IWA - YWP WORKSHOP:

INNOVATIVE TECHNOLOGIES

FORMATION OF AEROBIC GRANULES IN SEQUENCING BATCH REACTOR TREATING DAIRY INDUSTRY WASTEWATER

Ioana Alexandra Ionescu[1, 2], Costel Bumbac[1], Olga Tricolici[1]

[1] *National Research and Development Institute for Industrial Ecology – ECOIND, 71-73 Drumul Podu Dambovitei Street, 060653, Bucharest, sector 6, Romania, Phone: +40/21/4100377; fax: +40/21/4100575; e-mail: biotehnologi@incdecoind.ro*

[2] University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Bd., Sector 1, Bucharest, phone: +40/21/3182564/266, email: pccornea@yahoo.com

Aerobic granular technology, compared to conventional activated sludge wastewater treatment plants, is a novel alternative offering numerous advantages such as high biomass retention, good settling ability and simultaneous removal of organic load and nutrients. The main focus of research was to evaluate granules formation and evolution of treatment performances during startup and steady state conditions. The experiments were performed in lab scale sequencing batch reactors with automated control of the operational cycle: anaerobic feeding (45min.), aerobic reaction (11 h), settling (5min.) and effluent withdrawal (10 min.). One of the bioreactors (D) was inoculated with conventional activated sludge while the other one (GM) was inoculated with crushed aerobic granular sludge. Both bioreactors were fed with dairy industry wastewater with high organic and nutrients load (CODCr=1723 – 3550 mg O_2/L, BOD_5 = 492 – 1806 mgO_2/L; NH_4^+= 64,6 - 114 mg/L, P tot = 5,04 – 21,5 mg/L). Aerobic granular structures were observed even after 5 days (10 treatment cycles) with 67 to 556 µm in diameter in D bioreactor and with 392 to 1200 µm in GM bioreactor. The granules diameter in D bioreactor increased significantly after 25 days to diameters between 513 µm and 1276 µm and up to 2 mm by the end of the experiment. The granules in GM bioreactor increased to 764-1482 µm and up to 4 mm in diameter by the end of the experiment. Treatment performances increased rapidly along with the growth of granules size.

Keywords: aerobic granular sludge, dairy wastewater, SBR

1.Introduction

Granular sludge can be defined as a self-immobilized microbial consortium containing millions of individual bacteria (Liu et al., 2004). Granular sludge technology is one of the great achievements in environmental biotechnology of the twentieth century, and was first observed in a anaerobic upflow sludge blanket (UASB) reactor designed to treat industrial wastewater at the end of the 1970’s (Lettinga et al., 1980). However, the concept of aerobic granular sludge appeared later on - in the 1990’s when Mishima et al. (1991) reported the first aerobic granular sludge in an aerobic upflow sludge blanket reactor treating municipal wastewater. Later researches on biofilm structure and on the role of storage polymers (extracellular polymeric substances - EPS) on biofilm formation lead to the idea of growing aerobic granules without carrier material on readily biodegradable substrates in Sequencing Batch Reactor (SBR) (van Loosdrecht, 1997). In these aerobic reactors, it was proven to be possible to grow stable granular sludge with integrated simultaneous COD and nitrogen removal capacity.

Since that time, SBR has been intensively used by researchers worldwide to develop and understand the concept and mechanism of aerobic granulation (Liu et al., 2004) and to evaluate the performances and practical potential application of this technology.

2. Materials and methods

Experimental setup

Two identical column type SBR reactors with a height to diameter ratio of 10 and a total working volume of 8 L were used in order to evaluate the possibility of forming aerobic granules starting from different inoculum and to evaluate the evolution of treatment performances during startup and steady state conditions. Each of the SBR reactors, as it can be seen in the shematic representation of the AGSBR (figure 1) consisted of: influent vessel (60 L),), feeding pump (Heidolph, PUMPDRIVE 5001, peristaltic pump), effluent vessel (60 L) and effluent withdrawal pump (Heidolph, PUMPDRIVE 5001, peristaltic pump). The cyclic operation of the SBR systems was ensured by a Programable Logic Controller (PLC) which controlled the feeding pumps and air inlet and effluent outlet electrovalves. Each bioreactor had identical operational time sequence: anaerobic feeding (45 min.), aerobic reaction (11 h), settling (5min.) and effluent withdrawal (10 min.).

