RASĀYAN *J. Chem.*
Vol. 14 | No. 1 |51-57| January - March | 2021
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

ASSESSMENT OF HYDROLOGICAL DROUGHT CONDITION AND ITS IMPACT ON WATER QUALITY-A CASE STUDY IN PARTS OF CHENGALPATTU DISTRICT, TAMIL NADU, INDIA

M. Kamalanandhini✉, R. Annadurai, S. Dheepak, P. Deepak and J. Esther Metilda

[1]Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur-603203, Tamilnadu, India

✉Corresponding Author: nandhinimohan90@gmail.com

ABSTRACT

Irregular rainfall leads to over-exploitation of groundwater. The shortage of groundwater is a significant concern, and it contributes to the occurrence of hydrological drought. The study is proposed to measure the severity of the hydrological drought. Chengalpattu district located in Tamilnadu, India was identified as the study area because this district received irregular rainfall in the recent past. The hydrological drought assessment was performed with 30 years of rainfall data and the water quality data for the study area. Standardized Precipitation Index and Interpolation techniques were considered as measures of hydrological drought. Rainfall forecasting was done to identify the trend of rainfall over the next 30 years after studying the historical trend. Furthermore, the Water Quality Index was computed in multiple locations to categorize the water quality. Interpolation technique was used for ranging the water quality into nine classes. The result from the standardized precipitation index indicates, the study area is subjected to the occurrence of hydrological drought. The result from the water quality index indicates, there is no impact on the water quality due to the occurrence of a drought event.

Keywords: Standardized Precipitation Index, Rainfall forecasting, Interpolation technique, Water Quality Index, Hydrological Drought

RASĀYAN *J. Chem.*, Vol. 14, No.1, 2021

INTRODUCTION

Drought has always been a challenge to the socio-economic growth of society. The effects of drought on the environment, human society, and also the economy have made their evaluation a significant issue for the future[1]. The seriousness of the water scare situation has contributed to an extensive review of droughts[2]. Hydrological drought is identified as a cause of deficiency in rainfall and over usage of groundwater resources. This practice directly affects human society and indirectly the country's economic development. Assessment of hydrological drought represents the severity condition of drought event that occurred in a region. Rainfall deviation is considered a key source for both meteorological and hydrological droughts[3]. Drought can have different physical causes and factors, such as climatic conditions, soil moisture, surface temperature, etc., which leads to drought. Due to the continuous extraction of groundwater resources, there is a possibility of fluctuation in the quality of water, resulting in lowering of water table[4]. Degrading water supplies and the ecosystem would inevitably reduce the quality of life[5]. Water quality is a key aspect of refining the quality of life by preventing water-related diseases[6]. As rainwater is mixed into groundwater through the method of infiltration, the quality of groundwater is subject to change[7]. The groundwater resource is highly dependent on the hydrological cycle. Drought is a severe issue that directly affects plant growth and crop yields[8].

This study aims to assess the hydrological drought condition in the study area and to identify the impact on water quality due to the drought event. Rainfall data for the past 30 years (1989-2018) were used for calculating the Standardized Precipitation Index (SPI) which is an effective index for drought-related studies[9]. Rainfall data for the next 21 years (2019-2039) and the trend was observed. With the past trend of rainfall, it was identified that the region was suffering from a severe drought condition.

http://dx.doi.org/10.31788/ RJC.2021.1416095

Water quality parameters such as Nitrate, Fluoride, pH, TDS, Sulfate, Chloride, Calcium, Magnesium, and Total Hardness were collected for different sampling locations for Water Quality Index (WQI) calculation. According to the categories of WQI, the region was under the good water category in all the water sampling locations.

