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Water quality monitoring using soft computing techniques in Udupi Region, Karnataka, India

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ABSTRACT

A monitoring of water quality index parameters using soft computing technology is the current research focus as the main challenge of which is to design a soft computing algorithm with the highest accuracy and less computation time. For the secondary dataset obtained by the government database, this research proposes a water quality prediction and classification method based on decision tree algorithm. The comparative analysis is made for the different highest accuracy algorithms like decision tree algorithm with support vector machine (SVM), k-nearest neighbour (KNN) classifier, linear discriminant analysis, Naïve Bayes classifier and logistic regression. Decision tree algorithm had the highest accuracy compared to other algorithms. The KNN algorithm used as clustering algorithm to plot the two classes good and bad. The trend analysis of the water quality is performed with various water quality parameters like pH, fluoride and total dissolved solids (TDS) test results are plotted and observed for the variations of the values with respect to increase in time. The performance is measured with statistical indices and the prediction accuracy of 0.99 and mean squared error of 0.05. The results prove that the KNN algorithm found to be better for clustering purposes.

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1. INTRODUCTION

The availability of pure and sufficient drinking water is the primary need of every human being. In this research work the southern part of India, Karnataka state is considered as study area. In Karnataka, with an increase in population, the quality of consumable water is degrading every day. Along with this, the consumption rate is increasing due to agricultural, industrial needs and other requirements [1], [2]. Scientists test the water quality by traditional water quality monitoring methods involving water sample collection, testing and finally investigation, which is done manually [3], [4]. This traditional approach is not fully reliable, and cost incurred is more and the requirement for manpower is a recurring process. Nowadays soft computing is a trending technology to predict water quality and various studies are carried out in predicting the concentration of various water parameters which helps in timely improving the water quality [5], [6]. Machine learning, when integrated with hardware systems consisting of sensors (such as pH, turbidity, temperature) and combined with the internet of things (IoT), can be used to design a real-time system to monitor the water quality of tanks installed in houses, hospitals, colleges, ponds, rivers [7], [8]. Water is the lifeline of all the living beings in this direction monitoring the water quality of water tanks installed in houses/hospitals/colleges, ponds, rivers are very important [9], [10]. Here in this research work we are not focusing on the hardware implementation but rather only on the machine learning part of implementation.

Due to rapid increase in pollution, population and global warming the amount of clean drinking water is reducing every day [11], [12]. Therefore, there is a need for better methodologies for real-time water quality monitoring [13]. The central pollution control board (CPCB), in collaboration with the Karnataka State pollution control board (KSPCB), is implementing the national water monitoring program (NWMP) across 63 monitoring stations in the state [14], [15].

Chungyalpa [16] and Ravikumar *et al.* [17] investigated the assessment of water quality index (WQI) in the surface water of tank and lake water from Bangalore, Karnataka. They considered three sampling locations with a study period of 3 months during pre-monsoon season. They investigated a total of 14 parameters for physiochemical parameters. The study proves that the sodium adsorption ratio (SAR) values indicate that both the water bodies belong to the excellent class and are suitable for irrigation. There is a lot of research in surface water but limited research in groundwater quality. Giao *et al.* [18] discussed groundwater quality in the Mekong Delta of Vietnam using multivariate statistical method. They investigated a total of 8 water quality parameters from 64 sampling points. The results prove mixed results on groundwater quality and infer that the quality of groundwater depends on geological locations. Madrid and Zayas [19] investigated the issues related to monitoring practices on sampling in present scenarios. This work summarizes the points that need to be considered before sampling for chemical monitoring. Ahmed *et al.* [20] discuss issues and state-of-the-art technologies to address water quality. This work focusses on the advantages of modern technologies to monitor and assess water quality. They inferred that the latest technologies are an effective alternative to expensive laborious manual analysis. However, the traditional method of water quality monitoring is not feasible as the results are not so accurate and it is a time-consuming process to determine the water quality [21], [22]. Nayak *et al.* [23] explored the use of an electronic nose system integrated with an embedded peripheral interface controller (PIC) microcontroller to detect and quantify microbial contaminants. They analyzed assessment of water quality by detecting microbial water quality using experimental setup as well as embedded systems. The eNose system was found to be effective in detecting and accurately qualifying the microbial contaminants, specifically coliform group of bacteria.

