

Assessment of Groundwater Quality Index in and Around Sholinganallur Area, Tamil Nadu

S. Packialakshmi^{1*}, Meheli Deb² and Hrituparna Chakraborty²

¹Department of Civil Engineering, Sathyabama University, Chennai - 600 119, Tamil Nadu, India;
bagyaram@gmail.com

²Department of Civil Engineering, Sathyabama University, Chennai - 600 119, Tamil Nadu, India;
Meheli.sathyabama@gmail.com

Abstract

Groundwater is an essential and valuable natural source of water supply all over the world. To meet out the rising demand it is crucial to identify and recognize the fresh water resources and also to find out remedial methods for improvement of water quality. The present study aims in determining the groundwater quality in and around Sholinganallur area, Kancheepuram District. Sholinganallur is a suburban town of Chennai city situated on the southern IT corridor of Chennai in the Indian state of Tamil Nadu. The increase in growth of Sholinganallur's economy, population density and infrastructure developments aggravated the stress on water and land related issues. The areal extent of a study area is 46.25 km² from Navalur to Karapakkam. The Water Quality Index explains overall quality at certain location and time, based on several physio-chemical parameters. It provides an excellent representation of overall quality of water for various purposes in the arena of water management. Water samples were collected from ten sampling points and tested for several physio-chemical parameters like pH, Total Dissolved Solids (TDS), Hardness, Alkalinity, Sulphates, Nitrates, Chloride and Fluoride. Further the study uses Arc GIS for mapping the water quality to identify the spatial variation in groundwater quality. From the study, the presence of high TDS occurs in most of the locations and the ground water quality status of the selected area is found to be critical. Further the study identified potential suggestive measures and recommendations.

Keywords: Chennai, GIS Mapping, Groundwater, Piper Diagram, Quality Index

1. Introduction

Groundwater is an inevitable source of drinking water for both urban and rural India. Besides, it is a vital source of water for the drinking, agricultural and the industrial sector. Being a significant part of the hydrological cycle, its occurrence and availability depends on the rainfall and recharge conditions. Groundwater quality comprises the physical, chemical and biological characteristics of groundwater. The suitability of groundwater for various uses majorly depends on quality of groundwater. Hence protecting the quality of groundwater is a major concern⁸. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned people and comprehend the spatial and

temporal variation of quality. It acts as the indicator of the quality of water. The objective of the water quality index is to turn multifaceted water quality data into simple information that is useable by the public. Several researchers have conducted a study on groundwater quality by estimating the water quality index to substantiate the variation of groundwater quality^{4,7,11,13}.^{1,3} Research on spatial distribution analysis of groundwater quality index developed various thematic maps for the water quality parameters using geostatistical Approach. From the studies it is inferred that pH in most of the wells of the area is acidic and alkaline in nature and in most of the locations groundwater is not fit for drinking due to high concentration of chloride content. From the WQI index value it is clearly shown that majority of the bore wells are poor in

*Author for correspondence

quality.^{14,2} The studies on determination of groundwater quality using WQI in parts of Chennai city, Tamil Nadu stated that along the coast the chloride concentrations exceed the limits (74.445mg/l to 6747.908mg/l) and the quality of the groundwater is not good. The TDS and Total hardness are also playing a significant role in groundwater quality assessment. Chennai city was divided into three zones based on the legislative constituency and from these three zones three locations were randomly selected and nine groundwater samples were collected and analyzed for physiochemical properties. Results showed that with the exception of few parameters most of the water quality assessment parameters showed parameters within the permissible values according to the BIS. According to the Central Groundwater Board, eighty percent of Chennai's groundwater level got depleted and any further exploitation could lead to salt water ingress. ¹²In a study on GIS based evaluation of groundwater quality index of groundwater resources in and around Tuticorin coastal area, India. From the Piper plot, it is inferred that concentration of the alkalis (Na^+ and K^+) exceeds the alkaline earths (Ca^{2+} and Mg^{2+}) and strong acids exceeds weak acids. In the case of anions, strong acid proved dominance over weak acid and HCO_3^- and Cl^- have influences almost equal to Na^+ , which shows the saltwater ingress into the freshwater system of the study area. The study demonstrates that EC and TDS value in both pre and post monsoon period were found to be higher than the permissible limit due to sea water intrusion. ⁶In a study on groundwater quality for irrigation and drinking purposes for Birbhum district West Bengal, various water quality indices have been calculated for each water sample to identify the irrigational suitability standard. ⁵The several studies on characterization of groundwater hydrochemistry and quality assessment are conducted using various multivariate statistical techniques, piper diagram and water quality indices. The presented study investigated the groundwater quality in and around Sholinganallur area, Kancheepuram district by analyzing the different physio-chemical parameters presented in the groundwater. It determines the suitability for drinking purpose using water quality indexing method. Further it develops ground water quality mapping using ArcGIS to identify the spatial variation in groundwater quality.

