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Theoretical prediction of odour determining parameters in dairy effluent using adaptive neuro fuzzy inference system

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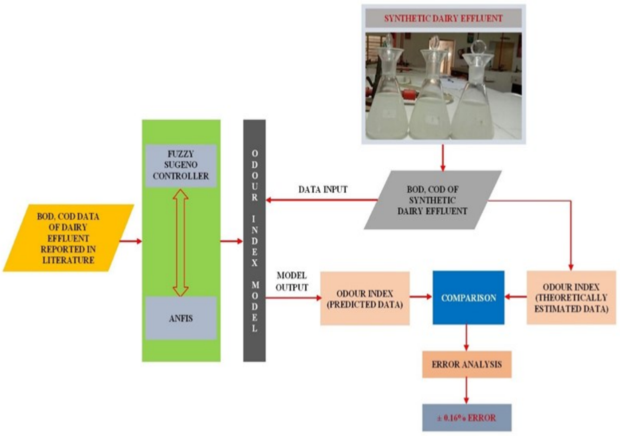
Graphical abstract



Abstract

People are prompted to complain about air pollution by offensive odours. They can produce psychological consequences, such as nausea, headaches, lack of appetite, breathing difficulties, and various adverse reactions in some circumstances. Among various industries, the dairy industry emits the most noxious odours. The human nose is the only trustworthy sensor, and numerous laboratory and field methods for quantifying human observations have been devised. Most odours are difficult to quantify, as evidenced by the fact that contemporary technology has yet to provide a fully precise method for quantifying them. As a result, the current study examines the possibility of employing fuzzy logic to predict odour intensity from dairy effluent characterisation. In this work, an Adaptive Neuro Fuzzy Inference System (ANFIS) based prediction model using Sugeno controller is developed for finding the Odour Index of the dairy effluent. COD and BOD are considered as input parameters for the model with triangular membership function for five linguistic variables. The standard odour index estimated from the literatures is used for modelling. The predicted odour index obtained from the ANFIS model for synthetic dairy wastewater is validated against the standard odour index and the average error is found to be ± 0.16 %.

Keywords: Dairy effluent, synthetic dairy effluent odour, linguistic variables, membership function, fuzzy logic controller

1. Introduction

Milk was among the most significant commodities traded in the world, and it is necessary in regular activities (Bharati S. Shete Å *et al.*, 2013). Currently milk demand is increasing by 15 metric tonnes per year, with the majority of this growth occurring in emerging countries. This is partly owing to population expansion and an increase in dairy consumption by 103.6 kg per capita per year (M.N.A. Siddiky *et al.*, 2017). In 2014 dairy industries all over the world generated more than 655 million tonnes of milk and by 2025 it was expected to rise by 23%. Dairy industry in India is of crucial importance as it contributes to 35% of the total Asian milk production (Maria Cynthia, R. Oliveros *et al.*, 2019). India is the world's greatest milk producer, consuming nearly all of its own dairy production (Wael Qasim, A.V. *et al.*, 2013). People in India rely on dairy products as an economical and healthy source of nourishment. Besides drinking milk directly, Indian tea and coffee lovers utilise a lot of milk in their drinks. Approximately 46% of India's average milk is consumed as fluid milk, although the remaining 54% is turned into conventional and complementary milk products such as butter, powdered milk, ice cream, cheese, and condensed milk. Formerly, a large amount of milk was transformed into ghee, which was used as a primary ingredient especially in the Indian subcontinent and was also India's principal dairy export (Ramphul Ohlan 2016). Concerns have been raised regarding the consequences of intensification for human health and the environment, as increased demand for dairy products has led to worldwide growth in dairy production (Wang Qingbin *et al.*, 2020, Leah Grout *et al.*, 2020]. Despite greater production could benefit with economic development and livelihoods, it can also lead to a variety of health consequences.

