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PREDICTION OF WASTEWATER TREATMENT PLANT EFFICIENCY BY USING ARTIFICIAL NEURAL NETWORK: A REVIEW

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ABSTRACT:
This paper aim to prediction of Waste Water Treatment Plant(WWTP) efficiency by using Artificial Neural Network (ANN) models. It provides as an assessment tool for design and modeling performance for WWTP to controlling the operation of the processes. This paper focuses on approach with a Feed Forward Back Propagation to predict the performance on the terms of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS), pH, Temperature (T) and other parameters data gathered during research. ANN process to assess the stability of environmental balance as well as these would minimize of operation cost performance of ANN models are Technique Forecasting data i.e. Statistical Analysis to compared via the parameters of Root Mean Squared Error(RMSE), Mean Absolute Error (MAE) and Correlation Coefficient(R) between the observed and predicted output variables reached upto the ranges 0.01 to 0.99which implies that the model is viable as a soft sensor for control and management systems for WWTPs. Overall, ANN models provides a simple approach for the data analyzing purposes used to MATLAB software most of the times in neural network analysis.

Key words: - Artificial Neural Network (ANN), MATLAB[b*], Modeling, Statistical Analysis, Waste Water Treatment Plant(WWTP)

INTRODUCTION:

Water quality plays an essential role in any aquatic system such as reflecting the degree of water pollution and influencing the growth of aquatic organisms. Main roles to predicting future water quality changes is for early water pollution control and plays acrucial role in environmental monitoring, ecosystem management and human health[1]. As a result, wastewater treatment plants (WWTPs) aredesigned to convert the wastewater into more environmentally friendly water and return it to the environment. Therefor, it is important for the plant operators and managers to know how the plant performances efficiently work [2].

Before discharge wastewater in to the environment, lakes or streams it has treated in WWTP. A standard wastewater treatment process consists of primary, secondary and tertiary treatment. In primary treatment we have to remove floatable and settleable solids. In secondary treatment which is mainly removal biodegradable of organic matter and dissolved solid. In tertiary treatment, biodegradable and non-biodegradable waste is removal which in organic matter in waste which can be broken down into carbon dioxide, water, methane or simple organic molecules by micro-organisms and other living things by composting, aerobicdigestion, anaerobic digestion or similar processes [3]. Physical, biological and chemical processes are involved which are highly non-linear and dynamic [4].

Industries use water for a variety of purposes.Most industries produce some wastewater. Recent trends have been to minimize such production or to recycle treated wastewater within the production process. Some industries have been successful at redesigning their manufacturing processes to reduce or eliminate pollutants.Sources of industrial wastewater include battery manufacturing, chemical manufacturing, electric power plants, food industry, iron and steel industry, metal working, mines and quarries, nuclear industry, oil and gas extraction, petroleum refining and petrochemicals, pharmaceutical manufacturing, pulp and paper industry, smelters, textile mills, industrial oil contamination, water treatment and wood preserving [5]. Treatment processes include brine treatment, solids removal (for example, chemical precipitation, filtration), oils and grease removal, removal of biodegradable organics, removal of other organics, removal of acids and alkalis, and removal of toxic materials [7].

An effective control of WWTP can be achieved by developing a well experienced mathematical tool for predicting the plant performance based on past observations of WWTP performance to create a decisionmaking model and shows high precision,capability and promising applications in engineering, Artificial Neural Network (ANN) will be used [9]. ANNs is very useful to control of dynamic system and in their determinationof face varying accuracy and size of input data are applied to major WWTPs [10]. Performance of aWWTP by ANN using 20 years of dynamic data and on the basis of that dataoperators will be able to anticipate theplant effluent. This study signifiedthat the ANNs operational characteristicswith a good degree of accuracy arecapable of capturing the WWTPs [6].Neural Networks are from a class of 'black box' models and ANN is one of the most popular machine learning techniques, which is a subset of artificial intelligence (AI) [11]. Itcreate a relationship between input and output variable and shows the number of publications on the modeling of the membrane. Radial Basis Function Neural Network (RBFNN), Recurrent Neural Network (RNN), Elman Neural Network (ENN) and Deep Neural Network (DNN) out some of the variation of MLP-ANNwith changes in model parameter structure and training algorithms [3]. The most commonly used ANN is BackPropagation (BP), feed forward neural network also known as multilayer perceptron (MLP) [8].

