The effect of different percentages of bulking agent (sawdust) on microbial quality of faecal sludge

P. Y. Mensah, R. A. Kuffour, P. K. Baidoo and E. Awuah

ABSTRACT

The use of raw sludge spread on land as conditioner and fertilizer has been practised over the years in urban agriculture. However, this raw sludge (biosolids) is associated with a potential health risk as a result of the pathogenic microorganisms it contains. The study considered the dewatering of faecal sludge (FS) mixed with sawdust to produce biosolids that can be applied as manure for agricultural use. It assessed the bacterial and helminth egg qualities of the biosolids produced from FS–sawdust mixture. Bench-scale unplanted filter beds were used for dewatering of FS mixed with different percentages of sawdust. The sludge consisted of public toilet sludge and septage in the ratio of 1:3. An analysis of variance of the completely randomized design was undertaken and a *P*-value below 0.05 was considered statistically significant. The sawdust–FS mixture analysed after complete dewatering showed significant reduction in microbial (bacteria) content ($P < 0.05$) and helminth eggs, making the biosolids produced safe for farmers and the environment. The bulking agent improved the quality of the biosolids, with greatest pathogen removal observed in the 150% sawdust, whilst the least reduction was recorded in the 0% sawdust (control).

Key words | biosolids, faecal sludge, pathogens, public toilet sludge, sawdust, septage

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INTRODUCTION

Faecal sludge (FS) from on-site sanitation systems of many cities of developing countries is usually disposed of untreated. This is due to the lack of appropriate FS treatment options.

Where wastewater treatment facilities are available, the combined treatment of FS and wastewater may be feasible if specific design rules are observed (Heinss 1997). In terms of microbiological pollution, FS usually contains various pathogenic agents such as bacteria, viruses, fungi, protozoa and helminthes. The potential risks of parasites of faecal origin are due to the fact that they are resistant to certain conditions and to their persistence in their infective state for long periods (Hays 1977; Capizzi-banas *et al.* 2004). Proper FS treatment either in combination with wastewater or separately is being practiced in countries such as China, Thailand, Indonesia and South Africa (Montagero & Strauss 2002). The treatment options that appear promising include batch-operated settling and thickening units, non-aerated stabilization pond and combined composting with municipal organic refuse and dewatering and drying on beds (Strauss *et al.* 1997). FS are disposed of or used in agriculture untreated creating health risk and water pollution. In many cities of developing countries, dumping sites and open defecation grounds are close to inhabited low-income areas where they theaten the health of the population. Children are at greatest risk of contact with indiscriminately exposed excreta (Montangero & Strauss 2002). The presence of bacteria, viruses and parasites in sewage spread on land implies a potential health problem (Dumontet *et al.* 1997).

Sawdust is an organic waste generated from the sawing of timber. Since sawdust is an organic material, man has tried to find profitable agricultural uses for this waste (Arends & Donkersdot-Shouq 1985). Several uses of saw dust have been found, including composting. Chemicals found in sawdust may affect the microorganisms that break it down. The study assessed the dewatering of a mixture of FS and different percentages of sawdust on an unplanted bed and how it affected the microbial quality of biosolids produced.

doi: 10.2166/wst.2013.047

MATERIALS AND METHODS

Filter bed preparation

Bench-scale drying beds were used to dewater the FS mixed with sawdust. The drying bed was prepared using a cylindrical plastic container, 0.85 m high and 0.175 m diameter. The base was filled with course gravel of 2.0–3.0 cm diameter to a depth of 15.0 cm followed by gravels of diameter 0.5–1.0 cm to a depth of 10.0 cm, followed by sand filled to a depth of 20.0 cm. The sand had particle size range of between 0.1 and 0.5 mm and a uniformity coefficient of less than 4. Nylon net was placed on the sand on which the FS was poured, to ensure easy removal of the dewatered biosolid.

The FS was obtained by mixing public toilet sludge (PTS) and septage in a ratio of 1:3 by volume. The total solids (TS) of the FS was determined. A graduated plastic container was used to measure four replicated quantities of 5 L each into separate containers. Dried sawdust quantities of 50, 100, and 150% by weight of TS of the FS were mixed with one of the FS measured and stirred with a wooden stick to ensure complete mixing. A fourth FS measured was not mixed with any sawdust and served as control. Each of the FS–sawdust mixtures was carefully poured on an already prepared filter bed. Three replicates were made for each giving 12 filter beds. They were arranged in a completely randomized design (CRD). Six cycles of dewatering were run. Each cycle started from the time of pouring the FS on the drying bed to the time the biosolid was removed. Percolate flow from the filter beds started between 1 and 5 min later. The dewatering was considered complete when the resulting biosolid was spadable for removal. The TS of each fresh biosolid was determined, which varied for each sample dewatered.