Increased productivity results in the production and discharge of toxic components into the surroundings, posing health risks and affecting eutrophication (Ahmed Hamdania *et al.*, 2020, B.V. Raghunath *et al.*, 2016]. Contamination of water resources in the form of the discharge of low-quality wastewater is a severe hazard to humans and marine ecosystems who live in the water for survival. The impact is particularly noticeable in emerging countries, where rapid population growth and industry have increased the complexity of wastewaters (Abdulmonem Elhassadi 2008, Paul J. Oberholster *et al.*, 2008, Edison Muzenda *et al.*, 2011). The milk and related product industry consume most of the water in its manufacturing processes and therefore becomes one among the largest generators of effluents per unit cost of production (V. B. Brião *et al.*, 2007). Many of these wastewaters are not processed and are directly discharged into streams, wherein they lead to algal blooms by adding phosphorus and nitrogen molecules to the water. Dairy wastewater is critical to the environment as 0.2 to 10 L is generated for every litre of milk produced (Mickael Vourch *et al.*, 2007). The dairy industry uses a lot of water to clean cans, machines, and floors, and the wastewater in a dairy derives from the production process, facilities, and service department. The clean water is used in many phases of dairy processes, such as milk processing, scrubbing, packaging, and washing of milk tankers, and then it is released as dairy effluent, which is a type of wastewater (Wael Qasim *et al.*, 2013). Leaks, overflows, freezing-on, boiling-over, and negligent treatment all cause spillage. Sediment release from the settling tank, discharges from bottles and washers, splashing, and container breakage in automated assembly equipment are all examples of manufacturing inefficiencies. Dairy waste is mostly neutral or slightly alkaline, but the fermentation of milk sugar to lactic acid causes them to become acidic quickly. Intense butyric acid odour and thick black precipitated sludge masses define dairy effluent (V. B. Brião *et al.*, 2007). Fats, oil, and grease (FOG) has an adverse influence on wastewater treatment plants (Adriano Aguiar Mendes *et al.*, 2010). Dairy effluent contains substantial amounts of milk components such casein and inorganic salts (Khalid Iqbal *et al.*, 2020), besides detergents and sanitizers (B.V. Raghunath *et al.*, 2016) used for washing. All these components contribute largely towards their high biological oxygen demand (BOD) and chemical oxygen demand (COD), which is much higher than the specified limits of Indian standard institute (ISI), now Bureau of Indian standard (BIS), for the discharge of industrial effluents; when these wastes are released to the nearby stream or land without any prior treatment, they cause serious pollution problems (Leah Grout *et al.*, 2020). Dairy effluents excrete efficiently deplete the amount of dissolved oxygen in nearby waters, causing anoxic environment and the release of strong foul odours (H.J. Porwal *et al.*, 2015). Flies and mosquitoes carrying malaria and other deadly diseases such as dengue fever, yellow fever, and chickenguniya incubate in the feed stream. Dairy waste is toxic to fish due to casein precipitation from waste, which decays into strongly odourous toxic sludge at certain different concentrations (B.V. Raghunath *et al.*, 2016). Dairy effluent contains soluble organics, suspended solids, trace organics. They reduce the amount of dissolved oxygen in the water. promote gaseous release, impart unfavourable flavour and aroma, impart colour or turbidity, and enhance eutrophication (Sanja Posavac *et al.*, 2010). Whey proteins, lactose, fat, and minerals are all found in large quantities in the dairy industry (Liebe, DL *et al.*, 2020, Rupak Mukhopadhyay *et al.*, 2003). Also, it has a foul odour due to the degradation of some pollutants, causing distress to the local population (Baisali Sarkar *et al.*, 2006).

People have long been aware that odours resulting from human activities might have a detrimental impact on them (Kirsten Sucker *et al.*, 2008). It is based on the amount and intensity of odour produced from the origin, the distances of emission sources from residential areas, weather conditions, topography, and human sensitivity and tolerance (N. Akdeniz *et al.*, 2012). Long-term noxious odour exposure has a negative impact on people's state of mind and conduct. It was found that they can cause many ailments, such as insomnia, stress, apathy, irritability, depression, headache, cough, runny nose, cramps in the chest, and allergic reactions (Sven Nimmermark 2004, Katja Radon *et al.*, 2004, Kelley J. Donham *et al.*, 2007).

Odour pollution is considered to be an ecological as well as social problem (Henshaw, P.; Nicell *et al.*, 2006, Jing-Jing Fang *et al.*, 2012). Odour emission from agricultural produce, particularly from animal ranches, can trigger negative reactions in humans. Source of odour in dairy industries arises from the use of fertilizers, sample feeds, bedding, and the livestock themselves (F. Chang *et al.*, 2018). The dairy effluent characteristics generally vary depending on the various processes involved, the type of product produced, composition of the feed and the sanitary conditions. Odours arising from the industries stimulate the olfactory receptors, lead to unpleasant sensations and cause major impact on the environment (Eva Agus *et al.*, 2012). Identifying and classifying the various sources of odour, evaluating the concentration and intensity is important for measuring and assessing the adequacy of mitigation procedures. In many countries, odour control is given utmost importance, different techniques and methods have been developed to ensure effective mitigation. State governments also regulate and control agricultural odours in certain states by adhering to regulations (Hyunook Kim *et al.*, 2014).

The various methods of odour measurement can be classified as sensorial method and instrumental method. Sensorial method of odour prediction is by dynamic olfactometry where a set of examiners are exposed to the odour at varying concentrations (Cecilia Conti *et al.*, 2020). It provides information about the concentration of the odour and its emission rate but cannot identify or distinguish between various odour sources. Moreover, it is a discontinuous method of odour measurement (Capelli, L.; Sironi *et al.*, 2013, Lucernoni *et al.*, 2016). Data obtained using instruments when compared with human nose is more reliable and efficient. Instrumental methods for odour monitoring include Chemical Analysis, use of electronic noses, Field Olfactometers and Gas Chromatography-Olfactometry (GC-O) (Cecilia Conti *et al.*, 2020).