2. Study Area

Sholinganallur area, Kanchipuram district, south India has been chosen for conducting the study (Figure 1). The area

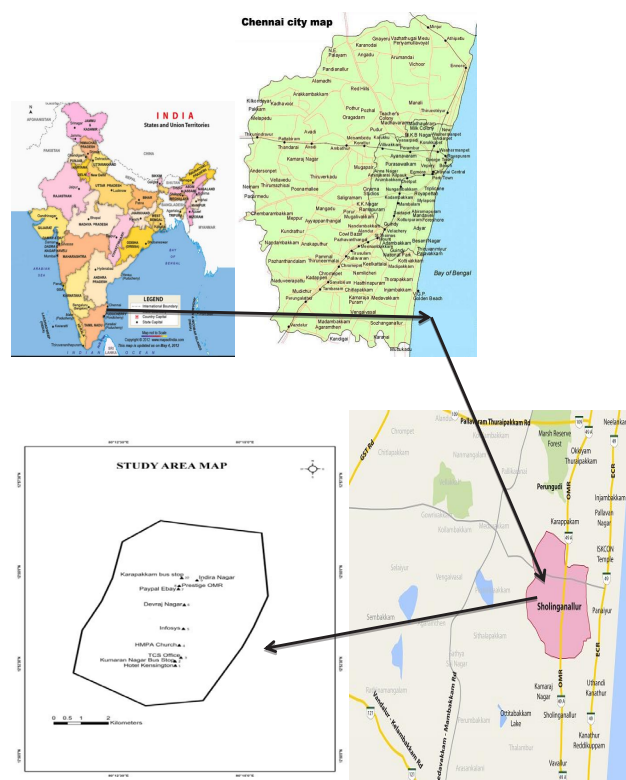


Figure 1. Administrative map of the study area.

is bounded by Bay of Bengal in the Eastern part and it is situated very adjacent to the east coast. The study area is located between latitude 12.87N to 12.92N and longitude 80.22E to 80.23E. The areal extent of the selected study area is 46.25 km². ¹⁶Climatically the area belongs to a tropical wet and dry climate. Several educational institutions, industries, training centres and multinational companies are established in this area. Due to the widespread infrastructural developmental activities, the people have moved from city environment to these peri-urban areas which make these areas as special economic and developmental zones.

3. Materials and Methods

Selection of monitoring wells in order to collect the groundwater samples is important for assessing the groundwater quality. A stratified random sampling technique was chosen and the wells were selected with coverage area of approximately 4 to 5 km². Ten sampling points were selected using Google Earth for the collection of water samples. The samples were collected during the post monsoon season of January 2015. Base map of the study area is prepared using ArcGIS software.

