GROUNDWATER QUALITY ASSESSMENT IN COASTAL REGIONS OF CHENNAI CITY, TAMIL NADU, INDIA – CASE STUDY

A.ANNAPOORANIA
Department of Chemistry, Vel Tech Multi Tech Dr RR, Dr SR Engineering College, Avadi, Chennai-600 062 (Tamil Nadu) India.
A.MURUGESAN
Department of Chemistry, Sriram Engineering College, Perumalpattu, Veppampattu RS, Chennai-602 024 (Tamil Nadu) India.
RAMU
School of Chemistry, Madurai Kamaraj University, Madurai – 625 021(Tamil Nadu) India.
N.G.RENGANATHAN
Department of Chemistry, Vel Tech Dr RR, Dr SR Technical University, Avadi, Chennai – 600 062 (Tamil Nadu) India.

ABSTRACT

Water pollution has become a growing threat to human society and natural ecosystems for the past two decades. Seasonal changes in water quality are the important tool for evaluating temporal variations of pollutants. The consequence of urbanization and industrialization leads to degradation of water quality for the survival needs. Groundwater is being explored in rural areas especially in the study areas owing to unavailing of other sources of water like dam and river or a canal. During last decade, it is observed that the groundwater polluted drastically because of increased anthropogenic activities. Groundwater samples were collected from Chennai City, Tamil Nadu, India. All the analysis was carried out using AR chemicals using double distilled water. The pH, EC, TDS, Ca, Mg, Na, K, Cl, bicarbonate, carbonate, sulphate, hydroxide, fluoride, hardness, DO, and BOD were analysed and compared with the WHO and ICMR standards of drinking water quality parameters to classify the water is suitable for drinking purpose or not. The inter-elemental correlation analysis has been carried out to identify how the elements are interdependent. Statistical analysis was carried out to fine the factors 1, 2, 3 which metal plays the main for the water quality. Piper trilinear diagram is used to find the hydro chemical type of ground water. Using GIS the Interpolation studies have been done to identify the spatial distribution. Thus an attempt has been made to find the groundwater quality and Sea water intrusion into the ground water in Chennai City.

Keywords: *Ground Water Quality, Coastal Regions, Chennai City, WQI, GIS*

INTRODUCTION

India had been blessed with a vast stretch of coastline. But coastal zones face many hydrological problems like flooding due to cyclones and wave surge and drinking fresh water scarcity due to problem of salt water intrusion[1-9]. As sea water intrusion progresses, existing pumping wells, especially close to the coast, become saline and have to be abandoned thus, reduce the value of the aquifer as a source of fresh water. However, in

coastal regions ground water quality[10-17] patterns are complex because of the input from many different water sources. These include precipitation, strong evaporation, seawater ascending deep groundwater and anthropogenic sources such as waste water or irrigation return flow.

