Experiments and modelling on biomass transport inside upflow sludge blanket reactors intermittently fed

Gilberto Garuti[1]*, Giuseppe Leo[2], Francesco Pirozzi[2]

[1] *Water Treatment and Water Cycle Division of National Agency for New Technologies, Energy and Environment (ENEA), Via Martiri di Monte Sole, 4, 40129 – Bologna (Italy)*

[2] *Department of Hydraulic and Environmental Engineering* Girolamo Ippolito*, University of Naples* Federico II*, Via Claudio, 21, 80125 – Naples (Italy)*

Abstract

This paper describes the experimental and theoretical activities developed to study the biomass transport phenomena occurring in upflow anaerobic reactors influencing the biomass washout. Particularly, the experimental investigations have been carried out on a full-scale ABR and on a pilot UASB intermittently fed with the aim to determine the extent to which washout is affected by: daily flow distribution; upflow velocity; concentration and sedimentation properties of the biomass. The theoretical study focused on the proposal of a mathematical model able to simulate the sludge transport phenomena in the above cited reactors, in order to obtain a tool to estimate sludge washout in different influent flow conditions.

The research has shown the considerable influence on the biomass behaviour of the time interval occurring between two successive feeds of the reactors. In fact, if this period is more than 1 h considerable losses of biomass into the effluent were found, independent of the upflow velocity. On the other hand, shorter periods give rise to a regular sludge expansion of the interface even with very high upflow velocities (up to 4 $m \cdot h^{-1}$), and consequently to limited sludge washout.

Keywords: UASB, sludge washout, solids transport model

Introduction

The anaerobic biological sludge blanket systems proposed over recent years have elicited considerable interest because of their good removal efficiencies of organic substrates, their relatively simple layout and the low capital and operating costs. The most successful systems include the upflow anaerobic sludge blanket (UASB - Lettinga et al., 1980) and the anaerobic baffled reactor (ABR – Bachmann et al., 1985; Barber and Stuckey, 1999). UASBs are comprised of a tank fed from below in which the wastewater to be treated flows vertically upwards: the biomass forms a thick layer of sludge on the bottom beneath a suspension composed of biologically formed granules (blanket). ABRs consist of two or more tanks (sections) arranged in series, each of which acts like a UASB, so that the acid-forming bacteria are separated from the methane-forming ones and the methane fermentation process is not affected by an over-production of organic acids (Barber and Stuckey, 1999).

The granule washout into the final effluent of UASBs and ABRs is obviously a critical feature in the operation of these systems. If this were to happen, system performance would drop as a result of the presence of organic solids in the effluent (Grobicky and Stuckey, 1991; 1992; Lettinga and Hulshoff Pol, 1991) and the reduction of the biomass in the system (Nachaiyasit and Stuckey, 1997). However, continuously fed systems have shown fairly small washout even with high average upflow velocities, in the order of 1to 1.5 $m \cdot h^{-1}$ (Barber and Stuckey, 1999; Orozco, 1997), a result which is essentially attributable to the good sedimentation properties of anaerobic sludges. There is no information available on the washout in systems intermittently fed, which is essential in the wastewater treatment plants of small communities (Garuti et al., 1992; Garuti et al., 2001).

This paper describes the problem of washout in intermittently fed anaerobic systems by referring to experimental tests carried out in a variety of working conditions. These were made possible by using the full-scale ABR and the pilot UASB respectively located at the Biancolina (Bologna, Italy) Wastewater Treatment Plant (WWTP) and at the laboratory of the National Agency for New Technologies, Energy and Environment (ENEA). The tests aimed to determine the extent to which treatment performance is affected by factors such as: daily flow distribution; upflow velocity; concentration and sedimentation properties of biomass. In order to generalise the obtained results, a simulation model of the sludge transport phenomena in the two biological systems is proposed.

The work was organised in three phases. Phase 1 analysed the washout phenomenon in the two anaerobic sections of the ABR at Biancolina WWTP by monitoring the sludge concentration under different flow conditions.

Phase 2 of the research was carried out in the laboratory using a plexiglass pilot UASB inoculated with the sludge from the first section of the ABR located at the Biancolina WWTP and fed with a flow having the same organic matter concentration so as to reproduce operating conditions close to those of the actual system and also physically observe sludge dynamics in the system. Repeated measurements of the total suspended solids (TSS) and soluble COD content of the effluent made it possible to determine washout entity and removal efficiencies according to the way the blanket expands.

Finally, Phase 3 deals with the implementation of a mathematical model that can simulate biomass transport in a UASB (or in each section of an ABR) in order to estimate washout under different influent flow conditions.

* To whom all correspondence should be addressed.
☎ +39 051 6098477; fax: +39 051 6098477;
e-mail: garuti@bologna.enea.it
Received 29 July 2002; accepted in revised form 23 October 2003.