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SPATIAL ANALYSIS OF RIVER WATER QUALITY USING INVERSE DISTANCE WEIGHTED INTERPOLATION IN NOYYAL WATERSHED IN COIMBATORE, TAMILNADU, INDIA

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ABSTRACT: The present study was proposed to calculate Water Quality Index (WQI) of a river, Noyyal, in Coimbatore district, Tamilnadu in order to find out the quality of water for public consumption, recreation and other purposes. Water samples were collected from the Noyyal River. The parameters were estimated such as dissolved oxygen (DO), pH, chemical oxygen demand (COD), total dissolved solids (TDS), Turbidity, Electrical conductivity, total hardness etc. This study had two phases. In the first phase, the estimation of water quality parameters was carried out and in the second phase water quality index have been determined based on the existing standards. Spatial variations of various surface water quality parameters were studied using the Geographical Information System (GIS). Among the sample locations, in most of the places, high concentration of TDS, Hardness, and low level of DO were observed. Our findings highlighted the deterioration of water quality in the river and are due to human activities. This analysis reveals that the surface water needs some degree of treatment before consumption. Spatial interpolation methods are frequently used to estimate values of physical or chemical constituents in locations where they are not measured. The study reported here uses water quality data from the Noyyal watershed and uses spatial interpolation technique, inverse distance weighting that incorporates output from a process based water quality model.

KEYWORDS: Physiochemical parameters, Water Quality Index, Geographical information system, Inverse distance weighted method.

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1. INTRODUCTION

Water is a colorless, transparent, odourless, liquid which forms the seas, lakes, rivers, and rain and is the basis of the fluids of living organism. Water resources are sources of water that are potentially useful to humans. It is important because it is needed for life to exist. Many uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually all of these human uses require fresh water. Only 2.5% of water on the Earth is fresh water, and over two thirds of this is frozen in glaciers and polar ice caps. Water demand already exceeds supply in many parts of the world, and many more areas are expected to experience this imbalance in the near future. It is estimated that 70% of world-wide water use is for irrigation in agriculture. Climate change is having the significant impacts on water resources around the world because of the close connections between the climate and hydrologic cycle. Due to the expanding human population competition for water is growing such that many of the world's major aquifers are becoming depleted. Many pollutants threaten water supplies, but the most widespread, especially in underdeveloped countries, is the discharge of raw sewage into natural waters. Unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilizers are deteriorating the water quality [1]. Nearly three billion people live without access to adequate sanitation systems necessary for reducing exposure to water-related diseases. The failure in solving this crisis leads to poor water quality in natural water resources [2]. Thus a practical action to protect the natural quality of water is essential. As many professionals point out, water quality mapping over extensive areas is the first step in water resources planning [3] and water can be optimally used and sustained only when the quantity and quality is properly assessed. The spatial distribution of quality of water displays some heterogeneity and the measurement of quality parameters at every locality is not always practicable on account of time as well as cost of the data collection. Therefore, prediction of values based on selectively measured values is one different while minimizing errors and enhanced rate of calculation accuracy. Geographical Information System (GIS) is an important tool and has great potential for use in environmental problem solving in numerous areas, including engineering and environmental fields. [4]. Due to the beginning of geostatistical analyst as an pioneering tool to fill up the gap between geostatistics and GIS, many researchers broadly used it for the analysis of spatial variation of water quality characteristics [5]. The author were [6] stated that spatial interpolation is a technique of predicting the value of attributes at unsampled sites from measurements made at point locations within the same area. Several studies have been undertaken to compare different interpolation methods in a variety of situations, using GIS in areas such as water quality, groundwater depth, groundwater contamination, groundwater quality, etc. The researcher has been argued that [7,8] Kriging, Inverse Distance Weighting (IDW), and Radial Basis Functions (RBF) are three well-known spatial interpolation techniques commonly used for characterizing the spatial variability and interpolation between sampled points and producing prediction maps [9]. The investigator revealed

by [10] local polynomial method and IDW were the best methods to estimate EC and pH, respectively in a study carried out in Hamedan-Bahar plain, west of Iran. Therefore, it is important to recognize an appropriate interpolation method for water quality mapping as different studies in different places indicated different results. The present study investigated the best interpolation method to illustrate the spatial distribution of the water quality parameters in Noyyal watershed, Coimbatore, Tamilnadu, India.

