Technology: Applied Data Science

Domain: Water

Title: Efficient Water Quality Analysis & Prediction Using Machine Learning

Abstract:

Water is one of the vital needs of all living beings. Humans need water in many daily activities like drinking, washing, bathing, cooking etc. If the quality of water is not good then it becomes unfit for drinking and other activities. The quality of water usually described according to its physical, chemical and biological characteristics. Hence it becomes necessary to find the suitability of water for drinking, irrigation and Industry purpose. The groundwater quality based on Sodium percent, Sodium Absorption Ratio and Residual Sodium Carbonate will help to identify the suitability of water for irrigation purpose. Rapid industrialization and use of chemical fertilizers and pesticides in agriculture are causing deterioration of water quality and depletion of aquatic biota. Due to use of contaminated water, human population suffers from water borne diseases. Parameters that may be tested include temperature, pH, turbidity, salinity, nitrates, TDS, Cations, Anions and phosphates.

Introduction:

Ground water, surface water (rivers, streams and ponds), atmospheric water (rain-water, snow and hail) and springs are the main source of water available to the people in general. The qualities of these water bodies vary widely depending on the location and environmental factors. The major source of ground water is precipitation that infiltrates the ground and moves through the soil and pore spaces of rocks. Other sources include water infiltrating from lakes and streams, recharge ponds and waste-water treatment system.

As ground water moves through soil, sediment and rocks, many impurities such as disease-causing microorganisms are filtered out. Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biological agents. To maintain a good health however, water should be safe to drink and meet the local standards and international standards to taste, odour and appearance. To monitor the water resource and ensure sustainability, national and international criteria and guidelines established for water quality standards are being used.(WHO-1993; 2005).The chemistry of water is very dynamic, largely controlled and modified by its medium of contact. Since the chemistry of water directly hints the quality of water for various purposes, its monitoring and assessment gained substantial importance in the present century.

A tremendous increase in the population increased the stress on both surface and the groundwater. It is believed at the beginning of the human civilization itself, groundwater was the most trusted form of drinking water because of the filtering effect of the aquifer. However, in the present world drinking the water directly from the source without proper treatment is a tough task. The groundwater analysis for physical and chemical properties is very important for public health studies. These studies are also main part of pollution studies in the environment. The groundwater contains dissolved solids possesses physical characteristics such as odour,

taste and temperature. The natural quality of groundwater depends upon the physical environment, the origin, and the movement of water. As the water moves through the hydrological cycle, various chemical, physical and biological processes change its original quality through reactions with soil, rock and organic matter. Natural processes and human activities cause the changes in groundwater quality, directly or indirectly. According to WHO organization, about 80% of all the diseases in human beings are caused by water.

Literature Review:

The extensive literature review was carried out by referring standard journals, reference books and conference proceedings. The major work carried out by different researchers is summarized below. Dinesh Kumar Tank et.al [01] study focused on the hydrochemistry of groundwater in the Jaipur city to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. Groundwater samples were collected from eleven stations of Jaipur city during monsoon season and were analyzed for physico-chemical parameters such as pH, EC, TDS, sodium, potassium, calcium, magnesium, chloride, sulphate, carbonate, bicarbonate, nitrate and fluoride. Comparison of the concentration of the chemical constituents with WHO (world health organization) drinking water standards of 1983, the status of groundwater is better for drinking purposes. The parameters like pH, sodium, potassium, carbonate, bicarbonate, chloride are within permissible limit as per WHO but calcium, magnesium and nitrate values exceeding the limit. The calculated values of SAR, RSC and percentage sodium indicate that the water for irrigation uses is excellent to good quality. US Salinity diagram was used for evaluating the water quality for irrigation which suggests that the majority of the groundwater samples were good for irrigation.

Vikas Tomar et.al [02] collected water samples from 67 locations during pre and post-monsoon seasons of the year 2011 from Karnal district, Haryana and were subjected to analysis for chemical characteristics. The type of water that predominates in the study area was of sodium-calcium bicarbonate and magnesium bicarbonate type during pre and post-monsoon seasons of the year 2011 respectively and based on hydro-chemical facies.Based on chemical analysis, the pre and post monsoon water samples were classified as per different standard irrigation criteria to study the chemical changes resulting due to rain and natural recharge. It indicates that Na-Ca-HCO3 type water dominates during pre monsoon and Mg-HCO3 during post monsoon seasons of the year 2011.