EXPERIMENTAL

Data Collection

The area chosen for the assessment of the hydrological drought is the Chengalpattu district of Tamil Nadu. The Palar River is one of the river basins most commonly used for agricultural purposes. The Palar Basin encompasses more than five districts of Tamil Nadu. The area of research selected for evaluation consists of forests, agricultural fields, and several reservoirs. The Mathuranthagam lake, located in the area, serves as a vast supply of water for the domestic population of the Chengalpattu district. The area consists mainly of deep loamy soil on the banks of the river basin, which is most suitable for agricultural purposes, and alluvial soil in other parts of the district. The next is the silty sand which is most commonly distributed in the eastern part of the river, which helps to recharge the groundwater table. The data collection was distinguished by two types of spatial and non-spatial data. Spatial data contains the Toposheet for the preparation of the base map in the ArcGIS software[10]. Rainfall data were obtained for the study for a period of 30 years from 1989 to 2018. To determine the drought situation using rainfall data, the Standardized Precipitation Index (SPI) was determined and the severity condition was categorized based on the values obtained. The SPI was calculated for 30-year rainfall data using the RStudio software.

The prevailing condition of drought can be accomplished by this approach, which has been confirmed by several researchers. After evaluating the drought, the forecast for rainfall is generated[11]. Rainfall data is projected for the next 21 years from 2018 to 2039, for future rainfall patterns and the potential risk of drought in the future. Inverse Distance Weighted (IDW) interpolation is used to determine the quality of groundwater[12]. The Standardized Precipitation Index is a commonly used index for the identification of droughts using precipitation data[13]. Precipitation data from 1989 to 2018 (30 years) were processed in the RStudio software and the drought index was calculated for the following years. The average rainfall data for all three rainfall measurement stations were grouped and the SPI was calculated.

RESULTS AND DISCUSSION

Standardized Precipitation Index (SPI) Result

In the years 1989 to 1993, the SPI values ranged from -0.5 to 0.5, which is in the normal category. In the years 1994 to 1999, the values ranged from -0.5 to 1.75, which are normal, wet, and moderately wet. In the years 2000 to 2005, the district suffered from dry and extremely dry conditions, the SPI values ranged from -1.5 to -2, which was an extreme drought and there was a severe water shortage in Chennai and Chengalpattu districts. In the years 2006 to 2013, the SPI values ranged from 0.5 to 1.5, which had a decent amount of rainfall. Owing to the lack of water in previous years, there has been a significant effect on the years ahead. Furthermore, in the near term, the district suffered from a lack of rainfall that directly affected the SPI values and went below -0.5 and suffered from water scarcity. The SPI values determined from the RStudio software clearly show that most of the years have suffered from an extremely dry condition in the district that encourages the drought. These SPI values are directly proportional to the precipitation data for the past 30 years because the low rainfall in those years was attributed to dry conditions and the years with more rainfall had rainy conditions for those specific years. The results obtained from SPI showed a dry condition in most of the year, and the condition was therefore very conducive to the occurrence of drought by this analysis. The rainfall trend analysis indicates that hydrological droughts have occurred in the study region and will continue if the same pattern of rainfall occurs in the future. Figure-1 shows the SPI values for the study area.

Rainfall Forecasting

Rainfall forecasting is a method for estimating the amount of rainfall that will occur in the future. The forecasting was made with data collected from three Raingauge stations, namely Chengalpattu, Karunguzhi, and Mathuranthagam. The forecast for 21 years from 2019 to 2039 and the forecast trend for the Chengalpattu station showed a similar pattern of rainfall in previous years, as shown in Fig.-2. Rainfall values ranged from 1 to 4 cm per year in almost all years, except for two years where the rainfall was above 4.5 cm. This indicates that the pattern of rainfall is close to that of previous years. If the trend is the same as the previous one and it is very likely that hydrological drought will occur in the future or that the drought will be prolonged in the future.