Nowadays researchers are carrying out new inventions for determining water quality. In the engineering field much research is going on in the soft computing field. Due to machine learning engineers can design devices which communicate among themselves and accordingly analyse the data intelligently to produce the water quality. This paper mainly focuses on the best suitable method for computing the water quality of the water bodies available for drinking purposes. The proposed method deals with soft computing techniques applied to various water parameters to check for drinking water consumption purposes like pH, turbidity, temperature, and dissolved oxygen.

2. METHOD

2.1. Study area

Situated along the Arabian Sea coastline in Karnataka, Udupi district forms part of the western margin of peninsular India and is topographically delineated from the interior by the prominent Western Ghats [24]. The district's river systems discharge into the Arabian Sea and are subject to tidal influence over considerable distances inland [25], [26]. Contemporary water management practices, notably sprinkler irrigation, are witnessing increased adoption in this region. The geographical location of Udupi district is depicted in Figure 1.

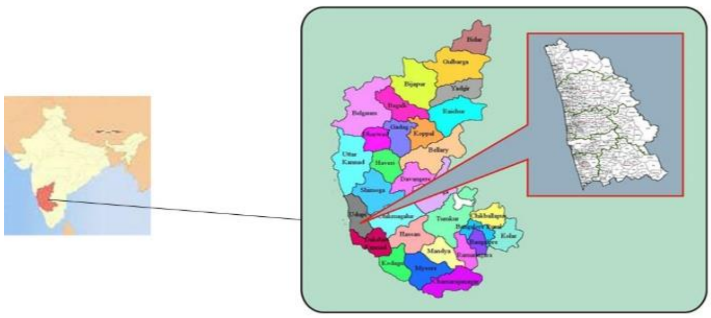

Figure 1. Location map coastal area of Karnataka, Udupi

The original WQI dataset was obtained from National Rural Drinking Water Programme (NRDWP) Udupi District Karnataka which conducts regular monitoring of the quality of the rivers in Udupi, Karkala, Kondapur, Bhatkal taluks regularly. This dataset comprised of 5000 data points which is derived from measurements of 14 water quality parameters (fluoride, calcium, iron, total dissolved solids (TDS), nitrate, chloride, TH, pH, magnesium, sodium, potassium, sulphate, alkalinity, and turbidity). For this study, historical data from 2015-2017 were collected. The data were classified into two categories: class 0 (unfit for drinking) and class 1 (fit for drinking). Table 1 presents the water quality index of drinking water in India.

Table 1. Comparison of groundwater quality with drinking water standards, Indian and WHO [20]

Parameters	Indian standard	Percent compliance	WHO standard	Percent compliance
pH	6.5-8.5	98.5	7-8	91
TDS	500	70	1000	96.5
Total hardness as $Caco_3$, mg/l	300	70	100	0.5
Chloride mg/l	250	97	250	97
Sulphate mg/l	200	100	250	100
Nitrate mg/l	45	51.5	50	56.5
Fluoride mg/l	1	30	1	30
Calcium mg/l	75	96	75	96
Magnesium mg/l	30	26	30	26
Iron mg/l	0.3	0.5	0.1	0.5
Manganese	0.1	17	0.05	17

2.2. Materials and method

The machine learning algorithms support vector machines (SVM), classification decision tree, linear discriminant analysis, logistic regression, Naïve Bayes, (used for variable importance tasks, regression and classification), K-nearest neighbours (KNN) and k-means clustering (used for unsupervised-classification) are employed to develop the WQI prediction and classification model. In this study, we evaluated the performance of six algorithms using a water quality dataset comprising 5,000 samples. The flowchart of the proposed model is presented in Figure 2.

