Research Article

Determination of Water Quality Index in Coastal Area (Nagapattinam) of Tamil Nadu, India

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Abstract

Study was undertaken to study the spatial distribution of groundwater quality in coastal region of Nagapattinam District is derived using the water quality index (WQI). Nagapattinam lies between Northern Latitude 10.7906 degrees and 79.8428 degrees Eastern longitude. The district spreads over an area of 2,715.83 sq.km. The data of pre and post monsoon were collected from Office of State Surface & Ground Water Data Centre, Public Works Department, Taramani, Chennai, Tamil Nadu and average was worked out and taken for analysis of physico-chemical compositions in the groundwater and also for water quality index for the year 1972-2013 (42 years). In this study water quality determined on the basis of various physical and chemical parameters like pH, Electrical Conductivity, Total Dissolved Solids, Nitrate, Calcium, Sulfate, Magnesium, Fluoride, Total Hardness, Sodium, Chloride, Fluride, Carbonate and Bicarbonate. The current groundwater quality study reveals that groundwater in the Nagapattinam block is unfit for drinking and is suitable for domestic usage and agriculture with effective crop management practices.

Keywords: Physico-chemical Parameters, Water Quality Index, Permissible limit, Pre and Post monsoon, groundwater quality

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Introduction

The groundwater demand was considerably increased due to development activities of coastal economy and urbanization in and around the coastal region. The groundwater is considered as a primary source of all human water demand particularly in coastal region due to lack of surface water availability. Groundwater level is gradually declining due to frequent pumping out of groundwater. Over exploitation of groundwater leads to quality deterioration and quantity of groundwater. Understanding the drinking quality of groundwater is an essential to ensure the human health. The quality of groundwater is depending upon the climatic, land use pattern and type of pollutant disposal. So that's why, it is essential to analysis the drinking quality standards of groundwater to ensure community health. Most of the Indian coastal regions are covered with high granulated sand with more infiltration capacity which is a key for contamination of pollutants. Quality of water is determined by consideration of parameters such as pH, Electrical Conductivity, Total Dissolved Solids, Nitrate, Calcium, Sulfate, Magnesium, Fluoride, Total Hardness, Sodium, Chloride, Fluoride, Carbonate and Bicarbonate. Many factors that control water quality are rock-water interaction, aquifer lithology and dissolution. In most of the coastal region, salt water intrusion is constant threat to groundwater quality. According to World Health Organization [1], about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to monitor regularly the quality of groundwater and to devise ways and means to protect it. Water quality index is one of the most useful tools [2, 3] to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption. The objective of the study is to discuss the suitability of groundwater for human consumption based on computed water quality index values.

Study area

The study was taken up in Nagapattinam, which is a coastal district of Tamil Nadu situated on the eastern side of

Nagapattinam (**Figure 1**). The district headquarter lie 326 km, south of the State capital, Chennai and 145 km from Tiruchirappalli. The district lies south of Cuddalore district and another part of the Nagapattinam district lies to the south of Karaikal and Tiruvarur districts. Nagapattinam lies between Northern Latitude 10.7906 degrees and 79.8428 degrees Eastern longitude. The district is spread over an area of 2,715.83 sq.km.

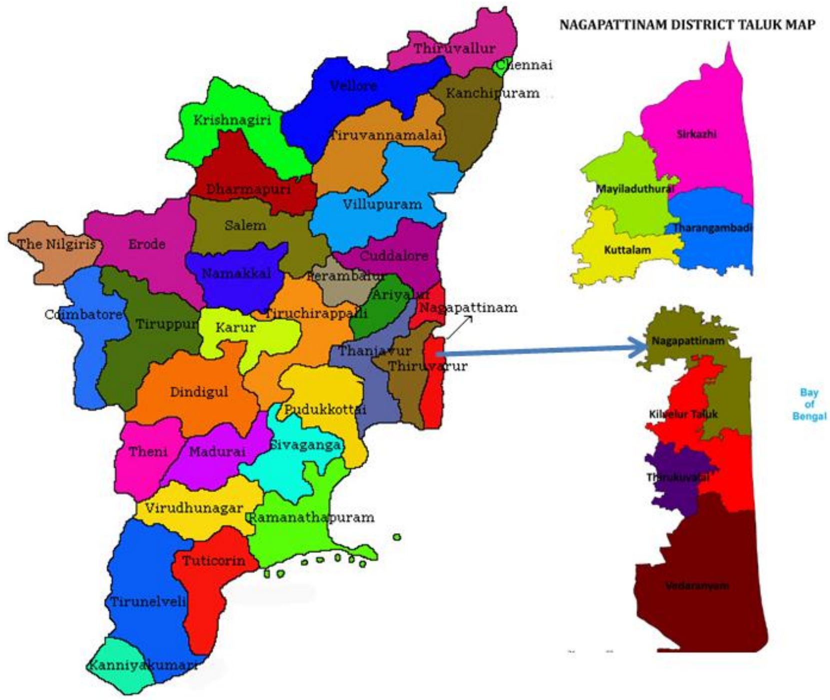

Figure 1 Location map of the study area

The average maximum temperature of the district as a whole is about 32^0 C and the average minimum temperature is 24.6^0 C. Dust storms whirl winds and dusty winds blow from various quarters towards the end of May. The Southwest winds sets in during April, it become strongest in June and continues till September. Northeast monsoon starts during the month of October and blow till January. Cyclonic storm with varying wind velocity affects once in 3 or 4 years during the months of November and December. The storms affect the plantation crop. During Southwest monsoon the air is calm and undisturbed. The Northeast monsoon which starts in October and ends in December contributes about 60 % of the total annual rainfall. The southwest monsoon rains occur from June to September. The rainfall pattern in the district shows interesting features. Annual precipitation, which is 1500 mm at Vedaranyam, the southeast corner of the Taluk, rapidly decreases to about 1100 mm towards the west of the district.

