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Review

Flocculants effect in biomass retention in a UASB reactor treating dairy manure

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Abstract

The performance and biomass retention of an upflow anaerobic sludge bed (UASB) reactor treating liquid fraction of dairy manure has been investigated at several organic loading rates. Two identical UASB reactors were employed. The biomass of one UASB reactor (FBR) had previously been treated with a cationic polyacrylamide, the other reactor was operated as a control reactor (CR). At 3 and 2 days of HRT both reactors functioned similarly, but at 1.5 days HRT some differences were observed between both effluents. Mean COD_T removal percentages were 83.4% and 76.5%; COD_{VFA} values in effluents were 977 and 2682 mg l^{-1} for the FBR and the CR respectively. The VSS initial value in both reactors was 25.66 g VSS, whereas after the experiment the quantities were 31.83 g VSS in the FBR and 23.18 g VSS in the CR reactors. Polymer addition resulted in a higher degree of biomass retention and better performance in the FBR reactor.

Keywords: Dairy manure; Solids removal; Liquid fraction; UASB reactor; Methane

1. Introduction

The chemical composition and the particle size distribution of dairy cattle manure varies with animal diet, material used as bedding, the manure collecting system and decomposition processes during storage. Due to the low concentration of plant nutrients it is expensive to transport the surplus plant nutrients from dairy farms to arable farms that have a nutrients deficiency. However, transport costs can be reduced by separating the manure into a nutrient-rich solid fraction and a liquid fraction (Møller et al., 2000). The separated solid fraction is suitable for the production of compost (Lo et al., 1993) or methane production by semisolid anaerobic digestion. The liquid fraction, which contains lower solids and nutrients, offers the benefit of odour reduction in storage pits or tanks and can be treated in a more easy and economic way (Zhang and Westerman, 1997). The majority of organic carbon and nutrients (especially nitrogen and phosphorus) are contained in the fine particles, which due to their faster decomposition are responsible for odours (Zhang and Westerman, 1997).

The solid–liquid separation processes include mechanical equipment (sedimentation, screening, centrifugation and pressing) and chemical treatment (coagulation and flocculation). Screen separators are used the most extensively and work better when the manure solids content is lower than 5% (Zhang and Westerman, 1997). The separation efficiency of a screw press separator was compared with that of a decanting centrifuge by treating cattle manure. In the raw manure more than 30% of the particles were larger than 0.025 mm, whereas in the liquid fraction obtained by centrifuging there were no particles larger than 0.025 mm. In the separated liquid fraction by the screw press (filter size 1 mm), 22% of the particles were larger than 0.025 mm and the results of the study indicates that aggregation of particles in the filter did not contribute to

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a significant retention of particles lower than 1 mm in the solid fraction (Møller et al., 2002). These results are in accordance with the fact that the centrifuging process removes all the particles larger than 0.02 mm (Sneath et al., 1988).

Due to the relatively low efficiency of mechanical equipment on organic solids and nutrients reduction in the liquid fraction, chemical treatment of manure must be considered. The most used synthetic polymers are the derivates of polyacrylamide (PAM). Similar to municipal wastewater treatment, adding chemicals can remove nutrients from dairy manure (Powers et al., 1995). Simulated flushed wastewaters containing up to 1.5% of dairy manure total solids were used in laboratory experiments; $FeCl_3$ salts were the most effective. Adding 278 mg l^{-1} Fe from $FeCl_3$ effected sedimentation in 89% TS, 56% N, 88% P and 60% K (Barrow et al., 1997). Flocculation and screening of dairy manure was accomplished by Zhang and Lei (1998). First, large particles were removed by screening, then cationic polyacrylamide polymers, $FeCl_3$ and $Al_2(SO_4)_3$ were tested. A sieve with 0.8 mm openings was used for the final screening. The optimum dosage of the polymer required was about 7.4% of the amount of TS contained in dairy manure (Zhang and Lei, 1998).

