Original Article

An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India

Abstract

Context: Water, the elixir of life, is a prime natural resource. Due to rapid urbanization in India, the availability and quality of groundwater have been affected. According to the Central Groundwater Board, 80% of Chennai's groundwater has been depleted and any further exploration could lead to salt water ingression. Hence, this study was done to assess the groundwater quality in Chennai city. **Aim**: To assess the groundwater quality using water quality index in Chennai city. **Materials and Methods:** 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:** With the exception of few parameters, most of the water quality assessment parameters showed parameters within the accepted standard values of Bureau of Indian Standards (BIS). Except for pH in a single location of zone 1, none of the parameters exceeded the permissible values for water quality assessment as prescribed by the BIS. **Conclusion:** This study demonstrated that in general the groundwater quality status of Chennai city ranged from excellent to good and the groundwater is fit for human consumption based on all the nine parameters of water quality index and fluoride content.

Key words:
Chennai city, groundwater, water quality, water quality index

Introduction

Water, the elixir of life, is a prime natural resource, a basic human need, and a precious national asset. The three major sources of water are rain, surface water, and groundwater. Rain water percolating into ground constitutes the groundwater. Groundwater is superior to surface water because of the effective filtering effect. It is the cheapest and most practical means of providing water to communities.[1]

The total annual replenishable groundwater resources in India have been assessed as 433 billion cubic meters (BCM) and the net annual groundwater availability is estimated as 399 BCM. Existing gross groundwater draft as on March 2004 for all uses is 231 BCM per year.[2]

Rapid urbanization, especially in developing countries such as India, has affected the availability and quality of groundwater due to its exploitation. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source.[3] The common pollutants of groundwater are discharge of agricultural, domestic, and industrial waste, pesticides, etc. which leads to water-borne diseases. Water-borne diseases may be of microbial origin such as diarrhoea, dysentery, cholera, and typhoid and chemical origin such as fluorosis and methemoglobinemia. Therefore, in order to have an idea about the quality of the consuming water, it is necessary to monitor its quality and to device ways and means to protect it.

Chennai is one of the four metropolitan cities in India. In 1960, the population of Chennai was 15 lakhs. In the last four decades, its population has raised to 7.6 million (2010).[4] With the increased number of buildings within the city and the ever-increasing growth of the city, the open land available for water retention has

Access this article online	
Website: http://www.cysonline.org	Quick Response Code
DOI: 10.4103/2229-5186.98688	

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gone down drastically. Chennai is highly urbanized and more people from various parts of Tamil Nadu move into it for their livelihood. All these leads to increased water consumption and receding water table resulting in leaching of more minerals into it affecting its quality. According to the Central Groundwater Board, 80% of Chennai's groundwater has been depleted and any further exploration could lead to salt water ingression.[5] Hence, this study has been undertaken to assess the groundwater quality in Chennai city and to provide basic information regarding the same.

Materials and Methods

This study was aimed to assess the quality of groundwater in Chennai city. For the purpose of this study, Chennai city was divided into three zones based on the Legislative constituency into North, Central, and South Chennai. From these three zones, three locations were randomly selected (Zone 1, North Chennai included Ayyanavaram, Villivakkam, and Purasawalkam; Zone 2, Central Chennai included Triplicane, Mylapore, Nungambakkam; and Zone 3, South Chennai included Guindy, Velachery, and St. Thomas Mount) for assessment of water quality. One water sample for each location was assessed in this study. Hence, total of nine groundwater samples were collected from nine locations.

Sample collection

The groundwater sample from each location was collected from wells not less than 50 feet in order to avoid bacterial contamination. Further, these wells also had a cement concrete platform surrounding them as a higher elevation from the ground level which might reduce the possibility of contamination.

The groundwater samples from each well were collected in a 2-litre clean polyethylene bottle from the nine locations. The samples were then analyzed for nine parameters such as pH, total dissolved solids (TDS), turbidity, total hardness, calcium, magnesium, sulphates, chlorides, and nitrates, using the following procedures: pH was assessed by electrometric method using pH meter; TDS were measured using gravimetry; turbidity was assessed using Nephelometer; hardness, calcium; and magnesium were assessed by EDTA titrimetric method; and sulphate was assessed by turbidimetric method using turbidity meter. Determination of chlorides was done by argentometric titration and nitrate was assessed using colorimetry. Fluoride content was measured by sulfophenylazo dihydroxynaphthalene-disulfonate method using UV spectrophotometer. Fluoride does not form a part of the water quality index, and it was assessed because of its relevance to dentistry. All the analytical procedures were carried out in the Chennai Metropolitan Water and Sewage Board, Chennai, during May 2011 using the procedures recommended in guidelines for water quality monitoring, Central pollution control board.[6]

Water quality index is defined as a rating reflecting the composite influence of different water quality parameters.[3] The water quality of this study samples was assessed using the weighted arithmetic index method by Brown *et al*,[7] taking into account the nine important parameters such as pH, TDS, turbidity, total hardness, calcium, magnesium, sulphates, chlorides, and nitrates.

