Impact Of Temporal Variability Of Rainfall ON Groundwater Quality OF Dindigul District, Tamil Nadu, India

Abstract

The present study aims to provide information regarding the temporal distribution of important physical-chemical parameters that affect water chemistry. Graphical representation is recorded for important physiochemical variables to understand groundwater quality and ecological status of the groundwater systems over a period of time in Dindigul district, Tamil Nadu. After 1995, that there was a gradual increase in the rainfall pattern and the excess rainfall was recorded as 1018.59 mm, 1052.82 mm, 1073.73mm during the years 1996, 2008, 2010 respectively. The lowest rainfall of 588.51mm was recorded in 2012. Apart from excess rainfall years, all the other cases recorded the minimum rainfall and showed the decreasing trend from1995 to 2012. After 1990s, release of untreated waste water from Tannery industry in to the water ways and lands - contaminated the groundwater. The change in the rainfall pattern and quantity played important role in the salinity of the groundwater. After 1995s**,** the NO3value of 16.8mg L^{-1} was recorded during **2010**. Accordingly it had the highest excess rainfall of 1073.73 mm, during **2010**.Deficit rainfall in 2000 ranges from 337.67mm, the NO3 value of 68.8 mg L^{-1} was recorded. The chemical characteristics of ground water are determined by the level of contribution from the geological sources and infiltration water from the surface sources. Monitoring of pollution patterns and its trends with respect to urbanization is an important task for achieving sustainable management of groundwater.

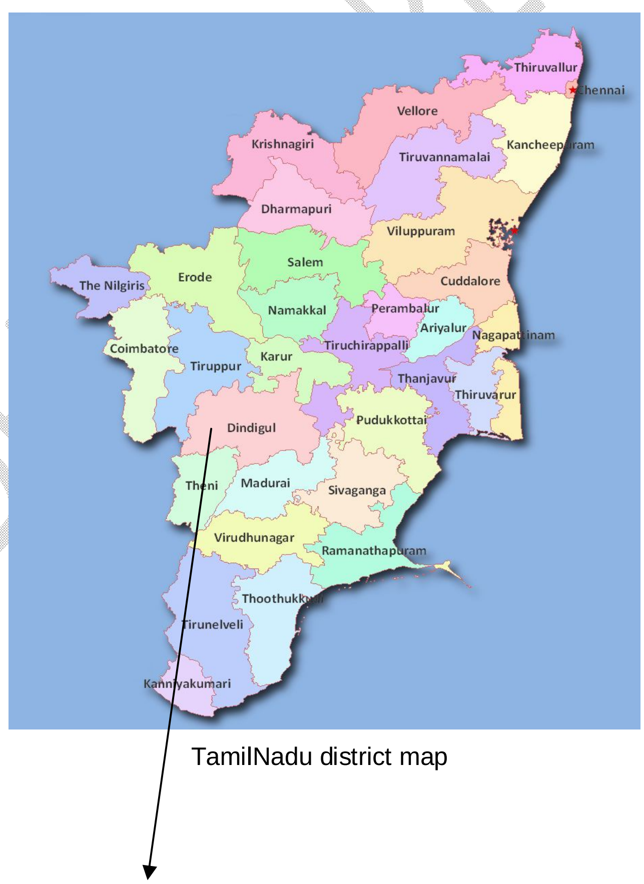
Keywords: Dindugul,Rainfall,Temporalvariability,Groundwater quality

Introduction

Groundwater resources are explored in nature with the development of irrigation activities, industrialization, and urbanization etc. This largest source of fresh water lying beneath the ground has become crucial for targeting potential zones, monitoring its quality is required for domestic and irrigation needs. Decline of water quality in general, and groundwater in particular is of great concern. Unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilizers and deteriorate the ground water. The study of rainfall pattern is very important for the agricultural planning of any region. Monsoon depressions and cyclonic storms are the most important synoptic scale disturbances which play a vital role in the space – time distribution of rainfall over India (Sikka, 1977). Water is the renewable resource and the per capita availability in India is fairly good. Present study area receives only two seasonal rains but sometimes the seasonal rainfall becomes inadequate. During such times the domestic, agricultural and industrial requirements are met by increased in subsurface water. Since groundwater is a major drinking water resource and critical for irrigation in all parts of the world, evaluating and predicting the availability and accessibility of groundwater under changing boundary conditions is one of the central tasks in integrated water resources management (IWRM) (Villholth, 2006; Holman, 2006). IWRM with respect to groundwater has two main objectives namely to provide water in sufficient quantity and quality equitably to different consumers and at the same time to maintain and guarantee a sustainable qualitative and quantitative status of the groundwater resource itself (Hiscock et al., 2002). A „good status" of groundwater refers to its function in water supply (drinking water, irrigation, industrial use etc.) but also to its role as a long term reservoir to sustain aquatic ecosystems (wetlands) and to provide a source of discharge in dry periods. India is a tropical country its agricultural planning and utilization water is depends on monsoon rainfall, more than 75% of rainfall accruing during the monsoon season The groundwater of Dindigul has been degraded due to rapid industrialization along with urbanization and agricultural activities in its surroundings areas. All the industrial units consume large amount of water which, together with dissolved toxic substances (acids, base or toxic chemical compounds) after processing is discharged into nearby agricultural lands, ponds, open ditches, rivers, streams and open land. The present study aims to provide information regarding the temporal distribution of important physical-chemical parameters that affect water chemistry. Graphical representation is recorded for important physiochemical variables to understand groundwater quality and ecological status of the groundwater systems over a period of time. In this chapter, impact of temporal variability of rainfall and groundwater quality in Dindigul district, Tamil nadu is discussed.

