composition of precipitation, anthropogenic activities, geological structure and mineralogy of the watershed and aquifers and geological processes within the aquifer medium (Andre et al. 2005). The industrial, domestic effluents and leaching of solid waste dump result in groundwater contamination, which is quite often an irreversible process. These geochemical processes are responsible for the spatio temporal variations in groundwater chemistry (Matthess, 1982; Kumar et al. 2006). Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interaction (Domenico, 1972; Schuh et al. 1997; Toth, 1984; Singh Kuldip et al. 2011). To gain a quantitative understanding on weathering process, to decipher types and rates of interaction of surfacial earth parameters such as bed rock geology, geochemistry, geomorphology, soil characters, hydrogeology, climate and aquifer parameters are essential to note the change in chemistry of groundwater. These data are fed to compute and generate maps, graphs and tables on individual and combined themes on systematic basis. Those patterns could be recognized and used for future groundwater targeting programme. The geochemical study indicates that the quality of water is suitable for drinking and irrigation uses.

Manuscript received April 23, 2015

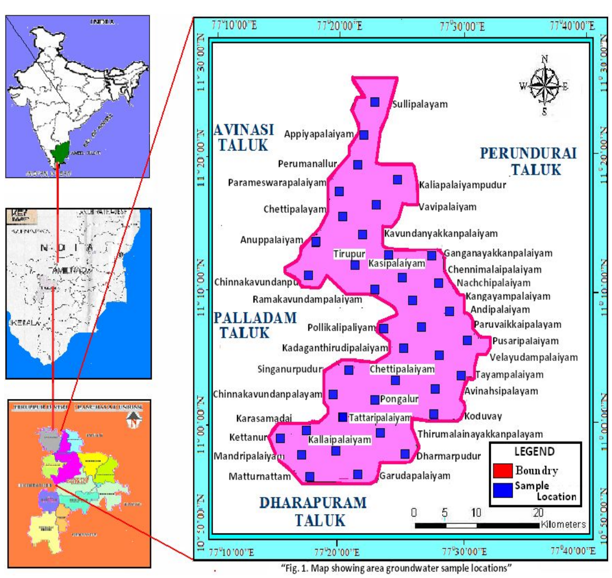
Pichaiah. S, Department of Earth Sciences, Annamalai University, Chidambaram, India
Senthil Kumar. G.R, Department of Earth Sciences, Annamalai University, Chidambaram, India
Srinivasamoorthy. K, Department of Earth Sciences, Pondicherry University, Pondicherry, India

II. GEOLOGICAL SETTING

The area is underlain and surrounded mainly by a wide range of Archaen group composed of high-grade metamorphic rocks of peninsular gneissic complex, extensively weathered and overlain by recent valley fills and alluvium at places. The most common rock types of the area are hornblende biotite gneisses and with alluvial rocks, few quartz veins and limestone deposit. The study area comprises of fissile hornblende biotite gneiss and hornblende biotite gneiss. It occupies in northern and southern parts. The charnockite are mostly occupies in the central and southern part of the study area. It shows weakly developed gneissic structure and has been referred to as charnockitic gneiss. The granite intrusives are in the form of veins, they show concordant relationship with the country rocks. Calc granulite and limestone occurred at the southern part of the study area. Anorthosite and amphibole are seen in some parts of study area. Tirupur is situated on a plateau in a part of the Precambrian shield area called Indian Peninsular complex which has a wide range of metamorphic rocks usually referred to as hard or crystalline rocks characteristics. These rocks are very similar from a hydrological point of view. They have a very low hydraulic conductivity and have no primary porosity and incapable of storing and transporting water. However, a secondary porosity permits flow and storage of substantial amounts of groundwater, this porosity is the result of weathering and fracturing (Larsson, 1984). Soils are moderately very deep red and deep red, deep black, moderately deep black and moderately shallow black soil having different depth and profiles.

