

Status of groundwater at Chennai city, India

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Abstract

Chennai formerly known as Madras, is the capital of the state of Tamil Nadu and India's fourth largest metropolitan city. The status of the groundwater depends on a large number of individual hydro-biological parameters. Pollutants are added to the groundwater system through anthropogenic activities and natural processes. Solid waste from industries is being dumped near the factories and subjected to reaction with percolating rainwater and reaches the groundwater level. The percolating water picks up a large amount of dissolved constituents and reaches the aquifer system and thus it contaminates the groundwater. The aim of the present study was carried out to assess the status of the groundwater in Chennai city using physicochemical and biological parameters according to the standard methods (APHA 1998). Two zones (North and South) from Chennai city were selected for the studies from each Zone 25 sampling stations were fixed and the analysis was made during summer and monsoon seasons (Jan - Dec) 2007. Results indicate that the groundwater of the study area is bacteriologically not safe and need treatment before it is used for drinking purposes. Thus, this study assumes greater importance in the public health management point of view.

Keywords: Groundwater, Chennai, pollution, public health, India

Introduction

Groundwater is ultimate, most suitable fresh water resource with nearly balanced concentration of the salts for human consumption. Over burden by means of population pressure, unplanned urbanization, unrestricted exploration policies and dumping of the polluted water at inappropriate place enhance the infiltration of harmful compounds to the groundwater (Pandey *et al.*, 2009). Water plays a vital role in human life. The importance of groundwater for existence of human society cannot be overemphasized. There are several states in India where more than 90% populations are dependent on groundwater for drinking and other purpose (Ramachandraiah, 2004, Tank & Singh Chandel, 2010). Most of the industries discharge their effluent without proper treatment into nearby open pits or pass them through unlined channels, resulting in the contamination of groundwater (Jinwal & Dixit, 2008). The incidence of groundwater pollution is highest in urban areas where large volumes of waste are concentrated and discharged into relatively small areas (Rao *et al.*, 2004). The hydro-geochemical conditions are also responsible for causing significant variations in groundwater quality (Mahanta *et al.*, 2004).

Groundwater is also an alternative source for agricultural and industrial sector. During last decade, it is observed that the groundwater pollution has drastically increased due to human activities. Consequently, number of water borne diseases has also increased among public. Contaminated drinking water is believed to be the cause of various diseases which is on raise during summer. Most patients, including children are admitted to the city's government hospital with the symptoms of

diarrhea and vomiting from certain parts of Chennai especially during summer or in rainy seasons. So, basic monitoring of groundwater has necessitated to observe the demand and status of groundwater quality.

This study is an attempt to carry out qualitative analysis of some physico-chemical and biological parameters of groundwater in the study area.

Materials and methods

Study area

Chennai, formerly known as Madras, is the capital of the state of Tamil Nadu and India's fourth largest metropolitan city. It is located on the Coromandel Coast of the Bay of Bengal. The latitude of Chennai city is 13.04° N and longitude 80.17° E. With the population of 4.34 million in the 2001 census, the 368-year-old city is the 31st largest metropolitan area in the world. The city is a large commercial and industrial centre and is known for its cultural heritage and temple architecture. The Chennai Metropolitan area consists of three districts namely Chennai city and the districts of Kanchipuram and Thiruvallur. The city covers an area of 174 km². The metropolitan area covers 1,177 km² (455 mi²). The city is divided on the basis of composition into four major parts: North, Central, South and West. The water supply to Chennai during years of normal rainfall is around 313 mld (78 litres per capita a day, or 1 pcd). But during the drought years availability has been as low as 127 mld (32 lpcd). There is considerable variation in the availability of water across different sections of the people.

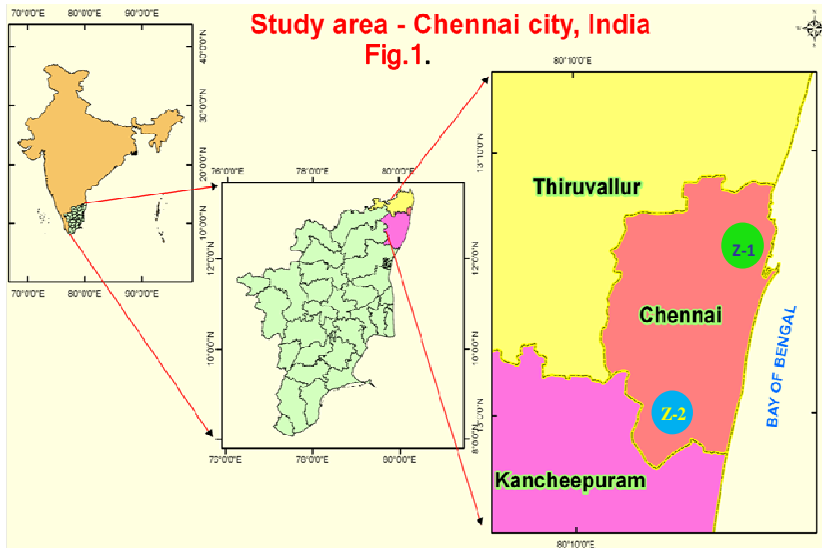
The city is splashed by Cooum river and Adyar river which flow through the center of the city. Apart from these two water bodies, there is the Buckingham