Study area

Dindigul district is an administrative region in the south of Tamil Nadu, India. The district was carved out of Madurai District in 1985. Dindigul is located at 10.35°N 77.95°E and has an average elevation of 265 m (869 ft). The town is in Dindigul district of the South Indian state, Tamil Nadu, 420 km from Chennai and 100 km south west of Tiruchirappalli. Dindigul is located in the foothills of Sirumalai hills. The topography is plain and hilly, with the variation resulting in climatic changes. There are no notable mineral resources available in and around the town. The soil type is thin veeneer soil, which is mostly black clayey soil with red soil. Summer season is from March to July, while December to January marks the winter season. The temperature ranges from a maximum of 37 °C (99 °F) to a minimum of 29 °C (84 °F) during summer and a maximum of 26 °C (79 °F) to a minimum of 20 °C (68 °F) during winter. It receives rainfall with an average of 812 mm (32.0 in) annually. The South west monsoon, with an onset in June and lasting up to August, brings scanty rainfall. Bulk of the rainfall is received during the North East monsoon in the months of October, November and December. The climate condition of the region is conducive for horticulture and agriculture. The district at large produces non food crops like, coffee, flowers, tobacco, and eucalyptus. It is the centre for wholesale trading of fruits like orange, pineapple, sappota and guava, and vegetables like onion. Dindigul, being the headquarters of the district, has registered growth in the secondary and tertiary sectors, with a corresponding decrease in the primary Sector. Major employment in the city is provided by industrial estates, hand loom, trading and commerce activities. Approximately 90 percent of the workforce is employed in tertiary sector. The district at large has only two industrial estates, with one of them located in the city. Dindigul was an important centre of trade in tobacco and manufacture of cigars during the British times.Well known brands of scented chewing tobacco like Angu Vilas, Roja Supari etc. operate out of the city and sent to various places in the state and outside. Dindigul is also one of the leading leather producers and suppliers in the state



TamilNadu district map

Map 1 :Block map of Dindigul district

Methodology

The rainfall data and water quality parameters data such as EC, TDS and nitrate were collected from PWD and Centar Groundwater Commission, Chennai from 1970 to 2020. The Dindigul District monthly rainfall data were collected from the Public Works Department (PWD), Surface and Groundwater Division, Govt. of Tamil Nadu. The monthly rainfall data are converted into yearly and annual average seasonal like winter (January and February), summer (March, April and May), southwest (June, July, August and September), and northeast (October, November and December) monsoon based on India Meteorological Department (IMD), Chennai.From the bulk data, the decadal mean data was extracted for the rainfall and water quality parameters (Asadi et al., 2007). The details for the extracted data is given below in the table 1. The database on the properties of various parameters is generated. The graphical representations were prepared for Electrical conductivity, Total dissolved solids and Nitrate using the database. The results were compared with standard values recommended by World Health Organization (WHO) guidelines for drinking water quality and also for irrigation standards (WHO, 2006).

