Doctoral School in Environmental engineering

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Application and operational optimization of membrane bioreactors for municipal wastewater treatment

Abstract

Due to the changing perception of water and environment authorities in 21st century, stringent discharge regulations are being imposed. In order to meet the criteria, the treatment of municipal wastewater renders challenges in terms of operational optimization even for novel and growing technologies such as Membrane bioreactors (MBRs). The applications of MBRs for municipal wastewater treatment have been studied well during the last decade, however, research based studies on real wastewater have been observed limited. Two major challenges of MBRs have been targeted in this research viz. biological process modelling and fouling behaviour modelling concerning MBRs treating municipal wastewater; a holistic approach to understand interlinks between these two problems has specifically been developed. Aiming at the first challenge, AQUASIM and ASIM software have been used for simulation of the dynamic biological processes addressing the sludge production modelling and nutrient removal modelling respectively; the modelling and simulation have been aimed at two different pilot plants viz. large pilot plant (200 PE, MBR-II) at Lavis (TN, Italy) and lab scale pilot plant (MBR-IV) at EAWAG (Switzerland), both working on denitrification-nitrification scheme. Modified Activated Sludge Model (ASM3e), coded into AQUASIM and calibrated entirely on the basis of repirometric measurements ($Y_{H,\ SS}$=0.61, $Y_{H,\ STO}$=0.71, Y_{STO}=0.82 gCOD/gCOD), has been observed to be able to predict the dynamics of sludge production for more than 4 months of experimental trial at the MBR-II plant. Further, several perspectives of biological phosphorous removal have been investigated using the Bio-P version of the activated sludge model on ASIM software base. The performance of treatment in both the cases have been found to be excellent in terms of COD and Nitrogen removal (more than 95% COD and Ammonia removal); also, another MBR plant (MBR-I) at the same location of Lavis (only nitrification scheme), mainly used for fouling behaviour study in this thesis, showed very good level of COD and Ammonia removal. The second challenge has been investigated with the help of two pilot studies viz. MBR-I (Huber VRM 20/36) and MBR-III (Zenon ZW 500c) studied at Pietramurata (TN, Italy). In the case of MBR-III, the predicted time of sustainability

during sub-critical flux operation (200 h) was found to be in good agreement with the observed one (190 h); similarly, for MBR-I, out of six different operating sub-critical fluxes ranging between 17-30 LMH (with critical flux value of 31 LMH) two cases were studied for sub-critical fouling behaviour and the predicted times of sustainability (380.5h and 208 h) were found to be in good agreement with the observed ones (350 h and 180 h).

The model ASM3e seems promising for biological process modelling inherent to MBRs; the Bio-P (associated with ASM3) can be used to model and study several interesting aspects of nutrient removal. A simple model for fouling behaviour, based on two forms of Extra-cellular Polymeric Substances (EPS) viz. bound and free, proposed and investigated in this research seems promising for the prediction of time of sustainability and hence aims at improved operational management of MBRs. Moreover, the holistic approach to MBR process modelling has been proposed here providing an integrated modelling framework combining concepts from both biological process and fouling process.

Keywords: *Activated sludge models; bound and free EPS; Critical flux; Membrane bioreactors; Nutrient removal modelling ; Modelling of subcritical flux fouling; Sludge production modelling*