Desalination 285 (2012) 324–335

Contents lists available at SciVerse ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Start-up of decentralized MBRs
Part I: The influence of operational parameters

J.A. Gil [a,*], E. Dorgeloh [a], J.B. van Lier [b], J.H.J.M. van der Graaf [c], D. Prats [d]

[a] PIA-Prüf- und Entwicklungsinstitut für Abwassertechnik an der RWTH Aachen e.V., Germany
[b] Department of Water Management, Section Sanitary Engineering, Delft University of Technology, PO Box 5048, 2600 GA Delft, The Netherlands
[c] Witteveen +Bos, Van Twickelostraat 2, Deventer, 7400 AE, The Netherlands
[d] University Institute of Water and Environmental Sciences, University of Alicante, Ap 99, 03080 Alicante, Spain

ARTICLE INFO

Article history:
Received 5 July 2011
Accepted 18 October 2011
Available online 30 November 2011

Keywords:
Decentralized MBR
Start-up
Initial inoculum
Operational parameters

ABSTRACT

This paper aims to be a quick reference guide to start-up decentralized membrane bioreactors (MBRs). The first part of this study focuses on the impact of different operational parameters on the start-up of decentralized MBRs, which can be easily reproduced in the field. Whereas wastewater is not an option to start-up decentralized MBRs, domestic activated sludge has shown to handle the input of wastewater in a better way than the municipal one. Starting-up at low mixed liquor suspended solids (MLSS) concentration is feasible, and a possible optimum concentration (~1 g L^{-1}) has been suggested. In turn, particle size distribution has shown how determined conditions release fine particles in the sub-micron range (0.1–1 μm), impacting negatively the filterability of the initial inoculum and thus the operation. However, in the case of the air scouring rate, even releasing sub-micron particles to the media, high rates demonstrated to extend the operation. Regarding ambient conditions, low temperatures and associated deflocculation processes should be avoided. Chemical oxygen demand and NH_4^+–N removal efficiencies showed values over 87% and 75% respectively whereas suspended solids and removal of pathogens maintained low values (50 mg L^{-1} and absence respectively) in the permeate, allowing the reuse of regenerated water since the first day of operation under the different conditions imposed. None of the analyzed parameters (i.e., MLSS, sludge volumetric index and dissolved organic carbon), influenced significantly the filterability of the initial inoculum. Contrarily, the input of wastewater has demonstrated to be the most important factor governing the fouling process of the membrane rather than the changes in the microbiology. As a final consideration, an efficient pretreatment and both low hydraulic retention time and fluxes can help to extend the operation and reach an easy transition between the start-up and the steady-state.

1. Introduction

The Water Framework Directive (2000/60/EC) has established a framework to commit European Union state members to achieve good qualitative and quantitative statuses of all water bodies. This framework prescribes steps to reach the common goal rather than adopting the more traditional limit value approach. In other words, every agglomeration, industry or single house decentralized or not within the European Union (EU), must be connected to an appropriate sewage system by 2015. Currently, more than 95% of the pollution load generated in the EU-15 member states is derived to collecting systems [1]. Figures reporting compliance results are normally centered in agglomerations bigger than the 2000 population equivalent. However, within the EU, a considerable amount of the population (10–20%) lives in decentralized areas where communal collecting systems are simply not available. In these remote areas the use of (private) small facilities to treat the wastewater is so far the only option to achieve the framework established by "the directive". To accomplish this directive, around 15 million of small wastewater treatment plants (SWwTP) are expected to be operative by 2015 in the EU.

Among the different domestic wastewater treatment plants available in the market, decentralized membrane bioreactors (MBR–SWwTP) offer low footprint, a high effluent quality and the possibility to reuse the permeate in tasks like irrigation. Since the vast majority of the membranes are in the microfiltration–ultrafiltration range, a high retention of pathogens is achieved, allowing the reuse of water without tertiary treatment. This feature together with both high mixed liquor suspended solid (MLSS) concentration and sludge retention time (SRT), confers the process a higher compactness with respect to alternative treatments. However, post-treatments (i.e., nanofiltration, ultraviolet) to increase the quality of the permeate have been successfully implemented [2]. On the other hand, this technology presents some economical drawbacks like both, higher capital expenditures (CAPEX) and operational expenditures

* Corresponding author. Tel.: +49 241 750 82 17; fax: +49 241 750 82 29.
E-mail addresses: gil@pia.rwth-aachen.de, josean.gil@ua.es (J.A. Gil), dorgeloh@pia.rwth-aachen.de (E. Dorgeloh), J.B.vanLier@tudelft.nl (J.B. van Lier), J.vdGraaf@witteveenbos.nl (J.H.J.M. van der Graaf), prats@ua.es (D. Prats).

0011-9164/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.desal.2011.10.022

(OPEX) — e.g., membrane replacement and energy costs respectively — [3]. Operational disadvantages mostly related with the fouling of the membrane due to colloidal and soluble fractions, and accompanying cleaning protocols must be also taken into account when comparing with alternative technologies. Even though, membrane bioreactor (MBR) is considered nowadays a key technology since no other treatment can beat its package compactness–effluent quality. The number of MBR–SWwTP installed in Germany (D) has increased up to 2500 by 2010.