Wastewater and Wastewater Treatment Plant:

Wastewater:Wastewater is that Grey-Blackdirty water which is released from hospital, industries, domestic waste, home, etc. with including organic and inorganic impurities, dissolved and suspended particles nutrients, bacteria, microbes, etc.

1) organic impurities - Human faces, animal waste, oil, urea(urine), pesticides herbicides, fruit and vegetable waste, etc.

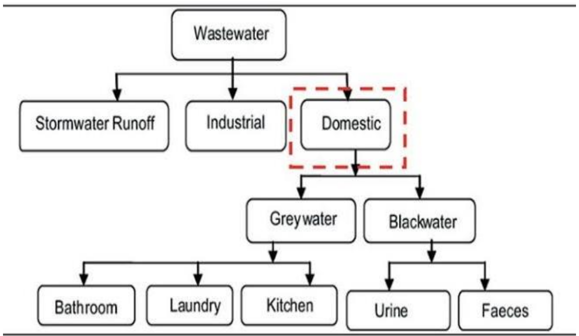
2) Inorganic impurities – Nitrate, phosphate, metals.

3) Nutrients- Phosphorous and nitrogen.

4) Bacteria- Such as cholera which causes cholera and salmonelia paratyphi which causes typhoid.

5)Other microbes- Such as protozoms which causes dysentery.

Types of Waste Water:



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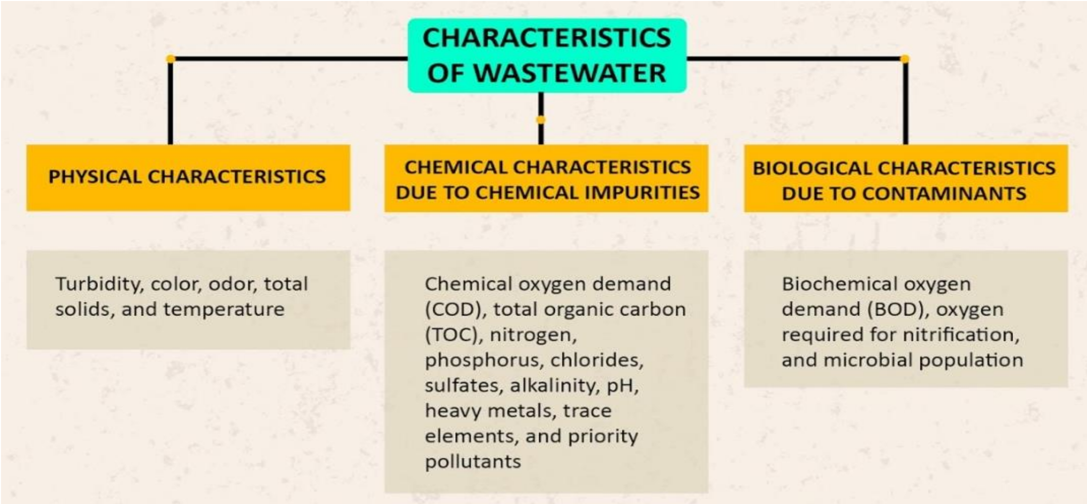
Characteristics of Wastewater: Wastewater is defined as any water that has been negatively affected in quality by human.



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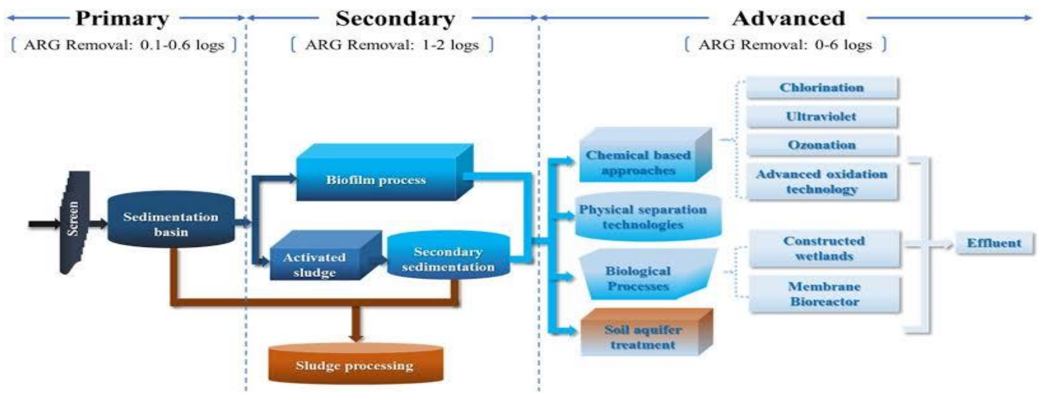
Wastewater Treatment Plant:Wastewater treatment applies special processes to wastewater to remove organic matter and other contaminants.Wastewater treatment programs aim to make the wastewater clean and safe enough to discharge back into the environment without harmingnearby residents or the local ecosystem.