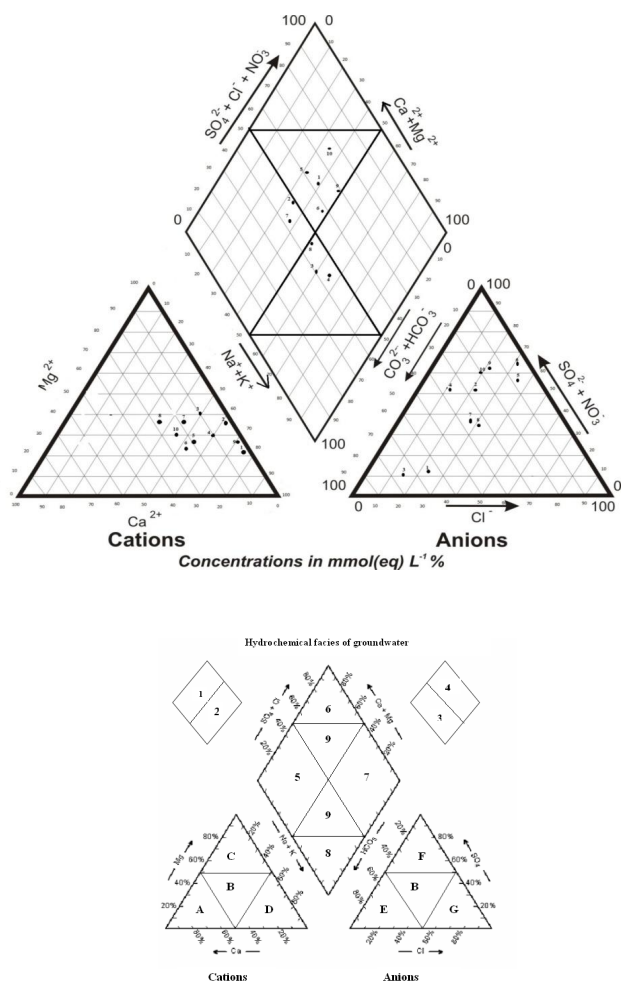


Figure 2. Piper diagram showing hydrochemistry of different cations and anions.

- A – Calcium type
- B – No Dominant type
- C – Magnesium type
- D – Sodium and Potassium type
- E – Bicarbonate type

Samples were for tested and test results were tabulated. The parameters are electrical conductivity, pH, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, chloride, nitrate, fluoride, TDS, TH and total alkalinity. ¹⁵These results were compared with Bureau of Indian Standards (BIS) limits. Thematic maps of the different physio-chemical parameters have been prepared with the help of ArcGIS software. The test results of the water quality parameters were analysed and the water quality index is calculated to understand the quality and suitability of groundwater. The Piper diagram is used to show the relationships between the different cations and anions to understand the hydrochemistry of groundwater.

4. Results and Discussions

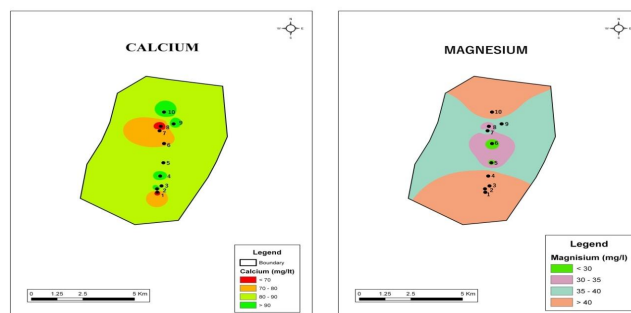
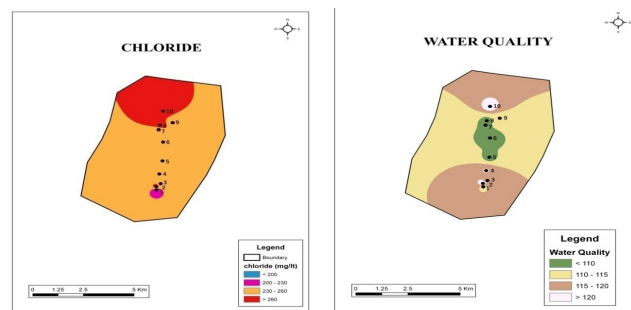
The analysis of test results indicated that values of Total Dissolved Solids (TDS), Total Hardness (TH), Alkalinity and Chloride exceeded the desirable BIS limits (Table 1). Figures 3, 4 and 5 show the spatial distribution of TDS, TH, Calcium, Magnesium and Chloride. Sample analysis explained the geological contribution of prevailing quality of groundwater. ¹⁰The study conducted by the Central Ground Water Board (CGWB) along the coastal stretch identified that there are two aquifer system i.e) aquifer system towards eastern border i) Aquifer system towards western border. Buckingham canal which is running towards south acts as a separator for these aquifers. On the western side of Buckingham canal, there exist two aquifer systems, i.e) Grey sand clay intercalation-un confined ii) weathered and fractured aquifer. System of clay intercalation is extended towards east and weathered and fractured aquifer is extended towards western region. As the study area is located on the clay intercalation and it is situated on the stretch of marshy land, the quality and quantity of the groundwater is not appreciable. Thus prevailing groundwater chemistry and its quality explains the significant contribution of geogenic factors. Table 2 explains the health impacts of water quality parameters.

