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Water Quality Index Calculation of River Ganga using Decision Tree Algorithm

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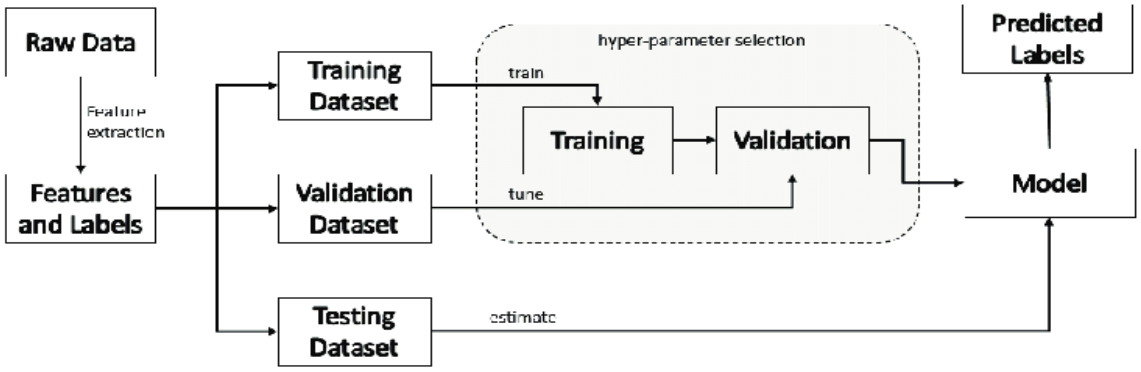
Abstract - *The Ganga is not only a pious river, but also a way of life for many citizens of India .It has cultural, spiritual as well as scientific importance. Our project research is based entirely on Machine Learning Application . Rapid urban sprawl, industrial development and high demand for water have caused major problems with water quality degradation and deterioration . Therefore, the aim of our project is to analyze the water quality of the Ganga River for three different seasons basically Summer, Monsoon and Winter to assess whether Ganga river water is potable or not. Rivers are under heavy degradation due to human activities such as dumping of waste, industrial activities, mining in the river, the water level of the river has dropped dramatically which has affected marine life and human health. The method we use in our research is to design a machine learning model based on ML algorithm which will calculate WQI and provide measurement of river water quality that will be used to determine whether the water is drinkable or not. It will be a python based WQI calculator.*

Key Words*: *Machine Learning, Decision Tree, WQI

1. INTRODUCTION

Ganga River is considered as the most prominent river of India .Using latest technologies like Machine Learning and Python Framework Flask , we are going to create a machine learning model which will predict the quality of the Ganga river water where the measuring parameters dataset is collected from the website of UCI Repository .Based on this collected data from different cities where Ganga riverbed is huge, the model will be trained and the prediction algorithm which will be most accurate and precise will be used.

1.1 Machine Learning (ML) is the study of computer science where algorithms can be used to make decisions on its own and decisions can be improved through learning and past experiences. It is one of the subsets of artificial intelligence. Machine learning algorithms build models based on training datasets or sample data to make predictions or decisions without being explicitly programmed. Now a days , Machine Learning can be seen in every field such as the health sector, finance sector, Aeronautical sector ,Agriculture ,email filtering, voice recognition, speech recognition, and computer vision, etc and it is quite not easy to develop traditional algorithms to perform the tasks which ML models can easily do . Machine learning uses data and learns from that data for better future predictions. Machine learning models can be improvised more by effective handling of training dataset so that no overfitting and underfitting comes into picture.



The three main types of machine learning tasks: supervised learning, unsupervised learning, and reinforcement learning.

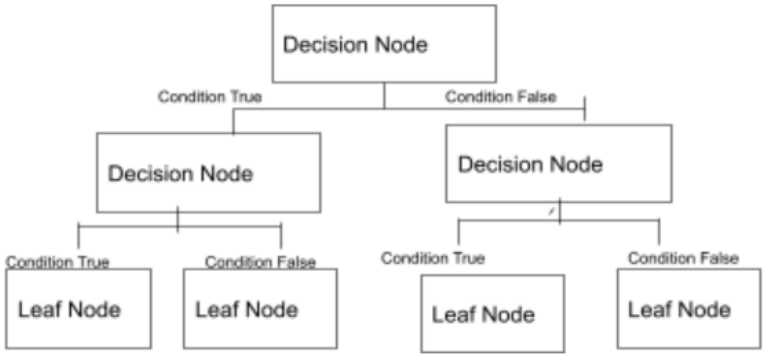
1.1.1 Supervised Learning, a set of examples (i.e. the training set) is submitted to the system as input during the training phase. Each input is labeled with the desired output value, so the system knows what the output will look like when the input comes in. For example, consider some experimental observations that can be grouped into N different categories. So we have a training set (a pair of sequences) {(x1,y1),(x2,y2).....(xn,yn)}, where xi is the input and yi is the class of the corresponding output. Training is performed by minimizing a specific cost function representing the bindings from the input xi and the desired output yi.

