Surface Water Quality Assessment, Prediction & Modelling of River Daya in Odisha

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Abstract

A decision tree-based approach is projected to predict surface water quality and is a good tool to assess quality and guarantee property safe use of water for drinking. The most objective of this study is to assess the surface water quality of the Daya watercourse to work out the quality of drinking functions. Samples were collected from designated locations throughout totally different seasons (winter, summer, rainy) over a amount of five years (2016, 2017, 2018, 2019, and 2020). Total dissolved solids, pH, alkalinity, chloride, nitrate, total hardness, calcium, magnesium, iron, fluoride, were all tested as well as total coliform, fecal coliform, and E. coli. The main goal is to use decision tree regression to construct a model to assess and predict water quality changes in the Daya geographic region of Odisha, India, and compare it to statistical methods.

I. Introduction

Water is the prime component accountable for life on earth. The six billion people on the planet use over a third of the world's total available renewing water. However, billions of individuals square measure empty basic water convenience. Among alternative countries within the world, the Republic of India is one of the few selected countries that invests moderately smart land as a water resource. The Republic of India could be a country with Brobdingnagian geographic, biological and climatic diversity. The average annual precipitation together with precipitation is approx. 4000 billion blocky meters (BCM) over the country. Annual water resources in various stream basins are estimated to be 1869 BCM, of which 1086 BCM is usable, with 690 BCM of surface water and 396 BCM of ground water. The remaining water is lost in a variety of ways, including evaporation, waste, and evaporation.

In India the surface water of flows through 14 major river basin. Additionally there are 55 minor and 44 medium watercourse basins. These rivers square measure quick flowing and square measure principally monsoon fed. With the increase in the population and improved living standards, as well as the spatial and temporal variations in precipitation, the demand for water resources and H₂O in sensible areas. Consequently, the per capita convenience of water is reducing daily. When compared to groundwater resources, however, the country's surface water resources have a far larger volume. Climate change influences precipitation, which has an impact on the amount of water available. Increased numbers from both point and nonpoint sources, on the other hand, have an impact on the quality of surface water. Since the majority of the country's rivers do not appear to be perennial, groundwater is the only thing that keeps the populace afloat during the dry months. In these watercourse systems, there is a huge difference in the amount and quality of discharge from one place to the next. With a few exceptions, all medium and minor watercourse basins begin in the highlands and contain fast-flowing, monsoon-fed streams within the cragged regions. Even by time they reach the plains, they are still mostly conveyed as periodic event streams. Due to the sheer seasonal flow characteristics of such rivers, treated or untreated outflows from certain resources would find their way into rivers that oscillate like an apparatus. As during monsoon season, when rain falls into a watercourse, the discharge of pollutants, as well as the rate and depth of flow, fluctuate according to the tides within the periodic event reaches. Because storm water goes

downstream, the time it takes for pollutants to be flushed out is significantly reduced. Several of the most major watercourse basins are also dried as during summer caused by a lack of water to dilute waste water dumped into them.

REVIEW OF LITERATURE

- Water is the catalyst for all biological reaction and maintaining life requires a comprehensive solution suggested by *Dugan et al.* [1972]
- *Pani et al.* [1986], in his study, realized that water supply demands have risen dramatically as a result of expanding industry on the one hand and exploding populations on the other. Furthermore, sewage, industrial waste, and a wide spectrum of synthetic chemicals damage a significant portion of this restricted water quality.
- Water analysis for the different parameters of River Mahanadi carried out by Khare et al. [2010]
- According to *Venkatesharaju et al.* [2010], freshwater resources are essential for ecological development. Farming, trade, and survival of the human race all require it. Freshwater is among the most common chemicals in ecosystems.
- *Lohani et al.* [2011] demonstrated water quality standard monitoring through several physical and chemical parameters and health concern problems with related treatment strategies in the city of Bhubaneswar, Odisha.
- *Debaprakash et al.* [2018] evaluated quality of the water along on the Mahanadi River (from Hirakud to Delta) and discovered that harmful polluted water had an effect on public health, aquatic habitat equilibrium, and the state's economic development.
- As per Sipra Mallick et al. [2017], the pollution level increases due to industrial effluents and domestic sewage, which is a threat to human consumption.

