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# Intelligent IoT Based Water Quality Monitoring System

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## Abstract

With rapidly rising population in India, Fresh Water Management is very much essential which demands an increase in agricultural, industrial and other requirements. The Quality of Fresh Water is characterized by “chemical, physical and biological” content

Traditional water quality monitoring involves three steps namely water sampling, Testing and investigation. These are done manually by the scientists. This technique is not fully reliable and gives no indication before hand on quality of water. Also with the advent of wireless sensor technologies, some amount of research carried out in monitoring the water quality using wireless sensors deployed in water and sending short message to farmer’s about water. Also research been carried out in analyzing the quality of water using machine learning algorithms too.

Now with the advent of Machine to Machine Communication which leads to devices communicating among themselves and accordingly analyzing the data intelligently, we here have developed an “Intelligent IoT based water quality monitoring system” pertaining to storage tanks being used by residential areas. The system here employs PH sensor and TDS meter for measuring the water quality parameters pertaining to hydrogen ion and total dissolved solvents. In addition, machine learning algorithm K-Means clustering been employed for predicting the quality of water based on trained data set from different water samples. This system been implemented as a small prototype using low cost embedded devices like Arduino Uno, Raspberry Pi3.

**Keywords:** M2M, K-Means, Arduino, Raspberry Pi3

## INTRODUCTION

With rapidly rising population in India, Fresh Water Management is very much essential which demands an increase in agricultural, industrial and other requirements. The Quality of Fresh Water is characterized by “chemical, physical and biological” content. Monitoring the water quality helps in detecting the pollution in water, toxic chemical and contamination. The traditional method still in vogue entails collection of water samples, analyzing it in lab and advice for any water treatment and so forth. Current water pollution monitoring method takes place in 3 main steps:-

- Water sampling
- Testing samples
- Investigative analysis

All of these 3 steps are very expensive, difficult, time-consuming, need expert advice and less efficient. So with the advent of technology, automation can be brought in water quality monitoring in taking action appropriately rather than relying on manual process.

So in automating the water quality monitoring some amount of technological innovation has creeped in which would help in monitoring the quality of water rather than relying on manual process.

In one of the system, EcoMapper [1] which is an autonomous underwater vehicle been employed which helps in mapping the quality of water, currents of water and so. Drawback of the system is that it has 8-14 hour life span at the speed of 2-4 knots. This method involves human need and risk of human health underwater in a contaminated environment is very high.

In one another research, robotic fish[2][3] is employed where oxygen levels in water can be measured. The control centre captures the data transmitted wirelessly for analysis. The main drawback of this system is battery depletion of robotic fish system leading to abrupt ceasing of fish while monitoring the water quality.

Also research been done by employing digital camera underwater [4] in monitoring the movement of the protozoa which is placed in sampling water. Biological and Chemical pollution can be detected by employing robotic fish methodology. The major drawback in this method is its inability to identify the pollutant until further analysis.

Research also has been done in algae detection by employing shining laser beam [5] into algae which determine the amount of contamination from the sound waves emitted under the water. Different sound waves are emitted based on different kinds of pollution affecting the algae.

This method is limited to algae detection only and not finding other physical and chemical properties of water.

In addition to monitoring the water quality using Technology, there has also been some limited amount of research been carried out in employing Machine learning technique in Water Quality Monitoring.

Machine Learning is a branch of Artificial Intelligence (AI) which allows devices to learn without being explicitly programmed. One of the research been reported employing Machine Learning in Water Quality Monitoring in rivers which is based on Least Squares Vector Machine [6].

So with the upcoming of Machine to Machine communication leading to Internet of things which involves devices interacting among themselves without any human intervention, we here have developed an Intelligent IoT based Water Quality Monitoring system where PH sensor and TDS meter deployed for collecting the water parameters periodically from different types of water.. These collected water parameters are sent to the microcontroller and same sent by means of serial communication to Raspberry Pi3. The Pi3 processor got the K-Means clustering algorithm in grouping the water parameters into different clusters based on PH and TDS and accordingly train the data set for predicting the quality of water as good or bad. This information is updated in webpage of cloud for water authorities to take action. This is been developed as a prototype using Arduino and Pi3.

## LITERATURE SURVEY

Before going into the details of our Intelligent IoT based Water Quality Monitoring system, we will review some of the existing system in vogue pertaining to Water Quality.