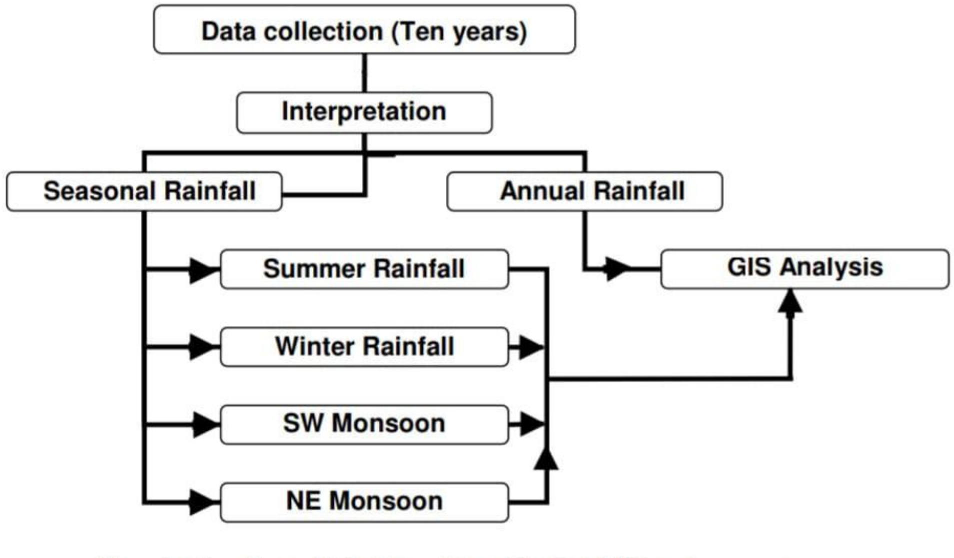


Figure 1: Flow Chart - Methodology Adopted for Rainfall Data Assessment

Description of the study area:

The present study was carried out in Dindigul District of Tamil Nadu State. Dindigul is an interior region of Tamilnadu. It lies on the banks of Kodaganar River. The Kodaganar River originates from the eastern slopes of the lower Palani hills. The study area is situated between 10°05'N and 10°9'N latitude and 77°30' E and 78°20' E longitude. The location of the Study area is shown in Fig. 1. The total area of Dindigul district is 6114 sq. km. There has been deterioration in groundwater quality due to overexploitation, excessive agriculture and untreated domestic as well as industrial effluents. Dindigul town is located within the watershed. Dindigul is one of the important places for its tannery units (Mondal et al. 2011). It has more than 80 tannery units in and around the city and nearly 50 units are under processing of leather. It is the fact that the processing of leather requires large amount of freshwater along with various chemicals. Groundwater is the main source of drinking water in Dindigul (Mohamed Hanipha& Zahir Hussain 2013). The leather industry in and around Dindigul city pollute both surface and groundwater by discharging their wastes. The study area enjoys a tropical climate. The climate is influenced by the monsoon winds, which causes the precipitation on the study area. It has a hot summer and a mild winter. The district receives the rainfall under the influence of both southwest and northeast monsoons. The relative humidity, in general, during the year, is between 65 and 80 percent in the interior parts of the district, except during the northeast monsoon season, when it is over 80 percent. The normal annual rainfall over the district varies from about 700 mm to about 1600 mm.

Results and Discussion

Ground water quality representation comprises the organization and presentation of knowledge about various parameters of the water, as they are classified and outlined on the graph or maps. A well prepared map of the ground water parameters, based on the sound classification system is useful as the base for the different forms of interpretation. These data can be used for the development of agriculture, recharge sites, water management, irrigation purposes etc. Based on the interpretation the potentialities and limitations of the ground water can be obtained and such information is used to construct a graph. The parameters that are recorded are EC, TDS, and fluoride. The study area is Dindigul District and the secondary data for the water quality parameters for excess, normal and deficit rainfall in Dindigul was collected and produced in the table 1 and graphical representations were prepared.

pH: pH is one of the important parameters of water and determines the acidic and alkaline nature of water. The pH of the good quality water ranges from 6.5 to 8. It also shows that major part of study area has the pH value in the suitable range. The villages namely Pallapati, Snarpatti and Samutrapatti have the pH value in unsuitable range.

Total dissolved solids: It is essential to classify the groundwaters depending upon their hydrochemical properties based on TDS values for ascertaining the suitability of groundwater for any purpose. The TDS was classified into three ranges (0-500 mg/L, 500-1000 mg/L, >1000 mg/L).. From the map it has been observed that major part of the study area has TDS values in the suitable range (500-2000mg/L). But the Western part of the district has an unsuitable range of >2000mg/L

Total hardness: The standard value of hardness ranges for a good quality water range is 300-600mg/L. Total hardness was classified to three ranges (0-300 mg/L, 300-1000, >1000 mg/L). From the spatial variation map it was observed that major part of the district has suitable range (300-1000 mg/L).

Calcium: Calcium was classified into three ranges (0-75 mg/ L, 75-200 mg/L, >200 mg/L).From the spatial variation map, it was observed that the Natham and Nilakkottai taluk have calcium values in the suitable range (0-75mg/L). It was observed that Midapati village and Ottanchatram block, located in the Western part of the study area, have the calcium value in the moderate range. **Magnesium:** Magnesium is one of the abundant elements in rocks. It causes hardness in water. From the spatial variation map, it was observed that major part of the study area has magnesium value in the suitable range (30-100 mg/L).

Fluoride (F): The allowable fluoride concentrations in potable waters is 1-1.5mg/L. Concentrations higher than this can cause dental fluorosis, mild skeletal fluorosis and crippling skeletal fluorosis. Fluoride was classified to three ranges (0-1mg/L, 1-1.5 mg/L, >1.5mg/L). It shows that major part of the study area has the fluoride value in the suitable range (1-1.5 mg/L). But the villages namely Thangammapatti and Thennampatti have the high fluoride concentration (>1.5 mg/L).