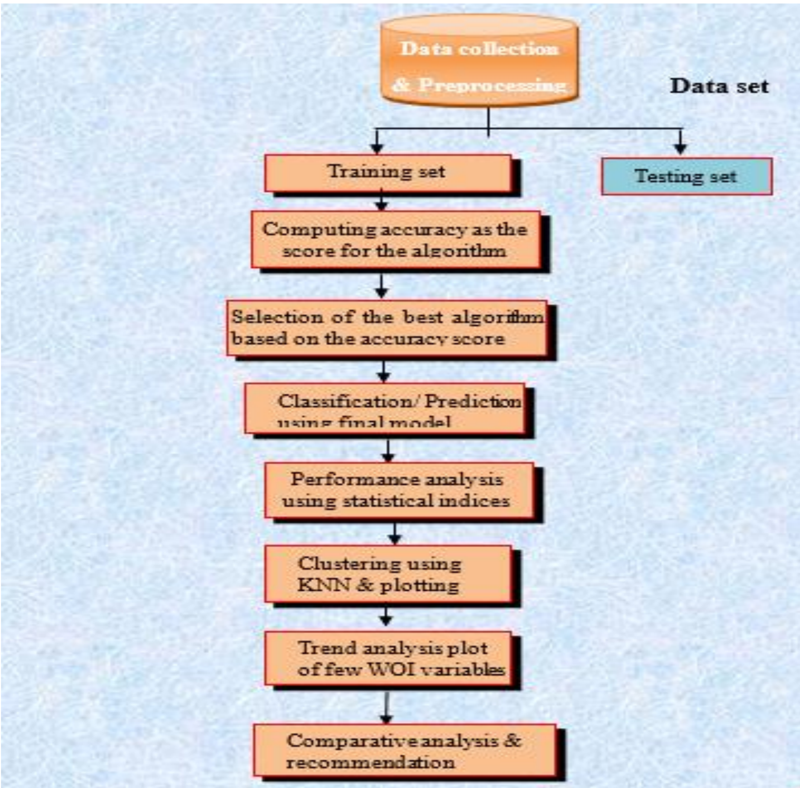

Figure 2. Flowchart of the proposed model

3. RESULTS AND DISCUSSION

The model performance was evaluated using statistical indices and prediction accuracy. Table 2 presents the overall mean and standard deviation with type accuracy scores. Figure 3 depicts the box-whisker plot of algorithm accuracy, highlighting the variance and mean values used to determine the best-fit model for the study. Figures 4 and 5, illustrates the distribution of 5,000 water samples through a box-whisker plot and histogram respectively, while Figure 6 shows the covariance plot of all 14 input water quality parameters along with the corresponding class type.

Table 2. Table of overall mean and standard deviation with scoring of type accuracy

Algorithm	Mean (accuracy)	Standard deviation (accuracy)
Logistic regression	0.994228	0.002884
Linear discriminant analysis (LDA)	0.991582	0.001319
KNN	0.968257	0.007843
Decision tree	0.995189	0.992427
Naïve Bayes	0.968505	0.031018
SVM	0.97908	0.010627

