Biomass activity and species assessment in a submerged membrane bioreactor operating at high SRT and low COD/N using respirometric analysis and modeling

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Abstract

In this paper, respirometric analysis and Activated Sludge Model (ASM) had been evaluated in order to identify and quantify the fraction of active biomass of activated sludge in a submerged Membrane Bioreactor (sMBR). Heterotrophic biomass (X_{BH}), Autotrophic biomass responsible of nitrite production (X_{BAI}) and Autotrophic biomass responsible of nitrate production (X_{BAA}) had been quantified within activated sludge fed with soluble and easily biodegradable substrate (ethanol/sodium acetate (1:1)). This synthetic wastewater, containing no hardly biodegradable organic or inorganic particulate matter, led to the generation of a sludge constituted essentially of two fractions: X_{BH} and X_{BA}. Specific respirometric measurements of endogenous and exogenous activities ensured the integrity of ASM and the development of equations for the quantification of active biomass in these models. The results highlighted the growth of this specific biomass under high SRT and substrate limited conditions.

Keywords: *Membrane bioreactor; Heterotrophic; Autotrophic; Respirometric activity; Activated sludge, soluble microbial products.*

I. Introduction

Conventional wastewater treatment systems have been improved by using membranes acting as solid/liquid separation devices, and these combined systems, which are called membrane bioreactors (MBRs), have been widely used in recent years in urban wastewater treatment [1]. It allows on one hand to increase significantly the biomass concentration within the biological reactor, and on the other hand, to reduce the volumes, and to reach a water quality much better than those obtained with conventional activated sludge (CAS) (specifically in terms of solid matter removal and effluent disinfection).

To optimize the functioning of sMBR, a thorough understanding of the impact of the operational parameters and conditions on the viability and activity of the overall biomass community is needed. In a sMBR, a modification in biomass activity and viability comparatively to CAS is often noticed. In this context, respirometric analysis is presented as a reliable tool in order to evaluate the representative biomass kinetic parameters to be inserted in mathematical models during the design phase, as well as to monitor the biomass viability and activity; especially when these processes are operating at high SRT values [2]. In subsequent section, a combination of well-known respirometric methods for X_H, X_{BAI} and X_{BAA} determination has been used to investigate the performance and biomass activity of a laboratory-scale sMBR operating at high SRT and a low COD/N ratio in the influent. The biological activity is monitored as a result of respirometric assessments by focusing on heterotrophic and autotrophic microorganism activities.

II. Materials and methods

II.1 Experimental set up and operating conditions

The study is achieved using a pilot-scale submerged membrane bioreactor (sMBR). It is consisted of two main compartments: the anoxic and the aerobic tanks, with 30 L volume each. Filtration module consists of flat sheet organic membrane (Micron-nadir, Germany) with a pore size of 0.04 µm and a surface area of 0.34 m^2. The trans-membrane pressure (TMP in kPa) is measured by specific pressure sensors positioned upstream and downstream the membrane. The mixed liquor present in the aerated tank is recycled and directed towards the first anoxic tank to ensure nitrate

reduction. The recycle ratio (R) is set at 400% with respect to the influent flow.

II.2 Analytical methods

The supernatant is sampled twice a week and filtrated through a dead end filtration (Whatman GF/C filter). MLSS and MLVSS are measured according to the Standard Methods [3]. In addition, Varion®Plus 700 IQ probes are used to continuously measure pH, temperature, ammonium and nitrate ions in the mixed liquor (Wissenschaftlich-TechnischeWerkstätten GmbH, Germany).

II.3 Respirometric measurement

Biomass activities are measured during the campaigns (60 days) by means of the oxygen consumption rate measurement by respirometer. Endogenous respiration is defined in conditions of deficiency of the exogenic substrate when the micro-organisms consume their endogenous cellular material to sustain vital function (after 24h aeration without the addition of exogenous substrate). Then, the addition of toxics or specific substrates allows the determination of respirometric activities of both heterotrophic and autotrophic micro-organisms [4- 6] (Fig. 1).

