Research Article

Assessment of Ground Water Quality Using Water Quality Index in Western Zone of Tamil Nadu, India

Angaleeswari M* and A. Valliammai

Department of Soil and water Conservation Engineering, AEC&RI, TNAU, Coimbatore-641 003

Abstract

Groundwater plays a vital role as important source of drinking water in rural and urban areas of India. It accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India. Over exploitation of ground water has become a major challenge not only to the present civilization and also for the future generations. Day by day increase of industrial areas in many places, lead to disposal of industrial effluent in to the water bodies without any proper treatments is one of the reasons for ground water quality deterioration. Maintaining the quality of water is very essential in order to utilize the resource effectively. The study was proposed to calculate the Water quality index (WQI) of western zone of Tamil Nadu for two decades (1994 to 2013). Data has been collected from the State Ground and Surface Water Resource Data Centre of Taramani for 20 years. Conventionally it has been used for evaluating the quality of water for water resources and factors included in WQI vary depending upon the designated water uses of the water body and local preferences. In this study water quality index was determined on the basis of 12 physico-chemical parameters like pH, Electrical conductivity(EC), Total dissolved solid (TDS), Total hardness, calcium, magnesium, chloride, sulphate, Nitrate, HCO_3 and Fluoride. The analysis examined for two seasons (pre and post monsoon) and compared. The pH value is lower in Post monsoon as compared to the Pre monsoon and most of the pH values are found to be within the permissible limit of WHO 1971 (6.5 – 8.5). The results clearly showed that first decade had good water quality condition than compared to second decade and post monsoon season the area felt in better water quality condition as compared to pre monsoon season.

Keywords: Physico-chemical, Monsoon, Irrigation, permissible limit, Industrial, waste disposal, rainfall

***Correspondence**

Author: Angaleeswari M

Email: eswarinaveenmani456@gmail.com

Introduction

Groundwater is used for domestic, industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for freshwater due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO, about 80% of all the diseases in human beings are caused by water [9]. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. If therefore becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it.

Ground water quality evaluation in the developing countries has become a critical issue due to fresh water scarcity. The quality of ground water is equally important as that of quantity. The Judicious management and monitoring of soil and water are essential for sustainable agriculture. Over drafting of ground water and its quality deterioration are the major threats to crop production in arid and semiarid regions. The characterization of irrigation water quality plays a vital role in deciding its management strategies for profitable farming. Ground water aquifer, a main source of water supply in arid and semiarid regions of India is most vulnerable to salinity and sodicity problem resulting in considerable reduction in crop productivity. Moreover, the non scientific water management practices have led to rise in water table in most of the canal command areas, aggravating the salinity and sodicity problems. Ground water in the canal command areas is used by farmers to supplement irrigation in various crops, without considering its impact on soil phyisco-chemical properties as well as on crop production in lean period when there is no canal water supply. Hence, an apprehension exists that the use of marginal or poor quality ground water in farmlands may pose serious threat to the soil health causing low land productivity [8]. The periodic monitoring of

ground water quality becomes a need to minimize the risk of soil health deterioration and its detrimental effects on crop production.

Water quality index is one of the most effective tools 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 calculated from the point of view of suitability of groundwater for human consumption. This work emphasizes the use of water quality index (WQI) approach in assessment of groundwater quality of Western zone of Tamil Nadu, India.

Materials and Methods

Study area

Western zone of Tamil Nadu it comprise 62 blocks of 9 districts are Coimbatore, Karur, Thiruppur, Namakkal, Salem, Dindugul, Erode, Theni and Nilgris. Area is geographically located between Latitude of 10^0 00' 00'' to 12^0 00' 00'' N and Longitude of 77^0 00' 00'' to 78^0 00' 00''E and cover the area of 472128.85 ha. The mean annual rainfall is 650-715 mm, Elevation is 200-600 m and soil types are Red soil, Laterite soil, Block soil and Red sandy soils. In the western zone of Tamil Nadu most of districts had lot of industries. Tiruppur is known for textiles industry, Coimbatore city is known for its machine tools, pumps, yarn and fabrics and Karur and Erode are known for bed sheets, curtain cloth, mosquito nets and other made-up items. Karur district also has lots of processing units for natural dyeing. Noiyal, Bhavani, Uppar, Sirvani and Amaravathi are the major rivers and Mettur, Bhavanisagar and Amaravathi are the major dams utilized by the zone.

