Smart Water Metering System

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Smart Water Meter

Smart Water Meter - Introduction

- A smart water meter is an advanced digital device used to measure and monitor water consumption and quality in real-time.
- Unlike traditional analog water meters, smart water meters can transmit data wirelessly to a central system, allowing for remote monitoring and management.
- These meters are commonly used in residential, commercial, and industrial settings for efficient water management.
- They can also be used to check water quality and take necessary action, when decline is quality is detected.
- They can be used to detect and prevent water leakage.

Smart Water Meter - Features

- **Real-time Data Collection:** Smart meters track water usage minute-by-minute and provide accurate readings, helping users and utilities manage consumption better.
- **Remote Monitoring:** Water usage data can be accessed remotely by utility companies or consumers via mobile apps or web portals, reducing the need for manual readings.
- **Leak Detection:** Smart meters can identify leaks or abnormal consumption patterns, alerting users to potential issues quickly.

Smart Water Meter - Features

- **Automatic Billing**: The data from smart meters can be automatically transmitted to billing systems, ensuring accurate and timely billing based on actual consumption rather than estimates.
- **Data Analytics:** Smart water meters often come with analytics tools to help users track usage trends, detect inefficiencies, and optimize water usage.
- **Integration with Smart Home Systems**: In some cases, smart meters can be integrated with broader smart home systems, allowing for automated water-saving actions.

Smart Water Meter - Advantages

- **Enhanced Accuracy**: Smart water meters provide precise, real-time data on water usage, reducing the risk of errors commonly associated with manual readings.
- **Leak Detection and Prevention**: These meters can detect small leaks or unusual water usage patterns early, allowing users to take action before leaks become costly or wasteful.
- **Remote Monitoring and Accessibility**: Consumers and utility companies can access water usage data remotely through apps or online portals, making it easy to monitor consumption anytime, anywhere.
- **Automatic and Accurate Billing**: With accurate real-time data, bills are based on actual usage rather than estimates, leading to fairer and often lower costs for consumers.

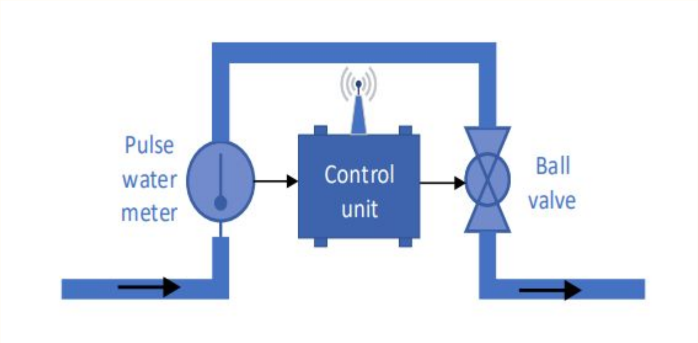
Smart Water Meter - Advantages

- **Water Conservation**: Smart meters allow users to see their consumption patterns, helping them make informed decisions to reduce usage and conserve water resources.
- **Early Warning System**: The data provided by smart water meters can help utility companies manage demand, predict peak usage, and detect potential infrastructure issues before they escalate.
- **Operational Efficiency for Utility Providers**: Smart water meters eliminate the need for manual meter reading, reducing labor costs and enabling faster detection of issues within the water distribution system.
- **Data-Driven Insights**: Advanced data analytics available through smart meters can help users and providers identify trends, optimize water usage, and promote sustainability efforts.

Literature Survey

Utilization of Machine Learning to Detect Sudden Water Leakage for Smart Water Meter

- Information from a smart water meter, which at hourly intervals provides information on the cumulative water consumption of the monitored object, was used as input data for finding the ML model.



A Unified Metering System Deployed for Water and Energy Monitoring in Smart City

- The integrated solution proposed in this research offers functions such as remote power and water shutoff, water and power reconnection, disconnection alert, power theft alert, and overloading alert, making the system unique among those already available.
- The design and development of scalable smart water and energy meters was discussed . The smart energy meter can monitor real-time energy consumption and detect overloading and energy theft
- The water flow and energy consumption data are wirelessly transmitted through LoRa

An Internet of Things-based Smart Water Meter with Machine Learning-aided Water Quality Assessment

- The system integrates both water quality and consumption monitoring into a single system by utilizing IoT technology
- Data-driven analysis of water quality by employing feature scaling ML algorithms to assess water quality and consumption in Uganda. This data-driven approach facilitates targeted interventions on the root causes of water pollution.
- An essential aspect of the system is the application of feature scaling ML techniques to determine key parameters for water quality assessment
- The assessment showed the most dominant parameters to be residual chlorine, pH, turbidity, conductivity, and apparent color
- The combined system contributes significantly to efficient water management

Intelligent Water Metering System: An Image Processing Approach (MATLAB simulations)

- This paper proposes simple image processing approach for an intelligent metering system involving conventional mechanical water meter, image sensor, DSP processor and GSM modem.
- The proposed device works like conventional mechanical meter for recording water usage. The power will be activated as per the billing cycle period for capturing image of water meter reading, and processing it to extract reading.
- The extracted meter reading is sent to the central server for analysis and billing. The power is automatically suspended after sending extracted meter reading to the central server, thereby reduces power consumption.
- This proposed system is able to detect water leakage through real time water monitoring

IoT based Smart Water Meter for Water Management

- By implementing smart technologies at urban scale by using sensors, smart meters and smart network etc.., we can make a more efficient billing system.
- Water meters are fitted in gated communities, that are used to generate bill for total consumption amount which is divided equally among the tenants in the apartment.
- By using smart meter, solution for this problem and the monitoring of the usage level for the water consumed are given.
- The charges are collected based on the consumption of each family instead of total consumption of all tenants.
- Monitoring the consumption of water will prevent over usage of water.

IoT Product on Smart Water Quality Monitoring System (Iot Wq-Kit) for Puducherry Union Territory

- Real-time wireless water quality data collection simplifies the task of maintaining water quality according to consumer preferences and facilitates year-round assessment of water quality.
- The proposed system aims to optimize manual data collection efforts and the logistics associated with sending samples to chemical laboratories for analysis.
- Traditional laboratory results often arrive after a considerable delay, rendering them outdated as water characteristics may have changed by then.
- Implementing real-time monitoring ensures that water quality adheres to the required standards for specific applications.

Smart Water Leakage Detection and Metering Device

- SWLDM is a system that will automatically and continuously inform the consumer about the water consumption levels at their designated households and the system should be able to detect if there are any possible water leakages in the consumer’s property.
- It is a system that will send data of the consumer’s water consumption levels to the water municipality for that area, for billing purposes and also to help determine the current water consumption of the area in real-time. Through these two sub objectives the aim is to decrease the water losses that contribute to the high water consumption and losses.
- The SWLDM device is also low-cost to ensure its commercial viability for large scale deployment as well as make it less vulnerable to possible theft