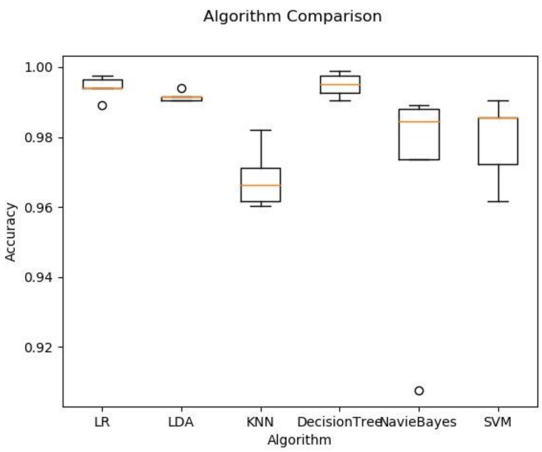

Figure 3. Algorithmic accuracy comparison

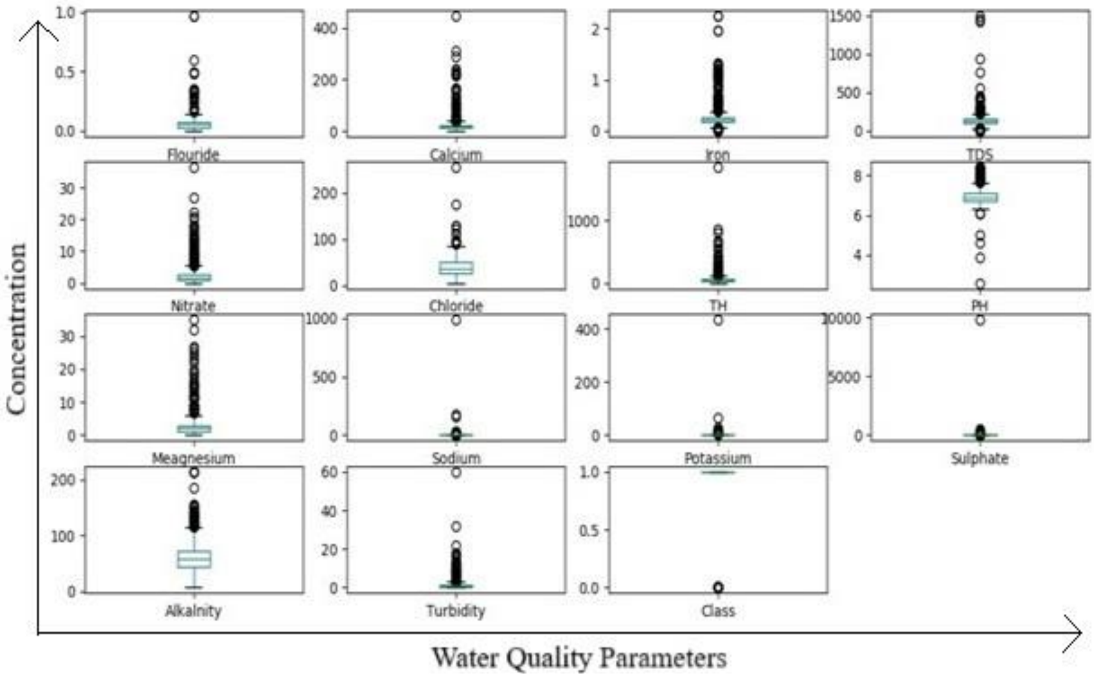

Figure 4. Dataset distribution plot: Box and Whisker plot

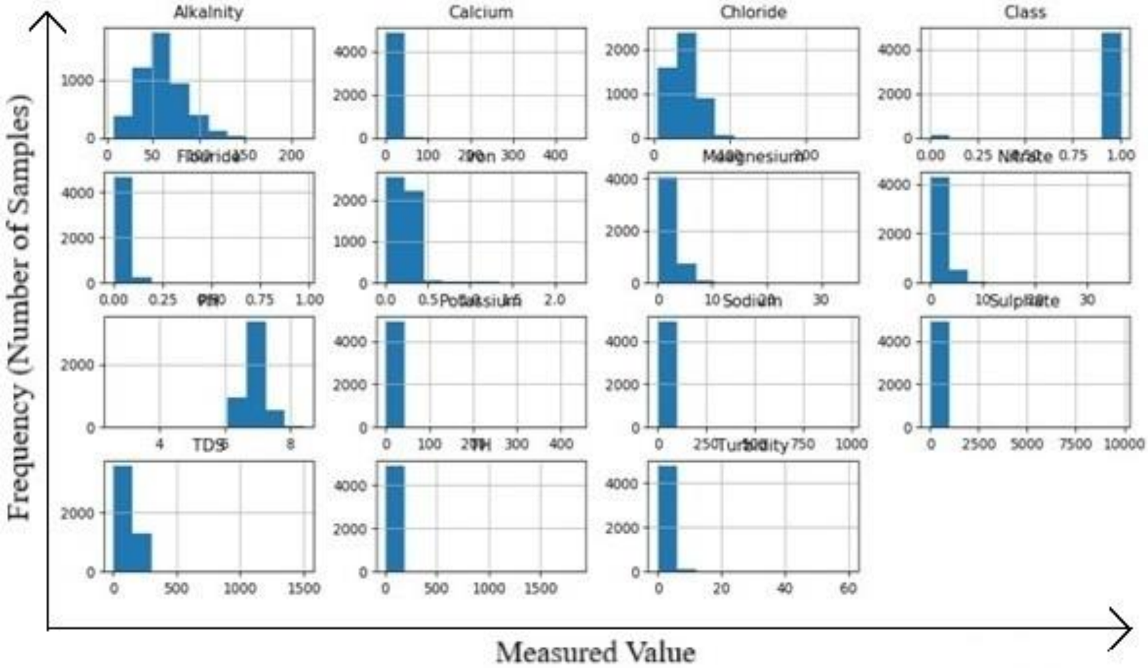

Figure 5. Data distribution plot: histogram plot

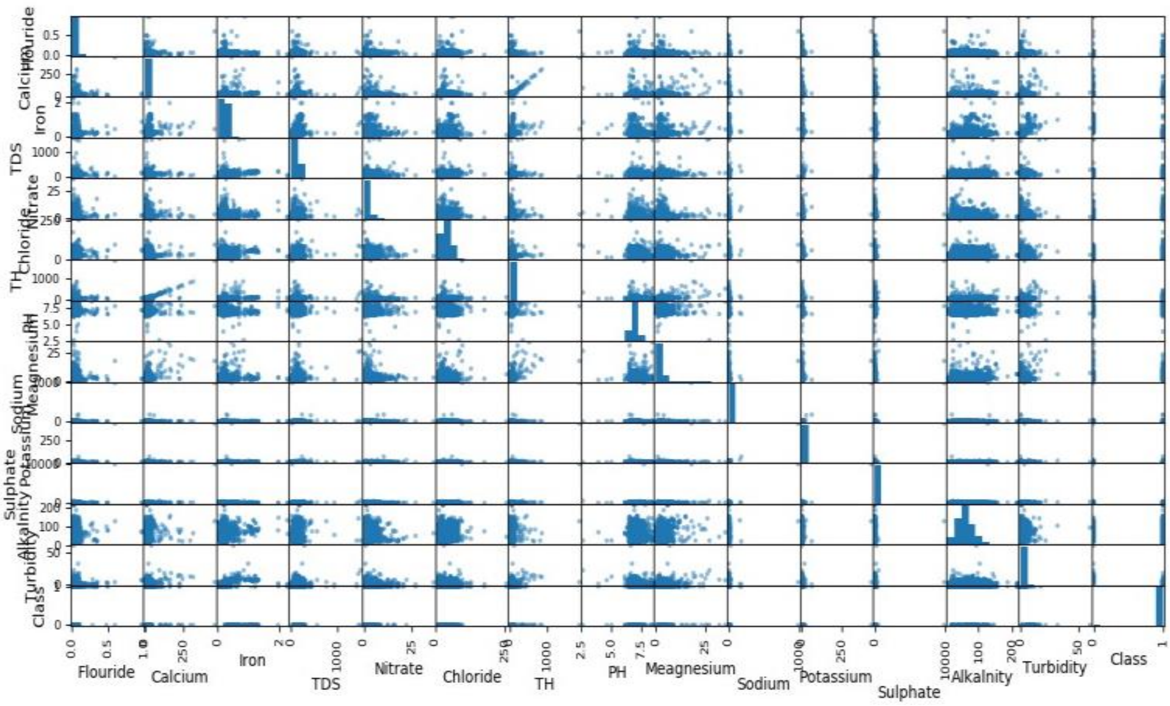

Figure 6. Covariance plot of data distribution

Among all the algorithms evaluated, the decision tree achieved the highest accuracy and was therefore selected for further analysis. The model attained a mean square error (MSE) of 0.05 and an accuracy of 0.9934895. The detailed classification report of the decision tree algorithm is presented in Table 3, while Figure 7 illustrates the trend analysis of the 14 water quality parameters from 2015 to 2018.