2. MATERIALS AND METHODS

Sampling

Schematic representation of base map of Noyyal watershed is as shown in Figure 1. In this study, it has been chosen that the confined stretch of the Noyyal River which passes through Perur, since the over exploitation of the river occurred over there. The samples were collected at different locations. The irregularities between the sampling locations are due to the bushes and sluggish in the river. This condition is practically not possible to collect water samples. 13 samples were collected from 13 locations such as Kamatchipuram, Vellalore, Valankulam, Athupalayam, Periyakulam, Selvapuram, Perur, Ravathur, Semmedu, Alandurai, Madampatti, Sengathurai, and Mangalampirivu. The samples were collected by grab sampling [11]. Each sample was analyzed for eight parameters such as dissolved oxygen (DO), total dissolved solids (TDS), chemical oxygen demand (COD), Electrical conductivity, Turbidity, pH, and Hardness etc. All water quality parameters were estimated by standard methods. (WHO, 1999).

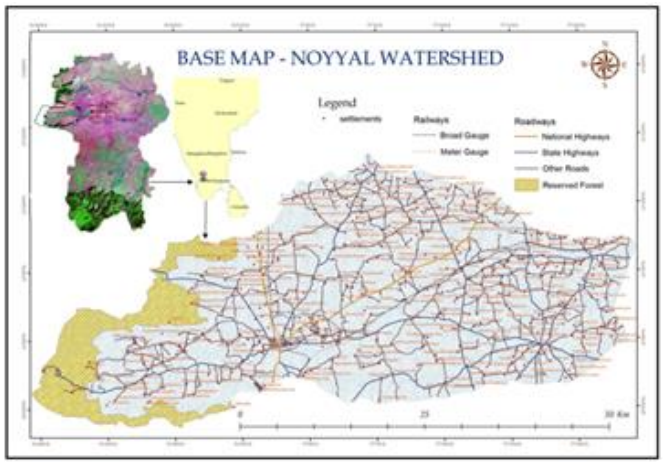


Figure 1: Study area map of Noyyal watershed

Water quality index

In this study, it was attempted to evaluate the quality of Noyyal River. It can be done using water quality index (WQI). WQI is defined as a rating reflecting the composite influence of different water quality parameters. Initially, WQI was developed by Horton (1965) in United States by selecting 10 most commonly used water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. and has been widely applied and accepted in European, African and Asian countries. Water quality index provides a single number that expresses overall

water quality at a certain location and time, based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is understandable and usable by the public. A single number cannot tell the whole story of water quality; there are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of water quality. In general; water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with number. In this study, for the calculation of water quality index, eight important parameters were chosen. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The weighted arithmetic index method has been used for the calculation of WQI of the river. Further quality rating or sub index (qi) was calculated using the following expression.

$$qi = 100\frac{vi - v10}{si - v10}$$

qi = Quality rating for the i^{th} Water quality parameter.

Vi = Estimated value of the i^{th} parameter at a given sampling station.

Si = Standard permissible value of the i^{th} parameter.

V10 = Ideal value of i^{th} parameter in pure water. (i.e., 0 for all other parameters except the parameters pH and Dissolved oxygen (7.0 and 14.6 mg/l respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value Si of the corresponding parameter.

$$Wi = \frac{K}{Si}$$

Wi=unit weight for the ith parameters.

Si=Standard value for ith parameters.

K=Constant for proportionality.

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \frac{\Sigma qiwi}{\Sigma wi}$$

Geographical Information System

Geographic Information Systems is a piece of software that captures geographic data for the purpose of manipulation, viewing and analysis in whichever context and parameters the user desires or needs. It can be used to analyze spatial data or geographic information for any given and possible purpose. The base map is prepared by delineating the watershed from the SRTM DEM map of India. GIS

technology proved to be very useful for enhancing the accuracy. Software which is used for this study is ARC GIS 10.1. Kriging, Inverse Distance Weighting (IDW), and Radial Basis Functions (RBF) are three well-known spatial interpolation techniques commonly used for characterizing the spatial variability and interpolation between sampled points and generating prediction maps. In this study, IDW was used.

