Artificial Neural Network Modelling for the Study of pH on the Fungal Treatment of Red mud

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Available online at: www.isca.in
(Received 16th April 2011, accepted 21st April 2011)

Abstract

The bioleaching of red mud a major waste in the aluminium industry obtained by alkaline treatment of bauxite was estimated in the present investigation by organic waste treatment. The waste was used as a media for fungal growth and maintained in the form of a solution. Red mud was added to the organic solution to prepare samples of different pulp density (i.e.20%, 40%, 60% and 80% w/v). The pH for different pulp densities of red mud with the period of incubation was observed after treatment with the fungal rich organic media. The pH as a fuction of initial pH, concentration of red mud and incubation period was modelled using the neural networks.

Keywords: Biological leaching, red mud, ANN, Aspergilus niger, Bayers process

Introduction

The present growing demand of materials is creating a situation of over exploitation of natural resources, which is resulting in an increasing accumulation of different types of wastes. Red mud is such a chemical waste produced from bauxite during its alkaline treatment for alumina extraction called as Bayers process. The composition of red mud varies depending upon the materials used[5]. In the process of aluminium production the compounds in the bauxite are dissolved chemically, using caustic soda, in an alumina refinery to produce aluminium oxide[6]. The waste left over after the removal of aluminium is in the form of slurry called as red mud. The typical red color of red mud is due to the presence of high iron compounds. The high alkaline nature and amount of red mud generated has created a major environmental concern. For every tonne of alumina produced nearly a tonne of red mud is generated as waste. In terms of metal production the ratio of alumina to red mud is 1:2. Aluminium is the most abundantly available metal and the third most plentiful available element (8%), next only to oxygen and silicon. It is light as metal, tough as an alloy, has good thermal and electrical conductivity, easy to fabricate, non magnetic in nature, has excellent resistance to many chemicals and is nontoxic. Because of these outstanding properties aluminium and number of aluminium based alloys are finding growing application in various fields of consumer goods. The utility of the metal is enhanced by its tendency to form a stable adherent oxide that resists corrosion. The only economic ore of aluminium is bauxite, $Al_2O_3.xH_2O$, which is always associated with silica, iron oxide; titanium dioxide and few others minor and traces impurities[5].

The crucial factors for the disposal of any solid waste are the cost of disposal and pollution associated with it. The disposal of wastes adds to the cost of production in the range of 2-5%.Therefore the disposal of red mud has been a major problem till date. Therefore different methods are being practiced throughout the world but none of them have been environmentally suitable[1,4]. Red mud has been used as a pH modifier for acid wastes obtained from the production of gypsum and titanium oxide[7]. Recovery of valuable and reusable substances from red mud is not feasible on an industrial scale due to their complexity and elevated cost[11]. Therefore researchers have tried bioleaching in these conditions.

The bioleaching of red mud from fungal species are known by the organic acids formed due to incomplete breakdown of carbohydrates by their metabolic activity[10]. The production of organic acids increases metal dissolution by lowering the pH and increasing load of soluble metals by complexion and chelating[9]. So the indigenous specimen fungi, *Aspergillus* and *Penicillium* can utilize red mud for alumina solublization[2]. So a fungal sample having a 5% pulp density of red mud can be used to obtain a high concentration of aluminum (20.82 g of Al_2O_3/l) and about 4g/l of Titanium when biologically leached using fungal metabolites and choleric acid[6]**.** The approach for metal extraction of red mud may be satisfying but unless an industrial approach is applied the process has no relevance.

Acid production by fungal Species: Citric and oxalic acids are the mainly produced by fungi by the incomplete break down of glucose[3]. Tests carried to observe the acid production capabilities of glucose showed positive results[2]. Studies show the acid production via incomplete oxidation of glucose is formulated by the following equations:

$$C_6H_{12}O_6 + 4.5\ O \rightarrow 3C_2H_2O_4\ \text{(oxalic acid)} + 3\ H_2O$$

$$C_6H_{12}O_6 + 1.5O_2 \rightarrow 3C_6H_8O_7\ \text{(citric acid)} + 2H_2O$$

Bioleaching of red mud: The production of organic acids results in a progressive decrease in the pH of the media which can also be associated with the fungal growth. The breakdown of glucose by glycolysis reduces the glucose flux and as a result causes a shift from citrate to oxalate accumulation. The leaching ability of fungi is due to its acidolysis and complexation phenomena. The citric acid being a tricarboxylic acid contains three carboxylic groups and a hydroxyl group as a possible donor of protons (H^+).

