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GREASE BIODEGRADATION: IS BIOAUGMENTATION MORE EFFECTIVE THAN NATURAL POPULATIONS FOR START-UP?

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ABSTRACT

Investigations were undertaken in order to compare the grease degradation rates for a natural population of acclimatised activated sludge micro-organisms with a commercial bioaugmentation product (bioadditive) under optimum conditions in laboratory-scale batch reactors. Lard was chosen as the source of grease because it contains the fatty acids more commonly found in urban wastewaters. During acclimatisation, the bioadditive reactor achieved a slightly better chemical oxygen demand (COD) removal efficiency than the activated sludge reactor. Therefore, under optimum conditions, activated sludge was able to degrade grease at nearly the same rate as a bioadditive solution. Moreover, the bioadditive and the activated sludge reactors had very similar kinetics of COD removal under different grease concentrations. It was concluded that the use of natural activated sludge micro-organisms was sufficient to acclimatise biological processes to removing grease. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Grease; bioaugmentation; biodegradation; activated sludge micro-organisms.

INTRODUCTION

Grease represents a group of compounds that can be commonly found in all types of municipal wastewaters in a concentration that varies from 40 to 100 mg/l (Mahlie, 1940; Bowerman and Dryden, 1962; Loehr and de Navarra, 1969; Young, 1979; Duchene, 1980; Bridoux *et al.*, 1994). It comes from four main sources: human excrement, kitchen wastes, garbage and industrial wastes (Banerji *et al.*, 1974). Grease can cause great problems in wastewater systems, from the blockage of sewerage pipes to interfering with activated sludge oxygen transfer rate. Although regulations on the amount of lipids to be discharged to sewers have been imposed internationally, these are not standardised and are normally based on the arbitrary limit of 100 mg/l stipulated by the Water Pollution Control Federation (WPCF) in 1968 (WPCF, 1968).

Aerobic biological treatment has been identified as an attractive solution for the treatment of grease residues (Grulois *et al.*, 1992, 1993). It has the advantage of degrading the grease into fatty acids and finally to carbon dioxide and water thus eliminating the inconvenience of residue. The bioreactor with specially acclimatised micro-organisms can be installed either as a separate unit or before an activated sludge basin and operate either continuously or as a batch process. As an alternative to standard aerobic treatment, bioaugmentation, bacterial augmentation, biomass enhancement or inoculum addition are processes that have also been employed for grease degradation in sewage (Chappe *et al.*, 1994). Most commercial bioaugmentation products consists of mixed microbial populations, wetting agents, buffers and nutrients (Stephenson and Stephenson, 1992). According to Chappe *et al.* (1994) the bacteriological activity from the grease bioaugmentation products is limited to hydrolysis; moreover, the micro-organisms survival in natural conditions can be questioned.

The aim of this study was to compare the grease degradation rates for a natural population of acclimatised activated sludge micro-organisms with a commercial bioaugmentation product (bioadditive) under optimum conditions in order to find out which method is more effective for start-up.

METHODS

In order to compare the rate of degradation of grease by a bioadditive and by activated sludge, two batch reactors of 2 l volume were operated using grease as the sole carbon substrate. Activated sludge from Cotton Valley sewage treatment works (Anglian Water, UK) was used in one reactor and a commercial bioaugmentation product in the other. The bioadditive consisted of flakes of lyophilised bacteria, surfactants and supporting nutrients. Both reactors had an initial suspended solids concentration of 2000 mg/l.

Lard was chosen as the source of grease in the experiment because it is rich in palmitic, stearic, linoleic and oleic acids (Fasman, 1975) which are the fatty acids more commonly found in urban wastewaters (Quéméneur and Marty, 1994). Moreover, lard is solid at ambient temperature so its mass can be measured accurately. Lard was added continuously to ensure that the micro-organisms had a permanent carbon supply. Nitrogen as urea (BDH Ltd., Poole, UK) and phosphorus as phosphoric acid (BDH Ltd., Poole, UK) were dosed to achieve a C:N:P ratio of 100:5:1 and the reactors were placed in a water bath at 35°C. The pH was monitored and kept between 6.5 and 8.5 with sulphuric acid (BDH Ltd., Poole, UK) and calcium carbonate (BDH Ltd., Poole, UK). Compressed air was used to maintain a dissolved oxygen concentration above 2 mg/l. No surfactant was added. The bioadditive reactor ran for more than 40 d, and the activated sludge reactor ran for 20 d. The chemical oxygen demand (COD) and volatile suspended solids (VSS) were monitored continuously and analysed according to recommended techniques (Greenberg *et al.*, 1992).

After acclimatising the micro-organisms to lard as the sole carbon source, individual tests were undertaken with the activated sludge and the bioadditive at different grease concentrations. From each initial reactor, 4 reactors each with a volume of 300 ml were prepared. From these, the first reactor was used as a blank, 0.2g of lard was added to the second, 0.5g to the third and 0.7g to the fourth. According to the COD of lard calculated previously, the initial COD in the reactors with lard was 2500, 6250 and 8750 mg/l, respectively. Therefore, eight 300 ml reactors were installed, four with bioadditive and four with activated sludge. Although grease was not measured directly, the COD values could be related directly to the grease content in the reactors by using lard as the sole carbon source. Conditions in the reactors were the same as in the feed reactors and total COD (COD_T) and soluble COD (COD_S) as well as VSS were monitored.