Inverse Distance Weighted (IDW) Method

Inverse distance weighted (IDW) is a deterministic estimation interpolator by which unknown values are computed by a linear combination of values at known points [12]. IDW assumes that each input point has a local influence that diminishes with distance [13]. IDW produce surfaces by establishing a neighborhood search of points and weighting these points by a power function. Often, with the increase of power the effect of the points that are farther diminishes. Lesser power distributes the weights more uniformly between neighboring points [14]. The advantage of IDW is intuitive and efficient and it works best with evenly distributed points and it is sensitive to outliers. Unevenly distributed data clusters result in introduced errors [15].

Steps were followed;

In ARC MAP → Arc Tool box →Spatial Analysis Tools → Interpolation→ IDW → Input point feature value field → Output raster → OK

By using ARC GIS 10.1 software, each physiochemical parameter is interpolated with IDW and maps were created. In the same way the Water Quality Index map also created for each sample location.

3. RESULTS AND DISCUSSION

Table1. Drinking Water standards recommending Agencies and unit weights. (All values except pH and Electrical Conductivity are in mg/L)

Parameters	**Standards**	**Recommended agency**	**Unit weight**
pH	6.5-8.5	ICMR/BIS	0.2170
Electrical conductivity	300	ICMR	0.0025
Turbidity	5	ICMR	0.3038
Total alkalinity	120	ICMR	0.0126
Dissolved oxygen	5	ICMR/BIS	0.3038
Total hardness	300	ICMR/BIS	0.0050
Chemical oxygen demand	10	ICMR	0.1519
Total dissolve solids	500	WHO	0.0030

Table 2. Water Quality Index (WQI) and status of water quality [16].

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 3. Water quality and quality index analysis of various sample locations of Noyyal watershed

Sr.no	Sample location	pH	EC	Tur	TA	DO	TH	COD	TDS	WQI
1	Alandurai	7.16	1.1	0	30	0.3	964	49	1	121.65
2	Athupalayam	7.69	2.5	0	35	0.4	1455	96	1.5	193.63
3	Kamatchipuram	7.95	2.4	0	0	0	1430	64	1.4	145.86
4	Madampatti	7.26	1.5	0	31	0.3	870	51	1	124.54
5	Mangalampirivu	7.97	2.5	0	43	0	1426	84	1	176.69
6	Perur	7.54	1.7	0	0	0	1290	0	1	553.44
7	Periyakulam	8.39	2.7	0	41	0.8	1120	64	1.6	50.20
8	Ravathur	6.97	2.3	2900	0	0	1450	0	1.3	656.39
9	Selvapuram	7.56	1.9	0	0	0	1300	64	1.1	145.64
10	Semmedu	7.05	0.9	0	26	0.2	800	46	1	117.09
11	Sengathurai	7.84	2.2	0	0	0	1382	86	1	179.21
12	Valankulam	8.48	2.1	0	51	0.8	1125	96	1.2	191.97
13	Vellalore	7.21	1.8	100	0	0	1270	64	1.1	753.32

*Tur-turbidity

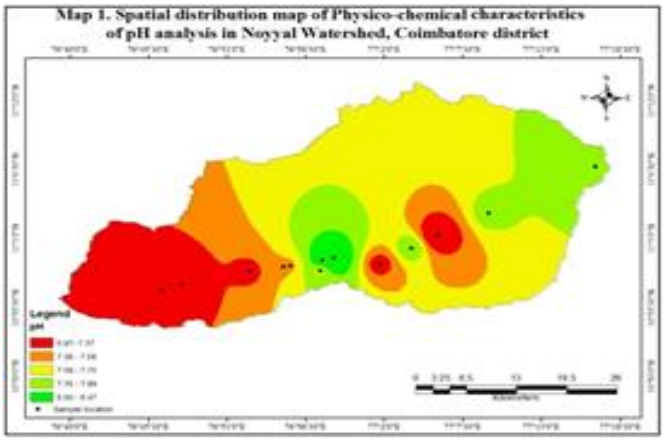
The WQI values (50.20 to 753.32) calculated for the different samples indicate that the water is unfit for drinking. Among the 13 sampling sites, The WQI of Perur is 50.20, that indicating poor water quality. Remaining sample locations have the WQI greater than 100, which indicate that the water is unsuitable for drinking. Only Perur shows WQI 50.20 that indicating poor water quality. The spatial distribution of WQI of the study area is shown below.

