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Poster paper

Anaerobic Degradability of Wool Scouring Effluent

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ABSTRACT

The anaerobic degradability of wool scouring effluent was investigated in batch cultures. The results were compared to the degradation of cellulose and sterile activated sludge. Wool scouring effluent was clearly more difficult to degrade anaerobically than cellulose or the biomass of activated sludge.The maximum biogas production rate from wool scouring effluent was about 46% and 31% of the maximal rates obtained from activated sludge and cellulose powder, respectively. The slow conversion rate and also the low percentage of the organics degraded showed that wool scouring effluent is particularly difficult to degrade anaerobically. Our results suggest that very long residence times (> 30 days) are required to successfully convert most of the organics in wool scouring effluent into biogas. The large digester size required questions the economics of such a treatment. However, in contrast to waste streams containing communal wastes, biomass waste or carbohydrates, wool scouring effluent as feed material is unlikely to cause digester failure by acidification, which would make its anaerobic digestion more stable and more easily controlable.

Keywords: Anaerobic digestion, lipids, lanolin, wool scouring effluent, detergent

INTRODUCTION

During wool scouring the raw greasy wool is washed with detergent in hot (70°C) water. This washing process removes dirt, the water soluble organic and inorganic salts (suint) and emulsifies the wool grease (lanolin). Only some of the wool grease is recoverable by hot centrifuging. The non recoverable wool grease represents the main organic pollutant in wool scouring effluent. Wool grease consists of a complex mixture of esters between long chain fatty acids and sterols or aliphatic alcohols. These ester compounds (waxes) account for the low water solubility of lanolin.The aqueous effluent from wool scouring plants is highly polluting (typically 30 000 mg/l COD). A single scouring line produces wastewater equivalent to that of 15 000 people. Therefore a treatment prior to sewer disposal is required. Physical and chemical treatments have proved to be unsatisfactory either in performance or economics (Gibson and Morgan 1981, Mozes 1982, Robinson and Gibson 1985).

Considering that most of its waste components are of natural origin, wool scouring effluent should be biodgradable. On the other hand, the low solubility of lanolin in water causes a potential barrier for microbial lanolin degradation, as bacteria only oxidize water soluble species. Biological treatments of wool scouring effluent, both anaerobic and aerobic have been described in the literature (McCracken and Chaikin 1980, Chao 1981, Rodmell and Wilkie 1983, Genon et al. 1984, Whittaker and Stewart 1986, Cail et al. 1986) but are not widely established in industry.

Reports of anaerobic degradation of wool scouring effluent vary widely in performance between laboratory experiments (Cail et. al. 1986) and large scale trials. The aim of this paper is to evaluate, independently of the treatment process used, the anaerobic degradability of wool scouring effluent and its individual components in comparison with two other wastes of industrial significance which are also difficult to digest: cellulose and autoclaved activated sludge.

MATERIALS AND METHODS

The anaerobic digester culture used in our batch experiments was obtained from the primary digester (32°C) of a local sewage plant (Subiaco, Western Australia). The feed for this digester was comprised of raw sewage sludge and excess activated sludge. The wool scouring effluent used was obtained from a local wool scouring plant (Jandakot, Western Australia). The strong-flow from the first and second wash bowls (primary centrifuge feed) was used as the substrate for the experiments. In order to provide consistent substrate characteristics for all experiments, one batch of wool scouring effluent was obtained and preserved by autoclaving. Before use the digester sludge was starved for 3 weeks.The response of the starved digester sludge to the batch addition was monitored by gas analysis and volatile fatty acid analysis. Incubation temperature was 35°C.

RESULTS AND DISCUSSION

Maximum anaerobic degradation rate of wool scouring effluent. The maximum biogas production rate from wool scouring effluent as a substrate (0.08 $l \cdot l^{-1} \cdot d^{-1}$) was lower than that of cellulose powder (0.55 $l \cdot l^{-1} \cdot d^{-1}$) and of sterile activated sludge (0.23 $l \cdot l^{-1} \cdot d^{-1}$). This result was not significantly changed after 60 days of adaptation of the anaerobic sludge to the same substrates (Figure 1). The slow maximal waste conversion rates mean that long treatment times are required to effectively degrade the waste. Because of the high organic load of wool scouring effluent (30,000 g/l of COD in the combined flow or up to 120 000 g/l of COD in the strong flow only) and because of the fact that the main organics (lanolin) are solid this waste is unsuitable for high rate anaerobic reactors such as the UASB. Hence the slow digestion rate will result in a large reactor size required.