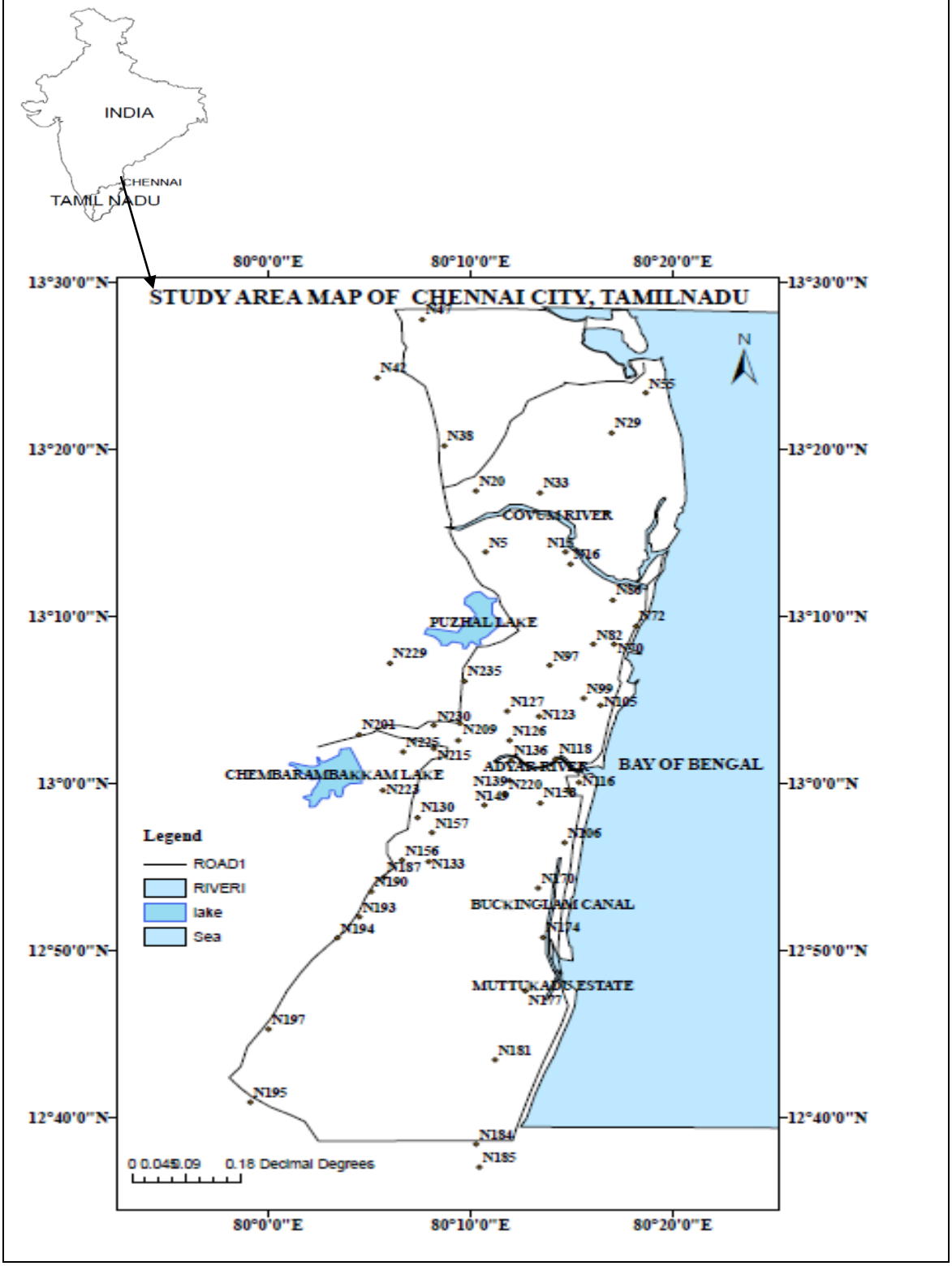
STUDY AREA

The 250 samples are collected from the entire region of Chennai city which is covered by sand up to a depth of about 18m. The latitude and longitude of the study area is 12.617 to 13.463 and 79.985 to 80.311(Fig I). The entire region is covered by sand up to a depth of abour-10m with respect to sea level. In some locations the inner horizon of sand is mixed with clay and made up of clayey sand. The sand and clayey sand region is followed by the weathered rock up to depth of about – 20 m with respect to sea level.

METHODOLOGY

Two hundred and fifty samples were collected from 72 places of Chennai from Elavur to Mahabilipuram. Water samples were collected in polythene bottles, Electrical conductivity, pH, Total dissolved salts are important parameters measured in the spot. Turbidity, Odor, Taste, Colour, were indentified on the spot. All the experiments were carried out using AR chemicals and double distilled water. Chloride, Alkalinity and Hardness was determined by the volumetric titration. Sodium and Potassium are determined by Flame Photometry. Sulphate, Nitrate, Phosphate, Fluoride are determined by Spectrophotometry. Calcium and

FIG I: STUDY AREA MAP OF CHENNAI CITY, TAMILNADU, INDIA



Magnesium are determined by volumetric titration. DO and BOD are analyzed by Iodometric Titration. Statistical Analysis was done using SPSS Software. Map of the study area and spatial variation was done using

GIS Software. Heavy Metals are analyzed using AAS. Out of 72 places, 25 places have chosen for seasonal variation studies in order to predict the water quality with contaminants status.

RESULT AND DISCUSSION

All the major elements are determined for 250 samples. Average Hydrochemical Parameters are presented in Table I. This table shows that ground water samples (pH 5.8 – 7.3) are acidic in nature. Electrical conductivity shows a wide variation from 793.7 to 20824 µS/cm. Based on Saxena et al 2003[18] classified the qualities of ground water samples were studied. Salinity character was dominated in 60% water samples of the study area. Total dissolved solids also showed a wide variation from 500 to 13390 ppm. Higher values of EC and TDS are recorded in George Town and Taramani. This is closer to Covum River or Adyar River or Buckingham Canal or Bay of Bengal. Based on Rabinove et al (1958) [19] classification the 35% of ground water samples are fresh water based on the Total Dissolved Solids which was generally less than 1000 ppm.

