Int.J.Curr.Microbiol.App.Sci (2017) *6*(11): 1445-1451

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 11 (2017) pp. 1445-1451**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.611.172

Tracer Study of Anaerobic Fixed Film Reactor used for Treatment of Dairy Effluent

Vivek Koshta[1], Anil R. Chaudhari[1*] and J.B. Upadhyay[2]

[1]Department of Dairy Engineering, MIDFT, Mehsana, Gujarat, India
[2]Department of Dairy Engineering, S.M.C. College of Dairy Science, Anand Agricultural University, Anand, Gujarat, India
**Corresponding author*

Keywords

Tracer study, Hydrodynamic characteristics, Morril Dispersion Index, Fixed film reactor, Dairy effluent.

Article Info

Accepted:
12 September 2017
Available Online:
10 November 2017

A B S T R A C T

Most of the anaerobic reactors employed for effluent treatment encounter the problem of short-circuiting of path and formation of dead spaces inside the reactor over a long period of time which results into a decline in performance of the reactor. The tracer study identifies any short-circuiting in the path of feed to the outlet and also determines dead spaces, present if any. Thus, it acts as a tool to have an insight of the reactor while they are also being operational, regardless of dismantling it. In present study, a tracer experiment was conducted in two laboratory scale reactors that were operated for treatment of dairy effluent and inferences were drawn for the hydrodynamic characteristics such as residence time distribution curve, mean residence time, dispersion index, volumetric efficiency, short-circuiting, and clogging inside the reactor.

Introduction

In continuous flow anaerobic reactors the average residence time of the effluent and the quality of mixing are important. The reactor performance is influenced by the hydrodynamic characteristics since it has direct impact on the extent of contact between the substrate and the microorganisms. The principle behind the tracer analysis is based on the fact that factors such as interstitial up-flow velocity, biogas lifting and mixing, and biomass accumulation affects the reactor performance. These factors can be collectively evaluated by examining the mixing dispersion and actual HRT, which could be used to evaluate the extent of short circuiting within the packed bed (Tembhurkar and Mhaisalkar, 2006). In tracer studies a known concentration of a non-reacting dye is injected as a pulse input inside the reactor and residence time distribution curves are plotted, based on which inferences are drawn (Tembhurkar and Mhaisalkar, 2006).

Materials and Methods

Two laboratory scale reactors were selected for the study, which were identical in every aspect except the packing media inside them. The reactors were named as reactor A for polypropylene saddles and reactor B for ceramic saddles as packing media. The packing media was supported inside the reactor with the help of a perforated plate. The packing media was placed in 20 % of the total volume of the reactor (Wu *et al.*, 2000). The schematic diagram of the reactors is shown in Figure 1. A perforated plate was placed at a height of 60 cm thereby providing a portion of 40 % height to the upper body and 60 % height to the lower body of the reactor. The lower portion was expected to work as UASB while the upper portion as fixed film reactor. A provision of recirculation of effluent was provided in the reactor as it would aid in degradation as it keeps the solids in suspension (Cheenicharo, 2007). The feeding of reactor was done through a peristaltic pump with a flow rate of 57.1 l/h. The specifications of the reactors are given in Table 1. The reactors were operational for six months at various HRTs viz. 15 d, 10d, 5d, 3d, and 2d. Tracer test was conducted at last after the operation of reactors at these HRTs.

Tracer step input technique was used to study the Residence Time Distribution (RTD) characteristics, dispersion index, short-circuiting and volumetric efficiency of the reactors. An inert tracer dye viz., Bromocresol Green was used for conducting the tracer experiment and the samples collected were observed at wavelength of 610 nm in UV spectrophotometer. A standard dye calibration curve was prepared by taking the readings of different known concentration of dye solution and measuring its absorbance in the spectrophotometer. This curve was later used to know the concentration of dye against absorbance reading measured in spectrophotometer during the tracer experiment. A tracer of concentration 50 mg/l was injected inside the reactor as a pulse input. The flow rate was 57.1 l/h which was kept exactly same as used during the operation of the reactors. The grab samples were collected for a period of three times the theoretical retention time at the outlet with an interval of 2.5 minutes. Later, the absorbance of the sample was checked in UV spectrophotometer and the concentration of tracer in the sample was obtained using the standard dye calibration curve. The method adopted was similar to that followed by Wu *et al.*, (2000), and the Noguera and Perez (2007). Another dispersion index viz., Morril Dispersion Index (MDI) was used for calculation of volumetric efficiency, short circuiting, average retention time and mean retention time.

