Mathematical Modelling of Upflow Anaerobic Sludge Blanket Reactor for Treating Sugar Mill Effluent

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Abstract : ***Sugar industries have shown us great growth in size and number in most countries of the world. The sugar mill effluent is characteristically biodegradable with BOD5, of 1200 to 2400 mg/l and COD restricted to 2500 to 3500 mg/l. The biodegradability range of sugar mill effluent is from 0.5 to 0.71. The anaerobic reactor was assessed with a pilot model (15.6 litres) for the treatment of sugar mill effluent. The present study evaluates the performance of anaerobic reactor run under varying operating conditions, viz, influent flow rate (0.875, 1.850, 2.825, 3.800, and 4.75 lit/hr) and influent COD (2003.66, 2584.86, 3060.26, 3556.62 mg/l), OLR (0.026, 0.0345, 0.0412, 0.0479 kg.COD/m2), and HRT (4, 8, 12, 18 and 24 hrs) are interpreted for the respective conditions. The COD removal was observed for maximum of 89.88% with the maximum biogas yield was observed at 0.28 m3/kg COD removed. Furthermore, neural network model and multiple regression models were successfully used to develop a kinetic model of the experimental data with a high correlation coefficient.***

IndexTerms - sugar mill effluent, UASBR, kinetic model, neural network model, multiple regression.

I. Introduction

Sugar industry is one of the most leading agro-based industries in India and has extensively contributed to economy of the country [1, 2 & 3]. As India is the biggest producer of sugarcane in the world with 550 sugar mills and 220 million tons cane per year and total sugar production 13.5 million tons per year. The Sugar production process requires huge amount of water for a number of steps and discharge almost equal quantity of waste water which contain toxic material [4, 5]. The effluent from sugar industry has ultimate disposal in the field of agriculture, which can alter the soil properties and crop yielding [6, 1, 7& 3]. So, there is every need to recycle the waste water generated with appropriate and efficient treatment methods. Biological wastewater treatment has been performed in many different ways. In order to conquer the drawbacks of suspended and attached growth systems Upflow Anaerobic Sludge Blanket reactors are designed [8]. It is a hybrid type of reactor, involving attached growth process [9]. This study involves the treatment of sugar mill effluent by UASB Reactor by altering the hydraulic retention time for a particular organic loading rate [10]. A laboratory scale model of UASBR mainly involved to evaluate the removal efficiency of COD. The data generated were used to establish the process kinetic value of substrate biomass [11].

II. Experimental Setup

The experimental set up consists of UASB reactor having 15.6 litres of effective volume. The physical description and process parameters are listed in Table1. The schematic diagram of the experimental setup was presented in Figure 1 and Table 1. The feed stock for the reactor was collected from M.R.K sugar mill industry, Sethiyathope, Cuddalore, Tamil Nadu, India. The cylindrical portion of the reactor have 180 cm height and 12 cm diameter was fabricated with fibre glass was provided with a five nozzles. To avoid air entrapment the top of the reactor hermetically sealed. A portion at the bottom of the reactor is packed with support media to develop the microorganisms. The influent is fed to the reactor by means of peristaltic pump of miclin's make and model pp-30. At the bottom, the influent is fed to the reactor and the wastewater passes through packed media. The reactor is provided with sampling ports at zones viz., hydrolysis, acids genesis and methanogenesis in the reactor. Separate ports were provided at bottom and top for desludge and for scum removal. To ensure the proper mixing of wastewater an agitator is provided in the influent tank. At the top of the reactor, the treated effluent is obtained by overflow through effluent pipe and the gas got separated and collected in a gas collector.

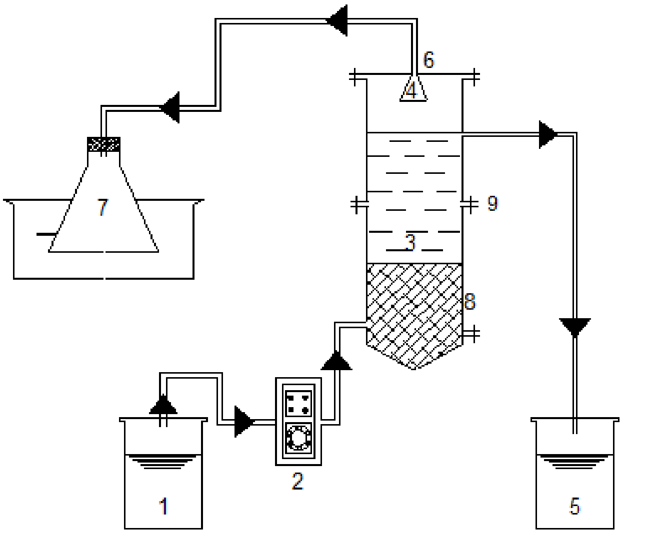
Table 1: UASBR – The physical description and process parameters of experimental model