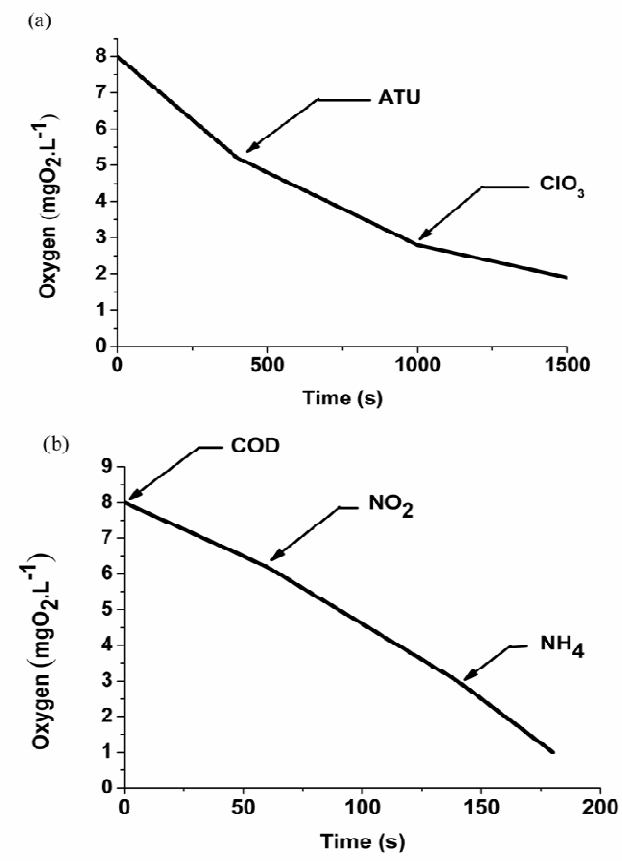

Figure 1. Profile of O_2 versus time for determination of biomass activity (a) by inhibitor injection, (b) by specific substrate addition.

III. Results and discussion

III.1 Biological activity

Endogenous respiration of heterotrophic and autotrophic microorganisms is investigated during the two campaigns (Fig. 2a, b). Exogenous respiration of heterotrophic and autotrophic microorganisms was also followed during the acclimations phase to characterize the microbial responsiveness. The autotrophic respiration increased while the heterotrophic activity decreased. autotrophic (BAI and BAA) exogenous activity remained constant around 0.57 Kg O_2 /m^3/d and 0.25 Kg O_2 /m^3/d. Longer acclimation with a high SRT may reveal a better development of autotrophic biomass in the MBRs. the heterotrophic exogenous activities never stopped increasing during the acclimations and reached a plateau after biomass stabilization with value of 1.46 Kg O_2 /m^3/d at 60 d.

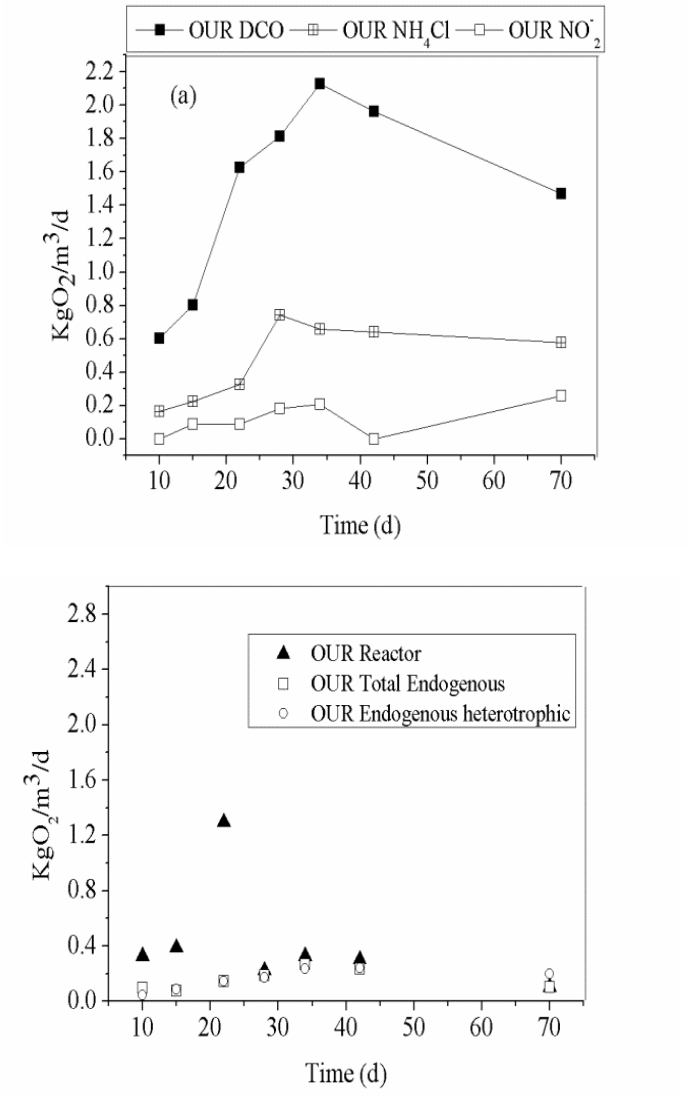

Figure 2. Endogenous and exogenous population needs versus time SRT=60d

The activities, measured in batch, with instantaneous flows of exogenous substrate are very much higher than the respiration requirements measured during operation in the reactor. This confirms that under high sludge retention time imposed on the system, the populations develop within the MBR in partial deficiency conditions of substrate.

