RJC

RASĀYAN ***J. Chem.***
Vol. 11 | No. 2 |806 - 818 | April - June | 2018
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

EVALUATION OF HYDRO GEOCHEMISTRY OF NORTH CHENNAI COASTAL AQUIFER TO ASSESS THE GROUNDWATER SUITABILITY FOR DRINKING AND IRRIGATION PURPOSES

T. Siva Subramanian* and Marykutty Abraham
Centre for Remote Sensing and Geoinformatics, Sathyabama Institute of Science and Technology, Jeppiaar Nagar, Chennai-600119.
*E-mail: tpshiva_mani@yahoo.com

ABSTRACT
Pressure on groundwater is increasing for domestic, agricultural and industrial requirements and the water level has fallen drastically. In coastal aquifers, the extraction of groundwater by overpumping leads to seawater intrusion. The present investigation focuses on the evaluation of hydrogeochemical parameters of groundwater of North Chennai area foritssuitability for various purposes. 33 groundwater samples collected from different locations in Araniyar and Kosasthalaiyar river basin in the North East coast of Tamil Nadu were analyzed according to APHA standards. Total Hardness, Sodium Absorption Ratio, Chloride Bicarbonate Ratio, Permeability Index and Kelly's Ratio values were calculated from major ionic concentrations of Na, Mg, Ca, HCO_3 for its suitability for drinking and irrigation purposes. Based on the parameters studied it was found that groundwater in most of the locations in the study area is not good for drinking and irrigation purposes. From this study, it is inferred that groundwater is undergoing quality deterioration near coastal areas. Continuous monitoring of groundwater quality is essential in coastal areas to control saline water intrusion and mange the aquifer from further damage.
Keywords: River basin, Hydrogeochemistry, Coastal aquifer, water quality, Salinity

INTRODUCTION

Groundwater plays a vital role in the sub urban development of Chennai. It is the important renewable resource for domestic, agricultural and industrial purposes in the coastal areas. Rapid urban development, industrial effluents, heavy usage of agricultural fertilizers, municipal wastewater, animal wastes, landfill leakage and extensive pumping are the major reasons for water quality deterioration and saline water intrusion[1].Hydrogeochemistry of groundwater is varying both laterally and vertically. There is a huge imbalance between recharge and discharge and as a result water level has fallen and the use of groundwater became non-potable. Analysis water quality is an important factor in groundwater studies. Groundwater quality is greatly influenced by geological formations, anthropogenic activities and seawater intrusion. The concentration of various dissolved salts present in groundwater depends on several factors like geological age of aquifer material, geologic features of the aquifer material, groundwater flow and contribution from recharge, physicochemical environment and presence or absence of catalytic substances and hydro geochemistry[2].The chemical quality of groundwater is also influenced by nature of soils, geological formation, drainage, irrigation practices, pumping and recharge. Extensive pumping can lead to saline water entering the inland. Continuous evaluation of hydro geochemical parameters is essential to protect the coastal aquifer from saline water intrusion and further contamination[3]. Hencethe geochemical study of the urban coastal aquifer is necessary to assess the suitability of groundwater for various purposes. The present investigation attempts to evaluate groundwater quality in the study area and analyze its suitability for drinking and irrigation purposes.

EXPERIMENTAL

Study Area

The study area is in the coastal zone composed of a wide range of unconsolidated alluvial formation of clay, silt and sand belonging to Tertiary to Quaternary age. The study area covers 296 km and lies

betweenthe northern latitude of 13°12'25.33"and 13°20'01.9" and eastern longitude of 80°19'21.51" and 80°08'44.85". Location map of the study area with sampling points is given in Fig.-1. The alluvium sediments deposited by Araniyar river basin comprises pure sand whereas the korattalaiyar river basin consists of reddish loamy sands with clay. This alluvium consists of potential aquifers known as Madras Aquifer System which provided water to industries and for domestic needs of Chennai city[4].The study area consists of geomorphologic features of coastal plain, beach and beach ridges and sedimentary alluvial plain. In the study area, the unconsolidated sediments are represented by the fluvial and coastal alluvium. Bottom sediments consist of particles have been transported by water, glaciers or air from the sites of their origin in a terrestrial ecosystem and have been deposited on the floor of a lake, river or ocean[5]. The land use/land covers of the study area include town, city, plantation andwaterlogged area. The temperature of the area ranges between a maximum value of 45°C in summer to a minimum value of 25° C in winter. Average annual rainfall is 1200 mm with maximum rainfall during North-East monsoon.

