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Determination of biochemical oxygen demand by adaptive neuro fuzzy inference system

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ABSTRACT

The industrial wastes are mainly consists of inorganic compounds, organic compounds and non-biodegradable substances which changes the biological and chemical properties of soil and water permanently. Textile industry processes are mainly based on chemical reactions in liquid medium. Its effluent creates a serious water pollution and enhance the value of Biological Oxygen Demand (BOD). The BOD is one of major physico-chemical parameter is used to found the quality of effluent. The main objective of this study is to compare between the predictive ability of statistical model and Adaptive Neuro Fuzzy Inference System model (ANFIS) to estimate Biological Oxygen Demand using four parameters of effluent namely pH, Total Suspended Solids (TSS), Sulphate (SO_4), and Chloride (Cl_2)in Textile industry as input of model.

Key words: ANFIS, Statistical Model, BOD.

INTRODUCTION

The textile industry is one of the rapidly growing sectors of Indian economy. It has the capacity to reduce the unemployment due to its large labour demands. Its processes are based on chemical reactions in liquid medium, thereby generating large volume of toxic wastewater. Main pollution in textile wastewater comes from bleaching-treatment of cotton and polyester to achieve white absorbent fabric that is suitable for dyeing, printing and finishing [1-3]. The bleaching process use oxidizing agents like chlorine and hydrogen peroxides. Dyeing and printing are achieved by the use of various types and colour of dyes such as azodyes and sulphur dyes. These effluents contain strong colour, a large amount of suspended solids, a highly fluctuating pH, a high temperature, COD, BOD etc., [4, 5]. Because of these characteristics, wastewater from the textile industry must be treated before being discharged into natural water system [6, 7, 8]. BOD has to moderate correlation with other physicochemical parameters like pH, TSS, SO_4 and Cl_2. The statistical multiple regression analyses can be effectively utilized in the prediction of dependent parameter (BOD) using other physico-chemical parameters of the textile effluent as the independent parameter [9, 10]. However, statistical modeling does not yield very accurate value of BOD. Fuzzy Logic has recently become a useful tool for modeling highly complex systems whose behavior is not well understood. Fuzzy rule base contains some rules that include all possible fuzzy relations between inputs and outputs. In fuzzy set theory, there are no mathematical equations and model parameters and therefore, all the uncertainties non-linear relationships, and model complications are included in the descriptive fuzzy inference procedure in the form of IF-THEN statement [11]. It becomes difficult to frame the rules and to find the rules with maximum firings strengths. These difficulties are overcome in Adaptive Neuro Fuzzy Inference System (ANFIS) architecture. ANFIS is a method based on the input-output data of the system under consideration. ANFIS have recently become a popular universal approximation that represents highly nonlinear function. Basically, a fuzzy inference system is worked on five function blocks[12] such as a rule base containing a number of fuzzy if-then rules, a database which defines membership function of the fuzzy set used in the fuzzy rules, a decision-making which perform the inference operation on the rules, a fuzzification inference which transforms the crisp inputs into degrees of match with linguistic values, a defuzzification inference which transforms the fuzzy results of the inference into a crisp output. ANFIS in corporate a Sugeno-type inference system into an adaptive neural network structure consisting of several nodes connected through directional lines. The parameter values are determined through the learning or training phase of a neural network, while model performance is evaluated by sufficiently fitted training data(Tr Data)and check data(Chk data). ANFIS generates automatically the fuzzy rules and select the rules with maximum firing strength. The main purpose of this study is to analyze and compare the performance of ANFIS and statistical modelling in predicting of Biochemical Oxygen Demand of textile effluent.

MATERIALS AND METHODS

Wastewater samples used in the work for physicochemical analysis collected in precleaned plastic containers from the area of textile industry over a period of one year. Then, the samples were prepared and analyzed as per standard procedure [13].

Statistical Analysis: All the data observed are subjected to statistical analysis. In statistical modeling, the equation $y = A+Bx$ is used to predict the dependent variable y from the independent variables 'x', whereA and B are regression coefficients. When several independent variables x_1, x_2… have influence on y, the multiple regression analysis of the type $y= \beta_o+\beta_1x_1+\beta_2x_2+$…..is more effective in predicting the variables, where β_o, β_1, β_2 etc, are regression coefficients. The multiple regression analysis are used to estimate the BOD values from four known parameter(pH, TSS, SO_4, Cl_2) of the effluent. SPSS 13.0 software is used for statistical analysis in the present work.

Table 1: Effluent characteristic parameters used as 'Training Data Set' in the present work:

Sample No	pH (mg/l)	TSS (mg/l)	SO_4 (mg/l)	Cl_2 (mg/l)	BOD (mg/l)
1	7.69	12	85	380	41
2	8.59	152	168	1525	38
3	8.2	128	120	1100	31
4	7.4	200	114	1050	21
5	6.52	60	347	285	32
6	7.5	89	190	433	42
7	7.11	160	299	1799	63
8	6.92	100	145	890	27
9	7.03	84	137	1924	46
10	6.42	168	249	1799	68
11	7.55	85	80	130	29
12	6.77	98	120	1175	18
13	8.83	92	224	1350	10
14	6.77	68	240	120	14
15	7.72	208	156	1749	34
16	6.75	100	250	200	41
17	7.1	76	276	835	25
18	6.41	12	134	145	17
19	7.31	40	149	145	15
20	6.84	52	127	690	16
21	7.32	104	86	800	18
22	7.18	48	108	565	15
23	7.11	40	60	450	16
24	6.84	48	127	690	16
25	7.58	272	218	124	57
26	7.18	16	154	739	10
27	7.12	60	113	256	16
28	7.14	40	223	916	10
29	7.64	32	75	532	10
30	6.82	70	329	550	35