Chemical analysis helps to gain information on the chemical composition which helps in evaluating the impact of odour on human health and environment. But it is less sensitive and not effective in characterizing complex odour samples (Jarauta *et al.*, 2006). GC coupled with human olfaction is used to characterize effluents with strong odours and provides data about the odour character. However, it is a time-consuming process, costly and is not used to estimate the concentration of the odour. Electronic noses are used for continuous odour characterizations, atmospheric odour monitoring and used both at receptor levels and emission levels. The disadvantage with E-nose is the intensity of the odour in the wastewater or the effluent and the hedonic tone cannot be predicted (Orzi, V *et al.*, 2018). Field olfactometers are used for quantifying odours in ambient air, provide data on the dilution rate needed to increase the hedonic tone of the odours air (Badach, J *et al.*, 2018).

For a comprehensive approach of odour management, combining 2 or more methods help in analysing the situation better and providing the best solution. Though many reported techniques are available for odour measurement, the present investigation has been done to explore the organic loading data in the dairy effluent using fuzzy logic and develop a mechanism to theoretical predict odour, based on the oxygen content and demand of the effluent, that will in turn be used in devising a methodology to eliminate odour related pollution caused by dairy effluents.

From the published literatures (Zulfadhli Mazlan *et al.*, 2012, J. Adeline Sneha *et al.*, 2014, G. Vijayaraghavan *et al.*, 2012) it is inferred that implementation of fuzzy logic controller has high potential in chemical industries. Also, applications that mostly rely on laboratory setups can adapt decision making based on fuzzy logics, which can be amazingly effective for nonlinear processes. Hence, in the paper an adaptive neuro fuzzy modelling is developed for odour intensity prediction.

Generally, the prediction model requires a mathematical relation between the input and output, whereas, Fuzzy logic deals with vogue or uncertain data which may be conflicting in nature. Fuzzy logic depicts human thoughts and the knowledge of the individual on the process for which the logic is implemented. It does not have rigid calculations rather has flexible rules (Shu-Yin Chiang *et al.*, 2008). Figure 1 represents the block diagram of fuzzy logic system.

The real time inputs are always crisp values. In fuzzification, these crisp values are converted in to Fuzzy with the use of linguistic variables, which represent a system's operating parameter (Tae Kyung Kim *et al.*, 2008). These linguistic variables are assigned to a membership function which represents the magnitude of participation of each input. A membership function (MF) is a curve that defines mapping of each point in the input space to a membership value (or degree of membership) between 0 and 1 (Timothy J 2011, Satyendra Nath Mandal *et al.*, 2012, Arpit Jain *et al.*, 2020). With the membership function and the linguistic variables, the crisp value is converted in to fuzzy. This fuzzy input is fed in to the Fuzzy Inference System (FIS).

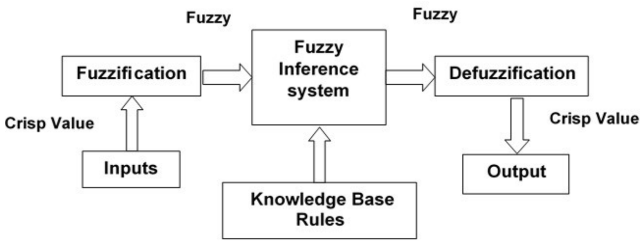


Figure 1 Block diagram of Fuzzy logic system

Fuzzy Inference System is the key unit of a fuzzy logic system having decision making as its primary work. Based on the knowledge of the system and the input, output relation, the fuzzy inference system uses the "IF…THEN" rules along with connectors "OR" or "AND" for drawing essential decision rules (Ahmed Maidi *et al.*, 2008). Two types of inference system are used, they are Mamdani controller and Sugeno controller. In mamdani controller, "*if – then"* rule is used for decision making. In Sugeno controller a function relating the input and output is used for decision making. Rule is framed according to the input and output of fuzzy sets. In Defuzzification, the fuzzy value is converted in to a crisp mean value based on the fuzzy inference system with strength of the membership function for each rule.

2. Materials and methods

2.1. Development of prediction model

In certain phases of wastewater treatment, organic particles, dissolved matter, and other nitrogenous chemicals in the dairy wastewater might cause malodour formation. In this study, strong correlations were produced for odour relating COD and BOD using the fuzzy prediction model (Guleda Onkal-Engina *et al.*, 2005). To develop a prediction model numerous data sets were acquired from previously reported literature of close relevance as reported in Table 1. The data will further be used to correlate malodour emitted from dairy effluents if improperly handled.

2.2. Optimization model

The objective of this research is to design an optimization model for the prediction of dairy effluent Odour Index. The prediction model is developed with the help of fuzzy inference system in MATLAB. Since the input is vague in nature Adaptive Neuro Fuzzy Inference System (ANFIS) model is used to generate the output. ANFISis an artificial neural network in Sugeno fuzzy inference system. It combines both fuzzy logic principles and neural network