Dye calibration curve

The dye calibration curve was prepared by placing different amounts (1, 10, 20, 50, 75 and 100 ml) of the dye solution in 100 ml volumetric flasks. The total volume in each flask was brought to 100 ml using the distilled water. The spectrophotometer was set to measure the absorbance at 610 nm; the distilled water was used to zero the equipment after each sample reading. The Pasteur pipette was used to take the sample from volumetric flask into the cuvet. The cuvet was placed in the spectrophotometer and the absorbance was measured at wavelength of 610 nm and the concentration of dye (mg/l) versus absorbance was prepared.

Tracer experiment method

The reactors were filled and completely filled with water with the help of peristaltic pump that was used for feeding of the reactors. The flow rate was set in the reactors as per the desired HRT. The stop watch and 1000 ml graduated cylinder were used to correctly measure the flow rate. After the flow rate got set, the dye solution was injected at the point of inlet as a pulse input using a syringe and at the same time clock was started. The dye concentration was measured at the outlet in equal interval of time i.e. 2.5 minutes. The samples were taken till 3-5 times the HRT or till the clean water is obtained at the outlet. The absorbance reading of these individual samples was taken at 610 nm in a spectrophotometer and the graph was plotted for absorbance versus time or concentration versus time.

Calculations of hydrodynamic characteristics

The mean residence time is calculated from the following formula:

$$T_g = \sum (T_i C_i D_{Ti})/\sum (C_i D_{Ti})$$

Where,

T_i = the time after tracer was introduced (min.)

C_i = the concentration of tracer in the sample taken at time T_i (mg/l)

D_{Ti} = the interval between successive samples (min.)

The variance describes the spread of the RTD curve and is given by formula

$$s^2 = \sum (T_i^2 C_i D_{Ti})/\sum (C_i D_{Ti}) - Tg^2$$

T_g and s^2 were used to calculate the dispersion number (Nd) from the equation given below:

$$s^2 = 2T_g^2 [Nd - Nd^2 (1 - e^{Nd})]$$

Where Nd is the dispersion number

Calculations of Morril Dispersion Index (MDI)

The parameters used for Morril Dispersion Index were MDI, Volumetric efficiency, Index of short circuiting, Index of average residence time, Index of mean residence time, that are as follows:

$$MDI = T_{90} / T_{10}$$

Volumetric efficiency = 1 / MDI
Index of short circuiting = T_f / T_h
Index of average residence time = T_g / T_h
Index of mean retention time = T_{50} / T_h

Where, T_h is Theoretical hydraulic retention time.

T_{10}, T_{50} and T_{90} are the time at which 10, 50 and 90 percent of the tracer had passed through the reactor.

T_f is time at which tracer first appears.

T_g is the mean time to reach the centroid of the curve.

Results and Discussion

The tracer curves obtained in the test resembled normal distribution with slightly skewed to the left. The curves had a long tail at the end. Escudie *et al.,* (2005) stated a similar characteristic long tail curve pattern with the tracer experiment on CSTR (Constant Stirred Tank Reactor). It is probably due to the diffusion of tracer into the biofilm on porous surface of the media.