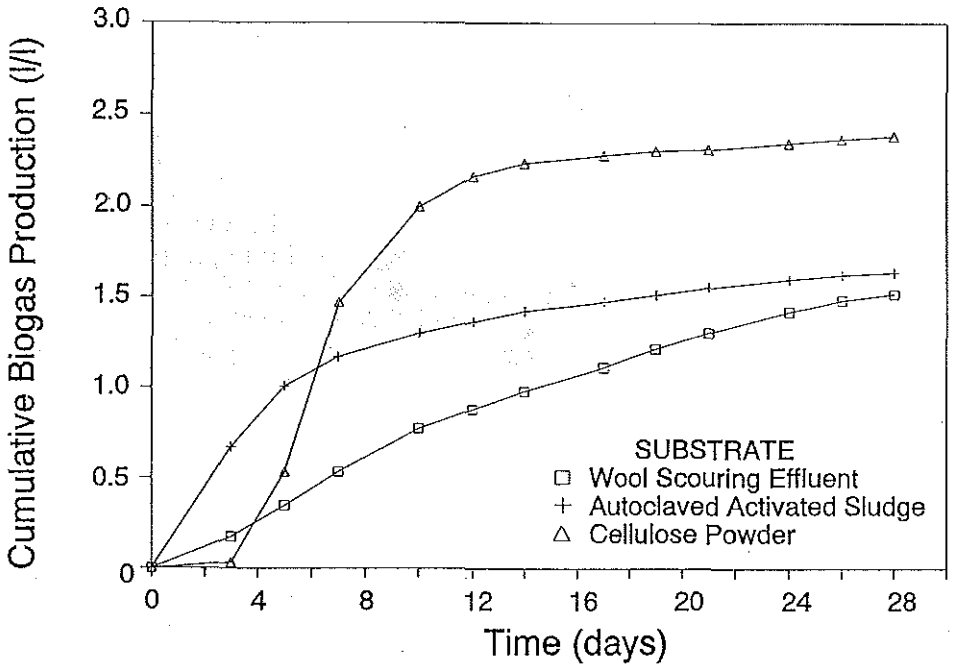

Figure 2: Biogas production of starved anaerobic digester sludge from the addition of three substrates.The sludge was previously adapted for 2 months to the respective substrates. Biogas produced in control assays (no substrate) was subtracted.

Total Degradability of Wool Scouring Effluent. The time required for 50 % conversion of the pollutants (measured as COD) added, was more than 30 days for wool scouring effluent compared to about 12 days for activated sludge and 7 days for cellulose. About 57 % of the COD in wool scouring effluent was not degradable under the test conditions after 100 days incubation, compared to 38 % for activated sludge and 5% for cellulose. The total amount of biogas produced per g of volatile solids added was lower for wool scouring effluent than for cellulose and activated sludge, respectively.Theoretically, however, the total gas produced per g of volatile solids is expected to be highest for highly reduced compounds such as lipids.Adaptation of the sludge to wool scouring effluent did not alter degradability or degradation rate significantly.

Effect of substrate concentration. To investigate whether the poor degradability of wool scouring effluent was due to unsuitable substrate concentrations, the biogas production from a range of substrate concentrations was monitored. The batch addition of wool scouring effluent of more than 5 g/l volatile solids (corresponds to approximately 10 g/l COD) caused a reversible inhibition in biogas production as evident from lag phases of 20 to 40 days (Figure 2). Addition of the same amounts of activated sludge did not cause any visible inhibition. Cellulose addition resulted in a similar inhibition pattern as observed for wool scouring effluent. However, the reason for the inhibition of methane production from high concentrations of cellulose was found to be due to sludge overloading, resulting in acidification of the sludge. The inhibition of biogas production from high batch loads of wool scouring effluent, however, did not cause any symptom of digester overloading such as hydrogen accumulation, volatile fatty acid acccumulation and pH decrease. The possible origin of inhibition was investigated (next paragraph).

