

# Prediction of Paper Mill Wastewater Treatment Process Parameters in Sequencing Batch Reactor using Fuzzy Logic Technique



Saranya S. N., S. Lakshmana Kumar, R. Raj Jawahar

**Abstract:** Integrated paper and pulp mills utilize logs and wood chips for the production of paper. During the process, the exposure of raw effluents affect the environmental factors. In this analysis, waste water from paper mills was processed with the SBR (sequencing batch reactor) cycle. The effect of microbes and aeration periods with varying amounts of waste water on the efficiency of SBRs has been evaluated. During the tests, removal efficiencies of COD, BOD and TDS have been tracked. For experimental design, study and optimization, Box-Behnken core composite architecture was implemented. To maximize SBR performance, Fuzzy logic control was used. The SBR demonstrated higher efficiency in removal output on the basis of the tests. At the optimum conditions of microbe dosage of 55 ml aeration time of 5 hrs and wastewater concentration of 75% and the SBR achieved maximum removal percentage of COD, BOD and TDS is 88.18%, 91.80% and 87.12% respectively.

**Keywords:** Paper mill wastewater, *Phenerochetes chrysosporium*, Wastewater treatment, Sequencing batch reactor, Optimization, Fuzzy logic control

## I. INTRODUCTION

The pulp and paper industry contains heavily toxic waste water in large quantities. Thanks to the implementation of strict regulations the pulp and paper sectors have been compelled in recent years to significantly reduce waste water discharge. Sustainable development and the increased awareness of the protection of natural resources has also brought public concern to a greater extent about bad pollution industries, especially in pulp and paper factories. The exponential increase in population and the increased demand for industrial facilities to satisfy human needs generated problems such as the use of available resources that led to soil, air and water contamination. The wood pulping and manufacturing of paper products lead to a significant amount of toxins, which are distinguished by BOD, COD, suspensive solids (SS), toxicity and color. One of the most water-dependent sectors is the pulp and paper industry.

The P&P sector faces challenges today, though, to conform with strict environmental standards. Currently, 500 m<sup>3</sup> of water needed to produce a ton of paper have been cut down, but recent technological advances have taken the requisite quantity of water down to 15 m<sup>3</sup>. To reduce the environmental affecting impacts of the wastewater from the paper mill industry varies methods had been proposed to treat the waste water includes,

Chemical and electrochemical oxidation process, aerobic and anaerobic digestion, reverse osmosis, coagulation-flocculation and membrane process. Among the different existing process, SBR applied to remove the pollutants from the waste with higher removal efficiency. The SBR method contrasts with activated sludge technologies, since SBR integrates each processing unit into a single tank or tank, whereas conventional processes are focused on separate tanks. Usually, the SBR has five phases—charging, responding, setting, drawing and idling. SBR is an active sludge process which ensures aeration, reaction and loaming in the same tank. In addition, the minimum of operator activity needed good oxygen contact with microorganisms and substrate due to versatile treatment with differing flows, good removal performance.

The performance of batch reactor series production in the biological treatment of waste water in olive mills was researched by Agostina Chiavola et al. (2014). They analyzed the impact on chemical oxygen demand and the elimination with polyphenols of various control organic loadings. More assessment through various steps of membrane separation (UF), nano-filtration (NF) and reverse osmosis (RO) pre-or post-treatment. SBR has announced the complete removal, with a median output of 90 per cent and 60 percent for COD and TPPs, of biodegradable organic content. Via coagulation, flow and sequencing of batch reactivity reactor cycle, F.El-Gohary.Tawfik (2009) researched the elimination of colored waste water and the reduction of COD. In the first step, the treatment of magnesium chloride with lime [MgCl<sub>2</sub>/CaO], alum[Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>] and lime[ CaO] was done before the chemical treatments for effluent.. They used cationic polymer namely cytec to enhancing the effectiveness of the alum. The method of sequencing the batch reactor with effluents was chemically treated to HRT at 5.0 h. The total amount of residual COD and the total requirement for biochemical oxygen (Total BOD<sub>5</sub> oxygen) in the final effluent was 78±7.7; the total capacity of elimination was 28±4.2 and 17±4.2 mg / l and that was 76.3 and 61.4 percent, respectively. Morgan-Sagastume and D. Fernando.

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Grant Allen (2003) investigated the impact on the output of an active slot-type system of regulated temperature transients. At the upper limit of mesophilic care (30–45°C), the results of a 10 °C increase in the temperature and the 10 °C rise on sludge activity, settling and bioflocculation properties were measured. We have assessed the possible improvement in sludge robustness by adjusting it to temperature oscillations to accommodate temperature changes.

In Sequencing Batch Reactors (MaB-flocSBRs) for waste water treatment, Sofie Van Den Hende et al. (2014) has developed a new solution named Microalgal bacterial flocs. In this way, photosynthetic aeration substitutes mechanical aeration and MaB-floc settles the processed wastewater from the biomass generated. The performance of MaB-floc SBRs for aquaculture wastewaters, fertilizer treatments, food processing, and chemical industries is studied. In which their nutrient (C, N, P) elimination and effluent efficiency (pH, C, N, P) for the assessment of the ability of MaB-flock SBRs to handle wastes are evaluated.