Chloride (Cl): Chloride is minor constituent of the earth's crust. Rain water contains less than 1 ppm chloride. Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion (WHO 1993). Its concentration in natural water is commonly less than 100mg/L unless the water is brackish or saline (Fetter 1999). The standard value of chloride for a good quality water is 250-1000 mg/L. Chlorides can be classified into three ranges (0-250 mg/L, 250-1000, >1000 mg/L). This figure clearly shows that the Palani and Natham taluk have good and moderate range of chloride.

Sulphates: Sulphate was classified into three ranges (0-200 mg/L, 200-400 mg/L, >400 mg/L) and based on these ranges the spatial variation map for sulphates has been obtained.

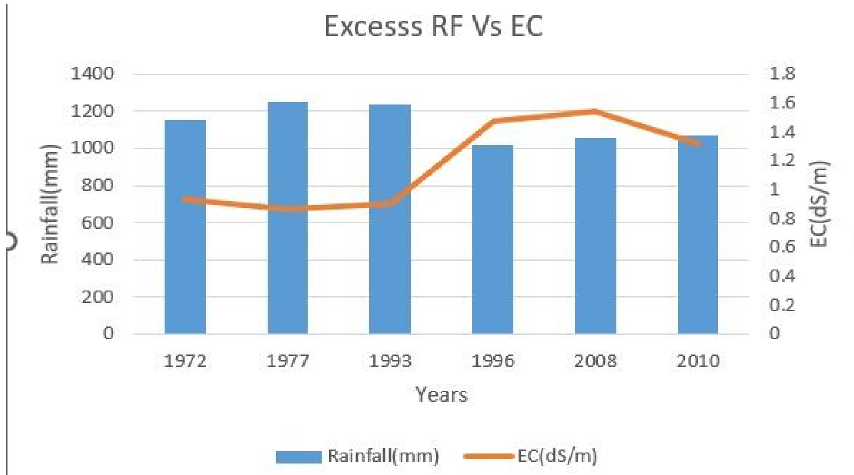
Annual average Rainfall (mm) before and after 1995

The rainfall of the district was studied for excess rainfall, deficit rainfall, normal rainfall patterns.Before 1995, the year 1977 recorded the highest rainfall of 1249.97mm and it showed the decreasing trend till 1988 where the lowest rainfall was found to be 573.72 during 1988. After 1995, that there was a gradual increase in the rainfall pattern and the excess rainfall was recorded the rain fall of 1018.59 mm,1052.82 mm, 1073.73mm during the years 1996,2008,2010 respectively. The lowest rainfall of 588.51mm was recorded in 2012. Apart from excess rainfall years all the other cases recorded the minimum rainfall and showed the decreasing trend from1995 to 2020. Even the average excess and normal rainfall patterns were decreased after the year 1995.All this temporal variability of rainfall shows the change and variation in water quality parameters of the groundwater resources of Dindigul district.

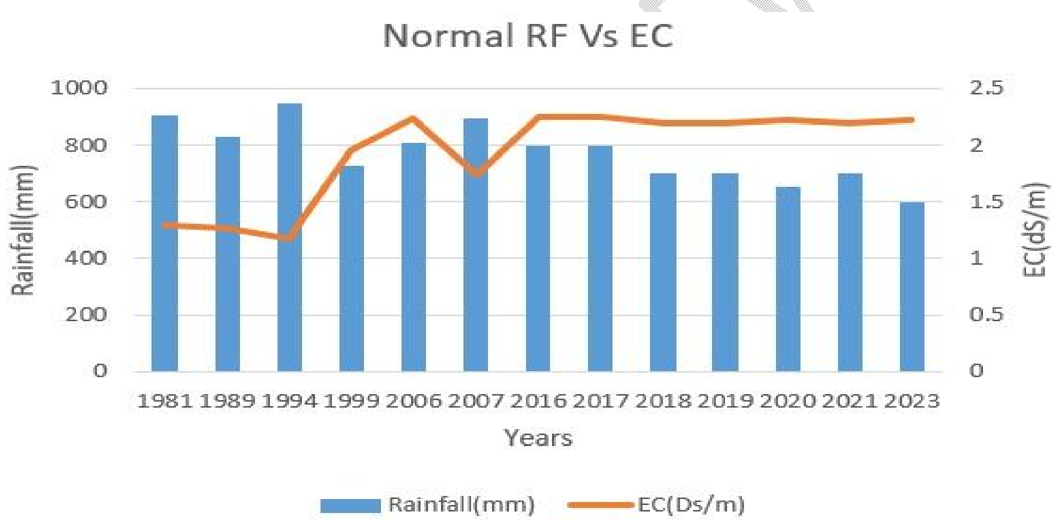
Groundwater quality (EC) of Dindigul District Before and after 1995

