2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

FLUID FLOW PROFILE IN A PACKED BEAD COLUMN USING RESIDENCE TIME CURVES AND RADIOTRACER TECHNIQUES

Ana Paula F. de Almeida[1], Eduardo Ramos Gonçalves[1]; Luis Eduardo B. Brandão[1] and Cesar M. Salgado[1]

[1] Instituto de Engenharia Nuclear (IEN / CNEN – RJ)
Rua Hélio de Almeida, 75
21941-906 Cidade Universitária - Rio de Janeiro, RJ
anacamiqui@gmail.com, egoncalves@con.ufrj.br, brandao@ien.gov.br ,otero@ien.gov.br

ABSTRACT

Filling columns are extremely important in the chemical industry and are used for purification, separation and treatment processes of gas or liquid mixtures. The objective of this work is to study the hydrodynamics of the fluid for a characterization of aqueous phase flow patterns in the filling column, associating with the methodology of the Curves of Residence Time Distribution (RTD) to analyze and associate theoretical models that put as conditions column operating. RTD can be obtained by using the pulse-stimulus response technique which is characterized by the instantaneous injection of a radiotracer into the system input. In this work, 68Ga was used as radiotracer. Five shielded and collimated NaI (Tl) 1x1" scintillator detectors were suitably positioned to record the movement of the radiotracer's path in the conveying line and filling column. Making possible the analysis of the RTD curve in the regions of interest. With the data generated by the NaI (Tl) detectors with the passage of the radiotracer in the transport line and inside the column, it was possible to evaluate the flow profile of the aqueous phase and to identify operational failures, such as internal conduit and the existence of a retention zone in the inside the column. Theoretical models were used for different flow flows: the piston flow and perfect mixing.

1. INTRODUCTION

The chemical industry has great importance in the Brazilian economy. Being present in several sectors, among them: agricultural, textile, ceramics, pharmaceutical, in the extraction of petroleum, mining, packaging, among others.

All industrial product is generated from a variety of raw materials associated with an appropriate sequence of processing steps, and it is at this stage that many problems occur. In order for the production process of the product to be economically viable the control of this whole process must be carried out in a rigorous way.

Since the design and construction phase of the industrial plant, several areas of knowledge are required (thermodynamics, chemical kinetics, fluid mechanics, heat and mass transfer), making the planning and operation of these units one of the most complex activities within the industrial environment. In this context, the radiotracer methodology presents itself as one of the most suitable tools for the evaluation / modeling of industrial units, since it allows complex systems to be studied in real time, indicating from specific component failures to the degree of poor performance of the plant.

For use of a radiotracer in a medium, many features are important, whether physicochemical and / or economical. At the outset, the use of radioisotopes as tracers has faced a number of technological challenges, especially for its reaction with the environment. Numerous radiotracers react with the medium, causing their physicochemical properties to be lost: thus, the creation of new techniques for the acquisition of radiotracer has become essential [1].

The use of radiotracer for modeling that describes the actual operating conditions in a filling column is of great importance. For, it is considered that these models can be used in the identification of situations of operational failures inside the filling column, from the behavior of the response curves of the unit. These curves are characterized by Residence Time Distribution (RTD). The residence time represents the time in which the fluid takes to transit through the system, from the entrance to the exit of the same. That is, it is the time when the fluid remains in the system.

Set of electronic modules containing detector / preamplifier / counting rate meter are essential for recording data from RTD curves [2]. RTD is experimentally determined by injecting radiotracer into a vase [3].

2. THEORETICAL FOUNDATIONS

2.1. Radiotracers

The use of radiotracer has utility in several areas, such as industry, research, medicine, agriculture [4]. Radiotracer is any substance whose atomic or nuclear characteristics, physical, chemical or biological, provide the identification and analysis of the behavior of various processes that occur immediately or in a certain period of time [5].

Radiotracers must have the following characteristics: they must be stable, incorporate the study phase with a density close to it, present accurate detection even at minimum concentrations, preferably non-toxic, must not leave residues and should not interact with the material used for analysis; the radiotracer as well as the fluid to be monitored must have similar velocities [6]. Injection, detection and analysis shall be performed in such a way that there is no disturbance in the environment [7].

There are many types of radiotracer. The ^{68}Ga radiotracer stands out for its characteristics: its decay is by emission of positrons with an abundance of 89%, and presents physical half-life time of 68 minutes, presenting compatibility with many molecules of low molecular weight. It is compatible with water, which was used to feed the transport line.

Traditional methods of radiation detection use Geiger-Muller detectors or scintillation detectors (organic or inorganic) integrated with appropriate electronic instrumentation for the recording of the radiotracer signal. Common NaI scintillation detectors are used in experiments to record the path signal of the radiotracer due to its high efficiency for capturing gamma radiation and the ease of handling in external places. In order to lessen the influence of background radiation, the detectors have to be shielded with lead absorbers and properly collimated [2].

