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Research Article

MODEL EVALUATION OF HYBRID ANAEROBIC REACTOR TREATING DAIRY WASTEWATER

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ABSTRACT
Dairy industries have shown us great growth in size and number in most countries of the world. In recent times, the dairy industries have started incorporating sophisticated processing equipments with CIP cleaning systems and PLC based process automation systems. The dairy mill effluent is characteristically biodegradable with BOD 5, of 2500-3500 mg/l and COD restricted to 4000-5000 mg/l and pH from 5.6-8.6. The biodegradability range of dairy effluent is from 0.63 to 0.72. The hybrid anaerobic reactor was assessed with a pilot model (8 litres) for the treatment of dairy effluent. The present study evaluates the performance of hybrid anaerobic reactor under different seasons, viz, rainy and winter for treating dairy effluent. The model was made run under varying operating conditions, viz, influent flow rate (2.083, 2.500, 3.571, 5.000, 8.330lit/hr) and influent COD (1599.88, 2091.98, 2564.46 mg/l), OLR (Rainy season) (0.025, 0.031, 0.036 kg/COD/m2 day), (winter season) (0.018, 0.026, 0.032 kg/COD/m2 day) and HRT (6.00, 10.00, 14.00, 20.00, 24.00hrs) are interpreted for the respective conditions. The COD removal was observed for minimum of 78.10% starting from 78.86% for rainy season and maximum of 79.10% from 80.61%COD removal for winter season. Furthermore, multiregional input- output model and neural network models were successfully used to develop a kinetic model of the experimental data with a high correlation coefficient.

Keywords: *COD, Dairy Wastewater, HRT, HUASBR, Microbial Support Media, OLR*

INTRODUCTION

In any dairy plant, the quantity and characteristics of effluent is depending upon the extent of production activities, pasteurization of several milk products. The anaerobic digesters are used in the first phase of treatment, which is followed by high rate aerobic treatment. It remains as the most common effluent treatment scheme for dairy plants. The Indian dairy industry is stated to have the growth at more than 15% and waste water is poised to cross 150 million tonnes / annum (Banu *et al.,* 2008).
The requirement for milk and milk products is keep growing in steady state, making a significant impact on the Indian agriculture domain. The dairy industries require large quantity of water for the purpose of washing of cans, machinery and floor, the liquid waste in a dairy originates from manufacturing process, utilities and service section. So, there is every need to reuse the waste water generated with proper and efficient treatment methods. Biological wastewater treatment has been performed in many different ways. In order to overcome the limitations of suspended and attached growth systems (Castillo *et al.,* 2007).
Hybrid Up flow Anaerobic Sludge Blanket reactors are designed. UASB is a hybrid type of reactor, involving attached growth process (Lettinga, 1994). This study involves the treatment of dairy industry wastewater by HUASB reactor by varying the retention times in days for a particular organic loading rate (Badroldin *et al.,* 2008).
The conventional anaerobic digesters are attached growth systems with a random packing fill media to support sustain the microbial growth are brought to the anaerobic digesters, essentially to enhance the wastewater reduction efficiency (Demirel *et al.,* 2005).
In this study, a system of HUASBR reactor is used to evaluate the removal of COD. A laboratory scale model of HUASBR mainly involved operating at reactor various condition of HRT and influent COD concentration. The data generated were used to determine the process kinetic value of substrate biomass (Azeera, 2010).

Experimental Setup

The experimental set up consists of HUASBR reactor having 5.00 litres of effective volume. The physical features and process parameters are listed in Table 1. The schematic diagram of the experimental setup was presented in Figure 1 and Table 1.

The feed stock for the reactor was collected from Aavin dairy industry, sethiyathope, Cuddalore, Tamil Nadu, India. A cylindrical vessel of 10 cm diameter and 100 cm height was fabricated with fibre glass was provided with a five nozzles. Out of five nozzles one nozzle was provided for sampling port another one was provided for extra sludge and the another two nozzles are provided for outlet and last one was used for gas collection.