### *A. Traditional Water Quality Monitoring*

In the traditional water quality monitoring system, different instruments been used to monitor the quality of water which include "Secchi disks (measure water clarity), probes, nets, gauges, meters", etc. The traditional method is just not enough to measure water quality and identify any drastic changes in it. This method not only impedes accurate water quality measurement but also at times fails to predict sudden changes in the water system. Hence, Information is also derived from satellite and aerial photographs by observing the surrounding environment and the changes in specific parameters such as flow of water, color in large overview, direction of water flow etc.

There are three major steps to execute traditional water quality monitoring. These three steps indulge different experts at different levels of the process. The major three steps are as follows:

- Water sampling
- Testing the samples
- Investigative analysis.

In Water Sampling, water samples collected in large mass using various tools. These water samples are then examined in the laboratories. Water sampling and analysis are only performed by ISO-certified laboratories. Unreliable results enhance issues concerning pollution when a corrective response cannot be performed within time. Sampling and monitoring tests can be conducted by expert technicians. Further to sampling, Testing is carried out. Testing procedures and parameters been classified into "Physical, Chemical, bacteriological and microscopic" categories.

**Physical tests:** These indicate properties that are detectable by the senses. They include Color, turbidity, total solids, dissolved solids, suspended solids, odor and taste.

**Chemical tests:** These tests determine the parameters in water like "pH, hardness, presence of a selected group of chemical parameters; biocides, highly toxic chemicals, and B.O.D".

**Bacteriological tests:** This test shows the presence of bacteria, a characteristic of faecal pollution. These tests examine to identify the presence of microbial pathogen in the water that might occur with contamination. The presence of such organisms indicates the presence of faecal material and thus of intestinal pathogens.

Finally the tested water samples are then thoroughly monitored and observed by an expert technician who can read through the lines of the resulted report. They then make an investigative analysis with a parallel consideration of the historical records of the previous water tests. Any similarity of the currently extracted results to the previous records will give way to an intense deliberation for prediction of any unknown changes or hazards to the water quality

### *B. Technology Based Water Quality Monitoring*

In one of the research, Dempster-Shafer (D-S) [7] method employed for detecting the contamination events of drinking water. Autoregressive model (AR) is employed for detecting the water Quality parameters.

The AR model been employed for predicting the water Quality parameters using automated (on-line) water-quality sensors. Finally, the D-S fusion method searches for anomalous probabilities of the residuals and uses the result of that search to determine whether the current water quality is normal (that is, free of pollution) or contaminated. The major drawbacks of this system are that this method requires lot of parameters for the data collected to determine the quality of water. It involves an expert technician to detect the water quality

In another research carried out towards Water Quality Monitoring, EcoMapper [1] which is an autonomous underwater vehicle employed. The method maps "water quality, the currents of the water and bathymetry". There is side scan sonar that can be added on.

The major drawback of this system is that only one person can deploy the EcoMapper which has 8-14 hour life span at the speed of 2-4 knots. This method involves human need and risk of human health underwater in a contaminated environment is very high.

Also research carried out towards deploying a robotic fish [2][3] which is battery powered for monitoring the water quality. Oxygen levels of water can be measured with the fish. Pressure and Current can be withstanded using a fish which is 5 feet long.

The Robotic fish will move at a speed of 1 m/s towards collecting the data with on board guidance system. This system will prevent from bumping into rocks, other fishes and even ships. They have a form of sonar attached allowing them to communicate in the water. With enough data collected, it will come to the surface and transmit to the control centre wirelessly. The drawback of this system is chances of battery depletion from the robotic fish and an abrupt cease of the fish while monitoring water quality.

Microbial Source Tracking[8] been used towards determining various hosts towards contributing to faecal pollution in water bodies. Faecal pollution can be traced using "microbiological, genotypic, phenotypic, and chemical" methods and these has been termed "microbial source tracking (MST)". MST provides a tool towards identifying the source of pollution and allowing proper remediation and preventive measures. Water contaminated with human faeces is generally regarded as more hazardous to human health.

Swimming Behaviorial Spectrophotometer[4[ been deployed in water sample towards monitoring the movement of the protozoa. Digital Camera along with specialized software stores about 50 behaviors or protozoan in 3D motion to identify the pollutants. Any other movements which are not programmed indicate a problem in the water which requires further testing. This method can detect both chemical and biological pollution such as "heavy metal, pesticides and industrial chemical". The major drawback of this method is inability to identify the exact pollutant until further analyses. This drawback will impede accuracy in detecting water quality and also may predict wrong consensuses.