1.1.2 Unsupervised Learning provides training examples that are not labeled with the class to which they belong. Therefore, the system develops and organizes data, looking for common characteristics among them and making changes based on internal knowledge.

1.1.3 Reinforcement Learning is a machine learning training method based on rewarding desirable behaviors and or punishing unwanted behaviors. In general, reinforcement learning agents can recognize, interpret, take action, and learn through trial and error in their environment.

1.2 Machine Learning Algorithm (Decision Tree)

Decision Tree is a non-parametric supervised learning machine learning algorithm used for classification and regression. It is a tree structured classifier where internal nodes represent the features of the dataset, branches represent the decision rule and leaf nodes represent the outcome and do not contain further branches. The objective is to create a model that predicts the value of a target variable by learning a training dataset of decision rules taken from the data features. Decision Tree Classifier is a classification algorithm capable of performing multiple class classification on a dataset .As with other classifiers, Decision Tree Classifier takes as input two arrays: an array X, sparse or dense, of size n samples, n-features holding the training samples, and an array Y of integer values, size n-samples, holding the class labels for the training samples.



A decision tree is a one of the types of supervised machine learning algorithms where both input and output data are labeled. It can be used for both Categorical and Continuous Output . The dataset is continuously divided into sub trees based on some parameter and calculation measure until the final output is achieved. A Decision Tree can be explained by two entities, decision nodes and leaf nodes . Leaf nodes are decisions or end results where further division of nodes will not be possible .Decision nodes are the nodes where data is split and further sub -trees are generated.

Decision Tree Main Components :

- Root Node : The node from where the decision tree starts .It represents the entire dataset which further gets divided into two or more sets.
- Leaf Node: The leaf nodes are the final outputs and tree can not be segregated furthermore after getting the leaf node as it is the final output .
- Pruning : The process of removing unwanted branches from the tree to reduce complexity and ambiguity .
- Child Node: The segregated nodes are child nodes.

1.2.1 Algorithm for Decision Tree

Step 1 : Begin the tree with the root node which contains the complete dataset.

Step 2: The best attribute in the dataset using Attribute Selection Measure is selected.

Step 3: Divide the dataset into subsets that contain all possible values to achieve the best attribute.

Step 4 : The decision-tree-node which contains the best attribute is generated.

Step 5 : Recursively new decision trees are created using the subsets of the dataset created in step 3. This process is continued until the final stage is reached called leaf node when further segregation will not be possible.

There are two types of decision trees:-

Classification trees : The decision variable is 0 or 1 type or Yes/No called as Categorical Value.

Regression trees : The decision or the outcome variable is Continuous in nature , for example, a number like 187.

There are many algorithms by which Decision Trees can be constructed , but one of the best is called the ID3 Algorithm. ID3 Stands for Iterative Dichotomiser .

1.2.2 Entropy: Entropy, also known as Shannon Entropy is denoted by H(S) for a finite set S, which is the measure of the amount of uncertainty or randomness in the data. In the Machine Learning paradigm, entropy measures unpredictability and impurity, it is related to randomness in the information being processed in the machine learning project.

Entropy(S) = -(P(y)log_2 P(y)-P(n)log_2 P(n))

1.2.3 Information gain: Information gain is also called the Kullback-Leibler divergence, denoted IG(S,A) for a set S, which is the effective entropy change after selecting a certain attribute A. It measures the relative entropy change with respect to independent variables.

$$IG(S,A) = H(S) - H(S,A)$$

Information Gain= Entropy(S)-{(weighted average)* Entropy(Each feature)}

Alternatively ,

$$IG(S,A) = H(S) - \sum_{i=0}^{n} P(x) * H(x)$$

where IG(S, A) is the Information gain by implementing feature A, H(S) is the Entropy of the entire dataset, $\sum_{i=0}^{n} P(x) * H(X)$ is the Entropy after applying the feature A and P(x) is the probability of event x.