III. MATERIALS AND METHODS

To assess the groundwater quality, forty five groundwater samples were collected systematically in the study area. The groundwater locations were selected to cover the entire study area and attention was been given to the area where contamination is expected. Sampling was carried out using pre-cleaned polyethylene containers, the groundwater samples were collected during the pre-monsoon period of July 2013. The water samples collected in the field were analyzed for electrical conductivity (EC), pH, total dissolved solids (TDS), major cations like calcium, magnesium, sodium, potassium and anions like bicarbonate, carbonate, chloride, nitrate and sulphate. The water samples were analyzed in the laboratory using the standard procedures of American Public Health Association (APHA, 1995).



"Fig. 1. Map showing area groundwater sample locations"

IV. RESULTS AND DISCUSSION

A. Geochemistry of Groundwater and its Suitability for Drinking Perpose

Groundwater quality assessment been carried out to determine its suitability in terms of drinking and irrigation purposes, the hydrochemical analysis result of groundwater samples is shown in Table I. The study area groundwater quality parameters were compared with the standard guideline values recommended by the BIS (1991) for drinking and public health purposes is shown in Table II.

pH is defined as the negative logarithm of Hydrogen ion. It is an indication of groundwater quality and geochemical equilibrium for solubility concentration (Hem, 1985). It is a quantitative expression for acidity or alkalinity of water. The pH value of groundwater ranged from 7.2 to 8.6 with an average value of 7.9. The sample No. 3, 6, 8, 10, 14 & 31 are exceeding the maximum allowable limit and majority of samples are indicating alkaline nature of the groundwater. The natural waters hold mineral salts in solution. The specific electrical conductivity is a sum parameter which approximately describes the salt concentration in the water. It has an ability to conduct electric current in an object which depends upon the presence of various ionic species in the water. Electrical Conductivity (EC) varies from 420 to 3970 µs/cm with an average value 2195 µs/cm. TDS, represents the sum of concentrations of all dissolved constituents in a water sample. The TDS concentration of groundwater is main factor which determines water suitability for any purpose. The suitability of groundwater for any purpose is ascertained by classifying the groundwater depending upon its hydrochemical properties based on TDS values (Freeze and Cherry 1979). The TDS values ranges from 249 to 2455 mg/l with an average value of 1352 mg/l, the sample No. 1, 10, 17, 26, 35 & 38 are exceeding maximum permissible limit prescribed by the BIS, (1991). Calcium is abundant in the earth's crust and extremely mobile in the hydrosphere; it is also one of the most common ions in subsurface water. The calcium concentration ranges from 8 to 160 mg/l with a mean value of 84 mg/l. The value of calcium of the groundwater samples is within the maximum allowable limit as per the standard prescribed by BIS (1991). The hydrochemistry of magnesium is quite similar to that of calcium which the magnesium is washed from rocks and later ends up in water. It also ends up in the environment from fertilizer application and from cattle feed. The value of magnesium ranges from 4 to 208 mg/l. The samples 10, 14,