The conventional treatment applied to animal manures has been the anaerobic digestion process which permits recovery of the biodegradable organic matter in the form of methane in the biogas. The nutrients remain in the stabilised manure, except volatilised ammonia. The methanogenic productivity of manure depends on the diet and kind of cattle, storage conditions from its production and pretreatment operations carried out. The methane productivity per unit VS destroyed was relatively constant, 500 l CH_4 kg^{-1} VS, for all animal waste types (Hill, 1984). The theoretical methane production for dairy cattle manure is 469 l CH_4 kg^{-1} VS, the ultimate methane production for dairy cattle manure was estimated at 148 ± 41 l CH_4 kg^{-1} VS (Møller et al., 2004). The anaerobic biodegradability of dairy manure was estimated to be 50% of the total COD based on results of laboratory research (Zeeman, 1991). Several studies revealed that the methane potential of organic particulate matter increases with decreasing particle size due to an increase in the specific surface area (Hartman et al., 2000). Dairy manure separation in solid and liquid fraction is a way to produce a solid fraction with higher methane potential based on volume, since the water has been drained from the solids, being the VS concentration higher for this fraction (Møller et al., 2002). The liquid fraction obtained, without organic particulate matter, will have higher methane productivity based on VS, since all of them will be as soluble compounds. In addition, by means of adequate treatments, subsequent to anaerobic treatment, it will be easier to discharge into the public water systems in accordance with present environmental regulations.

Since the 1980s, upflow anaerobic sludge blanket (UASB) technology has been employed for wastewater treatment (Lettinga et al., 1980; Alphenaar et al., 1993; Schmidt and Ahring, 1996; Tay and Yan, 1996). It is a reliably tested technology for the treatment of high-strength wastewater, when its organic matter is in soluble form, in addition it has low installation, operation and maintenance costs. More than 900 full-scale units are currently being operated all over the world (Alves et al., 2000).

Granulation process is an important factor in the performance of a UASB reactor (Fang et al., 1994). This process happens in a natural and spontaneous way when ambient conditions are suitable for bacteria trend self-immobilize (Jian and Lun, 1993). Factors affecting granulation and then efficiency in UASB reactors are composition and concentration of organic matter in wastewater to be treated, operating temperature, pH, high ammonia nitrogen concentrations, presence of polyvalent cations, hydrodynamic conditions, inoculated seed and the production of exo-cellular polymeric substances by anaerobic bacteria (Morgan et al., 1990; Kosaric et al., 1990; El-Mamouni et al., 1995, 1997; Kalyuzhnyi et al., 1996; Yu et al., 2000, 2001). A detailed review of the granulation process was realized by Schmidt and Ahring (1996).

When biomass has no good sedimentation characteristics in high load anaerobic reactors with suspended biomass, the biomass can be removed from the reactor with the effluent when the process is developed at determined organic loading rates.

It is possible to employ polymers in anaerobic reactors in order to fix anaerobic sludge on the gelatinous bed or to strengthen the existing granules covering its surface with a fine layer of polymer (Liu et al., 2002; El-Mamouni et al., 1998; Imai et al., 1997; Uyanik et al., 2002a,b; Show et al., 2004; Tiwari et al., 2005).

The supplementation of laboratory-scale UASB reactors with polymers, either natural or synthetic, enhanced the granulation in comparison to control reactors (El-Mamouni et al., 1998). In an anaerobic baffled reactor (ABR) treating ice-cream wastewater (Uyanik et al., 2002a), higher methane yields and a degree of biomass retention were got in the polymer-amended reactor compared to the control reactor, which had not been polymer amended. The addition of a cationic polymer in UASB reactors shortens start-up time, enhancing its behaviour (Show et al., 2004). Cationic polymers were more effective additives for enhancing sludge granulation in lab-scale UASB reactors treating low-strength synthetic wastewater, COD 750–850 mg l^{-1} (Tiwari et al., 2005). Cationic polymers were more effective additives for enhancing sludge granulation. Biomass retention within an UASB reactor could be improved by the addition of flocculating chemicals if it can stimulate the formation of denser flocs with better settling characteristics.

The objective of this study was to get a liquid fraction of dairy manure with high biodegradability to be treated in high load anaerobic reactors, such as UASB reactors. This is the first stage to obtain a liquid fraction suitable for being used on land for the whole year or discharged to