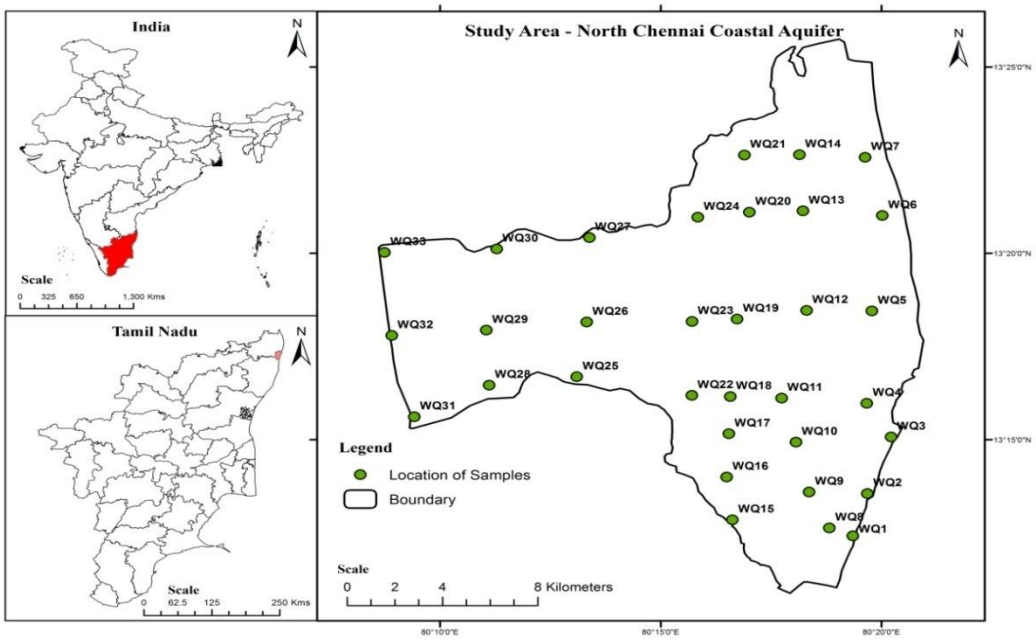

Fig.-1: Map of the Study Area showing locations of groundwater sampling

Groundwater Sampling and Analysis

A total of 33 groundwater samples were collected from 33 locations in the study area for geochemical analysis such as pH, Total Dissolved Solids, Electrical Conductivity, Bicarbonate, Calcium, Magnesium, Sodium, Chloride, Sulphate and Nitrate from dug wells and tube wells as per standard procedure. Locations of groundwater samples collected with distance from coast and elevation are given in Table-1. Groundwater samples from the study area were collected and analysed in three categories based on the location such as Type – I (Sample number 1 to 14) within a maximum 5 km from the sea coast, Type – II (Sample number 15 to 24) between 5km to 10 km from sea coast and Type – III (Sample number 25 to 33) above 10 from sea coast. Laboratory Analysis was carried out as per procedure is given by APHA (2005) [6]. The evaluation of hydrogeochemistry of the study area is based on WHO standard (2004)[7] and Indian standard (IS: 10500, 2012) for drinking[8].

The concentrations of Calcium, Magnesium, Sodium and Bicarbonate were used to calculate Total Hardness (TH), Sodium Absorption Ratio (SAR), Chloride Bicarbonate Ratio (CBR), Permeability Index (PI) and Kelley's Ratio (KR) as per the methods are given below to study irrigation suitability of groundwater samples.

Total hardness of groundwater was computed by the formula[9]:

TH = 2.497 Ca + 4.115 Mg expressed in ppm (1)

The Sodium Absorption Ratio was calculated using the following equation[10]:

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}} \quad (2)$$

The Permeability index was calculated by the following equation[11]:

$$PI = \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} \times 100 \quad (3)$$

The Kelly's ratio was computed using the equation given below[12]:

$$KR = \frac{Na}{Ca+Mg} \text{all ions in epm} \quad (4)$$

Groundwater quality was evaluated and suitability was assessed for drinking and irrigation purposes. The criteria used for categorization is as follows. If all the water quality parameters assessed for a sample fall within the desirable limit for drinking water standards of WHO, then the sample will be accepted in the desirable for drinking category. Similarly, if any parameter of the sample is beyond permissible limit then the sample will be considered unsuitable for drinking. If any of the parameters is only in permissible limit and no parameter is in the unsuitable category, the sample will be accepted in the permissible for drinking category. Similarly, suitability for irrigation will be made on a scale good, moderate and bad category based on parameters for irrigation water quality.

Table-1: Locations of Groundwater samples collected

Sample No.	Location	Latitude	Longitude	Distance from the coast (km)	Elevation (Ft)
1	Kathivakkam	13°12'25.33"	80°19'21.51"	0.06	18
2	Tulsikuppam	13°13'33.69"	80°19'40.57"	0.20	23
3	Mugathuvaram	13°15'05.61"	80°20'13.86"	0.25	2
4	Puzhuthivakkam	13°15'59.7"	80°19'40.54"	1.10	17
5	Kattupalli	13°18'28.75"	80°19'47.07"	1.90	21
6	Karungali	13°21'00.89"	80°20'01.59"	0.90	23
7	Thangalperumbalam	13°22'35.09"	80°19'38.23"	0.90	12
8	Nehru nagar	13°12'38.23"	80°18'49.23"	1.10	11
9	NTECL ash dyke	13°13'36.12"	80°18'22.00"	2.60	8
10	Athipattupudhunagar	13°14'56.55"	80°18'04.1"	4.00	12
11	Athipattu	13°16'07.05"	80°17'44.66"	4.60	11
12	Ooranambedu	13°18'28.5"	80°18'18.67"	4.60	13
13	Kadapakkam	13°21'08.67"	80°18'13.67"	4.90	16
14	Sirupazhaverkadu	13°22'39.37"	80°18'08.85"	3.50	15
15	Manali new town	13°12'51.14"	80°16'37.81"	5.30	16
16	Vallur	13°14'00.42"	80°16'30.22"	6.00	19
17	Vallur camp	13°15'09.78"	80°16'32.82"	7.00	20
18	Nandiyambakkam - H	13°16'09.75"	80°16'34.8"	6.70	20
19	Neidavoyal	13°18'14.45"	80°16'44.21"	7.40	28