RESULTS AND DISCUSSION

During the acclimatisation period, lard was added continuously and the bioadditive achieved a 92% removal of COD, while the activated sludge reached 86% removal (Fig. 1).

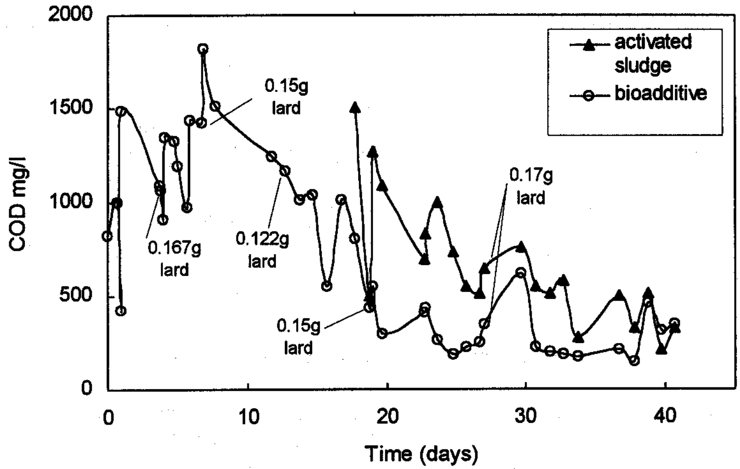

Figure 1. COD removal in the activated sludge and the bioadditive reactors during acclimatisation (amount of lard added is also shown).

The volatile suspended solids (VSS) in the bioadditive and the activated sludge reactors with 0.5 and 0.7g of lard showed that the VSS increased at the start of the experiment, reaching a maximum concentration between days 5 and 10, and decreased afterwards (Fig. 2).

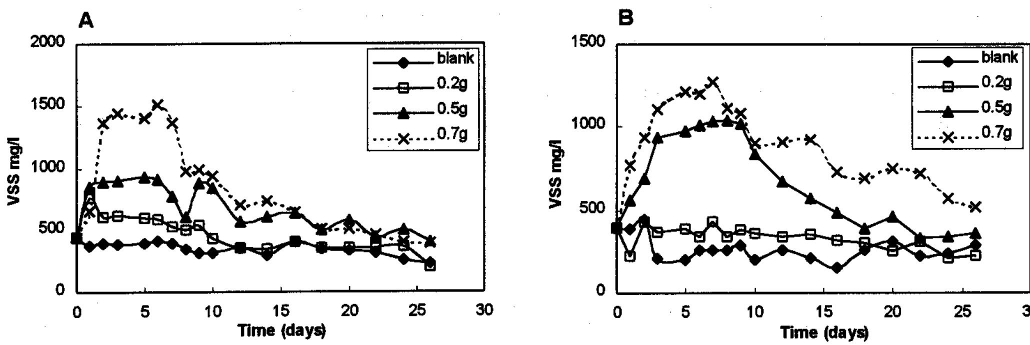

Figure 2. VSS removal in the activated sludge (A) and the bioadditive (B) reactors.

These results, combined with the total chemical oxygen demand (COD_T) removal pattern, demonstrated that the number of cells increased because of the presence of nutrients but once the carbon source was depleted their number started to decrease (Fig. 3).

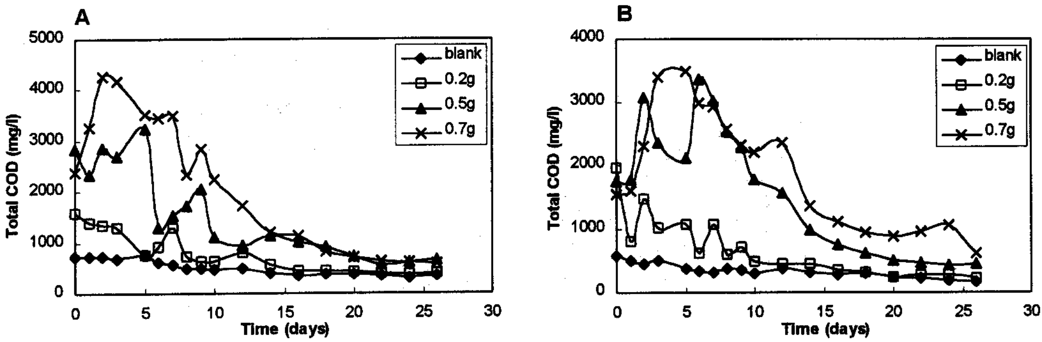

Figure 3. Total COD removal in the activated sludge (A) and the bioadditive (B) reactors.