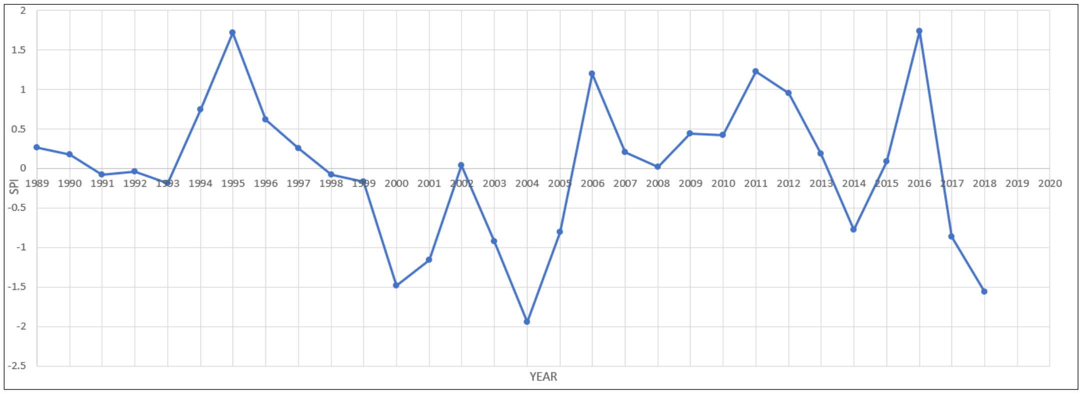

Fig.-1: SPI Value From the Year 1989 to the Year 2018

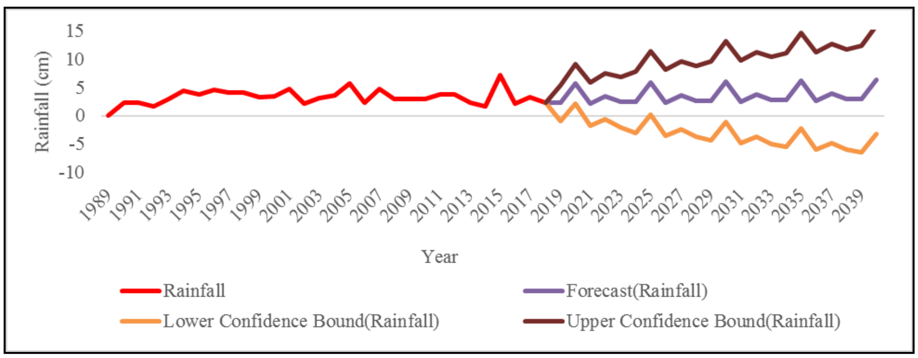

Fig.-2: Rainfall Forecasting of Chengalpattu Station

The forecasting rainfall trend for the Karunguzhi station also followed the same pattern as in previous years as shown in Fig.-3. The forecast amount of rainfall for the years was between 2 and 5 cm, which is much more than the normal amount of rainfall. The area covered by this station would therefore receive a good amount of rainfall relative to others, but on the other hand, the measured SPI values indicated the occurrence of a drought event.

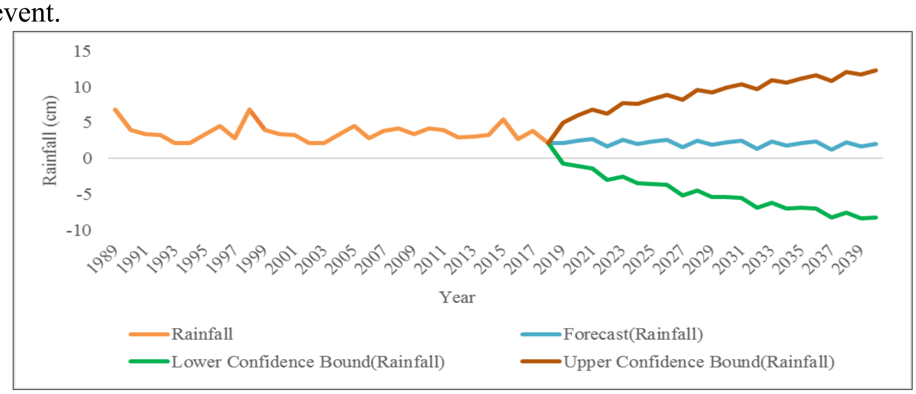

Fig.-3: Rainfall Forecasting of Karunguzhi Station

The forecasted data from the Mathuranthagam station showed a similar pattern of rainfall as in previous years, shown in Fig.-4. The predicted amount of rainfall for this station ranged from 2 to 3.5 cm, which is poor compared to other stations. This implies that the station would receive a low amount of rainfall that will lead to hydrological drought.