Table 1. Sampling locations within Chennai city

Zone 1	Land use data	
Sampling stations	Latitude "N"	Lantitude "E"
Tondaiarpet	13°07' 91.65"	80°17' 54.24"
Kasimedu	13°06' 59.50"	80°17' 38.99"
Natesan Nagar	13°09' 04.16"	80°13' 48.28"
Assis Nagar	13°09' 53.65"	80°14' 10.61"
Rayapuram	13°06' 51.32"	80°17' 26.38"
Pudumanikuppam	13°06' 36.45"	80°17' 41.53"
Thirumoorthy Nagar	13°11' 03.97"	80°18' 27.82"
Jeevarathinamal Nagar	13°10' 06.05"	80°18' 29.20"
Kondithope	13°06' 11.02"	80°16' 38.71"
Brindavan Nagar	13°11' 13.96"	80°18' 22.83"
Amman Koil (S)	13°06' 04.26"	80°17' 01.46"
Manikkam Nagar	13°09' 55.17"	80°18' 03.92"
Rattan Bazar	13°05' 15.15"	80°16' 48.82"
Charless Nagar	13°09' 53.67"	80°17' 28.95"
Singaravelan Nagar	13°06' 11.02"	80°16' 38.71"
Inder Nagar	13°06' 11.02"	80°16' 38.71"
Muthialpet	13°05' 44.58"	80°17' 22.98"
M.R.C.Nagar	13°01' 07.63"	80°16' 13.74"
Old washermenpet	13°06' 25.22"	80°17' 11.40"
Chettithottam	13°06' 24.71"	80°17' 37.59"
Thiruvattiyur	13°09' 36.90"	80°17' 23.94"
Kalmandabam	13°06' 49.21"	80°16' 13.74"
M.C. Road	13°06' 34.30"	80°17' 13.29"
Vallalar Nagar	13°06' 21.26"	80°16' 48.92"
Sowkarpet	13°05' 20.33"	80°17' 04.23"

Table 2. Sampling locations within Chennai city

Zone 2	Land use data	
Sampling Points	Latitude "N"	Lantitude "E"
Kodambakkam (S)	13°02' 56.76"	80°13' 25.61"
Krishnapuram	13°03' 30.78"	80°13'42.94"
Saidapet (W)	13°01' 28.34"	80°12' 50.35"
Mannurpet	13°05' 19.08"	80°10' 39.72"
Arntatiay Nagar	13°06' 24.41"	80°15' 09.73"
Saidapet (E)	13°01' 13.31"	80°13' 05.88"
Kalaiganar Karunanudhi Nagar	13°02' 32.37"	80°11' 45.10"
Seven wells (N)	13°06' 07.62"	80°16' 52.41"
Peters Colony	13°03' 17.49"	80°15' 31.77"
Anna Salai (Mount Road)	13°03' 59.05"	80°16' 08.07"
Guindy (W)	13°00' 46.51"	80°12' 30.12"
Guindy(E)	12°59' 53.25"	80°13' 45.65"
Anna Nagar	13°05' 07.32"	80°12' 14.83"
MMDA Colony	13°03' 59.52"	80°12' 52.74"
Jafferhanpet	13°01' 52.04"	80°12' 05.21"
Ekkattuthangal	13°01' 11.10"	80°12' 05.13"
KalaimagarNagar	13°01' 29.29"	80°12' 16.94"
Ambal nagar	13°01' 05.13"	80°12' 16.63"
Ambedkar Nagar	13°04' 21.58"	80°12' 42.14"
Thiru Vi ka Industrial Estate	13°02' 36.26"	80°11' 00.09"
Akshaya Nagar	13°05' 26.88"	80°10' 55.36"
Soudar Nagar	13°00' 52.83"	80°11' 52.63"
Jyothi Nagar	13°01' 18.70"	80°12' 02.55"
Meenambakkam	12°59' 34.69"	80°10' 14.69"
Manapakkam	13°01' 07.33"	80°10' 24.82"



Study area - Chennai city, India Fig.1.