The aerobic sequence reactor (SBR) was proposed to Jai Prakash Kushwaha et al. (2013). They indicated that increased HRT improves the removal output of COD and TKN (total kjeldahl nitrogen). The efficiency of a sequencing batch reactor (SBR–SND) device under different feed temperatures with synthetic wastewater was analyzed by JingboGuo et al. (2013). They stated that increased ventilation was advantageous for low temperature conditions (5–30°C), but no additional extension was required for improving performance. The Lignin-degrading capacities of fastened-growth fungi were studied by Juan Wu et al. (2005). They extracted black liquid with five different white rot fungi separately from a pulp and paper mill. We note that the significant effects on waste water treatment have been shown by *P. chrysosporium*, *P. ostreatus* and S22. YinethPineros-Castro et al. (2014) studied the biodegradation of oil-palme empty fruit bunches of *Phanerochaetechrysosporium* and *Pleurotusostreatus* from lignin, cellulose and hemicellulose. Compounds of pulp / paper mill sludge and hazelnut grains were analyzed by NurdanAycan et al. (2014). In order to maximize process parameters such as time period (weeks), humidity quality and transformation ratio we have measured using the statistical method. ShuokrQarani Aziz et al. (2011) investigated the treatment of waste leachate by load reactor (SBR) series process. The SBR parameters have been optimized using surface reaction techniques. Bagheri M et al (2014) has been developing a SBR architecture which operates urban wastewater at different levels, such als multi-layered perceptive and radial-based neural artificial network features and radial basis function (RBFANN), in different periods of sludge residence, filling times and reaction time and influential intensities (IC). Mohammed J.K. Bashir et al. (2010) examined the optimisation with the use of synthetic cation ion exchange resin for the elimination of ammonia-nitrogen ( $\text{NH}_3\text{-N}$ ) from Malaysia's half-aerobial leachate deposit. The Central Composite Model (CCD) and the Reaction Surface Methodology (RSM) are used to model an optimal application. The scope for reducing the need for chemical oxygen (COD), ammoniacal nitrogen ( $\text{NH}_3\text{eN}$ ) and 2,4-dichlorophenol (2,4-DCP) from recycled content

waste water using the response-floor technique has been explored by MohdHaFizuddinMuhamad et al. (2013) on a scale of a pilot-pilot granular activated carbon sequence batch reactor biofilms.

P.A. Soloman et al. (2009) investigated the increase in Decker filtrate stream biodegradability through electrochemical treatment and improved the process parameters by means of reaction surface methodology. The electro-coagulation process and the influence of the individual parameters on electro-coagulation effectiveness were also explored. Several pioneers have used the use of the furious logic method in various industrial processes to optimise machining parameters. Using Mamdani-based fuzzy logic controls, Pandu R et al. (2012) researched AWJM efficiency features. The method design of fused deposition simulation using the Fuzzy logic framework was researched by AnhuaPengetal. (2014). The literature review reveals that minimal number work is done only with the help of Fuzzy logic control to refine the SBR parameters. R. Boiocchi, et al. (2014) has been improving the FLD and FLC for fast and constant TN removal in one stage granular sludge CANR reactor. The impact of the microbe dosage and the specific discharge concentrations on COD, BOD and TDS treatment have not yet been investigated in the literature. In this analysis, an SBR model was developed for the treatment of waste water at varying microbe dose, aeration times and concentrations of waste water. A fluid-filled logic control technique for the concentration of effluent including COD, BOD, TDS and turbidity is created. The report attempts to resolve the void in the SBR cycle.

## II. MATERIALS AND METHODS

### Medium, pure culture and sample preparation

The medium used in this study was untreated paper mill wastewater effluent was collected from south Tamilnadu paper mill industry, India. Such waste was mixed with distilled water to reach three separate 50%, 75% and 100% concentrations for processing. Physico-chemical parameters such as pH, TDS, TSS, Turbidity, MLSS, MLVSS, COD, BOD and motility of the different wastewater concentration were presented in **Table 1**.