Study and Design a Low-Power Water Meter

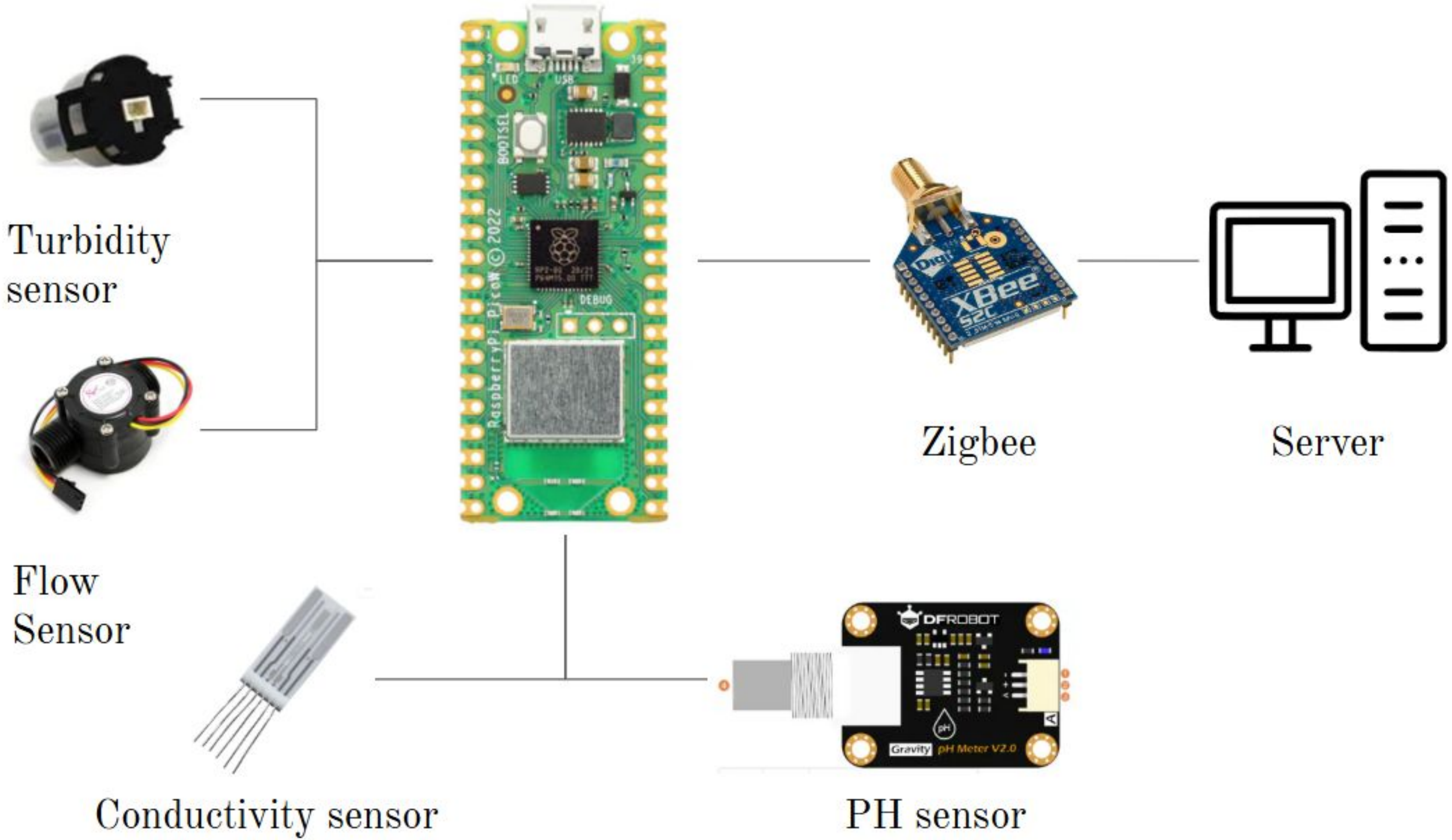
- Water meter based on Node-Red and STM32 is proposed to monitor the water consumption of a household and make the inhabitants aware of their consumption.
- The data of consumption is measured by a low-cost flow sensor, and the turbine generator is used alternatively to provide power to the system when the flow presents, the role of the water flow detector is used to wake up the microcontroller.
- The data is transmitted via the LoRa module to the gateway, which sends the data to HiveMQ's MQTT broker, then shows the data on the HMI based on Node-Red.

Proposed design

Smart Water Metering System

The functionality of our design will include

- Water consumption meter which calculates the water used and transfers the data using zigbee.
- Water Quality measurement using PH sensor, Turbidity sensor and other sensors. The water quality is measured and alarm is triggered if the quality is below the acceptable standard
- Water leakage tracking, which can be measured using the flow sensor used for consumption measurement. If the leakage is detected, the flow can be stopped.
- Machine learning algorithm can be performed on the collected data to find any anomaly and detect inefficiencies.


Turbidity sensor
Flow Sensor
Conductivity sensor
PH sensor
Zigbee
Server

Proposed Design

- Ph:https://www.mouser.in/new/dfrobot/dfrobot-gravity-analog-ph-sensor-module/?srsltid=AfmBOorfvaJqswodwFR8tJ0xUSZLehim7-wnZhLcxzb_fG0y8X7UdVP9
- Conductivity:https://www.mouser.in/ProductDetail/Innovative-Sensor-Technology/LFS1K0.1305.6W.B.010-6?qs=tlsG%2FOw5FFhl4e1AFMccaw%3D%3D&srsltid=AfmBOoo7zdJ1FD4grsiXkDLOoPHNcijL7K5GBTt6IXDkNv1UOS8brnJP
- Turbidity:https://www.mouser.in/ProductDetail/Amphenol-Advanced-Sensors/TSD-10?qs=cmBPKiaX3MylKvR%252BTrNAhw%3D%3D
- Zigbee:https://www.mouser.in/ProductDetail/Digi/XB24CDMUIT-001?qs=XmMZR4xR0DDvmrWWeyVnsQ%3D%3D
- Pi Pico:https://www.mouser.in/new/raspberry-pi/raspberry-pi-pico-boards/

ML Algorithm

Machine Learning algorithm

- Upon installation of the proposed design, we can collect the required data and use that live data for prediction.
- A data-set related to smart water was obtained and machine learning algorithm was trained to show how how system works.
- The water_potability.csv file contains water quality metrics for 3276 different water bodies.
- The data-set contained the following contents : ph, Hardness, Solids, Chloramines, Sulfate, Conductivity, Organic_carbon, Trihalomethanes, Turbidity and Potability
- The ML algorithm is initially trained with the collected data, and later can be used for prediction.

Machine Learning algorithm

- The ML algorithm is initially trained with the collected data, and later can be used for prediction.
- Based on the given factors, we can determine the potability of the water.
- The ML algorithms were trained with a part of the dataset and the remaining was used for predicting if the water is potable or not.
- We can perform same analysis and train the model with the data collected using the proposed design and predict if the water is potable or not and take necessary action.
- Now, the existing dataset was analysed and inferences were made based on it.
- dataset:https://github.com/born2win685/smart_water_meter/blob/main/water_potability.csv

Dataset-Summary

```
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   ph               2785 non-null   float64
 1   Hardness         3276 non-null   float64
 2   Solids           3276 non-null   float64
 3   Chloramines      3276 non-null   float64
 4   Sulfate          2495 non-null   float64
 5   Conductivity     3276 non-null   float64
 6   Organic_carbon   3276 non-null   float64
 7   Trihalomethanes  3114 non-null   float64
 8   Turbidity        3276 non-null   float64
 9   Potability       3276 non-null   int64
dtypes: float64(9), int64(1)
memory usage: 256.1 KB
```

