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ORIGINAL ARTICLE

Groundwater quality assessment using geospatial and statistical tools in Salem District, Tamil Nadu, India

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Abstract The water quality study of Salem district, Tamil Nadu has been carried out to assess the water quality for domestic and irrigation purposes. For this purpose, 59 groundwater samples were collected and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), major anions (HCO_3^-, CO_3^-, F^-, Cl^-, $NO_2^- + NO_3^-$, and SO_4^{2-}), major cations (Ca^{2+} Mg^{2+}, Na^+, and K^+), alkalinity (ALK), and hardness (HAR). To assess the water quality, the following chemical parameters were calculated based on the analytical results, such as Piper plot, water quality index (WQI), sodium adsorption ratio (SAR), magnesium hazard (MH), Kelly index (KI), and residual sodium carbonate (RSC). Wilcox diagram represents that 23% of the samples are excellent to good, 40% of the samples are good to permissible, 10% of the samples are permissible to doubtful, 24% of the samples are doubtful unsuitable, and only 3% of the samples are unsuitable for irrigation. SAR values shows that 52% of the samples indicate high-to-very high and low-to-medium alkali water. KI values indicate good quality (30%) and not suitable (70%) for irrigation purposes. RSC values indicate that 89% of samples are suitable for irrigation purposes. MH reveals that 17% suitable and 83% samples are not suitable for irrigation purposes and for domestic purposes the excellent (8%), good (48%), and poor (44%). The agricultural waste, fertilizer used, soil leaching, urban runoff, livestock waste, and sewages are the sources of poor water quality. Some samples are not suitable for irrigation purposes due to high salinity, hardness, and magnesium concentration. In general, the groundwater of the Salem district was polluted by agricultural activities, anthropogenic activities, ion exchange, and weathering.

Keywords Geochemistry · Water quality index · Wilcox diagram · Kelley index · Magnesium hazard · Residual sodium carbonate · USSL diagram

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Introduction

The groundwater chemistry is the essential factor, which is permitting its use for irrigation, domestic, and industrial. Most of the population in the world depends on groundwater for daily uses. More and more researchers are concentrating on hydro-geochemistry in recent decades, which is challenging to the scientific researchers based on hydrology and lithology (Guettaf et al. 2014; Kumar et al. 2014; Singh et al. 2014a, b; Srinivasamoorthy et al. 2011). The hydro-geochemical method can be used for identifying the interaction between rocks and waters (Basavarajappa and Manjunatha 2015; Qiyan and Baoping 2002; Zhang et al. 2001; Poroshin and Khaninak 2000; Cai et al. 1997). Developing countries, such as India, have extensive spectral differences of topographical, hydrological, meteorological, geomorphological, hydro-geological, and geological conditions (Kumar et al. 2015; Ahamed et al. 2013; Singh et al. 2014a, b). Groundwater origin, occurrence, and migrations depend upon several factors, such as drainage density, slope, geology, geomorphology, land use, and lineament density (Rajaveni et al. 2015). Groundwater, clean and safe in ancient days in contrast to present decades, shows how quick industrialization creates severe environmental issues in most countries (Santhosh and Revathi 2014). Once the groundwater is contaminated, it is very tough to recover its quality. Water in a few villages in Gangavalli Taluk in Salem district had a high hardness and fluoride content, characteristics which may be altered with softening and defluoridation, making the water useful (Florence et al. 2013). In Yercaud Taluk in Salem district, the groundwater conditions were good except fluoride content, which was more than the permissible limit by WHO (Florence et al. 2012). Geographic information system (GIS) is a valuable tool for mapping the water quality and effective for monitoring, which is used as a database system to create maps of water quality based on concentration values of various chemical constituents (Krishnaraj et al. 2015; Lozano et al. 2012). The aim of the present study is to demarcate the groundwater quality of the study area using geospatial and geostatistical tools.

Materials and methods

The groundwater quality data of the year 2014 were collected from the Public Work Department, State Ground and Surface Water Resources data center, Chennai. The physico-chemical characterization of the groundwater samples is evaluated with pH, EC, TDS, major anions (HCO_3^-, F^-, Cl^-, NO_3^-, and SO_4^{2-}), major cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+), alkalinity, and hardness (Table 1). The analyzed data were compared with World Health Organization (WHO 2006) and Bureau of Indian Standards (BIS 2012) for suitability of domestic uses. SPSS 16.0 software was used to prepare the correlation matrix of the groundwater parameters. For identification of water types, the data are plotted in the piper diagram using the AquaChem 2012.1 software. In addition, evaluation of water quality parameters for suitability of irrigation was analyzed in Wilcox, SAR, RSC, Kelly index, and magnesium hazard.

Wilcox diagram was prepared using sodium percentage and EC value. The Na% is determined by the following formula:

$$\text{Na\%} = \text{Na} + \text{K}/(\text{Ca} + \text{Mg} + \text{Na} + \text{K}) \times 100.$$

The SAR was evaluated by the following formula:

$$\text{SAR} = \text{Na}/[(\text{Ca} + \text{Mg})/2]^{0.5}.$$

RSC values were assessed by the following formula:

$$\text{RSC} = (\text{CO}_3 + \text{HCO}_3) - (\text{Ca} + \text{Mg}).$$

Kelly index was analyzed by the following formula:

$$\text{KI} = \text{Na}/(\text{Ca} + \text{Mg}).$$

Magnesium hazard values were measured by the following formula:

$$\text{MH} = \text{Mg}/(\text{Ca} + \text{Mg}) \times 100.$$

Study area

The present study concentrates on Salem district, Tamil Nadu, India, which is located North latitude between 11°14′ and 12°53′ and East longitude between 77°44′ and 78°50′. Salem district is one of the largest cities in respect to the Tamil Nadu population after Chennai, Coimbatore, Madurai, and Thiruchirappalli. The 2011 census recorded the population of 826,267 people. The total area covered by 5234 km^2 and the average mean sea level is 278 m. The study area is covered by hills, such as Jarugumalai, Nagaramalai, Kanjamalai, Kariyaperumal, Shervaroy, and Godumalai. There are two major river system flows which are the Cauvery and Vellar. The study area has a tropical climate. During the period November to January, the study area has a pleasant weather. In general, morning times are more humid than the afternoons, with the humidity above 75% on an average. During the period of June to November, the afternoon humidity is above 60% on an average. The total study area has a nine taluks and 653 villages. Salem district water sample location map is given in Fig. 1.

Geology of the area serves as the basis for groundwater condition and its occurrences, movement, and quality of groundwater (Rajaveni et al. 2015). Lithology of the study area exposes a highly dissected Precambrian shield terrain comprising rocks of diverse origin. In general, the area is made up of high-grade supra crystals of Archean age, comprising Khondalite group, Charnockite group and Satyamangalam group, and Younger intrusive alkaline syenite-carbonatite complex, ultramafics, basic, and acid rocks. The geological formation of Salem district is comprised of hard rock types of gneiss, granites, charnockite, dunite, pyroxenite, and quartzite, and the mineral formations are magnesite, bauxite, quartz, feldspar, soapstone, and limestone (Florence et al. 2013). The study area highly disturbed with a number of folds, lineaments, faults, shears, and joints (Srinivasamoorthy et al. 2011). Fissile Hornblende Biotite Gneiss and Charnockite are the major rock types in the study area.

Results and discussion

pH

pH is the expression of acidity or basic nature of a solution. The hydrogen ion concentrations in a solution determine the pH. The BIS (2012) and WHO (2006) have suggested that the limit of pH in drinking water is 7.0–8.5 and 6.5–8.5, respectively. In study area, the pH ranges from 7.7 to 9 and the mean value is 8.59 (Table 2). According to the BIS (2012) and WHO (2006) standard, the study area

Table 1 Physico-Chemical characteristics of groundwater samples of Salem district, Tamil Nadu