1.3. Iterative Dichotomiser ID3 Algorithm is a classification algorithm that follows the greedy approach of decision trees by selecting the optimal attributes that produce the maximum information gain (IG) or minimum entropy (H).

I(p,n) = entropy of a dataset

. = weighted summation of the logs of the probabilities of the each possible outcome

=-[(p/(p+n))log_2(p/(p+n)) + (n/(p+n))log_2(n/(p+n))]

ID3 procedure :

- Calculate the entropy of the dataset.
- For each attribute/feature.
- Calculate entropy for all its categorical values.

- Calculate information gain of the feature/attribute.
- Find the feature with maximum information gain.
- Choose the feature with maximum information gain as the root node for the tree.
- Repeat the above steps until the desired tree is obtained.

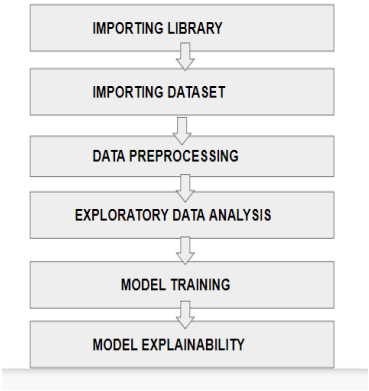
2. PROJECT OBJECTIVES

The objective of the machine learning project is to create a Water Quality Index (WQI) Calculator using python and Flask which will analyze the quality of Ganga river water and decide whether the water is safe for drinking by scaling the water in the score of (0-100).

3. IMPLEMENTATION & METHODOLOGY

3.1 Study Area: The present study was performed to study the surface water quality in the riverbed moving area of Ganga River at district namely; Varanasi, Kolkata, Jahangirpur, and Tribeni.

3.2 Sampling Procedure and Methods of Analysis: The physicochemical parameters used in this study are pH, Temperature, Total Dissolved Solid, Biological Oxygen Demand (BOD), Dissolved Oxygen , Turbidity, Nitrate, Phosphate and Fecal Coliform. We have combined data set of our study sites in three different seasons namely Summer, Monsoon and Winter for each of the districts. We have trained the combined data-set on the basis of machine learning algorithms and used Water Quality Index Calculation for Quality checking of water for different cities in different seasons and to check water is drinkable or not. The parameters which are finalized after pre-processing of the dataset are somehow interdependent on each other. The model will be trained on the basis of these nine physicochemical parameters which will be further used for calculation of Water Quality Index and deciding water is drinkable or not.



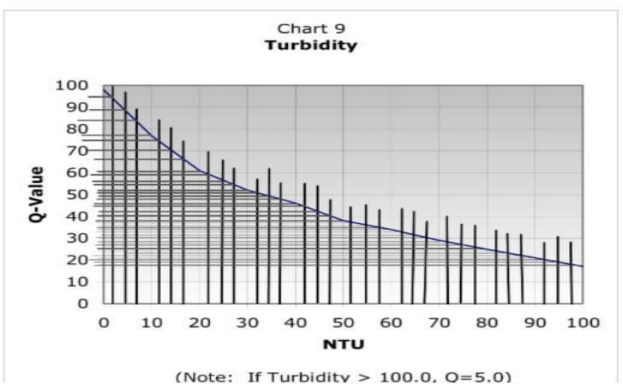
Flow of Model Creation

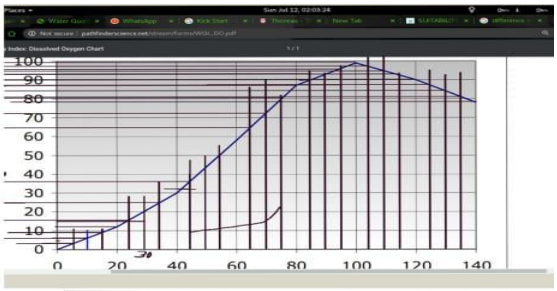
Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10	Column11	Column12	Column13
STUDY SITES	ES		Ph	Temp[C]	TDS	BOD	D.O.	Phos	Nitrate	Turbidity	fecal coliform	
Varanasi(Summer)			8.606519	31.102516	251.06278	69.390157	117.428165	1.72E-01	10.40525	25.349289	17.291851	
Varanasi(Monsoon)			7.901092	28.501417	163.695167	1	72.394007	1.50E-01	1.172739	187.187732	0	
Varanasi(Winter)			8.491275	20.264081	256.391651	4.04544	1.05E+02	1.40E-01	6.46837	12.622251	1.908191	
Kolkata(Summer)			7.634543	30.495379	141.717	73.186108	80.3227995	1.40E-01	6.463994	142.955594	30006.36267	
Kolkata(Winter)			7.761406	24.793024	161.431441	60.340382	76.6887022	1.72E-01	6.51207	92.4940131	28933.95133	
Jahangirpur(Monsoon)			8.108399	30.711971	137.951311	2.667603	95.2110955	1.50E-01	0.615716	22.094944	817.416667	
Jahangirpur(Winter)			8.555705	19.404757	179.808539	3.998461	93.6473165	1.40E-01	0.445903	30.675995	817.416667	
Tribeni(Winter)			8.599802	21.000916	183.944587	3.060917	101.359552	1.72E-01	0.368075	50.432606	6.706239	