Chemical analysis of samples indicates that most dominating ions sodium, chloride, calcium, magnesium, bicarbonate, sulphate, potassium, nitrate, phosphate and fluoride are in this order. The sodium is the dominating cation varied from 46 to 4624 shown in Fig IV. The potassium content of natural waters is usually less than that of sodium, calcium, magnesium. The cation such Ca, Mg, K are varied from 20 to 730, 36.8 to 1456 and 0.3 to 1893 ppm respectively.

The concentration of carbonate ions are in traces, and the bicarbonates concentrations are considerable in all water samples analysed. Amoung the anions chloride is the most dominating anion varied from 90 to 4500ppm shown in Fig IV. The high chloride content of the ground water is mostly due to sea water intrusion. Another important major anion is sulphate. Sulphate is found in the water samples may be due to geological sources. The other anion such as bicarbonate, sulphate, nitrate, phosphate and fluoride varies from 75 to 625, 12.6 to 1948.57, 0 to 500, 0 to 2 and < 1 ppm respectively. From the carefully observation of these data it is clear that the sodium and chloride ions showed a wide range of distributions and higher standard deviation. This suggests a possible incursion of nearby saline water which has comparatively high concentration of sodium and chloride. Water Quality Index is less 20% in 80% the water samples in Chennai city.

Table I: Average Physico-Chemical Parameters of Chennai city, Tamil Nadu

Sample Code	TH	Bicarbonate	Cl	TDS	Cl/Bicarbonate	Na+K	CR
N5	1250	425	396	1280	0.93	422.7	1.56
N15	800	250	289.8	1080	1.16	494.5	2.09
N16	535	375	144	870	0.38	345.5	0.78
N20	1500	325	918	2230	2.82	1065.6	4.48
N28	350	200	477	1450	2.39	826.1	6.26
N29	345	225	504	1570	2.24	689.3	3.86
N33	750	125	455.4	1050	3.64	801	6.29
N38	325	325	90	590	0.28	298.3	0.86

N42	370	225	250.2	850	1.11	306.8	2.34
N47	230	200	217.8	570	1.09	260.7	2.36
N55	850	375	750.6	1830	2	814.2	3.38
N70	390	350	198	710	0.57	267.7	1.18
N72	495	200	558	1820	2.79	716.8	4.66
N82	700	500	633.6	2250	1.27	884.5	2.38
N86	4950	300	2772	5480	9.24	2501.7	19.78
N97	1625	350	1656	3330	4.73	1000	10.4
N99	370	625	154.8	1000	0.25	386.8	0.44
N105	7600	375	4500	13390	12	4411	19.75
N106	4200	100	682.2	1780	6.82	2725.5	11.35
N112	2235	200	3528	8640	17.64	2092	29.73
N116	7400	325	657	1840	2.02	808	3.13
N118	1135	375	1119.6	1960	2.99	4882	5.52
N123	1020	250	918	1850	3.67	850	5.96
N126	1675	500	1103.4	2560	2.21	988	3.43
N127	450	500	156.6	740	0.31	53.1	0.55
N130	805	350	306	1170	0.87	265.6	1.47
N133	1045	550	383.4	1220	0.7	260	1.09
N136	450	325	133.2	720	0.41	62	0.73
N139	550	375	288	830	0.77	62	1.26
N145	580	450	2376	920	5.28	1040	7.68
N149	497.5	575	389.95	1130	0.678	272.1	1.04
N153	365	450	163.07	840	0.362	257.6	0.63
N156	430	350	418.31	1050	1.195	277.6	1.83
N157	407.5	250	294.24	900	1.177	275.2	1.86
N170	490	375	1226.6	2220	3.271	6517	4.73
N174	297.5	175	398.81	1160	2.279	3157.8	3.62
N177	475	125	368.68	1220	2.949	3032.8	4.54
N181	192.5	75	118.76	1500	1.583	1493.3	2.85
N184	770	375	946.52	1900	2.524	2381.8	3.68
N185	315	75	187.89	590	2.505	1033.3	4.25
N187	232.5	350	521.12	1200	1.489	461	2.22
N190	337.5	300	246.38	780	0.821	63.1	1.39
N193	190	125	159.53	500	1.276	137.3	2.13
N194	287.5	125	212.7	720	1.702	309	2.71
N195	302.5	225	186.11	710	0.827	318.5	1.38
N197	317.5	500	257.01	940	0.514	502.5	0.82
N201	250	300	287.15	820	0.957	504.6	1.41
N209	362.5	575	620.38	1210	1.079	452.3	1.54
N215	425	525	496.3	1320	0.945	572.3	1.36

N220	550	425	496.3	1120	1.168	353.9	1.71
N223	385	600	264.1	1170	0.44	540.4	0.65
N225	352.5	525	366.91	1030	0.699	406.9	1.02
N229	700	525	735.59	1830	1.401	1150.5	2.01
N230	387.5	375	393.5	1120	1.049	697.3	1.52
N235	932.5	400	716.09	1430	1.79	743.5	2.57

- Parameters are given in ppm and for EC it is given in µS/cm.