Village	pH	EC	TDS	HCO_3^-	CO_3^-	F^-	Cl^-	$NO_2^- + NO_3^-$	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	ALK	HAR	SAR	Na%	RSC	KI	MH	WQI
Units	–	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l						
Olaipatti	8.6	1690	969	366	60	1.49	177	29	96	28	77.76	207	10	400	390	5	53	0.2	2.0	74	106
Koonandiyur	9	1600	973	317.2	66	1.46	170	37	96	16	72.9	227	10	370	340	5	58	0.6	2.6	82	106
Nangavalli	8.9	2320	1308	323.3	42	1.5	376	30	196	28	162.81	193	15	335	740	3	36	0.0	1.0	85	150
Kunjandiyur	9	720	396	168.6	15.85	0.87	74	1	67	12	40.095	78	7	185	195	2	45	0.0	1.5	77	53
Navapatti	8.9	460	253	125.2	9.35	0.74	39	4	18	6	14.58	69	7	135	75	3	64	0.9	3.4	71	37
Thanda	7.7	1060	628	195.2	0	0.43	138	21	103	26	55.161	106	10	160	292	3	43	0.0	1.3	68	69
Mulakadu	8.6	950	609	30.5	60	0.71	89	36	105	42	44.955	83	10	125	290	2	37	0.0	1.0	52	71
Vepilaipatty	7.9	1790	1037	158.6	0	0.29	397	8	192	136	80.19	97	18	130	670	2	23	0.0	0.4	37	108
Vellalakundam	8.5	920	516	244	24	1.23	96	8	77	22	69.255	64	6	240	340	2	29	0.0	0.7	76	71
Attanurpatty	8.1	2070	1289	61	0	0.93	425	60	193	92	111.78	161	8	50	690	3	33	0.0	0.8	55	141
Kurichy	8.5	980	535	292.8	24	1.22	57	8	95	20	54.675	97	3	280	275	3	43	0.1	1.3	73	69
Minnampalli	8.7	2130	1236	390.4	24	1.46	411	3	144	28	72.9	340	9	360	370	8	66	0.0	3.4	72	125
Nirmullikuttai	8.5	1380	830	122	24	1.16	284	11	124	28	34.02	225	3	140	210	7	70	0.0	3.6	55	88
Panaimadal	8.1	1230	758	292.8	0	0.83	149	26	96	24	49.815	170	9	240	265	5	57	0.0	2.3	67	81
Chinnakrishnapuram	8.4	2280	1328	170.8	18	0.93	496	26	186	36	111.78	276	3	170	550	5	52	0.0	1.9	76	138
Ettapur	8.3	330	200	112.7	2.11	0.29	35	1	26	20	18.225	23	2	115	125	1	28	0.0	0.6	48	29
Singipuram	8.6	1010	563	79.3	36	0.64	184	3	118	28	66.825	69	10	125	345	2	30	0.0	0.7	70	70
Siruvachur	8.5	620	392	189.2	5.62	0.75	67	1	46	28	43.74	83	2	195	250	2	42	0.0	1.2	61	53
Thalaivasal	8.5	790	466	96.9	2.88	0.41	177	1	63	40	29.16	87	3	100	220	3	46	0.0	1.3	42	53
Aragalur	8.3	2100	1271	207.4	18	0.18	418	29	161	76	80.19	184	104	200	520	4	38	0.0	1.2	51	117
Veeraganur	8.9	2000	1236	323.3	42	0.12	347	22	118	40	51.03	271	106	335	310	7	57	0.5	3.0	56	103
Manjani	8.6	1150	760	122	30	0.66	174	35	86	44	18.225	189	5	150	185	6	68	0.0	3.0	29	76
Gangavalli	8.5	730	432	145.5	4.32	0.29	113	6	49	18	37.665	69	27	150	200	2	39	0.0	1.2	68	49
Attur	8.4	1420	836	250.1	18	0.16	262	9	74	32	68.04	115	100	235	360	3	34	0.0	1.1	68	79
Peddanaikanpalayam	8.5	2880	1633	237.9	24	0.53	773	3	80	40	38.88	543	4	235	260	15	82	0.0	6.9	49	137
Kirippatti	8.5	980	559	79.3	30	0.26	152	10	103	34	46.17	87	22	115	275	2	38	0.0	1.1	58	61
Sendarappatti	8.7	2210	1323	305	42	1.37	365	31	192	60	87.48	276	11	320	510	5	53	0.0	1.9	59	136
Elampillai	8.6	2380	1331	573.4	36	1.5	415	8	67	16	78.975	382	15	530	365	9	68	3.3	4.0	83	129
Nalikkalpatty	8.6	1480	893	73.2	36	0.55	291	33	100	52	63.18	166	4	120	390	4	48	0.0	1.4	55	94
Kamalapatty	8.7	850	518	103.7	36	0.87	110	22	67	70	38.88	46	3	145	335	1	23	0.0	0.4	36	66
Suramangalam	8.8	1630	987	115.9	42	0.51	284	43	115	28	97.2	170	3	165	470	3	44	0.0	1.4	78	106
Yercaud	8.5	380	205	130.9	3.89	0.28	35	2	7	20	18.225	30	5	135	125	1	33	0.0	0.8	48	29
Nagalur	8.4	230	135	97.6	2.3	0.2	14	2	2	20	6.075	23	2	100	75	1	39	0.2	0.9	23	21
Vedukattampatti	9	1820	1037	298.9	60	1.18	284	20	106	24	92.34	221	9	345	440	5	52	0.0	1.9	79	111
Kannankurichi	8.8	1750	928	366	36	1.12	277	8	110	32	131.22	124	2	360	620	2	30	0.0	0.8	80	111

Table 1 continued

Village	pH	EC	TDS	HCO_3^-	CO_3^-	F^-	Cl^-	$NO_2^- + NO_3^-$	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	ALK	HAR	SAR	Na%	RSC	KI	MH	WQI
Ammapet	9	2150	1235	341.6	66	1.06	333	23	144	24	94.77	294	5	390	450	6	58	0.0	2.5	80	124
Hastampatti	9	760	414	228	21.43	1.39	57	4	48	26	44.955	64	3	250	250	2	35	0.0	0.9	63	61
Kalvadangam	8.4	1000	605	109.8	24	1.31	82	8	228	28	63.18	74	18	130	330	2	31	0.0	0.8	69	80
Chinnagoundanur	8.4	1220	779	298.9	18	0.5	160	12	96	10	37.665	143	113	275	180	5	49	1.9	3.0	79	71
Iruppali	8.2	1000	598	195.2	0	1.31	85	8	196	32	66.825	69	18	160	355	2	28	0.0	0.7	68	80
Kunnipalayam	8.7	3800	2310	524.6	36	0.84	780	27	224	32	82.62	598	174	490	420	13	67	1.4	5.2	72	190
Konganapuram	8	1740	1034	195.2	0	0.61	340	42	105	52	114.21	124	15	160	600	2	30	0.0	0.7	69	114
Idappadi	8.1	1590	968	170.8	0	0.26	326	42	76	60	89.91	129	15	140	520	2	34	0.0	0.9	60	101
Pillukurichi	9	1410	838	195.2	54	0.77	213	13	144	24	82.62	143	23	250	400	3	42	0.0	1.3	77	92
Koranampatti	9	3650	2116	427	60	1.08	752	12	288	24	111.78	607	8	450	520	12	71	0.0	4.5	82	190
Pakkanadu	8.6	2090	1164	372.1	36	1.08	227	12	288	76	114.21	161	23	365	660	3	34	0.0	0.8	60	127
Danishpet	8.5	650	344	213.5	6.34	1.66	39	3	48	14	47.385	46	3	220	230	1	30	0.0	0.7	77	59
Lokkur	8.6	1340	795	390.4	36	1.18	135	5	96	24	24.3	225	38	380	160	8	70	4.4	4.7	50	78
Theevattipatti	8.5	700	420	150.4	4.46	1	96	7	62	22	41.31	69	5	155	225	2	39	0.0	1.1	65	57
Karuppur	8.7	1050	555	292.8	42	0.39	96	1	96	12	95.985	46	15	310	425	1	18	0.0	0.4	89	68
Muthunaickanpatti	8.7	1450	904	195.2	36	1.24	191	35	125	16	63.18	189	30	220	300	5	55	0.0	2.4	80	98
Omalur	8.6	1160	681	305	30	1.35	106	17	89	12	59.535	138	14	300	275	4	51	0.5	1.9	83	81
Tholasampati	9	1820	1024	555.1	60	1.65	170	4	87	16	21.87	368	4	555	130	14	86	8.5	9.7	58	97
Tharamangalam	9	2530	1476	610	60	1.29	369	22	96	40	46.17	455	6	600	290	12	77	6.2	5.3	54	131
Jalakandapuram	9	2710	1566	170.8	54	0.49	652	4	213	32	104.49	405	3	230	510	8	63	0.0	3.0	77	146
Marakottai	8.8	1840	1019	585.6	48	1.4	163	11	114	20	29.16	299	6	560	170	10	79	7.8	6.1	59	96
Thekkampatti	9	720	388	255.5	24.01	0.26	39	2	48	12	59.535	46	6	280	275	1	26	0.0	0.6	83	48
Gundaakkal	8.7	1810	1116	97.6	48	0.8	262	43	236	40	111.78	170	7	160	560	3	39	0.0	1.1	74	122
Manathal	8.5	1230	742	390.4	30	1.36	74	27	69	16	47.385	179	13	370	235	5	61	2.7	2.8	75	82

ALK alkalinity, *HAR* hardness, *EC* electrical conductivity, *TDS* total dissolved solids, *SAR* sodium absorption ratio, *KI* Kelley Index, *MH* magnesium hazard, *RSC* residual sodium carbonate