Table I. Ground Water Chemistry for Tirupur Taluk during July 2013

S.No	Village	Ca	Mg	Na	K	Cl	HCO3	SO4	NO3	CO3	F	pH	EC	TDS	TH
1	Sullipalayam	72	68.04	299	336	496	463.6	69	98	0	0.99	8.2	3010	2006	460
2	Appiyapalaiyam	8	34.02	74	25	82	178.27	24	7	1.68	0.66	8	690	388	160
3	Perumanallur	12	60.75	196	27	305	244	96	2	18	0.57	8.6	1480	846	280
4	Chettipalayam	136	92.34	74	137	390	305	72	50	0	1.58	8.2	2070	1277	720
5	Parameswarapalaiyam	16	21.87	37	18	32	156.96	10	5	2.94	0.6	8.3	450	257	130
6	Vavipalaiyam	12	31.59	92	14	28	211.87	14	9	7.93	1.59	8.6	710	407	160
7	Anuppalaiyam	54	40.10	150	31	191	115.9	154	35	12	0.63	8.5	1320	845	300
8	Kavundanyakkan palaiyam	26	49.82	97	15	174	146.4	38	25	0	1.47	8.6	1000	585	270
9	Kasipalaiyam	100	97.2	124	26	284	183	100	87	0	1.54	8.2	1830	1207	650
10	Kaliapalaiyam pudur	88	131.22	529	29	964	109.8	312	17	48	1.6	8.8	3640	2230	760
11	Chinnakavundanpur	26	42.53	78	111	71	244	149	17	24	1.36	8.3	990	701	240
12	Tirupur	34	18.23	196	39	181	305	86	7	18	1.82	8.5	1260	755	160
13	Chennimalaipalaiyam	116	72.9	184	15	269	305	211	48	0	1.22	7.2	1850	1232	590
14	Ganganayakkanpalaiyam	52	102.06	322	22	284	250.1	307	93	24	1.32	8.6	2480	1651	550
15	Kangayampalaiyam	34	46.17	69	27	85	276.66	42	4	3.27	0.86	8.1	880	491	275
16	Nachchipalaiyam	10	10.94	285	8	82	488	92	7	42	1.55	8	1350	805	70
17	Ramakavundampalaiyam	64	111.78	483	29	794	115.9	260	51	24	1.56	8.3	3360	2050	620
18	Pollikalipaliyam	84	70.47	267	22	248	262.3	239	84	0	1.04	8.1	2120	1434	500
19	Paruvaikkaipalayam	10	57.11	267	38	184	244	288	35	0	0.36	7.9	1700	1121	260
20	Andipalaiyam	28	69.26	64	133	110	488	53	4	30	1.47	8.5	1260	747	355
21	Karungulipalaiyam	84	31.59	216	30	149	732	10	9	0	1.5	7.8	1630	927	340
22	Kadaganthirudipalaiyam	60	80.19	129	34	177	390.4	109	25	18	0.92	8.4	1490	912	480
23	Kattupalaiyam	44	70.47	161	32	184	335.5	96	27	42	1.12	8.5	1430	916	400
24	Velayudampalaiyam	60	80.19	368	36	418	305	146	88	24	1.31	8.3	2550	1676	480
25	Pusaripalaiyam	28	43.74	64	31	71	247.62	48	11	2.33	1.4	8	820	486	250
26	Tayampalaiyam	64	208.98	474	24	801	341.6	323	80	36	1.05	8.5	3970	2455	1020
27	Avinahsi palayam south	18	27.945	104	16	78	227.81	14	14	2.14	1.06	8	780	461	160
28	Chettipalaiyam	160	80.19	90	41	362	97.6	336	3	12	0.17	8.4	1930	1145	730
29	Chellapalaiyam	36	75.33	152	34	213	176.9	94	61	0	0.56	8.1	1450	963	400
30	Koduvay	48	32.81	184	11	181	170.8	120	38	0	1.49	8.1	1300	830	255
31	Singanurpudur	96	72.9	207	12	482	73.2	192	15	24	1.07	8.6	2010	1191	540
32	Pongalur	34	19.44	104	16	74	183.59	67	14	1.37	0.85	7.9	820	489	165
33	Katturpudur	76	109.35	202	94	454	152.5	194	57	24	0.71	8.4	2190	1481	640
34	Chinnakavundanpalayam	44	3.65	41	8	25	165.96	10	3	3.92	1.95	8.4	420	249	125
35	Tattaripalaiyam	96	102.06	313	160	496	237.9	268	103	0	0.92	8.2	3010	2010	660
36	Thirumalainayakkanpalayam	50	29.16	92	29	131	164.7	124	14	0	1.21	7.6	980	599	245
37	Dharmarpudur	30	29.16	138	16	202	140.3	36	6	36	0.82	8.5	1010	584	195
38	Puttarichchal	136	77.76	368	184	411	170.8	672	60	24	0.31	8.4	3300	2223	660
39	Kallaipalaiyam	92	60.75	294	141	362	323.3	261	79	0	1.27	8.2	2480	1723	480
40	Karasamadai	50	51.03	152	29	106	494.1	141	3	0	1.46	8.2	1370	791	335
41	Kettanur	56	14.58	87	119	78	347.7	96	14	0	1.25	8	1100	685	200
42	Mandripalaiyam	48	48.6	64	37	117	244	48	28	0	1.48	7.5	980	609	320
43	Kottapalaiyam	120	136.08	92	37	376	115.9	194	90	24	1.38	8.3	2230	1437	860
44	Matturnattam	52	75.33	221	38	248	286.7	97	65	30	1.44	8.5	1820	1193	440
45	Garudapalaiyam	160	99.63	184	33	383	170.8	379	59	0	0.8	7.6	2370	1585	810