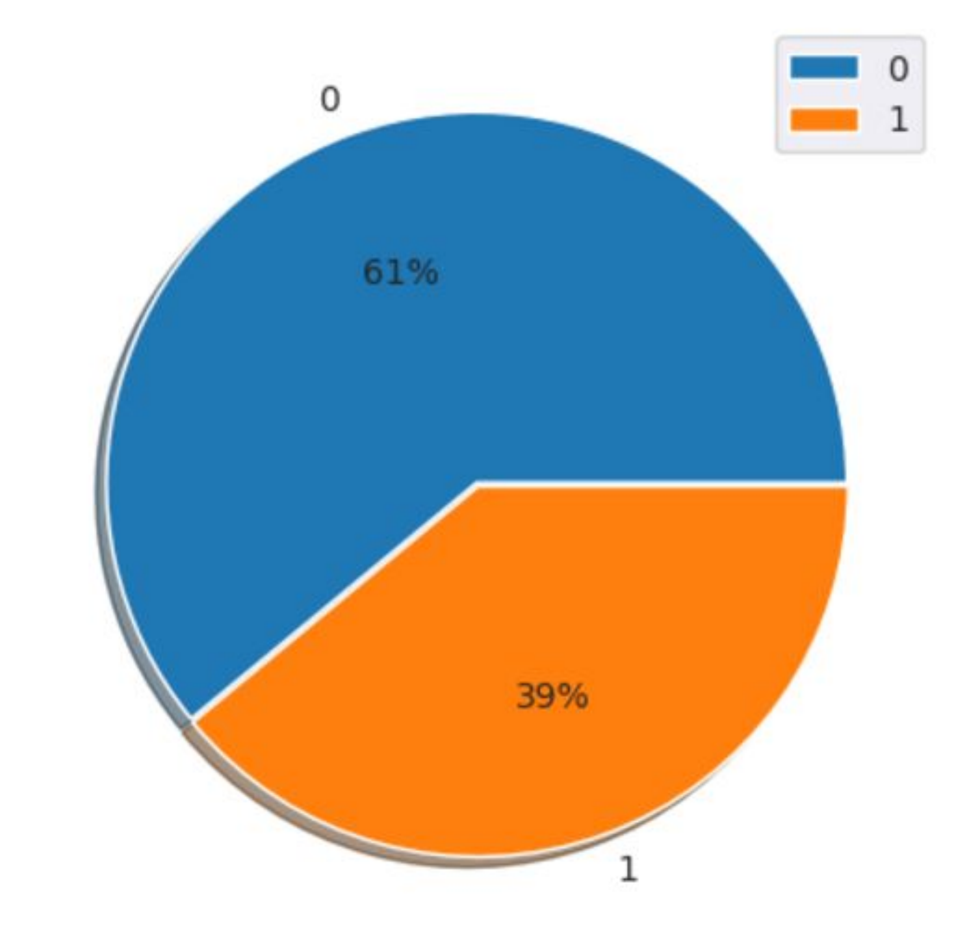
Dataset-Analysis

	min	50%	mean	max	std
ph	0.000000	7.036752	7.080795	14.000000	1.594320
Hardness	47.432000	196.967627	196.369496	323.124000	32.879761
Solids	320.942611	20927.833607	22014.092526	61227.196008	8768.570828
Chloramines	0.352000	7.130299	7.122277	13.127000	1.583085
Sulfate	129.000000	333.073546	333.775777	481.030642	41.416840
Conductivity	181.483754	421.884968	426.205111	753.342620	80.824064
Organic_carbon	2.200000	14.218338	14.284970	28.300000	3.308162
Trihalomethanes	0.738000	66.622485	66.396293	124.000000	16.175008
Turbidity	1.450000	3.955028	3.966786	6.739000	0.780382
Potability	0.000000	0.000000	0.390110	1.000000	0.487849