When aluminium cations (Al^{+3}) are present in system and citric acid is fully dissociated a complexation reaction may take place which is formulated by the following equations:

$$C_6H_8O_7 \rightarrow (C_6H_5O_7)^{-3} + 3H^+$$

$$(C_6H_5O_7)^{-3} + Al^{+3} \rightarrow Al(C_6H_5O_7)$$

[Aluminum citrate complex]

Similarly in case of oxalic acid which contains two carboxylic groups the reaction taking place can be formulated by the following equations:

$$C_2H_2O_4 \rightarrow (C_2HO_4)^{-1} + H^+$$

$$3(C_2HO_4)^{-1} + Al^{+3} \rightarrow Al(C_2HO_4)_3$$

[Aluminum oxalate complex]

Or

$$C_2H_2O_4 \rightarrow (C_2O_4)^{-2} + 2H^+$$

$$3(C_2O_4)^{-2} + 2Al^{+3} \rightarrow Al_2(C_2O_4)_3$$

[Aluminum oxalate complex]

Therefore citric acid and oxalic acids are considered good leaching agents for alumina solubilisation. In view of this the present study was carried to find elemental composition of red mud, the optimum load (pulp density) of red mud in the medium for neutralization and chemical analysis of liquor including leaching studies and obtain an alternate medium for fungal growth.

Material and Methods

Red mud: Red mud samples were obtained from National Aluminum Company, Damanjodi (NALCO). The red mud was dried and its chemical composition was analyzed using X-ray fluorescence technique. The initial composition of red mud is shown in Table1.

Fungi: Pure cultures of indigenous fungi (*Aspergilus niger*) were obtained from IMMT, Bhubaneswar. It was grown and maintained using potato dextrose agar and potato dextrose broth. The media composition was as follows (g/l): potato infusion, 300; dextrose, 50 and agar, 15. The broth composition was as follows (g/l): potato infusion, 300; dextrose, 50.

Alternative growth media: Fungal growth seems to be in the presence of carbohydrate. As most organisms, the fungi is also known to survive on glucose for its metabolic activities. Vegetables and leaves being a good source of glucose for their storage requirements in plants, so organic wastes like vegetable peels and leaves were collected from the canteen and sector-2 colony of NALCO to prepare a media for fungal growth. The media prepared was in the form of broth thus let us called as Organic Solution/Media. The organic solution composition was; 300g/l of organic wastes and

50g/L of dextrose. The organic media prepared was autoclaved at 121°C and 15lbs pressure for 15 minutes for sterilization and the solid suspensions were removed by filtration. The organic media thus prepared is enriched by our desired fungal species (i.e. *Aspergillus niger)* by adding 20gms of wet weight per 100ml of prepared organic solution. The fungal rich solution thus prepared is further used for the treatment of red mud for neutralization and metal extraction.

Experimental procedure: Erlenmeyer flasks of 250ml were used and four samples of 100 ml of metabolite of fungal growth medium (i.e. organic solution prepared from collected wastes) having red mud pulp density of 20%, 40%, 60% and 80 %(w/v) were prepared. Red mud was sterilized and autoclaved at 121°C and 15lbs pressure, along with the media to prevent fungal growth other than our required species. The flasks were incubated on a shaker at 150rpm for 24 h. The pH of the red mud in the solution was monitored using a standard pH meter.

Modeling and data analysis for pH neutralization: The functional relationship between the pH of red mud and influencing parameters like initial pH, concentration of red mud and period of incubation was derived using artificial neural network modeling technique.

Artificial neural network based models: Neural networks, either supervised or unsupervised have emerged as an important tool in various engineering applications; especially in modeling of non-linear systems. On the basis of supplied training data, the network learns the hidden relationship between the process input and output. The trained network then undergoes simulation to predict the output for unknown inputs. More than 50 types of neural network exist among them the most popular networks today are the Hopfield network, Artificial adoptive resonance (ART) theory network, Radial basis (RBF) network, Probabilistic neural network (PNN) and the most simple back propagation feed forward network. In this work networks used were simple Multiple Layer Perceptrons (MLP) for the model building. MLP is a feed forward network containing three layers namely input layer, hidden layer and output layer. The numbers of neurons in the hidden layers were varied and best of five network configurations were considered for the model building. The present work is an attempt to develop a neural model of the final pH affected by initial pH, pulp density of red mud and time period of incubation. The best five network architectures along with the training algorithm used, training, testing and validation performances and activation functions used are presented in the table 1. The neural model was developed using Statistica 9.0.

Results and Discussion

The 30 number of data generated for the pH with 30 combinations of the variables like initial pH, concentration of red mud and period of incubation. Figure 1 represents the experimental versus the neural network predictions of the pH of red mud. The residual error for training is depicted in the Figure 2.

Conclusion

The pH was observed for 30 different combinations of parameters like initial pH, concentration of red mud in media and period of incubation. The pH of as a function of initial pH, concentration and period of incubation has been modelled using the artificial neural network technique. The feed forward back propagation ANN's could predict the final pH with very good agreement. So the present technique could be used to predict the pH on fungal treatment of red mud.

