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RESPIROMETRIC ASSESSMENT OF HETEROTROPHIC AND AUTOTROPHIC BIOMASS ACTIVITY IN ALTERNATE OXIC-ANOXIC MBR PILOT PLANT

MARCO CAPODICI, SANTO FABIO CORSINO, DANIELE DI TRAPANI, CLAUDIA MORICI, MICHELE TORREGROSSA(*) AND GASPARE VIVIANI
Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali (DICAM),
Università degli Studi di Palermo, Viale delle Scienze, 90128, Palermo ITALY.
(*) corresponding author: michele.torregrossa@unipa.it

ABSTRACT

The paper reports the main results of an experimental study carried out on a Membrane Biological Reactor (MBR) pilot plant characterized by intermittent aeration. The effect of different aeration/non aeration ratio (T_A/T_{NA}) on biomass behavior, in terms of heterotrophic and autotrophic kinetic parameters and active biomass fraction, was studied. Moreover was proposed a method to evaluate the autotrophic active fraction, derived by a combination of the ASM1 model and biokinetic parameters directly evaluated by means of respirometry. The experimental observation outlined that T_A/T_{NA} in the cycle didn't affect heterotrophic biomass kinetic and active fraction. This one instead, resulted strongly depended from the soluble substrate present in the influent wastewater. Furthermore, it was observed that a higher aerated phase within the cycle, may lead to a higher autotrophic biomass active fraction.

INTRODUCTION

The paper reports the main results of an experimental study carried out on a Membrane Biological Reactor (MBR) pilot plant operated with the alternated cycle (AC) strategy. Several studies outlines that intermittent aeration, by introducing a cyclic stress on the biomass, might determine a modification of the kinetic parameters and the metabolism of the biomass (Fatone et al., 2005; Lorain et al., 2009). Hence determination of biokinetic parameters and active biomass fractions, using respirometric techniques, is a valid approach for the microbiological analysis of this complex system. The active biomass is generally estimated by fluorescent in situ hybridization (FISH) and flow citometry (FCM), or applying Activated Sludge Models (ASMs) (Aicha et al., 2012, Majewsky et al., 2011). Regarding heterotrophic active fraction, there are several standardized methods (Fall et al., 2012), while the assessment of the autotrophic active fraction is still difficult to obtain. The aim of this paper is to show the effect of different aeration/non aeration ratio in a AC-MBR pilot plant on biomass behavior. Furthermore, a method to evaluate the autotrophic active fraction was proposed.

MATERIALS AND METHODS

The experimental analysis was carried out on a AC-MBR pilot plant (fig.1), continuously fed with real municipal wastewater (flux 33.8 l/h). Aeration/non aeration periods were controlled by a programmable logic controller (PLC). Reaction tank was continuously monitored by an on-line real-time monitoring system, including OD, ORP, pH, SST, N-NH_4, N-NO_3 sensors. The experimental study was divided into three different periods, each characterized by a different duration of the reaction cycle and aeration/non aeration ratios.

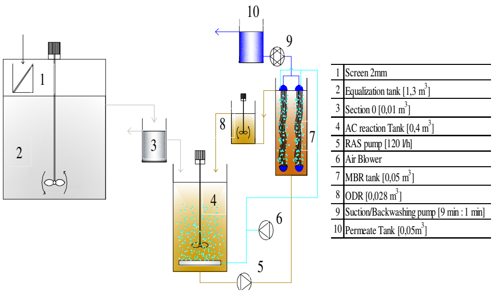

Fig.1: Pilot plant lay-out

The pilot MBR was operated with a sludge retention time (SRT) near 5 days for 22 days. However, due to the low strength of the influent wastewater, by day 22 the pilot plant was operated with complete sludge retention. In table 1 the main operational parameters are reported (as average values).