Lastly Research carried out in developing an Algae Detection method [5] where by Shining laser beam onto the algae, researcher could determine the amount of contamination from the sound waves emitted under the water. Underwater microphones are used to capture the sound waves which are analyzed to determine the health of the algae as well as status of the water. Different kinds of pollution affecting the algae will emit different sound. This method is limited to the presence of algae in the water and does not detect the complete physical and chemical properties of water. This makes the method inefficient to predict precise predictions

### *C. Machine Learning in Water Quality Monitoring*

Machine learning is a type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed. Foremost, for a machine to think like a human mind, it has to first think and learn like a human being. Human mind thinks from the past experiences and past data that is exposed to and based on that the human being takes decision for the future.

There has been one research carried out in employing machine learning in Water Quality monitoring where river water parameters are analysed based on Least Square Support Vector prediction model[6]. This method has been proven to have stronger ability to predict True value and Global optimisation and Good Generalization. The algorithm is applied for river water Quality towards predicting the total phosphorous with Back Propagation (BP) and Radial Basis Function (RBF) Network model for a comparative analysis.

## INTELLIGENT IOT BASED WATER QUALITY MONITORING SYSTEM

The existing Water Quality monitoring system employ human towards sampling the water Quality, Testing and perform the analysis. Currently some amount of technological innovation has been applied in water quality monitoring by using robotic fish, Digital camera and laser beam. Also research been done by employing wireless sensor also in water quality monitoring.

In addition to monitoring the water quality, very limited work carried out in employing machine learning technique in analyzing the quality of water based on collected water parameter for analysis rather than false alarm notification.

The challenge with the existing system is that there is no fully automated water Quality monitoring system employing Sensors. Also system possess no intelligence as such which allows for analysing the data for prediction. These systems so developed communicate within a small geographical area.

So with the advent of Machine to Machine Communication leading to IoT, we here have developed an intelligent IoT based Water Quality monitoring system where PH and TDS Sensors deployed in water tanks in residential area which communicate through the Arduino Microcontroller to the Raspberry Pi3 processors where K-Means clustering machine learning algorithm deployed towards analysing the data captured towards predicting the water quality as Good or bad. The predicted water Quality with PH and TDS for different types of water are updated in Webpage in Cloud for Water Department personnel to take action before affecting the residents. The complete system architecture of our IoT based System is shown in Fig.1

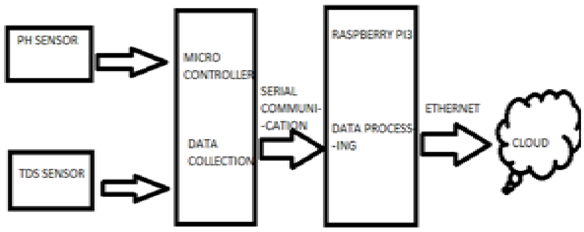


**Figure 1:** IoT Based Water Quality Monitoring System

The system here consists of three components. First component is the Arduino Microcontroller part where PH and TDS Sensor deployed in Water are connected to Microcontroller which gives the PH and Total dissolved solvents output based on Water Quality. The data received by Arduino are then sent to Edge level processor called the Raspberry Pi3 using Serial communication which is second component. In Pi3, K-Means Clustering Machine learning algorithm been employed for predicting the Water Quality based on PH and TDS.. The last and final component is recording the Water parameter and prediction with date and time in the cloud server for Water Authorities to access from their mobile to have good knowledge and understanding on water Quality being used by residents. The corresponding Data Flow Diagram, Sequence diagram, Context diagram and Use case diagram pertaining to IoT based system are shown in Figs 2 to 5.