Spatial distribution map of overall water quality analysis in Noyyal watershed analysis on distribution pattern of water quality parameters

pH

pH is a measure of the hydrogen ion concentration of a solution. Solutions with a high concentration of hydrogen ions having the low pH and solutions with a low concentration of H^+ ions are having the high pH. The values were obtained in the range 6.97 to 8.48. The pH values in study area range 6.97-

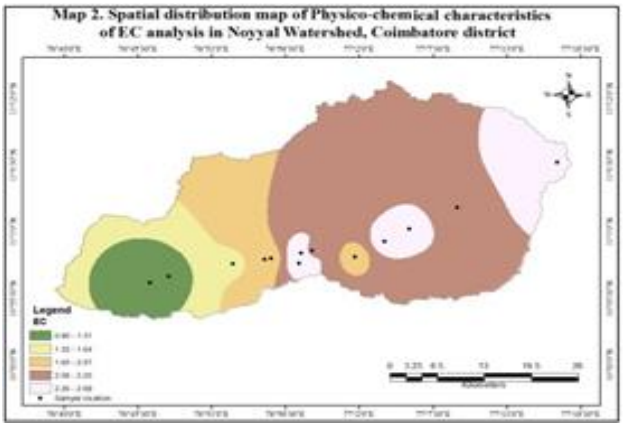
8.47. pH is one of the most important parameters in drinking water and determines the acidic and alkaline nature of water. As per ICMR the standard value of pH is 6.5-8.5. [17] have been examined that pH level of Noyyal River water samples, it was found to be in the range between 7.25 and 9.09 which indicate that the river samples was alkaline in nature. [18] have been suggested that a pH value of sample in the area varied from 6.96 to 8.5 which is similar to the findings of [17] indicates alkaline nature of the water. The water samples are within the permissible limit as shown in Table 2. The spatial distribution of pH map is shown below in Map1.



Map1. Spatial distribution map of pH analysis in Noyyal watershed

Electrical conductivity

Conductivity is a measure of current carrying capacity. Thus, as concentration of dissolved salts increases conductivity also increases. Many dissolved substances may produce aesthetically displeasing colour, taste and odour. The values obtained are in the range 0.9 to 2.7mmhos. The values of electrical conductivity obtained in the range of 0.9 to 2.7mmhos. As per ICMR the standard value of EC is 300. The water samples are within the permissible limit as shown in Table 2. The spatial distribution of Electrical conductivity map is shown in Map 2.

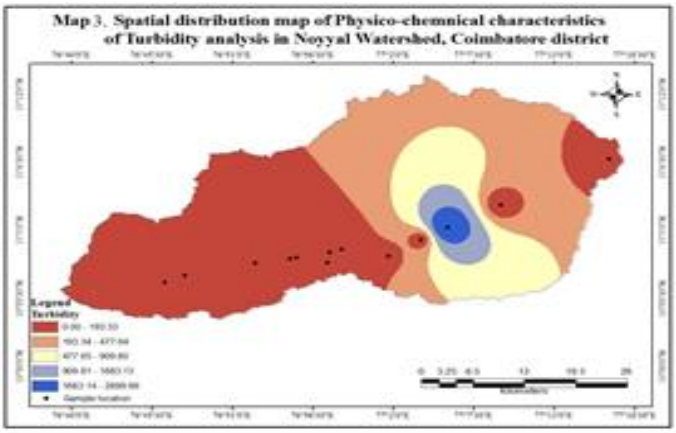


Map 2. Spatial distribution map of electrical conductivity analysis in Noyyal watershed

Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined

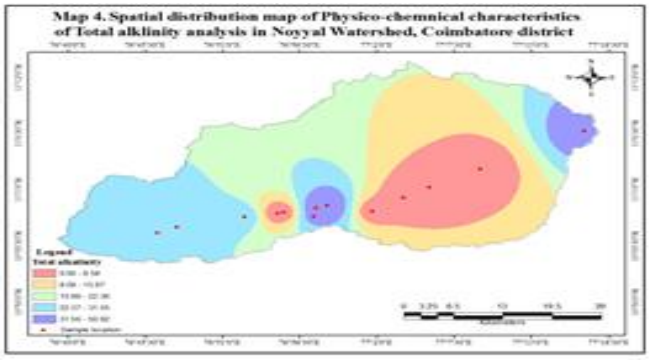
through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid includes clay, silt, finely divided inorganic and organic matter, algae, soluble coloured organic compounds, plankton and other microscopic organisms. The values obtained are in the range 0 to 2900 NTU. The values obtained are in the range 0 to 2900 NTU. As per ICMR standard value of Turbidity is 5. Vellalore and Ravathur areas show that higher turbidity. Remaining water samples are within the permissible limit as shown in Table 2. Spatial distribution of turbidity map is shown in Map 3.