Canal running parallel to the coast linking the two rivers. Several lakes of varying size are located on the western fringes of the city. Red Hills, Sholavaram and Chembarambakkam Lake supply water to the Chennai city. Located on the Bay of Bengal the city is divided majorly into four regions. The northern localities house some of the reputed manufacturing companies of India. The automobile industries located here have attractions for themselves. Sowkarpet is the leading area for automobile industry in the city and it has been referred as

Detroit of India. Fishing harbour is located at Tondiarpet in North Chennai. The harbour makes up a popular attraction in the north. The region is inhabited by a local population, most of which are employed in the industries located here. The eastern boundary of the northern localities is limited by the famous Buckingham Canal. Chennai South features with Meenambakkam- airport area with national and international terminals. Southern Railways provide railway services and a vast network of roads hooks up the place. Some of the localities that fall in Chennai South include K.K.Nagar, Kotturpuram, Meenambakkam, Saidapet, Teynampet, and Velachery. Some important tourist attractions located in the southern suburbs are Elliot's Beach, Guindy Park, Theosophical Society, Sivan Park, Periyar Science and Technology Centre, Kapaleeswarar Temple, Karaneeswarar Temple, Soundareswarar Temple, Marundeeswarar Temple, Santhome Basilica, etc. The difference between the North Chennai and South Chennai is that North Chennai mainly focused on the industrial area whereas the South Chennai focused on the residential area. Two zones each from North Chennai (Zone 1) and South Chennai (Zone 2) were selected for the study. These two zones were used widely by the public to meet their day to day activities.

Table 3.0. Seasonal variation data on Physico-chemical parameters of ground water samplings at during summer 2007

Zone -1														
Sampling locations	pH	TEM °C	EC µS/cm	SAL mg/l	TDS mg/l	PO ₄ mg/l	NH ₃ mg/l	NO ₂ mg/l	NO ₃ mg/l	Cl mg/l	SO ₄ mg/l	TH mg/l	CA mg/l	MG mg/l
Tondaiarpet	7.59	29.30	1406	0.748	1247	0.280	0.735	0.233	0.816	139	144	207	187	174
Kasimedu	7.89	28.87	1280	0.672	1121	0.380	0.681	0.211	0.738	186	92	157	177	165
Natesan Nagar	7.57	29.50	1454	0.777	1295	0.320	0.683	0.211	0.739	199	202	158	168	157
Assis Nagar	7.79	29.43	1452	0.776	1293	0.230	0.636	0.192	0.671	168	230	174	152	143
Rayapuram	7.92	28.51	1252	0.656	1093	0.230	0.537	0.150	0.527	157	127	186	147	133
Pudumanikuppam	7.86	29.54	1586	0.856	1427	0.350	0.816	0.267	0.933	246	142	284	186	175
Thirumoorthy Nagar	7.84	28.85	1527	0.821	1368	0.220	0.788	0.255	0.893	210	188	263	159	142
Jeevarathinamal Nagar	7.70	29.55	1492	0.800	1333	0.425	0.812	0.265	0.928	241	125	286	173	167
Kondithope	7.90	29.59	1367	0.725	1208	0.330	0.739	0.235	0.822	145	92	212	199	181
Brindavan Nagar	7.63	28.72	1445	0.772	1286	0.220	0.654	0.199	0.698	234	134	183	187	163
Amman Koil (S)	7.62	29.58	1352	0.716	1193	0.425	0.675	0.208	0.728	194	142	156	165	142
Manikkam Nagar	7.81	28.53	1382	0.734	1223	0.350	0.779	0.251	0.880	197	90	249	179	166
Rattan Bazar	7.50	29.57	1435	0.766	1276	0.250	0.684	0.212	0.741	169	159	174	185	179
Charless Nagar	7.57	29.53	1437	0.767	1278	0.260	0.737	0.234	0.818	141	169	209	176	163
Singaravelan Nagar	7.89	28.78	1643	0.890	1484	0.230	0.833	0.274	0.959	270	192	301	161	142
Inder Nagar	7.64	29.52	1594	0.861	1435	0.340	0.804	0.262	0.916	231	159	273	188	173
Muthialpet	7.69	29.51	1262	0.662	1103	0.370	0.609	0.180	0.631	172	81	176	173	168
M.R.C.Nagar	7.87	28.51	1377	0.731	1218	0.250	0.734	0.233	0.815	138	122	231	183	171
Old washermenpet	7.84	28.79	1539	0.828	1380	0.420	0.730	0.231	0.809	159	249	203	193	169
Chettihottam	7.79	28.54	1598	0.863	1439	0.260	0.843	0.278	0.973	282	189	310	170	152
Thiruvattiyur	7.36	29.96	1503	0.807	1344	0.220	0.694	0.216	0.756	194	248	169	178	159
Kalmandabam	7.56	28.75	1647	0.893	1488	0.420	1.208	0.339	1.187	270	92	270	276	236
M.C. Road	7.78	28.57	1624	0.879	1465	0.292	0.734	0.233	0.814	137	250	206	231	218
Vallalar Nagar	7.89	29.68	1484	0.795	1325	0.324	0.629	0.189	0.661	237	181	175	153	146
Sowkarpet	7.64	29.87	1348	0.713	1189	0.470	0.678	0.209	0.732	198	92	205	187	180