20	Kattur	13°21'06.61"	80°17'00.82"	6.30	16
21	Thattaimanji	13°22'38.74"	80°16'53.8"	5.80	17
22	Minjur	13°16'11.67"	80°15'42.54"	8.30	26
23	Maratoor / Kalpakkam	13°18'10.97"	80°15'42.87"	9.20	30
24	Somanjeri	13°20'58.64"	80°15'50.89"	8.50	19
25	Vannipakkam	13°16'41.52"	80°13'06.13"	13.70	43
26	Anuppampattu	13°18'09.73"	80°13'19.61"	13.50	28
27	Lingapayampettai	13°20'26.29"	80°13'23.33"	13.00	29
28	Jaganathapuram	13°16'28.38"	80°11'07.27"	16.50	40
29	Amoor	13°17'56.76"	80°11'03.29"	18.70	52
30	Ponneri	13°20'07.51"	80°11'17.42"	16.90	37
31	Janappanchathiramkoot road	13°15'37.23"	80°09'25.37"	19.50	53
32	Thatchoorkoot road	13°17'48.08"	80°08'54.62"	21.60	56
33	Pudhuvoyal	13°20'01.9"	80°08'44.85"	21.50	46

RESULTS AND DISCUSSION

Physicochemical characters of groundwater samples such as pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured in the field using portable meters. The in situ water tests such as pH, TDS and EC provide useful preliminary information about the water quality of water samples. The groundwater samples were analyzed in the laboratory for Bicarbonate (HCO_3), Calcium (Ca), Magnesium (Mg), Sodium (Na), Chloride (Cl), Sulphate (SO_4) and Nitrate (NO_3) as per American Public Health Association (APHA 2005) methods. Groundwater quality of the study area with locations is presented in table - 2. The analysis shows groundwater quality parameters of the study area vary with respect to distance from sea coast and geologic formation.

Table-2: Groundwater quality parameters of the study area

Sample Number	Location (Village name)	pH	TDS	EC	HCO_3	Ca	Mg	Na	Cl	SO_4	NO_3
1	Kathivakkam	7.26	685	1675	452	96	28.1	376	239	38	14.2
2	Tulsikuppam	6.89	532	2248	124	34	35.3	169	336	84	21.6
3	Mugathuvaram	7.15	897	1722	99	22	23.7	226	425	96	16.8
4	Puzhuthivakkam	7	1966	3530	460	130	166	324	874	214	0
5	Kattupalli	7.25	620	885	178	52	13	144	130	18	9
6	Karungali	8.7	956	1140	289	56	64	200	201	166	7
7	Thangalperumbalam	8.7	1381	2250	356	22	20	474	371	180	3
8	Nehru nagar	7.45	1030	1430	210	28	22	84	199	164	1.22
9	NTECL ash dyke	7.62	1550	2320	432	82	52	373	446	436	2.48
10	Athipattupudhunagar	7.15	647	915	112	22	18	56	140	60	0.4
11	Athipattu	7.2	369	521	96	14	12	64	156	15	0.8
12	Ooranambedu	6.4	741	1270	307	28	41	142	215	94	0
13	Kadapakkam	7.7	2674	5000	185	122	197	589	1392	267	3
14	Sirupazhaverkadu	6.99	647	1964	325	48	21.6	394	356	66	15.2
15	Manali new town	6.85	925	1887	205	136	28.4	365	471	128	26.2

16	Vallur	7.61	932	1102	450	142	11.4	43	331	56	10.4
17	Vallur camp	7.83	982.4	2468	158	59	24.6	69	316	42	9.4
18	Nandiyambakkam - H	7.21	782.2	1219	275	25	12.4	152	221	31	12.2
19	Neidavoyal	8.5	1079	2050	136	102	90	154	512	94	1
20	Kattur	8.4	2108	3160	356	46	122	566	895	190	15
21	Thattaimanji	7.32	546	1105	326	25	10.4	526	246	12	12.4
22	Minjur	7.22	1220	1848	258	22	12	134	236	180	0.84
23	Maratoor / Kalpakkam	7.18	1449	2070	327	150	48	164	422	253	20
24	Somanjeri	8.2	984	1720	307	78	44	225	357	106	3
25	Vannipakkam	8	540	1000	289	32	65	76	147	70	1
26	Anuppampattu	7.41	1220	1712	282	38	22	194	358	150	1.6
27	Lingapayampettai	7.28	893	1275	292	88	26	208	200	72	25
28	Jaganathapuram	7.28	1720	2440	484	44	28	386	428	456	2.64
29	Amoor	7.23	1360	1922	344	25	14	284	468	284	1.22
30	Ponneri	7.7	338	600	130	54	20	16	55	31	12
31	Janappanchathiramkoot road	6.55	297	394	378	58	40	58	184	78	1.62
32	Thatchoorkoot road	6.9	1170	1661	329	32	34	258	454	130	1.22
33	Pudhuvoyal	7.3	703	992	160	28	12	76	166	38	0.1

All units except pH and EC are in mg/l.
Electrical Conductivity (EC) is in µs/cm

Drinking Water Quality

The quality of groundwater samples was compared with the desirable and permissible limits for drinking water of WHO (2004) and Indian Standard (IS 10500: 2012) and are given in Table-3.

