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Bod from Plastic Industry – An Anfis Approach

KEYWORDS: ANFIS, BOD, industrial effluent, multiple regressions

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ABSTRACT *Effluent generated by the industries is one of the sources of pollution. Biochemical Oxygen Demand is one of the major parameter of effluents. In the recent years, new techniques such as: artificial neural networks and fuzzy inference system were employed for developing the predictive models to estimate Biochemical Oxygen Demand (BOD) of effluent. Soft computing techniques are now being used as alternate statistics tools. In this paper, use of ANFIS (Adaptive Neuro Fuzzy Inference System) for prediction of BOD of effluent from plastic industry was described and compared with traditional statistical model of MLR (Multiple Linear regressions). However, the accuracies of ANFIS and statistical models can be evaluated by calculating Average Percentage Error (APE), Worst Case Error (WE) and Chi squared value (χ^2) with observed BOD values. The comparison of results showed that ANFIS is a good tool for predicting the BOD of the effluent.*

1. INTRODUCTION

Industrial wastewater is major contamination sources of aquatic biota accounting for several chemical released into the environment [1]. Rapid industrialization has resulted of the rise of pollution. Biochemical Oxygen Demand (BOD) has been shown to be an important variable in water quality management and planning [2]. A BOD test is used to measure the amount of oxygen consumed by aerobic microorganisms during specified period of time. However, BOD is difficult to measure needs 5days to get results [3]. Fast monitoring of effluent can be achieved by a quick estimation of BOD values by software techniques [4, 5, 6, and 7]. The main objective of this study is to compare performance of ANFIS and statistical model in predicting the BOD of effluent from plastic industry.

2. MATERIALS AND METHODS

The effluent samples are collected from the plastic industry over a period of one year and samples were analyzed as per standard procedure [8, 9, and 10]. In the present study both the statistical multiple regression analysis and ANFIS modeling are employed to evaluate the BOD.

2.1 STATISTICAL MODELING

The general purpose of multiple regressions is to learn about the relationship between several independent variables and dependent variable. In this study multiple linear regressions (MLR) which are the most common method was used in the prediction of BOD.the general form of the regression equation is $Y= \beta_0+ \beta_1 x_1+ \beta_2 x_2+\ldots..$ Where Y is dependent variable , β_0, $\beta 1$, $\beta 2$……are the regression coefficient and (x_1,x_2,x_3.....) are independent variables[11]. SPSS 13.0 software is used for statistical analysis in the present work.

2.2 ANFIS MODELING

An adaptive network, as its name implies, is a network structure consisting of nodes and directional links through which the nodes are connected. Moreover, parts or all of the nodes are adaptive, which means each output of these nodes depends on the parameters pertaining to this node and the learning rule specifies how these parameters should be changed to minimize a prescribed error measure[12]. The ANFIS is a multilayer feed-forward network which uses ANN learning algorithms and fuzzy reasoning to characterize an input space to an output space [13]. In other words, the ANFIS combines ANN and fuzzy logic models and uses the advantages of both methods. The general architecture of ANFIS consists of five layers, namely, a fuzzy layer, a product layer, a normalized layer, a defuzzy layer and a total output layer that is depicted in fig1.Different layers with their associated nodes are described below [14]:

Layer 1. Every node I in this layer is an adaptive node. Parameters in this layer are called premise parameters.

Layer 2. Every node in this layer is a fixed node labeled ¶, whose output is the product of all the incoming signals. Each node output represents the firing strength of a rule.

Layer 3. Every node in this layer is a fixed node labeled N. The ith node calculates the ratio of the ith rules' firing strength. Thus the outputs of this layer are called normalized firing strengths.

Layer 4. Every node i in this layer is an adaptive node. Parameters in this layer are referred to as consequent parameters.

Layer 5. The single node in this layer is a fixed node labeled R, which computes the overall output as the summation of all incoming signals.

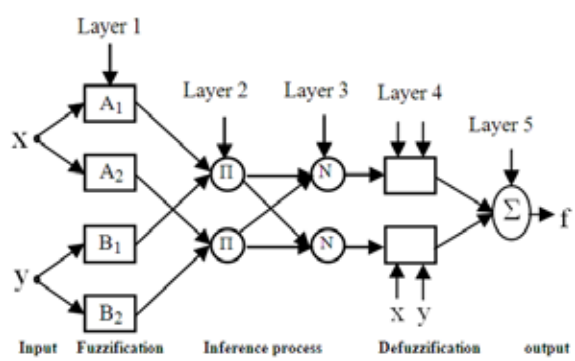

Fig 2.2.1. ANFIS architecture with two inputs and an output.

In the present work, program is written to work from the command line, using Fuzzy logic tool box supported in MATLAB version 5.3[15]. In the present work, pH, TDS, Cl2- O&G and SO42- of effluent from plastic industry are inputs of ANFIS. 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 estimated values of BOD can

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be verified by calculating the Average Percentage Error (APE),Worst Case Error(WE),Chi Square Test value(χ^2) using the relation[16].

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

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

$$WE = BOD_{(pred)} - BOD_{(obs)}$$

Where, n represents number of data pairs BOD (obs) represents observed values of BOD (pred) represents predicted values of BOD. Where Oi(i=1,2,3,.....n) is set of observed values and Ei(i=1,2,3,.....n) is the corresponding set of predicted data.