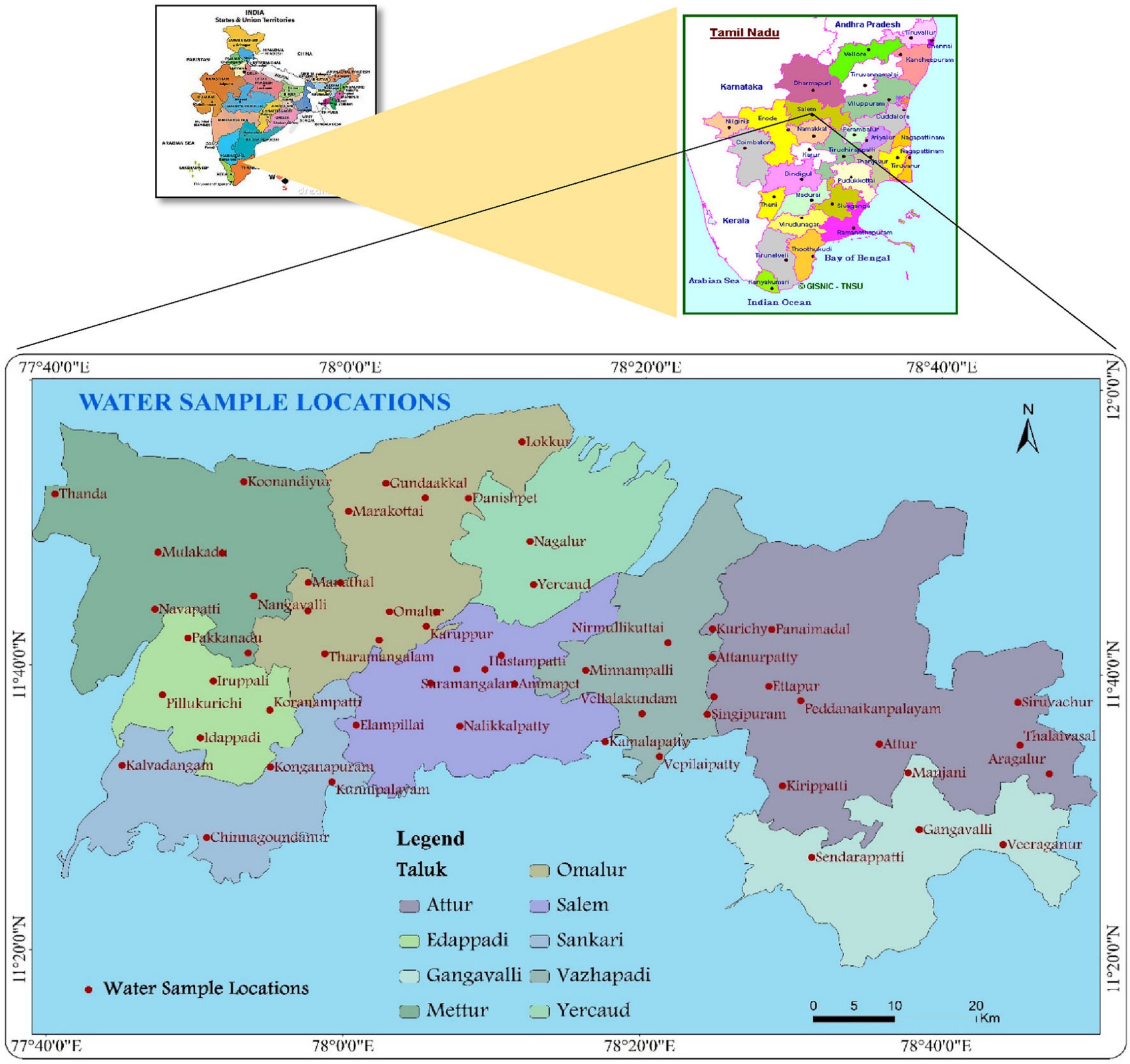

Fig. 1 Water sample location map of the study area

villages Thanda, Iruppali, Idappadi, Konganapuram, Kalvadangam, Chinnagoundanur, Nagalur, Panaimadal, Kurichy, Attanurpatty, Ettapur, Attur, Vepilaipatty, and Aragalur have a desirable limit of pH and the rest of the villages have above 8.5 pH. Excess amount of pH in the drinking water will affect the mucous membrane and water supply system (Napacho and Manyele 2010).

Electrical conductivity

EC is a measurement of the ability of an aqueous solution to carry an electrical current. EC measurement used for a number of applications related to water quality. These are to determine mineralization, changes in natural water and waste water quickly, and determining amounts of chemical reagents to be added to a water sample. In the study area, EC value ranges from 230 to 3800 µS/cm and the mean value is 1487 µS/cm (Table 2). The WHO (2006) guideline has suggested that the limit of EC in drinking water is 750 µS/cm. According to the WHO (2006) standard, the study area villages Ettapur, Theevattipatti, Danishpet, Nagalur, Yercaud, Kunjandiyur, Navapatti, Thekkampatti, Hastampatti, Vellalakundam, Kamalapatty, Kirippatti, Gangavalli, Siruvachur, Thalaivasal, and Kurichy have a desirable limit of EC in drinking water, and the rest of the villages have excess amount of EC in drinking water.

Total dissolved solids

TDS in water can originate from natural sources, livestock waste, sewage, nature of the soil, and urban run-off industrial wastewater. The concentration of dissolved matter in water is given by the weight of the material on evaporation of water to dryness followed by heating for 1 h at 180 °C. The BIS (2012) has suggested that the acceptable limit of TDS in drinking water is 500 mg/l and

Table 2 Comparison of the analytical data with WHO and BIS for domestic purposes

Parameters	WHO (2006) Maximum desirable limit	BIS 2012 (IS-10500)		Maximum	Minimum	Mean	Standard deviation
		Acceptable limit	Permissible limit				
pH	7–8.5	6.5–8.5	No relaxation	9	7.7	8.5	0.3
EC	750	–	–	3800	230	1487	757
CO_3^-	–	–	–	66	0	28	20
HCO_3^-	200	200	600	610	30.5	244.7	140.6
F^-	0–1.5	1	1.5	1.66	0.12	0.87	0.4
Cl^-	250	250	1000	780	14	235	185
NO_3^-	50	45	No relaxation	60	1	16.6	14
SO_4^{2-}	200	200	400	288	2	113	64
Na^+	200	–	–	607	23	179.5	138
Ca^{2+}	75	75	200	136	6	32.7	22
Mg^{2+}	30	30	100	162.8	6	64.73	32.8
K^+	200	–	–	174	2	19	32.6
TDS	500	500	2000	2310	135	872	445
HAR	300	200	600	740	75	348	160
ALK	–	200	600	600	50	252.4	131
SAR	–	–	–	15	1	4	3
Na%	–	–	–	86	18	47	17
RSC	–	–	–	9	0	1	2
Kelly index	–	–	–	10	0	2	2
Magnesium hazard	–	–	–	89	23	66	15
WQI	–	–	–	243	18	93	42

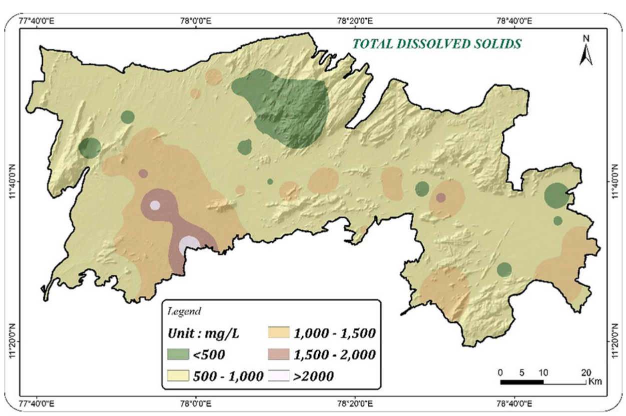

Fig. 2 Spatial distribution map of TDS

permissible limit of TDS in drinking water is 2000 mg/l. In the study area, the TDS ranges from 135 to 2310 mg/l and the mean value is 872 mg/l (Table 2). The spatial distribution of the TDS is given in Fig. 2. According to the Indian standard the study area, villages Danispet, Nagalur, Yercaud, Kunjandiyur, Navapatti, Ettapur, Siruvachur, Thalaivasal, and Gangavalli have desirable amount of TDS in drinking water and rest of the villages except Koranampatti and Kunnipalayam have a permissible limit of TDS in drinking water. Koranampatti and Kunnipalayam villages have not permissible limit of TDS. The excess amount of TDS concentration is due to weathering and agricultural runoff of the study area.