Chidanand Patil et.al [03] carried out Physical, chemical, bacteriological analysis of water samples from seven bore wells located around landfill site at Turmuri, Belgaum to ascertain the magnitude of dumpsite pollution on groundwater quality. During the study period,7 bore wells were selected around the landfill area at a distance of 500, 750 and 1000m.The parameters analyzed during the study period were pH, Total dissolved solids(TDS),Total Hardness, Nitrate, Most Probable Number (MPN) and heavy metal such as Lead using standard laboratory procedures. The pH ranged from 6.01 to 7.3 indicating acidic in nature in the month of Feb and March, but in the month of April and may all the wells within the levels.

The pHs of water in wells within 500-700m are contaminated by the leachate of landfill. Concentrations of Hardness, TDS, Nitrate ranged from 0 to 80 mg/L, 49 to 190 mg/L, 4 to 79.89 mg/L respectively. The analysis

was done for four months from Feb to May. The results showed that within 500 m bore wells were contaminated by E-Coli bacteria, also nitrate concentration is above the permissible level described by WHO and Bureau of Indian Standards for drinking water and pH were acidic in nature. The polluted water requires certain levels of treatment before use. Public enlightenment on waste sorting, adoption of clean technology, using climate change mitigation strategies and the use of sanitary landfill to prevent further contamination of ground water flow are recommended.

Sarala C.et.al [04] studied the groundwater quality parameters in the surrounding wells of Jawaharnagar, in upper Musi catchment area of Ranga Reddy district in Andhra Pradesh. The bore wells data was collected from the study area for two seasons i.e., post monsoon in December 2007and pre monsoon in June 2008. The groundwater is acidic in nature and very hard. It is done by using Arc GIS software. The study reveals that the concentrations of major constituents are well within the permissible limits of IS10500-1994, except in few cases where total hardness and fluoride concentrations are high. The fluoride conc. exceeded the permissible limit. From the analysis it was observed that the groundwater is polluted in the entire study area. During last few years, the utilization of surface and groundwater for drinking, industrial and agricultural purposes has increased manifolds but consequently it is observed that the water is polluted and affecting the human health, soil nutrients,livestock,biomass and environment in certain areas.

Priti Singh et.al [05] he assess and map the spatial distribution of ground water quality of the Dhankawadi ward,pune by using GIS.APHA's standard laboratory procedure has been adopted to assess the quality of ground water. The spatial distribution map of pH, Chlorides, Magnesium and Sulphate shows that, these parameters are within range as per standard.TDS and Nitrate concentrations in ground water of the study area exceed the permissible limit at central location at katraj dairy near katraj,Pune.

People can use the ground water for drinking and domestic purpose in study area except in upper katraj nagar, Pune. Priyanka Pandey et.al [06] he analysis the physiochemical properties of ground water near munciple solid waste dumping sites in Jabalpur. All the samples were collected from bore well and hand pump near the MSW dumping sites and stored at 40C. The temp. of ground water sample ranged from 25.11 to 27.310C.The study is carried out on parameters which are selected for testing are pH,TSS,TDS,COD,Nitrate,Cl,PO4 - ,Fetc.The parameters for both type water are within permissible limit for the use except TDS,TSS,TS.

Adetunde L.A.et.al [07] have studied the area and investigated Physicochemical and bacteriological qualities of well water in the Ogbomoso North areas and South local government areas of Oyo State, Nigeria. Water samples were collected from 20 hand dug wells in the Ogbomoso North and 20 hand-dug wells in the Ogbomoso South local areas. The results showed that most of the physical and chemical parameters were within the acceptable guide line limits of the WHO for drinking and domestic water. The well water is mostly soft, alkalinity ranged from 30- 390mg/l and 40- 236mg/l for North and South respectively. pH ranged between 6.2-8.8 in both areas, SO4 2- and CL- ions concentrations fell within WHO set standards. Hardness ranged between 40- 504mg/l and 60 to 384mg/l for North and South areas respectively. Well water in some areas is moderately hard to very hard. Such microbial contamination posed a threat to well water quality and could lead to an increase risk level of outbreak of water borne diseases in the two local government areas of Oyo State.

