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RESEARCH ARTICLE

GROUNDWATER QUALITY INVESTIGATION IN GANDARVAKOTTAI, KARAMBAKKUDI,
ALANGUDI, ARANTHANGI TALUKS, IN PUDUKKOTTAI DISTRICT, TAMILNADU

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ABSTRACT

Water is a vital resource for human survival. In the present study, the physicochemical characteristics of groundwater of Alangudi, Aranthangi, Gandharvakottai and Karambakkudi Taluks, Pudukkottai District, Tamilnadu, India. In the study area were assessed for its suitability for drinking and irrigation purposes. A total of 100 water samples were collected from tube wells from different parts of study area. In order to assess the ground water quality, the water samples were analyzed for different physicochemical properties, e.g., pH, electrical conductivity (EC), total dissolved solids (TDS), calcium, magnesium, total hardness (TH), sodium, potassium, carbonate, bicarbonate, chloride, and sulphate concentrations. The results were compared with the standards prescribed by World Health Organization (WHO) and Bureau of Indian Standard (BIS). All the physicochemical parameters were found to be in the prescribed permissible limit. The chemical composition of the ground water is controlled by rock water interaction with sandstone, clay and Archaean to Proterozoic deposits. The chemical quality was evaluated for drinking use following the guidelines of WHO. The water quality index indicated that most of the sampling locations come under good category indicating the suitability of water for human use. Due to the industrialization and agricultural disposal some of the sampling locations became unfit

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INTRODUCTION

Water is one of the most essential natural resources for eco-sustainability and is likely to become critical scarce in the coming decades due to increasing demand, rapid growth of urban populations, development of agriculture and industrial activities especially in semi-arid regions (Hajalilou, and Khaleghi, 2009). Variations in availability of water in time, quantity and quality can cause significant fluctuations in the economy of a country. Hence, the conservation, optimum utilization and management of this resource for the betterment of the economic status of the country become paramount (Singh *et al.*, 2009). The definition of water quality is very much depending on the desired use of water. Therefore, different uses require different criteria of water quality as well as standard methods for reporting and comparing results of water analysis (Khodapanah *et al.*, 2009). On the other hand, GIS is very helpful tool for developing solutions for water resources problems to assess in water quality, determining water availability and understanding the natural environment on a local and / or regional scale.

From GIS, spatial distribution mapping for various pollutants can be done. The resulting information is very useful for policy makers to take remedial measures (Swarna Latha and Nageswara Rao, 2010). Suresh and Kottureshwara (2009) have been studied the water quality studies of Hospet taluka region in Bellary district, Karnataka, 40 groundwater samples were collected and chemically analysed. The analysis revealed that the water was slightly alkaline (pH: 7.1 - 8.2), moderately hard (TH: 130 - 892 mg/L) and TDS values ranged from 240 to 1650 mg/L. The other parameters like SAR (2.7-13.5), percent sodium (10.2 - 54.0) and magnesium ratio (7.8 -21.5) were also below the desirable limits. Fluoride was most dominant ion responsible for contamination of the groundwater. Eleven water samples of the study area were prone to excess fluoride concentration (>1.2mg/L) and not suitable for drinking purpose. According to USSL diagram most of the samples falls in C_2S_1 , C_2S_2 , C_3S_1 and C_3S_2 , which indicating its suitable nature for drinking and irrigation purposes. Based on the Piper trilinear diagram it was confirmed that the dug wells were characterized by secondary alkalinity in the study area. The presence of *E-coli* in only five dug wells, and only one dug well indicated potential dangerous faecal contamination, which require immediate attention.

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Medudhula *et al.* (2012) have been suggested Analysis of water quality using physico-chemical parameters in lower manair reservoir of Karimnagar district, Andhra Pradesh. This study was aimed to estimate current status of physico-chemical characteristic of Lower Manair Reservoir at Karimnagar District, Andhra Pradesh. Monthly changes in physico-chemical parameters such as water temperature, pH, turbidity, transparency, total dissolved solids, total hardness, chlorides, phosphate, nitrates, dissolved oxygen and biological oxygen demand were analyzed for a period of one year from September 2009 to August 2010. The results indicated that physico-chemical parameters of the water were within the permissible limits and can be used for domestic, irrigation and pisciculture. Srinivas Kushtagi and Padaki Srinivas (2012) have been identified studies on water quality index of ground water of aland taluka, gulbarga District, Karnataka. Water Quality Index is one of the most effective tools to communicate information on the quality of ground water to the concerned citizens and policy makers. The objective of the present work is to assess the suitability of ground water for human consumption based on the computed water quality index values, ground water characteristics and quality assessment. Ten villages of Aland taluka are selected and at each village water samples at three places were collected using standard procedural methods and analyzed for pH, TH, Ca, Mg, Cl, TDS, Fe, F, NO₃, SO₄.

MATERIALS AND METHODS

STUDY AREA

The taluks located in the south eastern part of district. The taluks lies between latitude 10° 10' N to 10° 45' N Longitude 78° 50' E to 79° 15' E and falls in the survey of Indian Toposheets 58 J/14, 58 J/15, 58 J/16, 58 N/2, 58 N/3, 58N/4 in the scale of 1:50,000. The geographical extent occupies an area of 1794.14 sq.km. The location map of study area are given in figure 1.1. The study area bounded on the north by Thanjavur district, east by Orathanadu and Patukkottai Taluks, and pudukkottai taluk situated in the western part, and south part of manalmelkudi taluk. The study area is bounded by two rivers namely Vellur river on the west and Agniar river on the north. It has gentle slope towards west to east. The study area forms the elevation is plain terrain (Fig. 1).