Collection of groundwater samples and study period

Seasonal sampling programme was carried out at two zones and in each zone 25 locations were selected (Fig.1) (Table 1 and 2). Two seasons (Summer and Monsoon) were selected for the study mainly to focus the groundwater quality. Groundwater samples were collected from January 2007 to December 2007. The zones were selected in such a way that they covered a wide area of Chennai City. Groundwater samples were collected from 2 zones sampling both for biological and physico-chemical parameters. Sampling was done generally during morning 7.00 a.m to 9.00 a.m on the day of collection, monthly wise. Triplicate samples were collected for the study and mean averages were taken. Groundwater samples were collected in pre cleaned 1L polypropylene containers and kept in an ice box and transported to the laboratory within 2 hours for further analysis. 100 ml of samples were collected separately in a clean sterile glass container for microbial study (APHA, 1998).

Analysis of groundwater: physico-chemical and biological parameters

The collected samples were analyzed for different physico-chemical parameters such as pH, Electrical conductivity, Turbidity, TDS, Total hardness, chloride, sulphate, total phosphorous, nitrate, nitrite and ammonia as per the standard methods (APHA, 1998). The bacteriological analysis (CFU/100ml) were carried out immediately without storing the samples and the results were compared with the Indian Standards (IS: 10500) for potable water.

Results and discussion

The water quality analysis of two zones of water samples have been carried out for pH, Electrical conductivity, TDS, Total hardness, Chlorides and sulphates, Total phosphorous, nitrate, nitrite, ammonia. The status of water quality of these ground water sources are presented in Table 3.

In Zone 1, the pH value of the water was found to be maximum during summer 2007. pH value of ground water samples varied between 7.36 - 7.92 and 7.16 - 7.43

Table 3.1 Seasonal variation data on Physico-chemical parameters of ground water samplings at during summer 2007

Zone - 2														
Sampling Locations	pH	TEM °C	EC μS/cm	SAL mg/l	TDS mg/l	PO ₄ mg/l	NH ₃ mg/l	NO ₂ mg/l	NO ₃ mg/l	Cl mg/l	SO ₄ mg/l	TH mg/l	CA mg/l	MG mg/l
Kodambakkam (S)	7.87	29.53	1381	0.733	1222	0.253	0.634	0.191	0.669	147	130	241	168	155
Krishnapuram	7.68	29.85	1544	0.831	1385	0.280	1.001	0.344	1.203	230	89	269	232	221
Saidapet (W)	7.62	29.57	1608	0.870	1449	0.250	0.562	0.161	0.564	197	171	252	208	199
Mannurpet	7.69	29.56	1262	0.662	1103	0.240	0.620	0.185	0.648	146	92	189	153	148
Arntatiay Nagar	7.74	29.47	1499	0.804	1340	0.321	0.678	0.209	0.733	279	159	197	157	137
Saidapet (E)	7.65	28.75	1314	0.693	1155	0.235	0.717	0.226	0.790	205	93	191	163	159
Kalaiganar Karunanudhi Nagar	7.71	28.75	1654	0.897	1495	0.340	0.679	0.210	0.735	275	192	217	207	189
Seven wells (N)	7.64	28.67	1336	0.706	1177	0.290	0.733	0.232	0.813	183	93	206	178	172
Peters Colony	7.58	29.51	1318	0.696	1159	0.210	0.679	0.210	0.735	216	64	198	186	180
Anna Salai(Mount Road)	7.66	29.55	1501	0.805	1342	0.280	0.738	0.234	0.820	179	174	210	182	171
Guindy (W)	7.99	28.67	1800	0.985	1641	0.230	0.806	0.263	0.919	233	240	275	247	218
Guindy(E)	7.62	29.63	1276	0.670	1117	0.280	0.733	0.232	0.813	137	87	206	178	170
Anna Nagar	7.73	29.75	1482	0.794	1323	0.250	0.624	0.187	0.654	206	213	195	166	150
MMDA Colony	7.57	28.55	1533	0.825	1374	0.210	0.779	0.251	0.880	198	127	249	221	209
Jafferkhanpet	7.72	29.74	1410	0.751	1251	0.240	0.673	0.207	0.726	277	93	196	176	165
Ekkattuthangal	7.79	29.65	1527	0.821	1368	0.195	0.581	0.169	0.591	187	174	208	191	183
KalaimagarNagar	7.53	29.37	1593	0.861	1434	0.270	0.701	0.219	0.767	235	192	251	187	168
Ambal nagar	7.79	29.72	1445	0.772	1286	0.210	0.681	0.211	0.737	174	92	257	215	205
Ambedkar Nagar	7.62	28.63	1932	0.920	1773	0.250	0.944	0.320	1.121	286	257	308	287	209
Thiru Vi ka Industrial Estate	7.87	29.58	1763	0.963	1604	0.194	0.855	0.283	0.991	298	92	321	293	257
Akshaya Nagar	7.52	28.64	1420	0.757	1261	0.340	0.539	0.151	0.529	143	81	269	231	205
Soudar Nagar	7.78	29.63	1446	0.772	1287	0.251	0.665	0.204	0.715	126	171	208	187	173
Jyothi Nagar	7.64	28.54	1762	0.962	1603	0.364	0.891	0.298	1.043	265	203	278	265	179
Meenambakkam	7.53	29.61	1507	0.809	1348	0.287	0.694	0.216	0.757	165	249	169	176	165
Manapakkam	7.92	29.21	1604	0.867	1445	0.380	0.719	0.226	0.792	197	190	192	234	231