2.2 Residence Time Distribution (RTD)

The flow of a fluid in various process equipment such as vessels, reactors or filling columns, is subject to changes that are conditioned the properties of the equipment. In order to evaluate the performance of the fluid in an equipment, it is necessary to investigate the flow profile of this fluid by the system.

Theoretical studies of reactors consider that the flow has an ideal shape, when all the molecules of the fluid that left the reactor remained within the same for equal times. In fact, the flow parameters in real reactors are not identical to reactors that are considered ideal. However, the reach of the conversions in several real reactors approached the models of the reactors considered ideal [8]. The two types of flow of ideal reactor models are:

i. Piston flow, is characterized by the dynamics of fluid flow through the reactor, presenting an ordered form. That is, there is no mixing between the elements of the fluid, only, a lateral mixing of fluid occurs. An essential condition for the piston flow in the reactor is the residence time which must be equal for all the fluid elements.

ii. And the flow in the Perfect Mixing reactor, in this reactor all the fluid is stirred constantly and uniformly. Thus, the fluid composition of the reactor output stream is the same inside the reactor [9].

Deviations from the two types of runoff may occur. Deviations from the ideal flow may occur by forming preferred fluid paths, by recycling fluid or by creating stagnation regions in the vessel. All process equipment, such as: heat exchangers, filling columns and reactors, this type of flow must be avoided, as it leads to a decrease in unit performance [10].

The study of the measurement of the functions of residence time distribution (RTD), consists of a very effective analytical methodology. Because complex flow models can be monitored, using the technique that uses radiotracer. Enabling the unit response curve survey and assimilating existing operational problems. The importance of this methodology is that each particle of the radiotracer, when it traverses the unit under study, has its "history", according to the time in which it remains inside the system, associating to probability density functions (functions age), it allows relate the profile of its displacement by the unit, statistical parameters as mean, variance and statistical moments [11].

Among some RTD functions, only the E (t) function will be the focus of this work. Thus, we define: Function of the Distribution of Residence Time is represented the distribution of ages of elements of the fluid that left the unit at a certain time t. This is known as the frequency distribution of the fluid age E (t). Figure 1 shows the typical curve of this function.

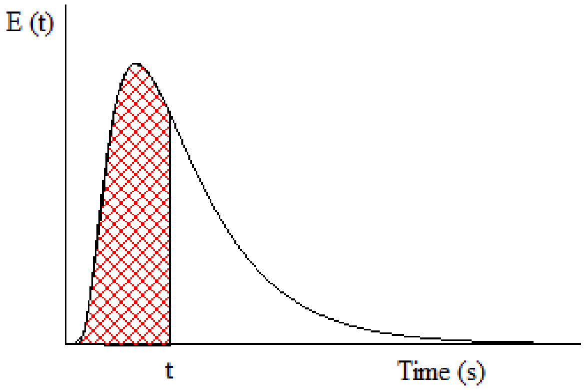

Figure 1: Typical E (t) curve measured by the radiotracer technique.

3. EXPERIMENTAL

The experimental tests were performed using a column consisting of an acrylic tube with 10.16 cm internal diameter and 43 cm height and, as filling material, acrylic balls with 0.7 cm in diameter were used. More details of this column are shown in figure 2.

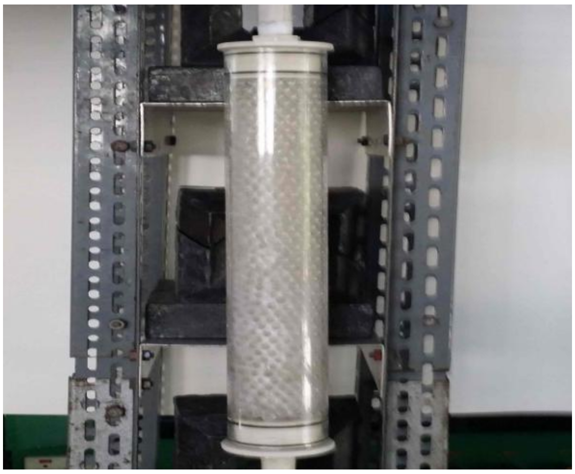

Figure 2: Filling column

In all studies, a fast and employed pulse technique and the tests were performed with a flow rate of 200 $L.m^{-1}$.

Five detectors were used (D1, D2, D3, D4 and D5) of NaI (T1) 1x1", two were respectively positioned at the beginning (D1) and at the end (D5) of the transport line and the other three were respectively positioned before (D2), in the middle (D3) and then (D4) of the filling column.

The ^{68}Ga was handled with a syringe and at the entrance site (J1) of the transport line, see figure 3, pulse-type injections were made for the experiments.