Table-3: Quality of groundwater samples based on WHO and Indian Standard

S. No.	Parameter	WHO (2004)		Indian Standards (IS 10500 : 2012)		Quality ofgroundwater samples of the study area		
		Desirable limit	Permissible limit	Desirable limit	Permissible limit	Minimum value	Maximum value	No. of samples and percentagein permissible limit*
1	pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.4	8.7	30 (91%)
2	Total Dissolved Solids	500	1500	500	2000	338	2674	28 (85%)
3	Electrical Conductivity	750	2300	750	3000	521	5000	27 (82%)
4	Bi Carbonate	-	300	-	-	96	484	18 (55%)
5	Calcium	75	200	75	200	14	150	33 (100%)
6	Magnesium	30	150	30	100	10.4	197	31 (94%)

7	Sodium	-	200	30	100	16	589	21 (64%)
8	Chloride	200	600	250	1000	55	1392	29 (88%)
9	Sulphate	200	400	200	400	12	456	32 (97%)
10	Nitrate	45	45	45	45	0	26.2	33 (100%)

All units except pH and EC are in mg/l
Electrical Conductivity (EC) is in µs/cm
*permissible limit as per WHO (2004)

pH

Hydrogen ion concentration (pH) is the measure of the acidity or alkalinity of a solution. During the present investigation, pH values of the samples ranged between 6.4 and 8.7 with an average value 7.44. The pH value as low as 6.4 was recorded in Oornambeduvillage which shows slightly acidic nature and the highest value was found in Karungali and Thangalperumbalam with a value of 8.7 which indicate that the water is slightly alkaline in nature in these areas. The central part of the study area has higher pH value. Thus the water quality varies from slightly acidic to alkaline.Groundwater classification based on pH value shows that 30groundwater samples are in the category of desirable for drinking which is91 percent of the total samples analyzed(Table-3). 9 percent of the samples i.e. three samples are coming in the category of unsuitable for drinking.

The total Dissolved Solids concentration

Total Dissolved Solids (TDS) indicate the presence of various types of minerals present in water. It composed of mainly carbonates, bicarbonates, calcium, magnesium, chlorides, sulphate, phosphate, sodium, potassium and silica. TDS values are ranging from 338 mg/l to 2674 mg/l with an average value 1028.62mg/l. The TDS value as low as 338 mg/l was recorded in Ponneri and the highest was found in Kadapakkam with a value of 2674 mg/l. This also indicates that the groundwater of the Eastern part of the study area which is nearer to the coast is saline in nature. Groundwater classification based on TDS, value shows that 28 groundwater samples i.e. 85 percent of the samples analyzed falls in the category of desirable for drinking (Table-3). 15 percent of the samples i.e. five samples are in the category of unsuitable for drinking.

Electrical Conductivity Concentration

Electrical conductivity (EC) is a measure of electrical conductance of the water which indicates the presence of salts in water. In the present study, EC values range from 521µs/cm to 5000µs/cm with an average value 1742.27µs/cm. The lowest EC value of 521µs/cm was obtained in Athipattu and the highest value of 5000 mg/l was found in Kadapakkam. The groundwater of Kadapakkam and nearby areas indicates seawater intrusion. Eastern part of the study area has high EC values due to seawater intrusion.EC value is high in some locations due to saline sources, mineral dissolution and influx of pollutants from anthropogenic activities[13]. Groundwater classification based on EC shows that 27 groundwater samples i.e. 82 percent of the samples analyzed come in the category of desirable for drinking (Table-3). Six samples i.e. 18 percent of the samples come in the category of unsuitable for drinking.

Bicarbonate Concentration

Bicarbonate (HCO_3) concentration indicates the weathering processes of carbonate rocks. The Bicarbonate concentration ranges between 96 mg/l to 484 mg/l for the study area with an average value of 276.09 mg/l. The Bicarbonate concentration is very high in Jaganathapuram and very low in Athipattu area. Bicarbonate concentration is high in some locations which are mainly due to the dissolution of carbonate minerals and agricultural return flow. Groundwater classification based on HCO_3, value shows that 18 groundwater samples i.e. 55 percent of the samples analyzed falls in the category of permissible for drinking (Table-3). 45 percent of the samples i.e. 15 samples are falling into the category of unsuitable for drinking.

Calcium Concentration
Calcium (Ca) concentration values vary from 14 mg/l to 150 mg/l with an average value of 58.79 mg/l. The Calcium concentration is very high in Kalpakkam and very low in Athipattu area. Calcium concentration may be developed from the dissolution of calcium carbonate materials and calcium rich rocks. Calcium and magnesium ions create hardness of groundwater. Groundwater classification based on Ca concentration reveals that all the groundwater samples tested falls into the category of desirable for drinking (Table-3).

Magnesium Concentration
Magnesium (Mg) concentration ranges from 10.4 mg/l to 197 mg/l with the average value of 41.75 mg/l. Magnesium concentration is very high in Kadapakkam and very low in Thattimanji. Magnesium also formed from carbonate rocks and all magnesium rich rocks.
Groundwater classification based on Mg, value shows that 31 groundwater samples i.e. 94 percent of the samples tested falls in the category of permissible for drinking (Table-3). Two samples i.e. 6 percent of the samples are falling into the category of unsuitable for drinking.