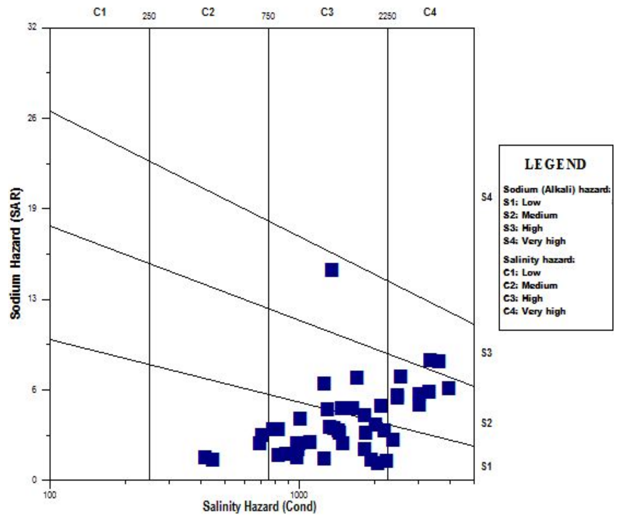
17, 26, 33, 35 & 43 are exceeding the maximum permissible limit. Calcium, magnesium, and carbonate are the major components of hardness, which is the amount of dissolved minerals in water. Total hardness is measured as a key point of drinking water. The hardness values ranged from 70 to 1020 mg/l with an average value of 415.6 mg/l. Samples locations: 4, 9, 10, 17, 26, 28, 33, 35, 38, 43 & 45 are exceeding the maximum permissible limit prescribed by the BIS (1991). The chloride concentration is an indicator in water quality monitoring which present in natural waters and can be attributed to dissolution of salts. Cl^{-} and HCO_{3-} are within the maximum allowable limits for drinking standards but the SO_{4-} exceeds the allowable limit in the location No.38. Though the Cl^{-} and HCO_{3-} concentration in the groundwater exceed the desirable limit of standards, the values are within the allowable limits prescribed by the BIS (1991). The primary source of most sodium in natural water is from the release of soluble products during the weathering of plagioclase feldspars. Sodium content in study area has shown variation from 37 to 529 mg/l with an average value of 283 m/l. Samples 10, 14, 16, 17, 18, 19, 21, 24, 26, 31, 33, 35, 38, 39 & 44 are crossing the maximum permissible limit prescribed by BIS (1991). The major source of potassium in groundwater consist of rain water, weathering of potash silicate minerals, use of surface water for irrigation and forever anomaly may be due to urban pollution and fertilizer leaching. Potassium values in groundwater of the study area ranged from 8 to 336 mg/l, with an average value of 52.1 mg/l.

B. Irrigation water quality

In the study area, the main source of irrigation depends on groundwater. So the quality of water is greater significance through the expanding demands on industries and agriculture and increase in standard of living. So the satisfactory quantity of water is very important for the accurate growth of plants but the water quality used for irrigation purpose should be within the permissible limit or else it could harmfully affect the plant growth. Permanent use of poor quality water and the lacking of drainage and soil management may lead to saline and sodic soil, especially in clayey soils. The quality of water used for irrigation plays a vital role in productivity of crops, yield and quality. So the water quality for irrigation depends on the occurrence of dissolved salts and their concentrations. The most important quality criteria, which influence the water quality and its suitability for irrigation is based on the sodium absorption ratio (SAR) and residual sodium carbonate (RSC).