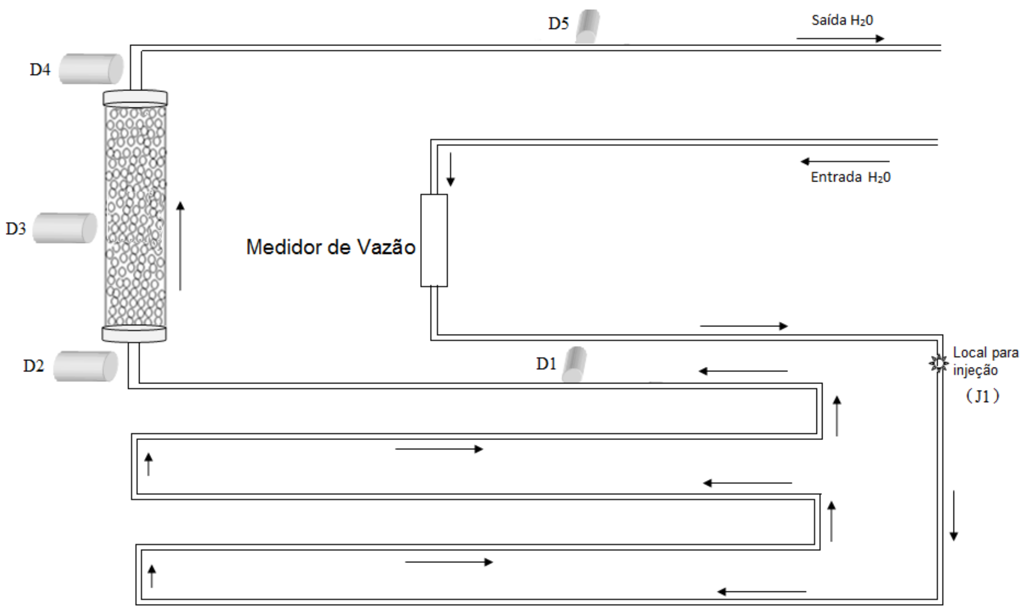

Figure 3: Representative scheme of the experiment.

4. RESULTS AND DISCUSSIONS

The experiment was carried out on a laboratory scale. The experimental tests were performed using the column without filling, in order to analyze the profile of the column and column with filling.

By analyzing the data recorded by the passage of the radiotracer through the pipeline and inside the column it was possible to evaluate the flow profile of the aqueous phase in the column and to identify operational failures, such as internal conduit and existence of retention zone inside the column.

Figure 4 shows the information recorded by D1 (start of transport line) and D5 (end of transport line). It can be seen that the D1 curve is symmetric while the D5 shows a dispersion of the radiotracer as a function of the path traveled.

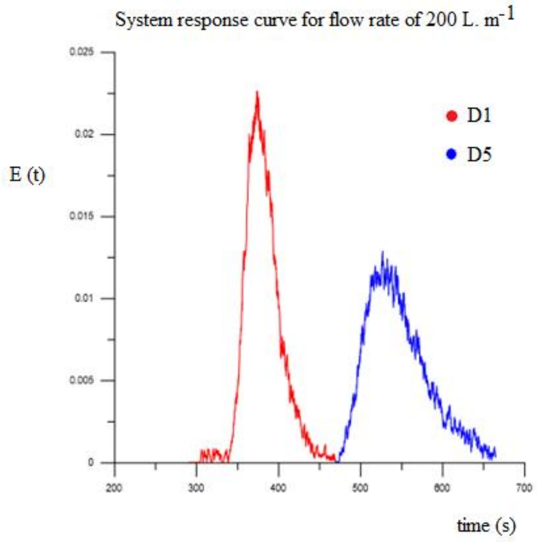

Figure 4: Transport line.

For the simulation of the empty column, ie without filling with the acrylic beads. It can be seen in Figure 5 that the column shows a channeling characteristic, observing a minimal retention, causing a small amount of fluid to have difficulty exiting the column. What is characterized by the tail effect observed in the curves.

