Disinfection of sludge using lime stabilisation and pasteurisation in a small wastewater treatment plant

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Abstract Removal efficiency of faecal coliforms and helminth eggs was evaluated in a small wastewater treatment plant (WWTP) serving a population of 1,000. This system was formed by the association in series of a UASB reactor and four submerged aerated biofilters. The density of faecal coliforms and the count of helminth eggs were estimated in the liquid and solid phases of the system. Two different methods of disinfecting sludge were investigated: (a) chemical treatment with lime and (b) a physical treatment by pasteurisation. As expected, the association UASB + BF was very efficient at removal of helminth eggs from the final tertiary effluent, but coliforms were still present at high densities. Lime treatment and pasteurisation of sludge were very effective methods of disinfection and produced a sludge safe for final disposal.
Keywords Helminth eggs; lime disinfection; pasteurisation; UASB reactor; wastewater

Introduction

For decades, wastewater treatment systems were concerned with the removal of solids and organic pollutants from wastewater. Only when enough knowledge about the role of wastewater in the transmission of diseases had been accumulated did the removal of pathogenic agents become an object of study. While many of these organisms are inactivated during the wastewater treatment, others resist these processes and may be found in the treated effluent and sludge, thus representing a risk to human and animal health. Therefore, it is extremely important to look for disinfection processes that eliminate pathogenic microorganisms to levels considered safe for public health. Many sludge disinfection processes are being studied. Alkali agents are responsible for the promotion of changes in the colloidal nature of cellular protoplasm, causing cell death (Metcalf and Eddy, 1996). Chemical treatment with lime is considered an efficient process for the elimination of pathogens as well as for the stabilisation and deodorisation of sludge. It also contributes to sludge dehydration and is easy to execute (Andreoli *et al*., 1997). Another disinfection treatment is pasteurisation, which may inactivate many microorganisms (viruses, bacteria, protozoa and helminth eggs) present in samples maintained at 70°C for 30 min (EPA, 1992). However, some studies have observed that re-growth of bacteria may occur in pasteurised sludge. Ward *et al*. (1999) observed that *Salmonella* spp. regrew in pasteurised sludge to higher densities than in raw sludge.

The objective of this study was to evaluate the efficiency of removal of faecal coliforms and helminth eggs in a wastewater treatment plant (WWTP) using a UASB and a submerged aerated biofilter (BF) by monitoring the liquid and solid phases of treatment. Two methods of sludge disinfection were examined: chemical (lime) and physical (pasteurisation) treatments.

Materials and methods

The WWTP comprised an association, in series, of an UASB reactor and four submerged aerated biofilters treating wastewater of predominantly domestic characteristics. The levels of faecal coliforms and helminth eggs were estimated in the liquid and solid phases of the system. For hygienisation studies the sludge was obtained from the UASB reactor.

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Chemical treatment. The prepared lime slurry was dosed to produce different concentrations (10–60%) of lime (CaO) in relation to dry sludge. Samples of the moist sludge + lime were collected to determine the levels of faecal coliforms (APHA, 1995) and helminth eggs (Meyer *et al*., 1975). Faecal coliform densities were obtained at 24 h, 48 h, 72 h, 96 h, 120 h, 30 d and 60 d after lime addition to evaluate the possibility of microorganism re-growth. Parasite analyses were carried out 24 h after lime addition. Analyses of pH and moisture were determined immediately after addition of lime, and hourly for 5 h. Samples were also collected 12 d, 30 d, 60 d and 90 d after lime addition.

Physical treatment. A pilot experiment was carried out to establish the parameters to be used in the study. Three independent experiments were used to verify the influence of the kind of vessel on the efficiency of pasteurisation and the influence of sludge temperature after pasteurisation on the re-growth of faecal coliforms. After dehydrating sludge to 20% total solids (TS), it was pasteurised for 30 min at 70°C. The efficiency of pasteurisation was analysed using two kinds of vessels (Becker or tray), both of 2 L capacity, and maintaining the vessels after pasteurisation at different temperatures (4°C, 25°C).