Shimaa M. Ghoraba et.al [08] collected 120 ground water samples from 29 Districts of Balochistan,Pakistan. The various parameters are selected for the testing of samples. All samples were analyzed for pH, Calcium, Carbonate, Magnesium, Sodium, Potassium, Chlorides, Sulphate and Nitrate, TDS and bicarbonate. The results revealed highly variable hydrochemistry. The chloride is found to be most predominating. The groundwater in Balochistan has high concentrations of fluoride, iron and nitrate in many districts. The pH part of the Durov diagram reveals that groundwater in study area is alkaline and electrical conductivity of most of samples lies in the range of drinking water standards adapted in Pakistan. From the SAR and conductivity plot it was found that most of groundwater cannot be used on soil without restricted drainage and special requirement of Management for salinity control. Comparison of data with WHO(2011) standards for drinking water indicate that the groundwater in the most of study area are suitable for drinking purpose except some few places. The groundwater recorded a wide range in TDS.

M.R.G. Sayyed et.al [09] assessed the groundwater from the south-eastern part of Pune city for the seasonal variation in their quality parameters. Using Piper diagram the hydrogeochemical facies were identified and the groundwaters were classified with regards to the changes in their major chemical compositions. Based on the hydrogeochemical facies it has been found that the groundwater regime is severly deteriorated by the anthropogenic activities. The predominant SO4 and Cl in the wells of Fursungi and Mantarwadi areas have strong influence of leachate throughout the year due to solid waste disposal site.

K.C.Khare et.al [10] he was done water quality assessment of Katraj lake, pune. He was done water analysis for the parameters like pH, DO, BOD, COD, TDS, Calcium, Magnesium and Hardness for lake water. The analysis of Water quality indicates the temperature in the range of 240 C.The pH was 7.3 to 8.45.It shows slightly alkaline water. The DO varied from 4.8 to 5.7 mg/l.The total hardness ranged from 160 to 298 mg/l which is higher than

Assessment of Water Quality:

In now days due to increase in population, industrialization, agricultural activities and urbanization, large quantities of sewage and industrial wastewater are discharged into water bodies has significantly contributed to the pollution of the surface and ground water. The objective of the present study was to assess water quality of various ground water sources in India for drinking and agriculture. For the assessment of water pollution status of the water bodies, the following water quality parameters were analysed:

- pH
- Conductivity
- Temperature
- Total dissolved solid (TDS)
- Total Alkalinity
- Hardness
- Cations and Anions
- Carbonates and Bicarbonates
- Sulphates

Measurement of pH:

The pH is important parameter of water, which determines the suitability of water for various purposes such as drinking, bathing, cooking, washing and agriculture etc. The pH level of water having desirable limit is 6.5 to 8.5 as specified by the BIS. Pure water is said to be neutral, with a pH of 7. Water with a pH below 7.0 is considered acidic while water with pH greater than 7.0 is considered as basic or alkaline.

Measurement of Conductivity:

Electrical conductivity is the capacity of electrical current that passes through the water. It is directly related to concentration of ionized substances in water and may also be related to problems of excessive hardness.

According to BIS and ICMR the desirable limit of Conductivity is 600 µm/cm. Solutions of most inorganic acids, bases, and salts are relatively good conductors. In contrast, the conductivity of distilled water is less than 1 µmhos/cm.

Measurement of Alkalinity:

The standard desirable limit of alkalinity of potable water is 120 mg/l. The maximum Permissible level is 600 mg/l. Excessive alkalinity may cause eye irritation in human and chlorosis in plants (Sisodia and Moundiotiya, 2006). It is measured by titration with standardized acid to a pH value of 4.5 and is expressed commonly as milligrams per liter as calcium carbonate.