Data Collection

Water quality Data was collected from the State Ground and Surface Water Resource Data Centre of Taramani. By using the data water quality index is calculated to the western zone of Tamil Nadu.

Water Quality Index Analysis

Water Quality Index provides a single number that express overall water quality of a certain location and time, based on several water quality parameters. Here we used 12 parameters for calculating the water quality index is given in **Table 1** WHO standard values [14].

Table 1 Water Quality parameters, WHO standard Values, Ideal Values and Weightage Factors of Water quality Parameters

SI. No	Parameter	Standard Values	Ideal Values	Weightage Factor (Wi)
1	pH	8.5	7	0.1176
2	Electrical Conductivity (µmhos/cm)	300	0	0.0033
3	Total Dissolved Solids(Mg/l)	1000	0	0.0010
4	Total Alkalinity	120	0	0.0083
5	Total Hardness (mg/l)	300	0	0.0033
6	Fluoride(mg/l)	1.5	0	0.6667
7	Chloride (mg/l)	250	0	0.0040
8	Nitrate (mg/l)	50	0	0.0200
9	Sulphate (mg/l)	250	0	0.0040
10	Iron (mg/l)	0.3	0	3.3333
11	Calcium(mg/l)	75	0	0.0133
12	Magnesium (mg/l)	30	0	0.0333

WHO standard values (WHO 1971).

Calculation of WQI

To determine the suitability of groundwater for human consumption and irrigation purpose, Water Quality Index was computed using Eq. (1).

$$WQI = \sum_{i=1}^{n} \mathbf{q}_i Wi / \sum_{i=1}^{n} \mathbf{W}_I \qquad (1)$$

Where, W_i is a Weightage factor. It is the ratio of proportionality constant and standard value of the i^{th} water quality parameter which is computed using Eq. (2).

$$W_i = K / S_i \qquad (2)$$

Where, S_i = Standard value of the i^{th} water quality parameter given in Table 1, K is a proportionality constant, which is taken as 1.0 [12], n is the total number of water quality parameters.

Quality rating (qi) is computed using Eq. (3).

$$q_i = \{[(v_a - v_i) / (S_i - v_i)]x100\} \qquad (3)$$

Where, q_i = Quality rating for the i^{th} water quality parameter, V_a = Actual value of the i^{th} water quality parameter obtained from laboratory analysis, V_i = Ideal value of the i^{th} water quality parameter obtained from standard tables, V_i for pH = 7 and for other parameters it is equivalent to zero). Ideal values, weightage factors & standard values of water quality parameters are listed in Table 1.

Result and Discussion

pH

pH of drinking water is normally between 6.5 to 8.5 while that of natural water between 4 to 9. The analysis showed that the pH values range of 8 to 8.2, indicating that the water is neutral. Minimum pH was observed at Somavarampatty village of Thiruppur district while maximum value was at Perisanampatti village of Thiruppur district. The pH value is lower in Post monsoon as compared to the Pre monsoon and most of the pH values are found to be within the permissible limit of WHO 1971 (6.5 – 8.5). The pH is important factor in maintaining the carbonate and bicarbonate level in water. The low pH does not cause any harmful effect.

Total Harness (TH)

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, sulphates, chlorides and nitrates. Total hardness is a measure of calcium and the analysis showed that the TH values range of 0.5-5000. Minimum of TH were observed at Nilgris and Namakkal districts and maximum was observed at Kuppam village of Karur district.

Electrical conductivity (EC)

Electrical conductivity is the ability of water to allow electric current through it and is expressed in micro mhos per centimeter (μ mhos/cm). Electrical Conductivity value of fresh waters is in the range of 5 to 500 μmhos/cm. Maximum value of 2242 μmhos/cm was observed at Perumalai village of Dindugul district while minimum value was 748 μmhos/cm at Kuppam village of Karur district.

Total Dissolved Solid (TDC)

Concentration of dissolved solids in groundwater decides its applicability for drinking, irrigation or industrial purposes. In the study area, TDS in groundwater ranges from 24 to 9662 mg/l. Minimum TDS was observed at Kodaikanal block of Dindugul district while maximum value was at Aravakuruchi block of Karur district. Groundwater containing more than 1000 mg/l of total dissolved solids is generally referred as brackish water.

