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DESTRUCTION OF FAECAL BACTERIA, ENTEROVIRUSES AND OVA OF PARASITES IN WASTEWATER SLUDGE BY AEROBIC THERMOPHILIC AND ANAEROBIC MESOPHILIC DIGESTION

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ABSTRACT

A new sludge treatment plant at Harrogate South Sewage Treatment Works is designed to handle up to 4 tonnes (dry solids) daily. Sludge is thickened continuously up to 8% (ds) and is then treated in parallel anaerobic mesophilic (AD) and thermophilic aerobic digestion (TAD) plants each with a maximum working volume of 530m^3. Microbiological studies were carried out to compare the destruction of pathogens and faecal indicator bacteria. The AD plant operated with a mean retention of 26 days at 34 °C and achieved 49% reduction of volatile solids. The TAD plant operated with a mean retention of 28 days at 55 °C and reduced volatile solids by 35%. Operation was on a pump in-pump out cycle, guaranteeing 4h retention for all sludge. The disinfecting ability of TAD exceeded that of AD since it reduced counts of Enterobacteriaceae, thermotolerant coliforms and faecal streptococci to below 103/100ml, rendered cytopathic enteroviruses undetectable and destroyed viability of Ascaris suum ova within 4h. The AD process reduced bacterial counts by 90% and enteroviruses by 99%, but has no effect upon viability of Ascaris ova.

KEYWORDS

Mesophilic anaerobic digestion; thermophilic aerobic digestion; sewage sludge; wastewater sludge; pathogens; enteroviruses; thermotolerant coliforms; faecal streptococci; Enterobacteriaceae; Ascaris.

INTRODUCTION

The main pathogens of concern when sewage sludge is used on agricultural land are Salmonella spp and eggs of Taenia saginata. Lesser hazards exist for Hepatitis A infection, ascariasis, aspergillosis and parasitic protozoal diseases (Block et al 1986). Both treatment of sludge and restrictions of use of land pose barriers to transmitting infection, as for example in US Federal regulations (US EPA 1989), EC Council Directive (1986) and the UK Code of Practice (Department of the Environment 1989), discussed by Bruce et al (1990). The UK Code recognises primary anaerobic digestion (AD), giving ≤ 12d retention at 35 °C ± 3 °C (or ≤20d at 20 °C ± 3 °C), followed by 14d mean storage as an example of a process providing effective stabilisation and pathogen destruction and thermophilic aerobic digestion (TAD; mean retention ≤ 7d, all sludge to be held 4h at ≤ 55 °C) as another. There is little operating experience with TAD. Yorkshire Water constructed a sludge treatment plant at Harrogate South Sewage Treatment Works, to a WRc design, offering parallel AD and TAD. This gave an opportunity to compare their efficacy when operated according to the Department of the Environment's (1989) Code.

THE SLUDGE TREATMENT PLANT AT HARROGATE SOUTH STW

The plant is designed to accept raw sludge (4t dry solids/d at 1-4% ds) and to thicken it to about 8% ds. It is then fed, on a controlled pump in - pump out cycle, guaranteeing 4h minimum retention in the TAD plant, to the AD and TAD plants. Both have insulated tanks, maximum working volumes 530m^3 but with variable level control; maximum loadings equal at 33m^3/d, 2t ds/d at 6% ds, giving 16d retention; temperatures AD 35 °C, TAD ≤ 55 °C.

MICROBIOLOGICAL METHODS

Weekly, during periods of stable operation, thickened raw sludge and treated sludge samples were collected, transported in cooled containers and analysed microbiologically within 18 hours. Parallel samples for virological analysis were submitted to Severn Trent Laboratories. The following methods were used:

Salmonellae - most probable number (4 tubes at each of 3 descending decimal dilutions) Carrington (1980); confirmation of presumptive colonies on urea agar, Kligler's iron agar and with polyvalent antisera. Thermotolerant coliforms and enterococci - plate-dilution frequency method (Pike and Carrington 1972) using MacConkey No 3 agar (Oxoid), incubated 4h at 30 °C then 18h at 44 °C and Slanetz and Bartley agar (Oxoid), incubated 4h at 37 °C then 44h at 44 °C respectively.

Enterobacteriaceae - Method of Geller (1982) and Strauch (1988).

Enteroviruses and rotaviruses - recovery (Hurst and Goyke, 1986) and analysis (Morris and Waite 1980, Lennette and Schmidt 1979).