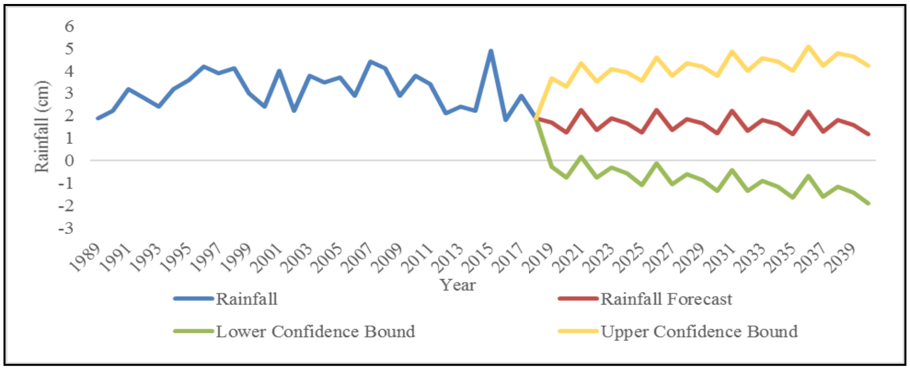

Fig.-4: Rainfall Forecasting of Mathuranthagam Station

Water Quality Analysis

Owing to a shortage of good quality water, people living in the area suffer by consuming low-quality groundwater. Sampling experiments were carried out to assess the level of groundwater in the area and the findings were analyzed to determine its quality. According to IS 10500:2012, the optimal and acceptable limits for drinking water quality parameters have been evaluated and IDW interpolation has been performed using GIS software to classify the extent of each quality parameter in the area.

Nitrates and pH

The acceptable level of Nitrates varies from 45 to 100 mg/l. Figure-5 shows the interpolation of nitrate values from 0.1 to 10 mg/l within the limit. The permissible pH range is between 6.5 and 8.5. Figure-6 demonstrates the interpolation of pH values ranging from 7.5 to 8.4 within the range.

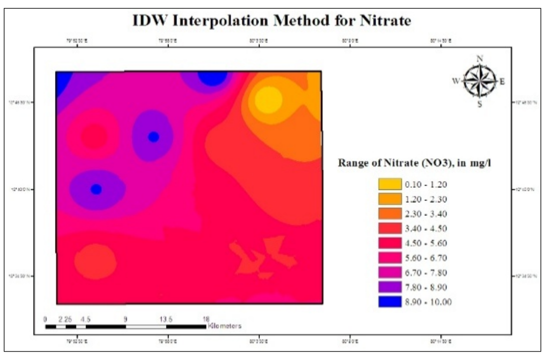

Fig.-5: IDW Interpolation for Nitrate

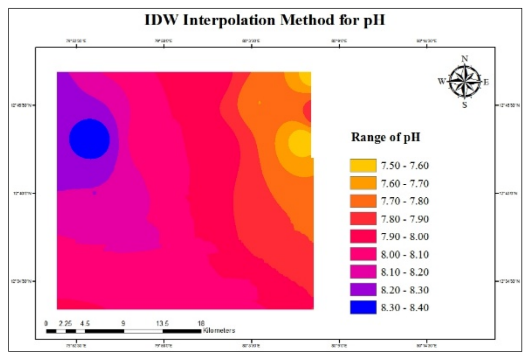

Fig.-6: IDW Interpolation for pH

Calcium and Chlorides

The allowable calcium limit in drinking water varies from 75 to 200 mg/l. The range of calcium is between 29 and 95 mg/l, which is within the limits as shown in Fig.-7. The allowable limit for chloride is between 250 and 1000 mg/l. The range of chloride in the study area is between 52 and 431 mg/l, which is within the limits as shown in Fig.-8.