Wastewater treatment systems break down into four main categories:

1) Sewage Treatment Plants (STPs)
2) Effluent Treatment Plants (ETPs)
3) Activated Sludge Plants (ASPs)
4) Common orCombined Effluent Treatment Plants (CETPs)

Existing Treatment Techniques:



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Artificial Neural Networks (ANNs):

ANN Basics*:* Artificial Neural Networks is also known as Neural Networks. (Neural-Neurons, Network-Numbers of neurons connected to each other). They have actually work to sharing information. An artificial neural network is a

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computational non-linear model that is inspired from the brain (i.e. biological neurons) like people its learn by examples. ANN can perform tasks like classification, prediction, decision making, visualizationand other just by considering examples.ANN consists of a large collection ofartificial neurons or processing elementwhich operates in parallel. Every neuron is connected with otherneurons through aconnection link andeach connection link is associated with a weight that has information about the input signal. Weight is the most useful information for neurons to solve a particular problem because it usually excites or inhibits the signals that is being communicated. Everyneurons has weighted input (synapse) an activation functions (that define the output given an input) and one output.

This is possible due to certain advantages of ANN over conventional models. These advantages are given as follows:

- Easy model building with less formal statistical knowledge required.
- Capable of capturing interactions between predictors.
- Capable of capturing nonlinearities between predictors and outcomes.
- Users can apply multiple different training algorithms.

With the advantages, there are also some limitations associated with the ANN modelling, which new data.

- Clinical interpretation of model parameters is difficult (black boxes).
- Sharing an existing ANN model is difficult.
- Prone to overfitting due to the complexity of modelstructure.
- Confidence intervals of the predicted risks are difficult to obtain.
- The model development is empirical. Few guidelines exist to determine the best network structures and training algorithms.

Model of ANN:

In above figure a_1, a_2, …., $a_n$represents various input (independent variables) to the network. Each of these input is multiplied by a connection weight or synapsis.

Weight: Weight w_{1j}, w_{2j}, …, w_{nj}shows the strength of the connection between nodes/neurons. A weight brings down the importance of the input value.

Nodes/Neurons: It is basic unit of neural network. It gets certain of inputs and bias value.

Bias: It is extra input to neurons and it is always 1 and has to own connection weight. When all the inputs are zero, value of bias inputted to an activation function.

Multilayer Artificial Neural Network:An ANN consists of artificial neurons or processing element and is organized in three interconnected layers.

1)Input Layer (Single)

2)Hidden Layer (One or more)

3)Output Layer (Single)

1) Input Layer: First layers in the neural network. This is layer contain neurons which receives input form the output world and passes them on the next layer (i.e. Hidden layer). It doesn't apply any operation on the input valuesand has no weight and biases value associated.

2) Hidden Layer: These units (neurons) are inbetween input and output layer. The jobs of hidden layer is to transform the inputinto something that output unit can use in some way.On increasing the hidden layers with neurons, the system's computational and processing power can be increased but the training process of two system gets more complicate at the same time.

3) Output Layer: It is the last layer in the neural network and it receives input from the last hidden layer with this last layer we can get desired number of values (outputs) and in a desired range