Piper diagram is the graphical representation of the hydrogeochemistry of collected groundwater samples. Figure 2 shows the piper diagram for the study area. It is very essential to assess the geochemical evaluation of nature of groundwater. The triangular and diamond shaped field shows the scale reading in 100 parts. The diamond illustrates the dominant cations and anions to identify the type of water. The water types are termed according to the area in which they positioned on the diagram segments. The percentage of cations and anions are plotted (according to the trilinear coordinates) at the lower left and right triangles, respectively. These are projected upwards, parallel to the sides of the triangles, to locate a point in the rhombus. The point is marked by a circle whose area is proportional to the absolute concentration (actual ppm) in water. The water quality types can be identified by the points which are located in the different zones of the diamond shaped field as shown in Figure 3.4.

Major anions and cations such as Ca^{2+} , Mg^{2+} , Na^+ , K^+ , HCO_3^- , CO_3^{2-} , SO_4^{2-} , and Cl^- in mg/lit were plotted in Piper diagram to evaluate the hydrochemistry of groundwater of the study area. The cations and anions are located

Table 1. Groundwater quality parameters of the study area

Sl. No.	Particulars	Unit	1	2	3	4	5	6	7	8	9	10
1	EC	$\mu\text{S}/\text{cm}@25$	1290	1940	1680	1880	1570	1530	1460	1740	1430	1890
2	pH		7.5	7.3	7.3	7.3	7.4	7.4	7.4	7.3	7.4	7.3
3	Ca	mg/lit	60	102	84	94	84	80	72	60	96	98
4	Mg	"	41	51	41	45	29	27	36	32	38	50
5	Na	"	141	216	200	224	198	199	174	257	138	212
6	K	"	15	28	20	26	20	17	18	24	15	27
7	HCO ₃	"	262	415	360	403	299	287	287	281	336	372
8	CO ₃	"	0	0	0	0	0	0	0	0	0	0
9	SO ₄	"	94	141	137	145	124	128	113	131	117	145
10	Cl	"	195	284	234	259	245	255	220	305	227	291
11	NO ₃	"	43	72	52	69	50	44	44	58	40	69
12	F	"	0.46	0.56	0.58	0.57	0.57	0.47	0.52	0.43	0.54	0.56
13	TDS	"	720	1102	949	1064	900	894	821	1008	840	1079
14	TH as CaCO ₃	"	320	465	380	420	330	310	330	280	395	450
15	TA as CaCO ₃	"	215	340	295	330	245	235	235	230	275	305

**Figure 3.** Thematic map showing the variation of i) TotalDissolved Solids ii) Total Hardness in different sampling locations.**Figure 4.** Thematic map showing the variation of i) Calcium (Ca) ii) Magnesium in different sampling locations.**Figure 5.** Thematic map showing the variation of i) Chloride(Cl) ii) Water quality index in different sampling locations.

by ternary plots. The apexes of the cation plot show the calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot indicate sulphate, chloride and carbonate plus hydrogencarbonate anions. The diamond is a graph of matrix transformation shows the anions (sulphate+chloride/total anions) and cations (sodium+potassium/total cations).

Figure 2 and Table 3 shows the domination of mixed ion category i.e no anion and cation dominant. Groundwater quality analysis results reported the values of physio chemical parameters that are exceeded the BIS limits. Based on this, water quality index was developed to assess the category of groundwater.

Table 2. Health effects of water quality parameters^{17,18}

Parameter	BIS Guideline value (Desirable)	General & Health effect
Total dissolved Solids(TDS)	500mg/lit	Undesirable taste; gastro intestinal irritations; corrosion
pH	6.5–8.5	Affects mucous membrane; bitter taste; corrosion; affects aquatic life
Alkalinity	200 mg/lit	Boiled rice turns yellowish
Hardness	300 mg/lit	Poor lathering with soap; deterioration of the quality of clothes; skin irritation; boiled meat and food become poor in quality
Calcium	70 mg/lit	Poor lathering and deterioration of the quality of clothes
Magnesium	35 mg/lit	Poor lathering and deterioration of clothes
Nitrate	45	Blue baby disease) algal growth
Sulphate	200	Taste affected; gastro intestinal irritation
Chloride	250	Taste affected; corrosive