**Table. 1. Physico -chemical properties of the paper mill waste water influent**

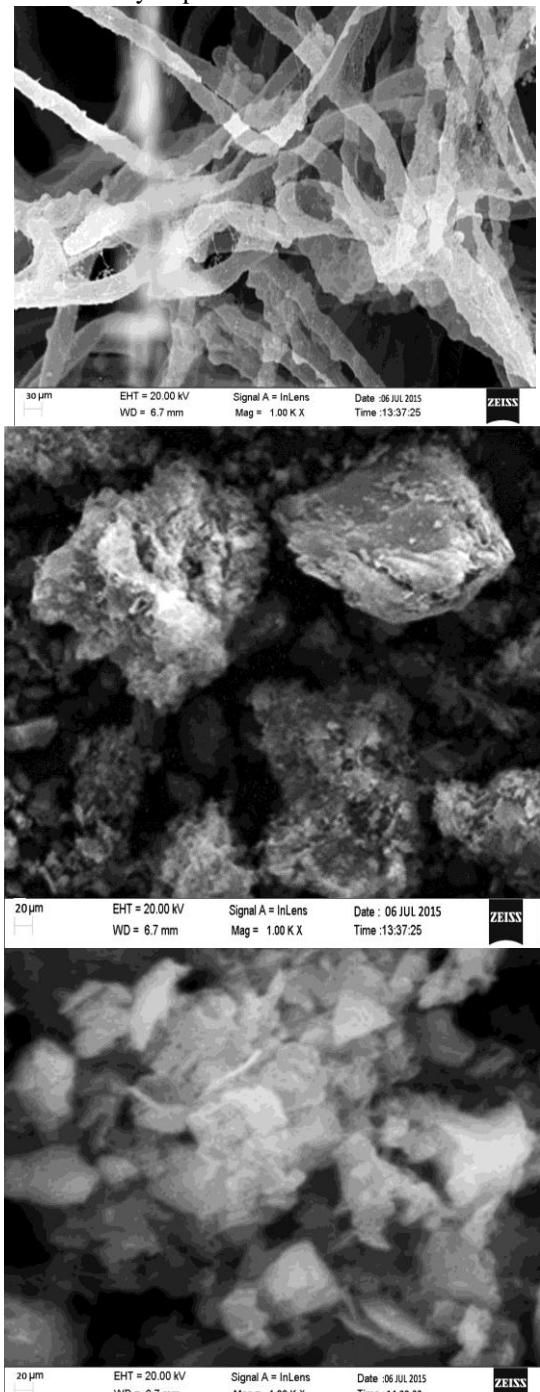
S.No	Parameters	Waste water concentration		
		Low	Medium	high
1	Color	Light grey	Light grey	Light grey
2	Odour	pungent	Pungent	pungent
3	Temperature (°C)	23	25	27
4	pH	8.2	8.5	8.6
5	Chemical oxygen demand (COD) (mg/l)	1264	2055	3420
6	Biochemical oxygen demand (BOD) (mg/l)	480	817	1295
7	MLSS (mg/l)	640	1048	1441
8	MLVSS (mg/l)	512	1352	1864
9	Total dissolved solids (TDS) (mg/l)	1160	1925	2834



10	Total suspended solids (TSS) (mg/l)	557	894	1314
11	Turbidity (NTU)	125	160	210

For one month, parameter study of waste water was conducted to cover differences in the properties of wastewater. The study of waste water has established *Phenerocheteschrysosporium* (fungus). The strain was treated with medium PDA (potato dextrose agar) and was cultivated for the preparation of inoculants for six days at 30°C.

Figure 1 shows the electron scanning microscopic image of the fungal, raw and treated waste water of *Phenerocheteschrysosporium*.



**Fig. 1. SEM image, (a) *Phenerocheteschrysosporium* (fungus), (b) raw paper mill wastewater, (c) Treated wastewater.**

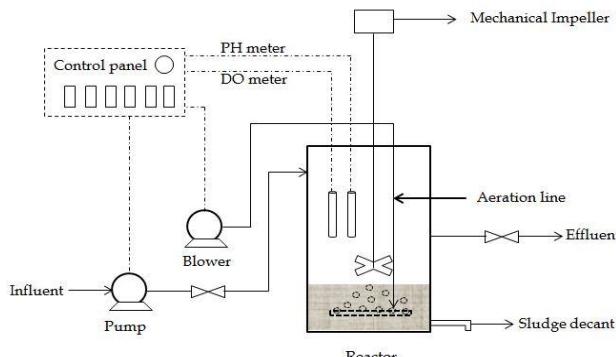
The composition of the inorganic nutrient medium used in fungus growth tests was as follows: Glucose- 10g; KH<sub>2</sub>PO<sub>4</sub>- 2g; Mg. SO<sub>4</sub>. 7H<sub>2</sub>O - 0.5g; CaCl<sub>2</sub> . 2H<sub>2</sub>O - 0.1g; Tween 20 - 0.5g; Thiamine • HCl - 1mg; Nitrilo-acito acid- 1.5g; Mg.SO<sub>4</sub>. 7H<sub>2</sub>O - 3g; Nacl- 1g; FeSO<sub>4</sub>. 7H<sub>2</sub>O - 0.1g; CO.SO<sub>4</sub> - 0.1g; Cacl. 2H<sub>2</sub>O - 0.1g; Zn. SO<sub>4</sub>. 7H<sub>2</sub>O - 0.1g; CuSO<sub>4</sub>. 5H<sub>2</sub>O - 0.01g; Al (SO<sub>4</sub>)<sub>2</sub>. 12H<sub>2</sub>O - 0.01g; H<sub>3</sub>BO<sub>3</sub> - 0.01g; Na<sub>2</sub>. MaO<sub>4</sub>. 2H<sub>2</sub>O - 0.01g; - 7ml; Sodium acetate - 1.7g; Di-ammonium citrate- 0.244g

#### Analytical methods

The techniques used for scientific research in this review were carried out according to Standard Techniques. The tests for chemicals oxygen requirement (COD) (standard code:5220), biochemical need for oxygen (BOD<sub>5</sub>) (standard code:5210B), MLSS (standard code:2540D) have been tested on a periodic basis. pH meter (Fisher Scientific Accumet pH meter 900) was checked for pH.