SodiumConcentration
Sodium (Na) concentration ranges from 16 mg/l to 589 mg/l with the average value of 229.36 mg/l. Sodium concentration value is very high in Kadapakkam and very low in Ponneri. Sodium concentration plays a vital role in deciding the suitability of water for irrigation purpose, because sodium can increase the hardness of soil and reduces the permeability[14].Groundwater classification based on Na, value shows that 21 groundwater samples i.e. 64 percent of the samples analyzed is occurring in the group permissible for drinking (Table-3). Twelve samples i.e. 36 percent of the samples are in the category of unsuitable for drinking.

Chloride Concentration
The concentration of chloride (Cl) ranges between 55mg/l and 1392 mg/l with an average value of 362.03 mg/l. The chloride concentration is very high in Kadapakkam and very low in Ponneri. If the concentration of chloride is above 250mg/l, the saltiness can be recognized. The sources of chloride concentration in groundwater samples are geological formations, wastage and sewage discharges, agricultural fertilizers, industrial effluents and sea water intrusion. Groundwater classification based on Cl, value shows that 29 groundwater samples i.e. 88 percent of the samples analyzed falls in the category of Permissible for drinking are given in Table-3. Four samples i.e. 12 percent of the samples are falling into the category of unsuitable for drinking.

SulphateConcentration
The sulphate (SO_4) concentration in the study area is ranging from 12 mg/l to 456 mg/l and the average value is 130.27 mg/l. Sulphate concentration is very high in Jaganathapuram and low in Thattaimanji area. Sulphate is dissolved mainly from sedimentary rocks containing gypsum, iron sulfides and due to some industrial wastes. High concentration of SO_4 in drinking water is toxic in nature. Groundwater classification based on SO_4concentration shows that of the 33 groundwater samples analyzed 32 samples i.e. 97 percent is in the category of desirable for drinking are shown in Table-3.

Nitrate Concentration
The nitrate (NO_3) concentration ranges from 0 to 26.2 mg/lwith an average value of 7.62 mg/l. The nitrate concentration is very high in Manali new town and low in Ooranambedu area. The concentration of nitrate is formed from the biosphere and chemical reaction of soil bacteria to ammonium[15]. High concentration of NO_3 in drinking water is toxic to life. Groundwater classification based on NO_3, value shows that all 33 groundwater samples analyzed are in desirable for drinking category are shown in Table-3.

From the study it is clear that quality of groundwater improves as the distance from coast increases. Groundwater of Kadapakkam village has the highest concentration of most of water quality parameters (TDS, EC, Mg, Na and Cl) due to saline water intrusion. Kadapakkam is 4.90km from the coast. Ponneri village shows the best water quality which is 16.90 km away from the coast. Also, Ponneri is near to Araniyar river which can further dilute the concentration of pollution load. Groundwater quality in the eastern side of the study area is exceeding the permissible limits prescribed by WHO (2004) and Indian Standard (IS: 10500:2012) for domestic purposes.

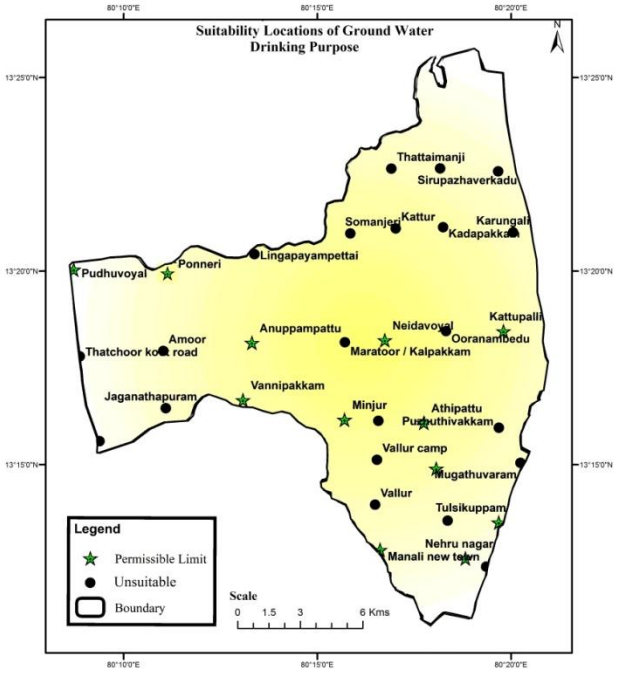

Fig.-2:Groundwater locations of permissible limit and unsuitable for drinking purpose

Based on the parameters studied, groundwater locations suitable for drinking purpose in the study areais given in Fig.-2. Interpolated map of areas is showing locations of villages which is in permissible limit and unsuitable for drinking only and no sample is available in the desirable limit as per WHO standard.The villages with groundwater quality within the permissible limit in the study area are Tulsikuppam, Kattupalli, Nehru Nagar, Athipattupudhunagar, Athipattu, Manali new town, Neidavoyal, Minjur, Vannipakkam, Anuppampattu, Ponneri and Pudhuvoyal. Other villages come under the unsuitable category. Groundwater quality in the northern part of the study area is unsuitable for drinking. In the eastern sidethough the influence of sea is there, dilution is taking place due to the presence of Bukingham canal and Pulicat Lake near the eastern boundary of the study area.

Irrigation Water Quality

Total Hardness (TH), Sodium Absorption Ratio (SAR), Chloride Bicarbonate Ratio (CBR), Permeability Index (PI) and Kelly's Ratio (KR) values for various locations in the study area calculated from major ionic concentrations of Na, Mg, Ca, HCO_3 are given in Table-4.