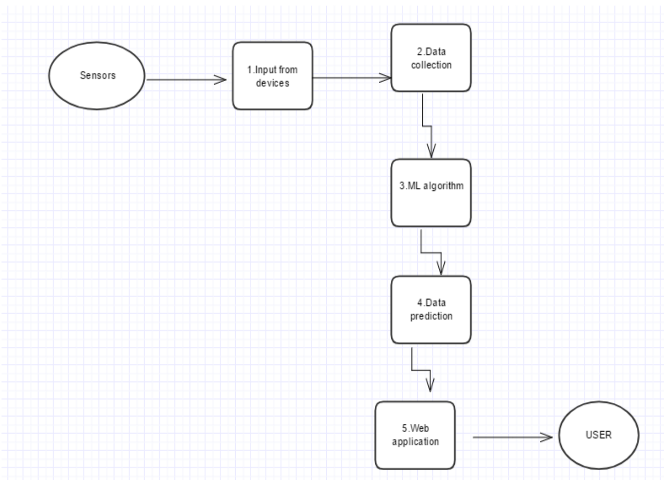


**Figure 2:** Data Flow Diagram

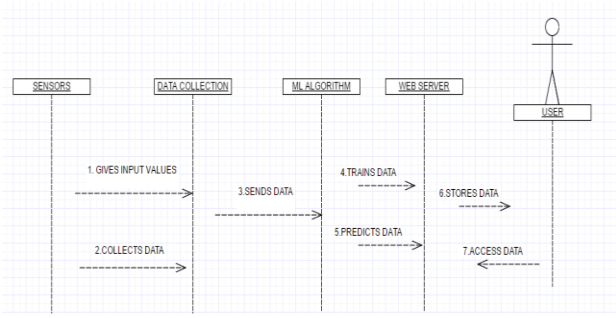


**Figure 3:** Sequence Diagram

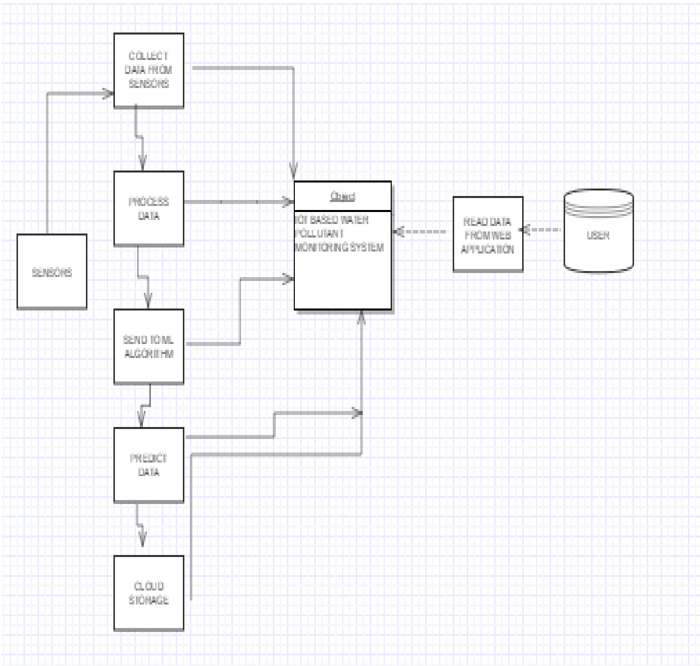


**Figure 4:** Context Diagram

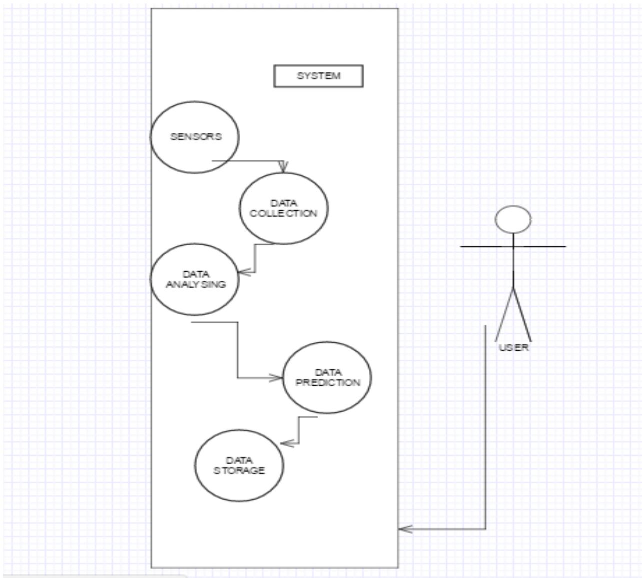


**Figure 5:** Use Case Diagram

### *A. Machine Learning Algorithm*

In terms of the IoT based Water Quality monitoring system, sensor data captured need to be analysed and accordingly prediction done. So towards this, we have deployed the K-Means Clustering algorithm where different types of Water i.e Mud, Lemon, Salt, Tap and Drinking water are taken for training the data set and accordingly prediction done towards consuming the water. The training of the data sets is done using k-means clustering algorithms. The data sets that have similar Ph and TDS value belong to a same kind of water. Hence, all the values in the dataset are clustered in such way that each cluster represents a specific kind of water like mud, lemon, salt, tap and drinking water. When a new entry of data set is tested using the algorithm, the machine will first classify which cluster the dataset falls in and results in the closest cluster name. It might be any kind of water. Hence monitoring and prediction of water quality are done using K-means algorithm in the stream of machine learning. The various advantages of this algorithm over the other algorithms are as follows:

- If variables are huge, then K-Means most of the times is computationally faster than hierarchical clustering, if we keep k small.
- K-Means produce tighter clusters than hierarchical clustering, especially if the clusters are globular.
- Fast, robust and easier to understand.
- Relatively efficient: O(tknd), where n is # objects, k is # clusters, d is # dimension of each object, and t is # iterations. Normally, k, t, d << n.

The algorithm of K-Means Clustering being applied for Water Quality analysis is given below: 3) Assign the data point to the cluster center whose distance from the cluster center is minimum of all the cluster centers. 4) Recalculate the new cluster center using:

$$v_i = (1/c_i) \sum_{j=1}^{c_i} x_i$$

where '$c_i$' represents the number of data points in ith cluster.

5) Recalculate the distance between each data point and new obtained cluster centers.

6) If no data point was reassigned then stop, otherwise repeat from step 3.

Let X = {x1,x2,x3,……..,xn} be the set of data points and V = {v1,v2,…….,vc} be the set of centers.

1) Randomly select 'c' cluster centers.

2) Calculate the distance between each data point and cluster centers.

**IMPLEMENTATION RESULTS AND ANALYSIS**

The Intelligent IoT based Water Quality Monitoring System developed involves Arduino and Raspberry Pi3 as microcontroller and processing unit. In addition, PH and TDS Sensor deployed in Water and same connected to Arduino microcontroller for collecting the water parameters which are hydrogen ion concentration and total dissolved solvents Also the Arduino unit connected serially to Pi3 for communication of data for analysis where machine learning algorithm K-Means Cluster been developed. The results been updated in Cloud server. This is shown in Fig.6.

Raspberry Pi3 is the edge level processor where intelligent analysis been carried out towards captured PH and TDS data for prediction based on data trained for different types of Water- Salt, Tap, Mud, Drinking and Tap Water. Fig.7 shows the Code Snippet of K-Means Clustering and Fig.8 shows the prediction based on trained data set in Pi3