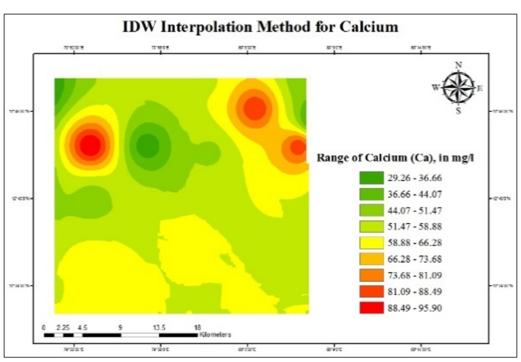

Fig.-7: IDW Interpolation for Calcium

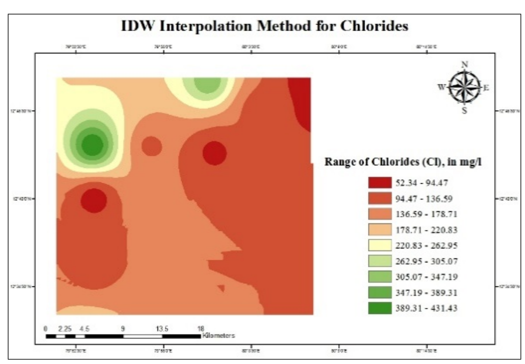

Fig.-8: IDW Interpolation for Chlorides

Magnesium and Fluorides

The permissible range of magnesium is between 30 and 100 mg/l. Magnesium ranges range from 17 mg/l to 86 mg/l within the limit as shown in Figure-9. The allowable fluoride limit ranges from 1 to 1.5 mg/l. Fluorides in the study area range from 0.09 to 1.08 mg/l which are within the limits as shown in Figure-10.

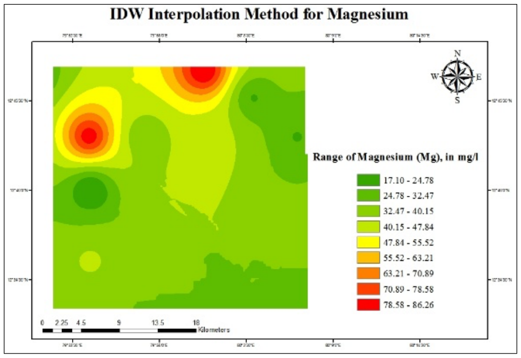

Fig.-9: IDW Interpolation for Magnesium

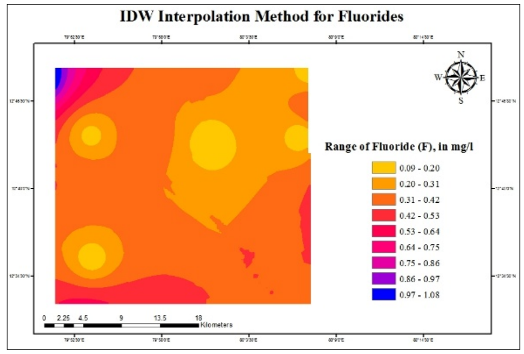

Fig.-10: IDW interpolation for Fluorides

Total Dissolved Solids(TDS) and Sulfates

The acceptable limit for total dissolved solids ranges from 500 to 2000 mg/l. The TDS range from 304 to 1007 mg/l, which is within the limits. Figure-11 depicts the interpolation values for TDS in drinking water. Sulfate limits range from 200 mg/l to 400 mg/l. Sulfates in the region range from 1 to 130 mg/l, which is within the limits. Figure-12 indicates the interpolation values of Sulphate in drinking water.

Total Hardness

The acceptable hardness limit ranges from 200 mg/l to 600 mg/l. The hardness varies from 190 mg/l to 580 mg/l, which is within the limits. Figure-13 shows the interpolation values for total water hardness.