Total Alkalinity (TA)

Alkalinity is caused due to the presence of carbonates, bicarbonates and hydroxides of calcium, magnesium, potassium and sodium. Calcium carbonate is the most usual constituent that causes alkalinity. Alkalinity is expressed in mg/l and the limit for drinking water is 200 mg/l. Minimum value of TA observed at Nilgiris district and maximum value observed at Coimbatore district.

Fluoride

Fluorine is one of the most common elements in the earth's crust and is most electro-negative of all elements. It

occurs in water as fluoride. It is expressed in mg/l. It is found in both igneous and sedimentary rocks in flat topography and semi- arid regions. The formation of high fluoride in groundwater is governed by composition of bedrock and hydrogeology. High fluoride in groundwater may also be formed as a result of evapotranspiration along the groundwater flow path [12]. Fluoride concentration in groundwater of the study area ranges from 0.01 to 6.2 mg/l. Fluoride of drinking water should ideally be between 1.0 to 1.5 mg/l. Minimum concentration of 0.01 mg/l was observed at Kothagiri village of Nilgris district while maximum of 6.2 mg/l at Palladam block of Thiruppur district.

Chloride

Sewerage waste disposal and leaching of saline residues in the soil, abnormal chloride concentrations may occur. Water quality analysis indicates that the chloride concentration ranges from 4 mg/l to 5459 mg/l. Minimum value of 4 mg/l was observed at Kodaikanal block of Dindugul district and the maximum value of 5459 mg/l at Kuppam village Karur district.

Nitrate

In the study area, the nitrate concentration ranges from 0.05 mg/l to 415 mg/l. Minimum value was observed at both Thanthoni village of Karur district and Kaliyappagoundanur village of Thiruppur district and maximum value was observed at Muduvelampatti village of Thiruppur district respectively. The desirable limit of nitrates in drinking water is 50 mg/l.

Sulphate

Abnormal concentrations of sulphate may be due to the presence of sulphide ore bodies like pyrite, lignite and coal. The study area was observed Sulphate concentration ranges from 1 mg/l to 2448 mg/l. minimum value was observed at Puduvadi village of Karur district and maximum value was identified at Vadamalai village of Thiruppur district.

Calcium

Permissible limit of calcium is 75 mg/l. Calcium concentration ranges from 0.34 mg/l to 900 mg/l was observed in water sample locations at Mohanur village of Namakkal district and Chinnapoolankinar village of Thiruppur district respectively.

Magnesium

Magnesium occurs in water mainly due to the presence of olivine, biotite, augite and talc minerals. Permissible limit of magnesium is 30 mg/l. Water quality analysis of the samples collected indicates that the magnesium concentration ranges from 1.25 mg/l to 972 mg/l. Minimum value of 12.25mg/l was observed at Kodaikanal village of Dindugul district and the maximum value of 972 mg/l at Aravakurichi block of Karur district.

Water Quality Index (WQI)

The results regarding the WQI for two decades of Western zone of Tamil Nadu from the period of 1994 to 2013 are given in the **Table 3-6**. **Figure 1** shows that in 5% of the years the area had excellent water quality and 40% of the years the area was observed Good water quality and remaining 55% of the yeas the area was observed poor water quality condition at pre monsoon season from period of 1994 to 2013. Figure 1 shows that 10% of the years the area was observed excellent water quality and 55% of the years the area was observed good water quality then remaining 35% of the years the area felt in poor water quality condition at post monsoon season from the period of 1994 to 2013. **Figure 2** shows that the observed water quality was lower in pre-monsoon season as compared to Post-monsoon season at both decades. To evaluate the two decades water quality at different monsoon period. In most of the years the area felt in good water quality condition the WQI values range of 26.6 - 49 and only remaining two years (2000 & 2003) the area have been identified poor water quality condition the WQI values of 51.4 & 56.7 at pre monsoon season of first decade(1994-2003).The 1999th year the area have been identified excellent water quality condition the WQI value of 22.7 and remaining years the area felt in good water quality condition the WQI values range of 26-41 at post monsoon season of first decade. In the year 2013 the area have been identified very poor water quality condition at WQI value of 77 and remaining years the area felt in poor water quality condition the WQI values range of 59.7-69.7 at pre monsoon season of second decade (2004-2013).