Laboratory analyses

Before mixing with the sawdust the FS was analysed for faecal coliforms, *Escherichia coli, Salmonella* sp., and helminth eggs. Samples of the biosolids and the percolates were taken for analysis. Samples collected were analysed for faecal coliforms, *E. coli, Salmonella* sp., and helminth eggs. These were analysed using the membrane filtration method (APHA 1992). Sulphate lauryl broth was used for faecal coliforms, while chromo cult agar was used for *Salmonella* sp. and *E. coli*. The helminth eggs were determined by sedimentation procedure using a centrifuge.

Microbial qualities of the biosolids were compared with those of the percolates. Logarithmic values of bacterial concentration were used for better comparison. The results were analysed using analysis of variance (ANOVA) where the *F*-value was significant; the least significant difference (LSD) was used to separate the means.

RESULTS

Bacterial and helminth egg quality of the biosolids

Faecal coliforms

Faecal coliforms levels ranged from 6.5 $\log_{10}$ colony-forming unit (CFU)/10 g dry weight in 100% sawdust to 9.2 $\log_{10}$ CFU/10 g dry weight in the control. There was a significant difference between the faecal coliforms counts from the various percentages of sawdust. The difference between the faecal coliform counts of 50 and 100% sawdust was not significant ($p = 0.181$), but the difference between 50 and 150% was significant ($p = 0.001$). The difference in faecal coliform counts between 150% sawdust and the control was significant. Addition of the sawdust to the FS significantly reduced the faecal coliform levels (Table 1).

E. coli

The largest *E. coli* count of 8.4 $\log_{10}$ CFU/10 g dry weight was recorded in the control whilst the smallest of 4.9 $\log_{10}$ CFU/10 g dry weight was recorded in the 150% sawdust (Table 1). The difference in the *E. coli* counts for the various percentage sawdust–sludge mixtures and the control was significant ($P = 0.001$).

There was no significant difference in *E. coli* counts between 50 and 100% sawdust, but the difference between 50 and 150% was significant ($P = 0.231$) (Table 1).

Salmonella sp.

The difference in *Salmonella* sp. counts was statistically significant ($P = 0.000$). Sawdust added to raw sludge significantly reduced *Salmonella* counts in the biosolids. *Salmonella* counts in the 50 and 100% did not differ significantly ($P = 0.599$) but the difference between 50 and 150% was significant (Table 1).

Table 1 | Bacteriological and helminth quality of faecal sludge and biosolids after the dewatering process

Percentage of sawdust added to sludge	TS of FS-sawdust (g/L)	Dewatering time LSD (0.53)	Mean concentration of bacteria (log_{10} CFU/10 g dry wt)			Helminth egg counts/10 g dw	
			Faecal coliforms	*E. coli*	*Salmonella*	Viable	Non-viable
Faecal sludge			14.1 (±0.55)	9.5 (±0.43)	8.6 (±0.22)	9.2 ± 4.6	14 ± 4.0
50	40.4	5.3	7.2 (±1.82)[a]	6.4 (±1.04)[a]	5.4 (±1.53)[a]	2.0 ± 1.8	4.5 ± 2.7
100	53.9	4.9	6.5 (±1.30)[a]	6.1 (±0.92)[a]	5.1 (±1.34)[a]	1.4 ± 1.3	3.1 ± 1.6
150	67.4	3.9	8.0 (±1.62)[b]	4.9 (±1.59)[b]	4.0 (±1.65)[b]	0.6 ± 0.6	1.4 ± 1.0
Control	26.9	5.6	9.2 (±1.83)[c]	8.4 (±1.91)[c]	7.2 (±2.17)[c]	2.3 ± 1.0	5.3 ± 2.5

[a]Within the same column, means followed by the same letter are not significantly different ($P > 0.05$).

