Back propagation Neural network modeling approach in the anaerobic digestion of wastewater treatment
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ABSTRACT

In this paper, the use of back propagation neural network for modeling is investigated from the experimental values obtained in a laboratory scale system of anaerobic tapered fluidized bed reactor. The input parameters considered for modeling are four inputs, flow of influent, COD, pH, hydraulic retention time and two outputs viz., COD, CH₄ gas yield. Back propagation neural network has great adaptability to the variations of system configuration and operation condition and the prediction results are found to be closer to the experimental results.

Keywords: Neural Network, Anaerobic Digestion, Modeling

1. Introduction

An artificial neural network is an information processing system that has certain performance characteristics in common with biological neural networks (Zadeh 1985; Hertz et al 1991; Zhang and Kandel 1993; Haykin 1994; Bishop 1995; Pal et al 2001). The feed forward back propagation network is a very popular model in neural networks and it does not have feedback connections, but errors propagate backward from the output layer during training. Back propagation is a good gradient method to minimize the total squared error of the output computed by the neural network (Nauck 1997; Nauck and Kruse 1997). Training a network by back propagation involves three stages: the feed forward of the input training pattern, the backward propagation of the associated error, and the adjustment of weights (Jang and Gulley 1997). The output errors determine measures of hidden layer output errors, which act as a basis for adjustment of connection weights. The process of adjusting the set of weights between the layers and recalculating the output continues until a stopping criterion is satisfied, such as the overall error falling below a given threshold. Once training is completed, the network can be used to find outputs for new inputs (Nguyen et al 1997).

2. Materials and Method

2.1 Experimental Set-Up

A schematic diagram of the experimental set up is shown in Figure 1. The Anaerobic Tapered Fluidized Bed Reactor (ATFBR) consists of conical shaped acrylic column of 5° tapered angle (Wu and Huang 1995, 1996) with a total volume of 7.8 L and the volume of tapered section was 1.5 L. The reactor column was of height 290 mm with a progressive increase in
diameter from 46.6 mm at the base to 91.5 mm at the top. An upper settling section was attached to it, which was 1073 mm high and 91.5 mm diameter.

Figure 1: Schematic diagram of the tapered fluidized bed reactor

A bed of Mesoporous Activated Carbon (MAC) was used as fluidized biomass carrier matrix. The effluent was recycled using a magnetic driven polypropylene centrifugal pump. Complete fluidization of the MAC was achieved by operating at a constant rate. The settlement zone of the reactor contained a conical gas liquid separator to allow venting of the biogas produced.

Ports were provided along the column length to measure the pressure drop during its operation. Synthetic sago wastewater was applied continuously at the bottom of the reactor using a peristaltic pump for low flow rates and a magnetic driven polypropylene centrifugal pump was used for higher flow rates. The treated wastewater was collected from an outlet located in the cylindrical section at a distance 55 mm below the top of the column. Biogas produced from the ATFBR was scrubbed in 5 % KOH solution contained in two aspirator glass bottles of capacity 20 L (Borosilicate glass) arranged in series. The scrubbed gas, mainly CH₄, was measured using a wet gas meter.
2.2 Synthetic Wastewater

The synthetic sago wastewater was prepared by mixing a finely ground sago powder (-500 + 400 µm DIN Standard sieve size) with ordinary tap water to represent the typical composition of industrial sago wastewater. (COD inlet range from 1100 to 7000 mg/L). The trace elements including sulfide were added to the synthetic waste water at a concentration of 1 mL/L and the macro nutrient concentration was twice. They were added for the growth and activity of the anaerobic bacteria which ensured that there was no nutrient limitation. The pH of the synthetic wastewater was maintained by the addition of ammonium carbonate or ammonium di hydrogen phosphate. The wastewater characteristics are analyzed as per the ‘Standard Methods for the examination of water and wastewater’.

2.3 Support Material

Mesoporous Activated Carbon (MAC) of 600 µm particles is used as carrier matrix for anaerobic bacteria and as a reservoir for storing methane gas (Liu et al 2006) and hydrogen gas (Erdogan and Kopac 2007). The methane gas formed during the anaerobic treatment of wastewater is stored in the pores of MAC which increases the buoyancy (lowering of apparent density) of the activated carbon particles and so it rises to the surface of the liquid medium where the methane gas is released. The MAC particles come down due to gravity settling. This transport of carbon particles creates a secondary swirling motion over and above the fluidized motion. The biofilm attached to the MAC also follows the secondary motion and thus mixes homogeneously with the wastewater. The second major advantage of MAC is to immobilize bacterial consortia present in wastewater, and the immobilized bacteria degrade the organic components of wastewater at a faster rate.

2.4 Reactor Operation

The experimental protocol was designed to examine the maximum effect of the OLR on the efficiency of the ATFBR. The ATFBR was subjected to an operation of 535 days over a range of hydraulic retention time of 26.74 to 1.97 hours. Initially it is operated for an OLR of 1 kg/m³/day and gradually increased to 85.44 kg/m³/day with the optimum superficial velocity (2.5 times minimum fluidization velocity) which gives the maximum COD removal. The COD concentrations were varied from 1100 to 7000 mg/L.

2.5 Experimental results

Four inputs viz., flow of influent (litres), COD inlet, pH inlet, hydraulic retention rate and two outputs viz., COD outlet, CH₄ gas yield are considered for modeling. The multivariate input and output attributes are visualized using gplot-matrix function in MATLAB 7.1 environment and the resultant plots are presented in Figure 2 and Figure 3.

The input and output were also analyzed for modeling purpose using normal probability plot. The purpose of normal probability plot is to assess whether the data could come from normal distribution. If data is normal, the plot will be linear, else curvature will be introduced in the plot. It can be observed that the plot is highly nonlinear and neural network modeling has been considered as it is well suited for data distribution of these types. Figure 4 shows the normal probability plot for the input variables and Figure 5 shows the normal probability plot for the corresponding output variables.
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Figure 4: Normal probability plot for the input variables

Figure 5: Normal probability plot for the output variables
3. Modeling using Neural Networks

All simulations for neural network modeling were done with MATLAB 7.1. A two-layer feed-forward neural network architecture is presented in Figure 6 is used for modeling the input and output data. The training and testing results for given data are shown in Figure 7 and 8 respectively. The result of full dataset evaluation on evolved neural network architecture is shown in Figure 9.

![Neural Network architecture](image)

**Figure 6: Neural Network architecture**

![Training and validation results with neural network](image)

**Figure 7: Training and validation results with neural network**

![Test data results and regression fitting of all test data with neural network](image)

**Figure 8: Test data results and regression fitting of all test data with neural network**
4. Conclusion

In this paper, artificial neural network has been used to model the parameters for the treatment of sago wastewater using anaerobic tapered fluidized bed reactor. The technique is validated by replicative testing and regression fitting results obtained was 0.99924 which is very much encouraging for further research in this area.

References