#### Sequential batch reactor treatment

The 25 L SBR has been constructed of acrylic plastic (a thickness of 5 mm) and worked cyclically, with each stage requiring fill times, aeration reaction, modification and drawing and idling, as shown in Figure 2.



**Figure. 2. Aerobic Sequencing batch reactor for wastewater treatment**

The reactor was estimated at a diameter of 28 cm and the height of 40 cm. There was 20 liters of working space. For the paddle form impeller the low-speed gear motor was used. The rotor speed was set to 60 rpm. For the delivery of air to reactors, Blower was used. The power from the feed tank (l) was pumped with a peristaltic pump into the reactor. The pH meter and DO meter were attached with the reactor to monitor the pH value and dissolved oxygen concentration in the reactor. Sequencing batch reactor operation was performed under room temperature condition.

### III. EXPERIMENTAL PROCEDURE

SBR process operating parameters optimization was performed based on Box-Behnken central composite design method. Input parameters such as microbe dosage, aeration time and wastewater concentration were selected and 15 set of experiments were performed. The experimental output response is shown in Table. 3

#### IV. RESULTS AND DISCUSSION

The optimization analysis of the sequence method parameters for a better removal of COD, BOD and TDS wastewater from paper mills is analyzed and the findings reported below. The results are listed below. Input variable levels for SBR operation was selected based on the literature and the levels were shown in **Table. 2**

##### **Multi-objective Methodology**

**Table. 2. Input variable parameters**

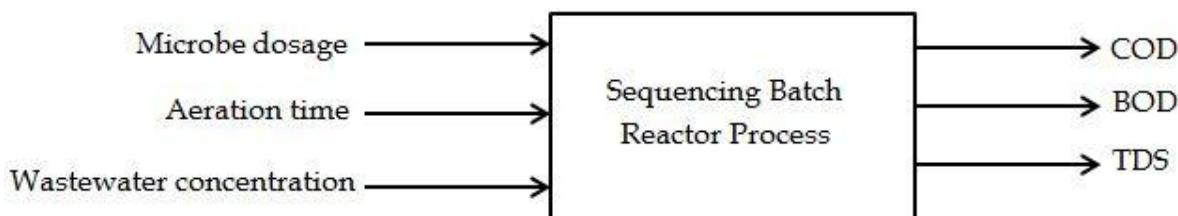
Parameters	Low	Medium	High
Microbe dosage (ml)	2	3	4
Aeration time (hrs)	4	5	6
Wastewater concentration (%)	50	75	100

**Table.3.Experimental results of sequencing batch reactor process**

Ex.N	Input variables			Responses		
	Micro	Aerati	Waste	CO	BO	TDS

O	be dosag e (ml)	on time (hrs)	water concentrat ion (%)	D (mg/ l)	D (mg/ l)	(mg/ l)
1	50	4	100	894	178	272
2	55	5	50	241	79	186
3	50	5	100	678	172	227
4	55	5	75	243	67	248
5	45	5	100	981	212	314
6	55	6	75	328	117	310
7	45	5	50	356	115	223
8	50	6	50	274	81	212
9	50	4	50	291	95	278
10	45	4	75	649	173	296
11	50	6	100	657	148	242
12	45	6	75	512	93	210
13	55	4	75	417	119	228
14	45	4	50	314	108	267
15	55	6	100	741	124	224

##### **Fuzzy logic control analysis of SBR process**



**Fig. 3.Input and output variables of Sequencing batch reactor process.**

Fuzzy logic is a mathematical theory of inaccurate reasoning which facilitates a linguistic modeling of the human reasoning process. The relation between device inputs and desired outputs can be very well established. An inferior generator, a database, a rule foundation and an outfuzzier are used in a fuzzy program. In this analysis, the fuzzifier primarily uses member features to transform the crisp inputs for fuzzy sets, and then the inference mechanism sends a fuzzy logic on fuzzy laws to produce fuzzy values. The predictions of output parameters were modelled using three input parameters, for example microbe dose, air times and wastewater concentration (Fig.), as shown by COD, BOD and TDS for the sequencer batch reactor cycle. 3. One first step in constructing a fuzzy model algorithm is for choosing the form of the fluidized process variables membership function or the fluid sets. The first step in the implementation of flush logic is to model the SBR process in order to evaluate the ranges of variables input and output. The selection is broken into fused subsets for each method component. A name is given to each fuzzy subset and a component function is allocated. Regardless of the experiment outcome, membership role is allocated. Membership features are generally classified as trapezoidal, triangular, quadrangular, etc. For fluid input and output parameters, "trimf" triangular membership functions are chosen. The 45–55 ml microbial dose can be divided into