C. Sodium Absorption Ratio (SAR):

There is a close relationship between SAR values in irrigation water and the extent to which Na+ is absorbed (Subba Rao, 2006). Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. Sodium adsorption ratios for groundwater samples of the study area thirty one samples (2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 20, 22, 23, 25, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 40, 41, 42, 43, 45) showing less than 10 which indicates excellent (S1) quality for irrigation and eleven samples (1, 14, 16, 18, 19, 21, 24, 35, 38, 39, 44) falls



"Fig.2. U S Salinity diagram of groundwater of study area"

between the range 10-18 indicates good (S2) categories, where three samples (10,17,26) falls as doughtful (Table 3). According to USSL classification, waters have been divided into low (C1), medium (C2), high (C3) and very high (C4) on the basis of salinity hazard and based on sodium hazard; water classified into low (S1), medium (S2), high (S3) and very high (S4). The SAR values ranges between 1.64 and 23.39. The analytical data plotted on the US salinity diagram (USSL, 1954) illustrates that 40% of the groundwater samples fall in the field of C3S2 (18%), C4S2 (16%), C4S3 (4%), C3S3 (2%) indicating high to very high salinity and medium to high sodium water, which can be applied for irrigation only in soils having good internal drainage, and the crops having good salt tolerance. Majority (60%) of the samples falls in the field of C3S1 (51%) and C2S1 (9%) in the wells indicating medium to high salinity and low alkalinity hazard (Fig.2).

D. Sodium Absorption Ratio (SAR):

Sodium is an important ion used for irrigation classification of water due to its reaction with soil, reduces permeability. Sodium is usually expressed as Na % (Wilcox, 1955). All the ions are expressed in meq/l (Table III). In the study area twenty nine groundwater sample locations exhibit that the sodium percentage in maximum allowable limit and sixteen locations shows above allowable limit with 64.44 and 35.56 % respectively. Higher Na % is observed locations indicate the dominance of ion exchange and weathering from litho units of the study area.

E. Residual Sodium Carbonate (RSC):

It is considered to be superior to SAR as a measure of sodicity particularly at low salinity levels. In water having high concentration of bicarbonates, there is tendency for calcium and magnesium to precipitate as carbonates. To qualify this effect, an experimental parameter termed as residual sodium carbonate, can be calculated. Groundwater having less than 1.25 or equal to 1.25 epm of RSC is safe water for irrigation purpose, water having less than 1.25 to 2.5 epm of RSC is marginally suitable for irrigation purpose whereas water having more than 2.5 epm of RSC is not

Table II. Comparison of study area groundwater quality parameters with BIS standards for drinking purposes.

Parameter	BIS, 1991 Standarad		Total no. of samples under desirable limit	Total no. of samples exceeds max. allow. limit	Sample location exceeds max. allow. limit	Percentage
	desirable Limit	max.allow. Limit				
pH		6.5 to 8.5	45	6	3,6,8,10,14 & 31	13 %
TDS	500	2000	45	6	1,10,17,26,35 & 38	13 %
Ca^{++}	75	200	45	0	NIL	-
Mg^{++}	75	100	45	7	10,14,17,26,33,35 & 43	16 %
Na^{+}	-	200	45	16	1,10,14,16,17,18,19,21,24,26,31,33,35, 38,39 & 44	36 %
Cl^{-}	250	1000	45	0	NIL	-
SO_4^{-}	200	400	45	1	38	2 %
TH	300	600	45	11	4,9,10,17,26,28,33, 35,38,43 & 45	24 %

Table III. Classification of groundwater on the basis of SAR, SSP, RSC and USSL.

Parameter	Range	Water Class	No. of Samples
SAR	< 10 10–18 18–26 > 26	Excellent (S1) Good (S2) Doubtful (S3) Unsuitable (S4)	31 11 03 Nil
SSP	<200 >200	Maximum allowable limit (safe) Above allowable limit (unsafe)	29 16
RSC	<1.25 1.25–2.50 > 2.5	Good Doubtful Unsuitable	13 08 24
USSL	(C3S1) (C3S2) (C4S2) (C2S1) (C4S3) (C3S3)	L.sodium-H.salinity M.sodium-H.salinity M.sodium-V.H.salinity L.sodium-M.salinity H.sodium-V.H.salinity H.sodium-H.salinity	23 08 07 04 02 01

suitable for irrigation purposes. Based on RSC values, thirteen samples of study area showing the values less than 1.25 and are safe for irrigation and eight samples shows the values between 1.25 and 2.50 are doughtful and twenty four samples shows more than 2.5 and are unsuitable. (Table III).

