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Physical characterisation of the sludge produced in a sequencing batch biofilter granular reactor

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ABSTRACT

Sequencing batch biofilter granular reactor (SBBGR) is a recently developed biological wastewater treatment technology characterised by a very low sludge production, among other numerous advantages. Even if costs for sludge treatment and disposal are mainly dependent on the amount of sludge produced, sludge properties, especially those linked to solid–liquid separation, play a key role as well. In fact, such properties deeply influence the type of treatments sludge has to undergo before disposal and the final achievable solids concentration, strongly affecting treatment and disposal costs. As sludge from SBBGR is a special mixture of biofilm and aerobic granules, no information is available so far on its treatability. This study addresses the characterisation of the sludge produced from SBBGR in terms of some physical properties (settling properties, dewaterability, rheology). The results show that such sludge is characterised by good settling and dewatering properties, adding a new advantage for the full-scale application of SBBGR technology.

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1. Introduction

Sludge treatment and disposal account for a large fraction of the operating costs of a wastewater treatment plant, even up to 50–60%. Therefore, a great research effort has been addressed to the individuation of technologies able to reduce the amount of sludge to be disposed of, leading to define different approaches, which can be grouped into two main categories. In particular, it is possible to change process characteristics in order to produce less sludge during biological treatment (extended aeration, ozonation, mechanical destruction of raw activated sludge, use of additives, metabolic-uncoupling, lysis-cryptic growth, etc.) or to adopt post-treatments such as heat treatment (incineration, gasification, etc.), chemical oxidation (wet air oxidation, etc.) or sludge digestion to reduce quantities to be disposed of (Liu, 2003; Mahmood and Elliott, 2006; Wei et al., 2003).

A critical evaluation of all technologies has indicated that sludge reduction through treatment process changes (i.e., in water line) is more appealing than post-treatment alternatives (i.e., in sludge line), as it reduces sludge production from the beginning, thus decreasing sludge management cost (Mahmood and Elliott, 2006). In this field, sequencing batch biofilter granular reactor (SBBGR), a recently developed system, could represent an optimal solution, as it couples a very low sludge production with other several points of strength, like low footprint and high compactness due to the possibility to simultaneously perform all the steps of biological treatment (carbon removal, ammonia oxidation, oxidised nitrogen reduction), great operating flexibility, capability to

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deal with wastewater with variable flow rate and composition, effective degradation of toxic and recalcitrant compounds (Di Iaconi et al., 2010). The biomass growing in this system consists of two different fractions: the biofilm attached to the carrier material and the granules entrapped in the pores produced by packing the filling material (De Sanctis et al., 2010). Therefore, the whole biomass is always completely separated from liquid phase and then a sedimentation step is no longer required.

Despite the low sludge production is an undoubtable advantage in terms of cost reduction, sludge physical properties have also a high effect on sludge treatment costs as they affect the type of treatment sludge has to undergo before disposal. In particular, the ease in the separation between sludge liquid and solid phase strongly influences the cost of dewatering, the final achievable sludge concentration and also the disposal cost. Due to the particular feature of the sludge produced in SBBGR system (i.e., the coexistence of biofilm and granular biomass), no information is available on its treatability so far.

This study presents the results of the physical characterisation of the sludge from two lab-scale SBBGRs treating mixed and textile wastewaters (Lotito et al., accepted for publication). Selected sludge properties (settling properties, dewaterability and rheology) have been investigated in order to get a glimpse of the main characteristics that affect the treatments sludge has to undergo before disposal. Such properties have been chosen because settling properties and dewaterability can be used to evaluate the easiness in achieving sludge with high solids concentrations, while rheological parameters are fundamental in sludge management (as they influence designing parameters in transport, storage, pumping and spreading operations) and treatment (controlling stabilisation and suitability for thickening, flocculation, centrifugation, etc.) (Lotito et al., 1997).

2. Materials and methods

2.1. *Reactor configuration*

Two lab-scale SBBGRs were run, each made up of a plexiglas cylinder with height of 1 m and internal diameter of 0.19 m, partially filled with a plastic support material (KMT-k1 elements from Kaldnes, Norway; 10 mm diameter, 7 mm height, 630 m^2/m^3 specific surface, 950 kg/m^3 density, 0.75 porosity) kept between two sieves (microbial bed). Head losses through the microbial bed were monitored in order to remove excess sludge using compressed air when they increased over a fixed threshold (washing operation).

The experimentation was carried out at first with biological treatment alone and later with integrated ozone treatment, withdrawing part of the liquid phase from the biological reactor into a 5 l ozone reactor equipped with a porous distributor of ozone. Ozone was produced from pure oxygen by an ozone generator Modular 8HC – WEDECO with maximum O_3 production capacity of 8 g/h. The ozonated liquid was recycled in the biological reactor by gravity.

Four different real textile wastewaters were treated as representative of the main textile processes. In particular, a mixed municipal-textile one and the effluent from a printing factory were treated (one after the other) in reactor A for about 400 d (200 d each), while two effluents from dyeing factories (fabric and yarn dyeing) were loaded to reactor B for about 460 d (260 d and 200 d, respectively). Further details can be found elsewhere (Lotito et al., accepted for publication).

2.2. *Sludge samples*

Sludge properties should be evaluated on the sludge from washing operation (indicated from now on as washing sludge), as this fraction represents the excess sludge removed from the system during normal operation. However, due to the low sludge production (Lotito et al., accepted for publication), the number of such samples, when available, was low. For this reason, all sludge samples, including microbial samples detached from the bed, have been considered, as they can give some interesting indications, which nevertheless deserve further investigations.

As previously said, washing sludge (WS) samples derived from washing the microbial bed with compressed air when head losses increased over a set value. Sludge was collected in part of the liquid phase over the bed and discharged by opening the motorised valve normally used for effluent discharge.

Microbial samples were drawn twice (at the end of the biological treatment alone and at the end of the ozone integrated treatment) from different heights of the microbial bed (top T, medium M and bottom B). The sludge was completely detached from the carrier elements and then washed in a known volume of tap water.

All considered sludge samples are shown in Table 1, together with their concentration of total and volatile suspended solids (TSS and VSS) measured according to standard methods (APHA, 1998). The values are the average of three determinations, each computed on not less than 50 ml of sludge in order to take into account sludge heterogeneity due to the presence of granules. Thanks to this procedure, the three values were always very close one to the other, with a maximum difference of 0.5 g/l between the maximum and the minimum value.

2.3. *Sludge physical properties*

The analysed properties include sludge settling properties, dewaterability and rheology.

The ability of sludge to settle was evaluated by recording the position of the solid–liquid separation interface in a graduated cylinder of 1000 ml or 500 ml, depending on the available sludge, without stirring. Settling tests were run until a constant sludge volume was achieved and no further settling took place. Sludge settleability was defined in terms of sludge volume index (SVI), the volume occupied by the unit of mass of sludge after 30 min. To evaluate settling rapidity the same index was computed after 5 min (SVI_5) and 10 min (SVI_{10}). Moreover, settling velocity was calculated in the linear part of the settling curve.

Capillary suction time (CST) has been established as a practical empirical method for the determination of sludge dewaterability, especially after the addition of coagulants (UNI

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