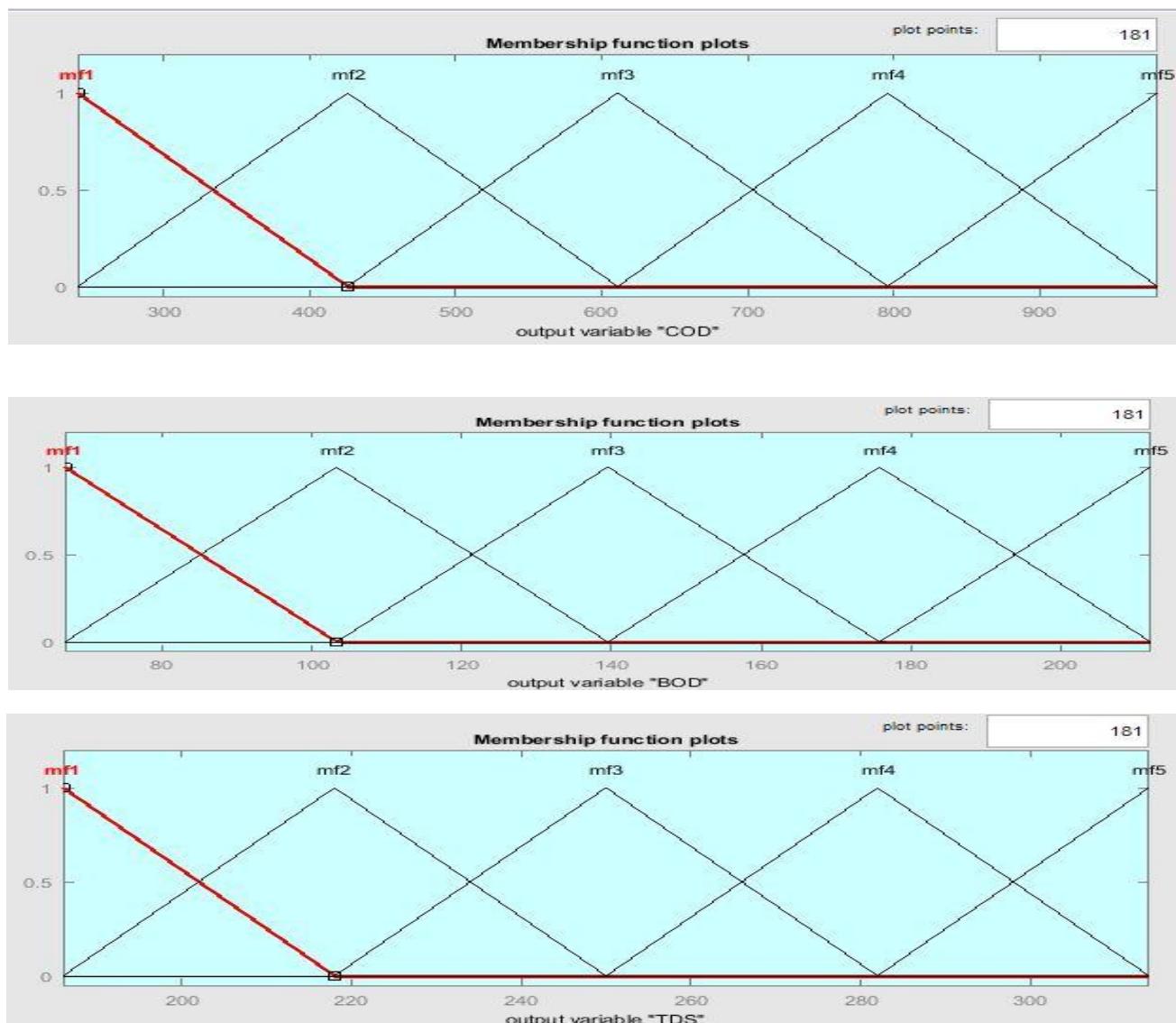
three fuzzy groups, represented in vector-like form: { low (mf1), medium (mf2), large (mf3)} and M={ M1, M2, M3}. The microbe dose, aeration duration and concentration of waste water membership is shown in the figure 4. The microbe dosage membership functions are described below:

$$M_1(x) = \frac{50 - x}{5}, x \in (45, 55)$$

$$M_2(x) = \begin{cases} \frac{x - 45}{5} \\ \frac{55 - x}{5}, x \in (45, 50) \& (50, 55) \end{cases}$$

$$M_3(x) = \frac{x - 50}{5}, x \in (5.0, 5.5)$$

Aeration time is 4 to 6 hours divided into three fluid groups, represented in a vector form: { low, medium, high} and A{ A1, A2, A3}. Likewise, the concentration of waste water is 50-100% divided into three fuszy groups of fluids as low, medium, high} and W as vector-like{ W1, W2, W3}. The parameters of the COD performance with a diameter of 363–542 ml are classified into five fuzzy sets with a diameter of{ very small (mf1), low (mf2), mild (mf3), large (mf4).