The EC is the measure of importance to salinity; which greatly affects the taste. Thus EC has a significant impact on determining the portability of water. The EC of water at 25°C is due to the presence of various dissolved salts. The EC varies with water sample and ranges between 0.40 -1.67 dS m^{-1}.Knowing that the maximum limit of EC for drinking and irrigation water is prescribed as 1.00 dS m^{-1}at 25°C, some of the values are not within the permissible limit. The EC was recorded during before and after 1995. The lowest EC value of 0.80 dS m^{-1} was recorded in1977, Accordingly it had the highest average rainfall of 1249.97 mm. The highest EC value of 2.14 dS m^{-1} was recorded in2012,Accordingly it had the lowest average rainfall of 588.51 mm.The similar trend of results were recorded during 1988, 2003, 2006 after 1995. Before 1995 of DindigulDistrict, recorded an increasing trend of rainfall from upto 1995 except the deficit rainfall years of 1975,1980, 1988. In Deficit rainfall years, increase in EC was more and it was more than 2 dS/m. The EC did not tend to increase before 1995 as compared to the average values of the EC after 1995 because there is no increase in groundwater salinity in the district (1.5-2.5dS m^{-1}).After 1995,there is an increase in the groundwater salinity, the EC of the groundwater tend to increase from 1995 to 2012. After intervention period of 1995– increase in EC level was more and it crossed the level of 0.86 to 2.40 dS/m – high salinity class to very high salinity class. It is due to the rainfall and other climatic factors influenced the Electrical Conductivity of Groundwater.Pollution due to Tannery industry waste water. After 1990s – release of untreated waste water from Tannery industry in to the water ways and lands - contaminated the groundwater. The change in the rainfall pattern and quantity played important role in the salinity of the groundwater. The EC range of the ground water samples in the study area before and after 1995 were tabulated in the table 1.

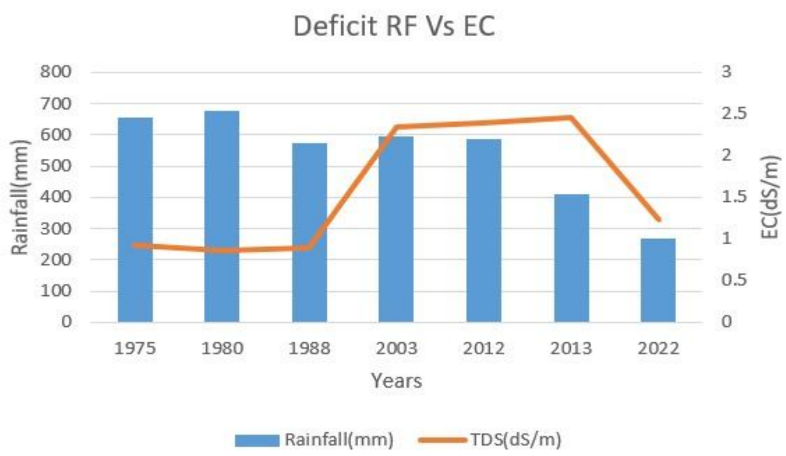
Picture 1- Excess RF years



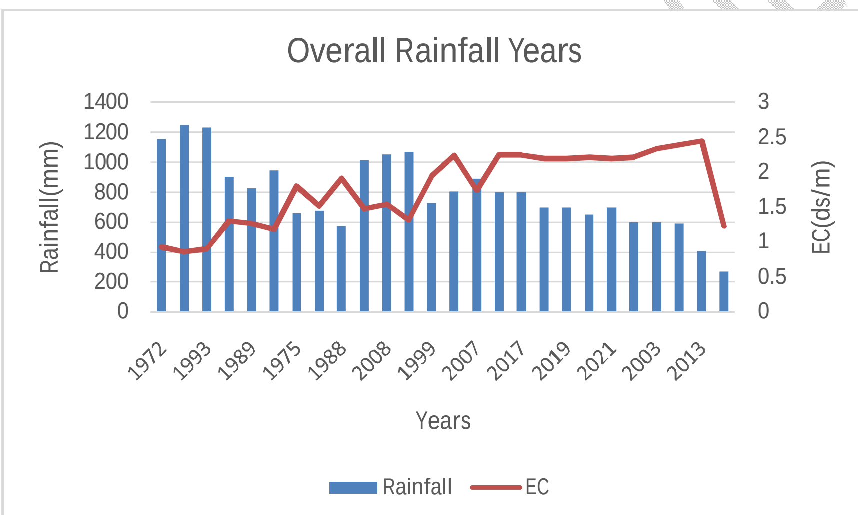
Picture 2- Normal RF years



Picture 3- Deficit RF years



Picture 4- Overall RF years



Total Dissolved Solids content of the groundwater from 1970s to 2010

Total dissolved solids- TDS in water are represented by the weight of residue left when a water sample has been evaporated to dryness WHO (2006). TDS are compounds of inorganic salts (principally Ca, Mg, K, Na, Chloride and SO42-) and of small amounts of organic matter that are dissolved in water. The TDS amount ranges between 486mg/l to 1864 mg/l before 1995 but it ranges between 648mg/l to 2142mg/l after 1995.From this variation, the inorganic salt load in the groundwater over the 40 years period can be calculated for the Dindigul district.