It was observed that the fastest removal of COD_T occurred during the first days of the experiment. From day 16 and until the end of the experiment (day 26) most of the COD_T had already been removed. Therefore, the percentage of removal between day 16 and day 26 was compared. It was found that, at day 16 and excluding the results from the blanks, all the reactors had removed 70% of the COD_T. Therefore, according to these results the optimum hydraulic retention time (HRT) for an aerobic reactor receiving a theoretical organic load of 1.6 to 4.3 $kgCOD/m^3$ is 16 days. Grulois *et al.* (1992) and Maes (1994) reported similar COD_T removal rates at organic loadings of 2.5 and 2.6 $kgCOD/m^3d$. However, it is not possible to compare them to the results directly since these authors achieved such organic loadings in continuous flow reactors and the tests in the present study were undertaken in batch reactors.

By plotting the F:M ratio against time it was possible to observe that during the degradation of lard in the reactors, the micro-organisms probably entered the exponential growth phase in the first days of the experiment but reached the declining phase and probably the endogenous phase at the end of it. Figure 4 shows that the reactors with the larger amounts of lard (0.5 and 0.7g) had greater decreases in the F:M ratio. Although the F:M ratio in the blank and in the reactor with 0.2g of lard appeared to decrease, it wass not as clear as the F/M decrease in the reactors with larger concentrations of lard.

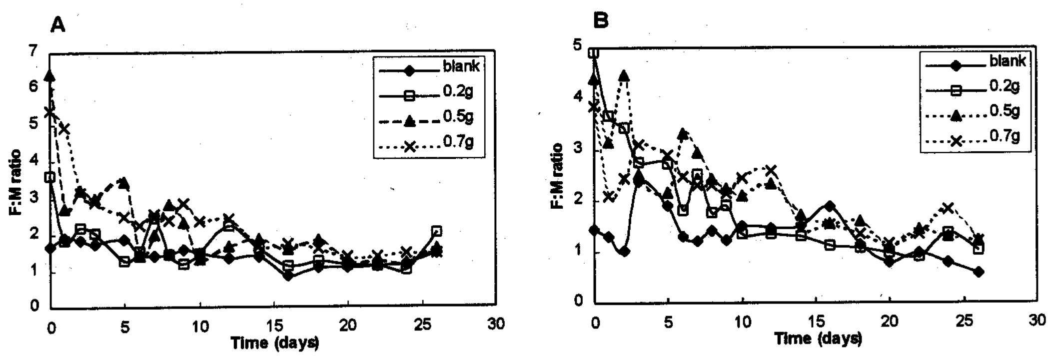

Figure 4. F:M ratio in the activated sludge (A) and the bioadditive (B) reactors.

According to a literature review by Stephenson and Stephenson (1992), bioaugmentation often failed in laboratory investigations, whereas at full scale it was often successful, probably owing to the imposition of steady state at laboratory scale. Gerrard and Stephenson (1990) mentioned that although there are many published accounts of inoculum addition solving problems at full scale, unfortunately it means that the results of a bioaugmented process cannot be compared with a control that has no dosing. Often historical data is used as a comparison but other factors also may have changed to cause an improvement in treatment.

Salome and Bonvallot (1994) experimented on five bioadditives for grease removal and found that none of them was capable of significantly degrading olive oil. They suggested that the action of the products is limited to the hydrolysis of the triglycerides because the breakage of the long-chain fatty acids appeared to be the most difficult stage in all the products that were studied. They also found that the bioadditives generally needed an adaptation period to the media that were going to degrade which obviously reduces the possibilities of the bioadditives being used in sewers. However, after testing 40 bioadditives in full scale treatment plants Maes (1994) found that they did enhance grease degradation. In one of the biological procedures tested he found a 40% elimination of total grease matter without bioadditives and 75% removal with bioadditives.

In the present study, it was found that the bioadditive and the activated sludge micro-organisms adapted to biodegrade grease at a similar rate. It was not possible to confirm that the use of the bioadditive reactor represented any significant enhancing removal effect on the COD. Therefore, the present study agrees with previous reports (Lewandowski *et al.,* 1986; Martin and Zall, 1985; Chappe *et al.,* 1994; Grulois *et al.,* 1993), in finding evident that the use of natural activated sludge micro-organisms acclimatised to a xenobiotic (in this case, grease) as a substrate is enough to achieve the elimination of the substrate.

If the bioadditives do prove to significantly enhance the grease removal, as reported by Maes (1994), it would be necessary to make comparisons between the capital and operating costs of typical aerobic biological reactors, and with the costs involved in using the bioadditives (Gerrard and Stephenson, 1990).

CONCLUSIONS

During acclimatisation, the bioadditive reactor achieved a slightly better COD removal efficiency than the activated sludge reactor. Therefore, under optimum conditions, activated sludge was able to degrade grease at nearly the same rate as a bioadditive solution.

The bioadditive and the activated sludge reactors had very similar kinetics of COD removal under different grease concentrations.

In this work the use of natural activated sludge micro-organisms acclimatised to a xenobiotic (grease) as a substrate was enough to achieve the elimination of the substrate.

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