(Zhiwen Wang *et al.*, 2007). it has potential to handle the benefits of both. Figure 2 shows the proposed adaptive neuro fuzzy optimization model using Sugeno fuzzy controller. The BOD and COD are considered as inputs for the fuzzy inference system. Output is the Odour Index, which is derived from the relation between COD and Odour index based on equation (1)

$$Odour\ Index\left(OI\right)=10\log(COD) \tag{1}$$

Table 1 Odour Contributing Parameters

S. No	COD (mg/L)	BOD (mg/L)	REFERENCES
1.	3400	726	(E.S. Glushchenko *et al.*, 2019)
2.	1600	102	(Jayesh H. Kabariya *et al.*, 2018)
3.	1110	430	(Lavvarma, Jyoti Sharma 2012)
4.	468	210	(Uttarini Pathak *et al.*, 2016)
5.	1686	226	(Ashwin T *et al.*, 2017)
6.	345	51.75	(Prashant A. Kadu *et al.*, 2013)
7.	3274	-	(L. H. Andrade *et al.*, 2015)
8.	2152.1	264	(Hee-Jeong Choi *et al.*, 2016)
9.	250	30	(Pawanr Wani *et al.*, 2017)
10.	1900	1200	(Bharati S. Shete À *et al.*, 2013)
11.	1049.57	355	(Aagosh Verma *et al.*, 2018)
12.	7100	-	(Chatterjee Sreemoyee *et al.*, 2013)
13.	903	565	(Anna S. Nyaki *et al.*, 2016)
14.	330	300	(S. Sharada *et al.*, 2014)
15.	1400	650	(Vishakha Sukha *et al.*, 2013)
16.	115	665	(L. Maria Subashini *et al.*, 2017)
17.	-	10	(Shemeera K. H *et al.*, 2018)
18.	140	50	(Rajkumar V. Raikar *et al.*, 2015)
19.	1331	1366	(Pratiksinh Chavda *et al.*, 2014)
20.	1486	717.8	(Vishakhasukhadevshivsharan *et al.*, 2017)
21.	1360	775	(P.G. Kulkarni *et al.*, 1998)
22.	6300	860	(Ozge Sivriolugu *et al.*, 2015)
23.	502.5	296	(Raed S. Al-Wasify *et al.*, 2017)
24.	1250	260	(Shalini. N 2015)
25.	359	68	(Rakesh Mehrothra *et al.*, 2016)
26.	1459	548	(Vishakha Sukhadev *et al.*, 2013)
27.	1250	454	(Alok Suman *et al.*, 2018)
28.	4800	1477	(Brazzale P *et al.*, 2019)
29.	431	246	(Ashish Tikariha *et al.*, 2014)
30.	4957	2100	(S. Shraddha *et al.*, 2014)
31.	1260	710	(Osama A *et al.*, 2015)
32.	350	250	(C.M. Noorjahan *et al.*, 2004)
33.	47	56	(Pooja Dahiya *et al.*, 2020)
34.	747	350	(Leena A. V, N. *et al.*, 2016)
35.	2100	1040	(T. Subramani *et al.*, 2017)
36.	250	30	(Sameer Saxena *et al.*, 2017)
37.	850	203	(Rabee Rustum *et al.*, 2020)
38.	1840	1110	(T. Viraraghvan *et al.*, 1990)
39.	2100	1040	(Gour Suman *et al.*, 2017)
40.	3795	2065	(B. Asha *et al.*, 2014)
41.	3113	626	(E.I. Vialkova *et al.*, 2019)
42.	2580	1240	(Dania Aburayyanhaneen *et al.*, 2018)
43.	320	90	(Pachpute A.A *et al.*, 2014)
44.	2880	-	(Asha Rani Garg *et al.*, 2017)
45.	717.6	242.9	(Jacineumo F. De Dliveira *et al.*, 2017)
46.	1000	-	(Sakshi A. Hattargi *et al.*, 2018)
47.	4958	1920	(Ashish Tikariha *et al.*, 2014)
48.	1500	600	(Vishakha Sukhadev Shivsaran *et al.*, 2013)
49.	4300	3100	(Shabna Banu A.M *et al.*, 2017)
50.	359.4	190.63	(Shilpi Rashmi, R.K.Sinha *et al.*, 2020)

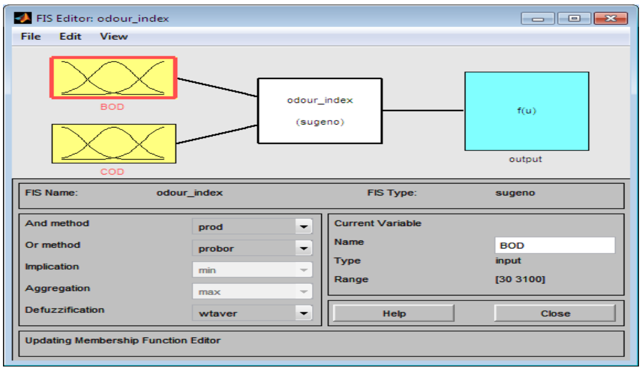


Figure 2 Proposed Adaptive Neuro Fuzzy Optimization Model

2.3. Membership function and linguistic variables for inputs

The membership function, fuzzification and defuzzification system used in this project are discussed further. The inputs chosen for the system are BOD and COD. Membership function is triangular with five assigned linguistic variables. The fuzzification process using triangular membership function is given in the Figure 3. The defuzzification method adopted is weighted average.