Before 1995, the lowest TDS value of 486 mg/l was recorded in excess rainfall. Accordingly it had the highest average rainfall of 1249.97mm in 1977. The highest TDS value of 1864 mg/l was recorded in 1988. Accordingly it had the lowest average rainfall of deficit rainfall of 573.72mm. The similar trend of results were recorded during 1975 and 1980. After 1995 the lowest TDS value of 786mg/l was recorded in excess rainfall during **2008**.Accordingly it had the highest average rainfall of1052.82 mm. The highest TDS value of 595.12 mg/l was recorded in deficit rainfall during 2003.Accordingly it had the highest average rainfall of2084mm. Similar trend of results were recorded during 2012.It would reflect in the groundwater TDS, the TDS of the groundwater tend to increaseafter 1995. The change in the rainfall pattern and quantity played important role in the salt load development of the groundwater (Suvarna tikle et al, 2012). The TDS range of the ground water samples in different cases of theDindigul District after were tabulated in the table 1 and shown in the fig

Groundwater quality (TDS) of Dindigul District Before and after 1995

Fig 2 - Excess RF years

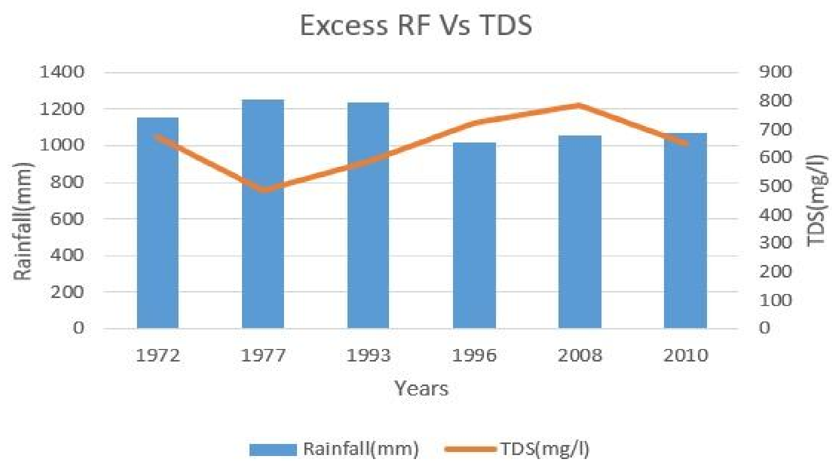


Fig 3 - Normal RF years