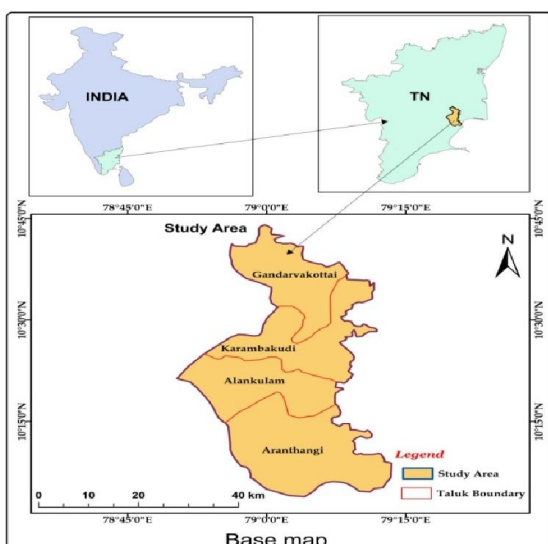


Fig.1 Study area map

The classical use of water analyses in groundwater hydrology is to produce information concerning the water quality. Understanding the groundwater quality is important as it is the main factor determining its suitability for drinking, domestic, agricultural and industrial purposes. The groundwater quality can be understood in two ways, i.e., Parts per million (ppm) or Milliequivalent weight (epm). The groundwater quality parameters and their minimum, maximum, and mean concentrations of physico-chemical parameters of water quality such pH, EC, TDS, and major anions and major cations are presented and BIS (1998) and WHO (1993) (PPM, Chemical Indices and Statistical Parameter) in Table 1, and 2 respectively.

Samples were collected from both dug and bore wells to evaluate the variation in chemical composition. A total of 100 groundwater samples were collected from the study area during the monsoon season. These water samples were collected in acid-washed, well-rinsed, and low-density polyethylene bottles. All of the samples were collected after pumping the wells for 15–20 min to ensure that water stored in the well is removed. Before sampling, bottles were thoroughly rinsed two to three times with representative groundwater samples. Electrical conductivity (EC) and pH were measured in the field using precalibrated portable conductivity and pH meters. In the laboratory (Agriculture Office, Mannarpuram, Trichy), the samples were filtered to separate the suspended sediments. Only highly pure (of analytical grade) chemicals and double-distilled water were used in preparing the solutions. The samples were analyzed for major ions in the laboratory using standard methodologies (APHA 1995). Calcium (Ca) and magnesium (Mg) were determined titrimetrically using standard EDTA; chloride (Cl) was determined by standard AgNO₃ titration; bicarbonate (HCO₃) was determined by titration with HCl; sodium (Na) and potassium (K) were measured by flame photometry; sulfate (SO₄) was determined by spectrophotometric turbidimetry (CL 22D); nitrate (NO₃) were determined by using UV spectrophotometer. Care was taken that the pH and EC and the HCO₃ and Ca ions were analyzed within 24 h of sampling.

RESULTS AND DISCUSSION

Hydrochemistry of groundwater

In the study area, the hydrogen ion concentration (p^H) in the samples ranges from 6.5 to 8.1 with an average around 7.24. As for ISI (1983) standards all the samples fall within the recommended limits (6.5 to 8.5) and suitable for human consumption (Fig. 2). EC is measured in microsiemens/cm (μS/cm) and is a measure of salt content of water in the form of ions (Karanth, 1987). The EC varies from 150.00 to 1640.00 μS/cm and average is 786.06. The classification of groundwater on the basis of irrigation quality (WHO 2008) shows that 92% of samples fall within the permissible limits (Fig. 3). Among the 100 samples only five samples exceeds the permissible limit of 1500 μS/cm set by WHO. These five samples viz., sample number 73,91,93,95 and 96 represents the water.

The TDS values vary from 96.0 to 1049.60 mg/L and average of 503.72 mg/l. Degree of groundwater quality can be classified as Desirable of drinking, if the TDS is less than 500 mg/L; Permissible for drinking, if the TDS is between 500-

Table 1. WHO Standard table

.No.	Parameters	BIS (1998)		WHO (1993)		Undesirable Effect on Human	
		Permissible	Excessive	Permissible	Excessive		
1	pH	-	6.5	9.2	6.5	8.5	Taste
2	Ec	-	-	-	-	-	-
3	Calcium	-	75	100	75	200	Scale formation
4	Magnesium	-	30	100	50	150	Scale formation
5	Sodium	-	-	-	-	200	-
6	Potassium	-	-	-	-	-	-
7	Sulphate	-	200	400	200	400	Laxative Effect
8	Chloride	-	250	1000	200	600	Salty Taste
9	Phosphate	-	-	-	-	-	-
10	Nitrate	-	45	45	-	45	Blue Baby disease
11	TDS	-	500	1000	300	600	Gastrointestinal irritation
12	Total Hardness	-	300	600	100	500	Scale formation
13	Total Alkalinity	-	200	600	-	-	-
14	Fluoride	-	1	1.5	-	1.5	Fluorosis

Table 2. Statistical parameter of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

Sl. No	Parameters	Unit	Statistics			
			Maximum	Minimum	Average	Std.Deviation
1	pH	Range	8.10	6.50	7.24	0.29
2	Ec	µs/cm	1,640.00	150.00	787.06	352.20
3	TDS	mg/l	1,049.60	96.00	503.72	225.41
5	HCO ₃ ⁻	mg/l	616.00	43.00	228.76	130.50
6	Cl ⁻	mg/l	305.00	14.00	119.42	70.50
7	SO ₄	mg/l	149.00	1.00	25.08	23.75
8	NO ₃ ⁻	mg/l	88.00	1.00	21.96	18.29
9	Ca ²⁺	mg/l	62.00	10.00	30.84	10.72
10	Mg ²⁺	mg/l	94.00	9.00	34.35	19.80
11	Na ⁺	mg/l	196.00	0.00	75.47	52.18
12	K	mg/l	94.00	0.00	9.91	14.71

