MEMBIOSIM: a Submerged Membrane Bioreactor simulator for teaching its functioning

Yusmel González Hernández[a1], Ulises Jáuregui Haza[1,2], Claire Albasi[3], and Marion Alliet[3]

[1]Instituto Superior de Tecnologías y Ciencias Aplicadas (InSTEC-UH), Universidad de La Habana, Cuba
[2]Instituto Tecnológico de Santo Domingo (INTEC), República Dominicana
[3]Laboratoire de Génie Chimique, Université de Toulouse, CNRS, INPT, UPS, Toulouse, France.

The development of a submerged membrane bioreactor computer simulator that integrates biological degradation process with physical separation process is a useful tool for teaching and research.[b]

The submerged membrane bioreactor (SMBR) technology has grown exponentially due to its advantages over conventional wastewater treatment processes, such as reduced environmental impact, improved effluent quality and better process control. The major potential advantage of this technology is found in the field of water reuse. Nevertheless, the effective application of membrane bioreactors (MBRs) is limited by membrane fouling and the associated cost and energy burdens [1]. At the same time, experimentation in these types of installations is very expensive and time consuming.

On the other hand, it is necessary to take all the elements mentioned above into account in the training of engineers and of the staff that will operate the SMBR. It is essential to develop tools, as simulators, that can help in the learning process, both at universities and at operator training centers. Another advantage of a simulator is its value in the training process from the research point of view: to help to solve problems that are as yet unsolved. Simulators are also an important support for the study of process optimization. The use of simulated experiments can considerably reduce the cost of a laboratory course, increase the number of experiments in the learning process and enable experiments to be carried out that would otherwise involve working with dangerous materials and/or in dangerous conditions [2]. The objective of this work is to develop a computer simulator of an SMBR and to show its potential in teaching how such processes work.

Description and operation of the simulator

Description and operation of the simulator For teaching use, the SBRM computer simulator should be user friendly and provide an easily accessible introduction to the subject. Since other uses are advanced training and research, many parameters should be easily modifiable. The simulator shows a general standard scheme of the SMBR, which allows the main structural components of the system to be apprehended, so that the user can gain a better understanding of the installation performance and thus a better understanding of the processes that are involved in these types of installations [3]. The simulator allows the user to study the influence of 35 model input variables on 16 output parameters, which can be displayed graphically or numerically.

Comparison of simulator performance with experimental data

To substantiate and justify the use of the computer simulator to study an SMBR, it is essential to know the level of approximation to which the mathematical model can reproduce SMBR operation. For this reason, the simulation results were compared with experimental data. The parameter chosen was the transmembrane pressure because of its importance in the operation of the SMBR [4, 5]. Figure 1 shows the experimental and calculated values of TMP.

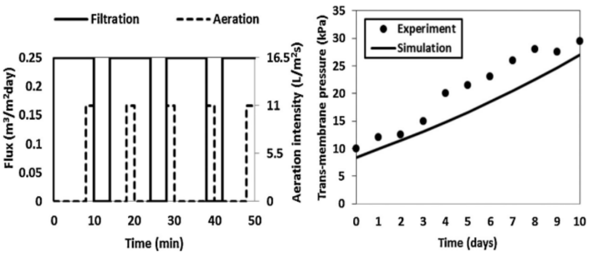

Figure 1: Comparison between the experimental data (points) and simulation results (line). The left-hand diagram shows the working conditions of the experiments.

A mean relative error of estimation of 15% was obtained. This result can be considered acceptable for predicting the behavior of a system of such complexity because, as explained above, the simulator was built by implementing a model that combines biological degradation with the filtration process. The biological system modelling introduces a high percentage of error as the input values of biological variables correspond to the mean values measured during the experiment [6]. Even with 15% of error, the simulator already gives the trends in the evolution of physical quantities and the order of magnitude of their values, which is the information sought.

Considerations about the practical activity

The practical activity [3]. was carried out successfully by the students. They showed their abilities in the use of computer programs and, in general, they managed the simulator with success. Nevertheless, there were some students who had difficulty solving this task because they did not understand the functioning of an SMBR correctly and others who had problems with the simulator language. However, with the instructor's help, they finished the proposed exercise correctly.