Water quality index[7]

The quantitative assessment of water quality index was calculated using the above nine parameters using ISI standards using the following formula,

$$WQI = \sum in=1\ qi\ w_i / \sum_{i=1}^{n} w_i$$

W_i is a unit weight factor and it is a constant for all nine parameters.

The quality rating q_i is determined by $q_i = 100\ (v_i - v_{i0})/(si - v_{i0})$

Where, V_i = estimated value of n^{th} parameter
S_i = standard value of n^{th} parameter
V_{i0} = ideal value of n^{th} parameter in pure water. All ideal values are taken as zero for drinking water except pH = 7.0.

The water quality index level and status of water quality as per Chatterji and Raziuddin 2002[8] have been given in [Table 1] and the standard value of each parameter as given by BIS[9] and their unit weight factors are given in [Table 2].

Results

This study was done to assess the quality of groundwater in different zones of Chennai city. [Table 3] shows the physicochemical parameters and the water quality index level in three different zones and their mean value. On assessment of pH of drinking water, location 2 of zone 1 had drinking water pH of 8.8 which was above the permissible limit for drinking water according to the BIS. However, the pH ranged from 7.3 to 7.8 in other locations. Similarly, turbidity of drinking water in location 3 of zone 1 showed the higher value compared with the rest. The TDS was also in excess in location 1 of zone 1

Table 1: The water quality rating[7]

Water quality index level	Water quality status
0–25	Excellent
25–50	Good
50–75	Poor
76–100	Very poor
> 100	Unfit for drinking

followed by location 1 of zone 2, while location 1 of zone 2 demonstrated a higher total hardness of drinking water and magnesium content which was above the standard values prescribed by the BIS. The sulphates and chlorides value were more in zone 1 and nitrates in zone 3. Calcium content was found more in water samples of zone 2. Water quality index level and status of water quality assessed by Chatterji and Raziuddin[8] showed that all water samples ranged from 19.21 to 48.36 which fell in the excellent and good category for water quality assessment. However, the mean water quality index score of zone 2 was found to be higher when compared with zone 1 and zone 3. The fluoride content of the drinking water in all the zones was found to be very less compared with the accepted water fluoride level as prescribed by the BIS.

Table 2: The unit weight factor and BIS drinking water standards (Is 10500 – 91, Revised 2003) of each parameter[8]

Parameters	Standard value (s_i)	Permissible values	Unit weight factor (w_i)
Ph	6.5–8.5	No relaxation	0.219
Turbidity (NTU)	5	25	0.08
TDS (mg/l)	500	2000	0.00370
Total hardness (mg/l)	300	600	0.00618
Sulphates (mg/l)	200	400	0.01236
Magnesium (mg/l)	30	100	0.0618
Nitrates (mg/l)	45	No relaxation	0.0412
Chloride (mg/l)	250	1000	0.00741
Calcium (mg/l)	75	200	0.02472
Sum of unit weight factor			$\sum W_i$ = 0.74638

Discussion

This study threw light on the groundwater quality status in different zones of Chennai city. Water quality index is a composite assessment of nine different parameters which determine whether the water can be used for drinking purpose. In this study, the TDS and hardness of drinking water were found to be more in zone 2. Earlier studies have demonstrated a indirect relationship between TDS concentrations in drinking water and the incidence of cancer,[10] coronary heart disease,[11] arteriosclerotic heart disease,[12] and cardiovascular disease.[13] Although turbidity of all the groundwater samples in this study was well below the accepted standard values, location 3 showed a higher value. Turbidity in water can serve as nutrient for water-borne bacteria, viruses, and protozoa, which can be embedded in or adhere to particles in water. The groundwater is generally free of microorganism because of the filtering effect of the aquifer.[14] Therefore, assessing

Table 3: The physiochemical parameters and the water quality index in the three zones

Parameters	Zone 1			Zone 2			Zone 3		
	Location 1 v_i	Location 2 v_i	Location 3 v_i	Location 1 v_i	Location 2 v_i	Location 3 v_i	Location1 v_i	Location 2 v_i	Location 3 v_i
Ph	7.3	8.8	7.8	7.4	7.6	7.7	7.6	7.7	7.8
Mean		7.9			7.6			7.7	
Turbidity (NTU)	1	1	10	1	1	5	3	5	5
Mean		4			2.3			4.3	
TDS (mg/l)	1110	250	360	780	560	680	410	430	335
Mean		573.3			673.3			391.7	
Hardness (mg/l)	210	124	112	450	284	320	116	116	96
Mean		148.7			351.3			109.3	
Sulphate (mg/l)	164	22	50	48	45	40	64	50	56
Mean		78.7			44.3			56.7	
Magnesium (mg/l)	14	15	13	80	45	60	15	14	10
Mean		14			61.7			13	
Nitrates (mg/l)	2.48	2.22	3.48	2.48	2.68	2.78	2.42	3.42	2.68
Mean		2.7			2.6			2.8	
Chloride (mg/l)	300	38	88	170	64	120	108	120	80
Mean		142			118			102.7	
Calcium (mg/l)	60	24	24	170	64	120	22	24	22
Mean		36			118			22.7	
Water quality index level	19.21	46.12	43.71	43.20	32.34	48.36	26.29	31.75	31.75
Mean		36.3			41.3			29.9	
Fluoride content (ppm)	0.10	0.15	0.20	0.10	0.15	0.10	0.25	0.10	0.15
Mean		0.15			0.11			0.17	

turbidity will give an indirect idea about the microbial content also. Further, turbidity can also interfere with disinfection methods, ultraviolet light in particular.[14] In India, 0.5 to 1.5 million children below 5 years die yearly from diarrhoea, and in Maharashtra State alone 0.7 million people suffer from water-related diseases of which 1,000 die annually.[15]