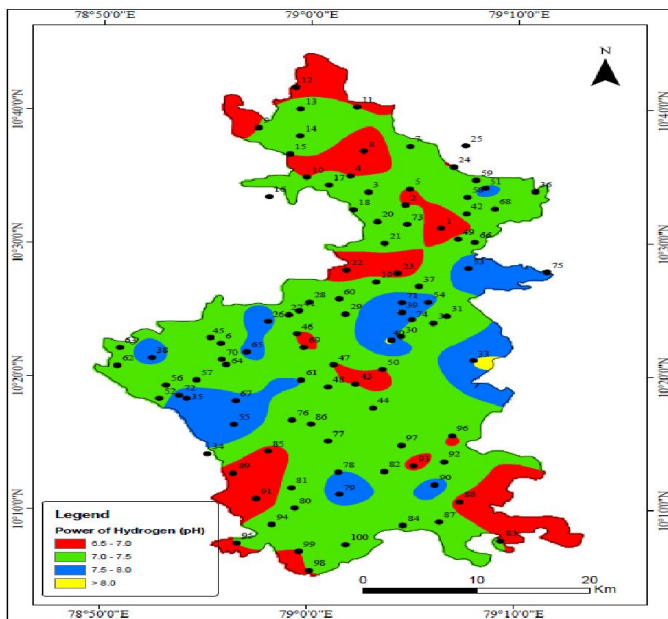


Fig. 2. pH map of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

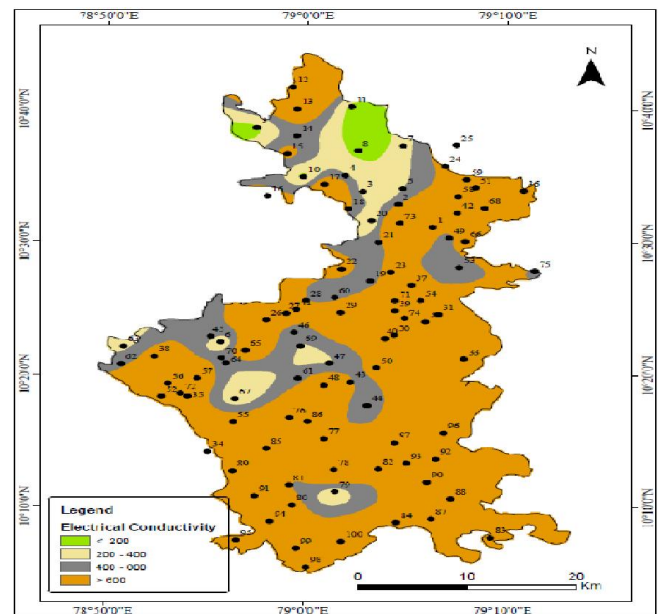


Fig. 3. Electrical Conductivity (µs/cm) map of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

1000 mg/L; Useful for Irrigation, if the TDS is between 1000-3000 mg/L and Unfit for drinking and irrigation if the TDS is >3000 mg/L (Fig. 4) (Davis and Dewiest 1966). Accordingly, the quality of groundwater in the present study area is classified as desirable and permissible for drinking in 51% samples. 47% of samples in pre monsoon are useful for irrigation. unfit for drinking and irrigation in 2%.

Degree of groundwater quality can be classified as fresh, if the TDS is less than 1,000 mg/L; brackish, if the TDS is between 1,000 and 10,000 mg/L; saline, if the TDS is varied from

10,000 to 1,000,000 mg/L; and brine, if the TDS is more than 1,000,000 mg/L (Freeze and Cherry.1979). Accordingly, the quality of groundwater in the present study area is classified fresh water type in 98% samples. Brackish water type in 2%. Saline and Braine Water type are not available in the study area as per the classification. The concentration of Ca²⁺ is between 10 and 62 mg/ L and average value of 30.84 mg/l while that of the concentration of Mg²⁺ varied from 9 to 94 mg/L with an average value of 30.84 mg/l. Degree of groundwater quality can be classified into Four types based on calcium and Magnesium; Such as Calcium < 15,15-30,30-45 and >45 for

magnesium < 20, 20-40,40-60 and > 60 mg/L. According to WHO 1993 and BIS 2003, the desirable to permissible limit for Ca^{2+} and Mg^{2+} in groundwater are 75-200 mg/L and 30-150 mg/L respectively.

permissible limits and K^+ 18% of samples falls above the allowable limit. The study area is covered by sandstone and recent formation. This is because of the silicate weathering and/or dissolution of soil salts stored by the influences of

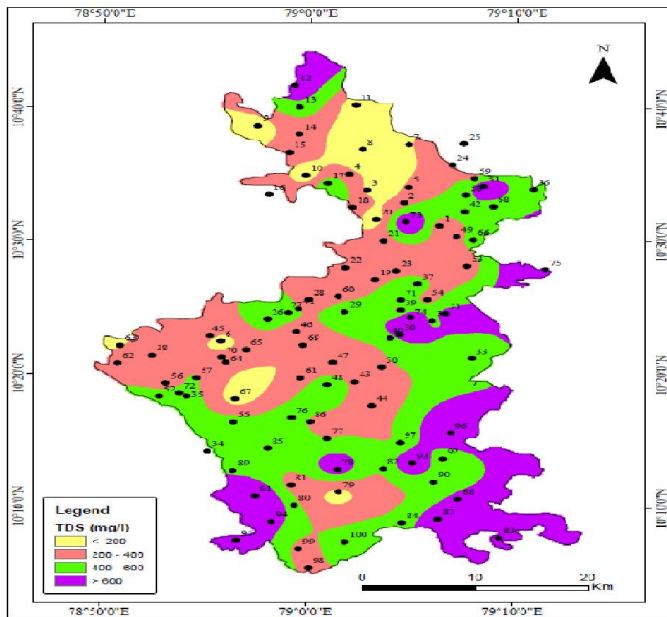


Fig. 4. Total Dissolved Solids map of Alangudi, Gandharvakottai, Karambakkudi and Aranthangi Taluks

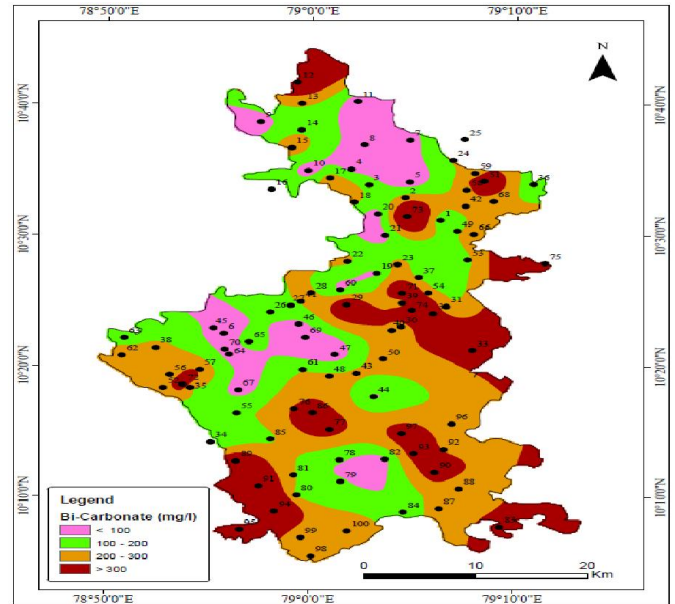


Fig. 6. Bi-Carbonate (HCO_3^-) Concentration map of Alangudi, Gandharvakottai, Karambakkudi and Aranthangi Taluks