Table II: Correlation Coefficients between major ions in Ground Water

Parameters	**EC**	**TH**	**Mg**	**Ca**	**Cl**	**TDS**	**Na**	**Sulphate**
EC	1							
TH	0.702	1						
Mg	0.614	0.909	1					
Ca	0.798	0.710	0.666	1				
Cl	0.918	0.647	0.558	0.763	1			
TDS	0.997	0.700	0.610	0.790	0.914	1		
Na	0.550	0.430	0.445	0.531	0.580	0.553	1	
Sulphate	0.705	0.569	0.424	0.620	0.749	0.705	0.404	1

Inter elemental correlation was shown in Table II for understanding the relationship between different ionic species. TDS was related to chloride, sodium and calcium with correlation coefficient (r) as 0.914, 0.553 and 0.79 respectively and EC was related to these with (r) as 0.918, 0.533 and 0.798 respectively. Positive relationship indicates that sodium and chloride plays a major role in sea water intrusion.

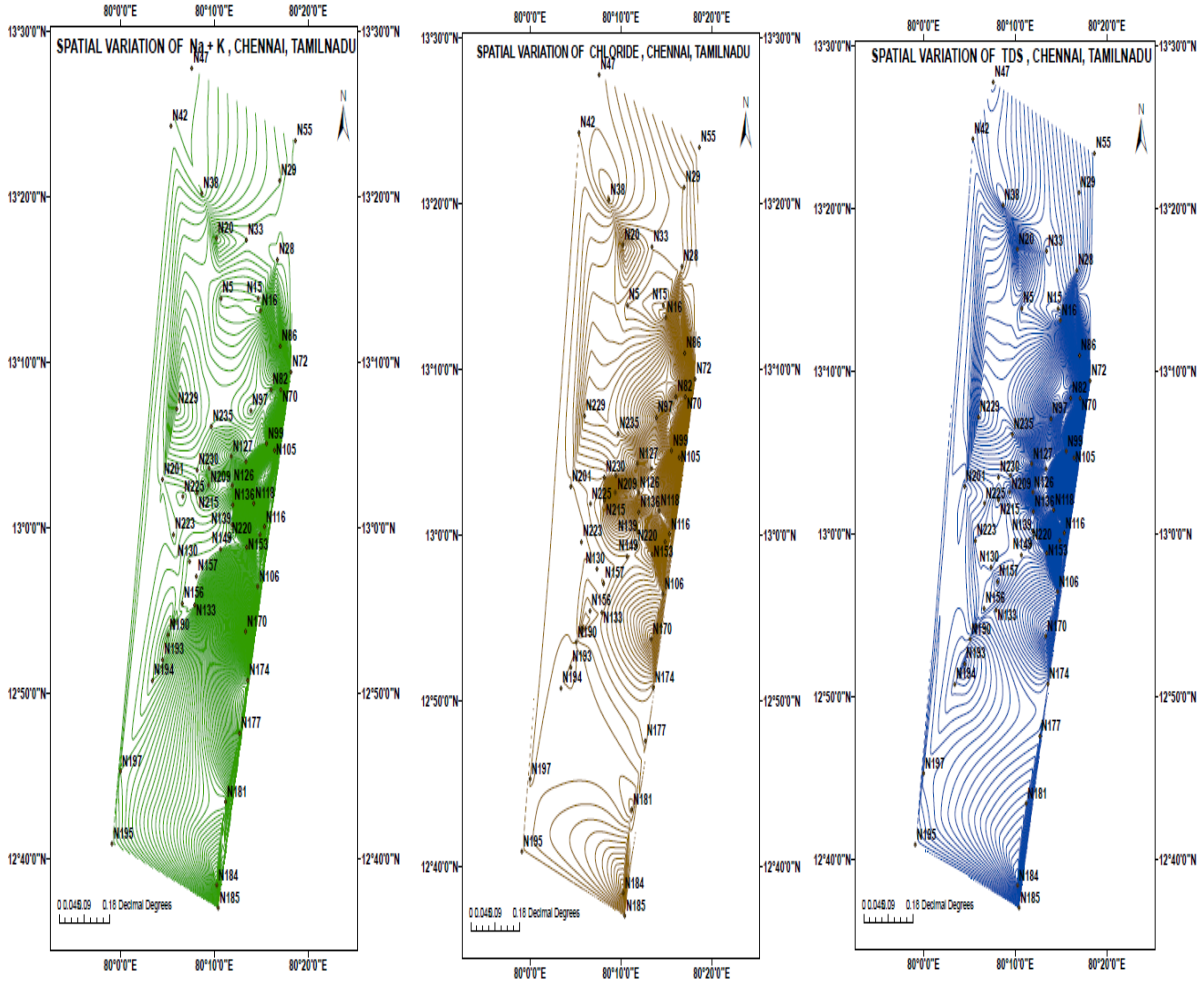
The chloride/bicarbonate ratio and magnesium/calcium ratio indicates that transformation of fresh groundwater to saline water in coastal aquifers. In my study area chloride/bicarbonate ratio is greater than 2 in the wells N20, N28, N29, N33, N55, N72, N86, N97, N106, N112, N116, N118, N123, N126, N145, N170, N174, N177, N184, N185 which is closer to Covum River or Adyar River or Buckingham Canal or Bay of Bengal indicating the intrusion of saline water. If the corrosivity ratio is greater than 1 indicates that water samples are corrosive in nature, 90% of the samples are corrosive in nature in Chennai city.