Methodology

The pre monsoon (July, 1972-2013) and post monsoon (January, 1972-2013) water quality data of observation well located in the Nagapattinam (Figure 1) were collected from office of State Surface and Ground Water Data Centre, Public Works Department, Taramani, Chennai, Tamil Nadu. The average of pre and post monsoon was derived and taken for analysis to evaluate the physico-chemical compositions in the groundwater and to determine water quality index for the years 1972-2013 (42 years).

Physico-Chemical assessment of groundwater

Water quality is a measure of its suitability for human consumption, irrigation and other purpose. The quality of water is characterized by various physico-chemical parameters such as pH, electrical conductivity, total hardness, total dissolved solids, nitrate, sulphate, calcium, sodium, magnesium, chloride, potassium, bicarbonates, fluoride etc.

Water quality parameters namely pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Calcium (Ca^{2+}), Chloride (Cl^-), Magnesium(Mg^{2+}), Bicarbonate(HCO_3),Carbonate (CO_3), Sodium (Na^+), Potassium (K^+), and Fluoride (F^-) were used for the assessment of quality of the water for drinking purpose whereas three parameters namely pH, Electrical conductivity (EC) and

Total Dissolved Solids (TDS) and three indices namely Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), and Residual Sodium Carbonate (RSC) were used for the assessment of quality of the water for irrigation purpose.

However, the use of water for any purpose is guided by standard set by any of the following: BIS (Bureau of Indian Standards), ICMR (Indian Council of Medical Research), WHO (World Health Organization) and CGWB (Central Ground Water Board). In this study, the results of the drinking water quality parameters were correlated with those of the ICMR/BIS/WHO standards and irrigation water quality parameters and indices with the CGWB classification. In the present investigation an attempt has been made to assess the quality of groundwater in Nagapattinam using statistical methods.

Water Quality Index

Water Quality Index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water. It reduces the large amount of water quality data to a single numerical value. It is calculated from the point of view of human consumption. Therefore, WQI is a very useful and efficient method which can provide a simple indicator of water quality and it is based on some very important parameters. Water Quality Index has been calculated from the selected physiochemical parameters with respect to ICMR/BIS standards (**Table 2**). Water quality Index is the most efficient tools to communicate information on the quality of any water body. It is a mathematical equation used to transform a large number of water quality data into a single number. It is simple and easy to understand for decision makers about quality and possible uses of any water body [4]. Also its serves the understanding of water quality issues by integrating complex data and generating a score that describes the water quality status (**Table 7**). In this method weightage for various kinds of Water proportional to the recommended standard for the corresponding parameters were taken.

In current study, WQI was calculated by methods proposed by Horton and modified by Tiwari and Mishra [5, 6]. In this method, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean. According to the role of various parameters on the basis of importance and incidence on overall quality of drinking water, rating scales were fixed in terms of ideal values of different physico-chemical parameters. Even if, they are present, they might not be ruling factor. Hence they were assigned zero values [7].

For assessing the quality of water in this study, firstly, the quality rating scale (Qi) for each parameter was calculated by using the following equation;

$$Qn = \{[(Vactual – Videal) / (Vstandard – Videal)] * 100\}$$

Where,
Qn = Quality rating of n^{th} parameter
Vactual = Actual value of n^{th} water quality parameter obtained from laboratory analysis
Videal = Ideal value of that water quality parameter can be obtained from the standard tables
Videal for pH = 7 and for other parameters it is equaling to zero
Vstandard = Recommended ICMR/BIS standard of that n^{th} water quality parameter.

Then, after calculating the quality rating scale (Qn), the Relative (unit) weight (Wn) was calculated by a value inversely proportional to the recommended standard (Sn) for the corresponding parameter using the following expression;

$$Wn = K/ Sn$$

Where,
Wn = Relative (unit) weight for n^{th} parameter
Sn= Standard value for n^{th} parameter
K = Constant of Proportionality.

Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = \Sigma QnWn/ \Sigma Wn$$

Where,
Qn = Quality rating
Wn = Relative weight

The WQI has been ranked by using standard of drinking water quality recommended by the Indian Council for medical research (ICMR).

Table 1 Water Quality Index and status of water quality [8]

Water quality index level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

Table 2 Drinking water standards and unit weight [9, 10]

S. No.	Parameters	Standards	Recommended agency	Unit weight
1	pH	6.5-8.5	ICMR/BIS	0.2190
2	Electrical conductivity (µs/cm)	300	ICMR	0.371
3	Total dissolved solids	500	ICMR/BIS	0.0037
4	Total alkalinity	120	ICMR	0.0155
5	Total hardness	300	ICMR/BIS	0.0062
6	Total suspended solids	500	WHO	0.0037
7	Calcium	75	ICMR/BIS	0.025
8	Magnesium	30	ICMR/BIS	0.061
9	Chlorides	250	ICMR	0.0074
10	Nitrate	45	ICMR/BIS	0.0412
11	Sulphate	150	ICMR/BIS	0.01236
12	Dissolved oxygen	5	ICMR/BIS	0.3723
13	Biological oxygen demand	5	ICMR	0.3723
All values except pH and Electrical Conductivity are in mg/L				

Results and discussion

Ground water quality

The intrusion of seawater into the inland aquifers due to the over-exploitation of groundwater along the coastal area is an environmental issue. To protect coastal groundwater, the sources of saline water and mechanisms of mobility need to be identified and investigated for sustainable development of groundwater resources. Ground water extraction is leading to drying-up of the wells in that area. The quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are substantially influenced by geological formations and anthropogenic activities.

pH

pH value of ground water is controlled by the amount of dissolved carbon dioxide gas and the dissolved carbonates and bicarbonates from mineral salts. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters [11]. In the study area pH ranged between 7.2 and 8.9 (an average of 8.05) and about 80% of the water samples relied within the desirable limit (7-8.5) and 100% of water samples were within the permissible limit (6.5-9.2) given by WHO/BIS standard and most of the samples were alkaline in nature and also pH remains within the permissible limit (6.5-9.2) over the 42 years. In general a reason for increasing pH concentration in coastal region related to the chloride in seawater or from marine clay which have increased the pH concentration. Hence the groundwater in the study area is not suitable for drinking but can be used for irrigation, industrial and domestic purposes.