during summer 2007 and monsoon 2007 season respectively. In Zone 2, the pH was found to be 7.52 -7.99 during summer 2007 and monsoon it ranged between 7.19 - 7.53. In both the zones the pH values were found to be within the permissible limit as per Indian Standards. In Zone 1, temperature ranged 28.51°C - 29.96°C during summer 2007 and 27.00°C- 28.60°C during monsoon. In Zone 2, the range was 28.54°C - 29.85°C in summer 2007 and 27.82°C - 29.23°C during monsoon 2007. The pH of the water is very important indicator of its quality. Most of the waters are slightly alkaline due to presence of carbonates and bicarbonates.

Electrical conductivity varied between 1252-1647μS/cm during summer 2007 and 957 -1249 μS/cm during monsoon 2007 in Zone 1. In Zone 2, the EC was 1262 -1939 μS/cm during summer and it was 974 - 1360 μS/cm in monsoon. Salinity was ranged between 0.465-0.657ppt. The same trend was observed in the case of TDS of various ground water sources, where the values were ranged between 1093 -1488 mg/L during summer and 1090-792 mg/L in monsoon 2007 (Zone 1) and the

values were estimated between 1103 - 1773 mg/L during summer and 815 - 1201mg/L during monsoon 2007 in Zone 2. The EC and TDS were correlated with each other where the values showed a high concentration during summer season. High EC values indicate the presence of high amount of dissolved inorganic substances in ionized form. TH in all the samples were found to be within standard limits (< 300 mg/l as CaCO₃) except sample number 15(301 mg/L) and 20 (310 mg/L) in Zone 1 and it was found to be within the limits except sample number 19 (308 mg/L) and 20 (321 mg/L) in Zone 2.

Calcium and Magnesium are directly related to hardness. Calcium concentration ranged between 147 - 267mg/L (summer) and 105 - 167 mg/L (monsoon) at Zone 1 and it was found to be 153 - 293mg/L and 103 - 187 mg/L (monsoon) in Zone 2. Values are slightly higher in summer than monsoon season and Zone 2 showed a higher concentration of calcium ions than Zone 1. In few samples the ions of calcium and magnesium have crossed the permissible limit (IS: 10500), except tube well sample collected at Zone 2. Magnesium content of the

Table 3.2 Seasonal variation data on Physico-chemical parameters of ground water samplings at during monsoon 2007