Hydrodynamic characteristics

The hydrodynamic characteristics were found using the equations suggested in Tembhurkar and Mhaisalkar (2006). The residence time distribution curves were plotted for both the reactors as shown in Figs. 2 and 3, and were analyzed for mean residence time T_g and the variance s^2. The mean residence time denotes the mean of RTD curve and the variance describes the spread of the RTD curve. T_g and s^2 were used to calculate the dispersion number (Nd) that measures the extent of axial dispersion in the reactor and to analyze the extent of dispersion using the Levenspiel and Smith's longitudinal dispersion model (Tembhurkar and Mhaisalkar, 2006). The model hypothesizes the flow in packed bed as in plug-flow pattern with different extents of dispersion or back-mixing in the axial direction with the varying intensities of dispersion.

The prediction of model ranges from zero dispersion number for ideal plug flow at one extreme to an infinite dispersion number ideal mixed flow at the other extreme, where the dispersion number approaches infinity. The values of dispersion index for various extent of mixing as predicted by the model are given in Table 2.

The values of T_g were 30.72 and 26.53 for reactor A before and after operation. Similarly, the values were 31.68 and 24.81 for reactor B. The values of s^2 were 376.06 and 289.42 for reactor A before and after operation. Similarly, the values were 266.18 and 223.55 for reactor B before and after operation. Table 3 shows hydrodynamic characteristics of both the reactors with the values of mean retention time, variance and dispersion number. After matching the values of dispersion index for both reactors as given in Table 2, it is concluded that the reactors had an ideal mixing inside it. The values of dispersion number fall in category of ideally mixed reactor.

Morril Dispersion Index (MDI)

The value of Morril Dispersion Index obtained was 20 for reactor A and 17 for reactor B. The value of MDI for an ideal plug flow reactor is 1 and about 22 for a complete mix reactor. Thus, from the results we can conclude that the reactor is close to the completely mixed reactor from the results.

Table.1 Specifications of the reactors

	Height (cm)	Diameter (cm)	Effective volume (l)	Actual volume * (l)
Reactor A	100	20	26.59	27.11
Reactor B	100	20	24.10	25.96

* Actual volume of the reactor is measured upto the top of packing media.

Table.2 Dispersion index for various extent of mixing

Degree of dispersion	**Typical value of Nd**
Ideal plug flow	0
Small amount of dispersion	0 – 0.002
Intermediate amount of dispersion	0.002 – 0.025
Large amount of dispersion	0.025 – 0.200
Ideal mixed flow	Approaches infinity

Table.3 Hydrodynamic characteristics of the reactors

For Reactor A	$T_g = 26.538$	$s^2 = 289.427$	Nd = 2.99
For Reactor B	$T_g = 24.814$	$s^2 = 223.54$	Nd = 2.706