Irrigation water can be classified as acid, neutral, or alkaline. The degree of acidity or alkalinity of water can be described by a pH value. pH values range from 0 to 14; any value below 7.0 is considered acid, a value of 7.0 is neutral, and a pH above 7 is alkaline. Thus, water with a pH of 5.8 is acidic, whereas water with a pH of 7.9 is alkaline. A water pH between 6.0 and 7.0 is normally considered to be the most desirable for irrigation. When the pH is outside of this range, it indicates that special actions may need to be taken to improve crop performance.

pH was increased over the decades gradually from 7.8 to 8.0. The maximum pH was observed during 1992-01 (8.4) and reduced to 8.0 during 2002-11.

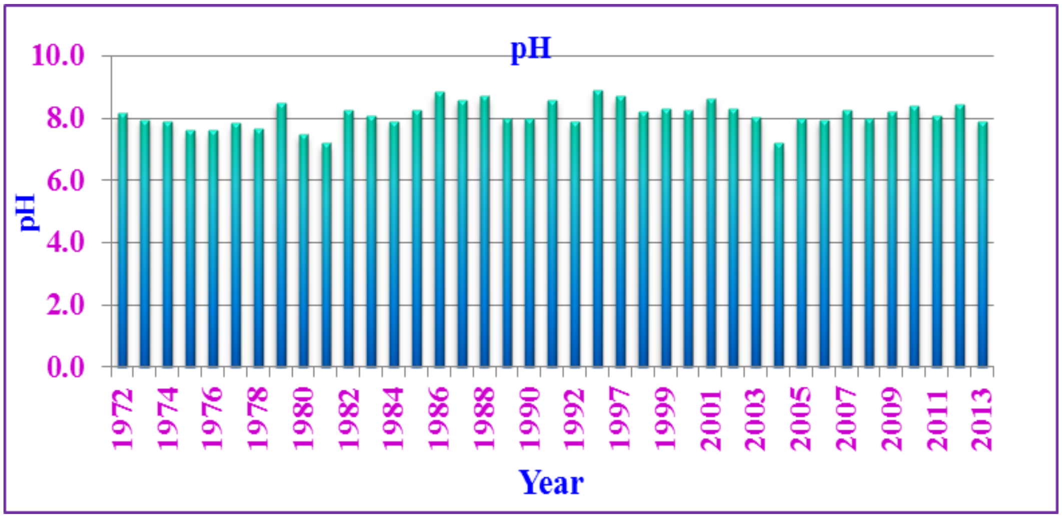

Figure 2 Status of pH in Nagapattinam

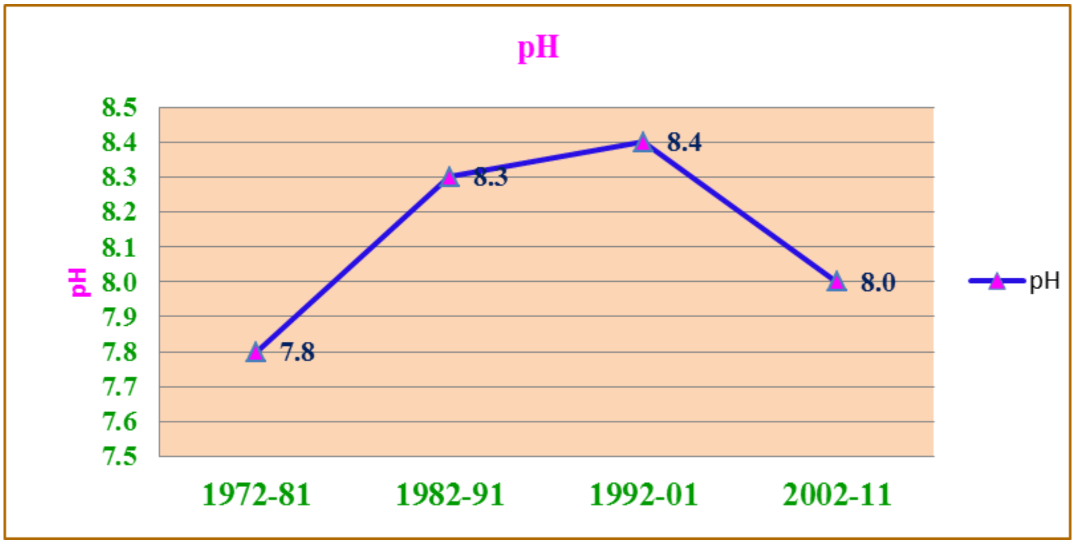

Figure 3 pH over the years in Nagapattinam

Table 3 Statistical measures of water quality parameters

Parameters	Minimum	Maximum	Average
TDS	393.0	1752.5	1072.75
NO_2+NO_3	1.5	46.5	24
Ca	16	134	75
mg	20.5	98	59.25
Na	92	474	283
K	6	128	67
Cl	107	600	353.5
SO4	40.5	408	224.25
CO3	15	63	39
HCO_3	122	628.5	375.25
F	0.05	1.25	0.65
pH	7.2	8.9	8.05
EC (µs/cm)	820	3090	1955
HAR	182.5	680	431.25
SAR	2.4	10.4	6.4
RSC	0.1	5.7	2.9
Na%	38.4	79.1	58.75

All values except pH and Electrical Conductivity are in mg/L

Table 4 Number of years exceeding the permissible limit set by ICMR

Water quality parameters	ICMR standards		No. of years exceeding permissible limits
	Desirable limits	Permissible limits	
pH	7- 8.5	6.5-9.2	0
EC(µS/cm)	300	1000	40
TH(mg/L)	300	600	1
TDS(mg/L)	500	1500-2000	0
SO_4^{2-}(mg/L)	200	400	1
NO_3^-(mg/L)	20	100	0
Ca^{2+}(mg/L)	75	200	0
Cl^-(mg/L)	200	1000	0
Mg^{2+}(mg/L)	50	100	0
HCO_3^-(mg/L)	244	732	0
Na^+(mg/L)	-	200	0
K^+(mg/L)	-	10	35
F^-(mg/L)	1	1.5	0

Average of physicochemical parameters ranges were observed within the permissible limit except EC and potassium. Water quality parameters like pH, total hardness, total dissolved solids, sulphate, nitrate, calcium, magnesium, chloride, carbonate and bicarbonate, fluoride were within the permissible limit. Electrical conductivity (40 years) and potassium (35 years) were beyond the permissible limit.