Major cations and anions were plotted in Piper tri-linear diagram. This is to evaluate the geochemistry of groundwater of Chennai city and it is shown in Fig III. The plots include two triangles, one for plotting cations and other for plotting anions. The cation and anion fields are combined to show a single point in a diamond shaped field, from which influence is drawn on the basis of hydro geochemical farcies concept. In the present study, the plot shows that alkali metals exceed alkaline earth metals in 80% of the samples. Again weak acid exceeds strong acids in 100% of the sample. This indicates that sodium exceeds other cations and chloride

exceeds other anions. This clearly indicates that the salt content is dominating in the bore wells which are situated towards the Covum River or Adyar River or Buckingham Canal or Bay of Bengal.

Spatial Variation of Na+K, Chloride, TDS shown in Fig II indicates that the sea water intrusion takes on the coastal regions of Chennai city. Schoeller diagram in Fig IV is indicating that sodium cation is dominating than other cations similarly chloride anion is dominating than other anions towards the Covum River or Adyar River or Buckingham Canal or Bay of Bengal indicating intrusion of salt water. Fig V is the cross plot of sodium and chloride ions indicating that both the cations and anions are occurring in similar ratio.

Fig II: Spatial Variation of Na+K, Chloride and TDS, Chennai, Tamil Nadu, India



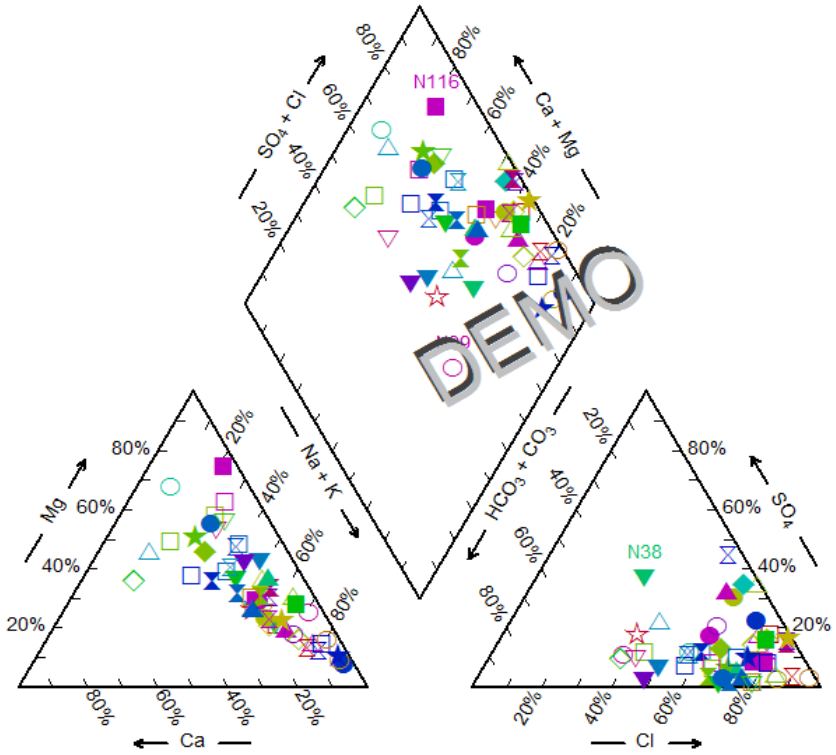


Fig III: The Piper Diagram for Chennai City.