Total Hardness

Total hardness of water samples shows the presence of calcium and magnesium in groundwater. The hardness of water is formed by dissolution of CO_2, which is released by bacterial action in the soil and also from percolating rainwater. Total Hardness for the study area varies between 84.338 ppm and 1115.289 ppm with an average value of 318.613 ppm. The lowest value of total hardness 84.338 ppm is obtained in Athipattu and highest value of 1115.289 ppm is obtained in Kadapakkam. According to WHO

standards, total hardness of samples 2, 3, 5, 7, 8, 10, 11, 12, 14, 17, 18, 21, 22, 26, 28, 29, 32 and 33 comes in excellent category (55), samples 1, 24, 25, 27 and 31 comes in good category (15%), samples 6, 9, 15 and 16 comes in medium category (12%) and sample 23 comes in bad category (3%). Total Hardness of samples 4, 13, 19 and 20 are of very bad category (12%). Total Hardness of most of the locations in the study area falls within excellent to good category.

Sodium Absorption Ratio

Sodium Adsorption Ratio (SAR) indicates the sodium/alkali contents. SAR is the proportion of sodium (Na) to calcium (Ca) and magnesium (Mg) ions in a sample. Sodium Absorption Ratio varies from 2.630 mg/l to 125.026 mg/l with an average value of 35.810 mg/l. The lowest value of SAR 2.630 mg/l is calculated in Ponneri and highest value of 125.026 mg/l is obtained in Thattaimanji. The classification of Sodium Absorption Ratio of samples 16, 30 and 31 falls under the category of low sodium hazard zone and is in the excellent category (9%). SAR of samples 8,10,11,17,19,23,25 and 33 falls in good category (24%). SAR of samples 5, 6 and 12 falls in medium hazard category (9%). SAR of samples 1, 2, 3, 4, 7, 9, 13, 14, 15, 18, 20, 21, 22, 24, 26, 27, 28, 29 and 32 falls under the category of high sodium hazards zone and is in bad category (58%). If irrigation water is high in sodium and low in calcium, the cation-exchange complex becomes saturated with sodium[16].This reaction can destroy the clay particles and the soil structure. High sodium content in the study area will require special soil management.

Table-4: Calculated values of Total Hardness, Sodium Absorption Ratio, Chloride Bicarbonate Ratio, Permeability Index and Kelly's Ratio

S. No.	Location (Village name)	Total Hardness (ppm)	Sodium Absorption Ratio (meq/l)	Chloride Bi Carbonate Ratio	Permeability Index	Kelly's Ratio
1	Kathivakkam	355.344	47.733	0.529	79.436	3.030
2	Tulsikuppam	230.158	28.710	2.710	75.592	2.439
3	Mugathuvaram	152.460	47.279	4.293	86.842	4.945
4	Puzhuthivakkam	1007.700	26.633	1.900	55.717	1.095
5	Kattupalli	183.339	25.259	0.730	75.283	2.215
6	Karungali	403.192	25.820	0.696	67.813	1.667
7	Thangalperumbalam	137.234	103.435	1.042	95.517	11.286
8	Nehru nagar	160.446	16.800	0.948	73.501	1.680
9	NTECL ash dyke	418.734	45.569	1.032	77.670	2.784
10	Athipattupudhunagar	129.004	12.522	1.250	69.357	1.400
11	Athipattu	84.338	17.750	1.625	81.998	2.462
12	Ooranambedu	238.631	24.176	0.700	75.603	2.058
13	Kadapakkam	1115.289	46.637	7.524	66.366	1.846
14	Sirupazhaverkadu	208.740	66.789	1.095	88.876	5.661
15	Manali new town	456.458	40.258	2.298	71.651	2.220
16	Vallur	401.485	4.910	0.736	32.695	0.280
17	Vallur camp	248.552	10.672	2.000	53.453	0.825
18	Nandiyambakkam - H	113.451	35.150	0.804	89.009	4.064
19	Neidavoyal	625.044	15.718	3.765	47.879	0.802
20	Kattur	616.892	61.756	2.514	79.682	3.369

21	Thattaimanji	105.221	125.026	0.755	96.910	14.859
22	Minjur	104.314	32.500	0.915	89.323	3.941
23	Maratoor / Kalpakkam	572.070	16.483	1.291	50.299	0.828
24	Somanjeri	375.826	28.808	1.163	69.891	1.844
25	Vannipakkam	347.379	10.913	0.509	53.757	0.784
26	Anuppampattu	185.416	35.419	1.270	82.989	3.233
27	Lingapayampettai	326.726	27.550	0.685	69.903	1.825
28	Jaganathapuram	225.088	64.333	0.884	89.083	5.361
29	Amoor	120.035	64.313	1.360	93.668	7.282
30	Ponneri	217.138	2.630	0.423	30.446	0.216
31	Janappanchathiramkoot road	309.426	8.286	0.487	49.642	0.592
32	Thatchoorkoot road	219.814	44.912	1.380	85.228	3.909
33	Pudhuvoyal	119.296	16.994	1.038	76.422	1.900

Chloride Bi Carbonate Ratio

The chloride bicarbonate ratio (CBR) of above 2 in groundwater indicates that the water is highly saline and can be due to saline water ingress[17].For the study areaCBR varies from 0.423 to 7.524 with an average value of 1.526. The lowest value of CBR 0.423 was obtained in Ponneri and highest value 7.524 was obtained in Kadapakkam. The CBR of groundwater samples 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 16, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32 and 33 (79%) is below 2, which indicates that the water is of low salinity and the CBR of groundwater samples 2, 3, 13, 15, 17, 19 and 20 (21%) is above 2, which indicates that the water has high salinity.