In the following experiments, the sludge was de-watered by centrifugation to concentrations of 10%, 15%, 20% and 25% TS and submitted to pasteurisation. Levels of faecal coliforms and helminth eggs were evaluated 24 h later. In order to verify the re-growth of faecal coliforms, samples were monitored for 5 d following pasteurisation.

Results and discussion

Microbiological monitoring of WWTP

The monitoring of liquid and solid phases of the UASB + BF system showed that the removal of faecal coliforms was 1-$\log_{10}$ in each reactor analysed and the global efficiency was about 2-$\log_{10}$ (Figure 1). The WWTP had a retention time of 8 h, and the final effluent presented coliform levels higher than that recommended by WHO for reuse in irrigation and thus needing disinfection treatment before effluent discharge (WHO, 1989).

In this system the levels of helminth eggs were reduced significantly as the wastewater passed through the reactors. At the end of the treatment process helminth eggs were not detected in the final effluent. However, they were found concentrated in the sludge of the UASB reactor and in the BF sludge. The eggs were removed by sedimentation in the UASB reactor or by adsorption onto the biofilter biofilm (Figure 2), but the number of helminth

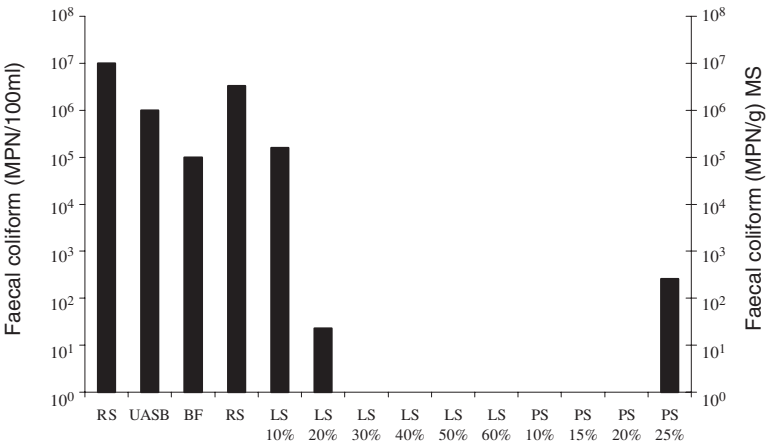

Figure 1 Faecal coliform levels obtained in the liquid phase (RS = raw sewage, UASB + BF) and in the solid phase (RS = raw sludge, LS = limed sludge, PS = pasteurised sludge) in the 50 d of hygienisation

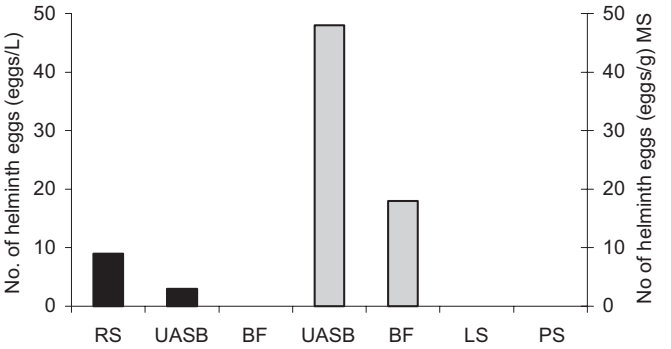

Figure 2 Helminth egg levels in the liquid and solid phases of treatment (RS = raw sewage; LS = lime stabilisation; PS = pasteurised sludge)

eggs present in the sludge was above that recommended by EPA for sludge class A, rendering impossible its ready utilisation for agricultural purposes. Thus, it was necessary to submit the sludge to hygienisation process before final disposal.

Lime stabilisation of sludge

Sludge is a concentrator of microorganisms, and the counts of coliforms found in raw sludge showed that their levels were higher than that allowed by EPA for agricultural uses. Using hydrated lime (CaOH) to promote the hygienisation of this sludge, we observed that at high concentrations of lime the pH of the moist sludge + lime was maintained above 12 for longer. A dose of 30% lime was efficient for eliminating coliforms present in the sludge. However, after 30 d, coliform regrowth was detected with a concurrent decrease of pH to levels below 12. These results indicated that at low concentrations of hydrated lime, elimination of faecal coliforms present in the sludge was incomplete. It is strongly recommended that the hygienisation of sludge with hydrated lime should use 50% or more of lime (wet weight basis) (Figure 1).