A large number of publications have focused during the last years in major problems like fouling, reduction of energy input or membrane development. However, not much has been investigated about the start-up phase, especially in MBR–SWwTP. Depending on the strategy selected, different performances can be expected. So far there is no standard protocol to start-up MBR–SWwTP. Manufacturers select and apply start-up strategies based on their own experience. This paper aims to provide a quick reference to start-up MBR–SWwTP, oriented mainly to manufacturers and MBR operators working with domestic wastewater. From a logistic and economical point of view, continuous surveillance and maintenance in MBR–SWwTP are no longer an option. Unlike the rest of SWwTP, MBR–SWwTP will overflow due to a fast colmatation of the membrane. Hence, an optimal start-up phase is a "must" for a reliable, safe and sustainable operation. To this end, different conditions, which can be easily reproduced by manufacturers and MBR operators have been selected and tested. Their influence on the performance of MBR–SWwTP, and their impact on the filterability of the initial inoculum during the start-up phase will be analyzed and discussed.

2. Materials and methods

2.1. Experimental setup

A setup composed of three identical MBR–SWwTP has been designed as shown in Fig. 1. Eight chlorinated polyethylene flat sheet membranes, type H-203 with a pore size = 0.4 μm (Kubota, Japan) were introduced in each tank (1 m^3) offering an effective filtration area of 0.88 m^2 $tank^{-1}$. Three identical Preston pumps (Manostat, USA) extracted the permeate. Aeration was supplied thanks to a Secoh air pump (Japan) providing air in excess. Air scouring was supplied through axial perforated tubes with 3 mm diameter holes whereas aeration for the microorganisms was supplied through 12 in. fine bubble diffusers. After a settling tank (>2 h), wastewater was pumped into the three tanks following the timetable indicated in the standard hEN 12566-3 [4]. Level sensors controlled the inflow and outflow, whereas the transmembrane pressure (TMP) and the flow were monitored thanks to pressure gauges C01 (STW, D) and flowmeters Promag 30 (E + H, Switzerland) respectively. The temperature was adjusted with a heater in each tank plus a thermopar in the first one. All experiments were conducted with dissolved oxygen (DO) in excess (>4 mg L^{-1}) and a hydraulic retention time (HRT) of ~65 h. No sludge was withdrawn except insignificant volumes for analysis. Experiments were terminated when the TMP reached 200 mbar following the recommendation of the manufacturer. Cleanings in line (CIL) with NaClO (0.5%) during 2.5 h were performed between experiments. Table 1 shows the operating conditions for the 3 MBRs during the different experiments.

2.2. Characteristics of the activated sludge and composition of the wastewater

Activated sludge (MLSS 5–6 g L^{-1}, SRT ~ 10 d) was taken from the Aachen–Soers wastewater treatment plant (WwTP) and exceptionally once for Exp. 1 (MBR2), from a SWwTP located at the same place as the experimental setup, the PIA-Prüf- und Entwicklungsinstitut für Abwassertechnik. Domestic wastewater was bypassed from a conduction coming from a residential area. All mentioned

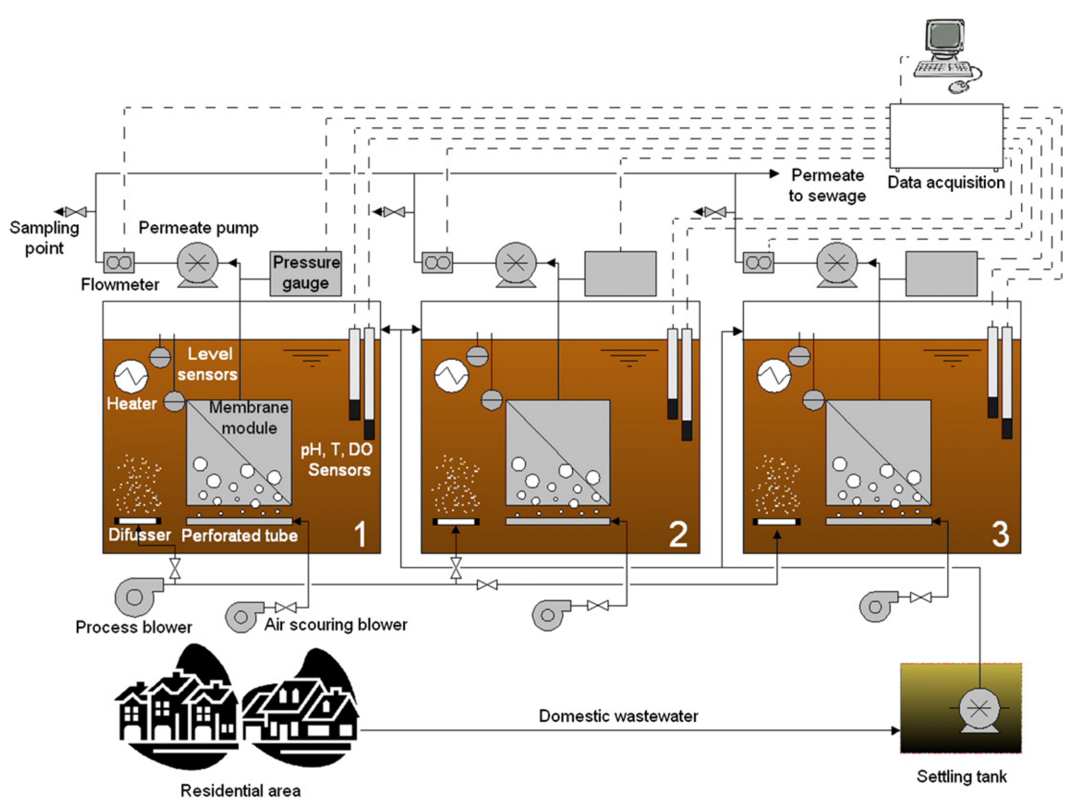

Fig. 1. Setup of the 3 identical MBR–SWwTP.