During aerobic reaction stage,an air compressor supplied each column at an airflow of 4 L/min. .

As settling time is an important hydrodynamic selection pressure operational parameter on the microbial community in the bioreactor, a short settling time was preferred and used to allow the selection and growth of fast settling bacteria and the wash out of the sludge with poor settleability.

At startup, the two bioreactors used in the experiment were inoculated as follows:

- 1st bioreactor (D) was inoculated with 5 g/L of conventional activated sludge sampled from a municipal wastewater treatment plant;
- 2nd bioreactor (GM)was inoculated with crushed and sieved (0.5 mm) aerobic sludge granules. The granules used were sampled from another lab scale working AGSBR which had granules of 4-8 mm in diameter. The idea was to evaluate how fast they recover the granular structure and treatment performances.

Both bioreactors were fed with dairy industry wastewater characterized by high organic and nutrients load as shown in table 1.

Table 1. Main quality parameters of the influent

Parameter	**Concentration range**
CODCr mg O_2/L	1723 – 3550
BOD_5 mg O_2/L	492 – 1806
NH_4^+ mg/L	64.6 – 114
Ntot mg/L	64 – 162
P tot mg/L	5.04 – 21.5

Analytical procedures

Treatment performances were evaluated based on COD, NH_4^+, NO_2^-, NO_3^- and PO_4^{3-}. COD was analyzed volumetrically based on potassium dichromate method according to the ISO standard (SR ISO 6060:1996) and using heating mantle (Model KI16, Gerhardt, Germany). NH_4^+, NO_2^- and NO_3^- were determined according to the SR EN ISO 14911:2003 and SR EN ISO 10304/1:2009 standards (for the last two indicators), respectively, using ion chromatography system ICS-3000 (Dionex, USA).
The granules formation and growth evolution were monitored by particle size analyses carried out using Malvern, Mastersizer S2600 and by microscopic investigation (trinocular Optech microscope and trinocular Motic stereomicroscope with built-in cameras).

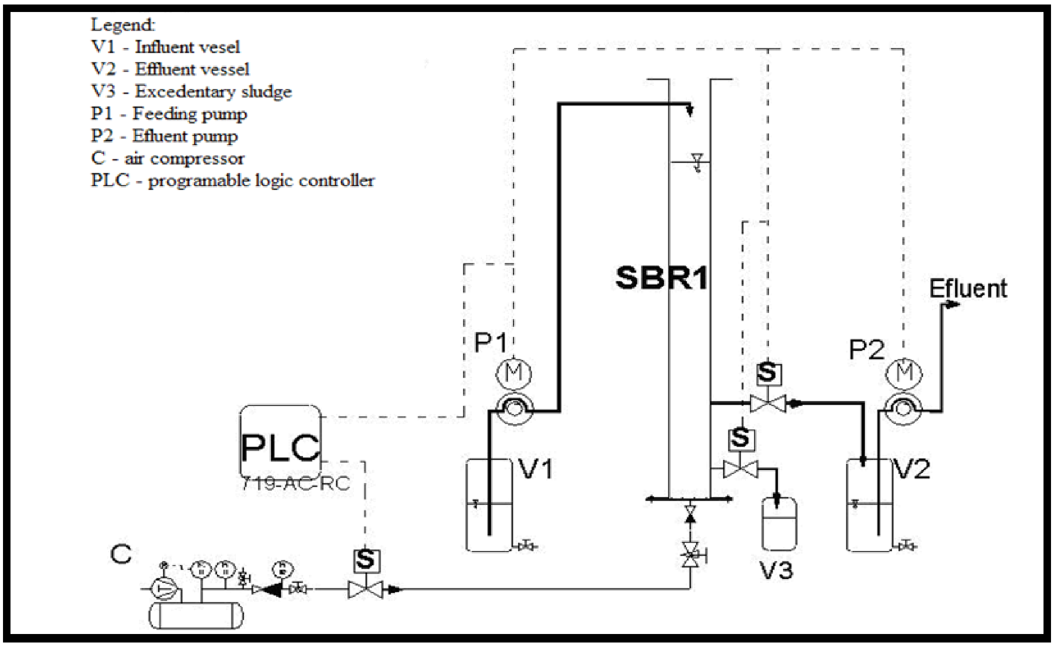

Fig. 1. Schematic representation of the aerobic granular sludge SBR

3. Results and discussion

Granule formation

In case of the 1st bioreactor (D) inoculated with conventional activated sludge, the first granular structures were observed after 5 days (10 treatment cycles) and continuously increased up to 2 mm in diameter after 22 days (fig.2, and 3). Microscopic investigations emphasized the tendency of flocs to adhere to each other to form granules and implicitly to grow in diameter. Thus, in figure 2 (a) representing the inoculum we can observe dispersed activated sludge flocs while in 2 (b) and 2 (c) we can observe that the flocs are more compacted and granules are being formed so that after 26 days, the sludge in the bioreactor is under the form of granules with diameter of up to 2 mm (fig.3 and 4).