The top of the reactor hermetically sealed to avoid any air entrapment. In the bottom portion of reactor packed with fujino support media to develop the microorganisms. The reactor is fed from the influent tank by means of a peristaltic pump of miclin's make and model pp-30. The influent to the reactor was at its bottom and the reactants move from the bottom passing through packed media. The reactor was provided with sampling ports at zones viz., hydrolysis, acids genesis and methaogensis in the reactor. Separate ports were provided for desludge at bottom and for scum removal at top. The influent tank was provided with an agitator to ensure proper mixing of the wastewater. The treated effluent from the top of the reactor is obtained by overflow through effluent pipe, and at the top where the gas got separated and collected in a gas collector (Tawfika *et al.*, 2008).

Biogas produced from the reactor was collected by water displacement method using Mariotte bottle. The operating temperature of the reactors was in the mesophilic range (29-35°C).

Table 1: HUASBR – The Physical Features and Process Parameters of Experimental Model

Description	**Measurements**
Total Volume of the Reactor, lit	8.00
Effective Volume of the Reactor, lit	5.00
Total Height of the Reactor, m	1.00
Effective Height of the Reactor, m	0.64
Height of the Microbial Support Media, m	0.15
Peristaltic Pump (Miclin's Make)	pp-30 model
Influent Flow Rate lit/hr	2.083,2.500,3.571,5.000,8.330
Influent Average COD mg/l	1599.88, 2091.98,2564.46,3091.26,3556.94
Organic Loading Rate kg/COD/m2 day	At 120C (0.025,0.031,0.036,0.031,0.034), At 180 C (0.018,0.026,0.032,0.035,0.037) At 260C (0.016,0.022,0.025,0.028,0.030)

MATERIALS AND METHODS

Experimental Methodology

The random samples were obtained from Aavin dairy industry, sethiyathope, Cuddalore, Tamil Nadu, India and analyzed for specific parameters. The synthetic sample was prepared to simulate the basis of studied factors value of samples. The HUASB reactor was acclimatized by feeding; municipal sewage for 2weeks. During this period the reactor was operated in batch mode (Gavala *et al.,* 2002). After acclimatization period, the reactor was operated in a continuous mode and dairy waste water was then gradually introduced. The synthetic critical wastewater was allowed into the reactor with an average OLR 0.019 kg COD/m^2.day; during this investigation the COD was measured. The process performance was

monitored and the COD removal efficiency of the reactor under different hydraulic retention time was noted (Munavalli *et al.*, 2009).
The performance of the HUASB was investigated for treatment of dairy wastewater through experiments at particular COD concentration with varying Hydraulic retention time (HRT), the COD removal was evaluated (Rajagopal, 2008). All samples were tested on a regular basis for pH, BOD, TSS, VSS, COD, and. 50 ml sludge samples were taken from the two lower sample ports and were tested for, TSS and VSS. All analyses were performed according to Standard Methods for the Examination of Water and Wastewater APHA (2005)**.**
The synthetic dairy effluent is prepared using milk powder and introduced into the reactor after the process stabilization. The experiment ran for different operating parameters conditions, hydraulic loading rates, m3/m2.day (0.280, 0.180, 0.140, 0.100, 0.040), organic loading rates (Rainy season) (0.025, 0.031, 0.036 kg/COD/m2 day), (winter season) (0.018, 0.026, 0.032kg/COD/m2 day) and HRT hrs (6.00, 10.00, 14.00, 20.00, 24.00). The minimum COD removal efficiency was observed at 78.10% starting from 78.86% for rainy season and maximum of 79.10% from 80.61% COD removal for winter season. Removal of COD efficiency was better during winter season when compared to rainy season.