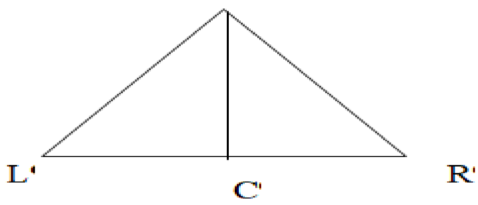


Figure 3 Triangular membership functions

The degree of membership function is given by equation (2)

$$\mu_{triang}(x)=\begin{cases} 0, & x<L \\ 1-\dfrac{|C-x|}{(R-L|2)}, & L<x<R \\ 0, & x>R \end{cases} \qquad (2)$$

Where, $\mu_{triang}(x)$ is the degree of membership function for a triangular fuzzy set on the universe of discourse x.

The BOD and COD values represented in Table 1 have been used as input data in the optimization model (as shown in Figure 4) using which the minimum and maximum values of BOD and COD are fixed to form a range as given in Table 2. According to equation (1), the relation between Odour Index for the COD dataset is determined, and the range of Odour Index is found to be varying from 16.7 to 38. Hence, this range is fixed for the Odour Index in the fuzzy Sugeno controller.

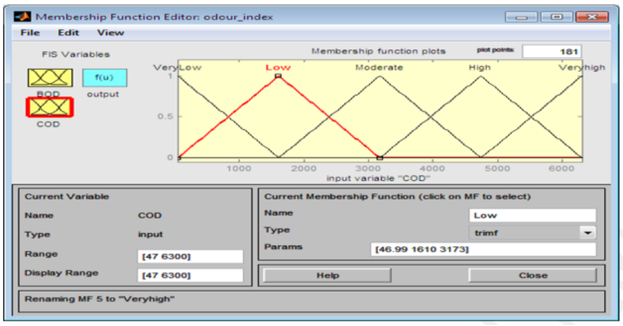


Figure 4 Membership function and Linguistic variables for COD

2.4. Adaptive neuro fuzzy inference system (ANFIS)

Adaptive neuro-fuzzy inference systemis an artificial neural network. In sugeno fuzzy inference system, both fuzzy logic principles and neural network is combined and it has potential to handle the benefits of both. The network structure consists of two parts consequence and premise part. ANFIS is composed of five layers. First is the Fuzzification layer which accepts the input value and determines the membership function and computes the degree of membership by premise parameter set. Second is Rule layer, which is responsible for generating the strength for the rules. Third is Normalizing layer that normalises the computed strength of input. Fourth is Consequence layer which takes the normalised input and consequence the parameters. Finally, the Defuzzification layer, results of the above step are obtained and final output is returned. In this work ANFIS is used for training the dataset and for testing the unknown values.

Table 2 Linguistic variable and Ranges for BOD and COD

Linguistic Variables	BOD		COD	
	Range	Mid Value	Range	Mid Value
Very Low	-737.5 to 797.5	29.99	-1516 to 1610	46.79
Low	30.01 to 1565	797.5	46.99 to 3173	1610
Moderate	797.5 to 2332	1565	1610 to 4737	3174
High	1565 to 3100	2333	3174 to 6300	4737
Very High	2333 to 3868	3100	4737 to 7863	6300

3. Implementation procedure in MATLAB

As shown in Figure 5 the training data is loaded in to the ANFIS model. Similarly test data is also loaded in to the model. Fuzzy Inference System is generated after loading the data. The number of membership function and the type of membership function are chosen. 5 membership functions are fixed for both the inputs and triangular membership functions are considered for the model. The output membership function is chosen as constant.

Optimization method used for this ANFIS model is hybrid of gradient descent (GD) and least squares estimator (LSE) through two pass learning algorithms. Gradient descentis afirst-orderiterativeoptimizationalgorithmfor estimating alocal minimumof adifferentiable function. Repeated iterations are performed in the opposite direction of thegradientof the function at the present point, which is the direction of steepest descent.Whereas, in least squares sum of the squares of the residuals are minimized. In ANFIS the combination of both the algorithms are used as an optimization technique.

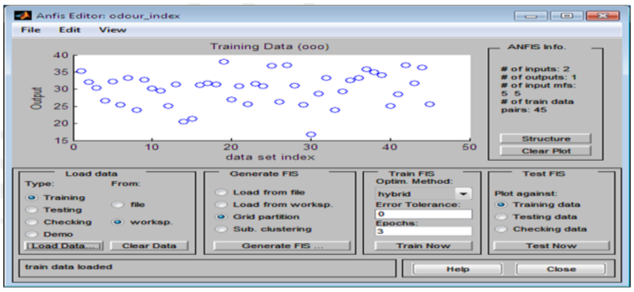


Figure 5 Training data loaded into ANFIS model

Figure 6 depicts the training of the adaptive neural network and the error after training the algorithm. The training epoch was set to 10, however training converged at second epoch and the error was found to be 1.1668.