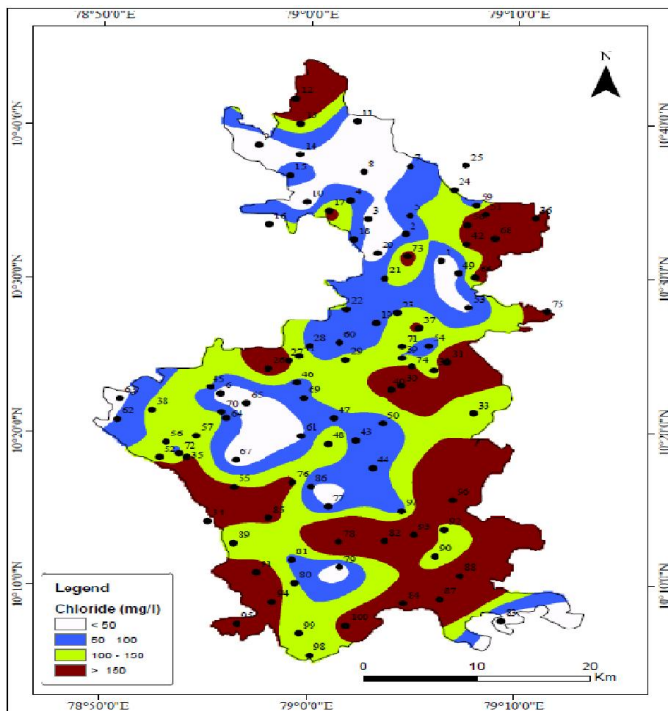


Fig. 5. Chloride (Cl^-) Concentration map of Alangudi, Gandharvakottai, Karambakkudi and Aranthangi Taluks

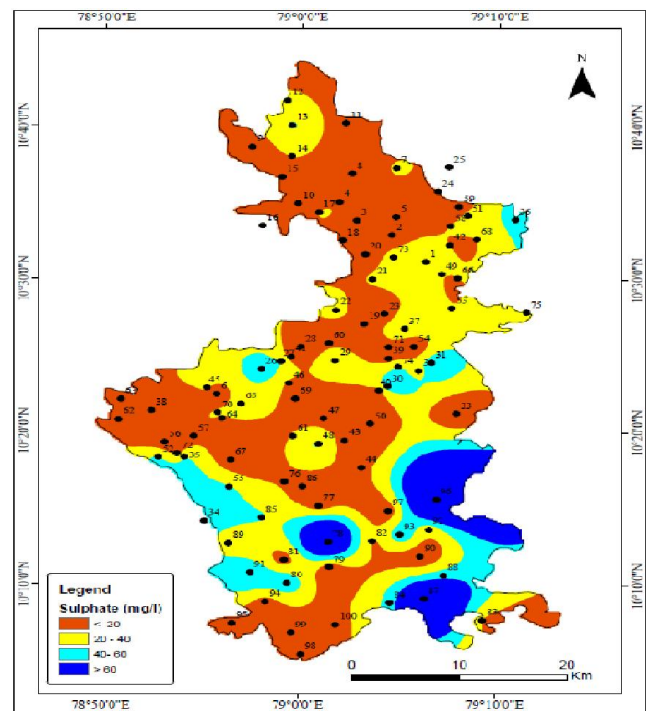


Fig. 7. Sulphate (SO_4^{2-}) Concentration map of Alangudi, Gandharvakottai, Karambakkudi and Aranthangi Taluks

The quality of groundwater in the present study area all samples fall within the permissible limit and the Magnesium is all samples fall within the permissible limit. The permissible limit of Na^+ and K^+ in groundwater is 200 mg/L and 12 mg/L respectively (WHO 1993). The concentration of Na^+ varied from 0 to 196 mg/L and an average of 52.18 mg/l; K^+ varied from 0 to 94 mg/L and an average of 14.71 mg/l. All samples for Na^+ within the

evaporation and anthropogenic activities (Subba Rao, 2002), in addition to the agricultural activities and poor drainage conditions. Moreover, the solubility of Na^+ -salts is generally high. The higher contribution of Na^+ than that of the contribution of Ca^{2+} to the total cations is expected due to influence of ion exchange. The spatial distribution of Na^+ ions along SW and SE direction higher concentration recorded in patches of study area. Potassium concentration in most of the