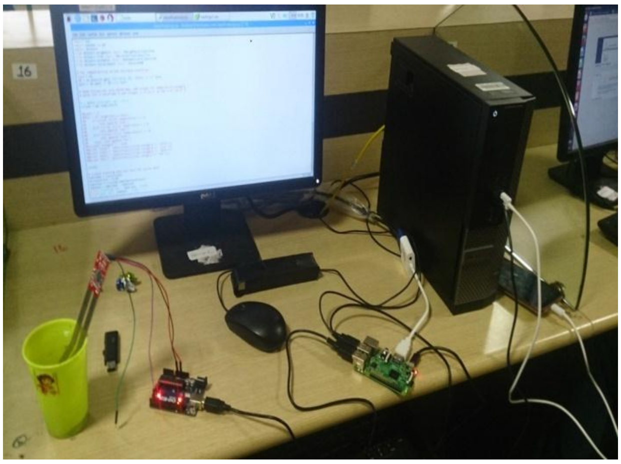

**Figure 6:** IoT Based Water Quality Monitoring System Prototype

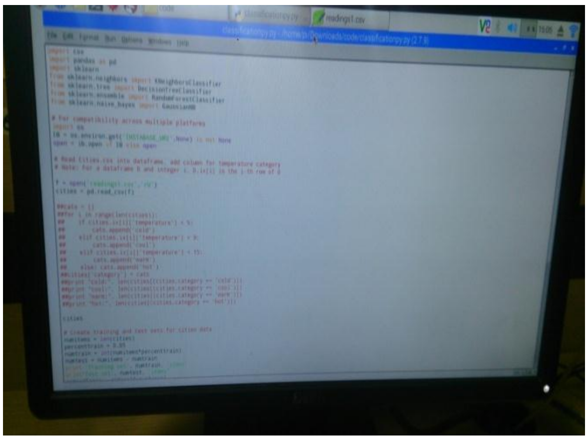

**Figure 7:** ML Code Snippet in Raspberry Pi3 Environment

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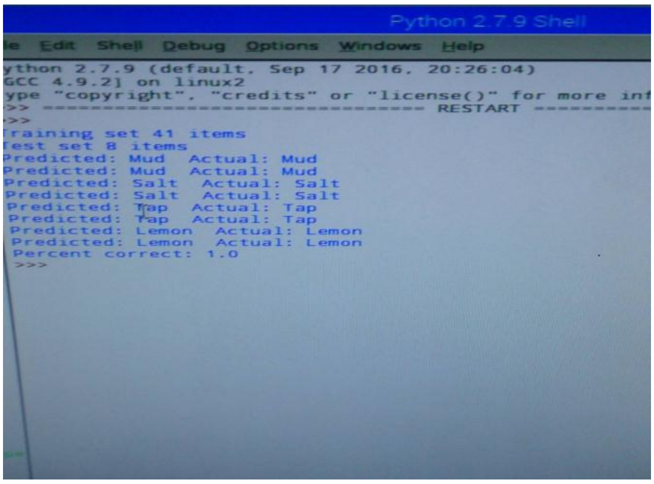


**Figure 8:** Predicted Output in Pi3

Figs 9 to 13 shows the PH vs TDS clustering based on different types of water which are Mud, Tap, Lemon, Salt and Drinking water.