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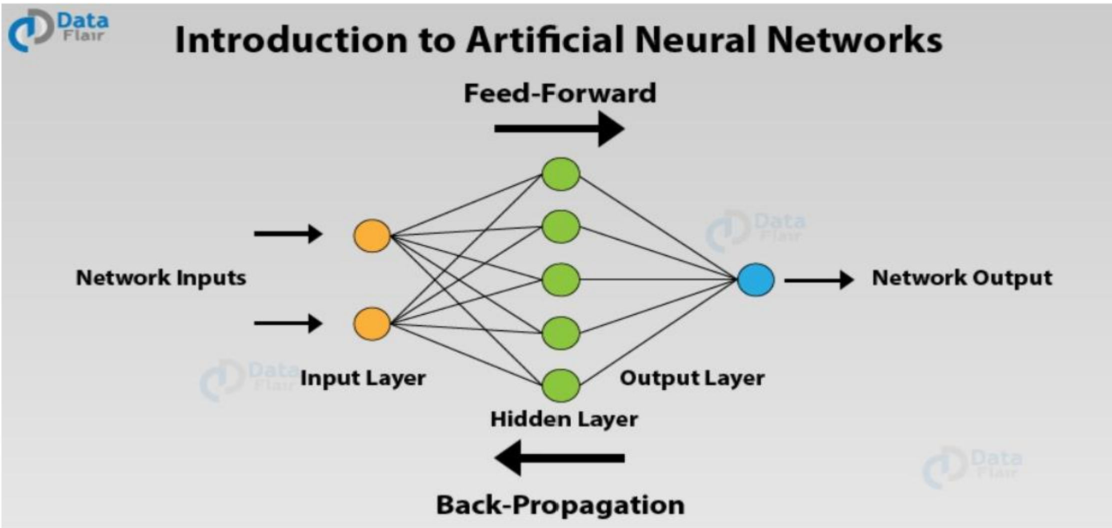

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Algorithms of ANNs functions:ANN receives input from the external world in the form of pattern and image invector form.The main purpose of activation function is to convert an input signal of a node is an ANN to as output signal. This output signal used as input to the next layer in the networks.In order limit the response to arrow at desired value the threshold value is set up.For these the sum is passed through activation Function.The activation function is set of the transfer function used to get desired output single range [0,1], [-1,1].

By considering figure 1 that is single layer of perceptron network its threshold value(b_j) or summing function is,

$$u_j = \sum_{i=1}^{n}(w_{ij} + a_i) + b_j \qquad ...... (1)$$

Node's output is determined using a mathematical operation on the node's net input. The operation is called transfer function or activation functions. The activation function can transform the node's net input in a linear or non-linear manner. Four types of commonly used activation functions are as follows:

1) Sigmoid (Logistic) Activation Function: It is one of the most widely used non-linear function. It transform the values between the range [0,1].

$$f(x) = \frac{1}{1+e^{-x}} \qquad 0 \le f(x) \le 1$$

2) Hyperbolic Tangent Transfer Function: It is similar to sigmoid function but better in performance. The advantage is that the negative input will be mapped strongly negative and the zero input will be mapped near zero in the tanh graph. The function range between [-1,1]. It is symmetric around the origin.

$$f(x) = \tan h = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \qquad -1 \le f(x) \le 1$$

3) Threshold Activation Function (Binary Step Function): Binary step function is a threshold base activation function. Also known as Heaviside Function.

$$f(x) = \begin{cases} x = 0, & x < 0 \\ x = 1, & x > 0 \end{cases}$$

4) Linear Transfer Function:

$$f(x) = x \qquad -\infty < f(x) < +\infty$$

The neuron's output o_j is found by performing one of these function on the neurons net input u_j.

Loss and Cost Function in Machines: Loss function is amethod ofevaluating how will machine learning algorithms models given data sets. If the prediction of models are wrong (means deviates to much form actual value) functionwill output a higher number and its prediction are goodit will outputa lower number. To improve the output (predictions) of machinelearning algorithm, loss function help us. With the help of some optimization functionlike gradient descent, loss function learns to reduce the error in prediction.A loss function/error function is for asingle training example.A cost function is theaverage loss over theentire training data sets. The optimization strategy like Gradientdescent aim at monitoring the cost function.

1)<u>Squared Error Loss</u>: Squared error loss for each training example is the difference between the actual and the predicted value.

$\therefore$ L=(y- f(x))^2<u>or</u> $\therefore$ L=(y-y^)^2

where, y=Actual value and y^=Predicted value

The corresponding cost function is the mean of these squared error (MSE).

$\therefore$ MSE= $\frac{\sum_{i=1}^{n}(y_i-y_i)^2}{n}$ where, n= number of observations

Mean square error is measured as the average of squared difference between prediction and actual observations. The losses the value of MSE, the better are the predictions.

2)<u>Absolute Error Loss</u>: Absolute error for each training example is the distance between the predicted and actual values irruptions of the sign.

$\therefore$ L=|y-f(x)| or $\therefore$ L=|y-y^|

The corresponding cost function is the mean of these absolute error (MAE).