Helminth eggs

In general, helminth egg counts reduced significantly with increasing percentage of sawdust ($P = 0.000$) (Table 1). The control biosolid recorded the highest helminth eggs count (viable and non-viable) of 7.6/10 g dry weight while the biosolid from 150% sawdust–FS mixture recorded the lowest helminth eggs count of 2.0/10 g dry weight. There was a significant difference between their means ($P = 0.000$). There was a significant difference in egg counts between biosolids from 50 and 100% sawdust–FS mixture ($P = 0.012$) and that between 50 and 150% sawdust ($P = 0.000$). Again, there was a significant difference in egg counts between biosolids of 50% sawdust–FS mixture and the control ($P = 0.038$), 100 and 150% ($P = 0.009$), and 100% sawdust and the control ($P = 0.000$). The non-viable counts of helminth eggs were higher than the viable counts in all the biosolids from the sawdust–faecal mixtures.

Bacteriological and helminth quality of the percolates

Microbial counts in the percolates with respect to the different percentages of sawdust revealed lower values compared to that of the biosolids. The largest faecal coliform count of 8.1 log_{10} CFU/10 g dry weight was recorded in the control whilst the lowest of 5.3 log_{10} CFU/10 g was recorded in the 150% sawdust–sludge mixture. Mean faecal coliform counts of the control and 150% sawdust were significantly differerent ($P = 0.000$), but there was no significant difference between 100 and 150% sawdust.

It can be seen that increasing sawdust led to a reduction in faecal coliform counts in the percolates (Table 2). *E. coli* and *Salmonella* counts in the percolates followed a similar trend as in the faecal coliforms. In the case of *E. coli*, the largest count was recorded in the control whilst 150% sawdust recorded the lowest (Table 2). *E. coli* counts in the 50 and 100% did not differ significantly ($P = 0.372$) but the difference between 50 and 150% was significant ($P = 0.045$) (Table 2). In the case of *Salmonella* sp., again the control recorded the largest count whilst 150% recorded the lowest. Mean *Salmonella* counts of the control and 150% sawdust differed significantly ($P = 0.000$) There were no helminth eggs counts in the percolates of all the treatments.

DISCUSSION

A larger pathogen reduction was recorded in the biosolids from the various drying beds with the different ratios of

Table 2 | Bacteriological quality of percolates produced from the various sawdust treatments

Percentage sawdust added to faecal sludge	Geomean of microbes (CFU/L) mean concentration of bacteria (log_{10} CFU/L)			Helminth egg counts	
	Faecal coliforms	*E. coli*	*Salmonella*	Viable	Non-viable
50	6.7 (±1.23)[a]	5.4 (±1.54)[a]	4.7 (±1.03)[a]	not detected	not detected
100	6.5 (±1.82)[a]	5.1 (±1.20)[a]	4.3 (±1.06)[a]	not detected	not detected
150	5.1 (± 0.89)[b]	4.5 (±1.30)[b]	4.2 (±1.48)[b]	not detected	not detected
Control	8.1 (±1.72)[c]	7.0 (±1.48)[c]	6.2 (±1.24)[c]	not detected	not detected

[a]Within the same column, means followed by the same letter in superscript are not significantly different ($P > 0.05$).

sawdust and FS. Faecal coliform reductions obtained as a result of dewatering were 78.3, 71.2 and 86.6% for the 50, 100 and 150% sawdust respectively compared to the FS. This reduction could be due to the continuous production of ammonia in the presence of lignin, a major component of sawdust. Lignin increases the production of ammonia, thereby negatively affecting the activities of the microbes (Arends & Donkersdot-Shouq 1985). The reduction by sawdust–FS mixtures may also be due to the ability of the lignin component in the sawdust. This contains carboxyl groups that have an ability to part with hydrogen and retain absorbed ions of ammonia (Wilde 1960), thereby increasing the pH, which can potentially kill microbes. Other potential reasons for the reduction of microorganisms include absorption of pathogens by the sawdust and also heat generated in the dry matter. Adding ammonia-generating substances such as sawdust and rice husk to sewage sludge facilitates the inactivation of pathogens. The levels of the microbial load in the percolates reduced further as the quantity of sawdust was increased. The 150% sawdust drying bed was most efficient in reducing the microbial load. Hence percolate with low microbial load was produced by the 150% sawdust.

E. coli is one of the commonest microbes in FS (Le Minor 1984) which has pathogenic strains. *Salmonella* sp., also found in FS, is considered the most specific and problematic microorganism from a hygienic point of view since it is a universal bacterium with a high growth capacity (Hay 1996). Therefore if FS is used as soil organic amendment without any treatment, users will be at high health risk. A constant reduction in *E. coli* and *Salmonella* sp. counts was observed in the dewatering beds for both the biosolids and the percolates. The increasing proportion of the bulking agent (sawdust) resulted in a decrease in *E. coli* and *Salmonella* sp. counts. This observation could be due to the continuous absorption of moisture from the sludge by the sawdust, thereby reducing the moisture available to the microorganisms. Liang *et al.* (2003) reported 50% moisture content as the minimum requirement for rapid increase in microbial activity in FS. This reduction might also be due to the production of NH_3, which is toxic to microorganisms, through the ability of lignin to hold ammonia ions (Ghiglietti *et al.* 1996; Vinneras *et al.* 2003).