Bicarbonate

Ecologically, bicarbonate is formed by the daylight photosynthetic activity of freshwater plants releasing gaseous oxygen into the water which simultaneously produces bicarbonate ions. The WHO (2006) has suggested that the limit of bicarbonate is 200 mg/l. In the study area, the bicarbonate ranges from 30.5 to 610 mg/l with a mean value of 244.7 mg/l (Table 2). According to the WHO (2006) guidelines, the study areas Navapatti, Thanda, Mulakadu, Vepilaipatty, Attanurpatty, Nirmullikuttai, Chinnakrishnapuram, Ettapur, Singipuram, Siruvachur, Thalaivasal, Manjani, Gangavalli, Kirippatti, Nalikkalpatty, Kamalapatty, Suramangalam, Yercaud, Nagalur, Kalvadangam, Iruppali, Konganapuram, Idappadi, Pillukurichi, Theevattipatti, Muthunaickanpatti, Jalakandapuram, and Gundaakkal have desirable levels of bicarbonate in water.

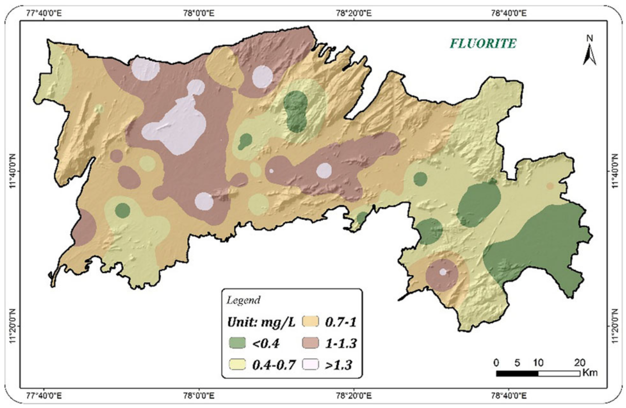

Fig. 3 Spatial distribution map of fluoride

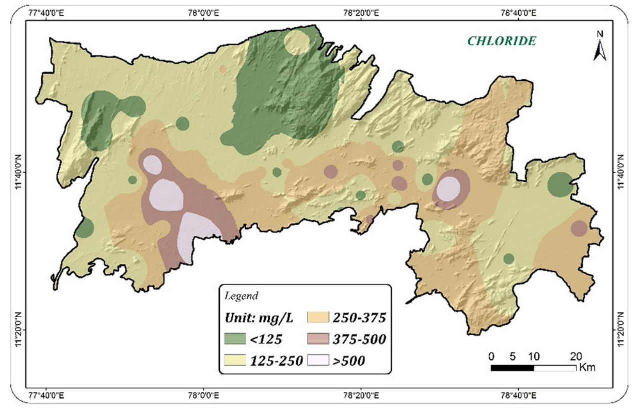

Fig. 4 Spatial distribution map of chloride

Carbonate

Most of the carbonate ions in ground water are derived from the carbon di-oxide in the atmosphere and soil. The study area showed the highest carbonate concentration in 66 mg/l at Koonandiyur, Thanda, Vepillaipatti, Attanurpatty, Panaimadal, Iruppali, and Konganapuram, with Idappadi villages having neutral carbonate content in water.

Fluoride

Fluoride ions can occur either naturally or artificially in drinking water, and are absorbed to some degree in the bone structure of the body and tooth enamel. The BIS (2012) suggested that the highest desirable limit of fluoride content in drinking water is 1 mg/l and the permissible limit is 1.5 mg/l. Excess amounts of fluoride compounds cause corrosion of piping and other water treatment equipment. In the study area, fluoride concentration ranges from 0.12 to 1.66 mg/l and the mean value is 0.87 mg/l (Table 2). The spatial distribution of fluoride concentration of the study area is given in Fig. 3. According to the BIS (2012) and WHO (2006) standards, the study area villages Thanda, Mulakadu, Kunjandiyur, Navapatti, Pillukurichi, Idappadi, Chinnagoundanur, Konganapuram, Kunnipalayam, Gundaakkal, Thekkampatti, Karuppur, Suramangalam, Nalikkalpatty, Yercaud, Nagalur, Panaimadal, Attanurpatty, Singipuram, Kamalapatty, Vepillaipatty, Kirippatti, Ettapur, Peddanaikanpalayam, Attur, Manjani, Gangavalli, Veeraganur, Aragalur, Thalaivasal, and Siruvachur have desirable levels of fluoride content in the drinking water and the villages Manathal, Nangavalli, Elampillai, Koranampatti, Iruppali, Pakkanadu, Kalvadangam, Omalur, Marakottai, Vedukattampatti, Hastampatti, Kannankurichi, Ammapet, Vellalakunda, Minnampalli, Nirmullikuttai, Kurichy, Sendarappatti, Koonandiyur, and Lokkur have high but permissible levels of fluoride content in the drinking water. The villages Danishpet and Tholasampati have the highest fluoride levels, which can lead to fluorosis diseases (Singh et al 2014a, b; Tiwari and Singh 2014). The excess amount of fluoride concentration in the study area is due to weathering and leaching of the high availability of fluoride minerals, such as amphiboles, apatite, biotite, and lepidolite.

Chloride

Chloride is the combination of the gas chlorine with a metal and is a minor constituent of the earth's crust but a major dissolved constituent of most natural waters. There are several sources of chloride in water, including agricultural runoff, rocks, wastewater from industries, road salting, and effluent wastewater from wastewater treatment plants (Guettaf et al. 2014). Chloride can contaminate freshwater and lakes. In the study area, the chloride ranges from 14 to 780 mg/l and the mean value is 235.6 mg/l (Table 2). The WHO (2006) standard of chloride acceptable limit in drinking water is 250 mg/l. The spatial distribution map of the chloride ion is given in Fig. 4. Based on the WHO (2006) standard guideline, the study area villages Thanda, Koonandiyur, Marakottai, Mulakadu, Kunjandiyur, Navapatti, Pakanadu, Iruppali, Pillukurichi, Kalvadangam, Chinnagoundanur, Manathal, Tholasampati, Omalur, Muthunaickanpatti, Marakottai, Danispet, Nagalur, Yercaud, Lokkur, Karuppur, Thekkampatti, Hastampatti, Vellalakundam, Kamalapatty, Kurichy, Panaimadal, Ettapur, Kirippatti, Gangavalli, Manjani, Siruvachur, Thalaivasal, and Vellalakundam fall under the safe zone. Rest of the villages have excess amount from permissible limit. The excess amount of chloride in groundwater is due to weathering of rocks in the study area.

Nitrite and nitrate

Nitrate and nitrite concentration range from 1 to 60 mg/l. The mean value is 16.6 mg/l (Table 2). The WHO (2006)

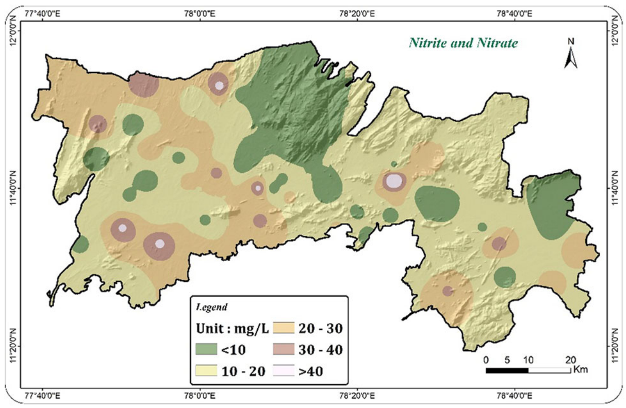

Fig. 5 Spatial distribution map of nitrite and nitrate

desirable limit of nitrate and nitrite concentration is 50 mg/l. The spatial distribution of nitrate and nitrite concentration is given in Fig. 5. According to the WHO (2006) standard, it falls under the safe zone except Attanurpatty. The excess concentration of nitrate and nitrite concentration can produce the "brown blood disease". These extreme amounts of nitrate and nitrite concentration mixed with water may occur through fertilizer runoff, animal wastes, leaking septic tanks, sanitary landfills, industrial waste waters, and discharge from car exhausts (Singh et al. 2014a, b). The excess amount of nitrite and nitrate concentration in attanurpatty is due to agricultural activities, such as high use of fertilizer in the study area.

Sulfate

Sulfate can be naturally occurring through rock or soil and other common minerals or formed artificially from runoff of fertilized agriculture lands. Sulfur is an important plant nutrient. The BIS (2012) and WHO (2006) have suggested that the desirable limit of sulfate is 200 mg/l and permissible limit is 400 mg/l. In the study area, the sulfate ranges from 2 to 288 mg/l, and the mean value is 113.4 mg/l (Table 2). According to Indian Standard the study area, villages except Pakkanadu, Jalakandapuram, Koranampatti, Kummipalayam, Kalvadangam, and Gundaakkal fall below the desirable limits and all other villages fall below the permissible limits. Sulfate is not considered toxic at normal concentrations; very high sulfate is toxic to cattle.