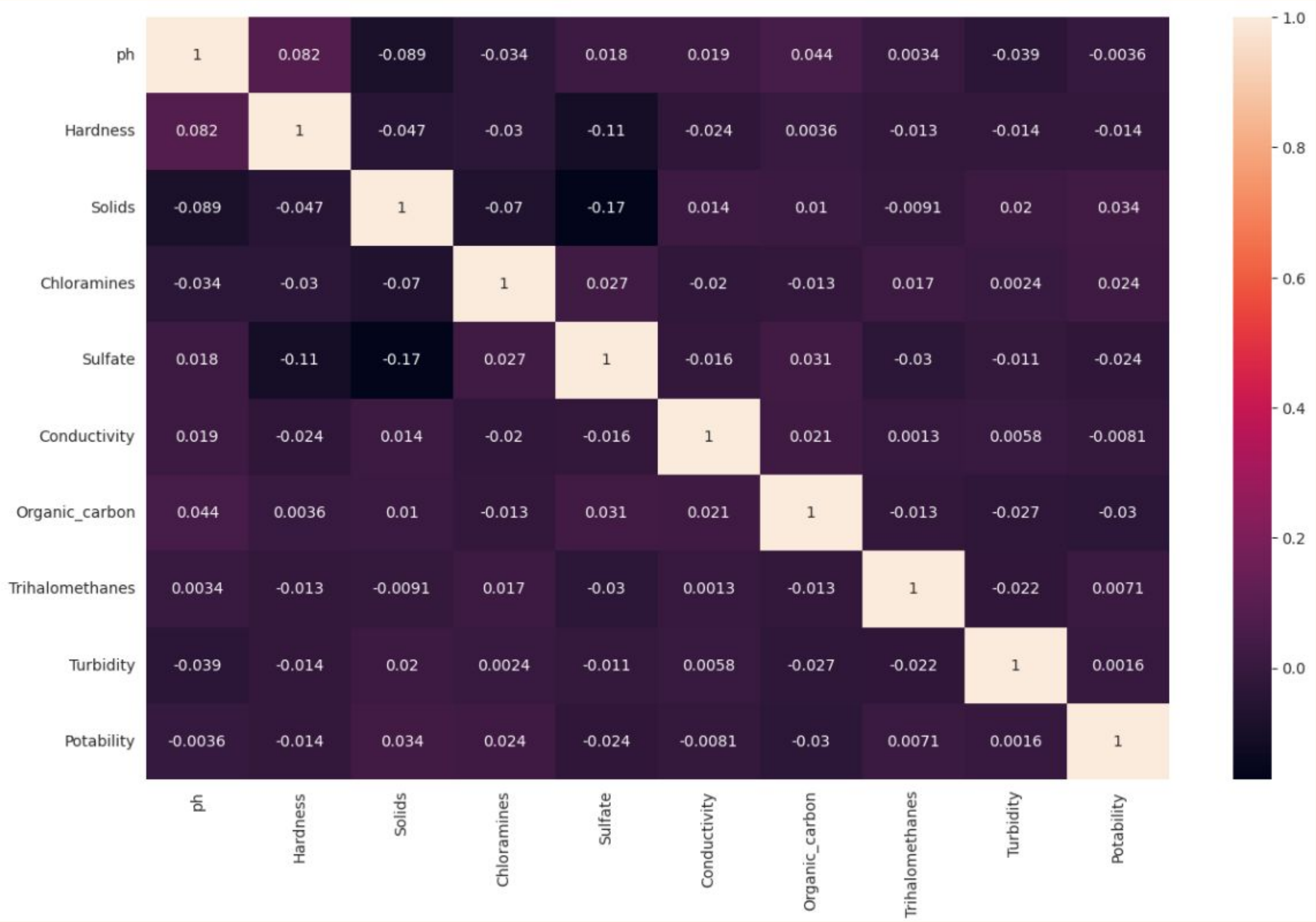
Dataset-Analysis

Most of the collected samples

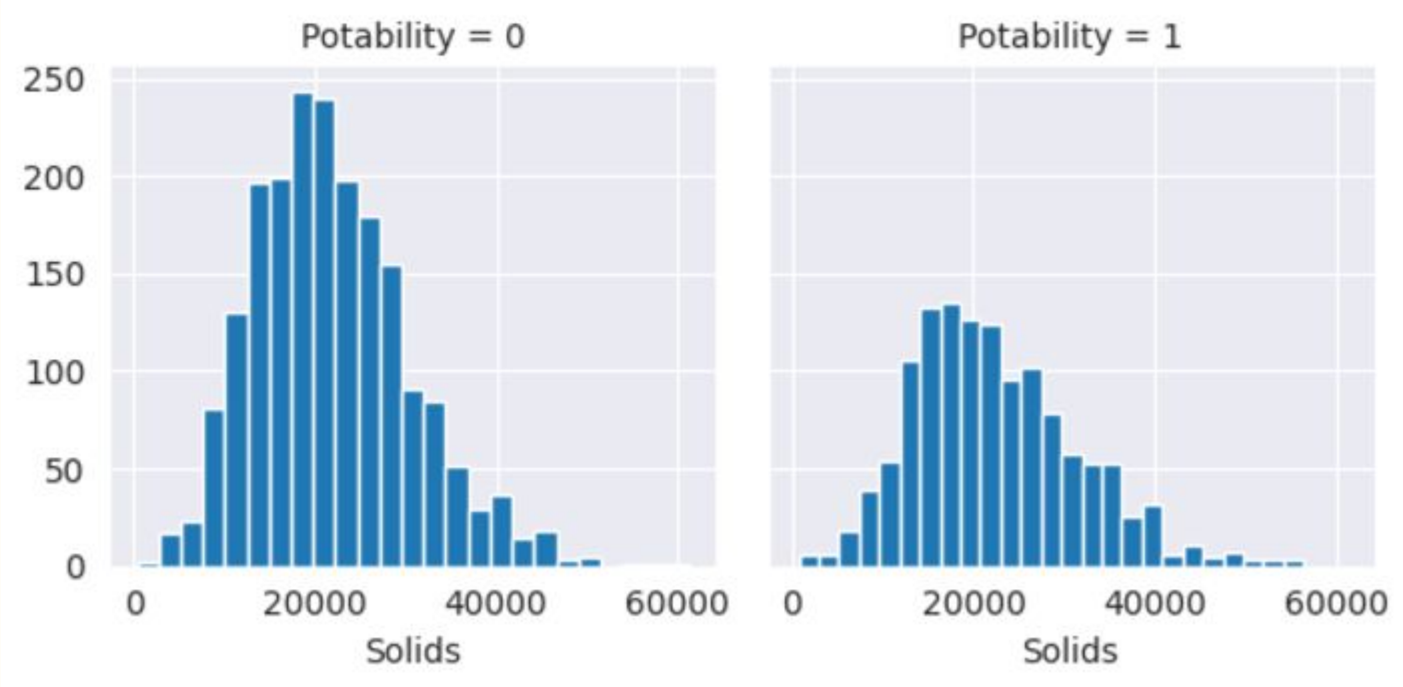
are not potable (Potability=0)



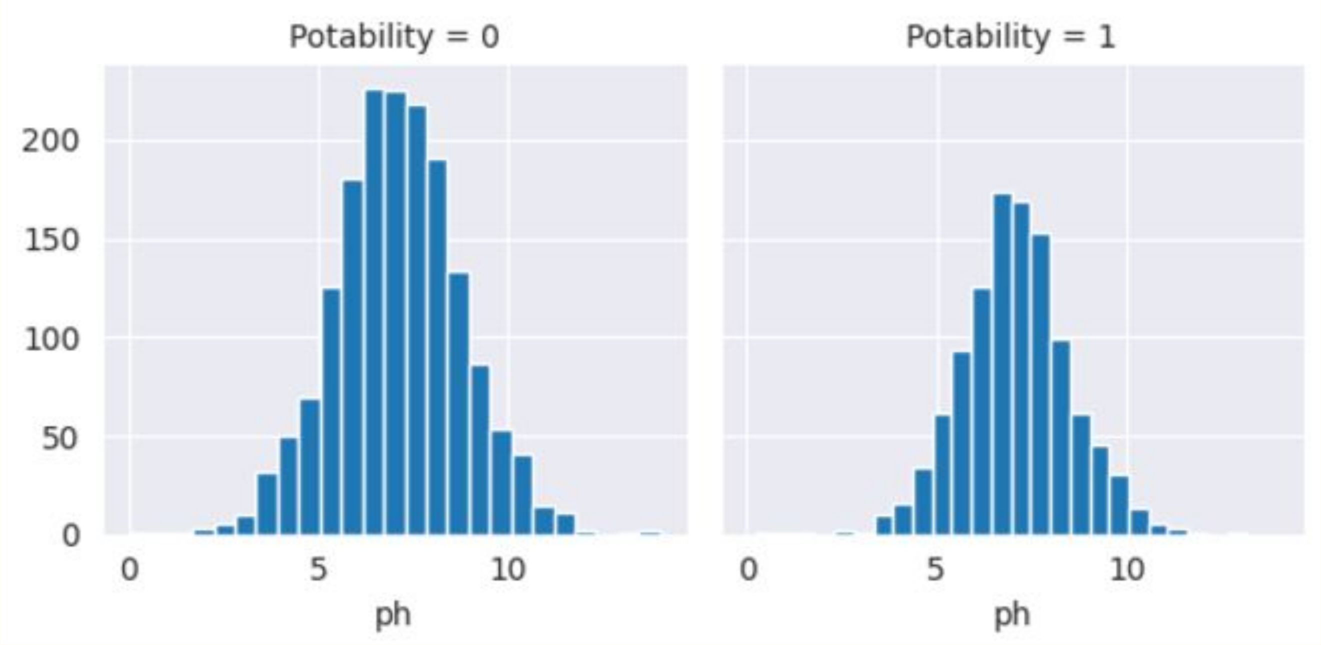
Correlation of the factors with each Other and with Water potability



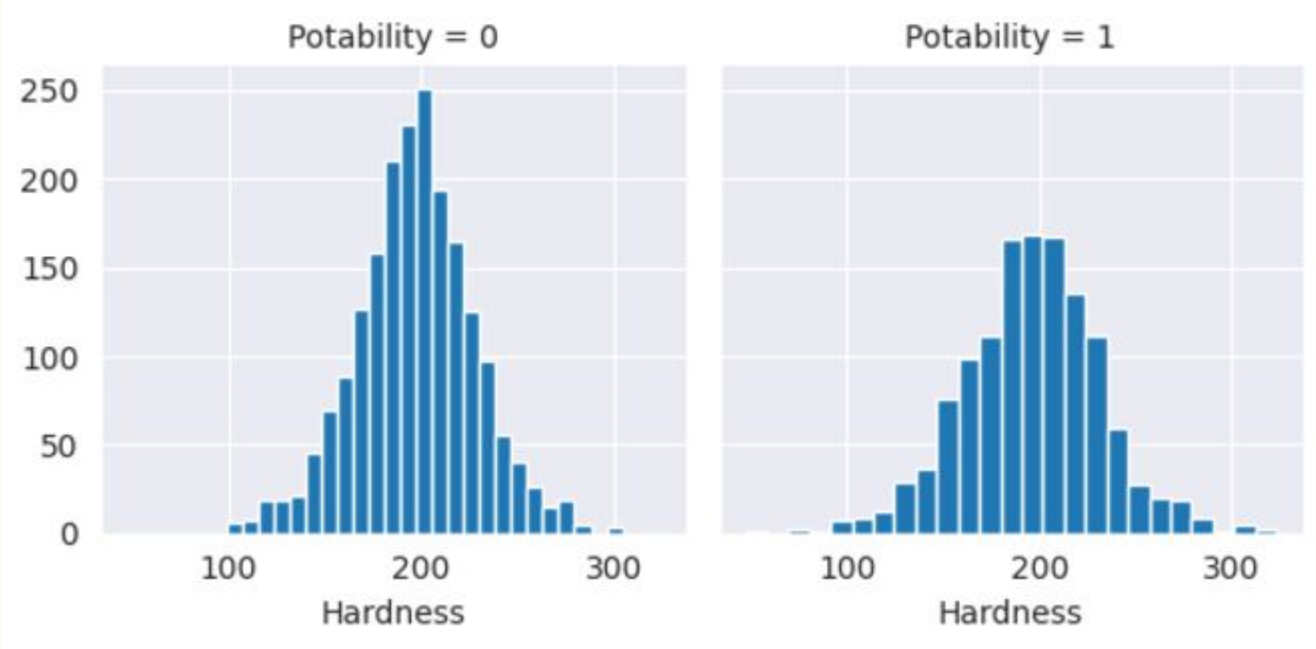
Distribution of Solids for each potability value