li. Study Area

The Daya River Basin is the subject of the planned study project (Fig-1). Latitude 19.8833, longitude 85.5833 are the coordinates for the basin. At Saradeipur (near Badahati), in Orissa, India, the Daya River begins as a branch of the Kuakhai River. Below Golabai, it is joined by the Malguni stream, which runs through the Khurda and Puri districts before emptying into Chilika Lake in the northeastern portion. On the banks of the Daya River, 8 kilometres (5 miles) south of Bhubaneswar, lie the historically significant Dhauli hills. The hill is surrounded by a huge open space, with major Ashoka edicts carved into a rock mass near the summit road. The Kalinga War is thought to have occurred on Dhauli Hill. The 37 km long river is polluted through the Gangua Canal by the discharge of wastes from different industries and human wastes. More 12lakh population is dependent on the daya river.

lii. Methodology

The surface water quality of the river basin was assessed through systematic sampling during the different seasons (Winter, Summer, Rainy) over a five year period(2016, 2017,2018,2019,2020). The data was divided into three seasons: summer, rainy season, and winter season. The months of March, April, May, and June make up the summer season. July, August, and September are the rainy seasons. October, November, December, January, and February make up the winter season. Fourteen physiological and biological water quality parameters were selected for analysis. The parameters are alkalinity, chloride, nitrate, total hardness, calcium, magnesium, iron,pH, total dissolved solids, fluoride, total coliform, fecal coliform, and E. coli. In the present study, 13 parameters were considered, and the WQI and correlation coefficients along with water quality characteristics were calculated.

IV. Corellation Analysis

Correlation may be a term that refers to the strength of a linear relationship between 2 variables. A robustness of high correlation implies that 2 of many variables have a robust relationship with one another, whereas a weak or low correlation implies that the variables are hardly connected. It's primarily used to investigate the link between two sets of statistical evidence. The most widely used type of correlation coefficient is Pearson's r. Auguste Bravais derived and published the mathematical formula in 1844 for a similar theory was proposed by Francis Galton in the 1880s, about which Karl Pearson improved it. Stigler's Law can thus be seen in the coefficient's name. Pearson's correlation is computed by multiplying two variables' variances by their standard deviations. The name's modifier product-moment comes from the structure of the definition, which contains a "product moment," which is the mean (the origin's mean) of the merchandise of the mean-adjusted stochastic processes. This metric determines if two variables are tightly related, that is, whether one rises as the other rises, or whether one falls as the other rises, or whether the correlation is completely unrelated.

DECISSION TREE-

A decision tree classifier has a simple structure that can be kept in a relatively small space and efficiently classifies incoming data. It can reduce complexity and select characteristics automatically, and its tree structure provides data on the classification's capacity to predict or generalize. Multistage decisions work on the premise of breaking down a big decision into a series of smaller ones. Period or stratified classifiers can be effectively implemented using classification trees.

Table 1: Summary of Descriptive Statistics for Water Quality Parameters

Statics for Summer Season

WQPs	Minimum	Maximum	Mean	STD	Variance
TDS (mg/l)	82.00	102.00	91.27	5.37	28.79
Ph	6.50	6.80	6.67	0.01	0.00
Total Alkalinity(mg/l)	36.00	41.00	14.00	4.20	11.00
Total Hardness(mg/l)	41.00	14.00	4.20	11.00	3.90
Calcium as Ca(mg/l)	14.00	4.20	11.00	3.90	1.00
Magnesium as Mg(mg/l)	4.20	7.50	5.65	0.71	0.51
Chloride as Cl(mg/l)	11.00	18.00	13.04	1.43	2.04
Sulphate as SO4(mg/l)	3.90	8.20	6.30	1.14	1.31
Nitrate as NO3(mg/l)	1.00	1.40	1.08	0.11	0.01
Total Iron as Fe(mg/l)	0.50	1.20	0.71	0.16	0.03
Fluoride as F(mg/l)	0.10	0.10	0.10	0.00	0.00
Total Coliform(MPN/100 ml)	17.00	31.00	25.22	3.04	9.27
Fecal Coliform(MPN/100 ml)	7.00	13.00	9.54	1.99	3.94