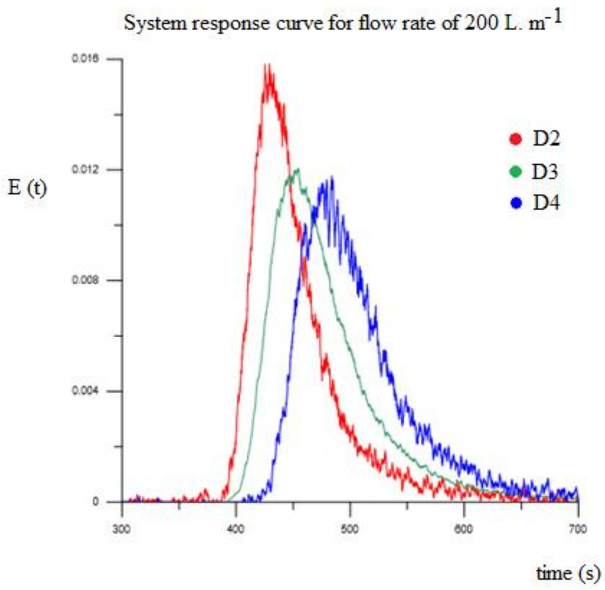

Figure 5: Column without filling

Different from Figure 6, where it is observed that a perfect blend occurred. Due to the filling of the column with the acrylic beads, a homogenization of the fluid occurs. The greater the uniformity of the graph curves, the flow profile is the same at the input (D2) and the output (D4) of the column.

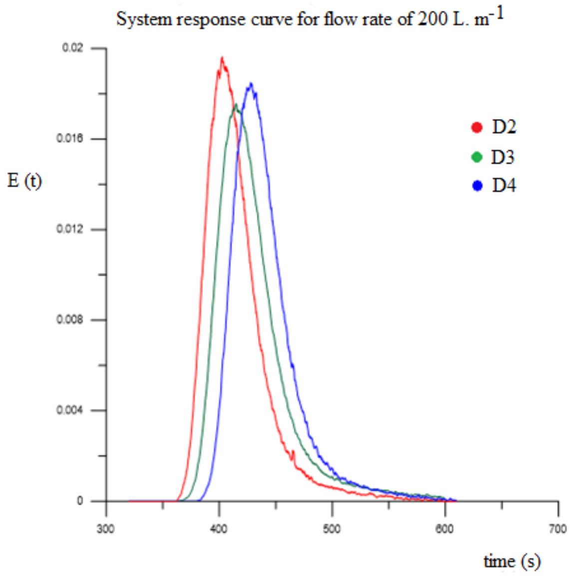

Figure 6: Stuffed column.

5. CONCLUSIONS

The technique used for pulse injection with the radiotracer used proved efficient to characterize as RTD curves. For simulation with an empty column, a column without a presence of the spheres, showed retention zones and channeling, proper of the column. For experiments with a column satisfactory results like acrylic beads satisfactory. For, it is observed that a uniformity of the fluid occurs, as observed by response curves, thus presenting characteristics of a perfect blend.

ACKNOWLEDGMENTS

The authors thank the IEN / CNES for works, support and services provided. And the cnpq for the financial support.

REFERENCES

1. Gonçalves, E. R. **Desenvolvimento de Metodologia para Medidas de Atividade Total de Amostras de Óleo Marcado com ^{198}Au**. 2013. 75 f. Dissertação de Mestrado - COPEE/UFRJ, Julho 2013.

2. Brandão, Luis E. B. "**Otimização de unidades de tratamento de águas residuais urbanas e industriais empregando-se traçadores radioativos**" Tese de Doutorado - COPEE/UFRJ Julho 2002.

3. Fogler H. S. *Elementos De Engenharia Das Reações Químicas* , Tradução de Verônica M.A. Calado, 4ª edição - Rio de Janeiro: LTC, 2009, P.703 - 705.

4. INTERNATIONAL ATOMIC ENERGY AGENCY. **Manual for reactor produced radioisotopes**. Vienna: IAEA, 2003. 1 p. (Technical reports series, 1340).

5. INTERNATIONAL ATOMIC ENERGY AGENCY**. Radiotracer residence time distribution method for industrial and environmental applications**. Vienna: IAEA, 2008. 13-14p. (Training course series, 31).

6. Héricka Oliveira Kenup Hernandes Cantuaria. **Produção de Traçador Radioativo Por Eletromarcação de Derivado de Petróleo com ^{123}I**. 2016. 7 f. Dissertação de Mestrado - COPEE/UFRJ. Julho 2016.

7. SILVA, L. L, et al. **Química. Nova**, v. 36, n. 6, p. 1576-1585, 2009.

8. Hill Jr., C. G; Root,T.W. **Introduction To Chemical Engineering Kinetics & Reactor Designs**, 2 ed. P. 337. Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2014.

9. LEVENSPIEL, O. **Engenharia Das Reações Químicas**, Tradução de Verônica M.A. Calado. São Paulo: E. Blücher, 2000, P. 75.

10. LEVENSPIEL, O. **Engenharia Das Reações Químicas**, Tradução de Verônica M.A. Calado. São Paulo: E. Blücher, 2000, P. 214.

11. BRANDÃO, L. E. B.; " **Análise de Unidades Industriais pela Técnica de Traçadores Radioativos - Funções Distribuição do Tempo de Residência ".** *Relatório Técnico* - IEN, n. 17. Instituto de Engenharia Nuclear. Rio de Janeiro.