DESCRIPTION	MEASUREMENTS
Total volume of the reactor, lit	20.80
Effective volume of the reactor, lit	15.6
Total height of the reactor, m	1.8
Effective height of the reactor, m	1.2
Effective diameter of the reactor, m	0.12
Peristaltic pump (miclin's make)	pp-30 model
Influent flow rate lit/hr	0.875, 1.850, 2.825, 3.800, 4.75
Influent average COD mg/lit	2003.66, 2584.86, 3060.26, 3556.62

Organic loading rate kg/COD/m2.day	0.026, 0.0345, 0.0412, 0.0479

III. Experimental Methodology

The random samples were obtained from M.R.K sugar 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 UASB reactor was acclimatized by feeding; municipal sewage for 2 weeks. The feed of sugar mill effluent is started in part viz., 20, 40, 60, 80, and 100%. After acclimatization period, the sugar waste water was gradually introduced into the reactor. The biomass acclimatization was observed for COD reduction of 70% and the steady condition of the reactor was reached at 15th day after the continual feed of sugar mill effluent. The process performance was monitored and the COD removal efficiency of the reactor under different hydraulic retention time was noted [12]. The performance of the UASB Reactor was investigated for the treatment of sugar mill effluent through experiments at particular COD concentration with varying Hydraulic retention time (HRT), the COD removal was evaluated [13]. All analyses were performed according to Standard Methods for the Examination of Water and Wastewater APHA (2005). The synthetic sugar effluent is prepared using sugar and introduced into the reactor after the process stabilization. The model was run under varying operating conditions, viz, influent COD (2003.66, 2584.86, 3060.26, 3556.62 mg/l), influent flow rate (0.875, 1.850, 2.825, 3.800, and 4.75 lit/hr), OLR (0.026, 0.0345, 0.0412, 0.0479 kg.COD/m2), and HRT (4, 8, 12, 18 and 24 hrs) are interpreted for the respective conditions. The COD removal was observed for maximum of 89.88% with the maximum biogas yield was observed at 0.28 m3/kg COD removed.



1. Influent tank
2. Peristaltic pump
3. Granulated UASB reactor
4. Gas/liquid/solid separator
5. Effluent tank
6. Gas outlet
7. Gas collection system & measurement of the displaced gas
8. Granulation zone
9. Sampling port

Figure. 1: Experimental model of the UASB reactor

IV. Mathamatical Model

Mathematical modeling is an analytical approach to illustrate 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 is neural network model.

4.1 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), H_2O_2/COD molar ratio, H_2O_2/Fe_2+ 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. The Structure of the Neural Network Model is given in fig.2.

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.

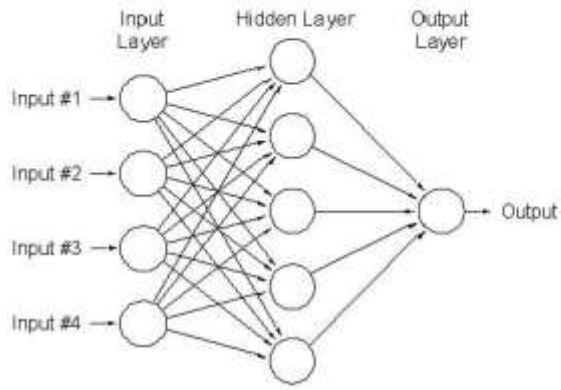


Figure 2: Structure of the Neural Network Model

4.2 Multiple regression analysis

Multiple regression is a statistical tool used to derive the value of a criterion from several other independent, or predictor, variables. It is the simultaneous combination of multiple factors to assess how and to what extent they affect a certain outcome.

The multiple linear regression equation is as follows:

$$Y = a + b1*X1 + b2*X2 + ... + bp*Xp$$

Y is the value of the Dependent variable (Y), what is being predicted or explained
a (Alpha) is the Constant or intercept
b1 is the Slope (Beta coefficient) for X1
X1 First independent variable that is explaining the variance in Y
b2 is the Slope (Beta coefficient) for X2
X2 Second independent variable that is explaining the variance in Y
b3 is the Slope (Beta coefficient) for X3
X3 Third independent variable that is explaining the variance in Y

V. RESULTS AND DISCUSSION

The sugar effluent was prepared synthetically to represent the evaluated characteristics and used in different influent COD concentrations. The average COD values of four different synthetic preparations 2003.66, 2584.86, 3060.26, 3556.62 mg/l. The model was run five different flow rates viz., 0.875, 1.850, 2.825, 3.800, and 4.75 lit/hr. The respective flow rates resulted in the operation of the model of HRT of 4, 8, 12, 18 and 24 hours. The respective values are varying from 0.026, 0.0345, 0.0412, 0.0479 kg COD/m2/day. The HLR varies from 0.042, 0.033, 0.024, 0.016 and 0.0077. Considering the performance of the model in respect of % COD removal efficiency, the experimental results were interpreted for OLR and HRT. The respective graphs were presented in figure. The COD removal was observed for maximum of 89.88% with the maximum biogas yield was observed at 0.28 m3/kg COD removed.

5.1 Neural Network Model

The data sets were used to feed the optimized network in order to test and validate the model. Figure 3 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 = (0.995) X + 2.907, correlation coefficient (R^2) 0.995.