Fig.1 Schematic diagram of the reactor

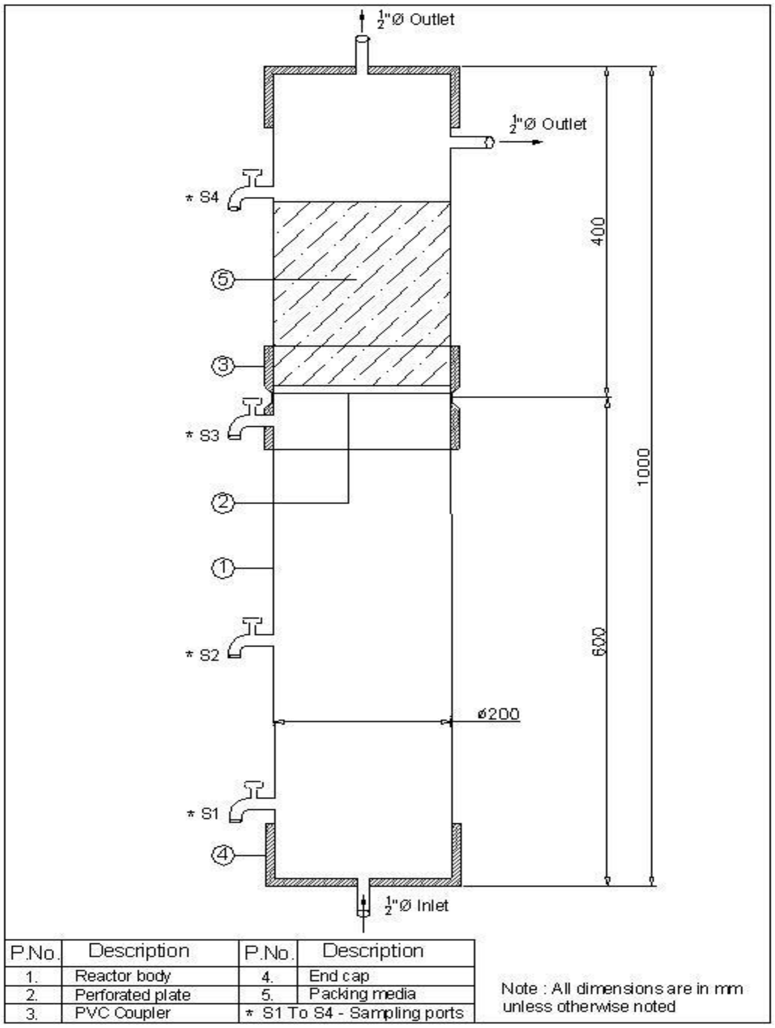


Fig.2 Residence time distribution curve for reactor "A" after experiment

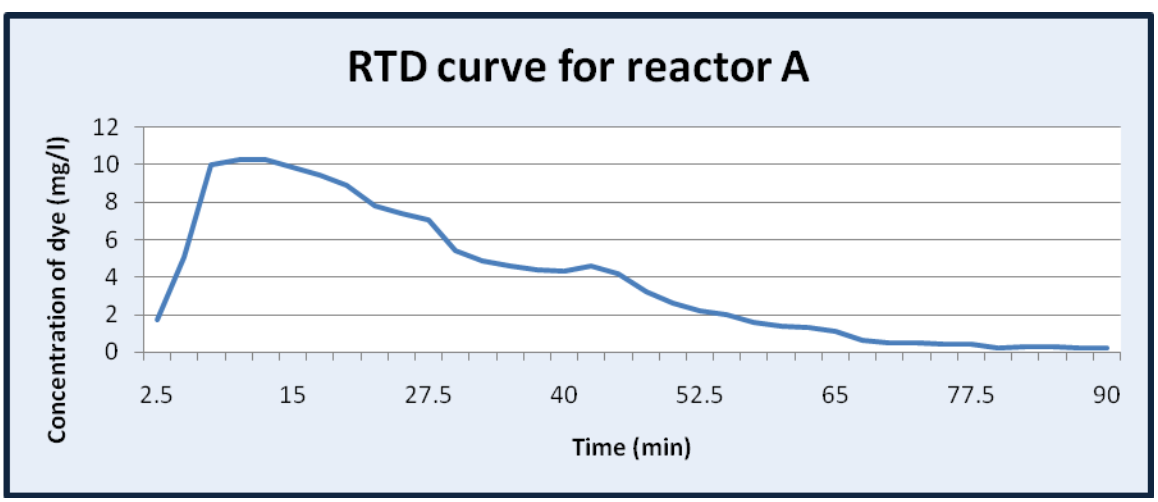
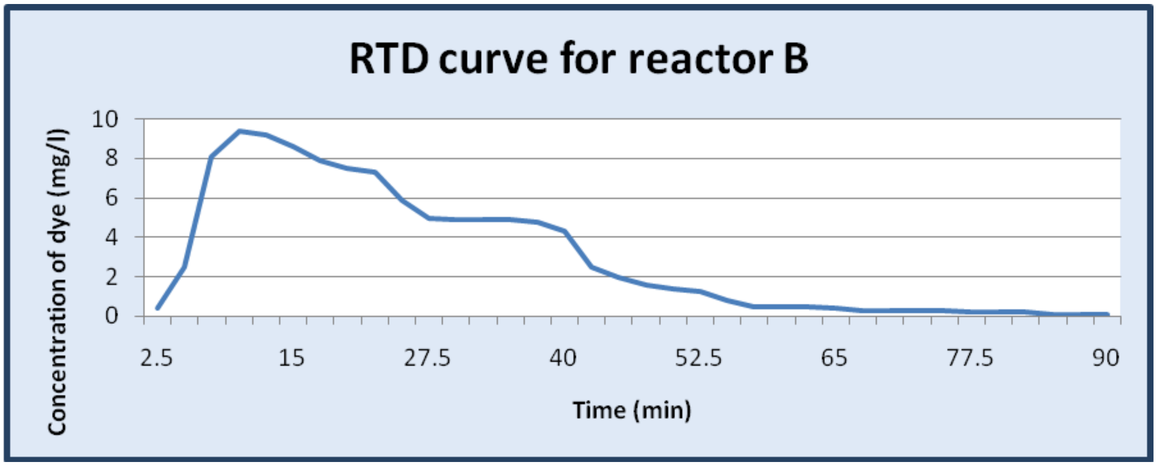