Table 2 Water Quality Index Scale [12]

Water quality classes	
Excellent	0-25
Good	25-50
Poor	50-75
Very poor	75-100
Unsuitable fordrinking/Irrigation	100 above

Table 3 Status of Water quality in first decade of Pre monsoon season (May to Jun first) for period of 1994-2003

Year	Theni	Coimbatore	Dindigul	Erode	Tiruppur	Namakkal	Karur	Nilgiris	Salem	Western Zone	Water Quality
1994	39.5	33.5	39.1	33.5	34.2	26.0	68.5	17.1	26.7	35.4	Good
1995	38.9	27.0	32.2	12.9	28.9	42.7	35.5	13.3	49.1	31.2	Good
1996	29.1	30.1	30.7	43.0	29.2	31.4	49.4	27.4	46.3	35.2	Good
1997	27.9	33.3	26.7	41.8	31.4	34.5	42.9	18.9	52.7	34.5	Good
1998	38.9	31.6	30.4	29.0	26.4	32.3	50.6	16.4	29.4	31.7	Good
1999	21.3	29.4	27.8	43.7	35.2	31.4	15.7	14.9	19.8	26.6	Good
2000	40.5	69.7	48.6	46.8	94.7	63.4	19.4	12.2	67.5	51.4	Poor
2001	42.3	52.6	13.5	49.7	64.3	50.5	15.4	16.6	64.1	41.0	Good
2002	49.6	59.8	57.1	54.9	59.3	59.6	25.7	13.5	61.1	49.0	Good
2003	49.0	59.3	59.8	75.1	67.1	77.4	27.8	12.2	82.6	56.7	Poor
Avg.	37.7	42.6	36.6	43.0	47.1	44.9	35.1	16.3	49.9	39.2	Good

Table 4 Water quality status in first decade of Post monsoon season (January) for period of 1994-2003

Year	Theni	Coimbatore	Dindigul	Erode	Tiruppur	Namakkal	Karur	Nilgiris	Salem	Western Zone	Water quality
1994	37.8	28.1	34.9	22.5	34.5	47.3	56.7	12.7	25.4	33.3	Good
1995	24.0	31.4	33.6	15.8	29.6	65.9	34.9	11.9	22.1	29.9	Good
1996	25.4	26.8	27.3	18.2	27.0	31.6	48.6	15.7	13.4	26.0	Good
1997	21.9	34.0	32.0	31.5	34.1	34.5	42.2	16.0	22.9	29.9	Good
1998	35.7	37.1	28.5	19.5	27.0	35.0	47.7	15.9	18.1	29.4	Good
1999	16.4	28.5	25.6	15.4	28.1	25.1	27.8	10.6	27.1	22.7	Excellent
2000	26.9	47.4	49.6	23.4	29.0	54.6	67.4	46.5	25.4	41.1	Good
2001	25.8	16.6	32.2	16.8	17.1	21.1	73.6	52.4	14.6	30.0	Good
2002	45.1	16.3	54.7	15.2	13.9	16.1	71.5	39.2	13.2	31.7	Good
2003	31.4	16.0	12.1	14.3	13.9	15.3	95.4	43.1	13.6	28.3	Good
Avg.	29.0	28.2	33.1	19.3	25.4	34.6	56.6	26.4	19.6	30.2	Good

Table 5 Water quality status in second decade of Pre monsoon season (May to Jun first) for period of 2004-2013

Year	Theni	Coimbatore	Dindigul	Erode	Tiruppur	Namakkal	Karur	Nilgiris	Salem	Western Zone	Water quality
2004	34.7	66.5	30.8	100.3	96.7	62.6	111.6	19.3	77.4	66.7	Poor
2005	55.7	57.5	55.0	80.2	71.7	68.6	73.8	18.5	58.6	59.9	Poor
2006	48.8	61.4	47.3	88.1	87.0	59.1	78.5	13.4	53.2	59.7	Poor
2007	36.0	58.4	56.6	93.5	83.7	46.2	90.9	46.5	58.2	63.3	Poor
2008	42.3	83.4	50.8	69.1	75.9	78.5	91.7	46.1	74.5	68.0	Poor
2009	56.9	74.3	53.4	75.9	84.1	69.6	80.8	52.5	57.6	67.2	Poor
2010	48.2	81.5	57.1	67.7	94.9	74.9	71.2	38.6	59.9	66.0	Poor
2011	65.5	61.4	63.2	85.7	88.5	87.7	73.7	33.4	67.9	69.7	Poor
2012	65.0	65.0	60.7	87.3	60.2	68.1	83.5	18.4	75.0	64.8	Poor
2013	55.1	83.4	61.0	89.5	127.1	86.1	88.6	26.8	75.6	77.0	V. Poor
Avg.	50.8	69.3	53.6	83.7	87.0	70.1	84.4	31.4	65.8	66.2	Poor