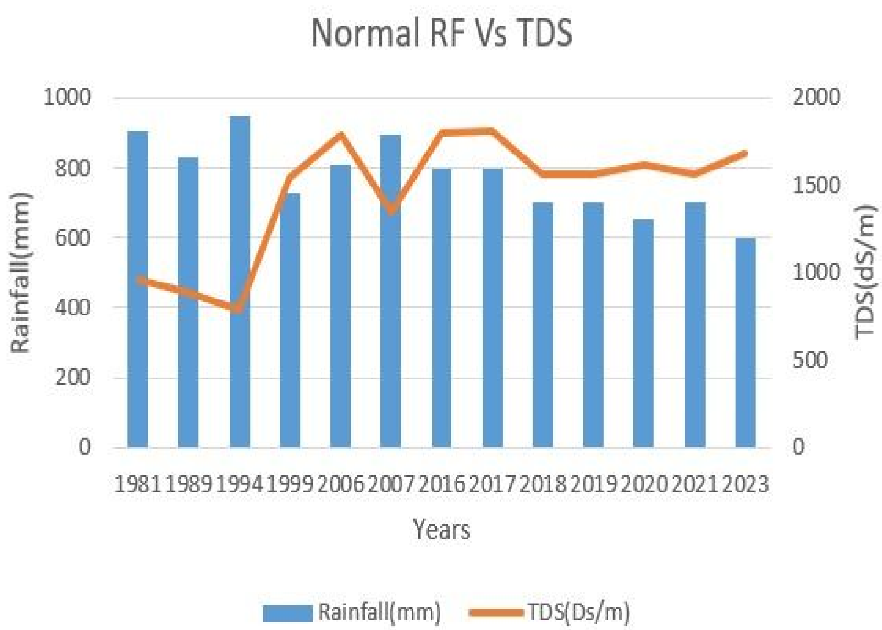


Fig 4 - Deficit RF years

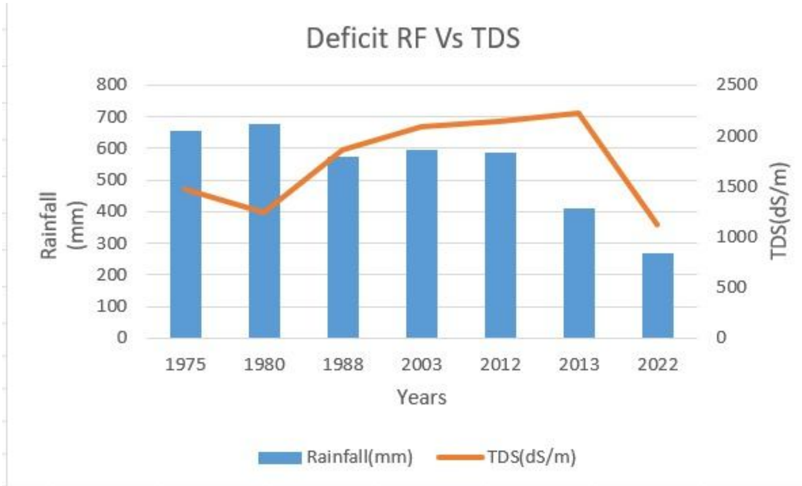
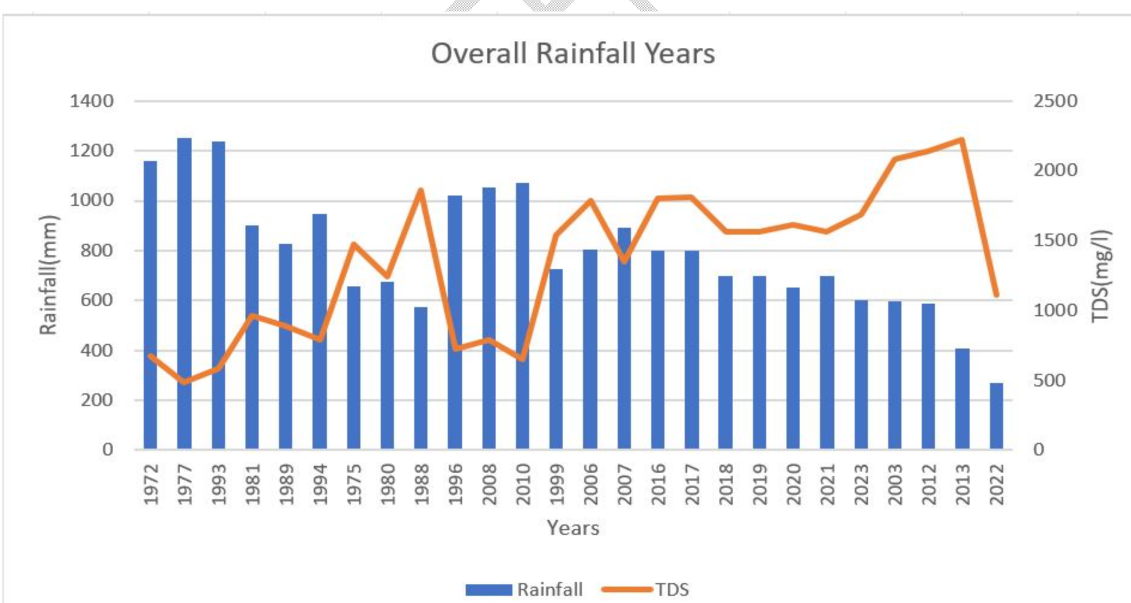


Fig 5 - Overall RF years



Groundwater quality (nitrate) of Dindigul District Before and after 1995

Excessive **nitrate** concentrations have been reported in ground waters in developed and developing countries including India. They are facing nitrate pollution problems which especially affects the children and also adults. The permissible limit of nitrate in drinking water is 45mg/L.Before

1995s**,**the NO3 value of 9.56mg L^{-1} was recorded during**1977**.Iit had the highest excess rainfall of 1249.97mm. During **1994**the NO3 value of 18.5 mg L^{-1} was recorded, it had the normal average rainfall of948.46mm. The similar trend of results in NO3 value of mg L^{-1} were recorded during 1998 and 1984.The deficit rainfall of 573.72mm,the NO3 value of 52.2mg L^{-1} was recorded in**1988**.After 1995s**,**the NO3 value of 16.8mg L^{-1} was recorded during **2010**. Accordingly it had the highest excess rainfall of 1073.73 mm,during**2010**.Deficit rainfall in 2000 ranges from 337.67mm, the NO3 value of 68.8 mg L^{-1} was recorded. Similar trend was seen during 2012.