Electrical conductivity (EC)

Generally, the electrical conductivity is a measure of the ability of water to pass on electrical current and is affected by the presence of dissolved solids. As the level of total dissolved solids (TDS) raises, the conductivity also increases. It is the most important parameter in determining the suitability of water for drinking water and irrigation use. It is used as a primary index to select the suitability of water for all purposes. In the study area, EC values in ground water ranged from minimum 820 µs/cm to maximum 3090 µs/cm.

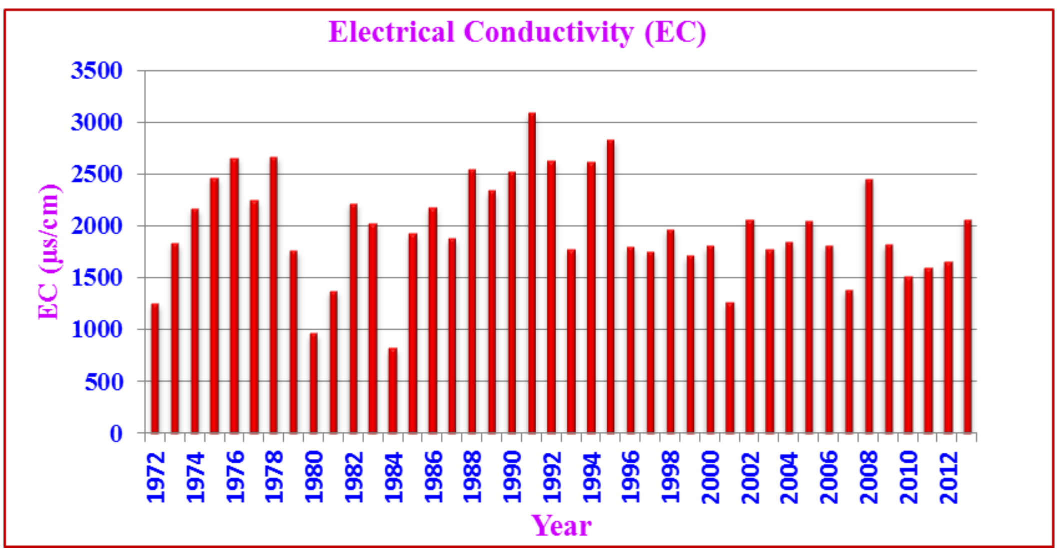

Figure 4 Status of EC in Nagapattinam

The high electrical conductivity value observed during 1991 (3090 µs/cm) might be due to high amount of total dissolved salts in ground water (1742 mg/L) followed by 2835 in 1995. Total dissolved solids and electrical conductivity is directly related. The high level of electrical conductivity in ground water is related to the input of sewage water, agricultural activities and seawater intrusion in the coastal aquifers. When compare with pre monsoon, post monsoon samples had high concentration of electrical conductivity this might be due to the enrichment salt due to evaporation effect in the previous summer season. Similar results were found by [12] that EC was low when the freshwater recharge during pre monsoon and progressively increases during summer (after post monsoon) along the Coastline.

Total dissolved solids

Concentration of total dissolved solids in groundwater decides its applicability for drinking, irrigation and other purpose. EC of water is a direct function of TDS and it is expressed in terms of mg/L. The maximum TDS 1752.5 mg/L was observed during 1999 whereas minimum (393 mg/L) was observed in 1984. During the entire period, TDS was not exceeding the permissible limit (1500-2000 mg/L) and it ranged from 393- 1752.5 mg/L. Based on the [13] classification, 30 years were comes under brackish water category and twelve years falls under fresh water category.

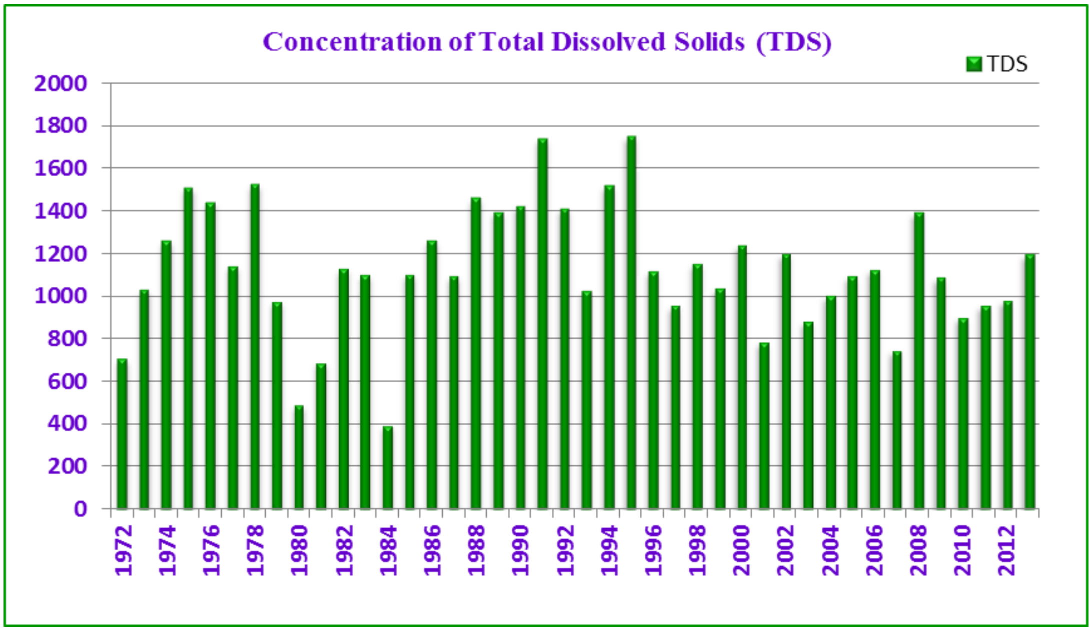

Figure 5 Status of Total Dissolved Solids in Nagapattinam

Table 5 Water quality classification based on TDS (Caroll 1962)