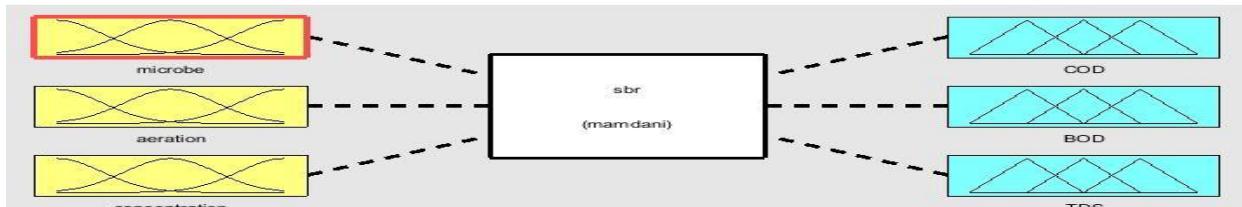


**Figure. 4. (a) membership function of COD, (b) membership function of BOD, (c) membership function of TDS**

Values of fluctuation are defined by the membership functions that describe the extent of entity membership in a dynamic collection. Nevertheless, no standard method for choosing the correct form of the membership functions for the fluorescent sets of control variables has been known until now. Tools of trial and error are typically included. The Mamdani intervention process, focused on the fuzzy laws, is used as shown in the Figure 5 for the broad inference logic in this report. Input-output interactions in the fuzzy method are defined by a series of language statements called fuzzy rules. We are focused on

experimental work, experience and technical know-how. One analysis leads to a dynamic law. If you save all of the fuzzy rules in a folder, you can set up a fuzzy rule foundation. The number of fuzzy rules in the fuzzy method refers to the number of fuzzy rules for each variable entry. Fifteen fuzzy rules are set out in this report. There are few instances of the vocabulary dynamic law hereafter. If MD is mf2, AT is mf1, and WC is mf3, then COD is mf5, BOD is mf4 and TDS is mf3

If MD is mf3, AT is mf2, and WC is mf1, then COD is mf1, BOD is mf1 and TDS is mf1 .....etc.



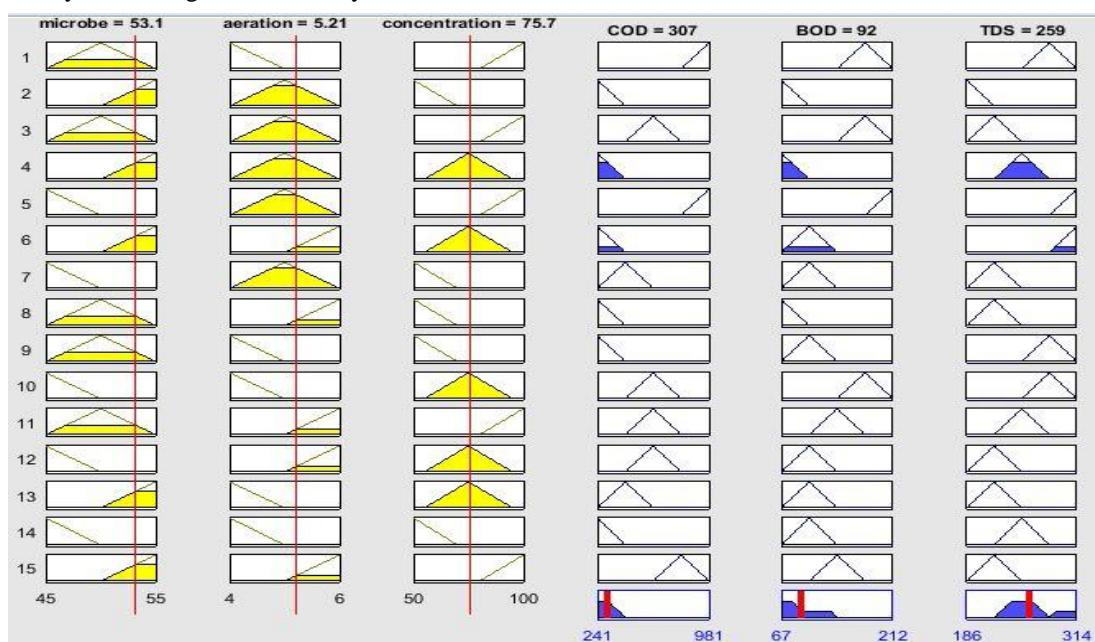
**Figure. 5.fuzzy logic Mamdani control for input and output**

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## Fuzzy inference and de-fuzzifier