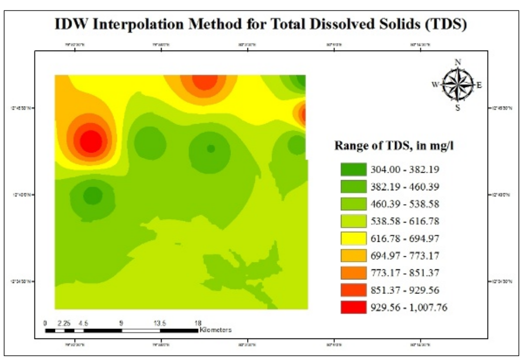

Fig.-11: IDW Interpolation for TDS

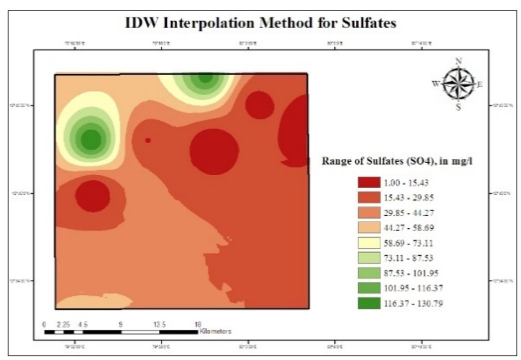

Fig.-12: IDW Interpolation for Sulfates

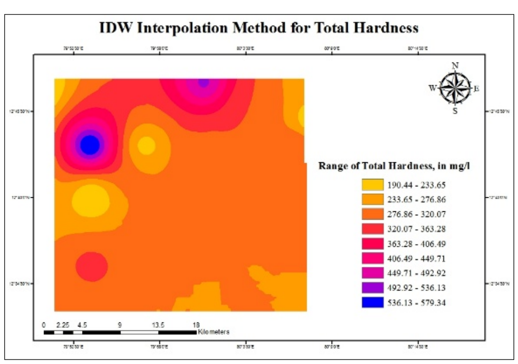

Fig.-13: IDW Interpolation for Total Hardness

Water Quality Index (WQI)

The Water Quality Index is a good administrative and management tool for the transmission of information related to water quality[14]. The WQI is an index primarily calculated to evaluate the effect of various water quality parameters. The groundwater quality index can be calculated by assigning weights on the basis of their relative value to the quality of the water. The water quality index shall be determined using equation 1 and equation 2).

$$q_i = (C_i/S_i)*100 \tag{1}$$

q_i – quality rating scale of i^{th} parameter
C_i – concentration of each parameter in mg/l
S_i – maximum permissible limit of each parameter in mg/l

$$WQI = \Sigma q_i*w_i/\Sigma w_i \tag{2}$$

w_i – the weight of i^{th} parameter

Parameters such as Nitrate, Fluoride, pH, TDS, Sulfate, Chloride, Calcium, Magnesium, and Hardness have been used for the measurement of WQI. Weights were assigned based on their value in terms of quality of view and their relative weights were calculated. The concentration of each parameter was compared to the maximum permissible limit and, ultimately, the water quality index was determined for each of the groundwater quality parameters. Table-1 shows the relative weights of each parameter.

Table-1: Relative Weights for Different Parameters

S.No.	Parameters	Standard Value (S_i)	Weight (w_i)	Relative Weight ($W_i = w_i/\Sigma w_i$)
1	Nitrate	45-100	5	0.1667
2	Fluoride	1.0-1.5	4	0.1333
3	pH	6.5-8.5	4	0.1333
4	TDS	500-2000	4	0.1333
5	Sulfate	200-400	4	0.1333
6	Chloride	250-1000	3	0.1000
7	Calcium	75-200	2	0.0667
8	Magnesium	30-100	2	0.0667
9	Hardness	200-600	2	0.0667
			$\Sigma w_i = 30$	$\Sigma W_i = 1.0000$

The Water Quality Index (WQI) was classified into five groups. When the value of WQI is < 50 it is excellent water, 50 - 100 it is under good water, 100 - 200 it is under poor water, 200 - 300 it is very poor water and > 300 it is unfit for drinking[15]. Five villages within the study area were compared to the WQI, namely Thimmavaram, Chengalpattu Police Station, Karunguzhi, Maduranthagam RDO (Revenue Division Officer), and Maduranthagam Tahsildar. The range of the water quality index in Thimmavaram was found to be between 5 and 88, indicating a good category of water. This is due to the pH range of 8.5, i.e. the maximum acceptable limit for pH. The range of WQI in Chengalpattu was 7 to 99, which comes under the good water category, and the higher range is due to the pH value of 8.4. Karunguzhi had a WQI of between 5 and 95, which is also a good water category, and the higher value range was due to the maximum of the allowable pH limit of 8.1. Maduranthagam (Revenue Divisional Office) had a WQI range from 3 to 93, a higher WQI value was due to a pH value of 7.9 and a Maduranthagam Tahsildar office was between 2 and 96, a higher WQI value was due to a pH value of 8.2, both of which are in the good water category.