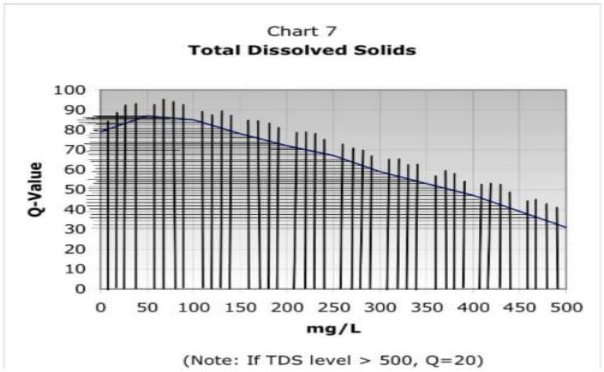
Table 1 : Table depicting mean values of parameters in Study Site

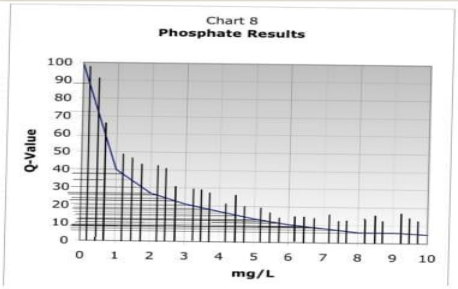
3.3 Graphical Representation of Water Quality Index Calculating Parameters

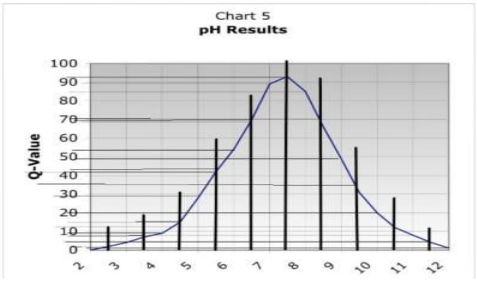
These graphical plotting of the nine parameters defines how the attributes are fluctuating in different seasons

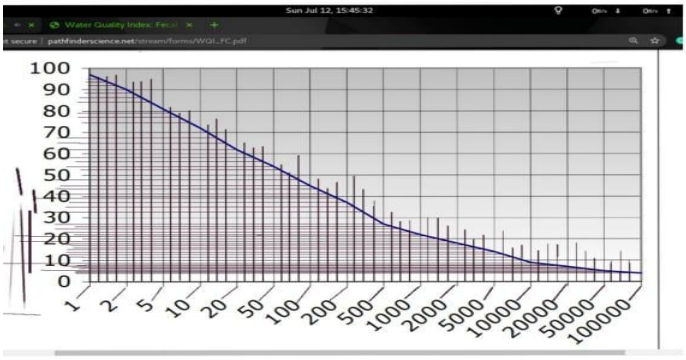


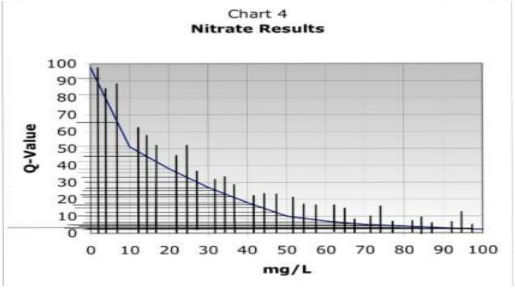












3.3.1 pH: pH is a scaling methodology which is used to determine the acidity or basicity of an aqueous solution. Low pH values denotes acidic character, while higher values denotes basic character of the solution. The pH scale is (0-14),where (0-7) denotes acidic character and (7-14) denotes basic character of the solution.The basic pH range for surface water is: (6.5 - 8.5) .pH is the crucial parameter associated with the other calculating parameters for WQI calculation. As pH can be easily affected by other chemicals in water, pH is necessary to be accurate for best results of the model. pH is calculated in logarithmic units of base 10 which means each number represents a 10-fold change in acidity or basicity depending on the pH value.