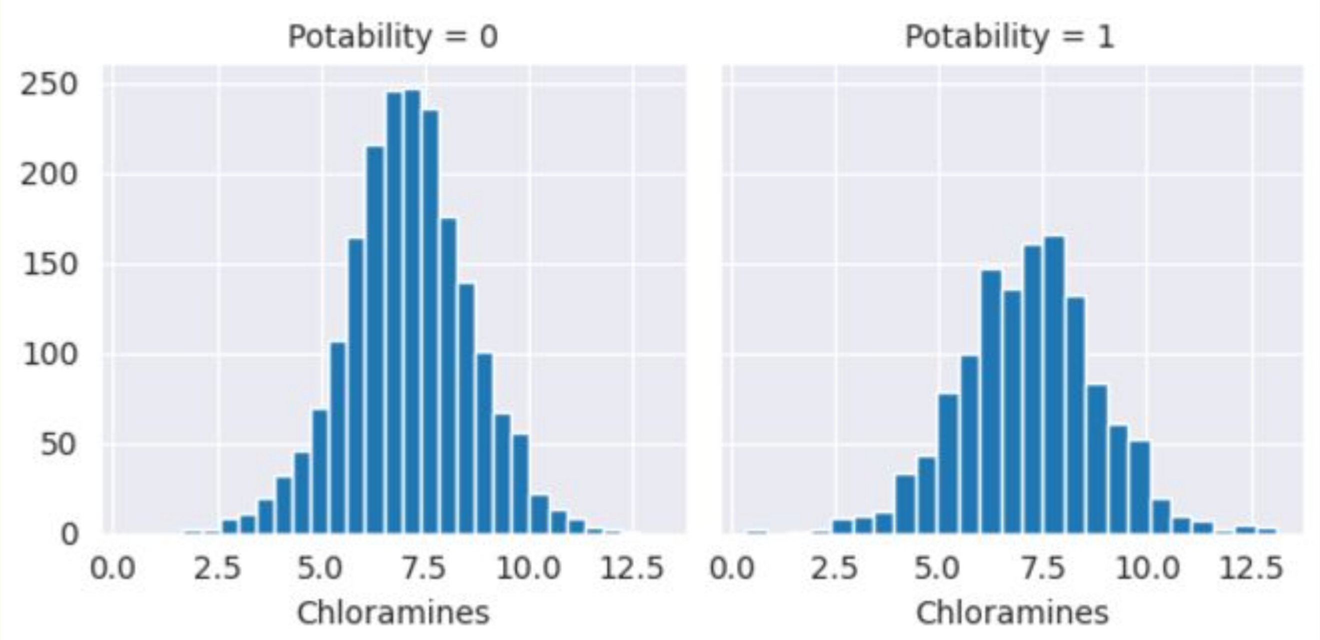
Distribution of ph for each potability value



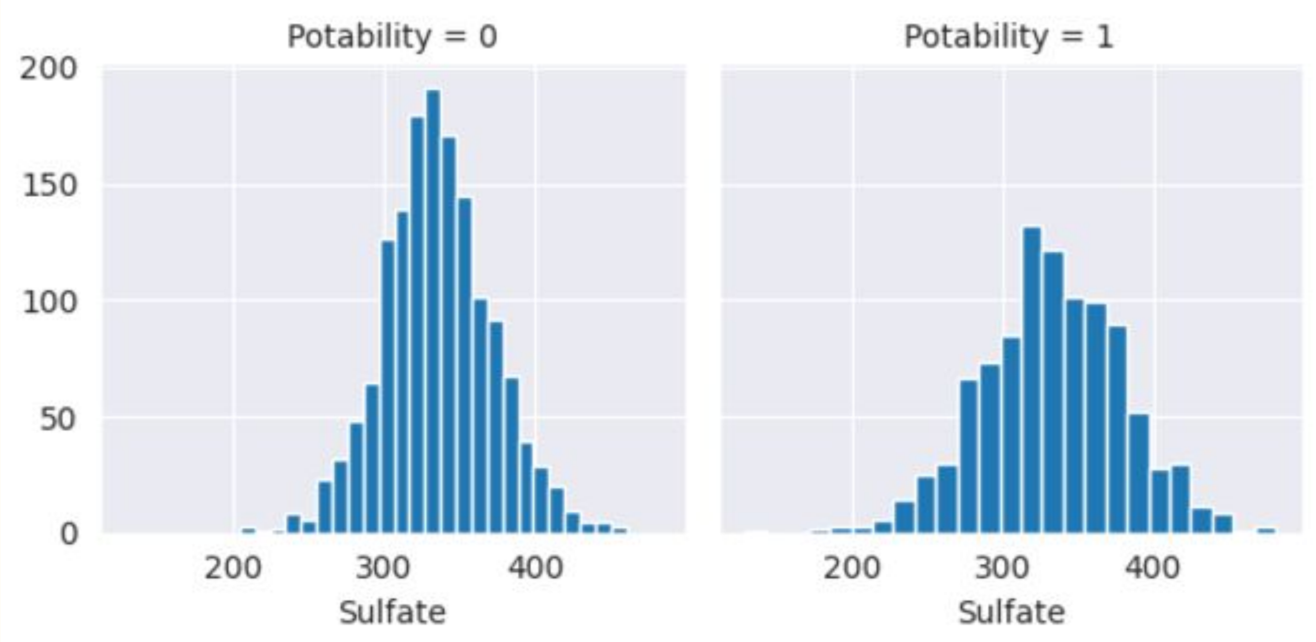
Distribution of Hardness for each potability value



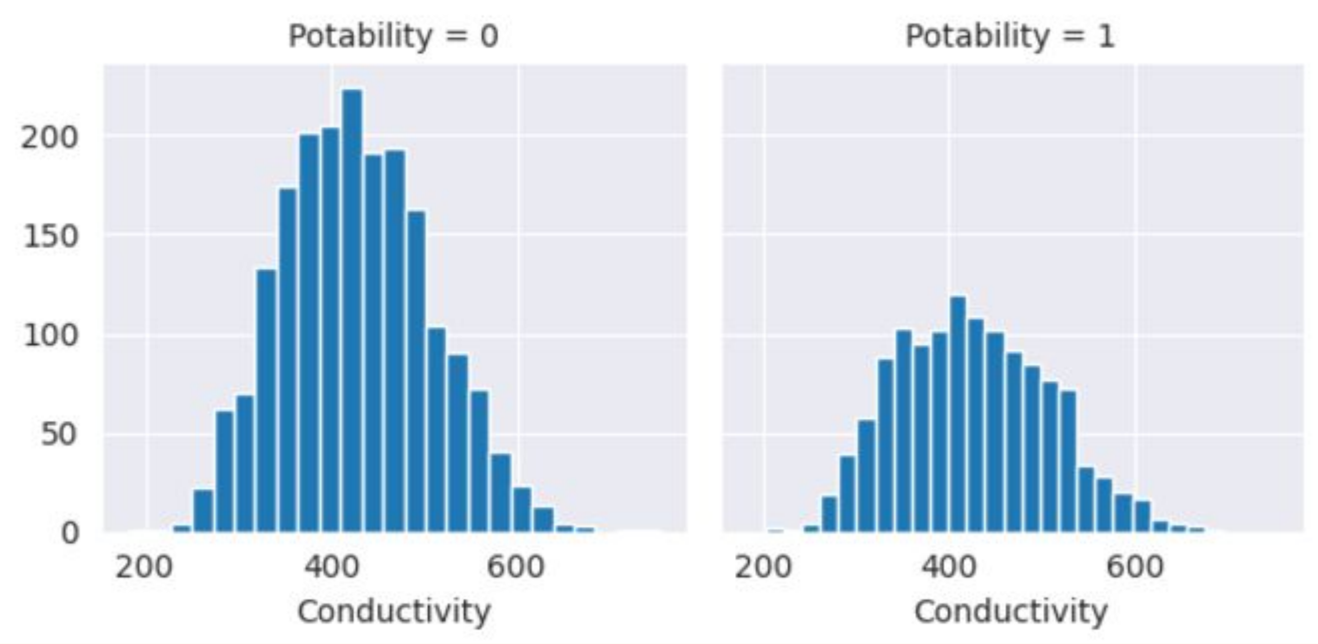
Distribution of Chloramines for each potability value