Statics for Winter Season

WQPs	Minimum	Maximum	Mean	STD	Variance
TDS (mg/l)	67.00	82.00	73.04	3.97	15.75
Ph	6.50	6.90	6.68	0.01	0.00
Total Alkalinity(mg/l)	28.00	33.00	14.00	4.00	10.00
Total Hardness(mg/l)	33.00	14.00	4.00	10.00	2.00
Calcium as Ca(mg/l)	14.00	4.00	10.00	2.00	1.00
Magnesium as Mg(mg/l)	4.00	8.00	6.08	1.11	1.24
Chloride as Cl(mg/l)	10.00	18.00	12.36	1.38	1.89
Sulphate as SO4(mg/l)	2.00	5.60	3.42	0.83	0.69
Nitrate as NO3(mg/l)	1.00	1.60	1.10	0.13	0.02
Total Iron as Fe(mg/l)	0.30	0.90	0.58	0.11	0.01
Fluoride as F(mg/l)	0.10	0.10	0.10	0.00	0.00
Total Coliform(MPN/100 ml)	17.00	31.00	21.99	2.77	7.65
Fecal Coliform(MPN/100 ml)	7.00	12.00	8.46	1.08	1.16

Statics for Rainy Season

WQPs	Minimum	Maximum	Mean	STD	Variance
TDS (mg/l)	98.00	127.00	113.87	7.67	58.76
pH	6.80	7.20	7.08	0.01	0.00
Total Alkalinity(mg/l)	28.00	48.00	17.00	6.10	10.00
Total Hardness(mg/l)	48.00	17.00	6.10	10.00	4.20
Calcium as Ca(mg/l)	17.00	6.10	10.00	4.20	1.00
Magnesium as Mg(mg/l)	6.10	8.50	7.16	0.54	0.29
Chloride as Cl(mg/l)	10.00	18.00	12.42	1.35	1.82
Sulphate as SO ₄ (mg/l)	4.20	8.30	6.28	1.11	1.23
Nitrate as NO ₃ (mg/l)	1.00	1.80	1.17	0.23	0.05
Total Iron as Fe(mg/l)	0.40	0.80	0.57	0.09	0.01
Fluoride as F(mg/l)	0.10	0.10	0.10	0.00	0.00
Total Coliform(MPN/100 ml)	19.00	32.00	23.87	3.25	10.59
Fecal Coliform(MPN/100 ml)	4.00	9.00	6.22	1.49	2.22

V. Results & Discussions

Statistics for the three season-based parameter values are shown in Table 1. The coefficient of correlation describes the relationship between two variables, indicating that one one predicts the opposite of the other. The constant is obtained by dividing the variance of the two variables by the merchandise of the variance of the two variables. The correlation coefficients (r) among multiple water quality measures of the surface water study space were calculated in winter, summer, and at other periods of the year, as well as the values of the correlation coefficients (r) are listed in the table.

Correlation Coefficient of Water Quality parameters in Summer Season-Table-2

	TDS (mg/l)	pH	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Calcium as Ca(mg/l)	Magnesium as Mg(mg/l)	Chloride as Cl(mg/l)	Sulphate as SO ₄ (mg/l)	Nitrate as NO ₃ (mg/l)	Total Iron as Fe(mg/l)	Fluoride as F(mg/l)	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)
TDS (mg/l)	1.000												
pH	0.014	1.000											
Total Alkalinity(mg/l)	-0.111	0.200	1.000										
Total Hardness(mg/l)	-0.059	0.141	0.815	1.000									
Calcium as Ca(mg/l)	0.012	0.015	-0.200	-0.018	1.000								
Magnesium as Mg(mg/l)	0.007	0.031	-0.107	0.003	0.768	1.000							
Chloride as Cl(mg/l)	0.059	0.111	0.127	0.203	0.258	0.092	1.000						
Sulphate as SO ₄ (mg/l)	0.126	-0.020	0.345	0.363	-0.133	-0.154	0.071	1.000					
Nitrate as NO ₃ (mg/l)	-0.055	0.193	-0.090	-0.105	-0.029	-0.082	0.003	-0.201	1.000				
Total Iron as Fe(mg/l)	-0.140	-0.167	0.075	0.118	0.164	0.121	0.011	-0.039	-0.111	1.000			
Fluoride as F(mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Total Coliform(MPN/100ml)	-0.015	-0.012	-0.103	0.041	-0.109	0.002	-0.053	-0.016	-0.063	0.181	0.000	1.000	
Fecal Coliform(MPN/100ml)	-0.043	-0.376	-0.026	0.001	-0.318	-0.077	-0.301	0.153	-0.152	-0.098	0.000	0.389	1.000

The statistical results shown in Table 2 (summer season) indicated that

- Sulphate and TDS has strong positive correlation with each other.
- Total hardness and alkalinity have a high positive association with pH.
- Total alkalinity and total hardness have a significantly positive correlation.
- Sulfate has a high positive association with total hardness.
- Calcium and magnesium possess a strong affirmative association, and magnesium and sulphate have a strong positive link.
- Total coliform shows a negative connection with chloride.
- Sulphate and nitrate have negative effects on nitrate and fecal coliform, respectively.
- Total iron has a high positive correlation with total coliform and a substantial negative correlation with fecal coliform.
- Total coliform and fecal coliform have a high positive connection.