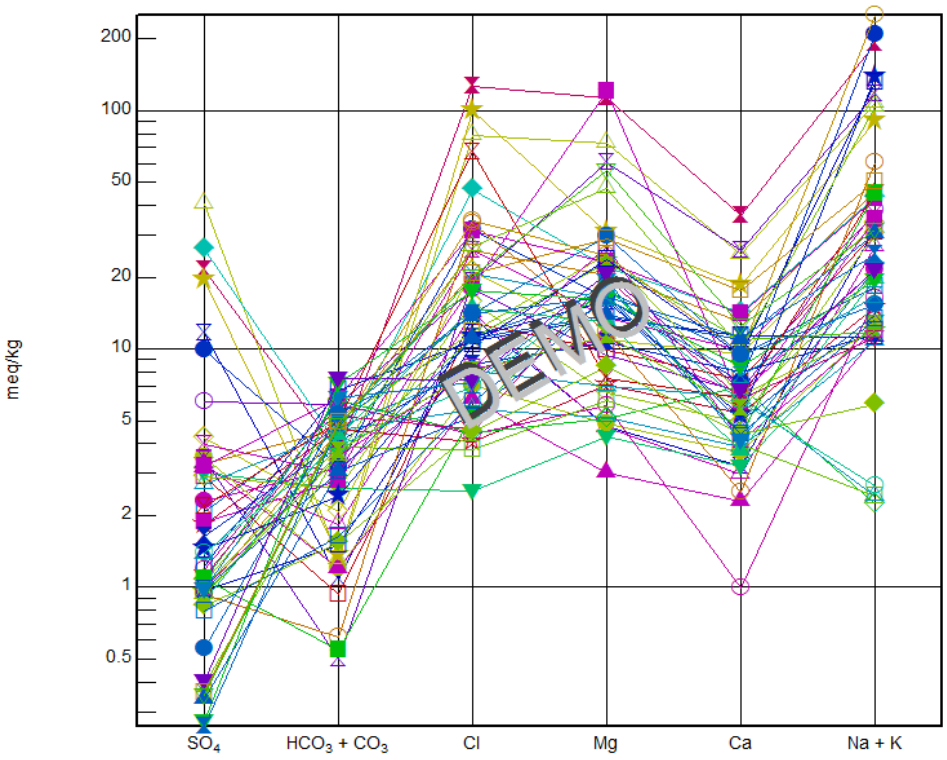


Fig IV: The Schoeller Diagram for Chennai City

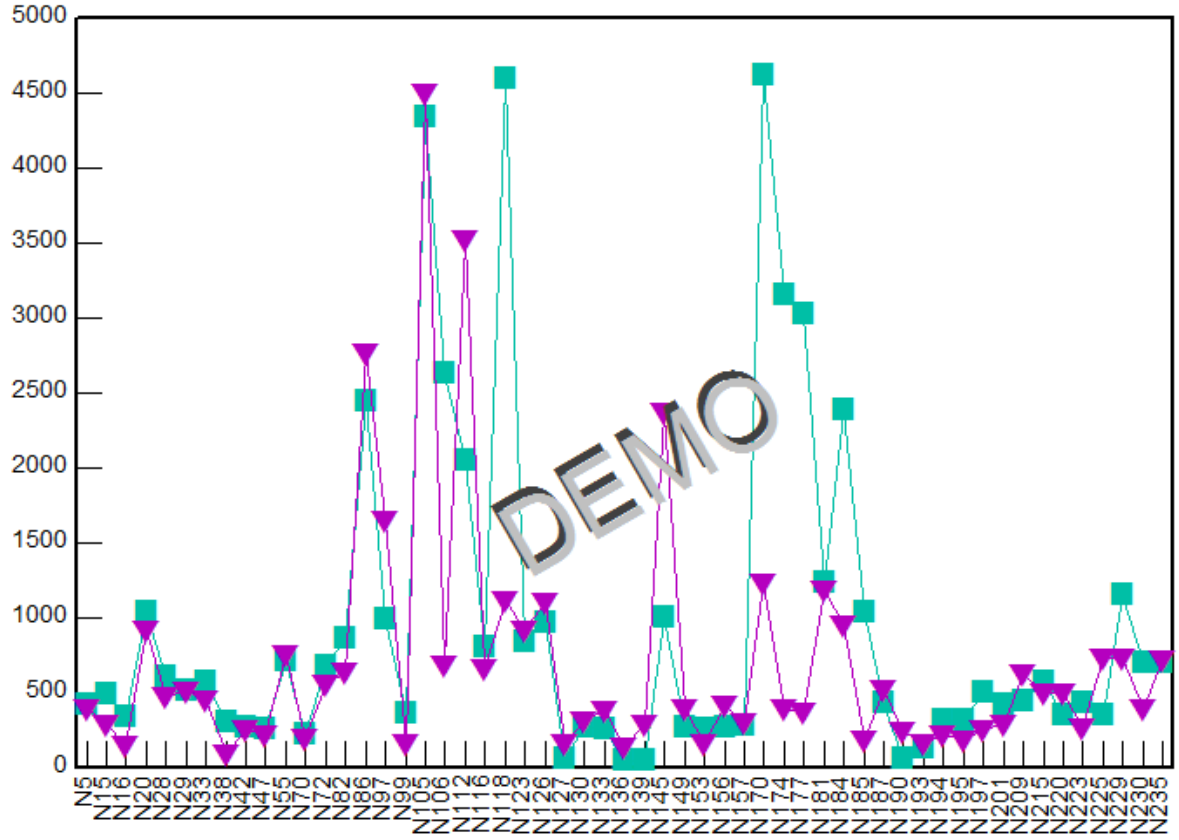


Fig V: Cross Plot of Sodium and Chloride

FACTOR ANALYSIS

SPSS version 9.05 software was used for carrying out the statistical analysis of the data after performing auto scaling of various parameters. Principle component analysis was carried out to extract the various factors. The factor F1, which explains 55.494 % of total variance, has high loading of TDS and Chloride. Anion which is responsible for sea water intrusion is chloride. It shows positive correlation with all the factors except bicarbonate. Therefore factor 1 chloride which is responsible for sea water intrusion. The factor F2 which explains 18.73% of total variance has high loading of Sodium and others shows negative correlation. Therefore factor 2 is sodium which is responsible for sea water intrusion. The statistical analysis indicates that impact of saline water and cation and anion exchange are the major controlling factors of the groundwater quality.

EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATION SUITABILITY

Electrical Conductivity and sodium ions play a vital role in suitability of groundwater for irrigation. Higher EC in water creates saline soil, whereas higher salt content in irrigation water causes an increase in soil solution osmotic pressure (Thorne and Petesonm 1954) [20]. Salts, besides affecting the growth of plants directly, also affect the soil structure, permeability and aeration which indirectly affect plant growth (Subba Rao 2006) [21]. The salinity hazards for the water wells are classified as low and medium are nil, 40% high and 60% very high. It is indicating that percentage of very high salinity well samples was unsuitable for irrigation purposes because they are close to canal and sea sides. This high salinity is due to the seawater and saline water incursion from the canal and sea, in addition