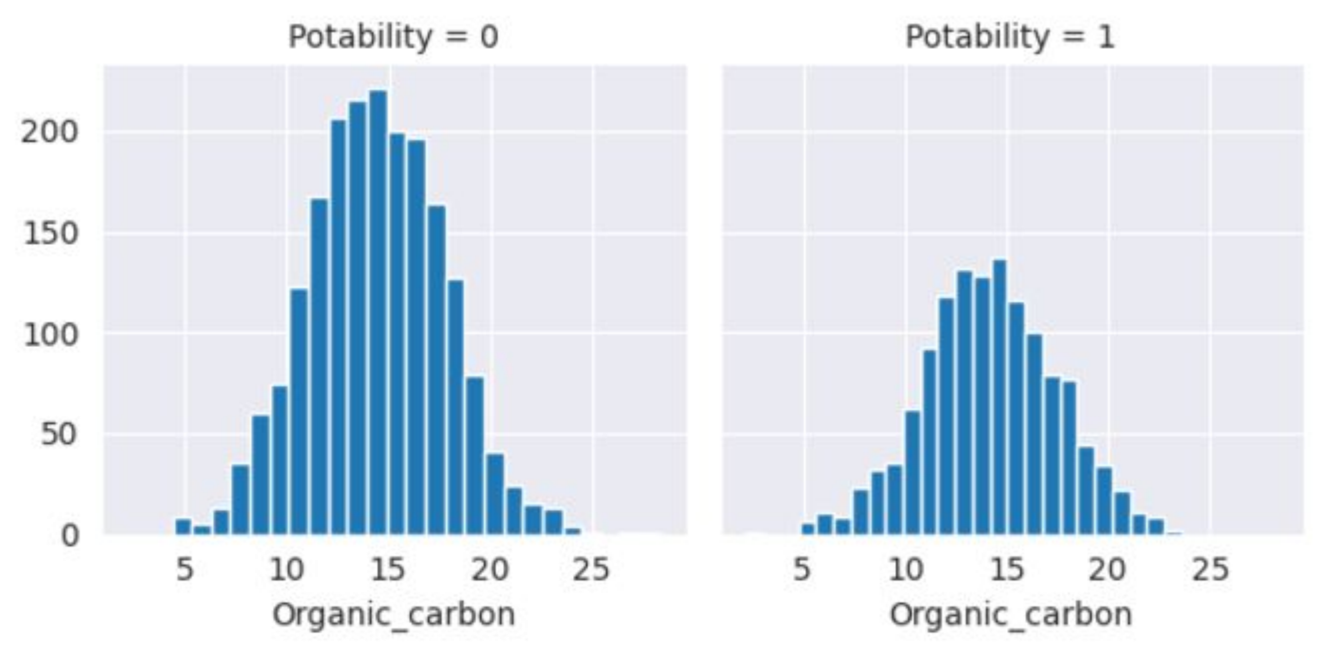
Distribution of Sulfate for each potability value



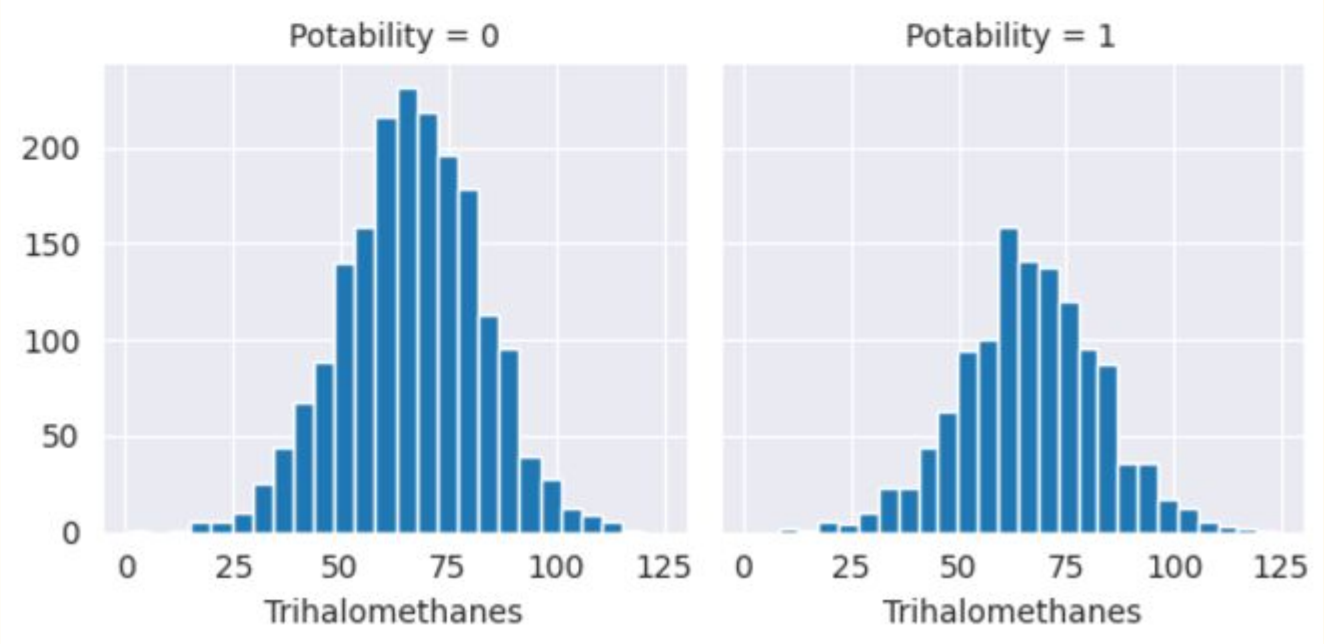
Distribution of Conductivity for each potability value