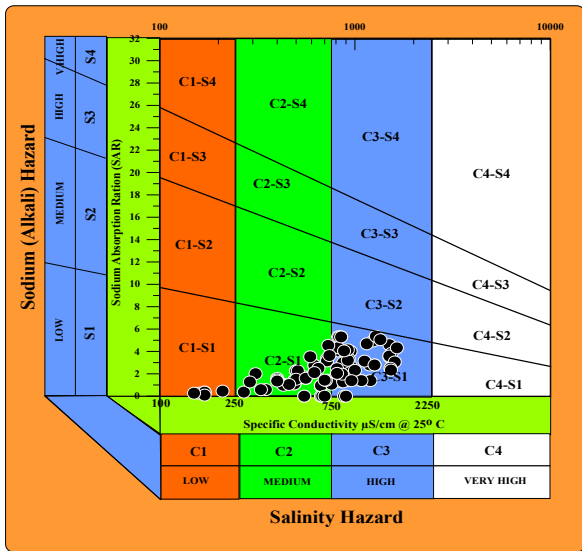


Fig. 8. USSS Diagram of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

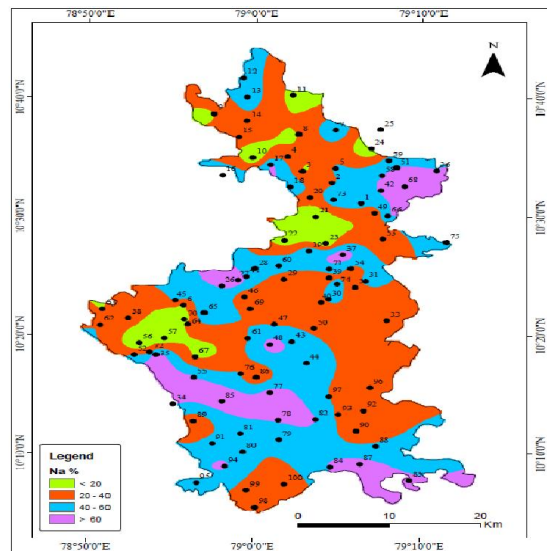


Fig. 11. Sodium Percentage map of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks.

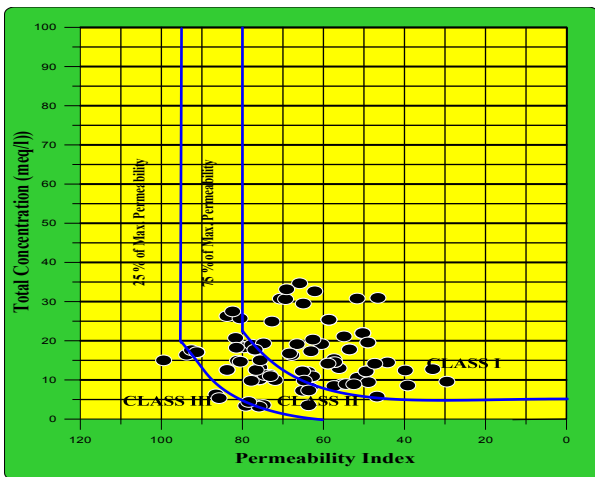


Fig. 9. Doneen Diagram of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

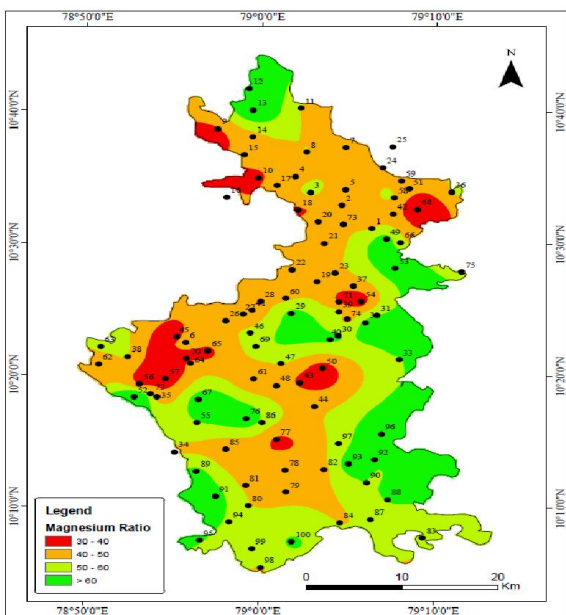


Fig. 10. Magnesium Hazard Concentration map of Alangudi, Gandharvakottai, Karambakudi and Aranthagi Taluks

sample fall in the category of < 5 mg/L. Sodium toxicity is recorded as a result of normal sodium in water as Na% and SAR ratios. Based on Na⁺ and K⁺ distribution the region can be classified zones. It's the most dominant ion in the anionic pool (Fig. 5). Its concentration ranges from 14- 305 mg/L with an average value of 119.42 mg/L. The maximum concentration (>200mg/L) of chloride were found in the SE and SW part of study area However 11 samples crossed the maximum allowable limit set by WHO. Sedimentary rock contribute little chloride in the groundwater. leaching of chloride that has accumulated in upper soil layer may be a significant source of chloride in dry climate. Chloride is the main anion considered to find the suitability of the groundwater for irrigated agriculture. The permissible limit of HCO₃⁻ in groundwater is 300 mg/L (WHO 2008). The concentration of HCO₃⁻ varied from 43 to 616 mg/L with an average of 228.76 mg/L. 79% of samples falls allowable limit. The spatial distribution map of HCO₃⁻ dominance of ions along SE 41 sample fall in below 200 mg/L category for entire area. (Fig. 6). Sulphate ion is the third important anion in the study area. The sulphate ion concentration ranges from 1- 147 mg/L with an average value of 25.08 mg/L. The maximum concentration (> 60 mg/L) were observed along the south eastern edge of the study area including Nakkudi,Rajendrapuram and melpanaikadu. The northwest side of study area were found to have least concentration (<20 mg/L) of sulphate ion However, all the samples were found below the permissible limit of WHO. (Fig. 7).

Salinity hazard versus sodium hazard (USSS)

For assessing the suitability of water quality for irrigation, the hazards, which are associated with the salinity and sodium, play a significant role in the development of plant growth. The salinity hazard is a measure of TDS expressed in terms of EC, which reduces the osmotic activity of plants and thus infers with the adsorption of water and nutrients from the soil (Saleh et al. 1999). High salt content forms saline soils, which is the major cause of crop loss. Whereas, the sodium hazard in the water renders it unsuitable for soils, containing exchangeable Ca²⁺ and Mg²⁺ ions, as the soils take up Na⁺ in exchange for Ca²⁺and Mg²⁺, causing deflocculation (dispersion of clay