The reduction of *E. coli* and *Salmonella* sp. in the percolates was due to reduction of organic matter by the bulking agent (sawdust). Inactivation of these can also be due to physico-chemical factors such as pH, temperature and exposure to air (Gerba *et al.* 1975). The bacteria were thus affected by similar environmental factors and ammonia content, hence the consistent reduction of both species with increasing percentage sawdust.

Helminth eggs, especially those of the *Ascaris* sp., are the most common in FS (Theis *et al.* 1978). They have high resistance to chemical and physical conditions such as lime, ammonia, temperature, and as such they are the most resistant form of parasites. They have the ability to survive long periods of time in sludges and in soil (up to 6 years from their initial application), much more than bacteria, viruses and moulds (Krasnonos 1978). Studies have revealed that *Ascaris* eggs can survive under high moisture content in biosolids stored in the environment (Whanton 1979; Stromberg 1997; Sanguinetti *et al.* 2005), but when biosolids are dried, it speeds up the desiccation rate of *Ascaris* eggs, reducing egg survival (Feachem *et al.* 1983; Gaspard & Schwartzbrod 2003; Cappizzi-Banas *et al.* 2004). The large concentration of helminth eggs in the FS was inactivated by dewatering on the drying beds. The results obtained in the biosolids showed significant reduction of viable helminth eggs, with increasing quantity of sawdust. This can be explained by the fact that, in the sawdust–FS mixture, the pH and temperature in the environment of the helminth eggs were more homogeneous than in the FS alone, which produced sludge flocs that provide protection for the eggs. Viable eggs are usually considered a better assessment than total egg count because many eggs are inactivated during the dewatering process. Viable eggs counts for the final products would therefore be lower than the total egg counts in the raw sludge since some of the eggs would be inactivated (IWMI *et al.* 2003).

The viability of the helminth eggs in the FS decreased to 21.7, 15.2 and 6.5% in the biosolids from 50, 100 and 150% sawdust–FS mixtures. Thus, not only the total amount of helminth eggs decreased, but also the viability of the eggs, which are a potential health threat, also reduced (Table 1). The decrease in viability with increasing sawdust percentage might be due to ammonia that is produced in the sawdust–FS mixture. The ammonia produced might have affected the viability of the helminth eggs. This has been observed by Reimers *et al.* (2001) who stated that, in addition to temperature, compounds present in sludge including ammonia, organic acids, aldehydes, and alcohols may inactivate helminth eggs, but little is known about their effective concentrations.

A larger number of helminth eggs was found in the biosolids but there was no helminth egg in the percolates. This was due to the fact that the filter beds acted as a sieve retaining all the eggs that tried to move along with the percolate, thus remaining in the biosolid or in the filter material (Cofie

et al. 2005). A study conducted by Montangero & Strauss (2002), comparing helminth egg levels in the percolates of pilot drying beds in Accra with the levels in the FSs applied, showed 100% helminth eggs removal from the sludge in 12 bed loadings. According to Cofie *et al.* (2005), drying beds have proved 100% efficient in removing helminth eggs from the percolate. Helminth eggs have been found to easily stick to silica (sand) (Jimenez 2007), which might have contributed to the 100% removal of the eggs. The biosolids which accumulate most of the helminth eggs need to be hygienized before reuse in agriculture.

CONCLUSION

There was a consistent reduction of pathogenic bacteria and helminth eggs in the biosolids with increasing percentage of sawdust. The level of bacteria in percolates from the dewatering decreased with increasing percentage of sawdust. The inactivation rate of the pathogens in the sawdust–FS treatment was highest in the 150% sawdust. This means that substantial benefits including reduction of potential health risk of the biosolids could be achieved before being used as a fertilizer.

Although the biosolids produced from dewatered sawdust–FS contained smaller numbers of pathogen, further research needs to be conducted to determine the possibility of total inactivation of pathogens. Until that is achieved, the biosolids must be hygenized before its application for crop production.

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First received 23 August 2012; accepted in revised form 4 December 2012