Measurement of TDS:

TDS in groundwater can also be due to natural sources such as sewage, urban runoff and industrial waste (Joseph, 2001; permissible limit. The turbidity of water was 28 to 42 NTU which is higher as per the APHA limit. Mona A. Hagras et.al [11] to assess the quality of groundwater and to characterize the hydrochemical characteristics of the groundwater in Punjab, groundwater samples were collected from different cities of Punjab Province and analyzed for 28 water quality parameters Groundwater suitability for domestic and irrigation purposes was assessed by using WHO and USDA standards.SAR values and the sodium percentage (Na%) in locations indicate that majority of the groundwater samples are suitable for irrigation. This investigational study indicates that water in many cities of Pakistan is unsafe for human consumption due to presence of both bacterial and chemical contamination. Swarna Latha, 2008). According to BIS and ICMR the desirable limit of TDS is 500 mg/l. If TDS value is more than 500 mg/l, it may cause gastro intestinal irritation. High TDS presence in the water decreases the quality and affects the taste of water (Guru Prasad, 2005).

Measurement of Hardness:

The limit of total hardness value for drinking water is to be within 300 mg/l of $CaCO_3$.Higher concentration of hardness was found may be due to natural accumulation of salt, or surface runoff, water enter from direct pollution by human activities.

Measurement of Chloride:

Chloride is one of the most important parameter in assessing the water quality and higher concentration of chloride indicates higher degree of organic pollution (Yogendra and Puttaiah, 2008). According to BIS and ICMR the permissible limit of chloride in drinking water is 250 mg/l. High concentration of chloride was observed may be due to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from industrial or domestic use (Renn, 1970). In drinking water, high chloride content may lead to laxative effects (Raviprakash and Rao, 1989; Dahiya and Kaur, 1999).

Measurement of Turbidity:

Nephelometer instrument measures the intensity of scattered light by turbid particles at right angle to the incident beam of light in comparison with the intensity of light passing through the sample. Scattering of light is a function of Tyndall effect exhibited by colloidal suspended particles. Turbidity of samples is measured by Nephelometer based on this principle. The maximum Permissible level is 5 NTU.

Measurement of Temperature:

The temperature is measured with help of Digital Thermometer. The thermometer is immersed in sample and temperature is recorded.

Sr. No	Parameter	BIS Specification
1	pH	6.5 – 8.5
2	Conductivity	600 Ms/cm
3	Alkalinity	200 Mg/l
4	TDS	500 Mg/l
5	Hardness	300 Mg/l
6	Chlorides	250 Mg/l
7	Turbidity	5 NTU
8	Temperature	23°C
9	Ca	75 Mg/l
10	Mg	30 Mg/l
11	Na	200 Mg/l
12	K	200 Mg/l
13	Carbonates and bicarbonates	-
14	Sulphate	150 Mg/l

Data Pre-processing:

Data pre-processing is a process of cleaning the raw data i.e. the data is collected in the real world and is converted to a clean data set. In other words, whenever the data is gathered from different sources it is collected in a raw format and this data isn't feasible for the analysis.

Therefore, certain steps are executed to convert the data into a small clean data set, this part of the process is called as data pre-processing Follow the following steps to process your Data

- Import the Libraries
- Importing the dataset
- Taking care of Missing Data
- Label encoding
- One Hot Encoding
- Feature Scaling
- Splitting Data into Train and Test

Step1: Importing the libraries

First step is usually importing the libraries that will be needed in the program. Import the pandas library and give a shortcut name as pd

```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
```

Step 2: Import the Dataset

We will need to locate the directory of the CSV file at first (it's more efficient to keep the dataset in the same directory as your program) and read it using a method called read_csv which can be found in the library called pandas

```
dataset = pd.read_csv(
r'C:\Users\Hari Chandan\Desktop\Data_Preprocessing\Data.csv')
```

Step 3: Taking Care of missing Data

Sometimes you may find some data are missing in the dataset. We need to be equipped to handle the problem when we come across them. Obviously you could remove the entire line of data but what if you are unknowingly removing crucial information? Of course we would not want to do that. One of the most common ideas to handle the problem is to take a mean of all the values of the same column and have it to replace the missing data.