Table 3. Geochemical parameters (in ppm) in the study area

S No	Location	Ec	pH	Ca	Mg	Na	K	Hco3	Cl	So4	No3	TH	TDS
1	Kallakottai	850	6.5	34	34	90	7	128	21	32	6	225	544
2	Vembanpatti	560	7	32	23	48	1	244	53	6	7	175	358.4
3	Mattangal	350	7.1	20	22	16	2	153	35	8	2	140	224
4	Pisanathur	430	7	26	21	30	1	73	89	18	27	150	275.2
5	Periyakkottai	400	7	20	16	39	1	43	92	11	30	115	256
6	Veeratipatti	170	7.1	10	11	7	0	61	21	3	12	70	108.8
7	Muthukulam	310	7.1	12	10	39	0	61	53	22	15	70	198.4
8	Pudunagar	160	6.9	10	10	5	5	61	14	2	19	65	102.4
9	Nodiyur	170	7	14	9	7	2	61	14	5	19	70	108.8
10	Aritapatti	170	7	16	10	2	1	61	14	5	19	80	108.8
11	Manjampettai	150	7	10	10	5	0	55	18	3	11	65	96
12	Kumpoondi	1500	6.9	40	73	161	0	458	230	24	1.1	400	960
13	Thachchankuruchi	950	7.1	20	49	99	10	220	142	41	68	250	608
14	Komapuram	490	7.2	26	22	41	1	183	43	21	25	155	313.6
15	Manganoor	670	7	40	32	30	33	250	71	1	7	230	428.8
16	Sothuparai	720	7.3	30	21	98	2	201	124	12	21	160	460.8
17	Gandharvakottai	920	7.2	30	26	108	39	250	160	20	20	180	588.8
18	Sunthampatti	620	7	28	18	76	3	214	78	9	25	145	396.8
19	Thuvar	500	7.1	20	18	58	1	98	82	15	56	125	320
20	Neppugai	210	7.3	12	11	9	11	73	25	6	11	75	134.4
21	Antanur	550	7.2	34	28	0	1	85	99	22	56	200	352
22	Vellalaviduthi	690	6.9	40	33	0	25	214	99	24	17	235	441.6
23	Athangaraviduthi	670	6.9	46	43	0	3	226	103	6	7	290	428.8
24	Nadupatti	680	7	30	26	0	4	214	106	7	12	180	435.2
25	Seviyarkudikkadu	880	7	50	30	0	22	293	121	15	26	250	563.2
26	Pisanathur	880	7.6	26	26	122	6	122	184	49	40	170	563.2
27	Mangottai	850	7.3	22	17	136	4	189	160	41	7	125	544
28	Tittanipatti	620	7.2	26	24	62	8	214	92	12	1	165	396.8
29	Ponnamviduthi	1080	7.3	42	72	64	4	427	110	34	16	400	691.2
30	Vanakkankadu	1260	7.2	40	61	120	18	232	266	54	16	350	806.4
31	Pattathikkadu	1190	7.1	40	61	120	18	232	266	54	16	350	761.6
32	Vadatheru	1200	7.2	42	72	64	4	427	110	34	16	400	768
33	Neduvasal melpathi	850	8	38	56	53	3	354	106	5	1	325	544
34	Isakkipatti	860	7.4	26	26	122	6	122	184	49	40	170	550.4
35	Kathakkurichi	820	7.8	22	17	136	4	189	160	41	7	125	524.8
36	Sengamedu	820	7.4	26	26	122	6	122	184	49	35	170	524.8
37	Pallavarayanpatthai	830	7.3	22	17	136	4	189	160	41	5	125	531.2
38	Thiruvarangulam	720	7.6	38	38	51	1	226	110	12	14	250	460.8
39	Mullanguruchi	730	8	34	38	51	2	226	103	11	16	240	467.2
40	Vandanviduthi	920	8.1	40	62	60	2	281	170	10	13	355	588.8
41	Pudupatti	720	7.3	30	21	92	2	201	124	12	21	160	460.8
42	Muthanviduthi	920	7.2	30	26	108	39	250	160	20	20	180	588.8
43	Kothamangalam	620	7	28	18	76	3	214	78	9	25	145	396.8
44	Kulamangalam	500	7.1	20	18	58	1	98	82	15	56	125	320
45	Manjuviduthi	550	7.2	34	18	50	1	85	99	22	56	200	352
46	Pachikkottai	430	7	26	28	30	1	73	89	18	27	150	275.2
47	Suranviduthi	400	7	20	21	39	1	43	92	11	30	115	256
48	Alangadu	950	7.1	20	16	99	10	220	142	41	68	250	608
49	Mayilankonpatti	490	7.2	26	49	41	1	183	43	21	25	155	313.6
50	Vadakadu	670	7	40	22	30	33	250	71	1	7	230	428.8
51	Papapatti	1500	7.6	40	32	161	0	458	230	24	11	400	960
52	Kallalangudi	950	7.3	20	73	99	10	220	142	41	68	250	608
53	Pilaviduthi	490	7.7	26	49	41	1	183	43	21	25	155	313.6
54	Elakadividuthi	670	7.6	40	22	30	33	250	71	1	7	230	428.8
55	Keezhaiyur	820	7.9	22	32	136	4	189	160	41	7	125	524.8
56	Vallathirakkottai	700	7.2	30	17	0	4	214	106	7	12	180	448
57	Sanmuganathapuram	900	7.3	50	26	0	22	293	121	15	26	250	576
58	Regunathapuram	930	7.4	30	30	108	39	250	160	20	20	180	595.2
59	Keerathur	650	7.1	28	26	76	3	214	78	9	25	145	416
60	Malaiyur	510	7.2	20	18	58	1	98	82	15	56	125	326.4