Calcium

Calcium ranges from 6 to 136 mg/l, and the mean value is 32.7 mg/l (Table 2). The BIS (2012) and WHO (2006) have suggested that the desirable limit of calcium concentration ion in the drinking water is 75 mg/l. According to the BIS (2012), the study area villages except Vepillaipatty, Kamalapatty, Aragalur, Attanurpatty, and Pakkanadu fall under the safe zone. Most part of the study area covered by low and very low calcium concentrations. Plagioclase feldspar and clinopyroxene are the main source of the calcium content in the study area. These are characteristically found in Charnockite rock. The Charnockite rock is generally high in the study area. The variations in topography, surface material (rock and soil), and land cover which influence the rate of weathering are the reasons for the differences in the concentration of calcium in the waters of the study area (Kumar et al. 2014).

Magnesium

The magnesium ranges from 6 to 162 mg/l, and the mean value is 64.7 mg/l (Table 2). The drinking water specification in the BIS (2012) and WHO (2006) has suggested that the desirable limit of the magnesium in water is 30 mg/l and the BIS (2012) permissible limit in the absence of an alternate source is 100 mg/l. (Rosanoff 2013) has stated that Universal drinking water and beverages containing moderate-to-high levels of magnesium (10–100 ppm) could potentially prevent 4.5 million heart disease and stroke deaths per year, worldwide, and this potential is calculated with 2010 global mortality figures combined with a recent quantification of water-magnesium inverse association with heart disease and stroke mortality. The spatial distribution map of the magnesium ion concentration is shown in Fig. 6. According to the above said standard, the magnesium ion concentration of study area villages Navapatti, Ettapur, Thalaivasal, Manjani, Yercaud, Nagalur, Lokkur, Tholasampatti, and Marakottai falls below the desirable limit and that of the rest of the villages except Nangavalli, Attanurpatty, Chinnakrishnapuram, Kannankurich Konganapuram, Koranampatti, Pakkanadu, Jalakandapuram, and Gundakkal fall within the permissible limit in the absence of alternative sources. The above said except villages fall under the above desirable level. The source of high

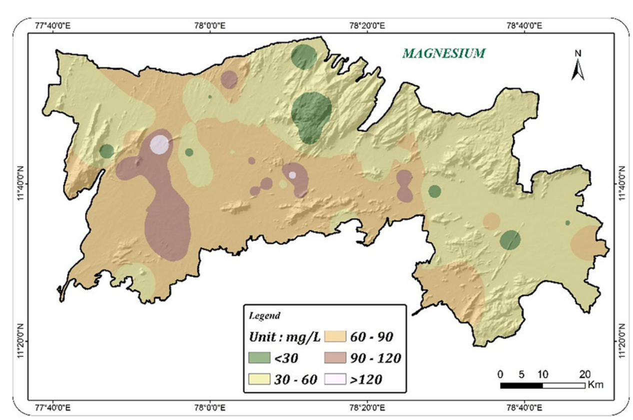

Fig. 6 Spatial distribution map of magnesium

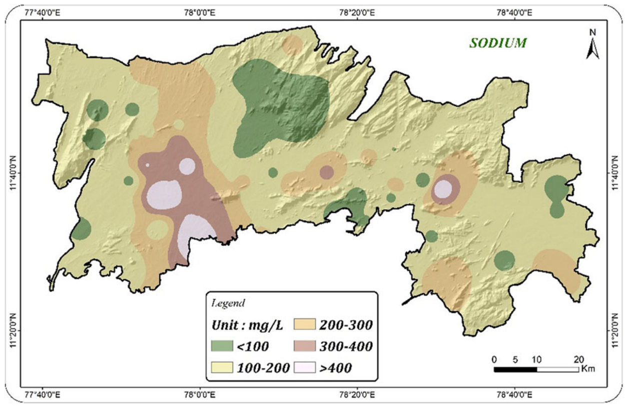

Fig. 7 Spatial distribution map of sodium

magnesium level in the groundwater is due to magnesite deposits and ultramafic rock occurrence of the study area. Natural water contains magnesium and calcium, which caused hardness of groundwater based on dissolved polyvalent metallic ions (Basavarajappa and Manjunatha 2015).

Sodium

Sodium is a very reactive and it does not occur in its free form in nature. The primary source of the sodium in the water is the weathering of plagioclase feldspars and clinopyroxenes which are essential constituents of the charnockite. Health-based guideline by the WHO 2006 has suggested the sodium ion in water be 200 mg/l. In the study area, the sodium ion ranges from 23 to 607 mg/l and the mean value is 179.5 mg/l (Table 2). The spatial distribution map of the sodium ion concentration is shown in Fig. 7. According to the WHO-2006 standard the study area, villages Thanda, Mulakadu, Kunjandiyur, Navapatti, Kalvadagam, Chinnagoundanur, Idappadi, Pillukurichi, Pakkanadu, Iruppali, Nangavalli, Konganapuram, Manathal, Gundakkal, Danishpet, Nagalur, Yercaud, Karuppur, Thekkampatti, Muthunaickanpatti, Omalur, Suramangalam, Kannankurichi, Hastampatti, Nalikkalpatty, Vellalakundam, Kamalapatty, Vepilaipatty, Singipuram, Kirippatti, Gangavalli, Attur, Aragalur, Thalaivasal, Siruvachur, Attanurpatty, Kurichy, and Panaimadal fall under the permissible limits and the rest of the villages have excess amount of sodium concentration. The excess amount of sodium ion in water can produce the high blood pressure and pregnant women suffering from toxemia (Haritash et al. 2014). The excess amount of sodium concentration in the study area is due to weathering of charnockite rock.

Potassium

Potassium is an alkali metal which is abundant in minerals of the earth's crust. The potash feldspar is an essential constituent of charnockite, and the rock type of the area is the major source for the presence of potassium in the subsurface water of the study area. In the study area, the potassium ranges from 2 to 174 mg/l and the mean value is 19 mg/l (Table 2). The WHO (2006) suggested that the permissible level of potassium is 200 mg/l. According to the WHO-2006 standard, the study area villages fall under the safe zone.

Alkalinity

Alkalinity or buffering capacity refers to capability of water to neutralize acid. Alkalinity is related to the hardness, because carbonate rocks are a main source of alkalinity. The BIS (2012) guideline has suggested that the total alkalinity of drinking water is 200–600 mg/l. In the study area, total alkalinity ranges from 50 to 600 mg/l and the mean value is 252 mg/l (Table 2). According to the BIS (2012) standard, the study area villages have an allowable limit of total alkalinity. The excess alkalinity levels in surface water lead to acid rain and can be harmful to aquatic life.

Hardness

The amount of calcium and magnesium in water is called hardness of water. In general, surface water is softer than ground water. The WHO (2006) suggested that the desirable limit of hardness in drinking water is 300 mg/l. In the study area, the hardness value ranges from 75 to 745 mg/l and the mean value is 348 mg/l (Table 2). The spatial distribution map of the hardness content in the study area is given in Fig. 8. The study area villages Nagalur, Yercaud, and Navapatti are containing a moderately hard water, Mulakadu, Thanda, Kunjandiyur, Marakottai, Danishpet, Lokkur, Nirmullikuttai, Mnanthal, Tholasampati, Chinnagoundanur, Thekkampatti, Hastampatti, Kurichy, Panaimadal, Ettapur, Peddanaikanpalayam, Kirippatti, Manjani,

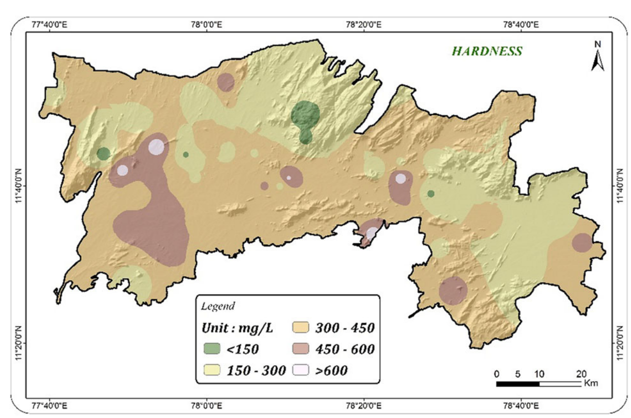

Fig. 8 Spatial distribution map of hardness

Table 3 Correlation matrix of water quality parameters

Parameters	pH	EC	TDS	HCO_3^-	CO_3^-	F^-	Cl^-	$NO_2^- + NO_3^-$	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	ALK	HAR
pH	1														
EC	0.22	1.00													
TDS	0.20	1.00	1.00												
HCO_3^-	0.36	0.55	0.51	1.00											
CO_3^-	0.74	0.49	0.47	0.46	1.00										
F^-	0.33	0.21	0.18	0.53	0.39	1.00									
Cl^-	0.09	0.93	0.93	0.29	0.27	−0.03	1.00								
$NO_2^- + NO_3^-$	−0.15	0.34	0.39	−0.10	0.19	0.04	0.26	1.00							
SO_4^{2-}	0.03	0.69	0.70	0.15	0.33	0.20	0.59	0.32	1.00						
Ca^{2+}	−0.41	0.27	0.29	−0.22	−0.17	−0.25	0.35	0.38	0.42	1.00					
Mg^{2+}	0.07	0.59	0.57	0.13	0.29	0.16	0.52	0.44	0.68	0.30	1.00				
Na^+	0.34	0.90	0.90	0.63	0.51	0.27	0.84	0.15	0.45	0.01	0.24	1.00			
K^+	−0.07	0.32	0.36	0.23	0.00	−0.28	0.31	0.10	0.20	0.07	0.04	0.25	1.00		
ALK	0.51	0.56	0.53	0.98	0.62	0.55	0.29	−0.08	0.17	−0.26	0.15	0.66	0.19	1.00	
HAR	−0.09	0.59	0.58	0.03	0.18	0.05	0.56	0.50	0.72	0.60	0.94	0.20	0.06	0.04	1