In the year of 2004 the area have been identified excellent water quality condition the observed WQI value of 17.9 and the years 2005 and 2006 the area have been identified good water quality condition the observed WQI values of 31.7 & 27.2 then remaining years the area felt in poor water quality condition the WQI values range of 60.4-70 at post monsoon season of second decade. The poor water quality condition in second decade due to higher level contamination present in the water. Natural (less rain fall) and the effect of anthropogenic actions (Industrial effluent, fertilizer application and Waste disposal) is the reasons for the high level contamination in water.

Table 6 Water quality status in second decade of Post monsoon season (January) for period of 2004-2013

Year	Theni	Coimbatore	Dindigul	Erode	Tiruppur	Namakkal	Karur	Nilgiris	Salem	Western Zone	Water quality
2004	11.7	12.7	7.6	39.1	11.5	11.2	10.6	53.2	3.6	17.9	Excellent
2005	27.3	26.9	27.9	24.9	26.0	31.8	33.8	59.3	26.9	31.7	Good
2006	24.8	20.6	22.9	23.8	13.4	24.9	36.2	55.8	22.5	27.2	Good
2007	38.1	58.1	35.7	90.9	80.9	60.3	87.0	38.3	53.8	60.4	Poor
2008	54.1	57.1	45.5	85.7	83.5	61.0	93.6	62.6	55.8	66.5	Poor
2009	54.0	70.0	47.4	61.5	83.9	90.4	88.2	20.6	73.3	65.5	Poor
2010	42.4	75.1	56.3	75.3	83.3	86.3	86.4	60.6	64.2	70.0	Poor
2011	43.5	76.8	60.2	72.7	79.9	72.9	78.5	48.5	59.3	65.8	Poor
2012	57.1	57.4	45.1	56.2	86.7	89.3	55.8	30.7	51.3	58.8	Poor
2013	64.7	57.9	50.2	59.3	79.1	88.2	82.5	16.5	51.8	61.1	Poor
Avg.	41.8	51.3	39.9	58.9	62.8	61.6	65.3	44.6	46.3	52.5	Poor

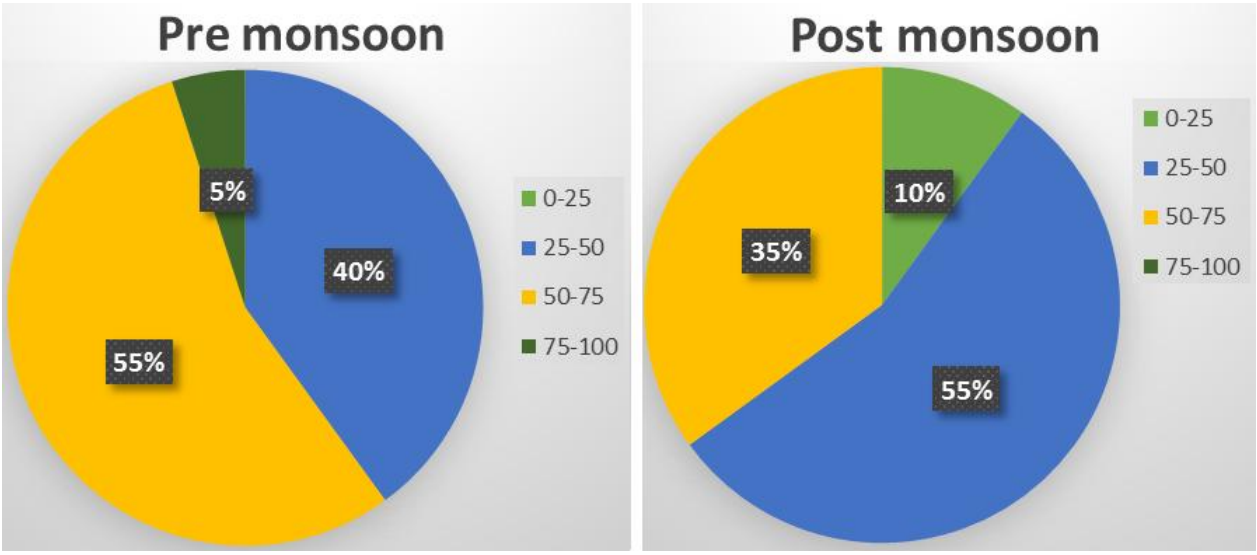

Figure 1 Graphical representation of WQI categories at Pre and Post monsoon season for the period 1994-2013