Permeability index

The Permeability index (PI) is an important measure to assess the suitability of groundwater for irrigation. Long-term use of irrigation water affected by Na, Ca, Mg and HCO_3 is the major cause of soil permeability[18]. PI of the study area varied from 30.466 to 96.910 with an average value of 72.167. The lowest value of PI, 30.466 was obtained in Ponneri and highest value of Permeability Index, 96.910 was obtained in Thattaimanji. According to permeability indices the groundwater samples may be divided into Class I (PI >75%), Class II (PI ranges from 25% to 75%) and Class III (PI ranges below 25%). According to the Permeability Index values, 55% of the samples (1, 2 ,3, 5, 7, 9, 11, 12, 14, 18, 20, 21, 22, 26, 28, 29, 32 and 33) come under Class I and the remaining 45% of the samples (4, 6, 8, 10, 13, 15, 16, 17, 19, 23, 24, 25, 27,30 and 31) come under the class II category. Groundwater in the majority of the areas is in good to moderate category for irrigation purpose as per permeability index.

Kelly's Ratio

Kelly's ratio (KR) above 1 in groundwater indicate sodium problem for irrigation and the groundwater is considered unsuitable for irrigation[19]. Kelly's Ratio of the samples in the study area varied from 0.216 to 14.859 with an average value of 3.112. The lowest value of Kelly's Ratio of 0.216 was obtained in Ponneri and the highest value of14.859 in Thattaimanji. According to the Kelly's Ratio values, 21% of the samples (16, 17, 19, 23, 25, 30 and 31) come under low sodium content category and the remaining 79% of the samples (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 20, 21, 22, 24, 26, 27, 28, 29, 30, 31, 32 and 33) come under high sodium content category. According to Kelly's Ratio, the majority of the groundwater samples in the study area fall under unsuitable for irrigation.

For agriculture development in the study area, irrigation suitability was evaluated from total hardness, sodium adsorption ratio, chloride bicarbonate ratio, permeability index and Kelley's ratio and the results of the analysis are presented in Table-5.

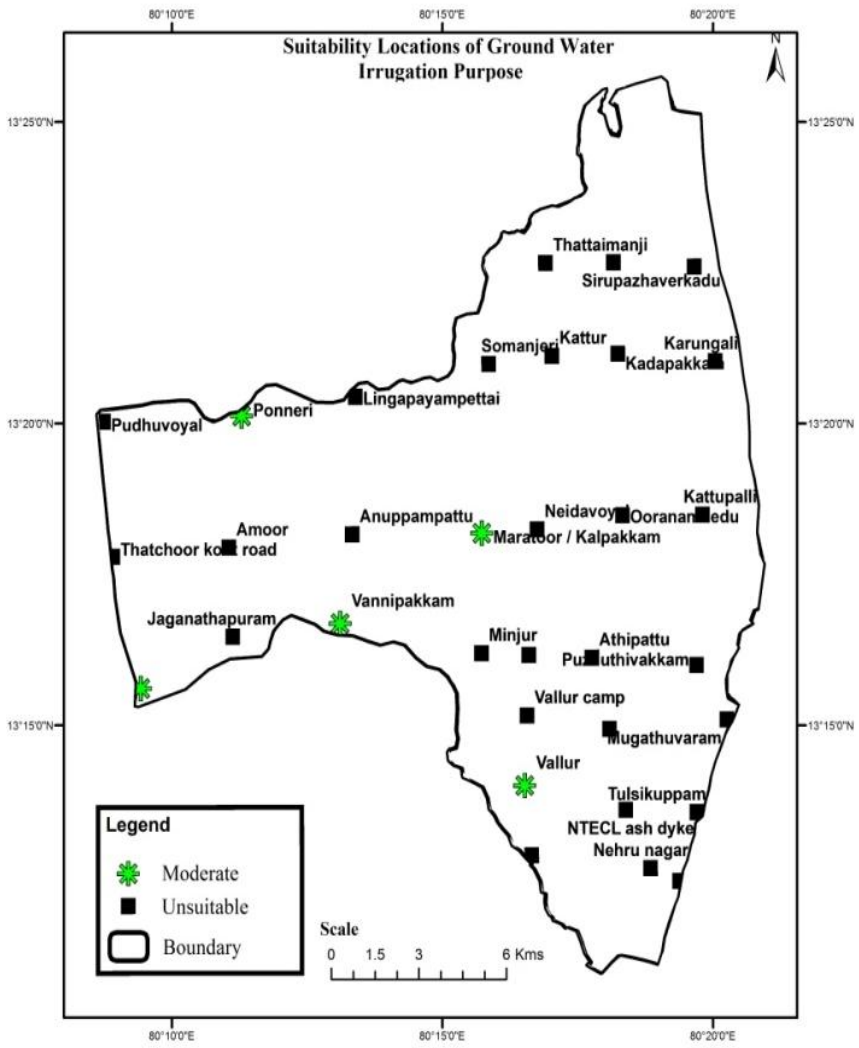

Fig.-3: Locations of groundwater suitable for irrigation purposes

Figure-3 shows the suitability of groundwater of the study area for irrigation purpose. The interpolated map shows that groundwater of the villages is falling in moderate category and bad category limit for irrigation purpose. Villages falling in moderately suitable for irrigation category are Vallur, Marattor/Kalpakkam, Vannipakkam, Ponneri and Janappanchathiram koot road. Other villages come under the bad category. The main reason for the unsuitability for irrigation purpose is the presence of sodium in the groundwater by salinity intrusion.