We will be suing dataset.isnull().any() method to see which column has missing values.

```
dataset.isnull().any()
```

Country	False
Age	True
Salary	True
Purchased	False
dtype:bool	

Word "True" that the particular column has missing values ie, in our dataset age and salary column has missing values.We can replace the missing values by, mean median or mode by using fillna method. The arguments that are to be passed are as follows:

```
dataset.fillna(dataset.mean(),inplace=True)
```

If you apply this to dataset where ever you find the missing values in any column that will be replaced.

Or you can also specify an individual column ,which is as follows

```
dataset['Age'].fillna(dataset['Age'].mean(),inplace=True)
dataset['Salary'].fillna(dataset['Salary'].mean(),inplace=True)
```

If you find textual data in the respective column then use mode to replace the missing values

Step 4: Label Encoding

Sometimes in the dataset we will find textual data like names, countries states, then the machine cannot do mathematical operations or cannot understand the textual data. So the textual data are to be converted in to numerical format which is called as label encoding. we make use of label Encoder class to convert textual data

in to Numerical data. In the given dataset country has textual data so we will be converting that particular columns textual data to numerical values.

```
from sklearn.preprocessing import LabelEncoder
labelencoder_y = LabelEncoder()
dataset['Country'] = labelencoder_y.fit_transform(dataset['Country'])
```

You have to apply this for every column which has textual data Now the country column with country names will be converted in to numerical values. These numerical values are assigned based on alphabetical order. In the data set we have three countries France Spain and Germany. France is assigned with 0, Germany is assigned with 1 and Spain is assigned with 2. If you consider mathematical expressions, then number 2 will be greater than 1 and 1 will be greater than 0. But here countries are assigned with numbers whenever your machine get this number then it will think Germany is greater than japan or vice versa so we have to encode these numerical values in to binary format so that our machine will not consider any priority to the country. Before converting into binary format lets split the data set in to independent and dependent variable

Step 5: Splitting Dataset in to Independent variable and Dependent variable

To read the columns, we will use iloc of pandas (used to fix the indexes for selection) which takes two parameters — [row selection, column selection].

```
x = dataset.iloc[:, 0:3].values
y = dataset.iloc[:, 3].values
```

From the above piece of code ":" indicates you are considering all the rows and "0:3" indicates we are considering column 0 to 2 as input values and assigning them to variable x. in the same way in second line ":" indicates you are considering all the rows and "3" indicates we are considering only one column 3 as output value and assigning them to variable y

Step 6: One Hot Encoding

As discussed in step3 we are converting numerical data in to binary data. This is what happens when you binaries your data

Country	X[0]	X[1]	X[2]
Spain	0	0	1
Germany	1	0	0
France	0	1	0

In the above table extra three columns are created. Based on the categories those many columns will be appended to the x variable To accomplish the task, we will import yet another library called OneHotEncoder. Next we will create an object of that class, as usual, and assign it to onehotencoder. OneHotEncoder takes an important parameter called categorical_features which takes the value of the index of the column of categories.

```
from sklearn.preprocessing import OneHotEncoder
onehotencoder = OneHotEncoder(categorical_features = [0])
```

The code above will select the first column to OneHotEncode the categories. we will use fit_transform OneHotEncoder and additionally include toarray()

```
X = onehotencoder.fit_transform(X).toarray()
```

If you check your dataset now, all your categories will have been encoded to 0s and 1s. we should remove the dummy variable with following syntax

```
X = x[:,1:]
```

The above piece of code will vomit the first column keeping all the other columns