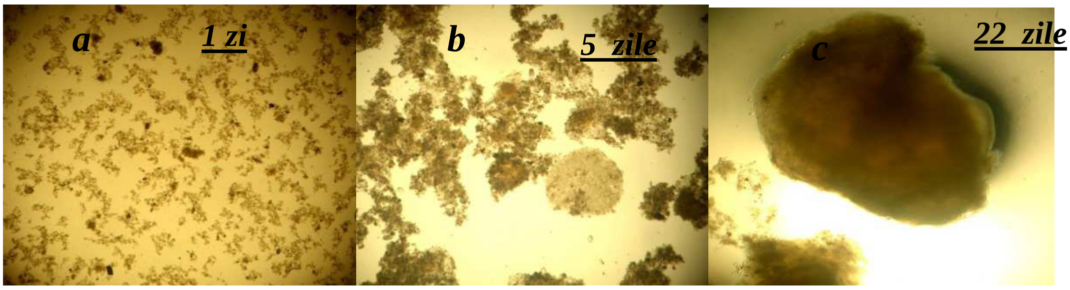

Fig.2. The evolution in time of aerobic sludge granules (microscopic images 4X)

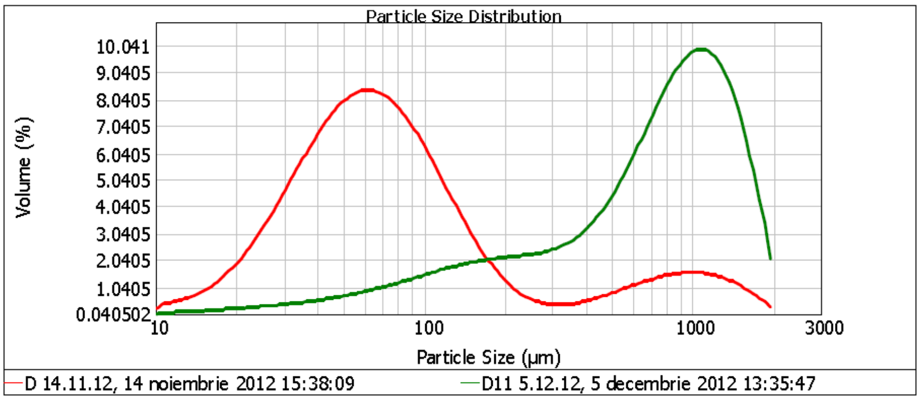

Fig.3. Granule size distribution in bioreactor D: red line – inoculum (conventional activated sludge flocs), green line – granular sludge (after 26 days).

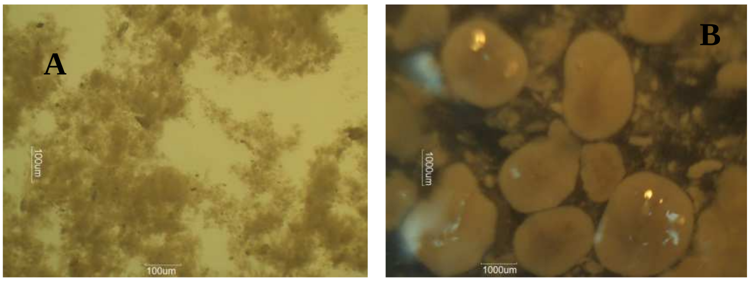

Fig.4. Stereomicroscopic images (10X): A – inoculum –conventional sludge; B – granules 0,1-2 mm (after 26 days)

In case of the second bioreactor (GM) which was inoculated with crushed and sieved granules, compared to the granules obtained in bioreactor D (round shaped and smooth surface) within the same period of time and under the same operational conditions, the granules formed in bioreactor GM had irregular shape variable size but compact structure. (fig.5 and 6)