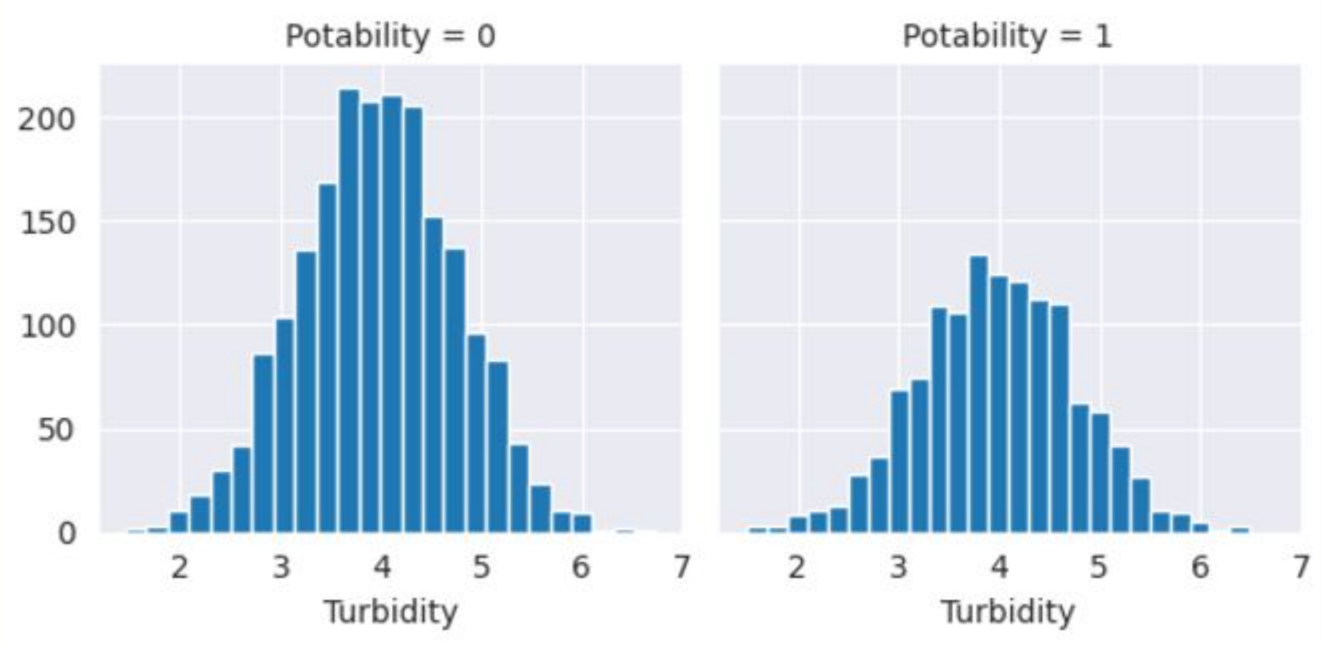
Distribution of Organic_carbon for each potability value



Distribution of Trihalomethanes for each potability value



Distribution of turbidity for each potability value



Correlation of the factors with Water potability. We can observe that solids have high correlation in the obtained dataset.

```
Potability         1.000000
Solids             0.033743
Chloramines        0.023779
Trihalomethanes    0.006887
Turbidity          0.001581
ph                -0.003014
Conductivity      -0.008128
Hardness          -0.013837
Sulfate           -0.020476
Organic_carbon    -0.030001
Name: Potability, dtype: float64
```

Dataset-Missing value handling

The null values are detected in the data set and are replaced with the median of the column

```
Percentage(%) of nulls for each columns :

ph                  14.987790
Hardness             0.000000
Solids               0.000000
Chloramines          0.000000
Sulfate             23.840049
Conductivity         0.000000
Organic_carbon       0.000000
Trihalomethanes      4.945055
Turbidity            0.000000
Potability           0.000000
dtype: float64
```

Dataset-Summary after processing missing values

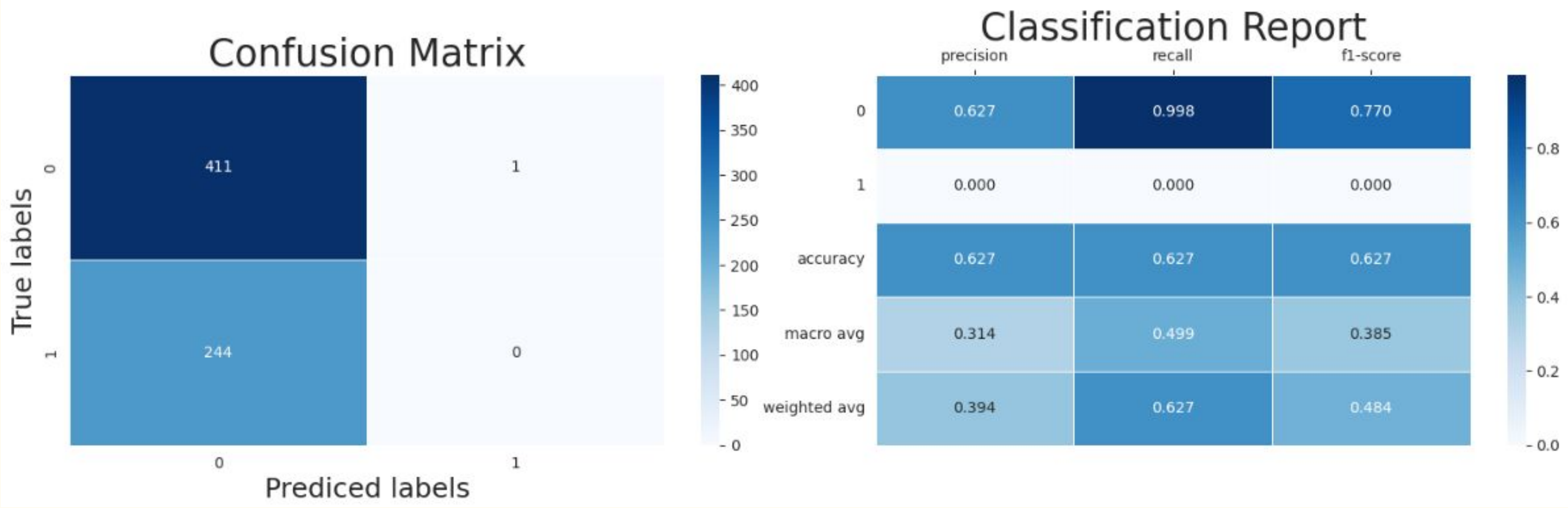
	min	mean	std	max
ph	0.000000	0.505300	0.105003	1.000000
Hardness	0.000000	0.540231	0.119263	1.000000
Solids	0.000000	0.356173	0.143968	1.000000
Chloramines	0.000000	0.529963	0.123921	1.000000
Sulfate	0.000000	0.581223	0.102672	1.000000
Conductivity	0.000000	0.427940	0.141336	1.000000
Organic_carbon	0.000000	0.463026	0.126750	1.000000
Trihalomethanes	0.000000	0.532763	0.127939	1.000000
Turbidity	0.000000	0.475853	0.147548	1.000000

Machine Learning algorithm-Results

- Logistic Regression
- Type: Linear Model (Supervised)
- Description: Logistic Regression predicts the probability of a binary outcome (e.g., yes/no, 0/1) by fitting data to a logistic function (sigmoid curve). It’s essentially a linear regression model modified for classification tasks.
- Key Features:
  - Simple and interpretable.
  - Effective for linearly separable data.
  - Prone to underfitting for complex datasets.