TDS in mg/L	Water quality	No. of years
0–1,000	Freshwater	12
1,000–10,000	Brackish water	30
10,000–100,000	Salty water	-
>100,000	Brine water	-

Calcium and magnesium

The analytical data showed that the concentration of calcium in the water samples during the study period ranged from 16 to 134 mg/L. In general, calcium concentration fluctuated throughout the study period (**Figure 6**). Calcium and magnesium are known to occur naturally in water due to its passage through mineral deposits and rock strata and contribute to its total hardness.

The concentration of magnesium observed during the study period ranged from 20.5 to 98 mg/L. The highest concentration of magnesium was observed during 1988 and the least was observed during 1979. In general, the source of magnesium in the groundwater is the lime deposits, marine deposits and fossilized area and if water close to saturation in terms of calcite and dolomite, it is considered the dissolution of gypsum adds calcium to the water and causes calcite precipitation leading to a decrease in the concentration of bicarbonate. The reason for the increase in magnesium in cultivated land is the use of $MgSO4$ as a fertilizer, which may lead to return flow into well water [14].

Potassium

Potassium is the most important mineral occurring naturally. The primary source of this action may be weathering of rocks beside the sewage and industrial effluents. In the study area potassium concentration varied from 12 to 128 mg/L. Most of the years (23 years) had higher values (>50 mg/L) owing to the precipitation or absorption of both the action by soils or coating on the minerals and also might be effluent percolation. The potassium concentration varied from 74 to 52 mg/L in the year of 1972 and 2013 respectively. Increase K in plant tissues, can lead to limited plant uptake of other required nutrients. [15]

Component	Severity		
	Not a Problem	Increasing Problem	Severe Problem
Potassium (K+) mg/L	< 20 mg/L	20 - 50	> 50

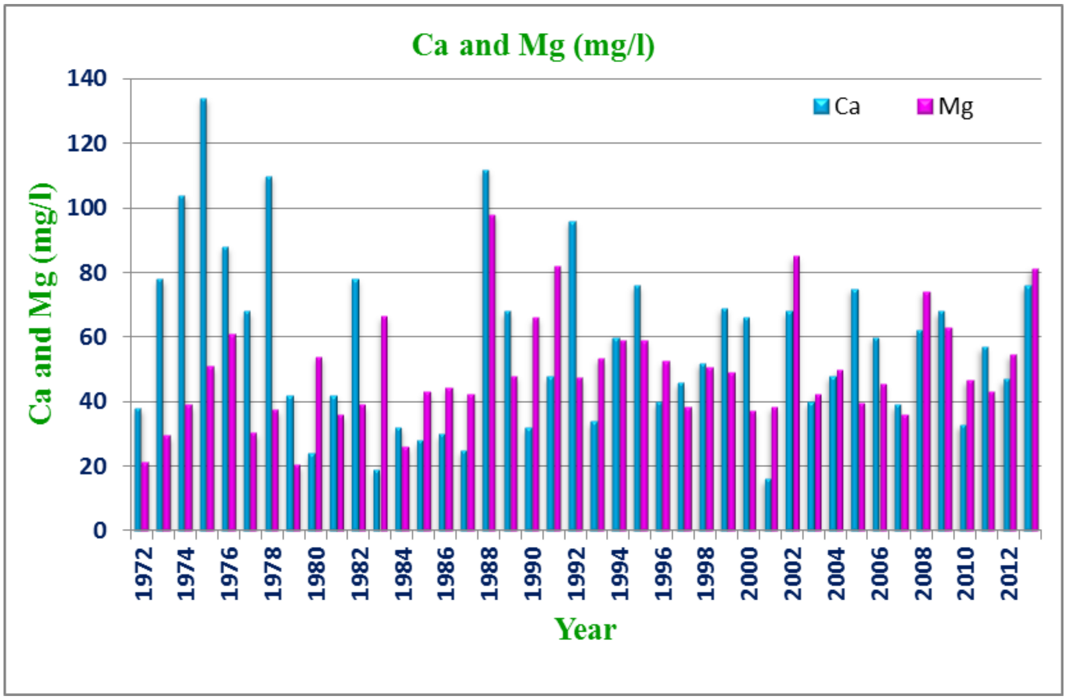

Figure 6 Status of calcium and magnesium (mg/L) in Nagapattiam

Chloride

Chlorides occur in all natural waters in widely varying concentrations. The chloride content normally increases as the mineral content increases [16]. The chloride ion is the most predominate natural form of the element chlorine and is extremely stable in the water. The chloride content varies between 107 to 600 mg/L over the years. A maximum chloride (600 mg/L) concentration was observed in 1991. As per ICMR standards, the desirable limit for chloride is 200 mg/L and permissible limit is 1000 mg/L. In the study area, it has been found that, the chloride concentrations were not exceeded the permissible limit over the years.