Table 3. Details of subdivision of Piper diagram⁹

Sl.No	subdivisions	Characteristics of corresponding subdivisions
	A	Calcium type
	B	No Dominant type
	C	Magnesium type
	D	Sodium and Potassium type
	E	Bicarbonate type
	1	Alkaline earth (Ca+Mg) exceed alkalies (Na+K)
	2	Alkalies exceed alkaline earths
	3	Weak acids (CO ₃ +HCO ₃) exceed strong acids (SO ₄ +Cl)
	4	Strong acids exceed weak acids
	5	Magnesium bicarbonate type
	6	Calcium-Chloride type
	7	Sodium-Chloride type
	8	Sodium - Bicarbonate type
	9	Mixed type (No cation-anion exceed 50%)

4.1 Assessment of water quality index (WQI)

The water quality index (WQI) of the study area is calculated using the formula

$$WQI = \sum q_i W_i / (\sum W_i)$$

Where,

W_i = Unit weight for the i^{th} parameter

q_i = Quality rating index for i^{th} water quality parameter ($i = 1, 2, 3 \dots \text{etc}$)

q_i is calculated using the following formula,

$$q_i = 100(V_i / S_i)$$

V_i = Measured value of the i^{th} parameter at a given sampling location

S_i = Standard permissible value for the i^{th} parameter.

W_i is calculated using the following formula,

$$W_i = K / S_i$$

K = constant of proportionality.

K is assumed as 5.3

The water quality index is calculated for the location 1.

$$WQI = \sum q_i W_i / (\sum W_i)$$

$$\begin{aligned} (WQI)_1 &= [(100 * 0.623) + (144 * 0.010) + (80 * 0.0706) + \\ &\quad (136.6 * 0.176) + (106.6 * 0.017) + (430 * 0.017) \\ &\quad + (78 * 0.021)] / (0.623 + 0.010 + 0.0706 + \\ &\quad 0.176 + 0.017 + 0.017 + 0.021) \\ &= 111.9 \end{aligned}$$

Table 4 shows the unit weight of chemical parameters which are used to assess the water quality index. Figure 5

Table 4. Groundwater quality parameters with their unit weights

Parameter	Recommended Limit (S_i)	Unit Weight (W_i)
Ph	6.5–8.5 (BIS)	0.623
Total dissolved solids	500 (BIS/ICMR)	0.010
Calcium	75 (BIS/ICMR)	0.0706
Magnesium	30 (ICMR/BIS)	0.176
Total Hardness	300 (BIS)	0.017
Electrical Conductivity	300 (ICMR/BIS)	0.017
Chloride	250 (ICMR/BIS)	0.021

Table 4. Groundwater quality parameters with their unit weights

Parameter	Recommended Limit (S_i)	Unit Weight (W_i)
Ph	6.5–8.5 (BIS)	0.623
Total dissolved solids	500 (BIS/ICMR)	0.010
Calcium	75 (BIS/ICMR)	0.0706
Magnesium	30 (ICMR/BIS)	0.176
Total Hardness	300 (BIS)	0.017
Electrical Conductivity	300 (ICMR/BIS)	0.017
Chloride	250 (ICMR/BIS)	0.021

Table 5. Groundwater quality index values for the selected sampling locations

Sl.No	1	2	3	4	5	6	7	8	9	10
WQI	111.9	127.2	116.2	121.7	108.5	106.6	110.7	108.65	114.70	125.8

Table 6. Water quality index (WQI) rating and inference of water quality according to BIS

Water Quality Index Level	Water Quality Status
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
>100	Unsuitable for drinking

(ii) shows the areal or spatial distribution of water quality indexing. Table 5 and 6 indicate the water quality index for the selected locations and inference on the values of water quality index. All the values are exceeded the acceptable level i.e greater than 100. It shows the unacceptable standard for drinking purposes.

5. Conclusion

The status of ground water quality in the study area is found to be critical. The presence of high TDS and hard water occurs in most of the locations. The water quality index shows the quality of the ground water is moderate to very poor and it is not suitable for drinking purposes. Further

the study emphasis the continuous seasonal assessment of groundwater quality. Even though treatments like reverse osmosis, distillation, activated carbon etc. can eliminate the prevailing contamination, the present scenario needs consideration on rainwater harvesting, waste water reuse and water treatment techniques. This will reduce the augmentation of fresh water needs considerably. Finally the present study draws the following recommendations for meeting the present as well as future water demands.