Zone -1 Sampling Locations	pH	TEM °C	EC µS/cm	SAL mg/l	TDS mg/l	PO ₄ mg/l	NH ₃ mg/l	NO ₂ mg/l	NO ₃ mg/l	Cl mg/l	SO ₄ mg/l	TH mg/l	CA mg/l	MG mg/l
Tondaiarpet	7.28	28.32	974	0.489	815	0.160	0.518	0.130	0.454	105	79	105	132	116
Kasimedu	7.31	28.34	1041	0.529	882	0.110	0.297	0.074	0.260	147	73	137	122	132
Natesan Nagar	7.19	27.72	1156	0.598	997	0.121	0.435	0.109	0.381	165	120	132	124	121
Assis Nagar	7.39	27.28	1181	0.613	1022	0.150	0.270	0.068	0.237	142	148	143	109	117
Rayapuram	7.36	28.29	951	0.475	792	0.139	0.232	0.058	0.203	103	87	136	105	124
Pudumanikuppam	7.38	27.00	1141	0.589	982	0.148	0.558	0.139	0.488	157	89	182	136	143
Thirumoorthy Nagar	7.39	27.71	1168	0.606	1009	0.140	0.575	0.144	0.503	180	106	161	121	120
Jeevarathinamal Nagar	7.25	28.43	1114	0.573	955	0.360	0.521	0.130	0.456	167	89	184	132	108
Kondithope	7.34	27.42	1015	0.513	856	0.154	0.527	0.132	0.462	117	59	147	133	143
Brindavan Nagar	7.22	28.31	1052	0.536	893	0.127	0.398	0.100	0.348	153	108	134	121	110
Amman Koil (S)	7.37	27.73	1029	0.522	870	0.280	0.344	0.086	0.301	146	95	131	116	107
Manikkam Nagar	7.27	28.14	1064	0.543	905	0.248	0.568	0.142	0.497	134	69	147	137	153
Rattan Bazar	7.33	28.17	1055	0.537	896	0.210	0.290	0.072	0.254	123	92	135	110	143
Charless Nagar	7.36	28.20	1051	0.535	892	0.154	0.347	0.087	0.304	115	87	146	116	126
Singaravelan Nagar	7.24	28.50	1147	0.593	988	0.142	0.593	0.148	0.519	94	110	199	139	121
Inder Nagar	7.42	28.50	1069	0.546	910	0.257	0.473	0.118	0.414	110	77	171	128	132
Muthialpet	7.34	28.30	971	0.487	812	0.180	0.286	0.072	0.250	132	52	134	110	117
M.R.C.Nagar	7.37	28.27	951	0.475	792	0.210	0.472	0.118	0.413	105	40	132	128	132
Old washermenpet	7.29	27.70	1174	0.609	1015	0.242	0.490	0.122	0.429	136	167	134	129	115
Chettihottam	7.36	28.12	1167	0.605	1008	0.123	0.562	0.141	0.492	164	107	208	136	119
Thiruvattiyur	7.23	28.59	1111	0.571	952	0.096	0.364	0.091	0.318	162	184	67	117	108
Kalmandabam	7.21	28.32	1016	0.514	857	0.231	0.773	0.171	0.600	128	65	118	148	126
M.C. Road	7.32	28.19	1249	0.654	1090	0.123	0.347	0.087	0.304	104	168	104	167	164
Vallalar Nagar	7.43	28.60	1123	0.579	964	0.130	0.343	0.086	0.300	176	99	138	121	116
Sowkarpet	7.16	28.23	1054	0.537	895	0.238	0.363	0.091	0.317	145	72	143	132	132

water samples were ranging from 133 - 236mg/L. According to WHO the desirable value of Mg²⁺ is 50 mg/L. Out of 50 samples analysed from Zone 1 and 2, Five samples were exceeding the limit. Excess of calcium and magnesium present in the ground water samples proves that the water is not good for drinking. Table 1 (Zone-1) and 2 (Zone - 2) shows the variation in chloride content of dug well and bore well water.

The chloride content of well water ranged from 137 - 282 mg/L during summer and 94-180 mg/L during monsoon at Zone 1. In Zone 2, the values ranged between the 126 - 298 mg/L during summer and it was 99 - 193mg/L in monsoon. The higher content of chloride in groundwater in Zone 2 may be due to high chloride content in groundwater. This may be due to the lack of underground drainage system and bad maintenance of environment around the sources. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Manivasakam, 2005). The sulphate concentration ranged between 81- 250mg/L during summer and 40-184 mg/L during monsoon at

Zone 1 and in Zone 2 it was 64 - 257mg/L during summer and in monsoon it was ranged from 31 - 175 mg/L. The results were within the prescribed limit except the few sampling point in Zone 1 and Zone 2. The presence of high concentration of sulphates in the study area can be attributed the discharge of domestic sewage and littering of organic wastes in the region.

Groundwater contains nitrate due to leaching of nitrate with the percolating water. Groundwater can also be contaminated by sewage and other wastes rich in nitrates. The nitrite content in the study area ranged from 0.527 to 1.187 mg/L during summer and 0.058 - 0.773 mg/L during monsoon at Zone 1 and it was 0.344-0.151 mg/L during summer and 0.173-0.062 mg/L during monsoon at Zone 2. Average nitrate was ranged between 0.203-0.600 mg/L (monsoon) and 0.527-1.18 mg/L (summer) at zone 1 and in zone 2 it was ranged between 0.153 - 0.604mg/L (monsoon) and 0.529-1.203 mg/L (summer). Ammonia was found to be ranged between 0.232-0.773 mg/L in zone 1 and in zone 2 0.175-0.691 mg/L during monsoon season. During summer, ammonia

Table 3.3 Seasonal variation data on Physico-chemical parameters of ground water samplings at during monsoon 2007