Gangavalli, Thalaivasal, and Siruvachur contain hard water, and the rest of the villages contain very hard water. For the drinking purposes, Nagalur, Yercaud, Navapatti, Mulakadu, Thanda, Kunjandiyur, Marakottai, Danishpet, Lokkur, Nirmullikuttai, Mnanthal, Tholasampati, Chinnagoundanur, Thekkampatti, Hastampatti, Kurichy, Panaimadal, Ettapur, Peddanaikanpalayam, Kirippatti, Manjani, Gangavalli, Thalaivasal, and Siruvachur have desirable limit of Hardness in drinking water and rest of the villages except Nangavalli, Pakkanadu, and Attanurpatty have permissible limit of hardness in drinking water.

Correlation matrix

The correlation statistical method used to identify the connection and variation between the groundwater samples with the help of physico-chemical parameters and ionic concentrations (Kumar et al. 2015; Ahamed et al. 2013). The correlation matrix of the all groundwater variables is shown in Table 3. In general, the matrix values are in between −1 and +1. EC and TDS show high positive correlation with Cl^-, SO_4^{2-}, and Na^+ and moderate correlation with HCO_3^-, Mg^{2+}, ALK, and HAR. There is a good correlation between HCO_3^- and ALK (0.98), and Cl^- and Na^+ (0.84), and moderate correlation between Na^+ and ALK (0.66), SO_4^{2-} and Mg^{2+} (0.68), Cl^- and SO_4^{2-} (0.59), F^- and ALK (0.55), CO_3^- and Na^+ (0.51), and CO_3^- and ALK (0.62). Thus, the good correlation between the quality parameters indicates similar source and/or geochemical behavior during various processes (Tiwari et al. 2015). The positive correlations between Cl^- and Na^+ (0.84), Cl^- and TDS (0.93), and Na^+ and TDS (0.90) are derived from anthropogenic sources (Tiwari and Singh 2014). The high positive correlation between Mg^{2+} and HAR are derived from ultramafic rocks in the study area. The poor correlation between Ca^{2+} and SO_4^{2-} (0.42) indicates that the gypsum dissolution could not be the major contributor for the dissolved ions in the water of the study area (Tiwari et al. 2015)

Piper analysis

Piper diagram is a way of visualizing graphical representation of chemistry in water samples in hydro-geological studies. The piper plot contained three pieces: these are lower left triangle diagram representing cations, lower right triangle diagram representing the anions, and a diamond plot in the middle representing a combination of the two. There are six ion groups considered in the piper plot, and they are calcium, magnesium and sodium plus potassium cations, and sulphate, chloride, and carbonate plus hydrogen carbonate anions. The study area water analysis result is plotted in piper diagram Fig. 9. According to the piper diagram, the villages Attanurpatty and Vellalapatty are dominant in Calcium–chloride type of water. The villages Tharamangalam, Elampillai, Chinnagoundanur, Veeraganur, Panaimadal, Minnampalli, Koranampatti, Manjani, Vedukattampatti, Danishpet, Chinnakrishnapuram, Sendarapatti, Jalakandapuram, Nirmullikuttai, and Kunnipalayam are dominant in the sodium chloride type of water. The calcium–chloride and sodium–chloride rich in these areas because of Fissile Hornblende Biotite gneiss and Charnockite are the parent rock, which have composed of sodium and calcium rich minerals. The villages Karuppur,

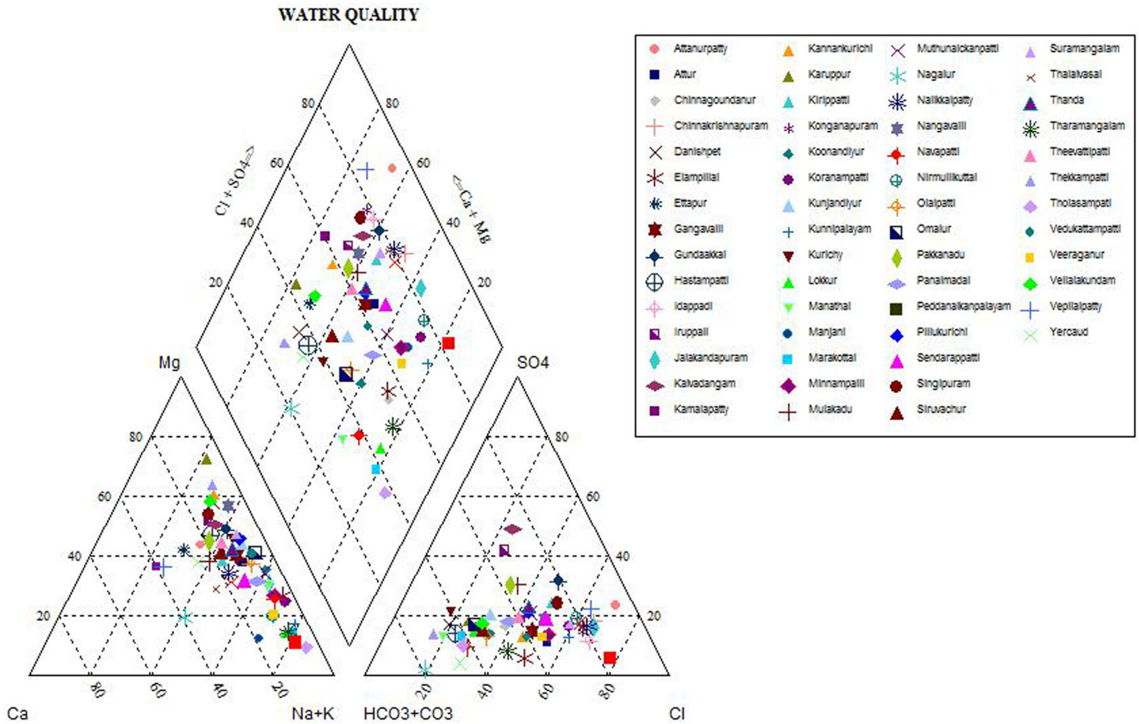

Fig. 9 Piper plot

Vellalakundam, Ettapur, Muthunaickanpatti, Thekkampatti, Hastampatti, Kurichy, Nagalur, Siruvachur, and Yercaud are dominant in the magnesium bicarbonate type of water, and because of these areas, they are influenced by magnesite deposits and ultramafic rocks. The villages Omalur, Olaipatti, Koonandiyur, Lokkur, Manathal, Marakottai, Tholasampatti, Navapatti, Attur, Gangavalli, Gundaakkal, Idappadi, Iruppalli, Kalvadangam, Kamalapatty, Kannankurichi, Kirippatti, Konganapuram, Kunjandiyur, Mulakadu, Nalikkalpatty, Nangavalli, Pakkandu, Peddanaikanpalayam, Pilluckurichi, Singipuram, Suramangalam, Thalaivasal, Thanda, and Theevattipatti are dominant in mixed type of water, which means no cations and anions exceeds 50%.

Water quality index

WQI is a significant way to assess and monitor the quality of water in the current years due to its usefulness for the understanding of water quality issues by integrating complex data (Mishra and Patel 2001; Singh et al. 2013; Tiwari et al. 2015). For computing WQI, three steps were followed. In the first step, each of the 12 parameters (pH, TDS, F^-, Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+,and HAR) has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 4). The maximum weight of 5 has been assigned to the parameters, such as TDS, Na^+, F^-, Cl^-, NO_3^-, and SO_4^{2-}, while HCO_3^- was assigned the minimum weight of 1, as it plays an insignificant role in the water quality assessment and other parameters, such as pH, Ca^{2+}, Mg^{2+}, K^+, and HAR were assigned weights between 2 and 5 depending on their importance in water quality determination (Vasanthavigar et al. 2009; Tiwari et al.