Table 3. Classification report of decision tree algorithm

Classification report	Precision	Recall	F1 score	Support
Class 0	0.86	0.8	0.83	15
Class 1	1	1	1	753
Micro Average	0.99	0.99	0.99	768
Macro average	0.93	0.9	0.91	768
Weighted average	0.99	0.99	0.99	768

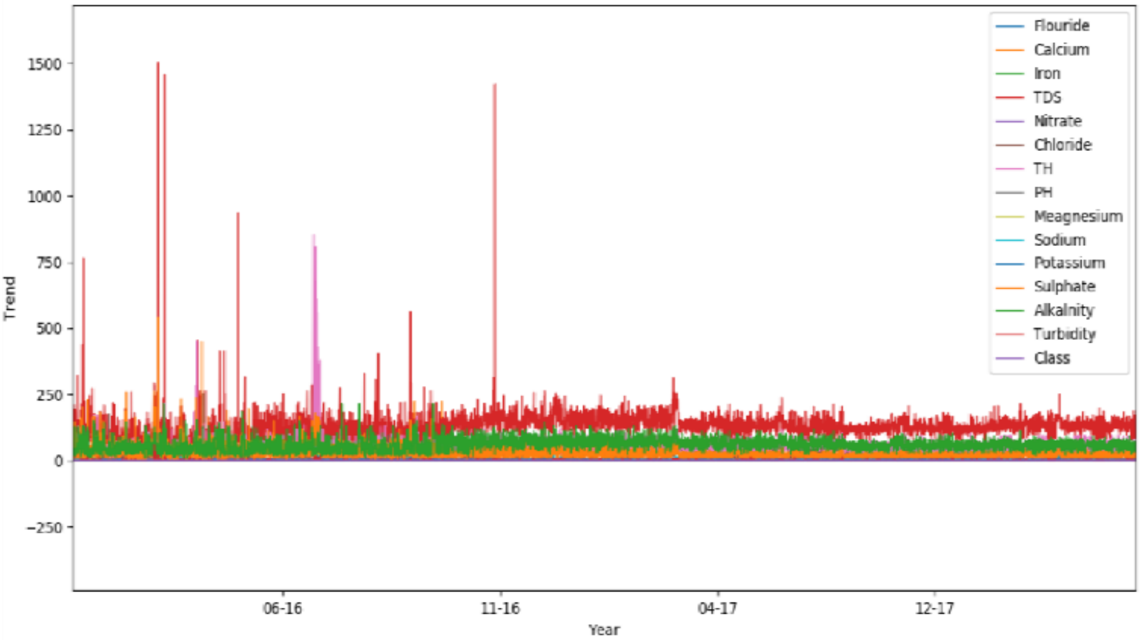

Figure 7. Trend analysis of water quality parameters

Figures 8 and 9 show the trend analysis of the class variable fluoride and TDS, pH respectively. The standard value of the fluoride, TDS should be around 500 ppm, and pH should be less than 1 and in between 6.5 to 8.5 respectively. Figure 8 shows the violin plot of the class, fluoride, and TDS, pH variable respectively.