$\therefore$ MAE=$\frac{\sum_{i=1}^{n}|y_i-y\hat{}_i|}{n}$

<u>Gradient Descent</u>: Gradient descent is one of the most popular and widely used optimization algorithm used for training machine learning models.The optimizes a search technique, which is used to update weight in the model or parameter. For a given machine learning models with parameters (weight and biases) a cost function used to evaluate the model.The aim of our learning problem (ANN) is tofind a good set of weight for our modelwhich minimizes the cost function.So Gradient descent is an optimization algorithmthat finds the optimal weight that reducesprediction error (cost function).

Model Design and Network Training:ANN studies is to final difficult tasks optimal network architecture its mainly depends on parameter setting. There are many heuristic technique described in the neural network literature to perform various tasks within the optimizing training, selecting an appropriately sized network, the supervised learning paradigm and predicting how much data will be required to achieve a particular generalization performance.Initial weight considerably change the performance of trained Neural Network (NN) even all parameter and NN architecture arekept constant in MATLAB NN toolbox. In this study MATLAB NN toolbox is used for ANN application. The suitable network architecture, several trails and errors have been conducted until the suitable learning rate, number of hidden layers and number of neurons (less than 30) pereach hidden layer were reached. This process is repeated N times, where N denotes the number of hidden nodes for the first hidden layer. In this study, a supervised training, back propagation algorithm is selected.This whole process is repeated for changing number of nodes in the second and third hidden layers.

Network Properties: After achieving the statistical analysis step, the neural network model was createdin MATLAB software. MATLAB Toolbox opens the Network, Data manager windows, which allows the user to import, create, use and export neural network and data. The Network properties are as follows:

- Network input: COD, BOD pH and SS
- Network output: COD, BOD IPH. SS
- Network type: Feed forward Back-propagation.
- Adaption learning function: LEARNGDM
- Training function: TRAINLM
- Training algorithm: Levenberg Marquardt

- performance function: MSE
- Number of hidden layers: 1, 2, 3

RESULT AND DISCUSSION:

For evaluation of WWTP performance, the value of BOD, COD, pH and SS in input and output of treatment were compared. The wastewater has a relatively good biological treatability considering the BOD / COD ratio of 0.6, relationship between COD and BOD of the wastewater was obtained by Linear regression (BOD=0.6COD). The realising wastewater parameters after treated should be in that desired ranges.

Sr. No.	*Parameters*	*Characteristics of composite wastewater generated (Range)*
1.	pH	7.9 - 8.5
2.	COD	720 - 784 (mg/l)
3.	BOD	298 - 340 (mg/l)
4.	Total solids	786 - 1164 (mg/l)
5.	Total dissolved solids	412 - 846 (mg/l)
6.	Total suspended solids	180 - 530 (mg/l)

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Sensitivity degree of impact of each of the input factors on the outcomes of the training, validation and testing data predicting BOD, COD and TSS model result presented in the following order: TSS > BOD> COD>pH. It can be concluded that the concentration of TSS has the highest influence on the developed ANN model [13].In this study, 70% of whole data is specified as the training data which the network would be adjusting according to its error.Similarly, 15% of database is considered as the validating data and 15% data is specified as the testing data for used to measure network generalization and to halt training when generalization steps improving. It is observed that the output tracks the targets very well for training (R-value = 0.93004), validation (R-value = 0.86323). and testing (R-value - 0.86289). These values can be equivalent to a total response of R-value = 0.90317. In this case, the network response is satisfactory, and simulation can be used for entering new inputs [12].

CONCLUSIONS:

The ANN models was developed to test its predictive performance on the quality of river water and WWTP and has a great opportunity as a predictive tool. Future research should direct attention to applying the same techniques to other catchments and consider relatively long data series to reasonably compare the performance of the models in water resources. The ANN model is a golden and valid instrument that optimizes the observational network by determining important monitoring sites and predicting river water variables quality with acceptable precision. This research line is crucial to understanding the means of linking together land use, water quality, disposal, pollutant loading and ecosystem impacts to efficiently model and predict water quality. The results of these study indicated high correlation coefficient (R-value) between the measured and predicted output variables, reaching up to 0.9 [12].

Future Perspective: Further research ANN are suggested and an improved understanding performance in predicting other water quality parameter such as nitrate and heavy metals and the waste water treatment plant performance then to compare the obtained results with the ANN technology [13].

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Figure 1. Perceptron(Single layer of ANN) [12].