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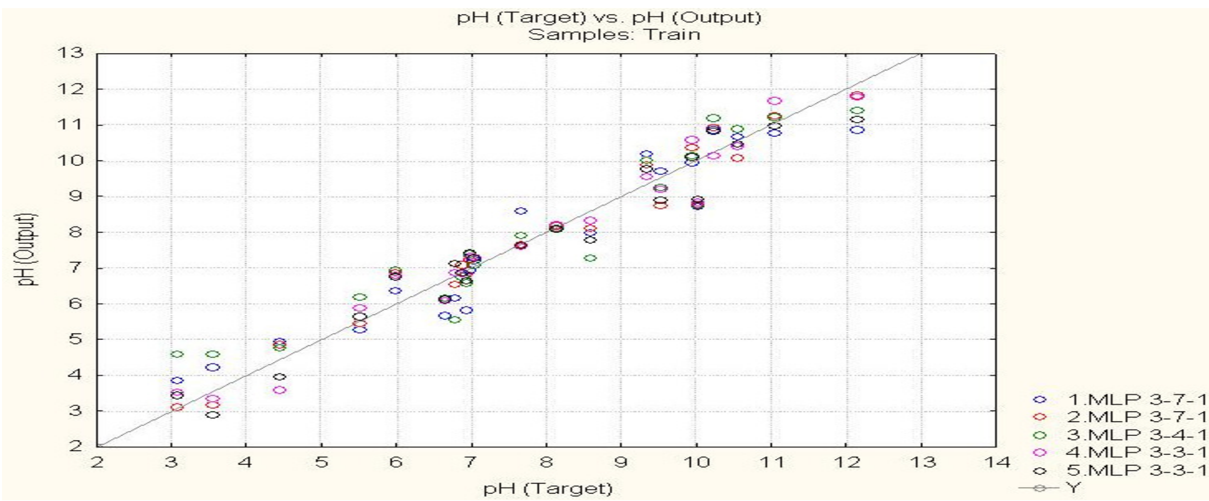

Figure-1: represents experimental versus neural network predictions

Table-1: Network architecture for the developed neural network model prediction for pH

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training algorithm	Error function	Hidden activation	Output activation
1	MLP 3-7-1	0.959	0.825	0.926	BFGS 8	SOS	Logistic	Tanh
2	MLP 3-7-1	0.978	0.999	0.995	BFGS 35	SOS	Tanh	Identity
3	MLP 3-4-1	0.949	0.795	0.952	BFGS 21	SOS	Logistic	Logistic
4	MLP 3-3-1	0.980	0.994	0.999	BFGS 66	SOS	Exponential	Logistic
5	MLP 3-3-1	0.976	0.986	0.999	BFGS 45	SOS	Logistic	Tanh

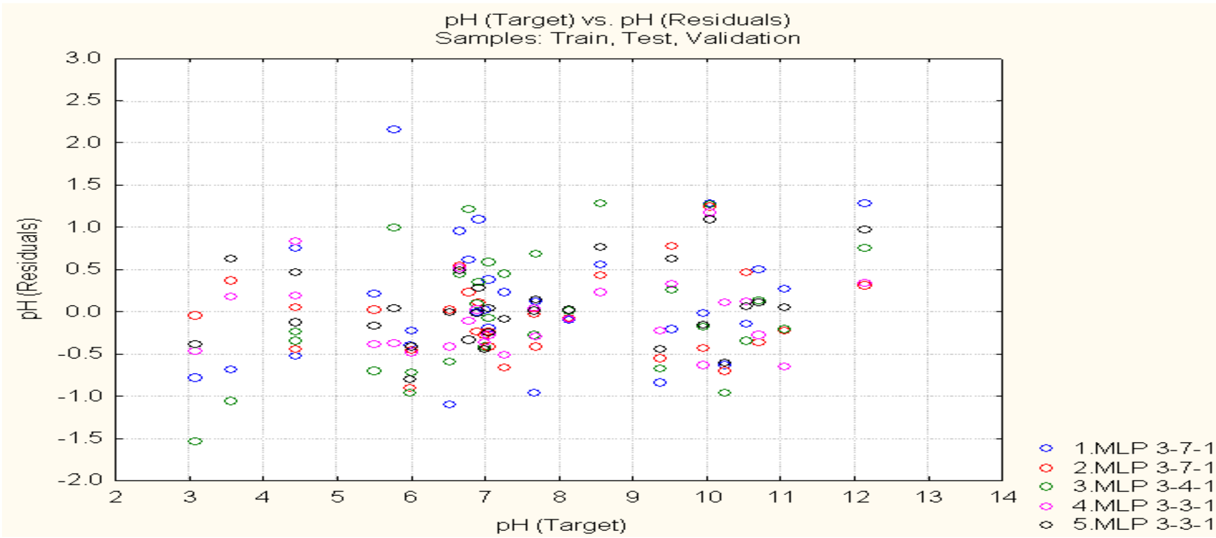

Figure-2: represents residual error and target