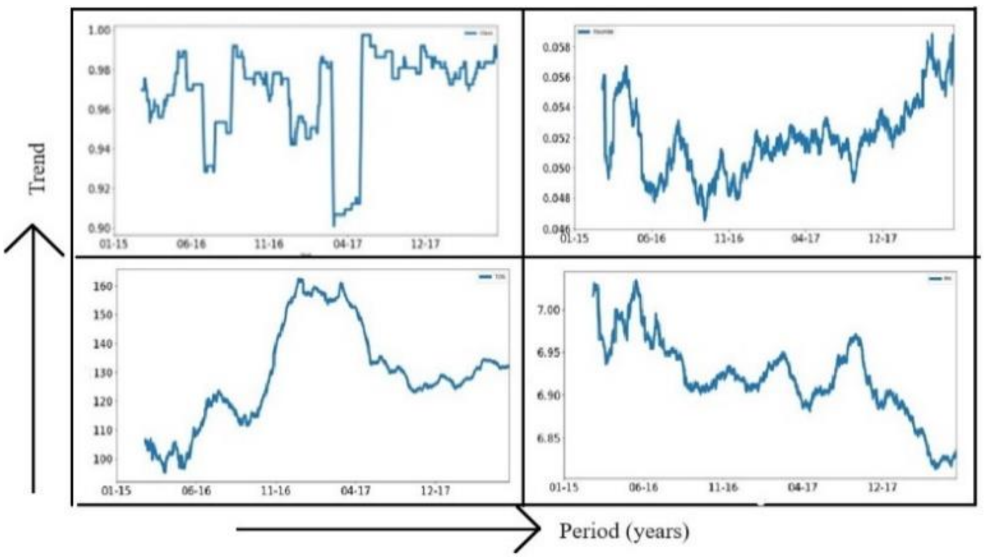

Figure 8. Plot of trend analysis, class variable and fluoride and TDS and pH

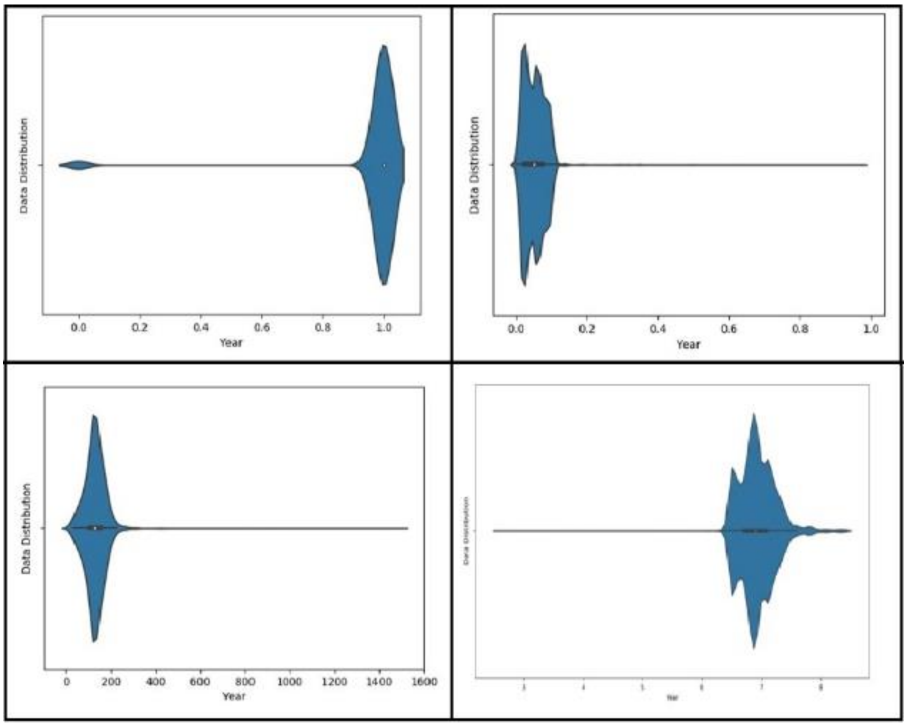

Figure 9. Violin plot, class variable and fluoride and TDS and pH

For clustering, which is also used as comparison algorithm, KNN is used. The overall MSE of 0.032 and accuracy of 0.974645 was achieved and the classification report of the decision tree algorithm is as shown in Table 4.

Table 4. Classification report of KNN algorithm

Classification report	Precision	Recall	F1 score	Support
Class 0	0.9	0.27	0.42	33
Class 1	0.98	1	0.99	953
Micro average	0.97	0.97	0.97	986
Macro average	0.94	0.64	0.7	986
Weighted average	0.97	0.97	0.97	986

4. CONCLUSION

In summary, using the historical data of the water quality of 5000 samples of 14 WQI parameters are trained and tested using different soft computing techniques like: decision tree algorithm with SVM, KNN classifier, linear discriminant analysis, Naïve Bayes classifier and logistic regression. All the algorithms are trained, and the accuracy of the algorithm is calculated. Out of all these decision tree algorithms had the highest accuracy and hence the study is further carried out with decision tree algorithms. The prediction accuracy (0.99) of this algorithm and MSE (0.05) is calculated which is found to be far better than other algorithms. Trend analysis of few important water parameters like pH, Fluoride and TDS is plotted which shows the variations of the values as time increases. KNN algorithm used as a clustering algorithm to plot the classes (good and bad). Also, the accuracy (0.97), and MSE (0.32) show its performance is poorer when compared to decision tree algorithm.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Sumukha K Nayak		✓				✓		✓	✓	✓	✓	✓		
Supreetha Balavalikar Shivaram	✓		✓	✓			✓			✓	✓		✓	✓

C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

Authors state that there is no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [Balavalikar Shivaram Supreetha], upon reasonable request.

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