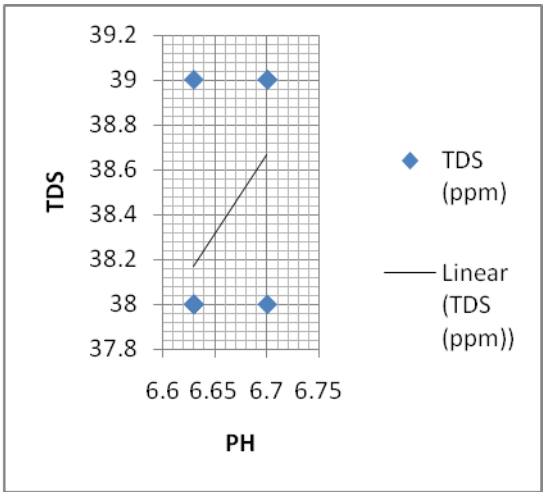


**Figure 9:** PH vs TDS for Drinking Water

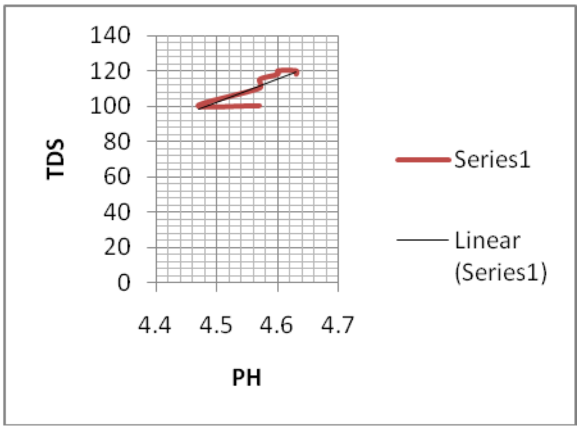


**Figure 10:** PH vs TDS for Lemon Water

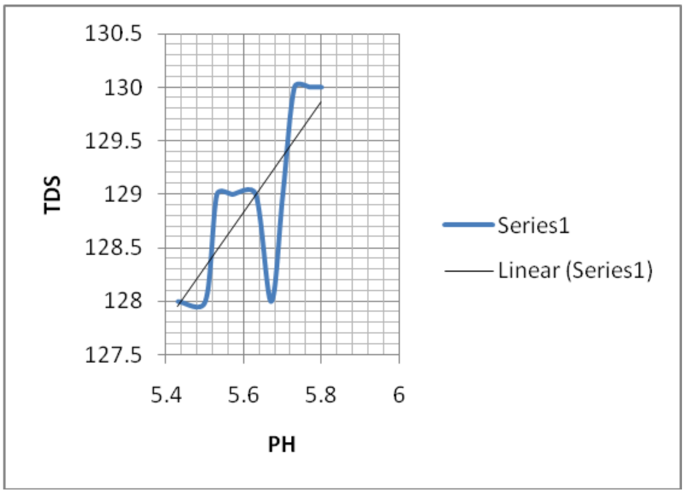


**Figure 11:** PH vs TDS for Mud Water

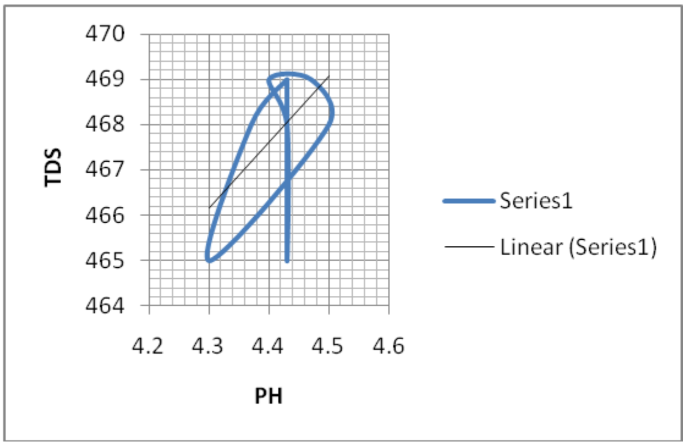


**Figure 12:** PH vs TDS for Salt Water

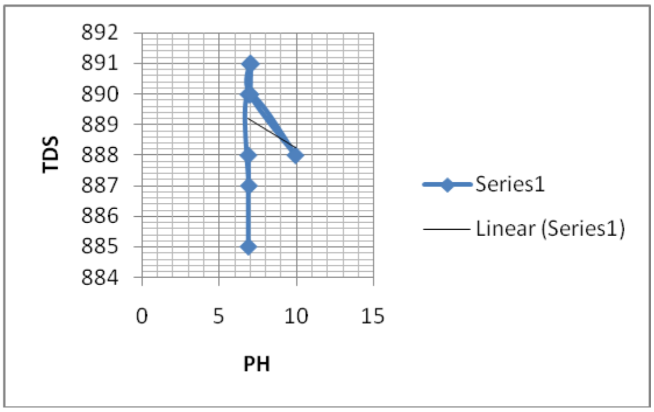


**Figure 13:** PH vs TDS for Tap Water

Fig.14 shows the Cloud server webpage of IoT based Water Quality monitoring system. Fig.15 shows the graph data sheet of Ph versus TDS.Fig.16 shows the CSV file of the trained data set for different types of water. Fig.17 shows the Predicted output file which can be accessed by mobile

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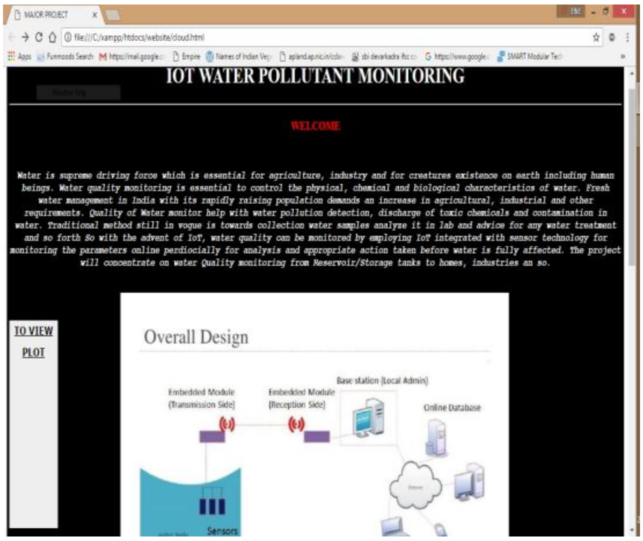