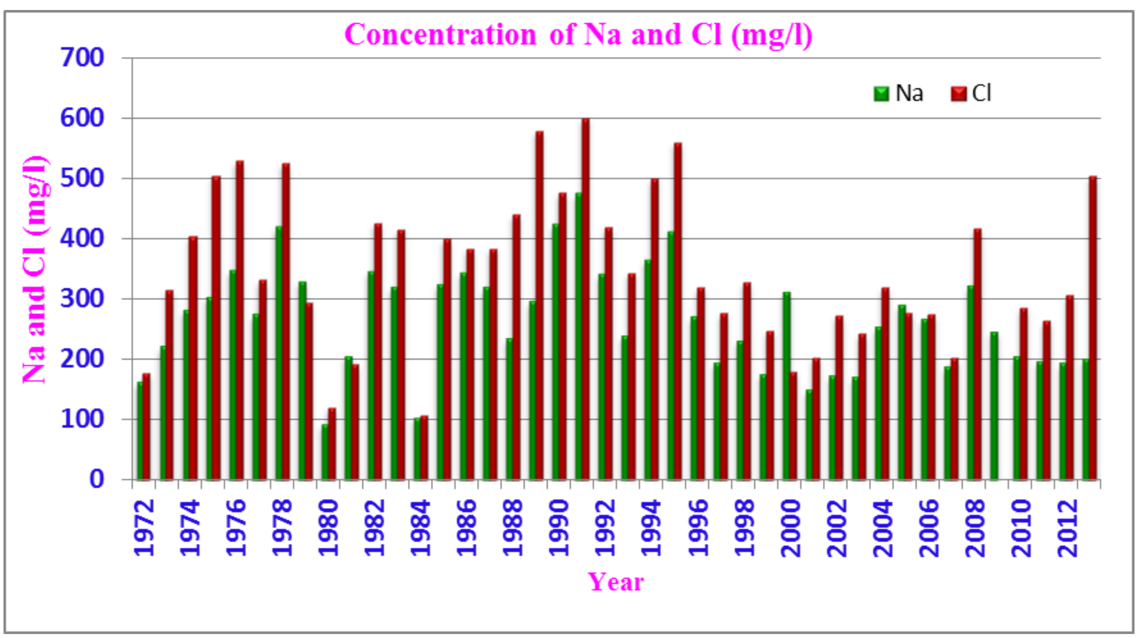

Figure 7 Status of sodium and chloride in Nagapattinam

Nitrate

Nitrate is the most important nutrient in an ecosystem. Generally water bodies polluted by organic matter exhibit higher values of nitrate. Maximum nitrate value obtained in the study area was 46.6 mg/L during 2005 and minimum was observed (1.5 mg/L) during 1997. In the present study, water samples of all the seasons showed low concentration of nitrate and below the permissible levels (100 mg/L) as per the standards.

Sulphate

Sulphate ion is one of the major anion occurring in natural waters. Sulphate ion does not affect the taste of water if present in low concentration. The sulphate ion concentration ranged from 40.5 to 408 with an average of 224 mg/L. The sulphate concentration in the study area was found within the permissible limit of 400 mg/L except during 2000 (408 mg/L).

Total Hardness

The observed minimum average value of total hardness was 182.5 mg/L during 1972 and maximum of 680 mg/L during 1988. Higher values of hardness can be attributed to low water level and high rate of evaporation of water and addition of calcium and magnesium salts. [17]) stated that addition of sewage, detergents and large scale human use might be the cause of increase in hardness. [18] has classified water on the basis of hardness values in the following manner, 0 – 60 mg/L as soft, 61 – 120 mg/L as moderately hard, 121 – 160 mg/L as hard and greater than as 180 mg/L as very hard. In the study area, the groundwater was very hard but the hardness values were within permissible limits (600) except in 1988 (680 mg/L). Hardness below 300 mg/L is considered potable but beyond this limit produces gastrointestinal irritation [19].

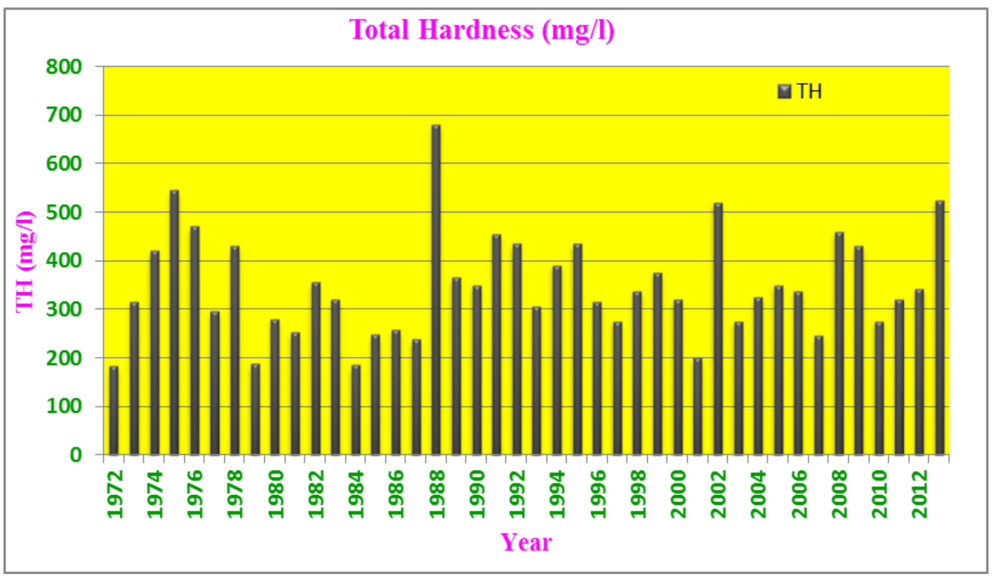

Figure 8 Status of total hardness (mg/L) in Nagapattinam

Fluoride

High concentration of fluoride in drinking water can cause an adverse effect on human beings. Continuous consumption of water having high fluoride content can cause diseases, like fluorosis, dental carries and bone diseases. The concentration ranges observed in this study were 0.05 to 1.25 mg/L. The high concentration of Fluoride values (1.25 mg/L) obtained in Nagapattinam on 2005. High concentrations of fluoride, often significantly above 0.19mg/L, constitute a severe problem over large parts of India.

Sodium adsorption ratio (SAR)

Irrigation water is classified based upon the sodium adsorption ration (SAR) and electrical conductivity (EC). The SAR indicates that the relative proportion of sodium to calcium and magnesium. In general, the classification of positively charged ions, especially of sodium, is more important than others. High concentrations of sodium, both in absolute and in relative terms, make water unsuitable for irrigation. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. Salinity of groundwater and SAR determine its utility for agricultural purposes, and salinity originates in groundwater due to weathering of rocks and leaching from topsoil, anthropogenic sources along with minor influence on climate [20]. SAR in the study area was maximum at 10.4 during 1979 and minimum (2.4) was observed in 1980.