As depicted in the figure 3, X_{BH} from exogenous respirations represent 22 %, of VSS composition for SRT = 60 d; On the other hand, X_{BAI} concentration represents only 5% of the VSS, while X_{BAA} concentration represents 10% for 60d days .

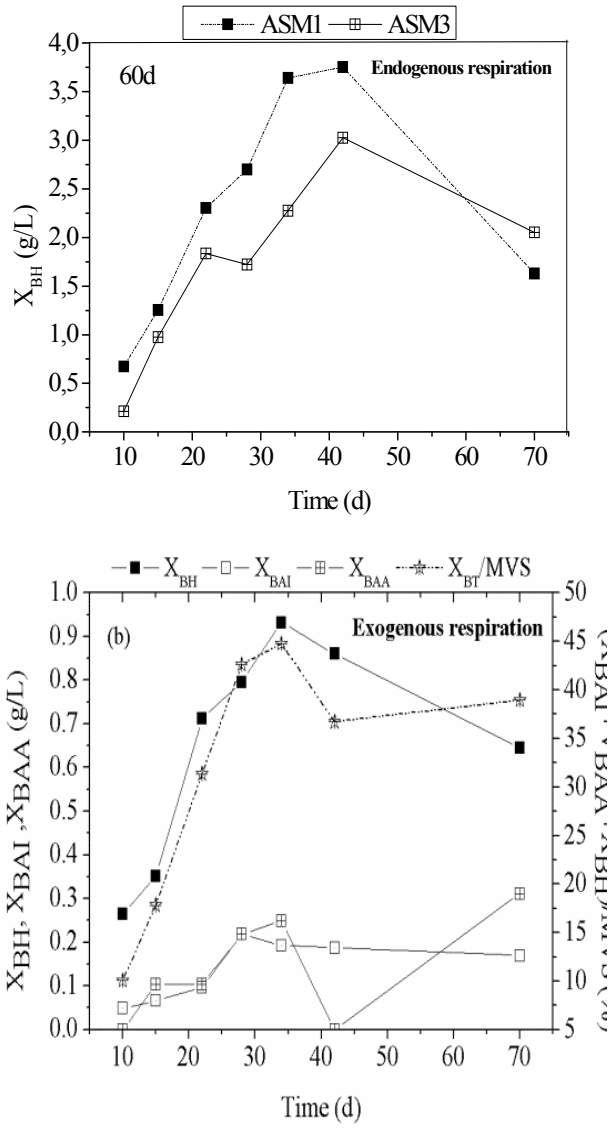

Figure 3. Biomass concentrations (X_{BH} X_{BAI} X_{BAA}) in endogenous and exogenous respiration, with ASM1 and ASM3 respiration (SRT= 60d)

IV. Conclusion

An experimental campaign on autotrophic heterotrophic MBR pilot plant, conceived for biological nutrient removal, was performed. One of the main aims of the study was the evaluation of the active fraction of both heterotrophic and autotrophic bacteria at low COD/N substrate ratio with the aid of respirometric batch tests. To achieve this, endogenous OUR equations were extracted from ASM. Then the obtain equations were validated thank to a simple software routine. And at the end the active biomass extracted from OUR measurement.

The respirometric batch test suggested that autotrophs were highly affected by the low COD/N ratio and the increase of SRT on membrane bioreactor; it had an important role in cell growth. Under high sludge retention time imposed on the system, the populations developped within the MBR in partial deficiency conditions of substrate. At a significant SRT (60d), the environmental conditions for active population in the sMBR were close to endogenous ones. Exogenous respirations represented 22 %, of VSS composition for SRT = 60d; On the other hand, X_{BAI} concentration represented only 5% of the VSS, while X_{BAA} concentration represented 10% for 60d days. The obtained results confirmed respirometry as a suitable tool for wastewater and biomass characterization, and that should provide a useful support in MBR design and management, as well as in MBR simulations.

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