61	Pattamaviduthi	500	7.5	26	18	41	2	190	43	21	25	155	320
62	Kaikkuruchi	560	7.3	32	22	48	1	244	53	6	7	175	358.4
63	Thirukattalai	330	7.4	20	23	16	2	153	35	8	2	140	211.2
64	Mekkapatti	460	7.2	26	22	30	1	73	89	18	27	150	294.4
65	Kovilur	870	7.6	34	21	90	7	128	21	32	6	225	556.8
66	Karambaviduthi	920	7.2	30	34	108	39	250	160	20	20	180	588.8
67	Vennavalkudi	270	7.6	14	26	10	11	73	25	6	11	75	172.8
68	Peyadipatti	920	7.2	30	13	108	39	250	160	20	20	180	588.8
69	Rasiamangalam	400	7	20	26	39	1	43	93	11	30	115	256
70	Kothakottai	550	7.2	34	16	0	1	85	99	22	56	200	352
71	Surakkadu	1120	7.8	44	28	108	2	482	113	14	6	325	716.8
72	Kanniyapatti	950	7.7	40	52	71	5	403	96	14	4	315	608
73	Chokkampatti	1540	7.5	60	52	168	23	543	177	29	68	375	985.6
74	Kottaikkadu	1500	7.5	62	55	161	8	598	160	41	40	450	960
75	Rangianviduthi	590	7.6	54	72	168	94	616	170	38	42	360	377.6
76	Paravakottai	1000	7.3	28	56	92	5	311	163	18	7	300	640
77	Avanathankottai	730	7.3	24	15	115	2	348	50	7	16	120	467.2
78	Rajendrapuram	1240	7.5	36	36	175	1	116	284	120	7	240	793.6
79	Rethnakottai	290	7.6	10	9	23	2	110	25	6	27	60	185.6
80	Aranthangi	810	7.1	32	33	83	9	189	110	55	53	215	518.4
81	Mukkudi	620	7.1	26	24	62	8	214	92	12	1	165	396.8
82	Mangudi	740	7.3	24	21	101	7	79	199	20	13	145	473.6
83	Vellatumangalam	1150	7	32	35	161	6	336	19	20	9	225	736
84	Memangalam	880	7.1	26	26	122	6	122	184	49	40	170	563.2
85	Chithambaraviduthi	850	6.9	22	17	136	4	189	160	41	7	125	544
86	Karakkadu	760	7.4	34	47	41	7	360	53	11	11	280	486.4
87	Nakkudi	1280	7.3	32	35	184	13	256	220	110	13	225	819.2
88	Subramaniyapuram	1260	6.8	40	61	120	18	232	266	54	16	350	806.4
89	Sengambarai	1080	6.8	42	72	64	4	427	110	34	16	400	691.2
90	Arasarkulam melpathi	870	7.7	38	56	53	3	354	106	5	1	325	556.8
91	Alapiranthan	1600	6.9	42	75	143	71	470	213	58	88	415	1024
92	Ayingudi	860	7.1	30	47	74	2	293	117	24	6	270	550.4
93	Vallavari	1520	6.9	48	90	127	2	348	305	53	1	490	972.8
94	Idaiyur	1350	7.1	32	45	189	6	519	177	12	5	265	864
95	Kummakkadu	1640	7	44	68	196	9	458	301	14	20	390	1049.6
96	Melapanaikkadu	1530	7	46	94	120	10	214	301	149	22	500	979.2
97	Perialur	810	7.3	34	40	74	7	348	85	5	11	250	518.4
98	Trivaipadi	710	7	38	38	51	1	226	110	12	14	250	454.4
99	Viramangalam	700	7	34	38	51	2	226	103	11	16	240	448
100	Kilcheri	960	7.2	40	62	60	2	281	170	10	13	355	614.4

particles) and impairment of tilth and permeability of soils. Sodium forms alkaline soils, with a combination of carbonates, and saline soils, with an association of chlorides, which do not support the plant growth.

Sodium hazard is a tendency of water to replace adsorbed Ca^{2+} plus Mg^{2+} with Na^+ , which is expressed in terms of sodium adsorption ratio (SAR). This is a ratio of Na^+ ion concentration to square root of half of combination of Ca^{2+} and Mg^{2+} ions concentration (Eq. 6). Another expression of sodium hazard is percent sodium ($\% \text{Na}^+$). This is a ratio of combination of Na^+ and K^+ ions concentration to combination of Ca^{2+} , Mg^{2+} , Na^+ , and K^+ ions concentration, which is multiplied by 100 (Eq. 7). Where the concentrations of all ions are expressed in milliequivalents per liter. The measured value of EC is varied from 150 to 1640 and the computed value of SAR is between 0 and 5.35 from the groundwater collected from the study area. The chemical data of the area are plotted in the salinity hazard versus sodium hazard diagram designed by the USSSL (1954; Fig. 8), which judges the water quality for irrigation.

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\frac{(\text{Ca}^{2+} + \text{Mg}^{2+})}{2}}}$$

$$\% \text{Na}^+ = \left[\frac{(\text{Na}^+ + \text{K}^+)}{(\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+)} \right] \times 100$$

The USSSL's diagram classifies the water quality into 16 zones to assess the degree of suitability of water for irrigation, in which the salinity hazard (C) can be divided into four sub-zones, such as low-salinity hazard (C1, <250 $\mu\text{S}/\text{cm}$), medium-salinity hazard (C2, 250 to 750 $\mu\text{S}/\text{cm}$), High-salinity hazard (C3, 750 to 2,250 $\mu\text{S}/\text{cm}$), Very high-salinity hazard (C4, 2,250-4,000 $\mu\text{S}/\text{cm}$) considering them as good, moderate, moderate to poor, poor, and very poor water classes, respectively. Similarly, the sodium hazard (S) can also be classified into four sub-zones, such as low-sodium hazard (S1, <10), medium-sodium hazard (S2, 10 to 18), high-sodium hazard (S3, 18 to 26), and very-high-sodium hazard (S4, >26), considering them as good, moderate, poor, and very poor classes, respectively. Approximately 44.94% of the total groundwater samples fall in

the zone of C2-S1, indicating a water of medium-salinity hazard (C2) and low-sodium hazard (S1), Crops of moderate salt tolerance can be irrigated with this water without special practices for salinity control and it can be used for irrigation on almost all soils, with little danger of the development of harmful levels of exchangeable sodium. USSL diagram depicts approximately 46.07% samples of the groundwater falls in the zone of high-salinity hazard (C3) and low- sodium hazard (S1). Even with adequate drainage, special management for salinity control may be required and crops of good salt tolerance can be selected. 6.74% and 2.25% for of the groundwater samples are observed from the zones of C1-S1, C2-S2 respectively.