**Figure 14:** Cloud server webpage system

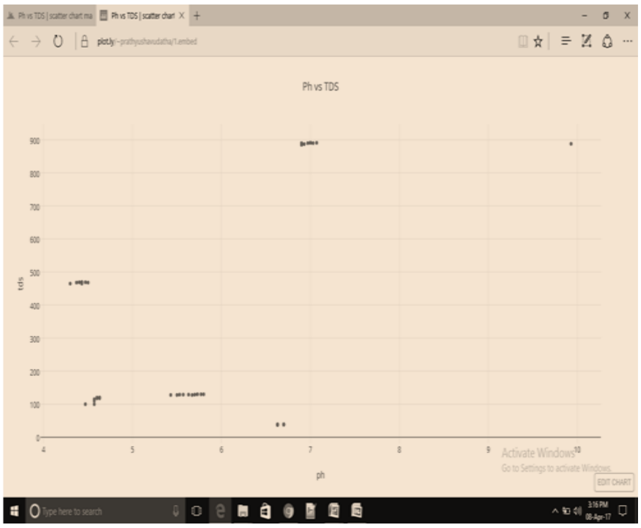


**Figure 15:** Graph data sheet of PH versus TDS

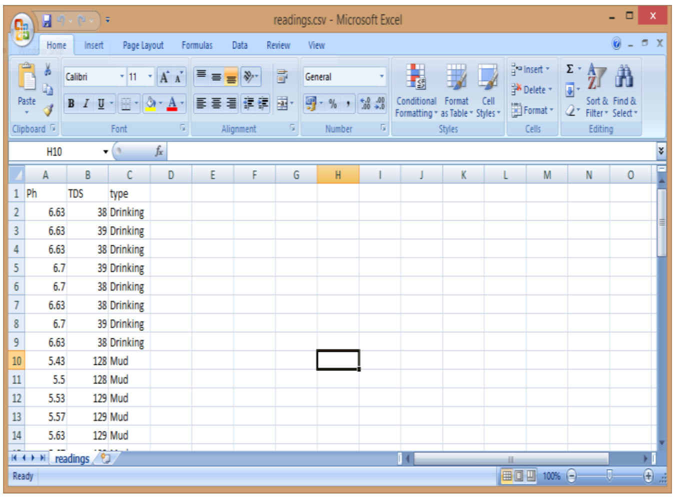


**Figure 16:** CSV File of Trained Data Set

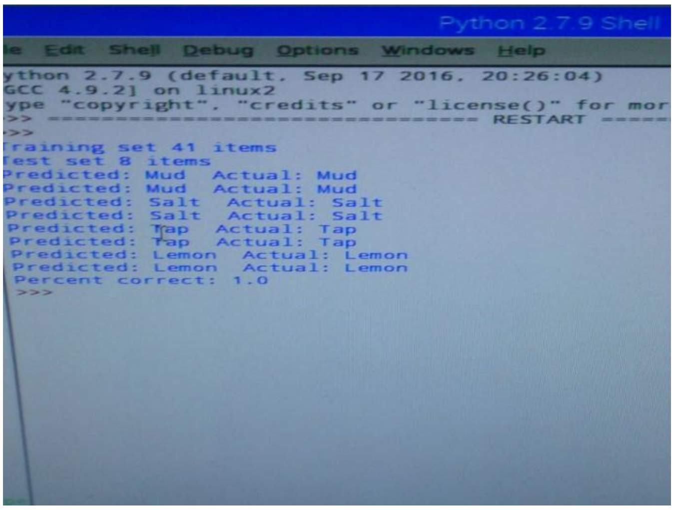


**Figure 17:** Predicted output file

## CONCLUSION AND FUTURE WORK

Water Quality monitoring is very much needed as it is consumed by residents. Traditional water Quality monitoring and some f the technology based Water Quality got lot of challenges. In addition there is no intelligence in existing water Quality Monitoring for analysis and prediction.

Now with the advent of Machine to Machine communication(M2M) which involves devices to communicate among themselves in taking action and this can be deployed over large geographical area compared to small area as seen in previous system.

So accordingly we here have developed an Intelligent IoT based Water Quality Monitoring system which is based on M2M. The system here receives the input to microcontroller where PH and TDS connected. The sensor input is transmitted serially to Pi3 which is edge level processor where machine learning algorithm employed for predicting the Water Quality based on trained data set. The trained data set and predicted data are stored in Cloud server for access via their mobile phone. This has resulted in complete automated Water Quality Monitoring system employing IoT Technologies where devices communicate among themselves in predicting the Water Quality for residential area. This proves that the water quality can be monitored automatically with no human involvement.

In Future, IoT based Water Quality monitoring system can be extended not just for Storage tank but also for deciding on Ponds, rivers and water pipes too. The same work can be extended by looking into other water parameters rather than just PH and TDS and accordingly control the flow of water based on water quality. Lastly the data security and integrity of data need to be secured while transmitting for analysis towards prediction and actuating the valve of water tank and storage area too.

## ACKNOWLEDGMENT

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