Recommendations:-

1. Rainwater Harvesting must be provided and should be made compulsory for each residential unit as it is considered as the economical solution.
2. Consideration of schemes to construct artificial recharge structures
3. Provision of government owned treatment units like reverse osmosis, desalination, ion-exchange process etc. to prevent the consumption of marginal quality water.
4. A groundwater assessment and estimation study should be conducted each year for better understanding of groundwater quality variation.
5. Public awareness programmes need to be developed for sustainable management of groundwater.

6. Acknowledgments

We are grateful to State and Central Groundwater Board, Chennai for providing necessary data to conduct the study. We thank the management, Sathyabama University for providing necessary support for completing the study successfully.

7. References

1. Ambica A. Ground Water Quality Characteristics Study by Using Water Quality Index in Tambaram Area, Chennai, Tamil Nadu. Middle-East Journal of Scientific Research. 2014; 11:18–23.
2. Balan I, Shivakumar M, Madan Kumar PD. An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India. Chronicles of Young Scientists. 2012; 3:146–50.
3. Gorai AK, Kumar S. Spatial Distribution Analysis of Groundwater Quality Index Using GIS: A Case Study of Ranchi Municipal Corporation (RMC) Area. SciTechnol Journal. 2013; 1:1–11.
4. Kumar S, Bharani R, Magesh NS, Prince Godson S, Chandrasekar N. Hydrogeochemistry and groundwater

- quality appraisal of part of south Chennai coastal aquifers, Tamil Nadu, India using WQI and fuzzy logic method. *Applied Water Sciences*. 2013; 13–148.
5. Lagos, Eti. Characterization of Groundwater Hydro-chemistry and Quality Assessment. *Ethiopian Journal of Environmental Studies and Management*. 2013; 6:63–75.
 6. Nag SK, Das S. Groundwater Quality for Irrigation and Domestic purposes – A GIS based case study of Surii and ii blocks, Birbhum District, West Bengal, India. *International Journal of Advancement in Earth and Environmental Sciences*. 2014; 2:25–38.
 7. Nagaraju A, Sunil Kumar K, Thejaswi A. Assessment of groundwater quality for irrigation: A case study from Bandalamottu lead mining area, Guntur District, Andhra Pradesh, South India. *Applied Water Sciences*. 2013; 1:14–154.
 8. Packialakshmi S, Ambujam NK, Nellyat P. Groundwater market and its implications on water resources and agriculture in the southern peri-urban interface, Chennai, India. *Journal of Environment, Development and Sustainability*. 2011; 13(2):423–38.
 9. Packialakshmi S, Ambujam NK. A Hydrochemical and geological investigation on the Mambakkammni watershed, Kancheepuram District, TAMIL Nadu, India. *Journal of Environmental Monitoring and Assessment*. 2011; 184(5):3293–306.
 10. Packialakshmi S, Balaji S, Kumaresan T. Inducing recharge of groundwater by treated waste water- A Pilot study in southern Chennai Metropolitan Area. *Indian Journal of Science and Technology*. 2015; 8(11).
 11. Rupal M, Bhattacharya T, Chakrabarty S. Quality Characterisation of Groundwater Using Water Quality Index (WQI). *India International Research Journal of Environment Sciences*. 2012; 1(4):14–23.
 12. Selvam S, Manimaran G, Sivasubramanian P, Balasubramanian N, Seshunarayana T. GIS-based Evaluation of Water Quality Index of groundwater resources around Tuticorin coastal city, south India. *Environmental Earth Sciences*. 2013; 71:2847–67.
 13. Singh AA, Singh PK, Dhakate R, Singh NP. Groundwater quality appraisal and its hydrochemical characterization in Ghaziabad (a region of Indo-Gangetic plain), Uttar Pradesh, India. *Applied Water Sciences*. 2013; 3(1):13–137.
 14. Srikanthan L, Jayaseelan J, Narendran D, Manikandan I, Singh SH. Determination of Groundwater Quality using WQI in parts of Chennai city, Tamil Nadu. *Indian Journal of Science*. 2013; 3(8):81–4.
 15. Indian Standard for Drinking Water – Specification IS 10500 : 1991
 16. State Profile. Available from: <http://www.cgwb.gov.in>.
 17. Available from: www.cpcb.nic.in
 18. Available from: www.twadboard.com