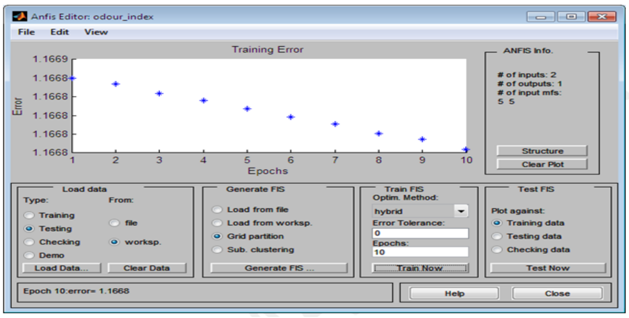


Figure 6 Training of Adaptive neural network

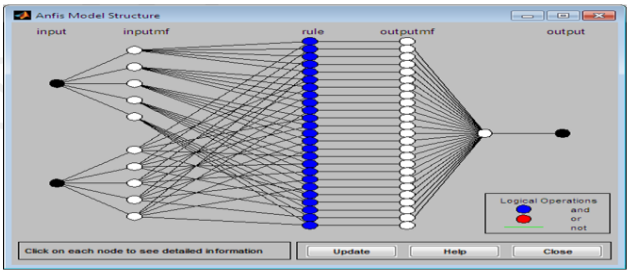


Figure 7 Generated Adaptive neural Network Architecture in FIS

Figure 7 shows the Adaptive neural network architecture generated in the fuzzy inference system. As shown, the input layer consists of two neurons, one for BOD and another for COD. The next layer corresponds to the membership functions. Each input neuron has five input membership functions. Each input membership function of one neuron is linked with the input membership function of other neurons. Hence, with these, all possible combinations (25 rules) were framed by the network and therefore 25 output membership functions were generated. These 25 output membership functions are linked to one output neuron. The network used "AND" logic for framing the rules.

3.1. Weighted average defuzzification

In weighted average method, each membership function in the output is weighed by its respective maximum membership value. This method is also known as Sugeno defuzzification method. The method is applied only for symmetrical output membership functions. The crisp value is found according to equation (3)

$$z^* = \frac{\sum \mu_{c_i}(\bar{z}).\bar{z}}{\sum \mu_{c_i}(\bar{z})} \qquad (3)$$

Where, µ is the degree of membership function, Ci is the output fuzzy set and $\bar{Z}$ is the value where middle of the fuzzy set C_i is observed. Z* is the defuzzified output. Figure 8 shows the Rule viewer in ANFIS editor, representing the relation between COD, BOD and Odour Index. The rule viewer provides the Odour Index as the crisp value for any possible combination of COD and BOD in the specified range.

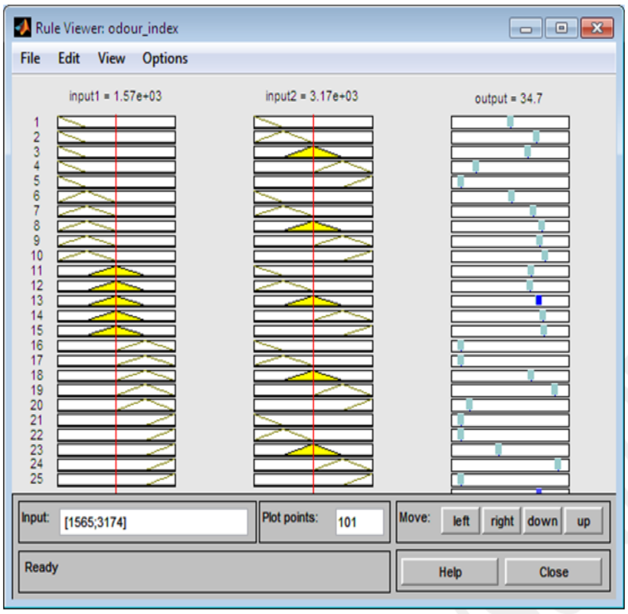


Figure 8 Rule viewer in ANFIS editor

4. Experiments for data validation

To validate the predicted model an experiment was conducted using synthetic dairy wastewater.

4.1. Sample preparation

Due to the wide variation in the characteristics of real time effluents from different dairy industries focusing demand-based milk products, a synthetically formulated effluent has been used to meet the consistency of quality parameters in the present study [(Magno dos Santos Pereira *et al.*, 2018)]. Synthetic dairy wastewater (SDW) was prepared by the dissolution of glucose (2.4 mg L−1), $FeSO_4.7H_2O$ (24.0 mg L−1), $NaH_2PO4.H_2O$ (900.0 mg L−1), $NaHCO_3$ (1560.0 mg L−1), $MgSO_4.7H_2O$ (600.0 mg L−1), $MnSO_4.H_2O$ (24.0 mg L−1), $CaCl_2{\cdot}2H_2O$ (36.0 mg L−1), NH_4Cl (583.3 mg L−1), $(NH_2)2CO$ (2700.0 mg L−1), and whole milk powder (1440.0 mg L−1) (Gustavo Lopes Muniz *et al.*, 2021). Reagents were dissolved in tap water.