Map 3. Spatial distribution map of turbidity analysis in Noyyal watershed

Total Alkalinity

Alkalinity value with less than 100mg/lt is desirable for domestic use. However, in large quantities imparts bitter taste to water. In the present investigation the total alkalinity of the water samples is found in the Range 0 to 51 mg/lt. The total alkalinity of the water samples is found in the Range 0 to 51 mg/lt. As per ICMR the standard value of Total alkalinity is 120. So the water samples are within the permissible limit. The spatial distribution of total alkalinity is shown in Map 4.

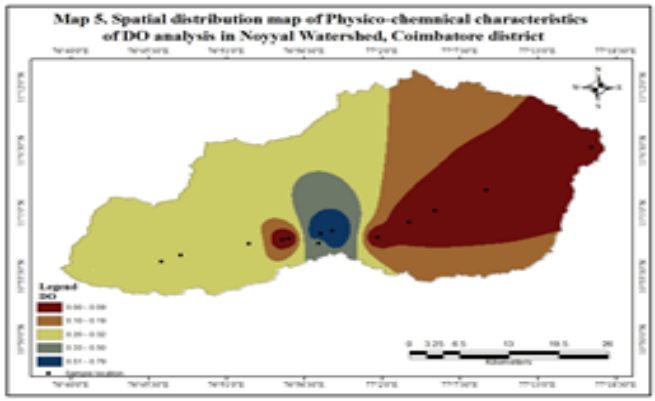


Map 4. Spatial distribution map of total alkalinity analysis in Noyyal watershed

Dissolved Oxygen (DO)

It is an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophs [19]. Oxygen can be rapidly removed from the waters by discharge of oxygen demanding wastes. The DO values obtained in the present study are within ICMR

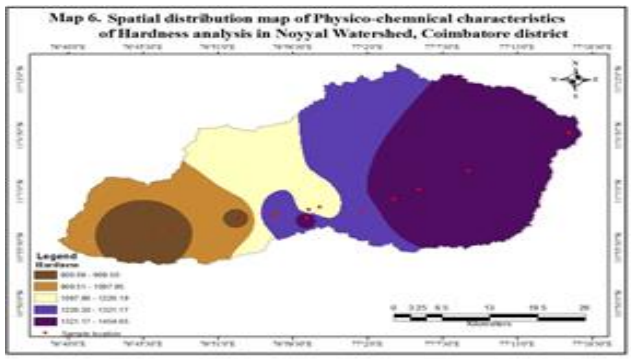
standards. The values obtained are in the range 0 to 0.8. The values obtained are in the range 0 to 0.8. The DO values obtained in the present study are within ICMR standards. The spatial distribution of dissolved oxygen is shown in Map 5.



Map 5. Spatial distribution map of dissolved oxygen analysis in Noyyal watershed

Total Hardness

Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing cat ions are calcium, magnesium bicarbonate, carbonate, chloride and sulphates. The hardness values of the present study were found to range between 800 to 1450 mg/lit. Total hardness was studied in Noyyal River basin by [18]. The result demonstrated that only one sample was available within the tolerance limit and 60% of samples exceeded maximum permissible limit As per ICMR the standard value of Total hardness is 300.So the study area shows higher value of total hardness. The spatial distribution of total hardness is shown in Map 6.