Results obtained with sludge treated with quicklime (CaO) showed that only at a concentration of 10% was regrowth of coliforms observed after 30 d storage concomitant with a decrease of pH. The temperature inside the stacks was monitored. At 60% quicklime the temperature rose to 70°C and was maintained for 60 min. At 50% lime, the temperature rose to 60°C, and at 40%, 30% and 20% the temperature was maintained at 30–40°C. Only at 10% was the temperature below 30°C (not shown). Accordingly, maintenance of pH above 12 and high temperatures were important factors that combined to eliminate faecal coliforms from sludge (Figure 1). Helminth eggs were not found in sludge treated with 30–60% lime. Only at low concentrations (10% and 20%) were a few, non-viable, eggs detected. In contrast, raw sludge had 15 eggs/g (dry mass) of which 53% were viable.

Similar results were found by Andraus *et al.* (1999), who analysed samples of digested aerobic sludge and compared the efficiency of hygienisation at 30%, 40% and 50% lime. In the raw sludge they detected 8.7×10^7 MPN/100 g faecal coliforms, whereas in limed sludge at 30%, 40% and 50% faecal coliforms were not detected, indicating that a complete removal was attained 30 d after treatment. However, after 60 d of sludge stocking, faecal coliforms were detected at 30% lime, showing that disinfection at this concentration was not completely safe. Therefore, to obtain a complete removal of bacteria from sludge, at least 50% lime must be used and special attention should be given to sludge stocking conditions. Hygienisation with lime was very efficient.

Pasteurisation experiments

A pilot study was carried out with sludge containing 20% total solids. Three experiments were conducted and we observed that the efficiency of pasteurisation varied significantly between experiments ($F = 3{,}577$; $p = 0.035$). The other parameters that could contribute to the efficiency of the pasteurisation (kind of vessel, temperature after pasteurisation) did not show statistical significance. Therefore, five controlled experiments were conducted to verify the efficiency of pasteurisation for the removal of faecal coliforms and helminth eggs from sludge at different concentrations of total solids (10–25%) and 5 d after pasteurisation.

Our results showed that pasteurisation was not able to eliminate completely all coliforms present in the sludge. We observed that coliform levels increased with the concentration of total solids. In fact, this process tended to lower faecal coliform density to non-detectable levels in the first 48 h after pasteurisation but, after a few days, regrowth of bacteria was seen (not shown). Furthermore, the concentration of TS in sludge seemed to influence the pasteurisation process, which may have been related to heat transfer within the sludge. When the TS concentration increased, the sludge behaved like a thermal insulating agent, which made it more difficult to reach the desired temperature (70°C in 30 min) in the sludge mass, thus reducing the efficiency of pasteurisation (Silva *et al*., 2001).

These results were also observed by others (Liu and Lee, 2000; Telles *et al*., 2000), who analysed the transfer of heat in anaerobic digested sludge and found that the concentration of total solids in sludge had great influence in the spread of heat, i.e. removal of water made it difficult to transfer heat within the sludge. Ward *et al*. (1999), studying pasteurisation of sludge with 0.2% total solids on a laboratory scale, obtained the complete removal of faecal coliforms inoculated into sludge, showing that this process was very effective when the content of water in the sludge was high.

Conclusions

The monitoring of the WWTP showed that the association UASB + BF was very efficient for removal of helminth eggs from final tertiary effluent. However, the sludge produced in the UASB reactor must be disinfected before discharge or agricultural use. Lime treatment and pasteurisation were shown to be very effective disinfecting methods for removing helminth eggs from sludge. However, both have advantages and disadvantages. Hygienisation with lime increased the final volume of sludge after treatment, which would increase the costs of transport and final disposal. Pasteurisation also increases the problem of odour in the plant, but, according to Gonçalves *et al*. (1998), this process may be economic, as it is possible to use the biogas produced in the WWTP as thermal energy for hygienisation of the sludge by pasteurisation.

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