SDW samples were prepared based on the three different concentrations by the dissolution of 2,4,6 g/l whole milk powder. Characteristics like pH, chlorides, ammonia COD, DO and BOD of the SDW were documented in Table 3.

Table 3 Characteristic Value of Synthetic Dairy Waste Water

S.NO	CHARACTERISTICS	Sample 1 (2g)	Sample 2 (4g)	Sample 3 (6g)
1.	pH	6.7	6.2	5.9
2.	BOD	2340	1903	1312
3.	COD	6448	5465	4897
4.	CHLORIDE	973	742	535
5.	DO	6.76	5.8	3.38
6.	AMMONIA	14.09	12.87	10.24

Table 4 Performance Analysis of ANFIS Model

BOD	COD	Standard Odour Index	Odour Index (ANFIS Model)	Error (%)
726	3400	35.3148	35.31429	0.00143
102	1600	32.0412	33.9418	-5.93173
430	1110	30.4532	29.98216	1.54675
210	468	26.7025	25.48702	4.55192
226	1686	32.2686	33.69837	-4.43084
51.7	345	25.3782	24.49485	3.48076
264	2152.1	33.3286	33.16859	0.48011
30	250	23.9794	23.75581	0.93242
1200	1900	32.7875	32.62968	0.48133
355	1049.6	30.2101	29.62296	1.94351
565	903	29.5569	28.49523	3.59196
300	330	25.1851	24.53597	2.57742
650	1400	31.4613	31.66446	-0.6457
665	115	20.607	23.3814	-13.463
50	140	21.4613	22.93477	-6.8656
1366	1331	31.2418	31.24156	0.0007
717.8	1486	31.7202	32.11243	-1.2365
775	1360	31.3354	31.23852	0.30916
860	6300	37.9934	37.99336	0.00011
296	502.5	27.0114	25.76425	4.61714
68	359	25.5509	24.61055	3.68030
548	1459	31.6406	32.20147	-1.7726
454	1250	30.9691	30.91776	0.16578
1477	4800	36.8124	36.81268	-0.0007
246	431	26.3448	25.23251	4.22204
2100	4957	36.9522	36.95275	-0.0014
710	1260	31.0037	30.69152	1.00692
250	350	25.4407	24.64919	3.11119
56	47	16.721	22.23443	-32.973
350	747	28.7332	27.49932	4.29425
1040	2100	33.2222	33.38677	-0.4953
30	250	23.9794	23.75581	0.93242
203	850	29.2942	28.27757	3.47040
1110	1840	32.6482	32.66972	-0.0659
1040	2100	33.2222	33.38677	-0.4953
2065	3795	35.7921	35.79202	0.00023
626	3113	34.9318	34.8711	0.17377
1240	2580	34.1162	34.06435	0.15199
90	320	25.0515	24.32947	2.88219
242.9	717.6	28.5588	27.30496	4.39039
1920	4958	36.9531	36.95222	0.00239
600	1500	31.7609	32.3905	-1.9823
3100	4300	36.3347	36.33464	0.00017
190.6	359.4	25.5558	24.6833	3.41408

S

4.2. *Analytical methods*

Commercial skimmed milk powder (Amulya brand, manufactured by Banaskantha District Cooperative Milk producer's Union Ltd., Palanpur, Uttarakhand, India) were purchased from Local Market, Kilakarai. Synthetic Dairy Wastewater samples were analyzed for pH, Biological oxygen demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), chloride and ammonia content according to the standard method. pH was measured by electrometric method using a digital pH meter (PH-016 Bench-top pH), supplied by Southern India Scientific Coorporation, Chennai. COD was measured by the dichromate method which is the American Public Health Association (APHA) standard method with the use of potassium dichromate followed by titration with standard ferrous ammonium sulfate. BOD results were computed using a YSI5100 dissolved oxygen metre provided by Southern India Scientific Coorporation, Chennai over a 5-day period at 20°C. Commonly used chemicals like NaOH, HCl, Sulphuric acid (98% pure) of LR grade were procured from Vinayaga Scientific Supplies, Trichy. Deionized water was employed for reagent preparation. The features of SDW generated in the research lab for this analysis are listed in Table 3.

4.3. *Characteristics of SDW*

The composition of the synthetic wastewater feed was found similar in concentration to dairy effluent collected from dairy industry. Synthetic Dairy wastewater have a large variation in pH, chloride, ammonia, dissolved oxygen, biological oxygen demand (BOD), COD. Typically, synthetic dairy wastewater was found white in colour and has an unpleasant odour and turbid character. pH was found to be between 6 and 7. Synthetic dairy wastewater is characterized by high BOD and COD values varying from 1000-2500 mg/L and 4000-6000mg/L respectively.

5. Result and discussion

5.1. *Characteristics of SDW*

Based on the properties of regular dairy effluent, the synthetic composition was generated to stimulate it. The composition of the synthetic wastewater feed was found similar in concentration to dairy effluent collected from dairy industry. Synthetic Dairy wastewater have a large variation in pH, chloride, ammonia, dissolved oxygen, biological oxygen demand (BOD), COD. Typically, synthetic dairy wastewater was found white in colour and has an unpleasant odour and turbid character. SBW was prepared for 3 different concentrations. SDW had slightly acidic pH of 6.2–6.8 and is characterized by high BOD and COD values varying from 1000-2500 mg/L and 4000-6000mg/L respectively.

