Laboratory-scale UASB digesters (with/without conditioning tank and recycle): Efficacy to treat increased hydraulic loads

BT Dudley[1]*, AR Howgrave-Graham[1], H Isherwood[2] and E Senior[3]

'Department ofMicrobiology and Plant Pathology, University ofNatal, PO Box 375, Pietermaritzburg 3200, South Africa
[2]Waste Water Treatment Plant, Prospecton Brewery, PO Box 833, Durban 4000, South Africa
^International Centre for Waste Technology (Africa), University ofNatal, PO Box 375, Pietermaritzburg 3200, South Africa

Abstract

Digester failure often results from hydraulic overload or organic shock load. Possible obviation of the former by the intervention of a conditioning tank and recycle was investigated with laboratory-scale upflow anaerobic sludge blanket (UASB) digesters. Brewery waste water (COD 4 500 $mg \cdot l^{-1}$) was the substrate of choice and the temperature used was 32°C. The results of this study demonstrated that the characteristic problems of lowered gas production rates, reduced soluble and total COD removals and lowered pH and bicarbonate alkalinity concentrations which accompany anaerobic digester hydraulic overload were not effectively negated by the provision of a conditioning tank and recycle. Under hydraulic overload conditions (scale equivalent to >3 000 $m^3 \cdot d^{-1}$ at the full-scale plant (1 700 m^3)) the provision of a conditioning tank and recycle was required to maintain digester sludge physical integrity. Image analysis summarises visual information into practical and productive statistical information which we have shown has an application in the monitoring of UASB digesters.

Introduction

The use of upflow anaerobic sludge blanket (UASB) digesters for high hydraulic load operation has received many endorsements (Hulshoff Pol et al., 1988; Morvai et al, 1990). Under normal operating conditions this technology is, often, self-regulating. Hydraulic or organic overload conditions or low influent alkalinity can, however, effect fermentation balance shifts so that resultant acidification may lead to process failure (Sam- Soon et al., 1991). To obviate the problems of low alkalinity, influent chemical oxygen demand (COD) variations and high COD *per se* provision of liquid recycle may be considered (Sam-Soon et al., 1991).

Further problems, typical of the full-scale Prospecton Brewery (South Africa, SA) digester under investigation, include the maintenance of operating conditions to provide constant selection pressure for sludge with good settleability (Ross and Louw, 1987; Isherwood, 1991). Selection pressures are those conditions, such as high upflow velocity, which allow well-settling granule formation to occur. Thus, for example, blocked sparge pipes have effected a volatile suspended solids (VSS) reduction in excess of 85%. Concomitant granule changes from black (1 mm dia.) particles to brown (0,5 mm) structures entrained within a filamentous matrix were also apparent (Isherwood, 1991). These results provided circumstantial evidence to support the selection theory of Hulshoff Pol et al. (1988) which states that retention of sludge within the digester is dependent on the selection pressures applied. Thus, appropriate upflow conditions facilitate the selection of microorganisms which adhere to each other and form granules which settle well (Guiot et al., 1991).

The number and size of granules within UASB digesters may provide an indication of prolonged digester stability (Dubourguier et al., 1988; Ross and Louw, 1987; Sam-Soon et al., 1987) and monitoring these parameters should allow continued optimisation of the granulation process. Use of image analysis simplifies this process as it combines the inherent accuracy and precision of microscopic techniques, based on direct visual observations of the object, with the speed of the digital computer (Kiss and Pease, 1982). It also reduces the human error factor especially when microscopic measurements must be made. Using image analysis an alteration in growth can easily be quantified and measured regularly (Bolton et al., 1991), without modifying the operating conditions.

This paper reports on laboratory studies made to examine the effects of increased hydraulic loading rates on granule integrity and the obviation of characteristic problems of lowered gas production rates, reduced soluble and total COD removals and lowered pH and bicarbonate alkalinity concentrations which accompany anaerobic digester hydraulic overload, by the inclusion of a conditioning tank and partial recycle.

Materials and methods

Digester

The laboratory-scale UASB digester (operating liquid volume 5,10 was based on the design of Sam-Soon et al. (1987). A 45° cone in the upper part of the digester acted as a phase separator and was intended to prevent granule loss. The operating temperature used was 32°C. Two identical digesters were built (Fig. 1) one of which had, in addition, a conditioning tank (1,14 (), fitted with a mechanical stirrer, and recycle. The recycle was maintained at approximately 20% (from the full-scale digester operating parameters (Isherwood, 1991)) of the current hydraulic loading rate.

Sludge inoculum

Granular sludge was collected from the Prospecton Brewery (SA) UASB digester and 104,67 gVSS (calculated to give an equivalent loading to the full-scale digester) inoculated into each digester. After 24 h under batch culture conditions continuous flow operation was initiated.

---

*To whom all correspondence should be addressed.
Current address: International Centre for Waste Technology (Africa), University of Natal, Pietermaritzburg 3200, South Africa.
Received 24 November 1992; accepted in revised form 22 April 1993.