Machine Learning algorithm-Results

- Logistic Regression

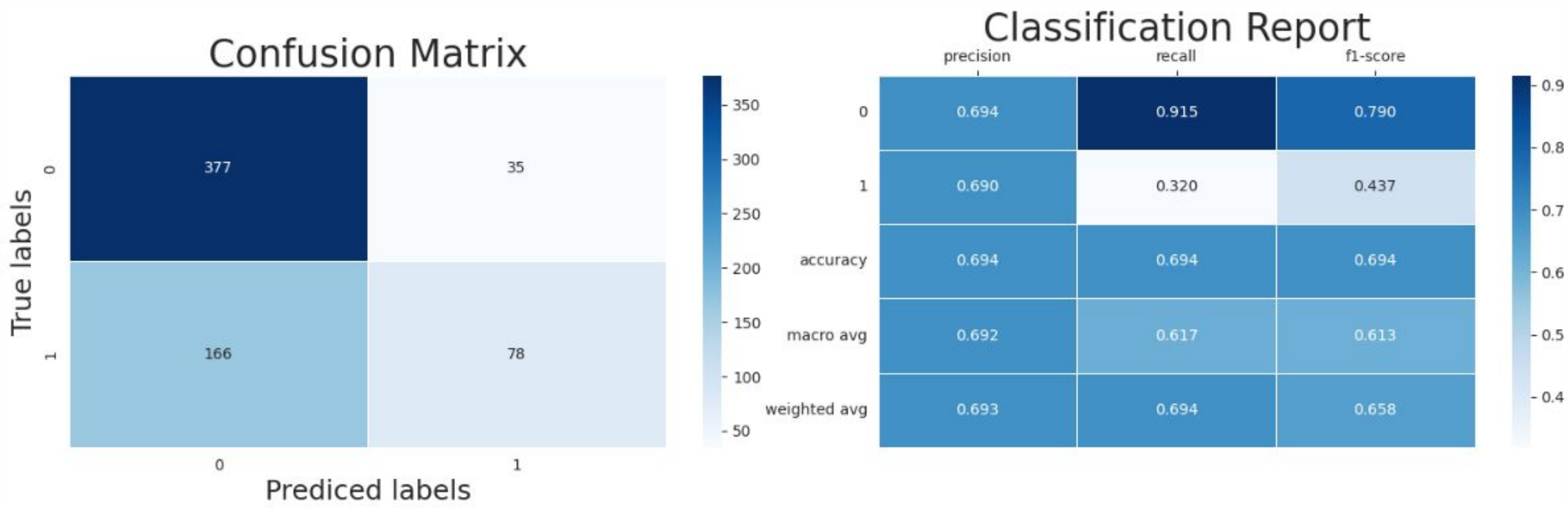


Machine Learning algorithm-Results

- Random Forest Classifier
- Type: Ensemble Learning (Supervised)
- Description: Random Forest is a collection of decision trees, where each tree votes, and the majority vote is chosen as the final prediction. It uses a technique called "bagging" (Bootstrap Aggregating) and random feature selection to reduce overfitting and improve accuracy.
- Key Features:
    - Handles both classification and regression tasks.
    - Robust against overfitting on large datasets.
    - Performs well even with missing data.

Machine Learning algorithm-Results

- Random Forest Classifier

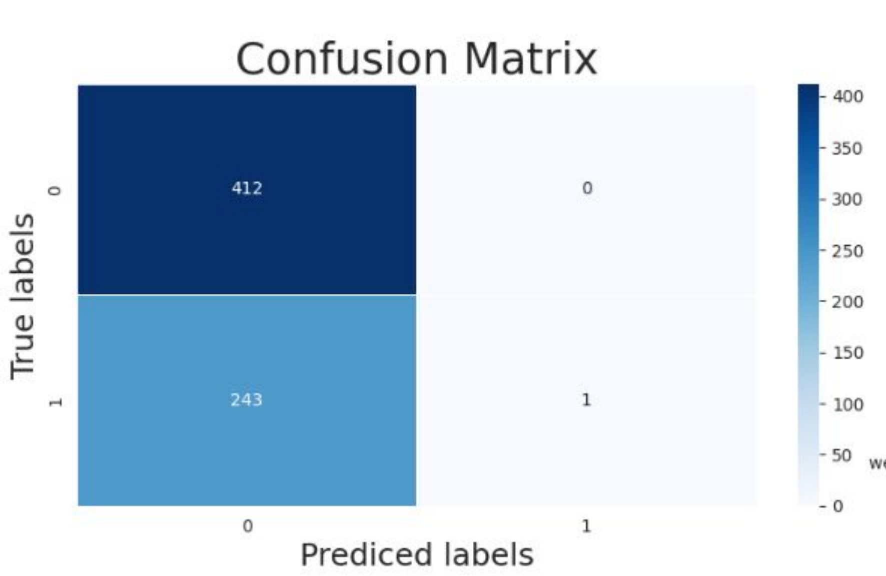


Machine Learning algorithm-Results

- MLP learning
- Type: Artificial Neural Network (Supervised)
- Description: MLP is a type of neural network that uses one or more hidden layers between the input and output layers. It relies on backpropagation for training and can learn complex patterns.
- Key Features:
  - Capable of modeling complex, non-linear relationships.
  - Requires careful tuning of hyperparameters (e.g., learning rate, number of layers).
  - Prone to overfitting without proper regularization.

Machine Learning algorithm-Results

- MLP Classifier

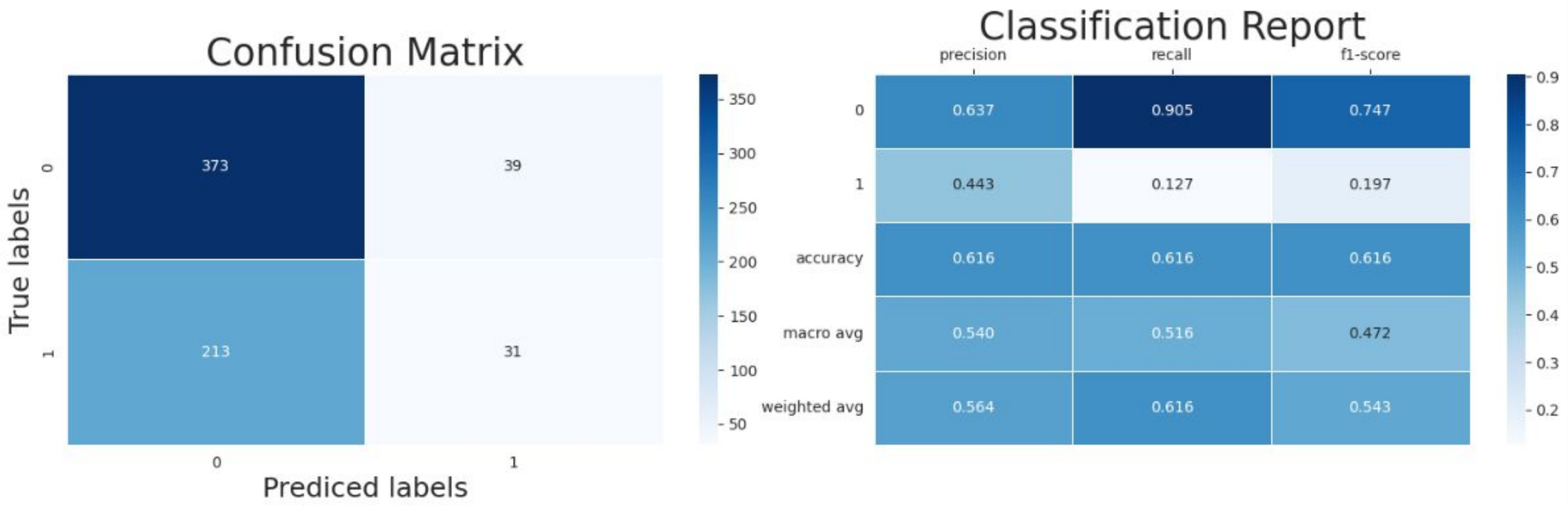


Machine Learning algorithm-Results

- K Nearest Neighbours
- Type: Instance-Based Learning (Lazy Learning, Supervised)
- Description: KNN classifies a new data point based on the majority class among its *k* k-nearest neighbors in the feature space. Distance metrics like Euclidean, Manhattan, or Minkowski are used to measure "closeness."
- Key Features:
  - Easy to implement and interpret.
  - Sensitive to the choice of *k* k and distance metric.
  - Computationally expensive for large datasets.

Machine Learning algorithm-Results

- KNeighboursClassification



Machine Learning algorithm

- The following prediction algorithms were tested and the score is listed along with them below.

0	RandomForestClassifier	0.695000
1	LogisticRegression	0.627000
2	KNeighborsClassifier	0.616000
3	MLPClassifier	0.630000