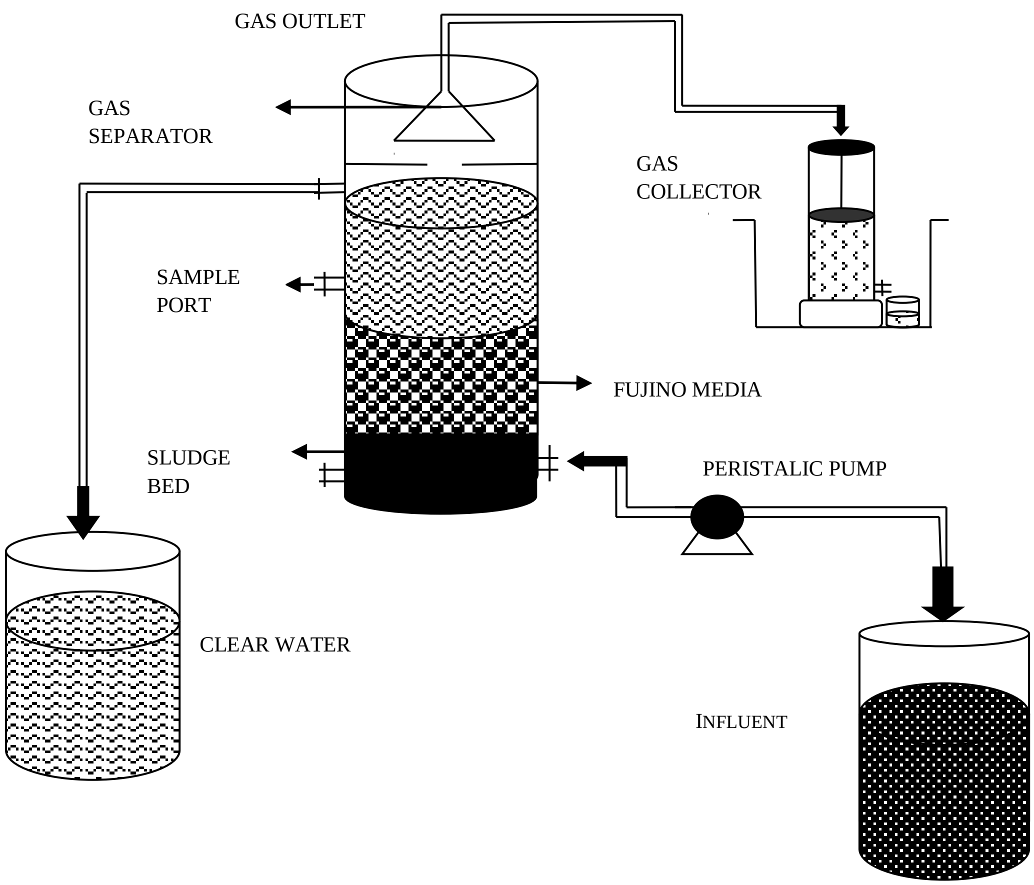

Figure 1: Schematic Diagram of the Hybrid UASB Model Reactor

Mathamatical Model
Mathematical modeling is an analytical approach to describe the specific parameters for monitoring the system performance and the results of kinetic studies obtained from experimental studies can be used for estimating treatment efficiencies of full-scale reactors with the same operational conditions.
The most widely used models in the literature for the development of study of kinetics in anaerobic digestion processes are multiregional input- output model and neural network model

Multiregional Input-Output

The extension of the input output model to multiple regions was first proposed by Isard (1960), who introduced a spatial dimension into the intersectoral:

$X_i^m = \sum_j x_{ij}^m \quad \forall i, m$ .... (1)

Where x_{ij}^m is the flow of sector *m* from region *i* to region *j*, and *i*, *j* =1, 2,..., *J*.

$\sum_i x_{ij}^m = \sum_n a_j^{mn} \sum_k x_{jk}^n + Y_j^m \;\; \forall j, m$ .... (2)

Where, $\{a_i^{mn}\}$ is the set of technical coefficients for production processes in region *i*, and *k* =1, 2,..., *J*.
Equation (2) describes the commodity balance condition, which requires that the flow of sector *m*'s goods into region *j* equals the use of that sector's goods for producing goods of other sectors (intermediate demand) plus any final demand. Of course, a region can acquire many or even all of its inputs locally (i.e., from itself), but this is not required.

As one can see, Equation (2) is insufficient for determining flows since it describes only the origin and destination flow totals. Denoting$c_j^m = \sum_j x_{ij}^m \;\; \forall i, m$ as the total consumption of commodity *n* in region *j*, one can rewrite (2) as the following:

$C_j^m = \sum_n a_j^{mn} X_j^n + Y_j^n \quad \forall j, m$ .... (3)

Where X_j^n is defined as in equation (1).