3. RESULTS AND DISCUSSION

The physico-chemical parameters of plastic industry effluent are used as training data given in table.1. The predicted values of BOD obtained from statistical and ANFIS modeling, using characteristic parameters are given in table.2. The Average Percentage Error (APE), Worst Case Error (WE) and Chi Square Error (χ^2) are calculated between predicted BOD values by statistical, ANFIS model with Observed BOD values are provided in table.2. Fig.2. drawn between sample numbers of plastic effluent and observed estimated values furnished in table2. Fig.2 shows that ANFIS modeling curve is lesser deviate from observed curve than statistical modeling curve. From this evident, the ANFIS modeling provides more accurate estimation of BOD.

Table.3.1 Characteristic parameters used as 'Training Data Set' of plastic Industry effluent

S. NO	Inputs (selectively used to train ANFIS)					Output
	pH	*TDS (mg/l)*	*Cl^- (mg/l)*	*O&G (mg/l)*	*SO_4^{2-} (mg/l)*	*BOD (mg/l)*
1	8.60	1400	155	1.4	30	3
2	7.25	880	95	2	21	3
3	7.94	1296	235	8	16	9
4	7.43	688	90	1.7	6	61
5	6.87	652	106	1.8	27	7
6	7.23	684	115	1.2	28	6
7	7.66	320	50	1.6	8	2
8	7.50	815	150	1.4	28	13
9	7.15	820	120	1.8	34	18
10	7.72	610	240	1.5	27	15
11	7.01	565	126	1.7	94	14
12	7.34	700	94	1.2	76	2
13	6.67	680	95	2.6	54	18
14	7.60	560	126	2.0	29	2
15	6.87	1268	260	2.0	142	43
16	7.25	624	105	2.0	71	10
17	7.15	676	130	2.0	256	28
18	7.60	654	203	2.4	30	5
19	8.15	674	115	2.5	28	6
20	8.06	654	204	2.4	102	8
21	6.85	715	220	1.8	30	15
22	7.53	560	120	1.9	92	12
23	6.82	730	230	1.7	85	11
24	8.07	504	84	2	40	3
25	6.52	592	120	1	100	3
26	6.91	480	165	2	106	10
27	6.96	964	275	1	98	2
28	7.50	552	55	1	5	10
29	8.05	484	100	4	15	6
30	8.12	634	123	2.2	37	7
31	8.01	674	143	1.8	97	5
32	7.15	844	342	1.9	15	16
33	8.15	812	138	1	7	6
34	7.18	544	126	1.6	95	16
35	7.56	556	190	2	80	12
36	7.48	560	130	2.1	7246	19
37	7.38	572	151	1.3	89	23
38	8.10	654	153	2.3	142	24
39	7.45	578	130	2.4	96	7
40	8.22	1032	148	1.9	214	2
41	7.62	532	312	2.0	116	11

Table 3.2 Characteristic parameters (with,and as inputs) of plastic industry effluents used as 'Check Data' the observed and predicted values of BOD.

Sample No	*pH*	*TDS (mg/l)*	*Cl^- (mg/l)*	*O&G (mg/l)*	*SO_4^{2-} (mg/l)*	*Observed BOD (mg/l)*	*Predicted BOD) (mg/l)*		Multiple regression parameters and coefficients
							ANFIS model	Statistical model	
1	7.51	808	145	1.5	27	12	11.9886	11.94	R^2 = 0.939
2	6.71	828	184	2.2	28	17	16.8241	16.42	P = 0.015
3	7.43	520	116	1.3	126	20	19.9285	19.70	F = 12.294
4	7.13	710	235	1.2	24	15	15.0413	15.07	
5	8.05	784	150	1.0	15	6	6.1615	6.99	β^0 = 215.432
6	6.97	760	196	1.6	91	11	11.2684	12.48	β^1 = -19.608
7	7.54	410	102	1.2	118	21	20.9225	23.93	β^2 = -0.030
8	6.52	692	120	4.2	100	7	6.7352	7.41	β^3 = -0.112
9	8.01	350	124	1.4	78	16	15.6374	15.26	β^4 = -9.138
10	7.48	529	119	1.0	128	22	22.0725	18.61	β^5 = -0.076
					APE (%) =		**1.36**	**7.67**	
					WE =		**0.4**	**3.4**	
					Chi-Sqr =		**0.0317**	**1.3791**	

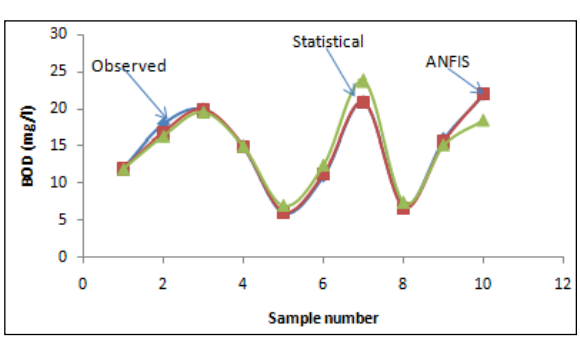

Fig .3.1 Plot of BOD verses Sample number (with, inputs)

4. CONCLUSION

In the prediction of BOD, it can be seen from table.2, the APE, WE, Chi-squared test values for ANFIS modeling are 1.36%, 0.4, 0.0317 and for statistical modeling are 7.67%, 3.4 ,1.3791. The above results showed that the prediction performance of ANFIS model is higher than statistical modeling.

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