Correlation Coefficient of Water Quality parameters in Winter Season Table-3

	TDS (mg/l)	pH	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Calcium as Ca(mg/l)	Magnesium as Mg(mg/l)	Chloride as Cl(mg/l)	Sulphate as SO ₄ (mg/l)	Nitrate as NO ₃ (mg/l)	Total Iron as Fe(mg/l)	Fluoride as F(mg/l)	Total Coliform(MPN/100 ml)	Fecal Coliform(MPN/100 ml)
TDS (mg/l)	1.000												
pH	0.065	1.000											
Total Alkalinity(mg/l)	0.455	-0.007	1.000										
Total Hardness(mg/l)	0.377	-0.015	0.647	1.000									
Calcium as Ca(mg/l)	0.289	0.091	0.510	0.823	1.000								
Magnesium as Mg(mg/l)	0.036	-0.154	0.022	0.304	0.137	1.000							
Chloride as Cl(mg/l)	-0.035	-0.124	-0.206	0.189	0.150	-0.013	1.000						
Sulphate as SO ₄ (mg/l)	0.217	0.134	0.282	0.410	0.345	0.114	0.469	1.000					
Nitrate as NO ₃ (mg/l)	0.071	0.078	0.037	-0.007	-0.058	0.069	-0.023	0.225	1.000				
Total Iron as Fe(mg/l)	-0.160	0.082	-0.221	-0.028	-0.120	-0.083	0.143	-0.020	0.222	1.000			
Fluoride as F(mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Total Coliform(MPN/100ml)	-0.306	0.383	-0.313	-0.162	0.036	-0.195	0.021	-0.015	0.051	0.086	0.000	1.000	
Fecal Coliform(MPN/100ml)	-0.191	-0.165	-0.186	-0.063	0.059	-0.123	0.211	0.140	0.157	0.159	0.000	0.330	1.000

The statistical results shown in Table 3 (winter season) indicated that

- Total Alkalinity and TDS have a strong positive relationship.
- Total coliform has a strong positive connection with pH.
- Total alkalinity and total hardness have a strong positive relationship.
- Total hardness and calcium have a strong positive relationship.
- Sulfate has a high positive association with magnesium and chloride.
- Sulfate and nitrate have a positive association, while nitrate and total iron have a good association.
- Fecal coliform was favorably linked with total iron and total coliform.

Correlation Coefficient of Water Quality parameters Rainy Season Table-4

	TDS (mg/l)	pH	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Calcium as Ca(mg/l)	Magnesium as Mg(mg/l)	Chloride as Cl(mg/l)	Sulphate as SO ₄ (mg/l)	Nitrate as NO ₃ (mg/l)	Total Iron as Fe(mg/l)	Fluoride as F(mg/l)	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)
TDS (mg/l)	1.000												
pH	0.169	1.000											
Total Alkalinity(mg/l)	-0.184	0.106	1.000										
Total Hardness(mg/l)	0.204	0.016	0.201	1.000									
Calcium as Ca(mg/l)	-0.153	-0.072	0.119	0.356	1.000								
Magnesium as Mg(mg/l)	-0.204	-0.251	0.257	0.426	0.629	1.000							
Chloride as Cl(mg/l)	0.135	0.036	-0.241	0.041	-0.019	0.007	1.000						
Sulphate as SO ₄ (mg/l)	0.052	0.086	0.113	-0.034	-0.076	0.045	0.002	1.000					
Nitrate as NO ₃ (mg/l)	0.076	-0.108	-0.038	0.187	0.187	-0.055	-0.166	-0.064	1.000				
Total Iron as Fe(mg/l)	0.059	-0.255	-0.071	-0.010	-0.070	-0.158	-0.134	-0.137	0.055	1.000			
Fluoride as F(mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Total Coliform(MPN/100ml)	-0.106	-0.112	-0.090	0.036	-0.137	0.216	0.187	0.122	-0.058	-0.056	0.000	1.000	
Fecal Coliform(MPN/100ml)	-0.272	-0.481	0.170	0.067	0.115	0.278	0.137	-0.209	-0.034	-0.008	0.000	0.197	1.000

The statistical results shown in Table 4 (rainy season) indicated that

- TDS and chloride have a significant relationship.
- Total alkalinity and pH are inversely proportional.
- Magnesium has a significant positive relationship with total alkalinity, total hardness, and calcium.
- Total coliform is strongly correlated with chloride and sulphate levels.
- Total iron and nitrate have a positive relationship.
- Total iron and total and faecal coliform have a negative connection.
- Fecal coliform and total coliform are strongly associated.