Since Leontief technology is linear, the average cost of input *n* in region *j* is taken to be the weighted average (across input origins, *i*) of purchase prices (b_j^n) plus the transportation prices (d_{ij}^n) to region *j*.

$C_j^n = \frac{\sum_i x_{ij}^n \, (b_{ij}^n + d_{ij}^n)}{\sum_i x_{ij}^n} \quad \forall j, n$ .... (4)

The sales price of a good produced by sector *n* in region *j*, b_j^n, is assumed equal to its manufacture cost3, which is given by the following:

$b_j^n = \sum_m a_j^{mn} \times c_j^m \quad \forall j, n$ .... (5)

Given$Y_i^m, a_j^{mn}, d_{ij}^n$, and λ^n,solve forx_{ij}^n, b_j^n and, $c_i^n$for all *i*, *j*, *m*, *n* .

Step 0: Initialization. Set all $x_{ij}^n, b_i^n$and $c_i^n$to initial values (usually zeros).

Step 1: Calculate all utilities from equation (3); calculate production levels $x_i^m$from (1) and consumption levels c_j^n from equation (5).

Step 2: Update all x_{ij}^n using equation (4).

Step 3: Convergence test. Check the predefined convergence criterion. (For example, max $\left(\left|x_{ij}^{n(t)} - x_{ij}^{n(t-1)}\right|\right) < 0.01 x_{ij,}^{n(t-1)} \;\; , \forall i, j, n$ where, *t* is the iteration number.) If the convergence criterion is met, then stop and the current solution { x_{ij}^n} is taken to be the equilibrium solution; otherwise, go to step 1.

Neural Network Model

A neural network model consists as a set of parallel inter-connected simple computational units, called neurons. A neuron (also known as node) is a non-linear algebraic function, parameterized with boundary values.

In this study, a three-layered back propagation neural network with tangent sigmoid transfer function (tansig) at hidden layer and a linear transfer function (purelin) at output layer was used. The back propagation algorithm was used for network training. Neural Network Toolbox V4.0 of MATLAB mathematical software was used for COD removal prediction. Data sets (120 experimental sets) were obtained from our previous study and were divided into input matrix [p] and target matrix [t]. The input variables were reaction time (t), H2O2/COD molar ratio, H2O2/Fe2+ molar ratio, pH and antibiotic concentration. The corresponding COD removal percent was used as a target. To ensure that all variables in the input data are important, principal component analysis (PCA) was performed as an effective procedure for the determination of input parameters. It was observed that all input variables were important. The data sets were divided into training (one half), validation (one fourth) and test (one fourth) subsets, each of which contained 60, 30 and 30 samples, respectively.

Software: For the development of the ANN models, Neural Network Toolbox 5 and MATLAB 9 (The Math works Inc. USA) were used.
A MATLAB script was written which loaded the data file, trained and validated the networks. The input and output data were normalized and de-normalized for application in the network. A computer with a Core™2 Duo 2.5 GHz processor and 2 GB internal memory took a few seconds for processing of each neural network