The study of groundwater quality in Dindigul District before and after 1995 reveals significant changes in EC, TDS, and nitrate levels, influenced primarily by variations in rainfall patterns and anthropogenic activities. The temporal analysis indicates that rainfall variability plays a critical role in groundwater quality. Excess rainfall years generally correlate with lower EC and TDS values, while deficit years show higher concentrations of these parameters due to reduced dilution and increased salt accumulation. The EC trends indicate increasing groundwater salinity, especially post-1995. This trend is likely due to both climatic factors and pollution, particularly from tannery industry wastewater, which has led to higher salinity levels. The EC exceeding permissible limits for drinking water suggests potential risks to water potability and agricultural suitability. The TDS levels show a marked increase after 1995, indicating rising levels of dissolved inorganic salts. This trend suggests a long-term accumulation of salts in the groundwater, likely exacerbated by industrial pollution and changes in rainfall patterns. Nitrate pollution is a critical issue, with post-1995 levels often exceeding the safe limit of 45 mg/L. This increase in nitrates poses significant health risks, particularly for children, and reflects broader issues of agricultural runoff and industrial pollution.

Conclusion

Ground water is mostly used drinking water and irrigation purpose. The chemical characteristics of ground water are determined by the level of contribution from the geological sources and infiltration water from the surface sources. The chemical characteristics of ground water under natural conditions vary spatially as result of variation in the chemical characteristics of their contributing sources. Hence the knowledge about the water parameters is important to determine its quality. Water quality is a critical factor in well-being of any area. The various parameters studied are within the permissible limits as per World Health Organization (WHO) and Indian Council of Medical Research (ICMR) norms for drinking water. In this situation any professional may need the water parameters data. This data is spatial in nature and they can be easily handled and analyzed using graphical method. This method is used in the comparing of data with various interpretations. From this study the ranges of various parameters in the study areas in and around Dindigul is estimated. The alarming rate of increase in some of the parameters in some study areas is observed. This would help in designing various strategies to bring them in control. The mapping of various water quality determine parameters of the selected study areas will be helpful for the conservation practices and also to minimize the ground water pollution potential due to the various environmental factors and this study shall illustrate the importance of spatial modelling and in solving the spatial problems encountered in the workplace. This will be beneficial to educators, students in determining the capabilities that are required in the public health sector. Monitoring of pollution patterns and its trends with respect to urbanization is an important task for achieving sustainable management of groundwater. The change in the rainfall pattern and quantity played important role in the salt load development of the groundwater. Mainly, the EC, TDS and nitrate content of the ground water samples in Dindigul District before and after 1995 were tabulated and graphical representation was done. When compared to before 1995, Now the values are not within the permissible limit in major part of the Dindiguldistrict

Table 1. Rainfall, Water level and Water quality parameters of Dindigul district before and after base year (1995)

S.No	Year	Rainfall (mm)	Water level (m)	EC (dS m^{-1})	TDS (mg L^{-1})	NO_3 (mg L^{-1})
Before 1995 Excess Rainfall						
1	**1972**	1157.00	7.17	0.93	675	17.5
2	**1977**	1249.97	10.43	0.86	486	9.56
3	**1993**	1235.89	10.00	0.90	588	16.24
Normal Rainfall						
4	**1981**	902.67	10.49	1.30	964	31.2
5	**1989**	827.48	11.35	1.27	886	27.8
6	**1994**	948.46	6.71	1.18	789	18.5
Deficit Rainfall						
7	**1975**	657.13	12.57	1.80	1473	44.3
8	**1980**	677.15	8.18	1.52	1245	38.1
9	**1988**	573.72	11.06	1.91	1864	52.2
After 1995 Excess Rainfall						
1	**1996**	1018.59	11.66	1.47	724	17.2
2	**2008**	1052.82	9.13	1.54	786	19.2
3	**2010**	1073.73	9.60	1.32	648	16.8
Normal Rainfall						
4	**1999**	725.29	8.69	1.95	1542	36.5
5	**2006**	805.72	6.14	2.24	1789	40.5
6	**2007**	891.81	9.41	1.74	1346	29.2
7	**2016**	800	6.10	2.25	1800	41.0
8	**2017**	800	6.12	2.25	1810	41.5
9	**2018**	700	8.75	2.20	1560	45.0
10	**2019**	700	8.75	2.20	1560	45.5
11	**2020**	650	8.95	2.22	1615	47.2
12	**2021**	700	8.78	2.20	1560	46.0
13	**2023**	600	8.56	2.22	1684	44.2
Deficit Rainfall						
14	**2003**	595.12	12.01	2.34	2084	54.6
15	**2012**	588.51	6.87	2.40	2142	58.4
16	**2013**	408.0	6.41	2.45	2225	60.0
17	**2022**	269.13	3.25	1.23	1114	30.0

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