to the leaching and dissolution of soil salts. Sodium Adsorption ratio indicates that 60% water samples are not suitable for Irrigation Purpose.If Sodium Percentage is high it is not suitable for irrigation purpose. In our study area 40% sample are having low sodium percentage, that is suitable for irrigation and 60% of water sample are having high sodium percentage, indicating that they are not suitable for irrigation purpose. If ESP is <15, that soils can be used for irrigation purpose. In our study area 40% of the samples are having ESP less 15, indicating that they are suitable for irrigation purpose. From this we conclude that normal soil was found in the central part of the area, whereas sodic and saline sodic soil towards the Covum River or Adyar River or Buckingham Canal or Bay of Bengal.

CONCLUSION

The sea water intrusion was studied in coastal regions of Chennai city, Tamil Nadu, India by analysing 250 samples. In about 35% of the wells are recommended limits for drinking water quality were exceeded in one of the other parameters. It is suspected that this may be due to indiscriminate disposal of domestic and industrial wastes. The ground water is slightly acidic, but mainly classified as sodiumchloride type. The sodium ions and chloride ions in groundwater systems increase towards coastal regions of Chennai city, which are located towards the Covum River or Adyar River or Buckingham Canal or Bay of Bengal. Representative ionic ratio of magnesium/calcium, bicarbonate/chloride, TDS levels differentiated groundwater strongly affected by saline water incursion/seawater intrusion from that nor or less affected. Principal component analysis shows that groundwater is affected by saline water incursion in coastal regions of Chennai city. Irrigation suitability study indicates that groundwater quality is safe in the central part, but it is not safe towards the Covum River or Adyar River or Buckingham Canal or Bay of Bengal.