(pH = $-log_{10}$ (H +).

3.3.2 Temperature : The surface water temperature is usually between (0-30) degrees Celsius. The temperature is the water parameter which refers to how cold or warm the water is. In monitoring water quality and in field of science, temperature is basically measured in degrees Celsius. Water temperature affects almost every other water quality parameter. Temperature affects other water quality parameters to a great extent ,also can change the physical and chemical properties of water too. The varied seasonal temperature fluctuations may be due to changes in air temperature, solar angle, weather events, global warming and the amount of material associated with the stream and water features.

3.3.3 Total Dissolved Solid : TDS is a measure of the dissolved solvents found in an aqueous solution. In fact, this is anything that contaminates the purity of water. Some of these solvents can cause a large number of health problems.TDS is an indicator of water quality. Having a high TDS does not always mean that water is dangerous. For example, some mineral water has very high levels of solids inside and this does not seem to be dangerous, but that is because real solid materials are. This is usually Ca, Mg or other substances that may not be harmful to the body

300 mg/L : Excellent

(300 – 600)mg/L : Good

(600 – 900)mg/L : Fair

(900 – 1200)mg/L : Poor

Above 1200mg/L : Unacceptable

3.3.4 Biological Oxygen Demand : BOD is another prominent water quality calculation term. A water supply with a BOD level of 3-5 ppm can be considered as moderate, with a BOD level of 6-9 ppm water is considered contaminated because there is usually an organism present and germs decompose the waste. When BOD levels are100 ppm or more, the water supply is considered to be highly contaminated by organic waste. The need for biochemical oxygen or the amount of oxygen needed to decompose organic matter per one liter of polluted water. The more polluted the water, the more BOD will be because most of it will be organic matter and, as a result, more oxygen will need to decompose. It is therefore a reliable gauge for the pollution of large amounts of water. One of the main reasons for treating contaminated water before it is discharged from a water source is to lower its BOD — that is, reduce its oxygen demand and thus reduce its need for the water from which it is released.

3.3.5 Dissolved Oxygen: Melted oxygen (DO) is a measure of how much oxygen is dissolved in water - the amount of oxygen found in aquatic organisms. The amount of oxygen dissolved in a stream or pond can tell us a lot about water quality. Melted oxygen saturation is reported in units of mg / l (mg / l is also called in fractions per million (ppm) because it is 1000 grams of pure water, and a milligram is a fraction of a million of that). Percentage filled space is reported by percentage units. The oxygen dissolves in the water until it is full, the normal amount of heat given. Percentage gain tells us which part of the catch capacity is actually taken. The high level of DO in a public water supply is good because it makes drinking water taste better. However, high levels of DO accelerate corrosion in water pipes.

3.3.6 Phosphate: Phosphates are the chemicals which contain the element phosphorus, and they affect the quality of water by causing algae growth in a huge amount. Phosphorus naturally occurs in rocks and other minerals. During the natural climate process, rocks slowly release phosphorus as phosphate ions dissolve in water and mineralized phosphate compounds break down, Phosphates

PO4-3 are formed from this component. Phosphates basically exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate; each compound contains phosphorus in a different chemical system. These types of phosphate occur in fossils of living and decaying plants, such as free or slightly ion-binding ions in aqueous systems, chemically synthesized in structures and soils, or as mineralized compounds in soils, rocks and objects.

3.3.7 Nitrate: Nitrate can also cause adverse health affects when present in high quantity. The EPA has established an official drinking water standard of 10 milligrams of nitrate per liter of water (10 mg / L). The question arises how does nitrate affect aquatic life? Nitrates have the same effect on aquatic plant growth as the phosphates as well as the same adverse effect on water quality. Plants and algae grow fast which provides fodder for fish which could lead to an increase in the number of fish. The demerit of it is that the oxygen levels in the water will drop and the fishes will die.