V. CONCLUSION

The values of TDS, Mg++, Na+ and TH and ion concentration is higher in few of the groundwater samples while compared with the BIS standard. The value of Ca++, Cl−and SO4 − ion concentration is within the limits in majority of the samples. The excess amount of TDS, Mg++, TH and Na+ in the groundwater is due to affluent anthropogenic factors and geological characteristics of the aquifer. The suitability of water for irrigation is evaluated based on SAR, SSP and RSC. Most of the samples in Tirupur Taluk fall in the suitable range for irrigation purpose, either from the SAR, SSP or RSC values. The U.S. salinity diagram indicating that the samples fall in C3S1, C3S2, C4S2, C2S1 and C4S1category showing medium to very high salinity and low to high sodium hazard. On basis of SSP 64.44% of samples falls within the maximum allowable limit which is safe for irrigation purpose and 35.56% of samples as unsafe. The overall hydrogeochemical studies indicates that in the study area majority of the sample locations are suitable for domestic and irrigation purposes, while compared with BIS,(1991).

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Mr. S.Pichaiah received his B.Sc (Geology) in Jawahar Science College,Neyveli,TamilNadu,India in 2000 and M.Sc,M.Phil (Applied Geology) in the Dept. of Earth sciences, Annamalai University,Chidambaram in 2003 & 2008. He is pursuing his Ph.D degree in Applied Geology,Department of Earth Sciences, Annamalai University, Tamil Nadu,India. He was experienced both in teaching (Civil Engineering) & Industry (Granite,Hydrogeology,Coal). He has published 2 research papers in international journals and published 4 papers in National Conference. He has attended 3 training programs on various features. He has guided 12 students for B.E/B.Tech degree. He has visited Singapore,Oman,Indonesia

Dr. G.R.Senthil Kumar did his M.Sc (Geology) and M.Phil (Geology) in the Dept. of Geology, Presidency College, Chennai and the degree was awarded in 1991 and 1992 respectively. He had his Ph.D degree in Geology in 2006 from Annamalai University, Tamil Nadu. In addition, he is in possession of a Diploma in Mining Engineering. Presently he is working as Associate Professor in Department of Earth Sciences, Annamalai University. He is a member of the Annamalai University Academic Council and Board of studies. He is also serving as a board member for question paper setting and script evaluation in various colleges and universities. To his credit, he has presented more than 30 papers in National seminars and 04 technical papers in International seminars. He has published 20 papers in International Journals and 10 Technical papers in National Journals. So far he has attended 13 training programs on various aspects. He has guided 08 students for M.Phil degree and 01 student in Ph.D, at present 05 students are doing research under his guidance for Ph.D program. He is a Life member in many organizations, namely GSI, MEAI (Exe. council member in TN Chapter), SGAT, etc. and Honorary fellow in FIMI. He has been certified as a RQP by IBM for preparation of mine plans. He visited Maldives and China and presented technical papers. Received the Pinnacle of Achievement award in Earth Sciences (2001), by American Biographical Institute, Raleigh, USA and named in the Marquis who's who in the world 2012, 29th edition.

Dr. K.Srinivasamoorthy did his B.Sc (Geology) in Madras University in 1994, M.Sc (Applied Geology) in Annamalai University in 1996 and M.Phil (Hydrogeology) in the Dept. of Geology, Madras University in 1999, Chennai,Tamil Nadu,India. He has completed his Ph.D (Hydogeology) degree in 2005 from Annamalai University, Tamil Nadu,India. Presently he is working as Associate Professor in Department of Earth Sciences, Pondicherry University. He has Specilisation/interest in the field of Hydrochemistry, Modelling, Hydrogeophysics, GIS. In addition, he is completed 2 research projects in 2007-2010 and 1 ongoing research project . He has organized 5 national training programs and conferences. He has published 11 papers in national & international journals for the past 3 years. He has published 10 papers in International & international conferences for the past 3 years. He has awards & Recognation of (1) Recipient of Panikishore award for Young Scientist and Best Paper presentation by the Association of Hydrologists of India, 2012 and (2) Recipient of INSA visiting fellowship for the year 2007. He has guided both for M.Phil & Ph.D degree Students.