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Gross parameters prediction of a granular attached biomass reactor through evolutionary polynomial regression

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ABSTRACT

Heavy fluctuations in wastewater composition, such as those typical of tourist areas, can lead to a deterioration in treatment plant performance if no action is taken in advance. Mathematical modelling, applied to treatment plant performance prediction, can provide valuable information to address the stress issue. The present study shows that the evolutionary polynomial regression methodology (EPR) is able to predict the performances of an attached granular biomass system so that it is possible to make the necessary operating changes in advance, avoiding deterioration in the quality of the effluent discharged. The present paper shows the results of EPR application to gross parameters of a granular attached biomass reactor. For each parameter, a model capable of predicting the effluent value was assessed, based on the knowledge of the influent characteristics. Coefficients of determination values (CoD) obtained during the models validation phase, can be said to be more than satisfactory, varying between 84.2% and 94.6%. Moreover, the applied tests showed typical behaviours commonly found when observed and predicted values are quite similar. This paper reports the first application attempt for modelling this kind of emerging treatment system and gross parameters.

1. Introduction

Aerobic granulation has the potential to play an important role in the field of wastewater treatment compared with conventional sludge flocks, due to advantages such as stronger structure, faster settling ability which ensures a better solid–liquid separation, higher biomass concentration and better handling of shock loads [1]. In this field, sequencing batch biofilter granular reactor (SBBGR), a recently developed system by the Water Research Institute (IRSA) of the National Research Council of Italy (CNR), could represent an interesting solution, as it couples the advantages of granular biomass systems (i.e. greater treatment capability and flexibility) with those of attached biomass reactors (i.e. greater robustness and compactness) [2]. In fact, the SBBGR is a unique system in virtue of its particular type of biomass, consisting of a mixture of biofilm and granules packed in the filling material of the reactor. The high biomass concentration in the SBBGR system offers great stability against short-term shock loads. This is an important feature, as the treatment plants are usually designed on average flow rates and wastewater composition, often disregarding peak conditions [3]. During longer-term shock (lasting days to weeks), however, a greater biomass concentration requires a longer time to achieve a new steady state. Taking into account the high operative flexibility of the SBBGR system, it would be of great relevance to be able to predict, with a good confidence level, the system performance at the new state, and thus to be able to make the necessary operative changes. In fact, whenever the monitoring highlights heavy influential load fluctuations, both positive and negative, reliable modelling can enable the plant manager to predict the biological reactor's response in order to put in place the needed engineering safeguards aimed at maintaining the reactor's performance at satisfactory levels. Consequently, it would be very useful to have a mathematical prediction tool that allows reliable estimates on system performance to be obtained as a support for the plant manager in decision making processes.

Several models have been reported in the scientific literature for process optimization and scale-up and for the design of aerobic granular reactors [1]. In fact, mathematical modelling has proven to be very useful to study complex processes, such as aerobic granular sludge systems [4]. Attempts have been made to model different aspects of granular biomass systems, such as: aerobic granules formation [5,6]; microbial species in aerobic granules [7]; nutrient removal [8,9]; storage processes in aerobic granules [10].

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A number of techniques have been proposed in recent years for identifying mathematical models of complex systems based on observed data [11]. Such techniques can be roughly ranked from white-box to black-box techniques depending on the level of prior information required or available. In between, there is a wide number of grey-box models whose mathematical structure can be derived through conceptualization of physical phenomena. These models usually need parameter estimation derived by means of input/output data analysis.

Among the various grey-box models, the evolutionary polynomial regression (EPR) methodology was selected for this study. EPR was first introduced by Giustolisi and Savic [12] with applications in hydroinformatics and related environmental problems. The EPR methodology returns the best model where the following objectives are all taken into consideration together: maximizing model accuracy, minimizing both model coefficients and the number of variables. The multi-objective analysis is performed resorting to a multi-objective genetic algorithm [13] based on the Pareto dominance criterion. A recent version of EPR, called EPR–MOGA, exploits Multi-Objective Genetic Algorithms (MOGAs) to search those model expressions which maximise accuracy of data and parsimony of mathematical expressions simultaneously.