Table 4 Relative weights of chemical parameters

Chemical parameters	Standards (BIS/WHO)	Weight (wi)	Relative weight (WI)
pH	8.5	4	0.09
TDS	500	5	0.11
F^-,	1	5	0.11
Cl^-	250	5	0.11
NO_3^-	45	5	0.11
SO_4^{2-}	200	5	0.11
HCO_3^-	200	1	0.02
Ca^{2+},	75	3	0.07
Mg^{2+}	30	3	0.07
Na^+	200	5	0.11
K^+	200	2	0.04
HAR	500	2	0.04
		$\Sigma wi = 45$	$\Sigma Wi = 1.00$

2015). The weightage of K^+ has been assigned according to its relative importance of quality of water.

The second step is the calculate the relative weight (Wi) by the following equation:

$$\mathrm{Wi} = \mathrm{wi} / \sum_{i=1}^{n} \mathrm{wi}$$

where Wi is the relative weight, wi is the weight of each parameter, and n is the number of parameters. The result of relative weight (Wi) is given in Table 4.

The third step is a quality rating scale (qi) for each parameter that is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 2012, and the result is multiplied by 100 (Vasanthavigar et al. 2009):

$$\mathrm{qi} = (\mathrm{Ci}/\mathrm{Si}) \times 100$$

where qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in milligrams per liter, and Si is the Indian drinking water standard for each chemical parameter in milligrams per liter according to the guideline of the BIS 2012.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation (Tiwari et al. 2015):

$$\mathrm{SI} = \mathrm{Wi} \times \mathrm{qi}$$

$$\mathrm{WQI} = \sum \mathrm{SI}i,$$

where SI i is the sub-index of ith parameter, qi is the rating based on concentration of the ith parameter, and n is the number of parameters. WQI can be classified into five categories based on their value: excellent water (<50), good water (50–100), poor water (100–200), very poor water (200–300), and unfit for drinking purpose (>300) (Vasanthavigar et al. 2009; Tiwari et al. 2015). The WQI of Salem district ranges from 18 to 243 with a mean value of 42. Among the all groundwater samples, the percentage of WQI categories are excellent (8%), good (48%), and poor (44%) for domestic uses (Fig. 10).

Suitability of irrigation uses

Wilcox The Wilcox (1955) diagram of the study area is given in Fig. 11. Based on Wilcox diagram, the results show that the following villages, such as Kunjandiyur, Navapatti, Ettapur, Siruvachur, Thalaivasal, Gangavali, Kamalapatty, Yercaud, Nagalur, Hastampatti, Danishpet, Teevattipatti, and Thekkampatti, fall below the excellent to good for irrigation water. The villages Olaipatti, Thanda, Mulakadu, Vepilaipatty, Vellalakundam, Kurichy, Singipuram, Attur, Kiripatti, Nalikkalpatty, Kannankurichi, Kalvadagam, Chinnagoundanur, Iruppali, Konganapuram,

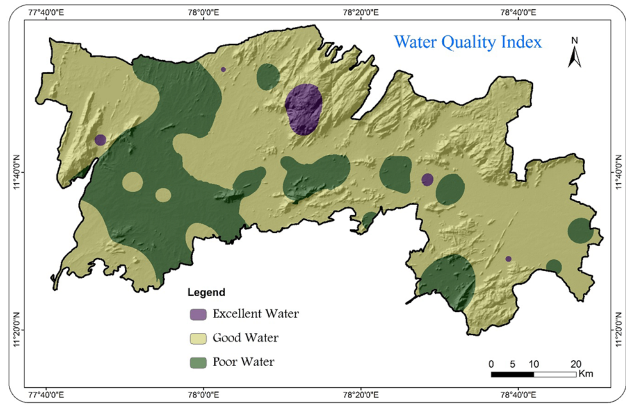

Fig. 10 WQI map for the Salem District, South India

Idappadi, Pillukurichi, Karruppur, Muthunaickanpatti, Omalur, Gundaakkal, Manathal, and Suramangalam fall below the good-to-permissible level. The permissible-to-doubtful level of the villages is Koonandiyur, Nirmullikuttai, Manjani, Vedukattampatti, Lokkur, and Marakottai. Then, the unsuitable for irrigation level of water occurs in Kunnipalayam and Koranampatti villages in the study area. Rest of the villages fall below the doubtful-to-unsuitable level.

Sodium adsorption ratio (*SAR*) USSL plot of the study area is given in Fig. 12. A high salt concentration in water leads to formation of saline soil and high sodium concentration may cause the development of an alkaline soil (Tiwari and Singh, 2014). On the basis of SAR value, water is classified into low (SAR <6), medium (SAR 6–12), high (SAR 12–18), and very high (SAR >18) alkali waters (Tiwari et al. 2016a). The SAR in the study area ranges from 1 to 15 (Table 2). According to USSL diagram, Nagalur village falls below the C1S1 level. Kunjandiyur, Navapatti, Ettapur, Siruvachur, Gangavalli, Yercaud, Danishpet, Theevattipatti, and Thekkampatti fall below the C2S1 level, and these categories are indicating that good-to-permissible quality of water for irrigation uses with little danger of development of exchangeable sodium and salinity (Tiwari et al. 2016a). C3S2 level covers Minnampalli, Nirmullikuttai, Veeraganur, Manjani, Ammapet, Lokkur, Sendarappatti, and Koonandiyur. C4S1 and C4S4 levels cover the Nangavalli and Peddanaikanpalayam, respectively. The villages Elampillai, Kunnipalayam, Koranampatti, and Thramangalam fall under the C4S3 level, and the villages Tholasampatti and Marakottai fall under the C3S3 level. The Jalakandapuram and Chinnakrishnapuram villages fall under the C4S2 level. Rest of the villages, such as Thanda, Mulakadu, Vepilaipatty, Vellalakundam, Attanurpatty, Kurichy, Singipuram, Thalaivasal, Aragalur, Attur, Kirippatti, Nalikkalpatty, Kamala patty, Suramangalam, Kannankurichi, Hastampatti, Kalvadangam, Irupali, Konganapuram, Idappadi, Pillukurichi,

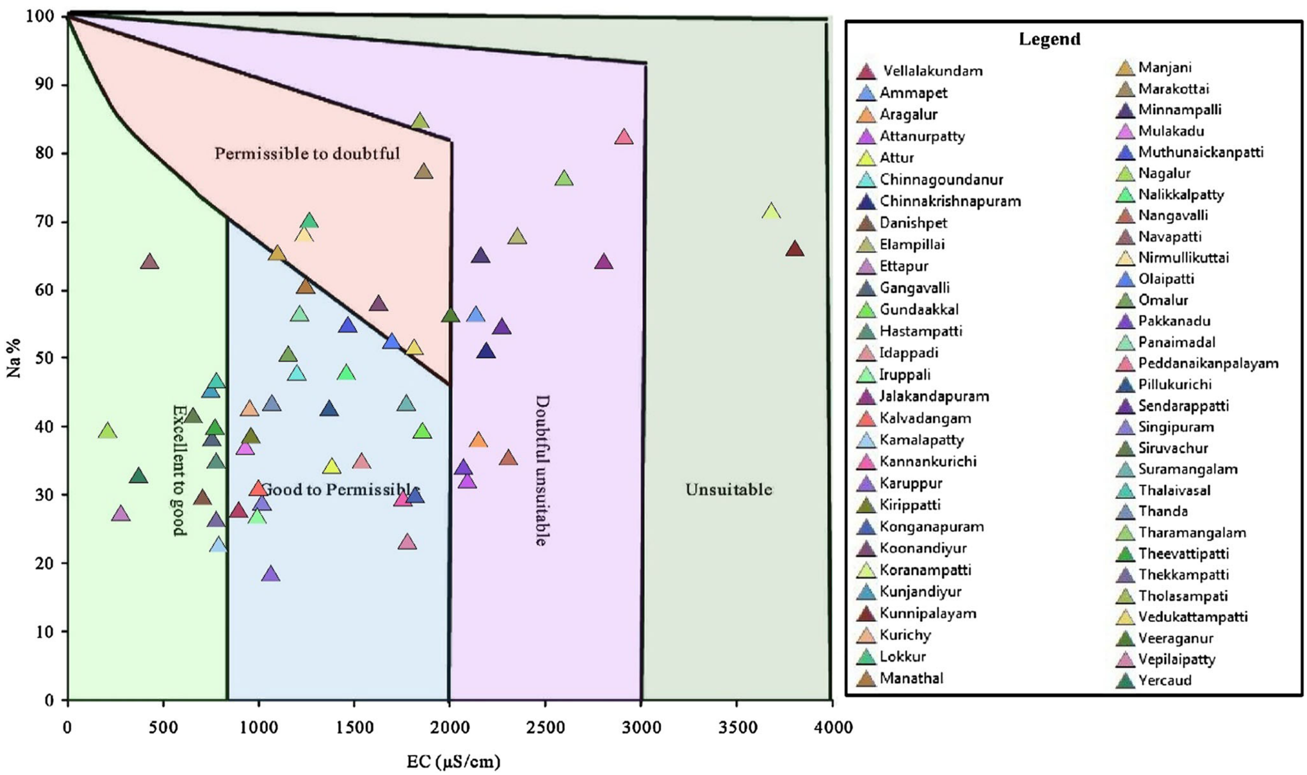

Fig. 11 Wilcox (1955) diagram for classification of groundwater based on EC and Na%