Because nitrate can be short-lived in a modified form of nitrites, and because nitrites can cause serious illness in both wildlife and humans, the acceptable nitrate levels in drinking water have been determined as 10 mg / l. Polluted water usually contains nitrate less than 1.0 mg / l.

3.3.8 Turbidity : Turbitity measures the relative clarity of the water .It is defined as the number of suspended particles in water . Debris in the water is caused by organic matter such as clay, mud, dust and organic matter as well as plankton and other microorganisms that interfere with the passage of light coming into the water. Turbidity can be referred to as total suspended solids (TSS) and it also involves plankton and other organisms. Natural water variations tend to rise during heavy flow due to increased ground runoff, river flow, and erosion. High turbidity can disturb the cleanliness and give an environment for bacterial growth as well as can increase the presence of microbes in water.

3.3.9 Fecal Coliform : The existence of fecal coliform bacteria in fluvial areas designate that water is infected with human or animal feces. Whenever this happens, the source water is likely to be infected with germs or pathogens that may be present in the soil.

Serial No	Temp[C]	pH	TDS[ppm]	D.O.[percent]	Turb[FNU]	Nitrates (Lab)	BOD (L)	Fecal Coliform(L)	Phosphate(P)
1	19.19	8.42	225.0	107.5	2.7	11.875	3.0	7	0.14
2	19.21	8.42	225.0	107.4	2.8	11.875	3.0	7	0.14
3	19.22	8.43	224.0	107.1	2.7	11.875	3.0	7	0.14
4	19.22	8.44	225.0	108.8	2.6	11.875	3.0	7	0.14
5	19.24	8.44	224.0	108.0	2.6	11.875	3.0	7	0.14

Table 2: Table of Ganga Dataset

3.4 Water Quality Index A Water Quality Index (WQI) is a methodology where water quality is calculated and analyzed. Just like Air Quality Index and UV Index ,it calculates index lying in particular range and describes whether the quality of water is safe for drinking or not and ultimately finalizes the result by scaling the water in different scores .

Table I - WQI Quality Scale	
91-100:	Excellent water quality
71-90:	Good water quality
51-70:	Medium or average water quality
26-50:	Fair water quality
0-25:	Poor water quality

The water quality indicator is a 100-point scale that summarizes the results from a total of nine different scales when completed. Field values can be converted to index values; respondents were asked a series of questions to include a water quality level graph (0 to 100) corresponding to field values such as pH (2-12). The curves are then weighed and are designed to calculate the optimum result . The calculator completes individual and group values and allows the respondents to generate custom reports of the water . WQI calculator will eventually create scaling of the river water tested .

Serial No	Temp[C]	pH	TDS[ppm]	D.O.[percent]	Turb[FNU]	Nitrates (Lab)	BOD (L)	Fecal Coliform(L)	Phosphate(P)	Water Quality Index
1	19.19	8.42	225.0	107.5	2.7	11.875	3.0	7	0.14	73.055
2	19.21	8.42	225.0	107.4	2.8	11.875	3.0	7	0.14	73.055
3	19.22	8.43	224.0	107.1	2.7	11.875	3.0	7	0.14	73.055
4	19.22	8.44	225.0	108.8	2.6	11.875	3.0	7	0.14	73.055
5	19.24	8.44	224.0	108.0	2.6	11.875	3.0	7	0.14	73.055
...	...	...	...	...	...	...	...	...	...	...
54292	20.00	8.68	215.0	102.9	38.4	0.440	8.0	15	0.14	68.085
54293	19.99	8.68	214.0	103.0	39.7	0.440	8.0	15	0.14	68.085
54294	19.93	8.72	213.0	103.4	38.4	0.440	8.0	15	0.14	68.085
54295	19.96	8.70	214.0	103.3	37.1	0.440	8.0	15	0.14	68.245
54296	19.96	8.70	214.0	103.2	39.5	0.440	8.0	15	0.14	68.085

54296 rows × 11 columns

Table 3 : Water Quality Index

In this study, the calculation of 9 analyzed physicochemical parameters i.e.. PH, Temperature, Solid Solid Core, Soluble Oxygen, Nitrate, Phosphate, Biological Oxygen Demand, Turbidity and Fecal Coliform were selected to assess the quality of the Ganga River in three different periods (Summer, Monsoon, Winter) on selected sites.