Fig.3 Residence time distribution curve for reactor "B" after experiment



The volumetric efficiency obtained was 5 % for reactor A and 5.8 % for reactor B. Volumetric efficiency of ideal plug flow reactor is 100 % and that of completely mix reactor is 4.5 %. The volumetric efficiency of reactors under test was closer to that of completely mix reactor.

The value of index of short circuiting obtained was 0.10 for reactor A and 0.09 for reactor B. Index of short circuiting is 1 for ideal plug flow reactor and approaches to zero with increased mixing. The value of reactor under test is 0.1 and 0.09 for reactor A and reactor B, respectively which falls in this range of CSTR.

The value of index of average residence time obtained was 0.46 for reactor A and 0.40 for reactor B. The value of index of average residence time as 1 indicates full use of the volume of the reactor and a value greater than or less than 1 indicates flow distribution is not uniform. The value of reactor under test came out to be 0.46 and 0.4 which shows the poor flow distribution inside the reactor.

The value of index of mean retention time obtained was 0.90 for reactor A and 0.80 for reactor B. The value of index of mean retention time of less than 1 corresponds to RTD curve skewed to the left and similarly for the values of greater than 1 the RTD curve is skewed to the right. The value of the reactors under test came out as 0.90 and 0.80, i.e. the RTD curve is skewed to the left. The tracer curves obtained in the experiment also confirms this inference.

The results showed that both the reactors followed an ideal pattern of mixed reactors at the given flow rate. The analysis of hydrodynamic characteristics revealed that the reactors were close to CSTR in flow pattern inside the reactor. The mean residence time curves showed that the reactors did not exhibited any signs of clogging of effluent. The volumetric efficiency of the reactors was less but there were no signs of short-circuiting in the path of the effluent. Also, the reactors did not exhibit the clogging over the period of time.

References

Escudie Renaud *et al.*, (2005). Hydrodynamic and biokinetic models of an anaerobic fixed-bed reactor. *Process Biochemistry*. (40): 2311 - 2323

Noguera Daniel R. and Perez R. (2007). Laboratory manual for "Environmental engineering processes". Department of

Civil and Environmental Engineering. University of Wisconsin – Madison. C-1.

Tembhurkar A. R. and Mhaisalkar V. A. (2006). Study of Hydrodynamic Behavior of a Laboratory Scale Upflow Anaerobic Fixed Film Fixed Bed Reactor. *Journal of Environmental Science and Engineering*. 48(2): 75 - 80

Wu M. *et al.*, (2000). Influence of media-packing ratio on performance of anaerobic hybrid reactors. *Bioresource Technology*. (71): 151 - 157

How to cite this article:

Vivek Koshta, Anil R. Chaudhari and Upadhyay, J.B. 2017. Tracer Study of Anaerobic Fixed Film Reactor used for Treatment of Dairy Effluent. *Int.J.Curr.Microbiol.App.Sci.* 6(11): 1445-1451. doi: https://doi.org/10.20546/ijcmas.2017.611.172