Tab.1: Main characteristics of the influent wastewater as well as operational conditions

Period	Cycle length [min]	T_A/T_{NA}	T_A/T_{tot}	Duration [d]	F/M [kg BOD_5 kg^{-1} SSV d^{-1}]	TSS [mg L^{-1}]	VSS [mg L^{-1}]	COD in [mg L^{-1}]	NH_4-Nin [mg L^{-1}]	ηCOD [-]	ηNH_4-N [-]
1	180	0.5	0.33	57	0.08	4810	2675.4	380	29	0.86	0.70
2	180	0.8	0.44	47	0.06	5875	4283	483	23	0.87	0.73
3	90	0.5	0.33	16	0.05	5975	3756.6	414	19	0.91	0.79

BATCH TESTS DESCRIPTION

Respirometric tests were carried out according to the procedure proposed by Andreottola et al. (2002). Respirometric station (fig.2) was constituted by a flowing-gas/static-liquid respirometer (Spanjers et al., 1995). A software (OURsys) provided to data acquisition and to aeration control. In particular, aeration started when oxygen concentration in the sample was less than 3.5 mgO_2/l and stopped at 5.5 mgO_2/l. The OURsys software calculated the oxygen uptake rate (OUR) as oxygen consumption slope in the range of

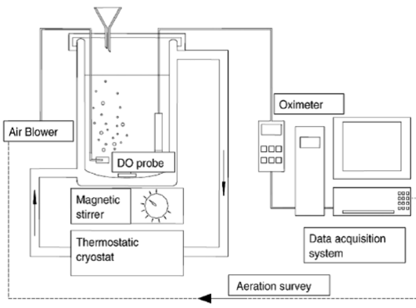

Fig.2 Configuration of the respirometric station

4-5 mgO_2/l, than provided the respirogram graph (fig.3a), showing exogenous and endogenous respiration periods of the biomass. Biokinetic parameters have been obtained from respirogram analytical analysis. The autotrophic decay rate (b_A) and the endogenous uptake rate of autotrophic biomass (OUR_{endAut}), have been determined according to the "multiple batch test" procedure proposed by Avcioglu et al., (1998). Each multiple batch test had a length of 4-6 days (fig.3a). Plotting $\ln OUR_{(t)}/\ln OUR_{(t0)}$ ratio vs time (fig.3b), OUR_{endAut} and b_A are derived from a linear regression model. By means of ASM1, the autotrophic active fraction has been evaluated using the kinetic parameters derived from the first respirogram graph analysis.

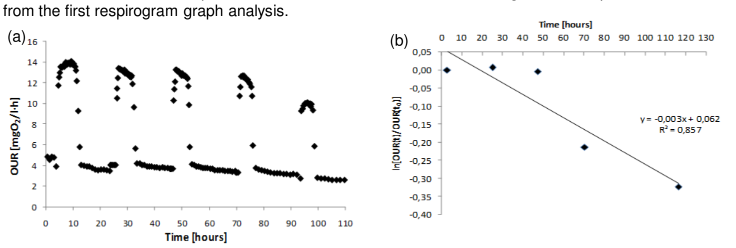

Fig3. Example of OUR profile of autotrophic endogenous decay rate estimation (a), and logarithmic OUR profile (b) derived from multiple batch test analysis

RESULTS

Table 2 reports the average values of the main kinetic parameters, referring to each experimental period. From the observation of table 2, it is worth noting how the main kinetic parameters of biomass (both heterotrophic and autotrophic) such as μ_H, μ_A, v_H, v_A and the specific oxygen uptake rate (SOUR) are decreasing throughout the whole experimental period. Furthermore, it was observed that the biomass activity is decreasing when the aeration length was reduced (period III).

Tab.2 : Average values of biokinetic parameters for both heterotrophic and autotrophic populations

Period	Y_H [mgSSV mg^{-1}COD]	Y_{Hsto} [mgSSV mg^{-1}COD]	μ_H [d-1]	Ks [mg L^{-1}]	v_H [mgCOD mg^{-1}SSV d^{-1}]	b_H [d^{-1}]	f_{XH} [-]	$SOUR_{max}$ [mgO_2 g^{-1}SSV h^{-1}]	$SOUR_{endogenous}$ [mgO_2 g^{-1}SSV h^{-1}]
1	0.38	0.49	1.65	3.12	4.03	0.64	0.18	26.57	3.91
2	0.42	0.50	1.51	2.92	3.50	0.82	0.09	10.38	1.68
3	0.43	0.51	1.17	1.87	2.49	1.04	0.07	5.70	1.08
Period	Y_A [mgSSV mg^{-1}N]		μ_A [d^{-1}]	KNH_4 [mg L^{-1}]	v_A [mgN-NH_4 mg^{-1}SSV d^{-1}]	b_A [d^{-1}]	f_{XA} [-]	$SOUR_{max}$ [mgO_2 g^{-1}SSV h^{-1}]	
1	0.29		3.46	0.31	15.59	0.27	0.0114	12.62	
2	0.27		1.67	0.75	8.92	0.09	0.0079	14.84	
3	0.19		0.28	1.27	1.99	0.08	0.0078	5.35	