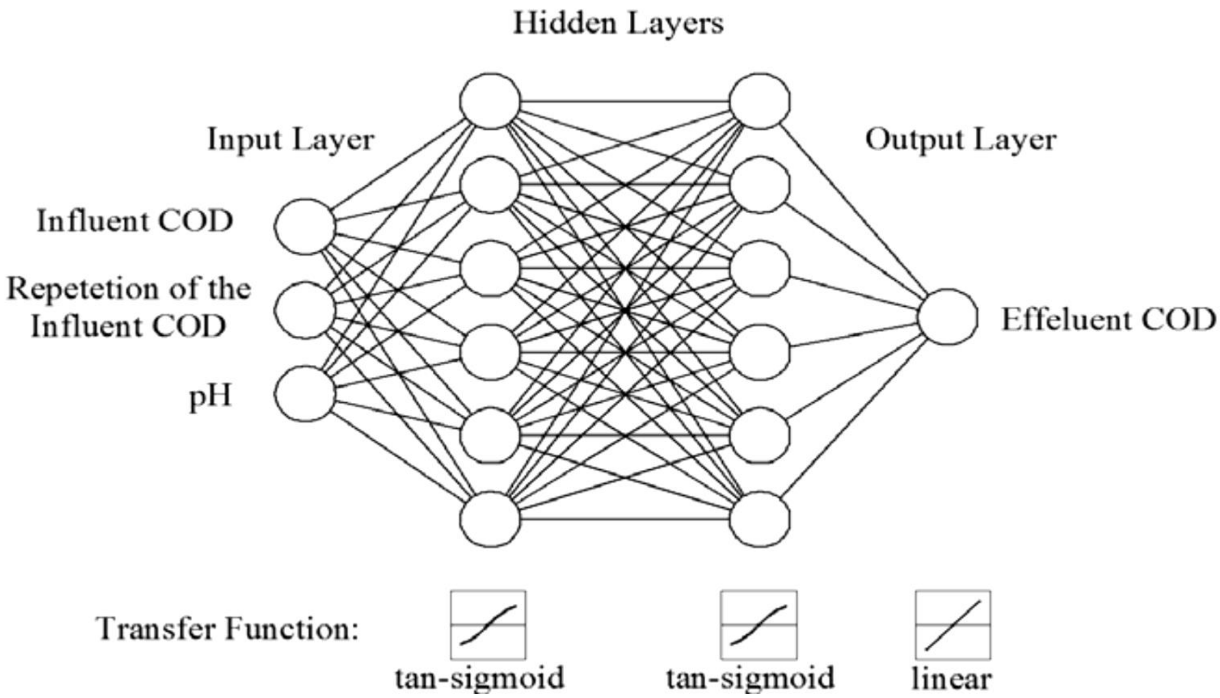

Figure 2: Structure of the Neural Network Model

RESULTS AND DISCUSSION

The dairy effluent was prepared synthetically to represent the evaluated characteristics and used in different influent COD concentrations .the average COD values of three different synthetic preparations 1599.88, 2091.98, and 2564.46 Mg/l.
The model was run five different flow rates viz., 2.083, 2.500, 3.571, 5.000, and 8.330 lit/day. The respective flow rates resulted in the operation of the model of HRT of 6, 10, 14, 20, and 24 hours.
The respective values are varying from (Rainy season) (0.025, 0.031, 0.036) kg COD /kg/m3/day, and (winter season) (0.018, 0.026, 0.032) kg COD /kg/m3/day. The HLR varies from 0.038, 0.024, 0, 016, 0.012, and 0.008.
Considering the performance of the model in respect of % COD removal efficiency, the experimental results were interpretated for OLR and HRT .The respective graphs were presented in figure.
The COD removal was observed for minimum of 78.10% starting from 78.86% for rainy season and maximum of 79.10% from 80.61%COD removal for winter season.

Multiregional Input-Output Model

The data sets were used to feed the optimized network in order to test and validate the model. Fig3,4 shows a comparison between experimental COD removal values and predicted values using the neural network model.
The figure contains two lines, one is the perfect fit y = X (predicted data = experimental data) and the other is the best fit indicated by a solid line with best liner equation y = (0.9968) X + 0.116, correlation coefficient (R^2) 0.9968.