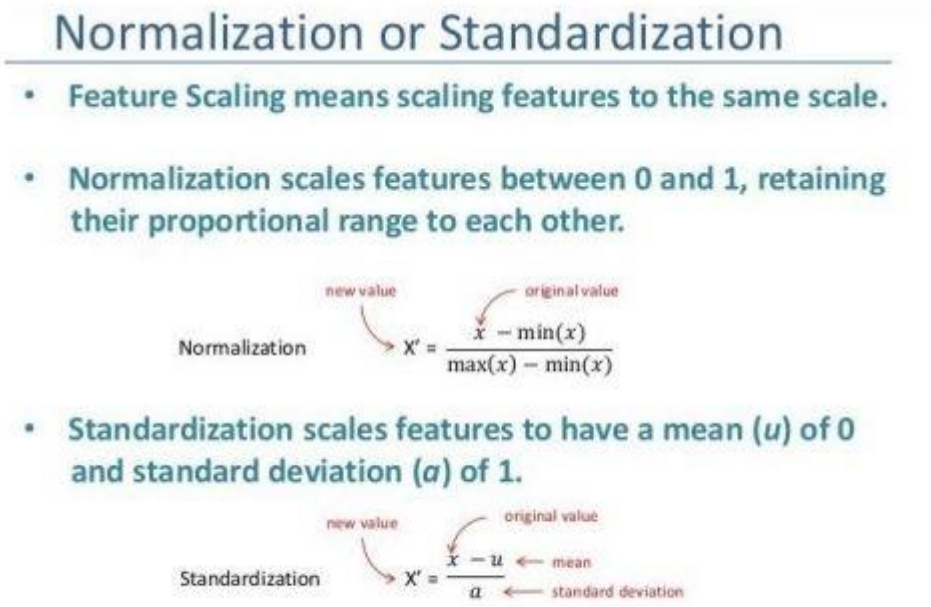
Step 7: Splitting The dataset in to Train set and Testing set

Now we need to split our dataset into two sets — a Training set and a Test set. A general rule of the thumb is to allocate 80% of the dataset to training set and the remaining 20% to test set. For this task, we will import test_train_split from model_selection library of scikit. Now to build our training and test sets, we will create 4 sets— X_train (training part of the matrix of features), X_test (test part of the matrix of features), Y_train (training part of the dependent variables associated with the X train sets, and therefore also the same indices) , Y_test (test part of the dependent variables associated with the X test sets, and therefore also the same indices). We will assign to them the test_train_split, which takes the parameters — arrays (X and Y), test_size (if we give it the value 0.5, meaning 50%, it would split the dataset into half. Since an ideal choice is to allocate 20% of the dataset to test set, it is usually assigned as 0.2. 0.25 would mean 25%, just saying).

```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y,
                                   test_size = 0.2, random_state = 0)
```

Step 8: Feature scaling

The final step of data preprocessing is to apply the very important feature scaling. It is a method used to standardize the range of independent variables or features of data. A lot of machine learning models are based on Euclidean distance. If, for example, the values in one column (x) is much higher than the value in another column (y), (x2-x1) squared will give a far greater value than (y2-y1) squared. So clearly, one square difference dominates over the other square difference. In the machine learning equations, the square difference with the lower value in comparison to the far greater value will almost be treated as if it does not exist. We do not want that to happen. That is why it is necessary to transform all our variables into the same scale. There are several ways of scaling the data. One way is called Standardization which may be used. For every observation of the selected column, our program will apply the formula of standardization and fit it to a scale.



To accomplish the job, we will import the class StandardScaler from the sckit preprocessing library and as usual create an object of that class. Now we will fit and transform our X_train set (It is important to note that when applying the Standard Scalar object on our training and test sets, we can simply transform our test set but for our training set we have to at first fit it and then transform the set). That will transform all the data to a same standardized scale.

```
from sklearn.preprocessing import StandardScaler
sc1 = StandardScaler()
x_train = sc1.fit_transform(x_train)
x_test = sc1.transform(x_test)
```

These are the general 8 steps of pre-processing the data before using it for machine learning. Depending on the condition of your dataset, you may or may not have to go through all these steps.

Conclusion

- Total Hardness was observed some evidence indicates its role in heart diseases and hardness of 150-300 mg/l and above may cause kidney problems and kidney stone formation, as it causes unpleasant taste and reduce ability of soap to produce lather. Hard water is unsuitable for domestic use.
- The suggested measures to improve the ground water quality includes total ban on the activities that causes pollution, avoid use of pesticides and prevent entrance of sewage in to ground water.
- Water quality assessment shows that the most of the water quality parameters slightly higher in the wet season than in the dry season.
- Water quality is dependent on the type of the pollutant added and the nature of self purification of water.

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