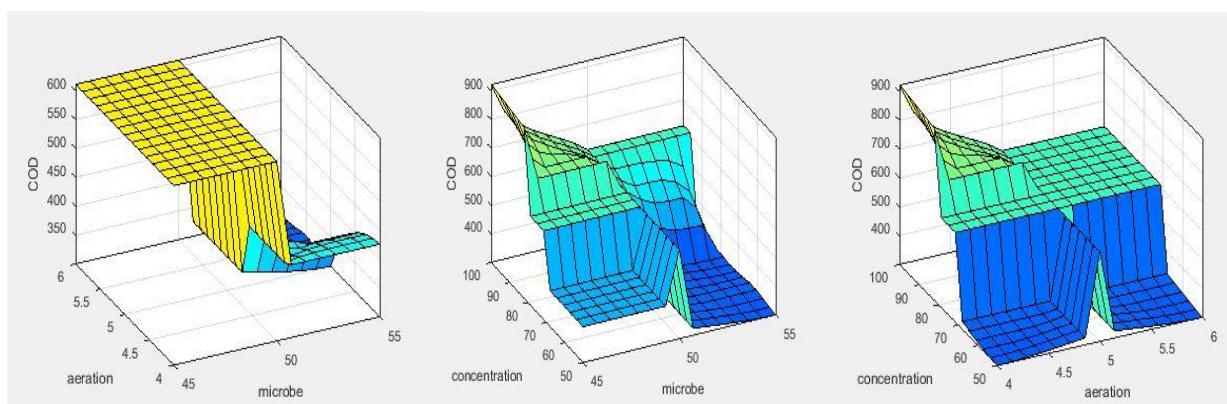
The crisp number of CR as shown in the Figure 6 can be accessed once you have generated fuzzy sets and their

membership and changed the fuzzy rules of FIS Code Editor Matlab..

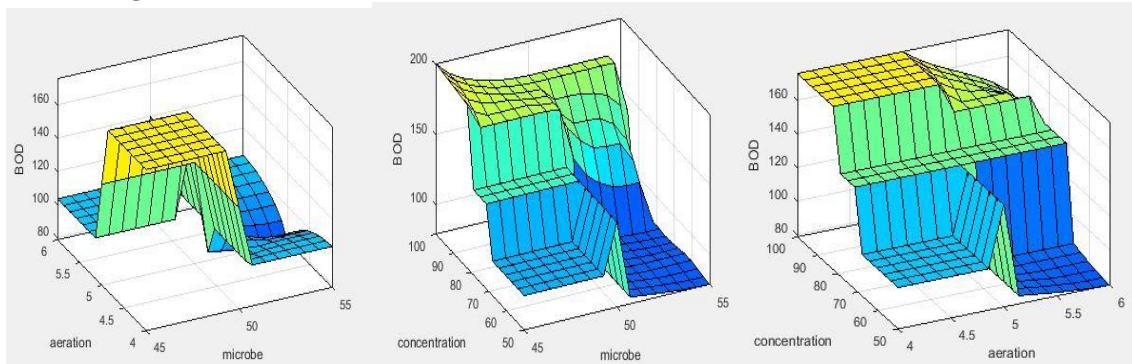


**Figure. 6.Fuzzy logic reasoning results for SBR process**

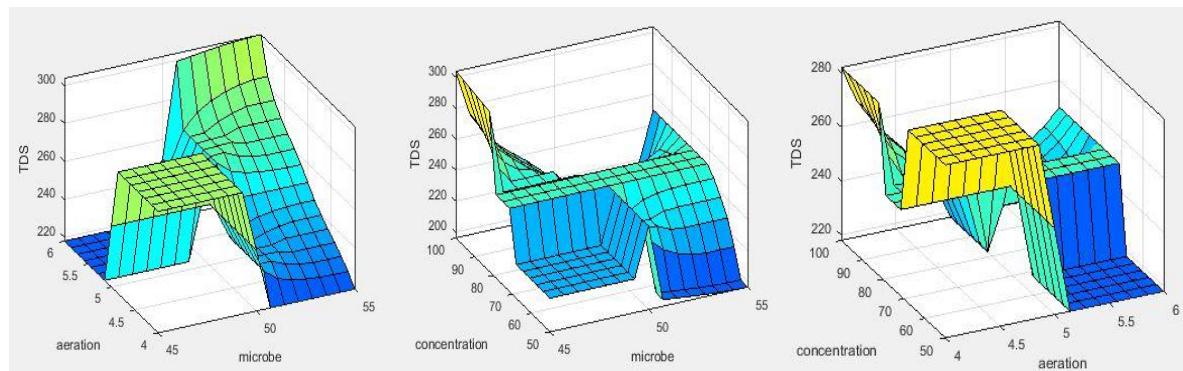
## 3D surface plot results and discussion



**Fig. 7.Surface data analysis of SBR method performance parameters: (1) microbe dosage and aeration time, (2) microbe dosage and wastewater concentration, (3) aeration time and wastewater concentration for COD.**



**Fig. 8.Surface data analysis of SBR method performance parameters: (1) microbe dosage and aeration time, (2) microbe dosage and wastewater concentration, (3) aeration time and wastewater concentration for BOD.**



**Fig. 9.**Surface data analysis of SBR method performance parameters: (1) microbe dosage and aeration time, (2) microbe dosage and wastewater concentration, (3) aeration time and wastewater concentration for TDS.