CONCLUSION

The rainfall pattern analysis of all stations showed various variations. For most of the years, the district has suffered from a low amount of rainfall that favors the drought. The SPI has shown that most of the years were under dry to moderately dry conditions. There were several years of dry conditions due to lack of rainfall, so it can be inferred from these findings that the drought has occurred in the study region. Drought has been established, and with the rainfall prediction results, it is clear that the drought will appear to persist in the coming years. This is because the predicted rainfall displayed a similar pattern of rainfall patterns as in the past. Much of the years have seen a poor amount of rainfall in the past and will be the same in the future. So there are a lot of possibilities that the drought will extend. The review of the water quality showed that the parameters were below the acceptable limit and that the quality was not significantly affected by the prevailing drought conditions. The Water Quality Index was determined to categorize the water quality in the region. The WQI value obtained at all the locations of the sample collection showed that the range of the index value was in the category of good water. It can be concluded that there is not much harm to the quality of the water due to drought in the study region. However, if there is a prolonged action of low rainfall and inadequate water storage facilities, the groundwater table will fall considerably, which in turn affects the quality of drinking water.

REFERENCES

1. Zekai Sen, Applied Drought Modeling, Prediction and Mitigation, *Elsevier*, (2015)
2. George Tsakiris, *Procedia Engineering*, **162**, 15(2016), **DOI:**10.1016/j.proeng.2016.11.004
3. Reza Ravanshad, Maruthi N.E., and Basavarajappa H.T, *International Journal of Research and Analytical Reviews*, **6(1)**, (2019)
4. Kamalanandhini M, Kalaivizhi R, Golda Percy VP, Srividhya S, Dheepak S, and Thiyaneshwaran K, *Rasayan Journal of Chemistry*, **12(2)**, 849(2019), **DOI:**10.31788/RJC.2019.1225232
5. P.K. Raji and Marykutty Abraham, *Rasayan Journal of Chemistry,* **11(2)**, 828(2018), **DOI:**10.31788/RJC.2018.1122005
6. Rakesh Kumar Yadav and M.R. Augur, *Rasayan Journal of Chemistry*, **11(2)**, 537(2018), **DOI:**10.31788/RJC.2018.1122089
7. P. Vijayalakshmi and Marykutty Abraham, *Rasayan Journal of Chemistry*, **11(2)**, 728(2018), **DOI:**10.31788/RJC.2018.1122051
8. Esther Metilda J, Annadurai R, and Kamalanandhini M, *International Journal of Advanced Science and Technology*, **29(4)**, 699(2020)
9. Sorin Cheval, *Romanian Journal of Meteorology*, **12(1-2)**, (2015)
10. Nadine Nicolai Shaw, Jakob Zscheischler, Martin Hirschi, Lukas Gudmundsson, Sonia I. Seneviratne, *Remote sensing of Environment*, **203**, 216(2017), **DOI:**10.1016/j.rse.2017.06.014
11. Eskinder Gidey, Oagile Dikinya, Reuben Sebego, Eagilwe Segosebe, and Amanuel Zenebe, *Environmental Systems Research*, **7(13)**, (2018), **DOI:**10.1186/s40068-018-0115-z
12. M. Kamalanandhini, Nagalakshmi R, Srividhya S and Golda Percy V P, *International Journal of Pure and Applied Mathematics*, **118(20)**, 4343(2018)
13. Ye Zhu, Wen Wang, Vijay P Singh, and Yi Liu, *Science of the Total Environment.*, **571(1)**, 1058(2016), **DOI:** 10.1016/j.scitotenv.2016.07.096
14. P.S. Bytyci, H.S. Cadraku, F.N. Zhushi Etemi, M.A. Ismaili, O.B. Fetoshi and A.M. ShalaAbazi, *Rasayan Journal of Chemistry*, **11(2)**, (2018), **DOI:**10.31788/RJC.2018.1123015
15. Batabyal, A.K, and Chakraborty S, *Water Environment Research*, **87(7)**, (2015), **DOI:**10.2175/106143015X14212658613956

[RJC-6095/2020]