Anfis modelling: ANFIS is composed of antecedent and conclusion, which are connected to each other by fuzzy rules based on the network form. There are two learning methods in neural section of the system: Hybrid learning method and Back Propagation learning method. In fuzzy section, first order Sugeno inference system can be used, and output variables are obtained by applying fuzzy rules to fuzzy sets of input variables [14, 15, 16, 17]. In the present work, program is written to work from the command line, using the Fuzzy Logic Toolbox supported in MATLAB version 5.3[18].Out of 40 data obtained from textile effluent samples,30 data are used as trained data are presented in table 1.The remaining 10 data are used as another group. The radius and number of epochs are so selected that the training is completed and the Training Root Mean Square Error (Trn RMSE) and the Check Root Mean Square Error (Chk RMSE) are minimum. The performance of estimated values of BOD by both ANFIS and statistical modelling can be assessed by calculating the Average Percentage Error (APE),Chi Square Test value(χ^2) using the following relations.

$$APE - \frac{1}{n}\sum_{i=1}^{n}\frac{|BOD_{(obs)}-BOD_{(Pred)}|}{BOD_{(obs)}} \times 100\%$$

where n is number of data pairs, BOD(obs) represents observed values of BOD, BOD(pred) represents predicted values of BOD, and i=1,2,3,………,n.

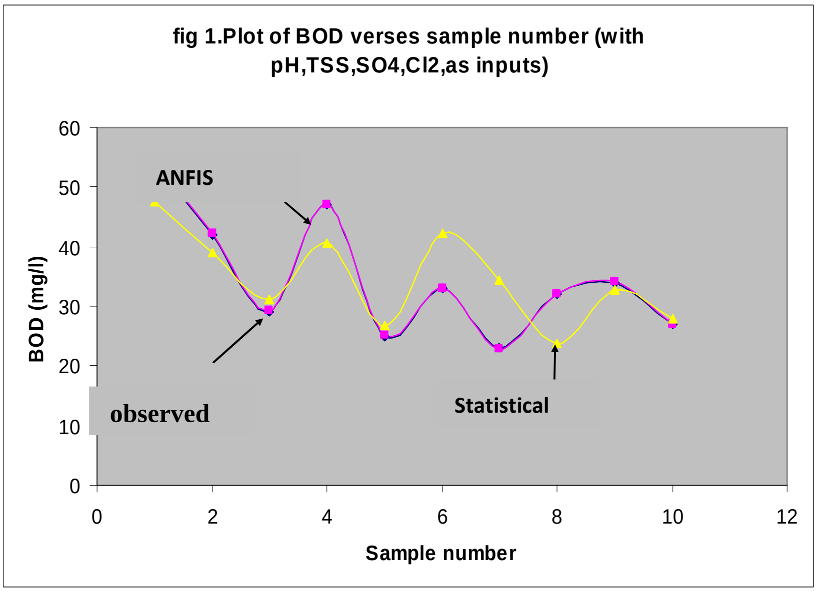
$$\chi^2 = \sum_{i=1}^{n}\frac{(O_i - E_i)^2}{E_i}$$

Table 2 : Effluent characteristic parameters used as 'Check Data' , the observed and the predicted values of BOD:

Sample No	pH (mg/l)	TSS (mg/l)	SO_4 (mg/l)	Cl_2 (mg/l)	BOD(mg/l)			Multiple regression parameters & coefficients
					Observed	predicted		
						ANFIS model	Statistical model	
1	8.22	100	95	313	54	53.9102	47.62	R^2=.577
2	7.51	88	186	437	42	42.1594	39.09	P=.285
3	7.52	82	72	140	29	29.3838	31.18	F=1.702
4	7.01	121	278	960	47	47.0448	40.59	β_0=-117.123
5	6.45	108	306	150	25	25.0869	26.68	β_1=18.107
6	6.86	114	420	448	33	33.0896	42.19	β_2=0.093
7	7.34	106	82	895	23	22.9317	34.46	β_3=0.053
8	6.29	108	259	630	32	32.0456	23.69	β_4=0.005
9	6.85	50	349	520	34	34.0461	32.66	
10	7.38	24	135	410	27	26.9012	27.94	
					APE (%) =	**0.35**	**15.77**	
					WE =	**0.4**	**11.5**	
					Chi- Sqr =	**0.007**	**11.156**	

RESULTS AND DISCUSSION

The estimated values of BOD obtained from statistical and ANFIS modeling using other characteristic parameters are given in Table2.The corresponding APE values, WE values ,Chi square test values(χ^2) and multiple regression coefficients are provided in the respective places of Table 2. From Table 2, it can be noted that APE value, WE value and Chi Square (χ^2) value are low for ANFIS modelling. A fig.1 is drawn between sample number of textile effluent and observed, estimated values of BOD furnished in table 2. The fig.1 shows that ANFIS modelling curve is slightly deviate from observed curve than statistical modelling curve. From this evident, the ANFIS modelling provides more accurate estimation of BOD.



CONCLUSION

ANFIS modelling is the best method for estimation of pollution parameters like BOD in effluents. The results overall indicated that the ANFIS modelling approach can be suitable to fast performance of accurate prediction and implement the proper control processes in effluent. ANFIS is a sophisticated system with a large number of training data implemented; its result would be very accurate.

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