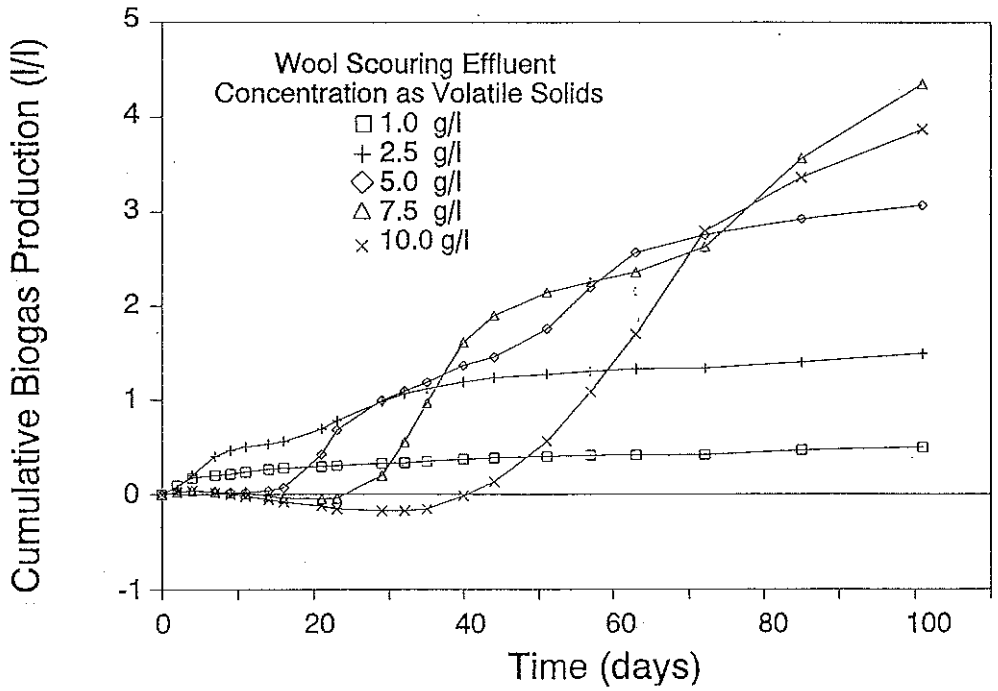

Figure 1: Effect of substrate concentration on biogas production from the anaerobic digestion of wool scouring effluent. The low background gas production of the starved digester sludge was monitored in parallel (control) was subtracted. Negative gas production shows less than in the control.

Degradation of the individual fractions of wool scouring effluent. The three main organic waste fractions of wool scouring effluent (lanolin, suint, detergent) were added separately to digester sludge, to find the origin of poor degradability and inhibition. Plain lanolin was not found to be degradable under our test conditions. The addition of **emulsified lanolin,** however caused an increase of biogas production of the sludge which stayed linear over incubation periods of up to 100 days. Within this time less than 40 % of the added substrate was converted into

biogas. Again, this confirms the low degradability of wool grease.The addition of **suint** to starved digester sludge caused a sponteneous increase in gas production ($0.1\ l \cdot l^{-1} \cdot d^{-1}$) until about 30 % of the COD added was converted into gas. The remaining suint proved to be anaerobically non degradable. Suint addition (5g/l volatile solids) did not cause inhibition of gas production.The **detergent** (TN 450) used caused inhibition of methanogenesis at concentrations higher than 0.1 % (v/v). Since this is in the order of concentrations used by wool scourers the inhibition of methanogenesis by wool scouring effluent is likely to be due to the toxicity of the detergent. At lower concentrations the detergent proved at least partially biodegradable as evidences from gas production (data not shown).

Some fundamental aspects of anaerobic lipid digestion. An overloading situation (acidifiation due to imbalance between fermentation and methanognesis) is theoretically unlikely to occur and in fact was never observed with wool scouring effluent. This is due to the high reduction level of the wool grease which makes wool grease a "non fermentable" substrate. Bacterial fermentation (usage of internal electron acceptor) is a disproportionation (dismutation) reaction which partially oxidizes and partially reduces the substrate. In contrast to carbohydrates or proteins, highly reduced compounds such as lipids can not be further reduced and thus not fermented. This prevents the accumulation of organic acids (usually volatile fatty acids) as fermentation endproducts and hence digester acidifcation. Thus the generally feared failure of anaerobic digestion (Chiew and Cord-Ruwisch, poster paper, this conference) due to acidification is unlikely to occur with wool scouring effluent.
Bacterial degradation of lanolin requires the reduction of an external electron acceptor. Carbon dioxide, the major electron acceptor in anaerobic digestion can not be used by the lipid degrading (mainly via beta-oxidation) bacteria. Lipid oxidizing bacteria use hydrogen as an electron carrier to allow lipid oxidation via interspecies hydrogen transfer. Because of thermodynamic reasons these obligate hydrogen transferring bacteria are known to be very slow growing and easily inhibited by hydrogen accumulation. These considerations correspond to our findings about the poor degradability of wool scouring effluent.
Another consequence of the fact that wool scouring effluent contains highly reduced organics, is the theoretical consideration that lipid digestion results in a high methane content of the biogas produced. The methane content in the biogas produced from lanolin was between 70 and 85 %. The higher methane content produced and the fact that wool grease degradation can not result in digester acidification might make lanolin containing wastes a useful additive to sewage sludge digesters.

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