The Q-value for each test should be multiplied by the rating scale shown on the Worksheet for each test, and the answer should be recorded in the "Total" column. The measurement factor indicates the importance of each test for overall water quality. For example, the weighting factor of fecal coliform is 0.16, so it is considered more important in assessing total water quality than nitrate, with a measuring factor of only 0.10. Finally, add the numbers shown in the Content column to determine the total Water Quality Index (WQI) of the tested water source. Compare your Index result with the ratio shown in Table I to measure the water level of the tested water supply

The algorithm used in this study is "Decision Tree Classifier" so the water quality after calculating 9 parameters is determined by categories and eventually classified into varied classes on quality scaling. The Water Quality Index Calculator uses a scaling from 0 to 100 to measure water quality, where 100 is the highest score.

4. RESULTS

Information about river water quality is important for the conservation and survival of marine animals. People, somehow, rely on rivers to meet their daily needs and human intervention in rivers makes water levels worse. To maintain this perspective, the current study was designed to assess the surface water level of the Ganga River using ML Applications to IoT. In the present study, nine physicochemical parameters were analyzed. The algorithm used in this study is "Decision Tree Separator " so water quality after calculating 9 parameters is determined in stages. The Water Quality Index Calculator uses a scaling from 0 to 100 to measure water quality, where 100 is the highest score. Once all the WQI points are known, they can be collectively used to determine how healthy the water is on a particular day.