Zone -2 Sampling Locations	pH	TEM °C	EC µS/cm	SAL mg/l	TDS mg/l	PO ₄ mg/l	NH ₃ mg/l	NO ₂ mg/l	NO ₃ mg/l	Cl mg/l	SO ₄ mg/l	TH mg/l	CA mg/l	MG mg/l
Kodambakkam (S)	7.37	27.82	1046	0.532	887	0.090	0.308	0.077	0.270	113	126	167	104	114
Krishnapuram	7.29	28.28	994	0.501	835	0.120	0.691	0.173	0.604	127	45	138	125	123
Saidapet (W)	7.26	28.22	1130	0.583	971	0.106	0.289	0.072	0.253	143	89	173	136	126
Mannurpet	7.24	28.25	981	0.493	822	0.120	0.175	0.062	0.153	112	49	161	122	118
Arntatiy Nagar	7.43	28.14	1049	0.534	890	0.150	0.449	0.112	0.393	165	77	153	103	100
Saidapet (E)	7.27	28.31	974	0.489	815	0.090	0.521	0.130	0.456	123	51	142	116	108
Kalaiganar Karunanudhi Nagar	7.23	28.25	1199	0.624	1040	0.078	0.392	0.098	0.343	168	110	161	153	123
Seven wells (N)	7.19	28.54	1014	0.513	855	0.090	0.497	0.124	0.435	128	39	156	135	129
Peters Colony	7.34	28.52	1033	0.524	874	0.060	0.367	0.092	0.322	139	31	163	152	143
Anna Salai (Mount Road)	7.46	28.12	1132	0.584	973	0.120	0.458	0.114	0.401	143	92	174	132	125
Guindy (W)	7.53	28.11	1263	0.662	1104	0.112	0.532	0.133	0.466	124	158	173	144	132
Guindy(E)	7.43	29.23	1069	0.546	910	0.106	0.496	0.124	0.434	117	62	163	157	139
Anna Nagar	7.47	29.12	1137	0.587	978	0.120	0.356	0.089	0.311	154	103	134	121	118
MMDA Colony	7.29	28.16	1126	0.580	967	0.109	0.513	0.128	0.449	132	98	179	158	136
Jafferkhanpet	7.32	28.12	1072	0.548	913	0.100	0.390	0.098	0.341	157	65	156	143	136
Ekkattuthangal	7.36	28.26	1157	0.599	998	0.090	0.300	0.075	0.262	132	92	168	140	159
KalaimagarNagar	7.33	28.67	1173	0.608	1014	0.090	0.411	0.103	0.359	125	110	167	155	131
Ambal nagar	7.45	28.56	1104	0.567	945	0.123	0.369	0.092	0.322	127	57	175	138	167
Ambedkar Nagar	7.41	28.16	1360	0.721	1201	0.112	0.614	0.154	0.537	193	175	167	154	143
Thiru Vi ka Industrial Estate	7.33	28.26	1146	0.592	987	0.094	0.564	0.141	0.494	166	43	179	167	153
Akshaya Nagar	7.37	28.37	1013	0.513	854	0.124	0.263	0.066	0.230	106	46	165	136	146
Soudar Nagar	7.42	28.31	1028	0.522	869	0.134	0.395	0.099	0.346	99	89	136	121	120
Jyothi Nagar	7.48	28.14	1341	0.709	1182	0.178	0.616	0.154	0.539	187	121	205	187	146
Meenambakkam	7.23	28.34	1138	0.588	979	0.121	0.394	0.098	0.345	122	167	67	122	119
Manapakkam	7.41	28.67	1091	0.559	932	0.150	0.461	0.115	0.404	137	108	90	142	132

ranged between 0.537-1.28 mg/L at zone 1 and 0.539-1.001mg/L at zone 2. Phosphate may occur in groundwater as a result of domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water. The phosphate content in Zone 1 ranged between 0.220 - 0.470 mg/L (summer) and 0.096-0.360 mg/L (monsoon) and in Zone 2 0.194 - 0.380 mg/L (summer) and 0.060 - 0.178 mg/L (monsoon). The physicochemical parameters in all the samples were within permissible limit in both the season.

Total faecal coliforms and *E. coli* indicate are the indicative of water contamination by human or animal wastes. Fecal coliforms ranged between 6 - 30 CFU/100ml during summer 2007 and 1 - 10 CFU/100ml during monsoon at Zone 1. During summer, the CFU were ranging from 4-35 numbers per 100ml and 2 - 13 CFU/100ml during monsoon at Zone 2. *E. coli* was observed in summer in the range of 3 - 23 CFU/100ml and 0 - 6 CFU/100ml (monsoon) at Zone 1 and 1 - 16

CFU/100ml (summer) and 0 - 8 CFU/100ml (monsoon) of the groundwater samples at the same region wells, respectively (Table 4.0 - 4.1).