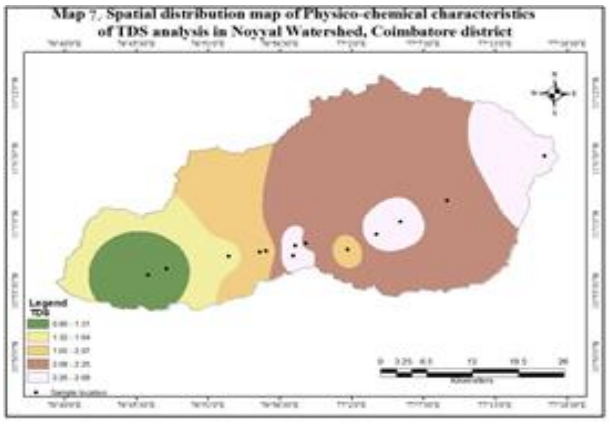


Map 6. Spatial distribution map of total hardness analysis in Noyyal watershed

Total Dissolve Solids

TDS values ranged within 1-1.6mg/lt. as per standards and in this respect this water is suitable for drinking purposes. The WQI values of the present investigation (Table 4) from different sampling stations are calculated as per the procedure described earlier. However the WQI values (50.20 to 753.32) calculated for the different samples indicate that the water is unfit for drinking. Among the 14 sampling sites, The WQI of Perur is 50.20, that indicating poor water quality. TDS values ranged within 1-1.6mg/lt. as per standards and in this respect this water is suitable for drinking purposes. The

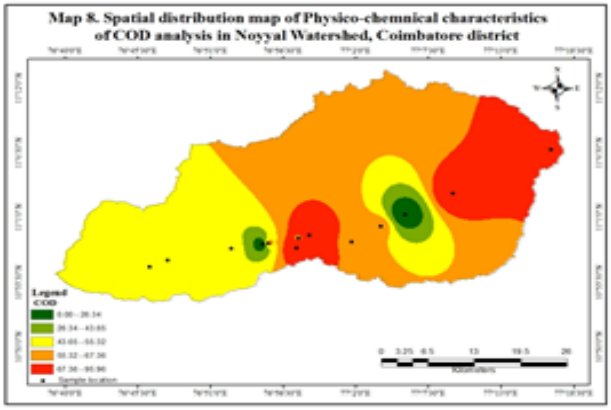
spatial distribution of total dissolved solids is shown in map 7.



Map 7. Spatial distribution map of total dissolved solids analysis in Noyyal watershed

Chemical oxygen demand

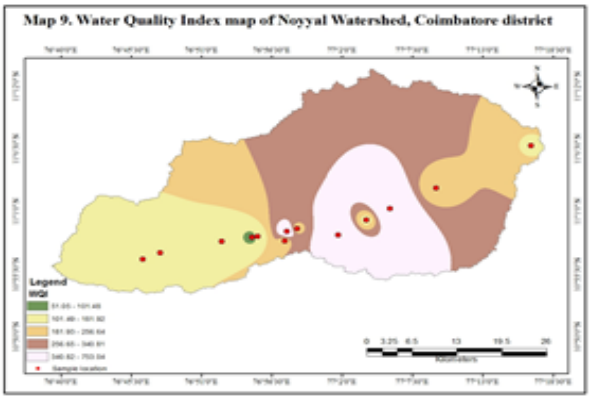
Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. The COD values of the present study were found to range between 0-96 mg/lit. The COD values of the present study were found in the range between 0-96 mg/lit. As per ICMR the standard value of COD is 10 mg/lit.So the COD value of the study area is in the permissible limit. The spatial distribution of chemical oxygen demand is shown in Map 8.



Map 8. Spatial distribution map of COD analysis in Noyyal watershed

Water quality index

The WQI values (50.20 to 753.32) calculated for the different samples indicate that the water is unfit for drinking. Among the 13 sampling sites, The WQI of Perur is 50.20, that indicating poor water quality. Remaining sample locations have the WQI greater than 100, which indicate that the water is unsuitable for drinking. Only Perur shows WQI 50.20 that indicating poor water quality. The spatial distribution of WQI of the study area is shown in Map 9.



Map 9. Spatial distribution map of Water quality Index in Noyyal watershed

4. CONCLUSION

The WQI value of the Noyyal River is not suitable for domestic and agricultural purposes as per drinking water standards of Bureau of Indian Standards and WHO guidelines. Regular monitoring of river and taking suitable remedial measures like collection of domestic sewage and setting up the common treatment plant before discharge of sewage in to river system is required. This will control pollution and prevent the depletion of the quality of Noyyal River water. It can be concluded that geostatistical interpolation method performs better than deterministic interpolation methods for mapping of water quality.

CONFLICTS OF INTEREST

None

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