The SAR is used to predict the danger of sodium (Na) accumulation in the soil. While some plants such as beets, spinach, celery, and possibly others have a relatively high requirement for, or tolerance of Na, most plants have minimal needs for, or tolerance of high Na levels. The SAR relates the relative concentration of Na to the combined concentration of Ca and Mg. Another hazard that excess Na presents in natural soils is the danger of loss of soil structure with the resulting reduction in soil permeability and aeration. The interpretive guidelines for SAR are as follows.

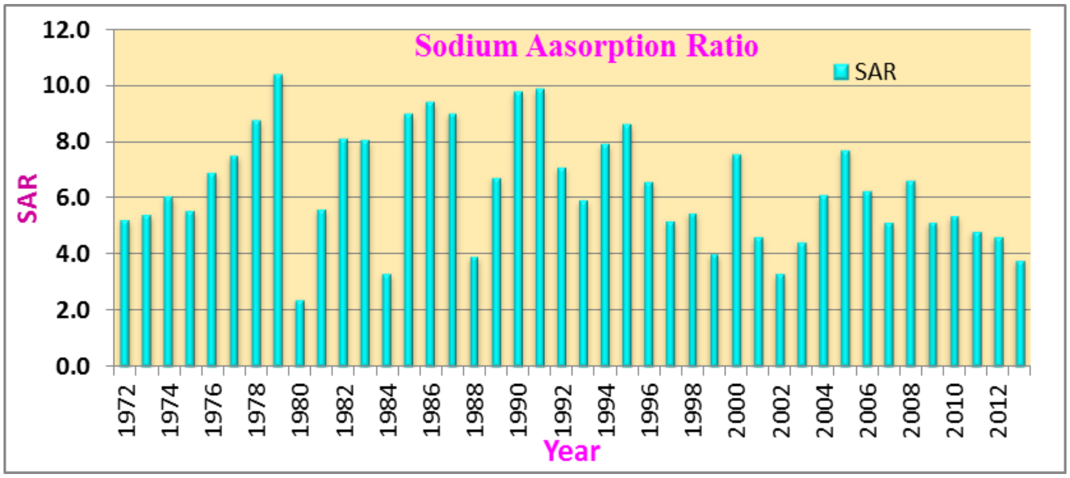

Figure 9 Status of sodium adsorption ratio in Nagapattinam

Application	None	Increasing	Significant	High	Severe
Most production systems	<1	1-2	2-4	4-5	>5
Hydroponics	<3	3-7	7-8	8-9	>9

In recent years SAR observed below 5 but an average of 42 years showed 6.4. It falls under severe hence should follow proper management practices to overcome this concentration for crop production.

Sodium

The sodium and chloride are the two important parameters in the coastal areas. The Na–Cl relationships have often used to identify the mechanisms for acquiring salinity and saline intrusions in semi-arid regions [21, 22]. The analytical data showed that the concentration of sodium in water samples were ranged from 92 to 474 mg/L with an average of 283 mg/L. Sodium content present in the water sample was within the permissible limit (200 mg/L) for few years and fluctuate up to 474mg/L. High concentrations of sodium can speed up corrosion by other elements and can also burn foliage.

Carbonate and bicarbonate

The carbonate (CO_3) is detectable only above pH 8.0. The highest carbonate value (>63 mg/L) was recorded in 1994. With respect to bicarbonate, 33 years of values lies within the permissible limit of WHO (500 mg/L) and 9 years crossed the permissible limit and maximum was observed in 1978 (628.5 mg/L). If bicarbonate and/or carbonate levels are high (>120 and 15 mg/L, respectively), these ions can react with calcium and magnesium in the soil to form insoluble calcium carbonate and magnesium carbonate (lime). This reaction reduces the amount of free calcium and magnesium in soil, allowing sodium to compete for and occupy negatively-charged exchange sites on clay particles. Excess sodium in clay results in destruction of soil structure and reduced water percolation though the soil profile. This effect is referred to as the sodium permeability hazard and is assessed by calculating a residual sodium carbonate value.

Residual Sodium Carbonate (RSC)

Residual sodium carbonate (RSC) exists in irrigation water when the carbonate (CO_3) plus bicarbonate (HCO_3) content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where the water RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. The sodium permeability hazard for irrigation water is usually assessed when bicarbonate and carbonate levels are >120 and 15 mg/L, respectively. Residual sodium carbonate (RSC) is a common means of assessing the sodium permeability hazard, and takes into account the bicarbonate/carbonate and calcium/magnesium concentrations in irrigation water. RSC is important because it's not the absolute bicarbonate and carbonate concentrations that are important, but instead, the relative concentrations of bicarbonate and carbonate compared to concentrations of calcium, magnesium, and sodium. In this study RSC ranges between 0.1 to 5.7 mg/L. The minimum RSC was observed during 2012 and maximum was in 1979.

Over the decades RSC values varies from 1.9 mg/L to 0.2mg/L in 1972-81 and 2002-11, respectively. It shows that gradual reduction been happen in RSC concentration over the years. [23]

Component	**Severity**		
	Not a Problem	**Increasing Problem**	**Severe Problem**
Residual Sodium Carbonate (RSC) meq/L	<1.25	1.25-2.50	>2.50

Among the 42 years only 4 years crossed the severe problem range (>2.50) and majority comes under <1.25 category.

