Research Article

Received: 23 January 2013 Revised: 24 April 2013 Accepted article published: 3 May 2013 Published online in Wiley Online Library: 5 June 2013

(wileyonlinelibrary.com) DOI 10.1002/jctb.4115

Residence time distribution determination in a submerged filter with and without aeration using a tracer

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Abstract

BACKGROUND: Commercial filter media are commonly regular in shape and the flow patterns can be predicted with simple tools. Using lava stones as filter media, this study analyzes the influence of particle size and aeration on the hydraulic behaviour of a submerged filter prior to biofilm colonization.

RESULTS: The filter was packed, separately, with two different sizes of lava stones (4.7 and 9.5 mm) and operated under different hydraulic retention times to establish the causes of deviations from ideal models. Tracer curves were analyzed using two mathematical models (Axial Dispersion and Wolf and Resnick models). The curves show that the tracer appeared in the effluent in a shorter time than expected indicating an effective volume reduction. It was estimated that the dead volume of the filter with aeration was 83% and 22% for the filter without aeration.

CONCLUSION: The dead volume is caused, in the case of the filter with aeration, by the combination of two phenomena: the liquid volume displaced by the air bubbles and the turbulence caused by aeration generating preferential channelling along the filter media and creating large zones of stagnant liquid. In the case of the filter without aeration the volume reduction is caused by channels developed by the media irregular shape.

Keywords: BAF; submerged biological filter; hydraulic behaviour; mathematical models; non ideal flow; tracer studies; lava stones

INTRODUCTION

The increasing improvement in reactor configuration has allowed better performance by wastewater treatment systems and enhancement of their process performance and stability. However, most of the existing biological filters have been designed based on empirical parameters selected to guarantee the process self-control by the biomass and often, in terms of hydrodynamic behaviour, they are limited to the ideal assumption of a plug flow reactor (PFR) or complete mixed reactor (CMFR).[1–3] Although some reactors are designed using this ideal approach, in practice some can be operated with good results and others fail to achieve the expected performance. Failure is caused, in most cases, because of substrate transport limitation, hydraulic short-circuits and deficient mixing; dead volume zones decrease the reactor effective volume and, consequently, the contact times.[4–7]

The hydraulic behaviour of a system can be evaluated using stimulus–response tracer assays with the injection of an easily detectable tracer that does not participate in any of the physical and chemical processes that can affect hydrodynamics.[8,3] Tracer curves can provide information on the residence time distribution to determine the real residence time. Different mathematical and simulation models allow an understanding of the system hydraulics and assist its start-up, operation and control.[2,5,9]

Hydraulic short circuits and mixed patterns affect the hydrodynamic behaviour of a reactor; the result may lead to dead volume zones. Tracer studies are used to quantify these as well as deviations from ideal flow patterns.[6,9,10] Three methods may be employed to analyze the residence time distribution (RTD) using tracers: (1) the determination of the mean hydraulic retention time using the area under the tracer curve; (2) the use of mathematical models to assess the flow pattern by fitting the RTD curves shape (such as tanks in series model, axial dispersion model, combined models, etc.[8,11] and (3) the calculation of indexes or parameters that have an empirical or semi- empirical support based on the most important characteristics of the curve, i.e. its height and eccentricity.[10] If correctly obtained, RTD curves allow the identification of dead zones, short-circuiting or channelling.[1,3] Although the role of media-related factors on filters performance has been widely investigated, limited studies have been conducted to examine the hydraulic behaviour of submerged biofilters in their start-up phase or prior to biofilm colonization in the filter media.

The aim of this study was to evaluate the influence of particle size and aeration on the hydraulic behaviour of a submerged filter prior to biofilm colonization. Filters packed with two different particle sizes of lava stones, under different hydraulic retention

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