The observed results are showed that all the districts lie between excellent to good water quality condition in first decade at both the seasons. Water quality condition of three districts are Erode, Karur and Thiruppur was observed very poor water quality condition at pre monsoon season and poor water quality condition at post monsoon season and Nilgris district had good water quality condition at both the seasons then remaining districts felt in poor water quality in pre monsoon season and good water quality in post monsoon season except two districts are Coimbatore and Namakkal at the second decade.

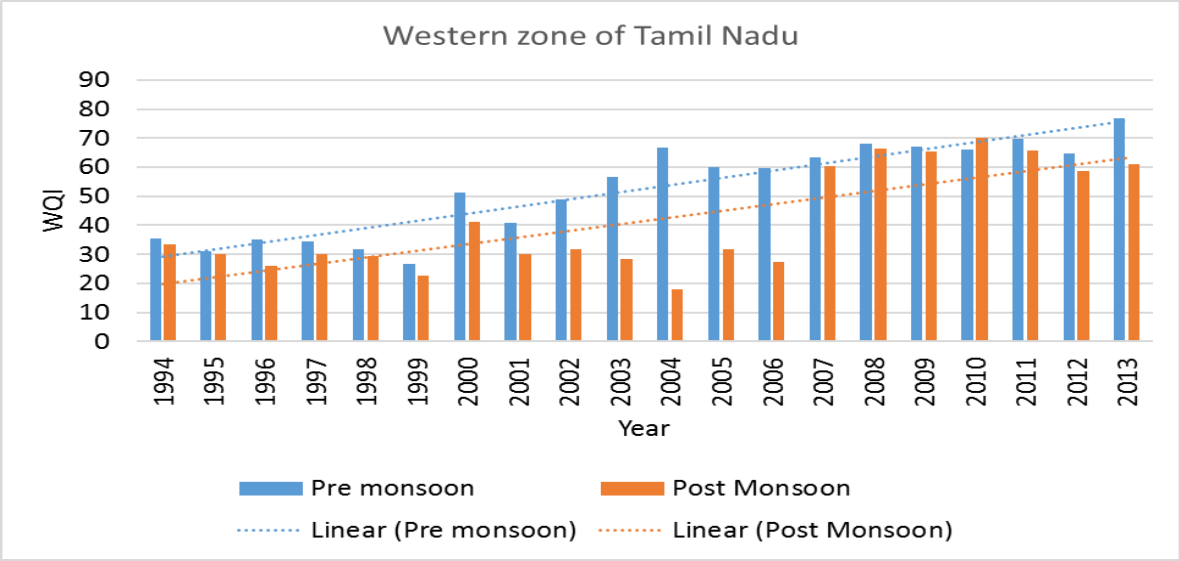

Figure 2 Seasonal variation of WQI range for periods of 1994 to 2013

Conclusion

The results clearly showed that 100 % of the years the area have been identified excellent water quality condition at pre monsoon season and 10 % of the years the area have identified excellent water quality and remaining years the area felt in good water quality condition at post monsoon season of first decade. In Second decade of pre monsoon season the 90 % of years the area was observed poor water quality condition and remaining year the felt very poor water quality condition then second decade of post monsoon season 10% of years the area was observed excellent water quality, 20% of the years the area was observed good water quality and remaining 70% of the years the area have been identified poor water quality condition. The observed water quality was lower in pre-monsoon season as compared to Post-monsoon season at both decades. Due to the ground water recharge good water quality was observed in post monsoon season compared to the pre monsoon season. The study showed good water quality condition in first decade and poor water quality condition in second decade because of industrial area more and less rainfall in second decade as compared to the first decade. To improve the water quality condition first we have to monitoring the existing water quality condition for that purpose we used water quality index study. The water quality index was devised to analyze the combined impact of different quality parameters on drinking and irrigation purposes. The WQI developed and proposed in this study provides an easy to use tool that could help analyze the overall quality of ground water.

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