Ascaris viability - c. 400 ova of *Ascaris suum* with sludge (5 ml) placed in chambers with micromesh (35μm) screen (Spaull *et al* 1989). Chambers were immersed in the digesters for specified periods and withdrawn. Viability of recovered ova assessed by embryonation (Carrington and Harman 1981).

RESULTS

Difficulties, inevitable in novel and newly commissioned processes, arose with the sludge supply and in the thickener and required extensive modifications in September - mid-November 1988. Table 1 shows that the supply of sludge did not reach the design loading. This restricted the operating temperature of TAD. Removal of volatile solids was more complete with AD (49%) than with TAD (35%), but the fertiliser values of both sludges were similar.

Table 1 - Average performances (August 1988, November 1988 - March 1989)

Measurement (units)	Thickened raw sludge	TAD plant	AD plant
Solids load (t/d)	1.9	0.7	1.2
Total solids (% dry weight)	5.2	3.8	3.3
Volatile solids reductions (%)	-	35	49
Residence period (d)	-	28	26
Temperature (°C)	-	55	34
Total Kjeldahl N (mg/l)	1700	1800	1700
Ammoniacal N (mg/l)	220	680	680
Total P (mg/l)	610	590	580
Total K (mg/l)	97	92	94

Table 2 shows that the TAD plant was greatly superior to AD in removing faecal indicators and cytopathic enteroviruses. Neither salmonellae nor rotaviruses were found in the treated sludge. Rotaviruses were absent from raw sludge. *Ascaris* ova displayed an initial viability of 48%, reduced to 23% after 1 hour, 1% after 2h and zero after 4 and 8 hours in the TAD plant at 58.7 °C.

Table 2 - Median numbers of faecal indicator bacteria and enteroviruses in raw sludge and their destruction by treatment

Determinand	Median MPN/ml*			Survivor ratio	
(no of samplings)	Raw	TAD	AD	TAD/raw	AD/raw
Thermotolerant coliforms (17)	1.4×10^6	47	3.6×10^4	3.4×10^{-5}	0.026
Enterococci (16)	5.5×10^4	<47	6100	$<8.4 \times 10^{-4}$	0.11
Enterobacteriaceae (16)	9.3×10^7	26	9.3×10^5	2.8×10^{-7}	0.01
Cytopathic enteroviruses (13)	25.4	<0.1	0.2	<0.0039	0.0079

* For periods of Table 1 except enteroviruses - January - May 1989, plaque-forming units/ml

DISCUSSION

When the TAD plant was operated at 55 °C with guaranteed 4h retention (Department of the Environment 1989) disinfection met the US EPA (1989) criteria for a process significantly reducing pathogens, e.g. 90% reduction of pathogens and 99% reduction of faecal indicator bacteria and the recommendations proposed for West Germany (Strauch 1989), that sludge should be considered hygienically safe when it contains (per g) no salmonellae, $< 10^3$ Enterobacteriaceae and enteroviruses < 200 pfu/l. Strauch's criterion for viral reduction to exceed 99.9% was approximated. Carrington (1985) showed that exposure exceeding 53 °C for 1h was needed to destroy viability of A.suum ova and that treatment at 45 °C for 3h, or anaerobic digestion at 35 °C for 13.3d mean retention, had no effect. This and the present results suggest that the killing of A.suum ova is very much affected by temperature in the range 45-55 °C and that complete destruction may not be attained if the TAD process does not operate at 55 °C or above. In earlier experiments with a WRc pilot-scale TAD plant, the fraction of infective T. saginata eggs surviving batch exposure for 5d at 55 °C was 0.00036, equivalent to 0.057 for daily feeding (Pike 1988). At the Haltwhistle TAD plant, the fractions of cysts of the potato cyst nematodes Globodera rostochiensis and G.pallida remaining viable after 1 day at 60 °C was 0.001 (Spaull et al 1989). The TAD process can therefore be regarded as a process combining stabilisation and disinfection in a single treatment.

Mesophilic AD is not designed or intended to disinfect sludge. It has no effect upon viability of Ascaris ova (Carrington, 1985). The removals of faecal indicator bacteria are not large, but those of salmonellae in primary and secondary (storage) digestion together are at least 90% (Bruce et al 1990) and of infective T.saginata eggs at least 99 per cent (Bruce et al 1990). The AD process at Harrogate South reduced cytopath enteroviruses by more than 99 per cent. It can be regarded, when used with storage, as a process offering a high degree of stabilisation and giving significant reduction in the two pathogens of greatest concern.

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