Comparison of Water Quality parameters –Alkalinity for all the seasons

Comparison of Water Quality parameters –TDS for all seasons

Comparison of Water Quality parameters –Hardness for all seasons

The fig-2, 3,4 defines the seasonal variations of parameter like Alkalinity, TDS & Hardness with respect to days of all season. There is a variation in season wise which can be noted from the figs.

Prediction with Decision tree regression models-

Flow diagram (Fig-5) is a decision tree for the numerical variable 'TDS'. Regression is done when multiple variables are correlated with the target variable and they all are numerical. Regression analysis based on a method helps us find out which variables have an impact on the target variable and to what degree.

Decision tree was chosen as a method for 2 reasons:

I. TDS came out to be the most significant and instrumental variable indirectly contributing to water quality. All the other variables (pH, Total hardness, and total alkalinity) had high correlations with TDS.

II. All variables (except for E.coli presence) were numerical variables.

It handles large volumes of data well, and it is precise for any number of variables with varying correlation with the target variable.

From the TDS decision tree regression analysis, TDS is a significant variable for the river bed pollution. It can be varied by controlling the other variables-pH, Total hardness and Iron content. By decreasing the pH towards acidic, we can improve the water quality. based on correlation data, it will choose a variable from the data with highest correlation with the DV, here it is pH. It will take an average value of the DV and divide the pH data into 2 groups (branches) with higher than avg., other lower than/equal to avg. Here, that value is 6.85

Here, the 1st category i.e TDS(cutoff) is 100 mg/L, and the 2nd cutoff is 120 mg/L. And in the bottom, it gives the regression analysis prediction results with different variables. For instance (refer to the last but one column), for pH value ≤ 6.65 , the model predicts TDS value to be = 95.50 and it too $n=267$ (degree of freedom) i.e., it made that prediction after taking 267 parameters (coefficients). Hence, it's a pretty fit prediction.

Fig-6 defines the regression path. Here pH is highly correlated so chosen 1st. This model evaluation is like this-

Mean Absolute error: 4.413

Mean Square error: 32.54

R^2 : 0.819

Features ranked on their importance:

pH 0.8599379611801762 #most important

Total_hardness 0.0310171529289313

Total_coliform 0.027485875769070467

Total_alkalinity 0.023753893552309755

SO4 0.015083898956899688

Ca 0.011245407054822432

Fe 0.009271138163701278

Cl 0.008072309189455193

Mg 0.007090445377883532

fecal_coliform 0.00672509448095333

NO3 0.00031682334579684053

Vi. Conclusion

In this study, a powerful, easy and applicable call tree methodology was developed for the classification of surface water quality. These regression model predictions are exploitation R^2 scores (higher the better) and MAE (less the better). The variance score is the equivalent of the accuracy score for regression models. Variance score: 0.8076 for the model (closer to one the better). Therefore, accuracy score would be 80.76%. It will be a more indicative tool for humans since water contamination is an older website daily. The following are the most suggestions/recommendations to address water shortages/crises.

1. Water is often quite safe once boiling, whereas developing the correct angle toward the sanitary atmosphere is tedious.
2. If the degree of pollution is significant, the user should demand proper chlorination; nevertheless, this procedure requires the expertise of a trained chemist, as additional chlorination is hazardous to human health.
3. Economical system for trash collection and disposal outside town areas.
4. Sewerage waste treatment.
5. Usage of waste into helpful merchandise, like fertilizers.
6. Education of individuals through media regarding the protection of atmosphere.

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Figures

Figure 1

Figure 2

Alkalinity Variations with respect to days

Figure 3

TDS Variations with respect to days

Figure 4

Hardness Variations with respect to days

Figure 5

Flow diagram of TDS regression

Figure 6

Flow diagram of the regression path of each variable.