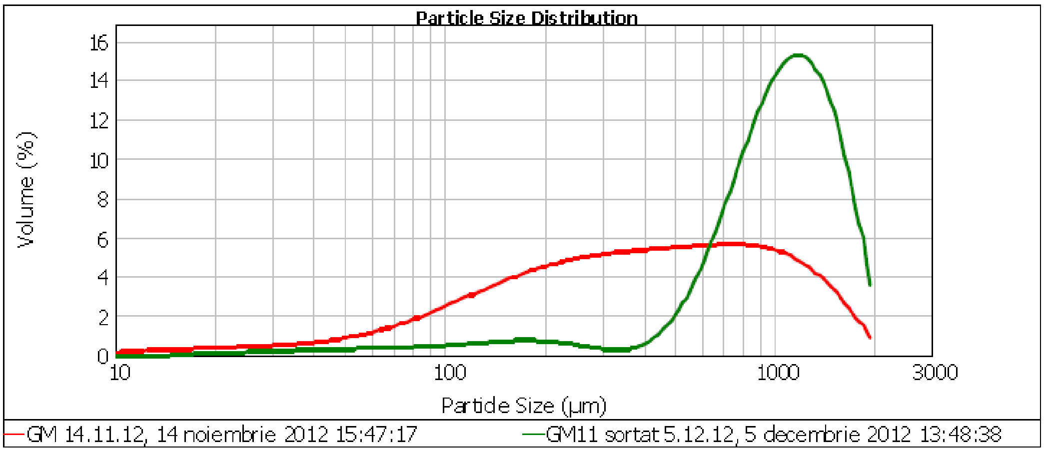

Fig.5. Granules size distribution evolution: red line – inoculum (crushed aerobic granules), green line – granular sludge (after 26 days).

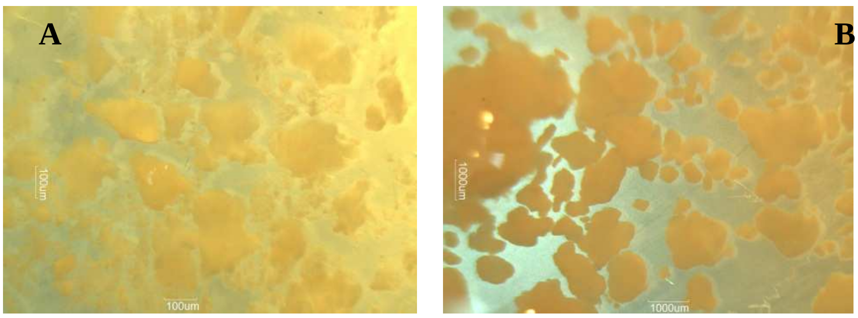

Fig.6. Stereomicroscopic images: A – inoculum –crushed aerobic granular sludge (40X); B – sludge granules (10X) ~0,5-1,6 mm (after 26 days)

Once with the increase of size granules the sludge settling speed and biomass concentration in the bioreactors increased leading to good treatment performances considering the nutrient and organic load of the influent, the total hidraulic retention time of 12 hours and the fact that it is only a one step process (aerobic).
The treatment performances obtained in the two experimental SRB reactors, D and GM, are presented comparatively in table 2.

Table 2. Comparative presentation of the treatment performances in both reactors

Parameter	Bioreactor D	Bioreactor GM
CODCr	91 – 95 %	70 - 91 %
BOD_5	93 – 97 %	75 - 93 %
NH_4^+	94 – 99 %	82 - 94 %
P tot	65 – 93 %	65 – 90 %
Ntotal	48 – 81 %	50 – 80 %

Treatment efficiency was higher in D bioreactor than in GM bioreactor. This can be explained by lower specific surface area of the granules and lower diffusion gradients of nutrients within the granules.

4. Conclusions

The focus of the research was to evaluate the granules formation and performances evolution during startup and steady state conditions. In both cases the first granules formation were observed after 5 days of inoculation.
Even though the two bioreactors used in the experiment underwent the same operational conditions GM bioreactor, inoculated with crushed granular sludge, has shown slightly lower treatment performances during start-up compared to D bioreactor, inoculated with conventional activated sludge.
The aerobic granular sludge proved to be stable and adaptable to high nutrients concentrations succeding to efficiently remove the organic load and nutrients from the influent wastewater

5. References

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