WQI Scale : CATEGORY QUALITY

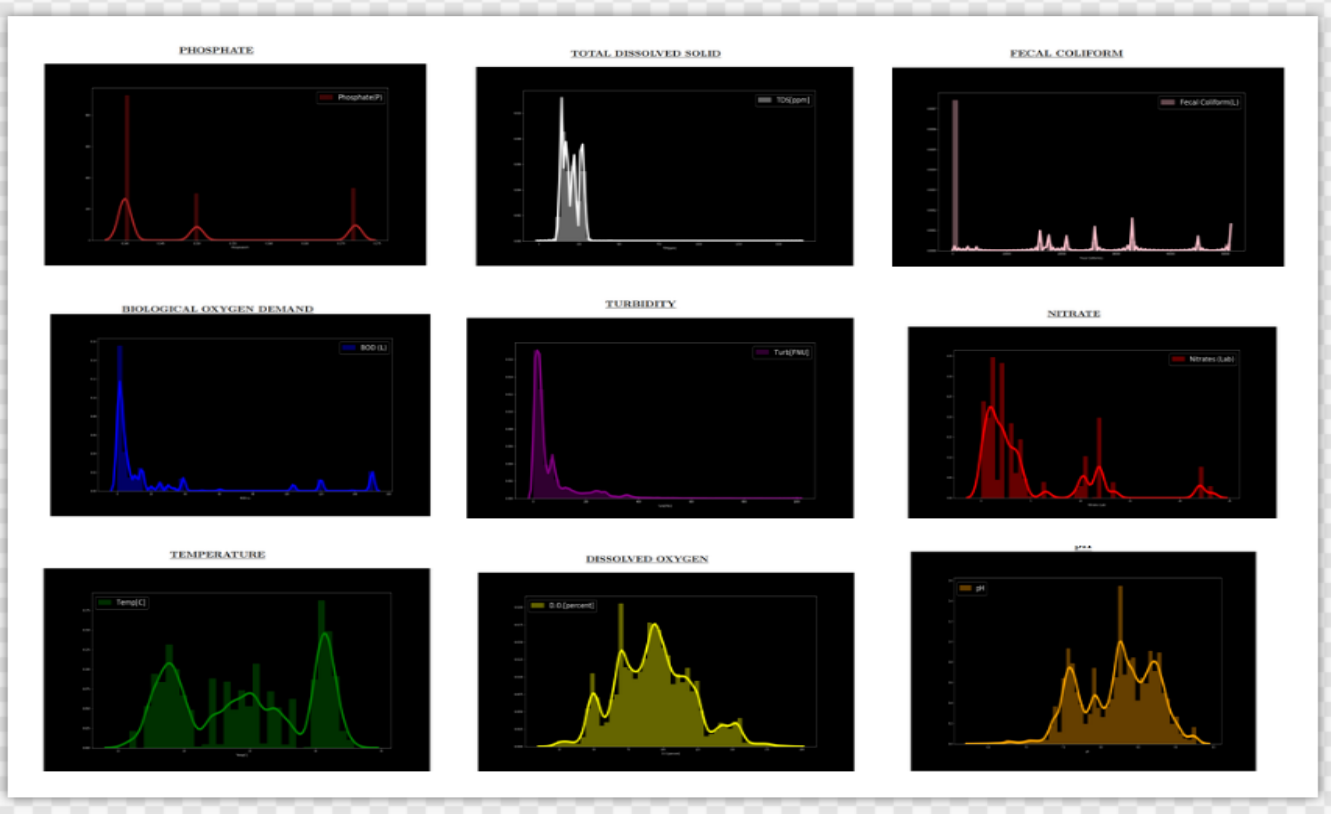
91 – 100 : Excellent Water Quality

71 – 90 : Good Water Quality

51 – 70 : Medium or average water Quality

26 – 50 : Fair Water Quality

0 – 25 : Poor Water Quality



4.1 Accuracy Score

Accuracy is a metric for the evaluation of classification models. It is the fraction of predictions our model calculated right.

Accuracy = Number of Accurate Predictions / Total Total Predictions

For binary calculations, accuracy can also be calculated according to the positives and negatives as shown below:

Accuracy = (TP + TN) / (TP + TN + FP + FN)

where TP = True Positive, TN = True Negative, FP = False Positive, and FN = False Negative

```
              precision    recall  f1-score   support

           2       0.91      0.78      0.84      2168
           3       0.91      0.97      0.94      8481
           4       0.97      0.88      0.93      2925

    accuracy                           0.92     13574
   macro avg       0.93      0.88      0.90     13574
weighted avg       0.92      0.92      0.92     13574
```

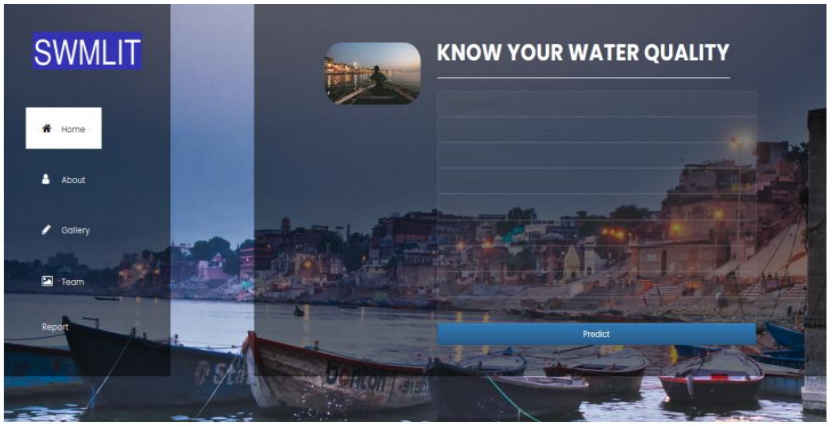
```
print("Accuracy Score is : ",loaded_model.score(x_test,y_test)*100,"%")
✓ 0.1s
Accuracy Score is :  92.20568734345072 %
```

5. CONCLUSION

The present study investigates the quality of the surface water of the Ganga River in the active river mine area of Varanasi, Kolkata, Jahangirpur, and Tribeni. The study concluded on the basis of the ML Algorithm accuracy points indicating the quality of water that was slightly polluted during heavy rainfall. at all sample sites. During the summer, WQI scores indicate an acceptable level of water quality and during the winter, it reflects the excellent water quality of the Ganga River. The water level of the Ganga River is recorded and polluted during storms due to high runoff from the river compared to summer and winter seasons. During the WQI quality inspection, at least a good condition was recorded during heavy rains. The study revealed that the WQI of the Ganga River was not found to be suitable for drinking purposes during the rainy season, it may be suitable for irrigation purposes. The outcome of this current study requires careful monitoring of the ecological features of the aquatic environment especially in the active Ganga rivers due to the potential natural hazard.

5.1 Know Your Water Quality We have made a website named KNOW YOUR WATER QUALITY which will predict the quality status of water ,all we have to do is to feed the details of 9 parameters required for WQI calculation.

LINK:https://gangawaterproject.herokuapp.com/



6 . FUTURE SCOPE

- Accuracy Score can be further improved and more parameters can be included in the WQI Calculation for the better results.
- A study and a website can be made for many rivers of India together .
- The future scope of this study is that it can be further deployed on Django rather than Flask at this time so that User Experience can be more interactive and an app can also be made for the same so that one can use it on their respective smartphones.
- As AQI is a prominent term due to high pollution in metropolitan cities ,Similarly WQI should also be in more consideration for the riverine systems.

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