The students' correct use of the different simulator tools and their understanding of the SMBR operation was evaluated from their analysis of the results they reported.

The reports were corrected and graded according to the French norm, which gives points out of 20, with the following appreciation: 10 = pass, 12 = quite good, 14 = good, 16 = very good, 1 = excellent, and 20 = congratulations. The average was 13.6/20 with a minimum of 12/20 and a maximum of 16/20, which is a rather good result. Parts 1–4 were achieved very well, with only minor mistakes. Part 5 was completed in a more variable way, mainly due to a lack of time (and to the French way of teaching, which discriminates using time).

Students' opinions

The students' responses to the questionnaire [3] are presented in Figure 2. A grading scale obtained by using numerical equivalents for the opinions: "Strongly agree" = 20, "Agree" = 13.33, "Disagree" = 6.67, "Strongly disagree" = 0 (in order to correspond to the French grading system, which is out of 20) has been added. For each of the statements proposed in the questionnaire, a "grade" is indicated, which was obtained by averaging the answers. To analyze these responses, the questions with the most numerous answers "Disagree" were considered as well as the ones with less good grades. The students' evaluations were very positive. This simulated laboratory aroused great interest in more than 95% of the students.

As noticed by the teaching staff during the practical activity, although some students had some difficulties in understanding the functioning of the simulator by themselves (Q4), the participation of the teacher helped them in this task (Q5).

Slightly more than 10% of the students did not agree that this laboratory was relevant to their program and the lowest evaluation concerned the situation of this laboratory in the education program (Q8). A discussion with the students showed that an additional experimental activity may help to improve this impression. The teaching staff is thinking about a convenient and not too expensive way to include it (visit to a water treatment plant, visit to a research experimental device, short experimental practical activity, etc.).

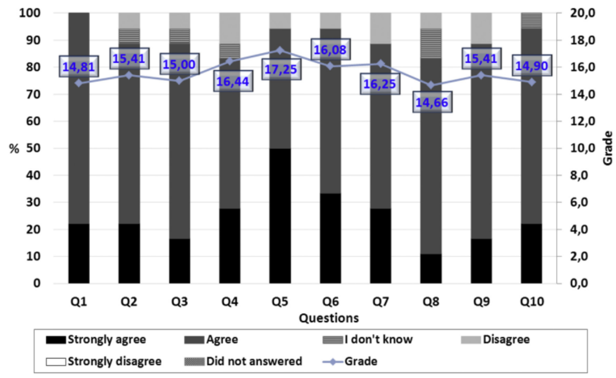

Figure 2: Results of the anonymous questionnaire.

Summary

An SMBR computer simulator was built with recent modelling knowledge and a friendly interface. The results given by the simulator are accurate enough to provide the trends and orders of magnitudes of physical quantities needed for the teaching application of the simulated MBR. The practical use of the simulator was evaluated with the development of simulated laboratory work lasting three and a half hours, which gave results that would take more than fifteen months of real-world experiments. It was successfully applied and, achieved the most difficult objectives of enabling the students to analyze the influence of operating parameters on the SMBR functioning and being largely accepted by the students. While this has not been tested, it appears clear that the dynamic model used would permit the training of professionals.

Notes

a. Email: yusmel@instec.cu

b. The original version of this article is Ref. [3]

References

[1] A. Menniti, E.J.W.R. Morgenroth., *Water Research,* **44** (2010) 5240-5251

[2] E. Skorzinski, M. Shacham, N. Brauner. *In Computer Aided Chemical Engineering,* Elsevier (2009) 1233-1238.

[3] Y. Hernández-Gonzalez, U. Jauregui-Haza, C. Albasi, M. Alliet., *Education for Chemical Engineers,* **9** (2) (2014) e32-e41.

[4] F. Meng, et al., *Water Research,* **43** (2009) 1489-1512.

[5] A. Fenu, et al., *Water Research,* **44** (2010) 4272-4294.

[6] A. G. Zarragoitia, et al., *Journal of Membrane Science,* **325** (2008) 612-624.