REFERENCES

1. A depelumi,A.A., Ako,B.D., Ajayi,T.R., Afolabi.O., & Omotoso, E.J.,(2009). Delineation of saltwater intrusion into the freshwater aquifer of Lekki Peninsula, Lagos, Nigeria. Environmental Geology, 56, 927-933.
2. Terzic, J., Markovic, T., Pekas, Z.,(2008) Influenece of sea water intrusion and agricultural production on the Blato Aquifer, Island of Korcula, Croatia, Environ Geol 54: 719-729.
3. Franco, R., Biella, G., Tosi, L., Teatini, P., Lozej, A., Chiozzotto, B., et al (2009). Monitoring the saltwater intrusion by time lapse electrical resistivity tomography: the Chioggia test site (Venice Lagoon, Italy). Journal of Applied Geophysics, 69(3-4), 117-130.

4. Nasab, A.A., Boufadel, M.C., Li, H., & Weaver, J.W. (2010). Saltwater flushing by freshwater in a laboratory beach. Journal of Hydrology, 386(1-4), 1-12
5. Pujari, P.R., & Soni, A.K., (2009), Sea water intrusion studies near Kovaya Limestone mine, Saurashtra Coast, india. Environmental Monitoring and Assessment 154(1-4), 93-109.
6. Elango.L, 2009j, Groundwater modelling to assess the feasibility of pumping seawater from a beach well for Chennai desalination plant, Dept. Of Geology, Anna University, Journal of Applied Hydrology, Vol. XXII, NoI, PP.54-92.
7. Mondal, N.C., Singh, V.P., Singh, S., & Singh, V.S., (2010a). Hydrochemical characteristic of coastal aquifer from Tuticorin, Tamil nadu, India. Environmental monitoring and Assessment. Doi:10.1007/s10661-010-1549-6.
8. Rao, N.S., Nirmala, I.S., & Suryanarayana, K. (2005) Ground water quality in a coastal area: A case study from Andhra Pradesh, India. Environmental Geology, 48(4-5), 543-550.
9. Anitha Mary.I, Ramkumar.T&Venkatramanan.S, 2000m Application of statistical analysis for the hydrogeochemistry of saline groundwater in kodiakarai, Tamilnadu, India, Department of Earth Science, Annamalai University, Journal of Coastal Research, West palan beach.
10. Giridharan.L, Venugopal.T, Jayaprakash.M, Assessment of water quality using chemometric tools: A case study of river cooum, South India, Arch Environ Contam Toxicol (2009) 56:654-669.
11. Lakshmanan.E, Kannan.R,& M.Senthil Kumar in 2003, Major ion chemistry and identification of hydrogeochemical analysis of groundwater in Kancheepuram District, Tamil Nadu, Environmental Geosciences, V.10, No.4, PP.157-166.
12. Nabanita Haloi & Sarma H.P. in 2010, Assessment of ground water quality of a part of Brahmaputra Flood plain in Barpeta District, Assam, Int.J.Chem.Sci: 8(3),2010, 1983-1991.
13. Sivakumar.C & Elango.L in 2008, Assessment of water quality in Kalpakkam region, Tamil Nadu, Dept. Of Geology, Anna University, Chennai, Nature Environment and pollution technology, vol.7, no.4, 687-691.
14. Subba Rao, N.,(2006). Seasonal Variation of GroundWater quality in a part of Guntur district, Andhra Pradesh, India. Environmental Geology , 49, 413-429.
15. Senthil Kumar, G., Ramanathan, A.L., Nainwal, H.C., & Chidambaram, S. (2008). Evaluation of the hydrogeochemistry of groundwater using factor analysis in the cuddalore coastal region, Tamil Nadu, india, Indian Journal of Marine Sciences, 37(2), 181-185.
16. Elango.L.,Ramachandran.S.,and Chowdary.Y.S.N 1992 Ground water quality in Coastal regions of South Madras. Indian J Environ.Hlth.34(4) 18-32.
17. Rengaraj.S., ElamPooranan.T.,Elango.L., and Ramalinagam.V., Groundwater quality in Suburban Regions of Madras City, India. Poll.Res. 15(4):325-328(1996).
18. Saxena V.K., Singh.V.S.,Mondal,N.C., and Jain,S.C.,(2003) Use of Chemical Parameters to delineation fresh water resources Potharlanka Island, India. Environmental Geology, 44(5), 516-521.
19. Rabinove,C.L., Longford,R.H., and Brookhart,J.W.,(1958) Saline water resources of north Dakota (p 364) Us Geographical Survey Water Supply, Paper 1418.
20. Thorne,D.W., & Petersonm,H.B.,(1954). Irrigated soils, London: Constable and Company
21. Subba Rao,N.(2006) Seasonal variation of groundwater quality in a part of Guntur district,Andhra Pradesh, India, Environmental Geology, 49,413-429.