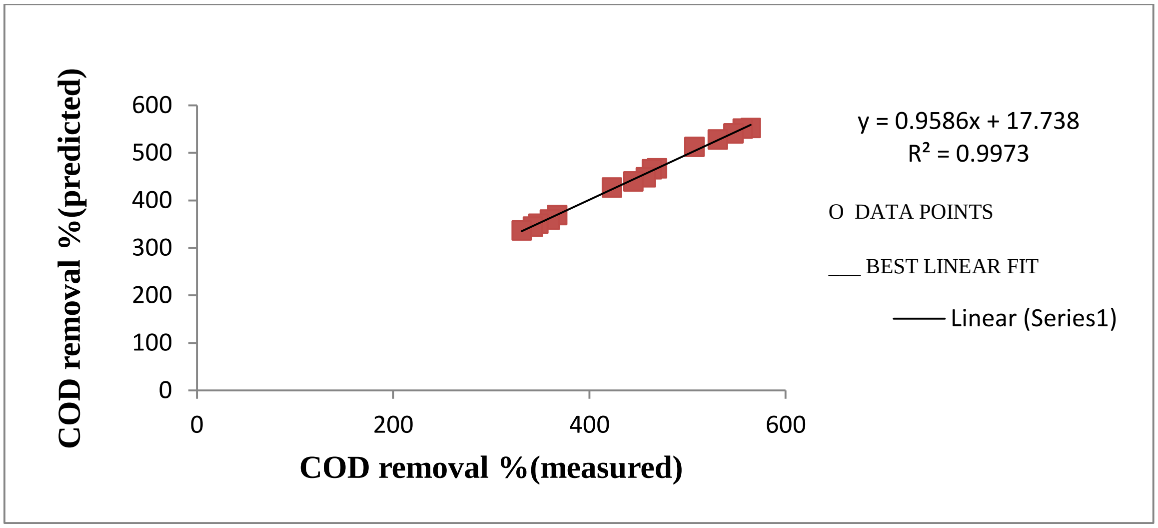

Figure 3: Comparison between Predicted and Experimental Values of the Output (RAINY SEASON)

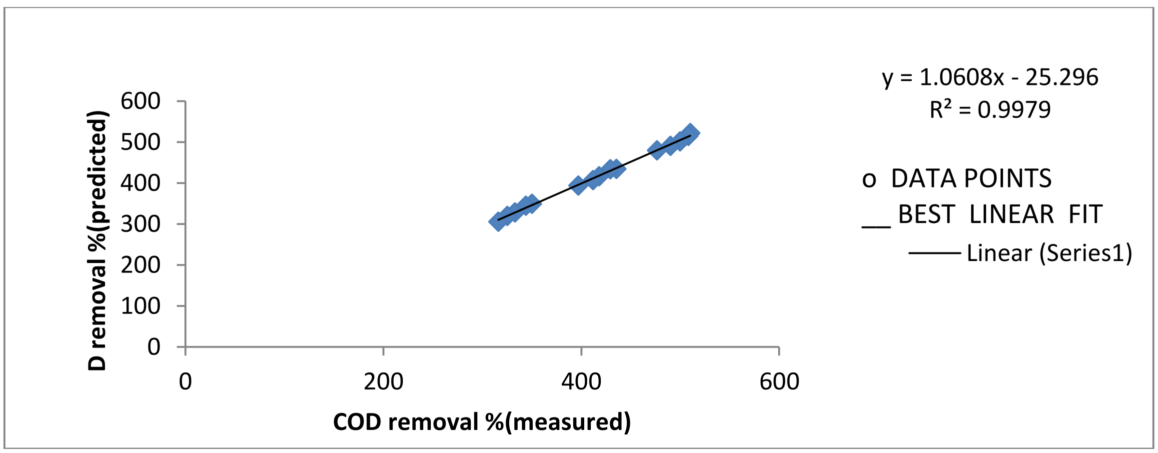

Figure 4: Comparison between Predicted and Experimental Values of the Output (WINTER SEASON)