Referring to the autotrophic populations in particular, it was observed that when the non-aerated phase was increased, the nitrification process was partially hindered, with a significant decrease of the nitrite oxidizing bacteria (NOB) activity. In fig.2, the biomass active fraction is reported, for the heterotrophic (fig.4a) and the autotrophic (fig.4b) populations, respectively.

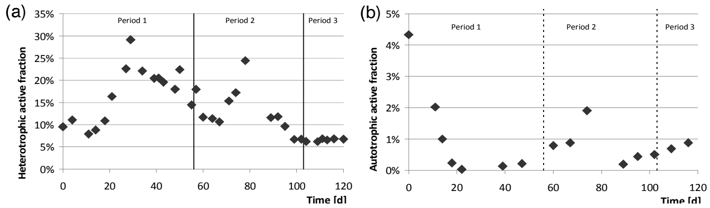

Fig.4: Heterotrophic (a) and autotrophic (b) active fractions throughout the experimental period

Moreover, it was noticed a significant correlation between the heterotrophic active fraction and the soluble COD values fed to the pilot (fig.5a) as well as a good correlation between the heterotrophic/autotrophic active fraction ratio and the ratio NH_4-N/COD_{sol} of the feeding wastewater (fig.5b).

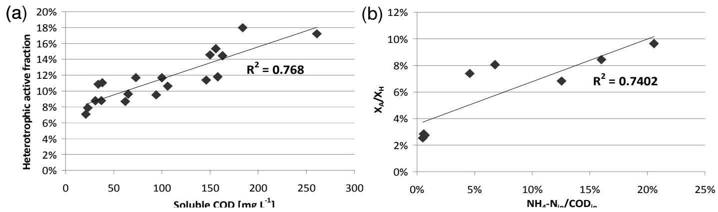

Fig.5: Heterotrophic active fraction versus soluble COD (a) and heterotrophic on autotrophic active biomass ratio versus nitrogen on carbon ratio (b) throughout the experimental period

As shown in figure 6a, nitrification efficiency and active fraction curves follow a quite similar trend; it is worth to notice that although the proposed method requires further validation, for example applying FISH techniques, it should be already considered a valid approach to quantify autotrophic active biomass fraction in bioreactor. Moreover, the correlation between active fraction and nitrification efficiency showed that, with a low ammonia influent load, an active fraction of 1-1.5%, is already enough to obtain nitrification efficiency exceeding 90% (fig.6b).

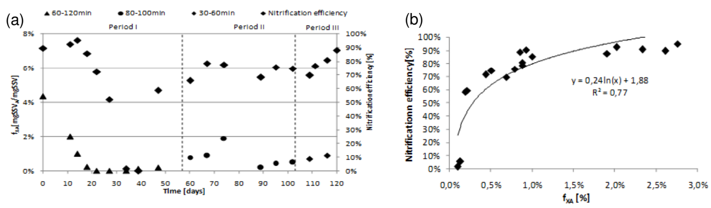

Fig.6: Time course of autotrophic active biomass fraction and nitrification efficiency (a), and correlation between active fraction and nitrification efficiency (b)

CONCLUSIONS

The paper reports the main results of an experimental study carried out on a Membrane Biological Reactor (MBR) pilot plant operated with the alternated cycle (AC) strategy. The experimental observation outlined that T_A/T_{NA} ratio in the cycle didn't affect heterotrophic metabolic activity, maybe due to the very low strength of the influent wastewater; instead T_A/T_{NA} ratio increasing, results in a greater autotrophic biomass development. Concerning heterotrophic active biomass, our study demonstrated that it developed independently from T_A/T_{NA} ratio, moreover it strongly depended from influent wastewater soluble substrate amount; instead for autotrophic one, irrespective of sludge age, higher aerated phase within the cycle, may lead to a higher active biomass amount. At least, the method proposed to autotrophic active biomass evaluation showed a good reliability, although it requires further validation.

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