5.2. *Analysis of ANFIS Model*

Table 4 shows the performance analysis of ANFIS model. The odour index obtained from ANFIS model is given in column 4 of Table 4. Column 5 shows the percentage error of the predicted value against the standard Odour Index. The average error in the prediction is found to be ± 0.32201.

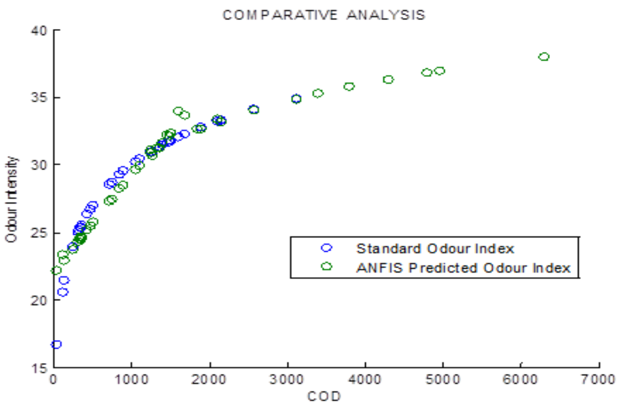


Figure 9 Characteristics graph of the ANFIS Prediction model

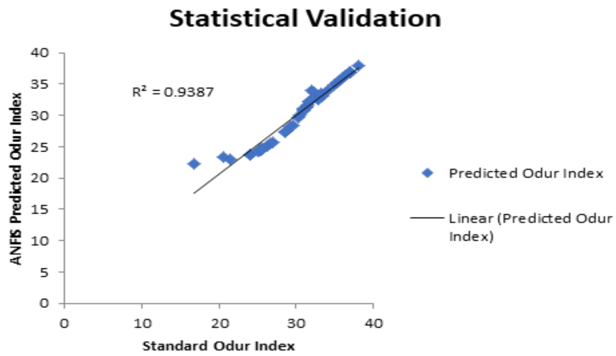


Figure 10 Validation of the ANFIS predicted model

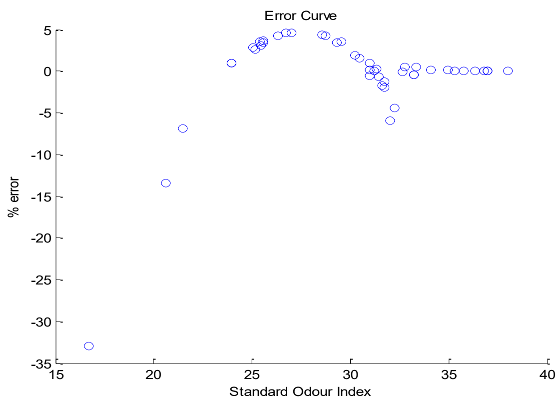


Figure 11 Error graph of ANFIS Prediction model

Table 5 ANFIS prediction of Odour Index for Synthetic Dairy Effluent

BOD	COD	Standard Odour Index	ANFIS Predicted Odour Index
2340	6448	87.71	87.69
1903	5465	86.06	86.24
1312	4897	84.96	84.68

Figure 9 shows the characteristics of the ANFIS prediction model compared to the standard Odour Index. As seen in the Figure, the prediction model has small deviation initially, then for higher values of COD, the deviation got reduced. Figure 10 shows the validation graph done by performing regression analysis with best fit. As seen from the graph, the R^2 value is 0.9387, which is a better fit, i.e closer to the linear approximation. Similarly, Figure 11 depicts the error graph of ANFIS prediction model. It is observed that the error is almost nil for higher values of odour index and comparatively larger for lesser values. Table 5 shows the Odour Index predicted by the ANFIS model for the synthetic dairy effluent. The average error of the test data is ± 0.16 %. Similar prediction can be made possible with the developed model for any kind of waste water provided its BOD and COD are known. Hence, the methodologies for minimizing the odour and the effects can be taken up for further analysis.

6. Conclusion

The purpose of this study is to design a prediction model for estimating the Odour Index of Dairy Effluent. The prediction model is developed with the help of fuzzy editor in MATLAB and Sugeno controller is used, which incorporates Adaptive Neuro Fuzzy Inference System as a decision-making algorithm. The system applied hybrid optimization technique which involves gradient descent and least square estimator. The dataset for the training is obtained from 50 literature reviews. COD and BOD are considered as the parameter for estimating the odour index. The ANFIS Prediction model was able to determine the odour index with an average error of ± 0.32201. The accuracy of the prediction model can be increased by giving a greater number of training samples. In addition, the algorithm was also tested for synthetic dairy waste samples and is validated against the standard odour index with an error percentage ± 0.16 %. Thus, the predicted model proves to be suitable in correlating organic loading of dairy effluents and the odour index. The study may further be extended for evaluating odour indices of other noxious effluents and its organic loading.

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