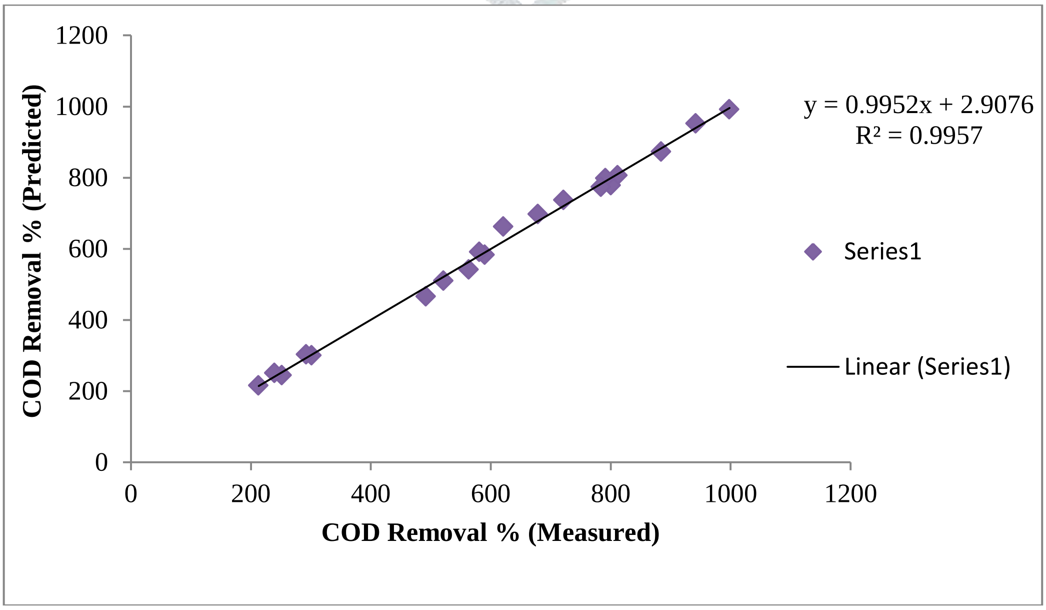


Figure.3 Comparison between Predicted and Experimental Values of the Output

5.2 Multiple regression analysis

The data sets were used to feed the optimized network in order to test and validate the model. Figure 4 shows a comparison between experimental COD removal values and predicted values using the Multiple regression 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 = (0.987) X + 7.406, correlation coefficient (R^2) 0.987.

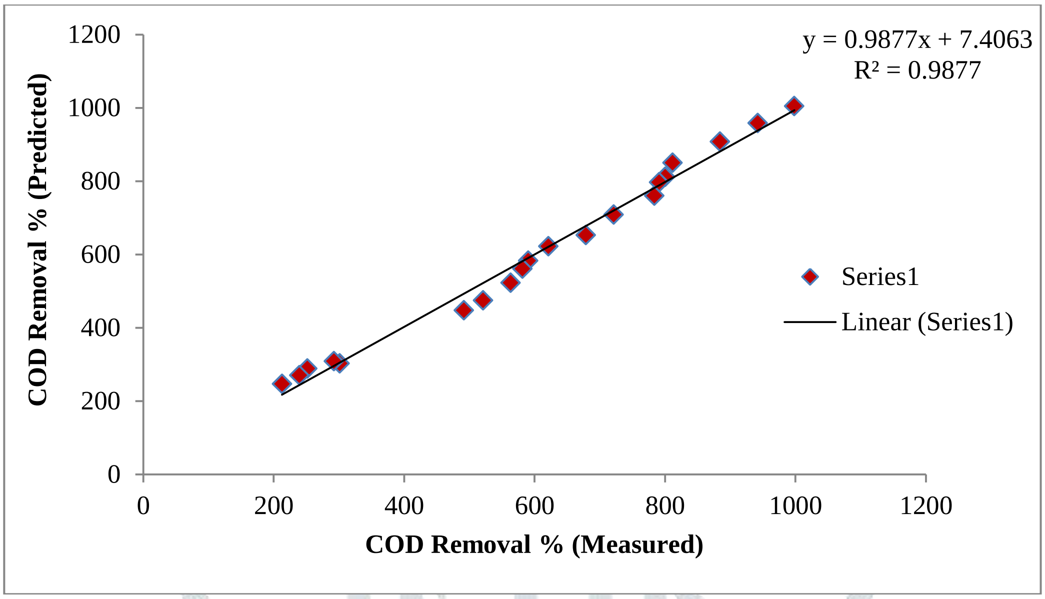


Figure.4 Comparison between Predicted and Experimental Values of the Output

VI. CONCLUSION

Maximum COD removal efficiency of 89.88% with the maximum biogas yield was observed at 0.28 m3/kg COD removed. 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 (R2) of 0.995. The Multiple Regression model constant value is obtained from the slope of the straight line and with linear correlation value (R2) of 0.987. Neural Network model is comparatively more suitable than Multiple Regression model for treating sugar mill effluent using Upflow Anaerobic Granulated Sludge Blanket Reactor.

VII. ACKNOWLEDGEMENT

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