CONCLUSION

Unplanned urbanization, industrialization, agricultural development, over-extraction of groundwater and poor water management practices are causing water quality deterioration in the coastal areas of Chennai. Groundwater samples were collected, analyzed and evaluated with respect to distance from the sea coast. It was found that groundwater of the study area is not falling in the desirable category for drinking. Samples in the Northern and Eastern part show that they are unsuitable for dinking. The study reveals that sodium content in most of the groundwater samples is high and hence unsuitable for irrigation. The main reason is saline water intrusion in the coastal area. The present study indicates that sea water intrusion has occurred with reference to distance from the sea coast. Impact of Pulicat Lake, Buckingham canal and

anthropogenic activities by industries in the study area are also influencing the extent of salinity in the groundwater. It can be controlled by minimizing the overpumping and recharging groundwater through rainwater harvesting. The present study of hydrogeochemistry recommends the importance of regular monitoring and proper management of existing fresh groundwater resources for domestic and irrigation purposes.

Table-5: Groundwater quality evaluations for irrigation suitability

TH		SAR		CBR		PI		K R	
Criteria	No of samples and% age	Criteria	No of samples and Percentage	Criteria	No of samples and Percentage	Criteria	No of samples and Percentage	Criteria	No of samples and%age
Excellent < 300	18 (55%)	Excellent < 10	3 (9%)	≤ 2 Good	26 (79%)	Class I (≥ 75%) -Good	18 (55%)	≤ 1- Good	7 (21%)
Good 300 to 400	5 (15%)	Good 10 to 18	8 (24%)			Class II (between 25% and 75%)- Moderate	15 (45%)		
Medium 400 to 500	4 (12%)	Medium 18 to 26	3 (9%)						
Bad 500 to 600	1 (3%)	Bad > 26	19 (58%)	> 2 Bad	7 (21%)	Class III (≤ 25%)- Bad		> 1 - Bad	26 (79%)
Very bad > 600	4 (12%)	Very bad > 26	-						

ACKNOWLEDGMENT

The authors express their sincere thanks to Scientist Dr.L. Stanley Abraham, Sathyabama Institute of Science and Technology for his support in analyzing the groundwater samples. The authors also wish to thank Mr.Parthiban. S and Mr.Pushparaj. S, Sathyabama Institute of Science and Technology for their theoretic help. At last, authors want to thank anonymous reviewers for their useful comments on the manuscript.

REFERENCES

1. S. Selvam, R. Iruthaya Jeba Dhana Mala and V. Muthukakshmi, *South India International Journal of Advanced Engineering Applications*, **2(3)**, 25 (2013)
2. A. PonniahRaju, Dr.N. Chandrasekarand S. Saravanan, *International Journal of Water Research*, **1**, 1 (2013)
3. D. Gnanasundarand L. Elango, *Indian Journal of Environmental Protection*, **18(10)**, 752 (1998)
4. MadhaviGanesan and Thayumanavan, *J. Sustainable Development*, **2(1)**, 94 (2009)
5. B. PrabhuDassBatvari and V.E. N. Mariappan, *Rasayan J. Chem*, **9(3)**, 424 (2016)
6. APHA Standard Methods for the Examination of Water and Wastewater, 21st Ed., American Public Health Association, New York, USA (2005)
7. WHO Guidelines for Drinking Water Quality, Vol. 1, Recommendations 3rdedn. WHO, Geneva, 515 (2004)
8. Indian Standard, Drinking Water-Specification (Second Revision), IS 10500 : 2012(2012)
9. K.R. Karanth, Groundwater Assessment Development and Management, 610 (1987)
10. LA. Richards, Diagnosis and Improvement of Saline and Alkali Soils, USDA handbook, 160, 60 (1954)

11. L.D. Doneen, Notes on Water Quality in Agriculture, Water Science and Engineering, University of California (1964)
12. W.P. Kelley, S.M. Brownand G.I. Jr. Leibig, *Soil Science*, **49**, 95 (1940)
13. K. Srinivasamoorthy, M. Vasanthavigar, K. Vijayaraghavan, R. Sarathidasan and S. Gopinath, *Arab J. Geosci*, **1** (2011), **DOI:** 10.1007/s12517-011-0351-2
14. M.N. Tijani, Environmental Geology, **24**, 194 (1994)
15. A. Saleh, F. Al-Ruwaih and M. Shehata, *J. Arid Environ.*, **42**, 195 (1999)
16. S. Venkateswaran and S. Vediappan, *International Journal of Innovative Technology and Exploring Engineering*, **3**, 2 (2013)
17. R.J. Desai, S.K. Gupta and M.V. Shah, *Hydrol. Science Bull.*, **24**, 71 (1979)
18. N. Janardhana Raju, *Env. Geol*., **52**, 1067(2007)
19. R. Ayyandurai, M. Suresh and S. Venkateswaran, *International Journal of Innovative Technology and Exploring Engineering*, **2**, 3 (2013)

[RJC-1991/2017]