Pakkanadu, Karuppur, Omalur, Gundakkal, Manathal, Olaipatti, Panaimadal, Vedukattampatti, Chinnagoundanur, and Muthunaickanpatti, fall under the C3S1 levels. The zones of C4S2 and C3S1 indicate high-to-very high salinity and low-to-medium alkali water, which are not suitable for soils with restricted drainage and it requires a special management for salinity control (Sappa et al. 2014)

Residual sodium carbonate (*RSC*) RSC is measured to indicate the sodium hazard in water. Irrigation water having >5 RSC value is considered as harmful to the growth of plants, whereas water having >2.5 RSC value is not considered suitable for irrigation, and <2.5 RSC value is considered as suitable for irrigation (Tiwari et al. 2016b). The study area RSC value ranges from 0 to 9 with the mean value of 1 (Table 2). Tholasampatti, Tharamangalam, and Marakottai villages are harmful to growth of plant. Elampillai, Lokkur, and Manathal villages are considered as not suitable for irrigation. Rest of the villages are having RSC value below 2.5, which are suitable for irrigation.

Kelly index (*KI*) Water with less than 1 Kelly's index value indicates suitable for irrigation (Kelley 1940; Paliwal 1967). Kelly index value of study area ranges from 0 to 10 with mean value of 2 (Table 2). The villages Vepilaipatty, Vellalakundam, Attanurpatty, Ettapur, Singipuram, Kamalapatty, Yercaud, Nagalur, Kannankurichi, Hastampatti, Kalvadangam, Iruppali, Konganapuram, Idappadi, Pakkanadu, Danishpet, Karuppur, and Thekkampatti (30%) have good quality of groundwater for irrigation purposes. Rest of the (70%) samples are not suitable for irrigation purposes based on KI value.

Magnesium hazard (*MH*) The excess amount of Mg in the groundwater affects the quality of soil, resulting in poor agricultural returns (Tiwari et al. 2016b). Magnesium hazard in groundwater >50 is considered as harmful and unsuitable for irrigation use (Szabolcs and Darab 1964). The study area MH value ranges from 23 to 89 with a mean value of 66 (Table 2). Mulakadu, Vepilaipatty, Ettapur, Thalaivasal, Manjani, Peddanaikanpalayam, Kamalapatty, Yercaud, Nagalur, and Lokkur have a suitability of irrigation water. Rest of the (83%) samples are not suitable for irrigation purposes based on MH value.

Conclusion

Water chemistry of the Salem district highly reflects the primary sources from weathering of rocks and its minerals, with secondary dominance of anthropogenic activities. The results of the investigation show that the following types of water dominates in the Salem district were calcium chloride type (4%), magnesium bicarbonate type (18%), sodium chloride type (27%), and mixed type of water (51%). Rock water interaction is the main sources of the chemical composition, and the study area predominantly

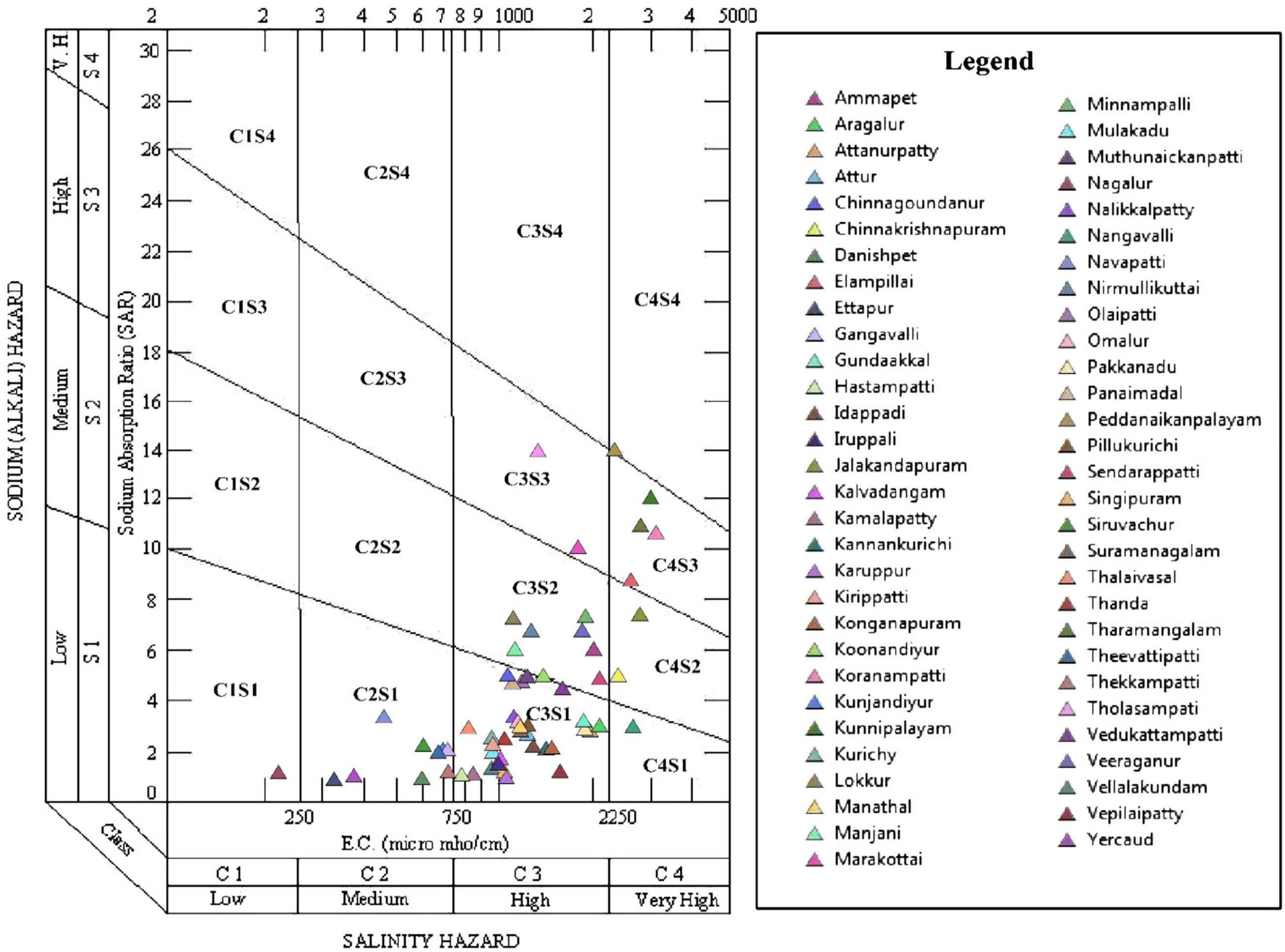

Fig. 12 USSL diagram for classification of irrigation

comprised by fissile hornblende biotite gneiss and charnockite.

The WQI results show excellent water (8%), good water (48%), and poor water (44%) of samples for domestic and irrigation uses. 44% of poor water samples mostly were observed in the western part of the study area. The western part and other parts of poor water quality in the study area were obviously covered by agricultural land and settlement area. Due to these agricultural wastes, fertilizer used, soil leaching, sewage, livestock waste, and urban runoff were highly contaminated the groundwater. The total dissolved solid, anions (F^-, Cl^-, and NO_3^-), and cations (Mg^{2+} and Na^+) are more responsible parameters of poor water quality for drinking purposes of the study area.

Some samples of groundwater in the study area are unsuitable for irrigation uses, because these samples have high salinity, hardness, and magnesium concentration. If it is used for irrigation, it will affect the plant growth and contaminate the quality of soil. In general, the impact of agricultural runoff, anthropogenic activities, ion exchange, and weathering is the sources of the groundwater pollution in the study area. In this situation, the following suggestions are necessary to manage the water quality of the study area. The farmers should take an effort to mitigate the effects of agricultural runoff. Government must initiate and create awareness of the vulnerability of high using fertilizers. Anthropogenic activities should be controlled by government, management, and maintenance and should carry over the water resources to break the contamination.

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