Conclusion

The present investigations made on the groundwater of North and South Chennai revealed that the water quality was within the ISI standard except the few parameters this may due to the intrusion of sea water, industrial effluents intrusion into the groundwater and improper maintenance of the sewage system. Hence, there is a need for groundwater treatment before it is used for consumption.

References

1. APHA (1998) Standard methods for the examination of water and waste water. APHA-AWWA-WPCF. Washington D.C.
2. Dinesh Kumar Tank and Singh Chandel CP (2010) Analysis of the major ion constituents in groundwater of Jaipur city. *Nature & Science*, 8(10).1-7.

Table 4.0. Sampling location during summer and monsoon season at Chennai city of 2007

Zone - 1	Summer		Monsoon	
	FC CFU/100ml	EC CFU/100ml	FC CFU/100ml	EC CFU/100ml
Tondaiarpet	30	23	6	3
Kasimedu	25	14	4	2
Natesan Nagar	16	10	3	0
Assis Nagar	11	7	4	2
Rayapuram	18	13	1	0
Pudumanikuppam	14	12	6	2
Thirumoorthy Nagar	9	4	3	0
Jeevarathinamal Nagar	14	10	5	3
Kondithope	10	9	6	4
Brindavan Nagar	9	7	2	1
Amman Koil (S)	13	6	4	0
Manikkam Nagar	15	8	5	3
Rattan Bazar	7	5	6	0
Charless Nagar	8	6	3	2
Singaravelan Nagar	13	9	7	5
Inder Nagar	16	10	5	2
Muthialpet	8	4	8	6
M.R.C.Nagar	6	4	4	2
Old washermenpet	10	5	4	3
Chettithottam	17	8	3	0
Thiruvattiyur	15	7	9	2
Kalmadabam	26	15	6	3
M.C. Road	17	9	10	4
Vallalar Nagar	9	3	5	2
Sowkarpet	12	5	6	4

Table 4.1 Sampling location during summer and monsoon season at Chennai city of 2007

Zone -2	Summer		Monsoon	
	FC CFU/100ml	EC CFU/100ml	FC CFU/100ml	EC CFU/100ml
Kodambakkam (S)	21	15	12	6
Krishnapuram	8	3	9	3
Saidapet (W)	10	4	7	2
Mannurpet	8	2	12	6
Arntatiy Nagar	10	6	9	6
Saidapet (E)	11	4	5	0
Kalaiganar Karunanudhi Nagar	9	2	6	2
Seven wells (N)	10	8	3	0
Peters Colony	9	4	13	6
Anna Salai (Mount Road)	5	2	9	7
Guindy (W)	19	15	4	0
Guindy(E)	9	3	9	4
Anna Nagar	7	5	12	8
MMDA Colony	12	6	8	2
Jafferkhanpet	7	3	10	4
Ekkattuthangal	5	1	7	5
KalaimagarNagar	13	8	12	6
Ambal nagar	10	3	9	7
Ambedkar Nagar	9	4	11	0
Thiru Vi ka Industrial Estate	8	2	6	2
Akshaya Nagar	7	3	3	1
Soudar Nagar	23	14	5	1
Jyothi Nagar	35	16	4	0
Meenambakkam	9	5	3	1
Manapakkam	4	1	2	0

- IS:10500 (1991) Indian Standards of Drinking Water Specification. Bureau to Indian Standards (BIS), New Delhi, India.
- Jinwal A and Dixit S (2008) Pre and post monsoon variation in physio-chemical characteristic in groundwater quality in Bhopal, India. *Asian J. Exp. Sci.* 22 (3), 311-316.
- Mahanta BN, Sarkar BC, Singh G, Saikia K and Paul PR (2004) Multivariate statistical modeling and indexing of ground water quality in and around Jharia coalfields, Jharkhand. Proc. of the National Seminar on Environmental Engineering with special emphasis on Mining Environment, NSEEME-2004, 19-20, March. Indra N. Sinha, Mrinal K. Ghose & Gurdeep Singh (Eds). pp:1-14.
- Manivasakam N (2005) Physicochemical examination of water sewage and industrial effluent. 5th Ed. Pragati Prakashan Meerut.
- Pandey, Sandeep K and Tiwari S (2009) Physico-chemical analysis of ground water of selected area of Ghazipur city-A case study. *Nature & Science.* 7(1) 17-20.
- Ramachandraiah C (2004) Right to drinking water in India. Centre for Economic and Social Studies.56
- Rao Sudhkar M and Mamatha P (2004) Water quality in sustainable water management. *Cur. Sci.* 87 (7), 942-947.
- WHO (1984) Guidelines for drinking water quality. Vol.1. WHO, Geneva.