The three-dimensional control surface includes the input and output cohesion driven by the different rules of the defined discourse universe. The regulations have been applied in MATLAB using the Fuzzy inference method Mamdani-type using the Fuzzy toolbox principle. 3D surface graph shows the interdependence of COD in the treatment of bacteria, aeration periods and concentrations of waste water. Results from the SBR-Process fuzzy model were contrasted with the testing experimental results. The 3-dimensional surface trace of the SBR cycle results in high microbe dosage and reasonable aeration cycles, with low COD performance, decreased microbial dosage, then enhanced COD, and BOD,

too. The optimum parameter design allows for better elimination of COD, BOD and TDS. The SBR method parameters for removal of CODs, BOD and TDS are shown in Fig. 7, Fig. 8 and Fig. 9. Table 4 measures the measured error percentage between the fuzzy reasoning and experimental significance percentages of the expected and test results in each experimental setting:

$$\text{Error (\%)} = ((\text{Experimental value} - \text{predicted value}) / \text{Experimental value}) \times 100$$

The overall variation from the expected COD, BOD, and TDS errors for the SBR method is -5.76-5.10%, -7.66-4.53%, -16.05-6.32% and -10.13-12.10% respectively.

**Table. 4. Error prediction of fuzzy logic model for SBR response parameters**

E.No	COD				BOD				TDS			
	Exp.	Fuzzy predicted	% removal	% error	Exp.	Fuzzy predicted	% removal	% error	Exp.	Fuzzy predicted	% removal	% error
1	894	887	73.86	0.78	178	189	86.25	-6.18	272	281	90.40	-3.31
2	241	252	80.93	-4.56	79	91	83.54	-	186	196	83.97	-5.38
3	678	665	80.18	1.92	172	169	86.72	1.74	227	250	91.99	-
4	243	257	<b>88.18</b>	-5.76	67	63	<b>91.80</b>	5.97	248	218	<b>87.12</b>	12.10
5	981	994	71.32	-1.33	212	211	83.63	0.47	314	304	88.92	3.18
6	328	336	84.04	-2.44	117	129	85.68	-	310	297	83.90	4.19
7	356	341	71.84	4.21	115	126	76.04	-9.57	223	231	80.78	-3.59
8	274	268	78.32	2.19	81	94	83.13	-	212	208	81.72	1.89
9	291	284	76.98	2.41	95	89	80.21	6.32	278	286	76.03	-2.88
10	649	639	68.42	1.54	173	167	78.82	3.47	296	291	84.62	1.69
11	657	651	80.79	0.91	148	141	88.57	4.73	242	249	91.46	-2.89
12	512	503	75.09	1.76	93	103	88.62	-	210	217	89.09	-3.33
13	417	406	79.71	2.64	119	112	85.43	5.88	228	236	88.16	-3.51
14	314	298	75.16	5.10	108	115	77.50	-6.48	267	259	76.98	3.00
15	741	735	78.33	0.81	124	127	90.42	-2.42	224	241	92.10	-7.59

#### Confirmation test

Three tests were performed as shown in the table to verify the accuracy of the built model. The test conditions were picked so that they are within the previously defined level range. The projected outcomes were correlated with the

corresponding experimental values. The percentage of error is reduced. So the fluid-logic regulation strategy will effectively be employed to forecast COD, BOD and TDS in the experimental fields for any variation between the dose, breathing period and concentration of the microbe.

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**Table. 5. Confirmation test.**

S. No	Microbe dosage	Aeration time	Wastewater concentration	Experimental				Fuzzy predicted			% error	
				COD	BOD	TDS	COD	BOD	TDS	COD	BOD	TDS
1	52	4.75	70	684	154	227	667	147	241	2.49	4.55	-6.17
2	54	5.2	74	257	78	266	249	80.5	272	3.11	-3.21	-2.26
3	56	5.5	80	389	164	315	407	154	304	-4.63	6.10	3.49

## V. CONCLUSION

The current study explored the optimisation of COD, BOD and TDS recovery from waste water in paper mills with an aerobic series batch reactor. Optimisation of treatment procedures based on running factors such as the dose of bacteria, the airing time and the accumulation of wastes using dynamic functional tests. We determined that a micrometer dose of 55 ml, 5 h aeration time and 75 percent of wastewater would be the appropriate treatment. However, with increased dosing of microbes, performance of COD and BOD removal has improved and efficiency of TDS removal has not changed significantly. The results have shown that Fuzzy's logic control will model a batch reactor to process waste water from the Paper mill. To determine the fuggish reasoning of expected results, the validation check was carried out. The tests of the fuzzy logic values revealed close equivalent experimental values with a small error percentage.

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