Permeability index (pi) doneen (1964)

Doneen (1964) has classified the irrigation water on the basis of permeability index (PI) (Fig. 9) which indicate the rate of suitability of water for irrigation. Permeability is greatly influenced by Na,Ca,Mg,HCO and Cl contents of soil and hence is affected by long-term use of irrigation water, with high salt content. The PI is a ratio of combination of Na and square root of HCO ions concentration to combination of Ca , Mg and Na ions concentration, which is multiplied by 100 (Eq.3)

$$PI = \left[\frac{(Na^+ + \sqrt{HCO_3^-})}{(Ca^{2+} + Mg^{2+} + Na^+)} \right] \times 100$$

Where all ionic concentrations are expressed in milliequivalents per liter. The water quality can be classified into three classes on the basis of PI. They are a) Class I, (b) Class II, (c) Class III. The class I, which has 100% maximum permeability, is suitable for irrigation. The class II, which shows 75% maximum permeability, is marginally suitable for irrigation. The class III, which is associated with the 25% maximum permeability, is unsuitable for irrigation. The PI is observed to be varied from 29.54 to 99.45 with average are 67.22 from the present study area. According to the classification of PI, approximately 55% groundwater sample come under the class I (Suitable), 35% groundwater sample under the class II (marginally suitable) for Irrigation, and 10% groundwater sample under the class III (Unsuitable for irrigation).

Magnesium Hazard (MH)

Szaboles and Darab (1964) have proposed a magnesium hazard for assessing the suitability of water quality for irrigation. Generally, Ca²⁺ and Mg²⁺ maintain a state of equilibrium in water, and they do not behave equally in the soil system. Magnesium damages soil structure, when water contains more Na⁺ and high saline. Normally, a high level of Mg²⁺ is caused by exchangeable Na⁺ in irrigated soils. In equilibrium, more Mg²⁺ can effect soil quality by rendering it alkaline. Thus, it affects crop yields. The magnesium hazard is expressed in terms of magnesium ratio (MR). This is a ratio of Mg²⁺ ion concentration to combination of Ca²⁺ and Mg²⁺ ions concentration, which is multiplied by 100 (Eq. 9).

$$MR = \left[\frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} \right] \times 100$$

where all ionic concentrations are expressed in milliequivalents per liter. If MR exceeds the value of 50, the water associated with such a value is considered to be harmful and hence is unsuitable for irrigation, because it adversely affects the crop yields. In the present study area, the MR is varied from 30.23 to 78.49 an average of 50.18. The MR exceeds the value of 50 in approximately 39% of the groundwater samples, which are not suitable for irrigation. In the remaining 61% of the groundwater samples, the MR is less than the value of 50 and hence they are suitable for irrigation. (Fig.10).

Corrosivity Ratio (CR)

Corrosivity ratio (CR) denotes susceptibility of groundwater to corrosion and is expressed as ratio of alkaline earths to saline salts in groundwater. The corrosivity ratio is defined by formula:

$$Corrosivity\ Ratio = \frac{(Cl/35.5)+2(SO_4/96)}{2(CO_3 + HCO_3)/100}$$

All ions are in parts per million. The effects of corrosion are losses in the hydraulic capacity of pipes. Many researchers have used the ratio to evaluate corrosive tendency of groundwater on metallic pipes in different areas (Balasubramanian 1986; Sankar 1995; Aravindan et al.2004). The corrosivity ratio of groundwater samples of the study area ranges from 0.22 to 7.32 with an average value of 1.77. The groundwater samples have a CR of less than 1 (<1) to be safe zone and more than 1 (>1) to be unsafe. Pre monsoon 39% groundwater sample falls in safe zone and rest of 61% samples are falls in the unsafe zone. Its reveals that noncorrosive pipes, viz., polyvinyl chloride, should be used for water supply instead of metal pipes in the study region.

Sodium Percentage (NA%)

The sodium percentage (Na%) is calculated using the formula given below.

$$Na\% = \frac{Na + K}{Ca + Mg + Na + K} \times 100$$

Where all ionic concentrations are expressed in meq/L.

Sodium content is a major parameter to assess it suitability of water for irrigation (Wilcox, Op. cit). Excess of sodium combining with carbonate can lead to the formation of alkaline soils and at the same time with chloride the saline soils are formed. Both these soils would not support growth of crops. A maximum of 60% sodium in groundwater is permissible for agricultural uses (Ramakrishna, 1998). It can be classified into three horizons in various ranging from less than 20%, 20-40%, and 40-60% and greater than 60%. 60% samples fall in category of 20-40 and 40-60% and rest of the samples fall in other category. (Fig.11).

Conclusion

In this study characterization of the physiochemical parameters of groundwater from twenty five tube wells at different locations in Ambala Cantonment area was carried out. To assess the quality of ground water each parameter was compared with the standard desirable limits prescribed by

World health organization (WHO) and Bureau of Indian Standard (BIS). From the study it can be concluded that groundwater is safe for drinking purposes from the point of view of levels of pH, EC, TDS, Ca^{2+} , Mg^{2+} , Na^+ , K^+ , CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} . The EC varies from 150.00 to 1640.00 $\mu\text{S}/\text{cm}$ and average is 786.06. The classification of groundwater on the basis of irrigation quality (WHO 2008) shows that 92% of samples fall within the permissible limits. Among the 100 samples only five samples exceeds the permissible limit of 1500 $\mu\text{S}/\text{cm}$ set by WHO. These five samples viz., sample number 73,91,93,95 and 96 represents the water. The TDS values vary from 96.0 to 1049.60 mg/L and average of 503.72 mg/L. Degree of groundwater quality can be classified as Desirable of drinking, if the TDS is less than 500 mg/L; Permissible for drinking, if the TDS is between 500-1000 mg/L; Useful for Irrigation, if the TDS is between 1000-3000 mg/L and Unfit for drinking and irrigation if the TDS is >3000 mg/L (Davis and Dewiest 1966). Accordingly, the quality of groundwater in the present study area is classified as desirable and permissible for drinking in 51% samples. 47% of samples in pre monsoon are useful for irrigation. unfit for drinking and irrigation in 2%. According to the classification of PI, approximately 55% groundwater sample come under the class I (Suitable), 35% groundwater sample under the class II (marginally suitable) for Irrigation, and 10% groundwater sample under the class III (Unsuitable for irrigation). The MR exceeds the value of 50 in approximately 39% of the groundwater samples, which are not suitable for irrigation. In the remaining 61% of the groundwater samples, the MR is less than the value of 50 and hence they are suitable for irrigation.

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