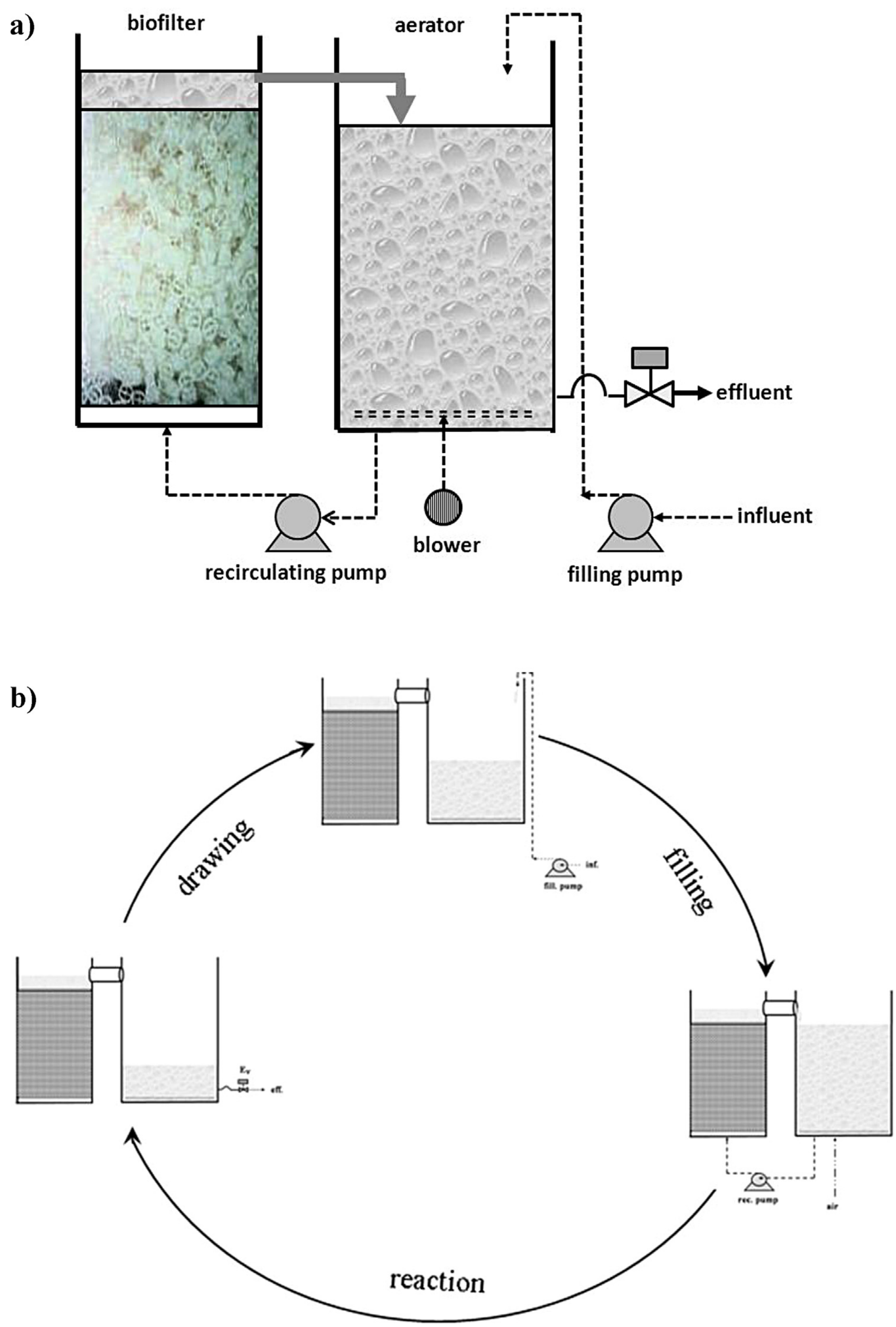

Fig. 1. Sequencing Batch Biofilter Granular Reactor (SBBGR) sketch (a) and its working cycle (b).