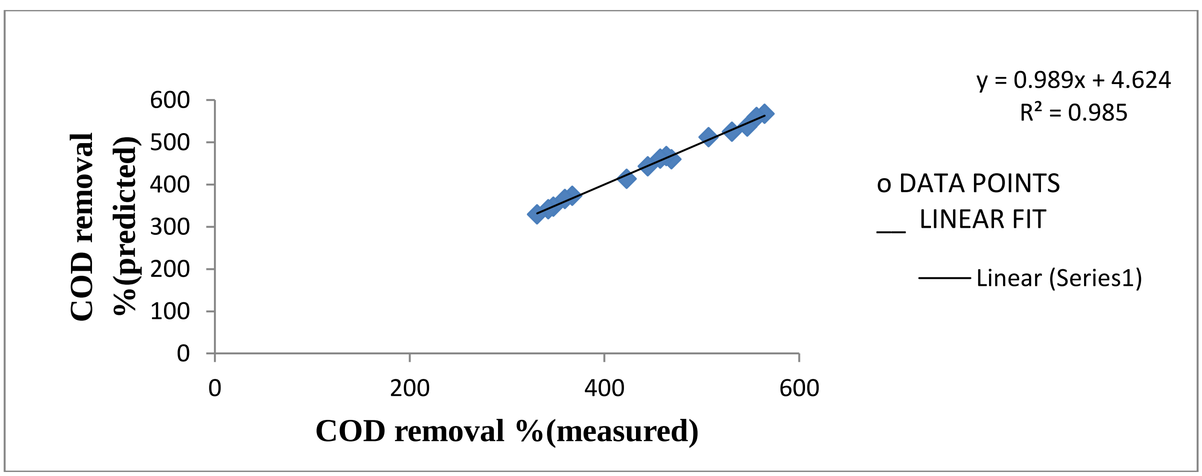

Figure 5: Comparison between Predicted and Experimental Values of the Output (RAINY SEASON)

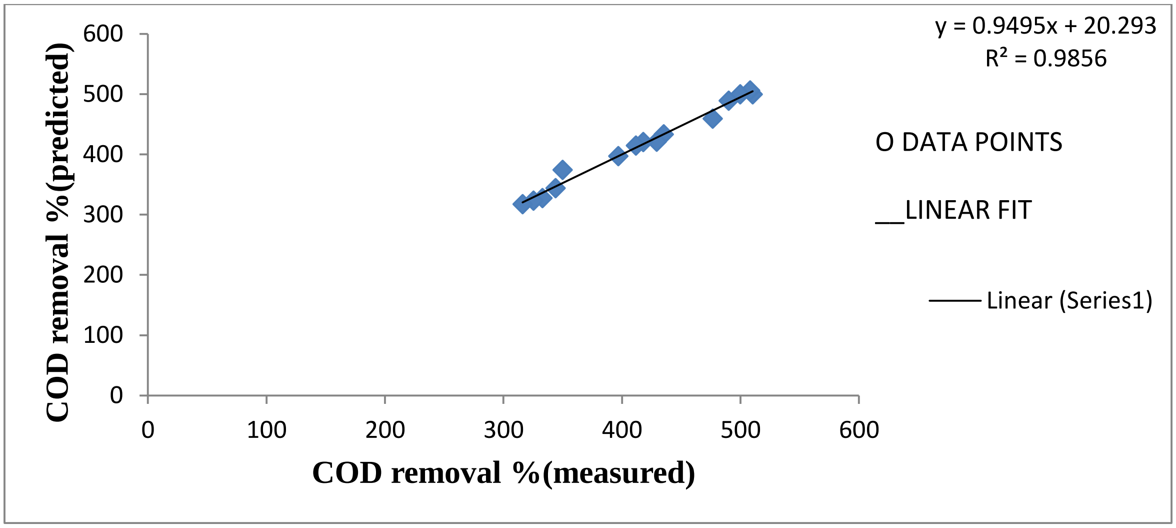

Figure 6: Comparison between Predicted and Experimental Values of the Output (WINTER SEASON)

Neural Network Model

The data sets were used to feed the optimized network in order to test and validate the model. Figure 5, 6 shows a comparison between experimental COD removal values and predicted values using the neural network model. The figure contains two lines, one is the perfect fit y = X (predicted data = experimental data) and the other is the best fit indicated by a solid line with best liner equation y = (0.974) X + 0.116, correlation coefficient (R^2) 0.974.

Conclusion

Maximum COD removal efficiency of 80.61%was observed, Removal of COD efficiency was better during winter season when compared to rainy season.

The multiregional input-output model constant value is obtained from the slope of the straight line and with linear correlation value (R^2) of 0.9968**.**

ANN results showed that neural network modelling could effectively simulate and predict the behaviour of the process. ANN predicted results are very close to the experimental results with correlation coefficient (R^2) of 0.974.

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