This study demonstrated a higher value for sulphates and chlorides in zone 1. Ingestion of sulphates in large quantities has demonstrated to cause catharsis and gastrointestinal irritation.[1] Higher concentration of magnesium and calcium in zone 2 which was also reflected at the higher water quality index scores and total hardness in zone 2 compared with the rest. Drinking calcium-rich mineral water several times a day could be recommended, because it would provide both supplemental calcium and adequate hydration in addition to the inhibitory effect on parathyroid hormone secretion and bone resorption.[16]

The primary health concern regarding nitrate is the formation of methemoglobinemia, so-called "blue-baby syndrome." Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize hemoglobin (Hb) to methemoglobin (metHb), which is unable to transport oxygen around the body. The reduced oxygen transport becomes clinically manifest when methemoglobin concentrations reach 10% or more of normal hemoglobin concentrations; the condition, called methemoglobinemia, causes cyanosis and, at higher concentrations, asphyxia.[14] In this study, the nitrate content ranged from 2.22 to 2.48 mg/l, which was very much below the standard limit.

Fluoride ingestion is useful for bone and teeth development, but excessive ingestion causes fluorosis. BIS:10500-1991 permits only 1.5 mg/l as a safe limit of fluoride in drinking water for human consumption.[1] The fluoride content in this study ranged from 0.10 to 0.25 ppm.

In this study, except the pH of location 2 of zone 1 all the parameters are well within the permissible limits. Suresh T reported 92% of water samples have physicochemical properties well within the permissible limits except fluoride in Hospet taluk region, Karnataka.[17] Ramakrishnaiah et al reported 63.5% water samples are poor in water quality in Tumkur Taluk, Karnataka[3] using National Sanitation Foundation software. Turbidity, manganese, zinc, and copper were within permissible limits and TDS, hardness, chloride, and fluoride exceed the permissible limits in Bhavnagar region.[18] Loganathan et al reported that the groundwater in Chennai city is suitable for drinking and domestic uses in respect of all the constituents expect total hardness and Nitrate.[19] In 2005, a study by Public Works Department revealed that Chennai has no good quality groundwater anymore and the quality of the available groundwater is fast deteriorating with the water table falling to below sea level in some areas.[20] Investigations made on groundwater of North and South Chennai by Loganathan D etal in 2011 revealed that the groundwater quality was within the ISI standards.[21] This was similar to this study results.

In the peninsular states of Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, and Tamil Nadu, the general scarcity of sustainable water supply has led to overstress on the groundwater regime. The number of overexploited and critical administrative units was significantly higher in Andhra Pradesh, Delhi, Gujarat, Haryana, Karnataka, Punjab, Rajasthan, and Tamil Nadu, and also the Union Territories of Daman and Diu and Pondicherry.[2]

Although the overexploitation was well documented in Tamil Nadu by Public Work Department in 2005,[20] it was vital to know the quality of groundwater at present. Hence, this study was carried out to assess the groundwater quality taking into account nine parameters that best suits to assess the groundwater quality. Groundwater is stored in aquifer which acts as a filtering medium for the microbes, hence microbial content was not analyzed. The results of this study have limitation such as the collection of samples was done only from nine locations and the samples were collected only during premonsoon season. The value of these parameters might change significantly between pre and postmonsoon seasons. Further, this study provides only baseline information on groundwater quality in Chennai and hence further studies covering a larger number of samples should be done.

Conclusion

This study demonstrated that in general the groundwater quality status of Chennai city ranged from excellent to good according to criteria of Chatterji and Raziuddin,[8] and the groundwater is fit for human consumption based on all the nine parameters of water quality index[7] and fluoride content. Except for pH in a single location of zone 1, none of the parameters exceeded the permissible values for water quality assessment as prescribed by the BIS.[9]

A significant amount of disease could be prevented especially in the developing countries through better access to safe water supply by periodically monitoring the quality, providing adequate sanitation facilities and better hygiene practices. Once the water quality index was brought to the notice of the public, they can effectively monitor their water quality and they serve as a convenient tool to highlight specific environmental conditions, and to help governmental decision makers in evaluating the effectiveness of regulatory program.

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How to cite this article: Balan IN, Shivakumar M, Kumar PDM. An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India. Chron Young Sci 2012;3:146-50.

Source of Support: Nil, **Conflict of Interest:** None declared