Table 6 Guidelines for interpretations of water quality for irrigation [23]

Potential irrigation problem			**Units**	**Degree of restriction on use**		
				None	**Slight to Mod**	**Severe**
Salinity (affects crop water availability)						
	ECw		dS/m	0.7	0.7 - 0.3	>3.0
	or					
	TDS		mg/L	<450	450-2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)						
SAR	= 0-3	and ECw	=	0.7	0.7-0.2	<0.2
	= 3-6		=	>1.2	1.2-0.3	<0.3
	= 6-12		=	>1.9	1.9-0.5	<0.5
	= 12-20		=	>2.9	2.9-1.3	<1.3
	= 20-40		=	>5.0	5.0-2.9	<2.9
Specific Ion toxicity (affects sensitive crops)						
	Sodium (Na)					
	Surface irrigation		SAR	<3	3-9	>9
	Sprinkler irrigation		me/l	<3	>3	
	Chloride					
	Surface irrigation		me/l	<4	4-10	>10
	Sprinkler irrigation		me/l	<3	<3	
	Boron		mg/L	<0.7	0.7-3.0	>3.0
Miscellaneous effect (affects susceptible crops)						
	Nitrogen (NO3-N)		mg/L	<5	5-30	>30
	Bicarbonate (HCO3)					
	(overhead sprinkler only)		Me/l	<1.5	1.5-8.5	>8.5
	pH			Normal range 6.5-8.4		

In the study area, TDS ranged from 393 to 1752.5 which did not cross the limit of slight to moderate (450-2000) on mentioned in above Table 6. Similarly, sodium also falls within the range over 38 years (3-9). Hence it could be concluded that the present study stay on slight to moderate rating for irrigation. Hence it is suitable for surface irrigation.

Water Quality Index (WQI)

Water quality index (WQI) is defined as a Technique (rating) which gives a complex influence of individual water quality parameters on the overall quality of water for human consumption. **Figure 9** and **Table 7** showed that the values of WQI in the study area and its suitability for use. The calculated water Quality Index for the area varied from 77 to 303.7. From the Water Quality Index values, it has been observed that almost all the years were coming under the category that is unsuitable for drinking purposes (40 years) except two years which falls under very poor quality. It may be observed that after 1984 onwards the groundwater falls under the category of unsuitable for drinking with water quality index (WQI) more than 100.

Table 7 Water Quality Index (WQI)

Year	WQI	Rating	Year	WQI	Rating
1972	126.5	Unsuitable for	1993	187.0	Unsuitable for
1973	178.4	drinking	1994	243.1	drinking
1974	200.2		1995	262.9	
1975	235.8		1996	169.0	
1976	246.6		1997	179.7	
1977	204.7		1998	195.7	
1978	244.4		1999	161.4	
1979	159.8		2000	185.2	
1980	93.4	Very poor quality	2001	138.7	
1981	127.7	Unsuitable for	2002	213.8	
1982	203.3	drinking	2003	178.6	
1983	200.9		2004	177.7	
1984	77.0	Very poor quality	2005	241.2	
1985	177.7	Unsuitable for	2006	185.9	
1986	200.3	drinking	2007	148.2	
1987	190.5		2008	240.0	
1988	261.9		2009	186.5	
1989	226.7		2010	163.1	
1990	245.3		2011	163.7	
1991	303.7		2012	175.3	
1992	251.5		2013	210.2	

Water quality index of the Nagapattinam is established from various physicochemical parameters over the years (42 years). This water quality index rating clearly shows that the status of water in Nagapattinam block is unfit for drinking over the years. The last decade data's shows that WQI lies below two hundred except 2005 (241.5), 2008 (240) and 2013 (210.2).

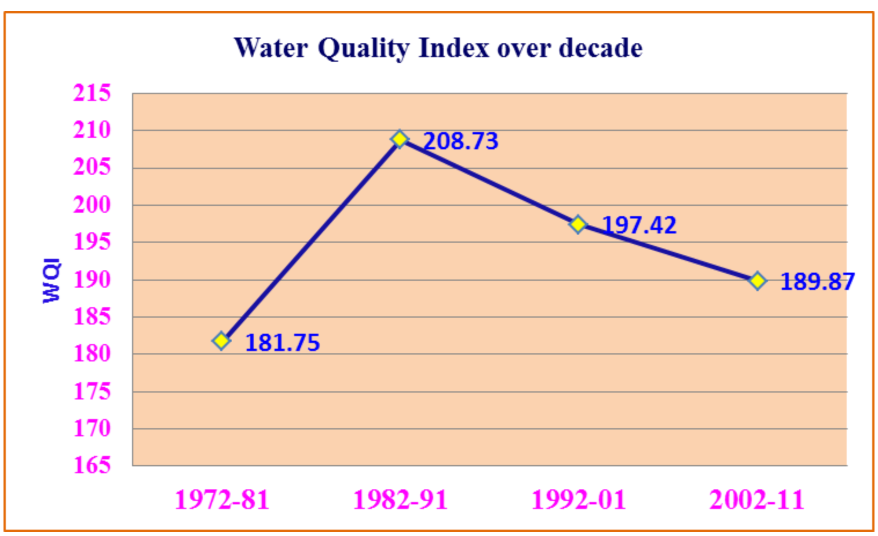

Figure 10 Status of water quality index over decade in Nagapattinam

Water quality index over the decade shows that in 1982-91 had high range of WQI (209) when compared to 1972-81 (182). Later, WQI has reduced to 197 during 1992-01 and further it reduced to 190 during 2002-11. Gradual decrease could observe over the years.

Conclusion

In the present study, the collected water samples of observation wells in Nagapattinam block area were utilized for obtaining water quality information of the study area. The physiochemical analysis result of the ground water samples was compared with the ICMR/BIS drinking water specification. Water quality index offers a useful representation of overall quality of water for public or for any intended use as well as in water quality management. Water quality index of the study area was calculated based on the basis of various physical chemical parameters like pH, electrical conductivity, total dissolved solids, nitrate, calcium, sulfate, magnesium, fluoride, total hardness, sodium, chloride, carbonate and bicarbonate of 42 years (1972-2013). Average values of pre and post monsoon were taken into account for calculation.

From the analysis, the groundwater in the study area is alkaline in nature but falls within the desirable/permissible limit. There were less in concentration of Nitrates and Sulphate which revealed that there is less possibility of contamination through agricultural practices. Water Quality Index (77 to 303.7) confirms that most of the years, the groundwater appears to be unsuitable for drinking and it can be used for irrigation with proper management practices.

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