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Efficiency of Helminth eggs removal in dewatered faecal sludge by co-composting

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This study aimed at investigating helminth eggs removal efficiency in dewatered faecal sludge (FS) co-composted with organic solid waste as related to the turning frequency. A mixture of fresh public toilet sludge and septage mixed in a ratio of 1:2 was dewatered on a drying bed. Biosolids with initial load of 25-83 helminth eggs/g TS was mixed with solid waste as bulking material in a volume ratio of 1:2 for co-composting. Two replicate sets of compost heaps were mounted in parallel and turned at different frequencies: i) once each 3 days, ii) once each 10 days, during the active composting period, to study the influence of the operational conditions on the compost hygienic quality. The helminth egg removal efficiency was not different for the two turning frequencies. In both setups helminth eggs were reduced from 25-83 /g TS to a, < 1-3 viable eggs/g TS level, allowing a safety reuse in agriculture.

Introduction

In Ghana, like in many other West African countries, two basic types of FS are produced, viz. high-concentrated, biochemically unstable sludges (mostly those collected from unsewered public toilets or non-infiltrating latrines), and lower-concentrated, partially stabilized sludges collected from septage tanks. Within these two categories, characteristics vary greatly, too. Table 1 shows the characteristics of the two types of FS as observed in Accra, Ghana.

In Kumasi, the second biggest city of Ghana (1 million inhabitants), 58% of the population rely on unsewered latrines and septic tanks and 38 % of the population use unsewered public toilets. Approximately 500 m³ of faecal sludges are being hauled daily. The FS produced contain high concentration of solids that need to be separated from the liquid part for adequate treatment.

Apart from the general goal of providing environmentally sound sanitation service to citizens, the recovery of nutrients and carbon from faecal sludge treatment plants has become a major challenge for city authorities. There is potential to re-use urban waste in Ghana as several urban and peri-urban farmers expressed willingness to use recycled urban wastes as organic fertilizers if available on the market at affordable price (Danso et al 2002).

In the framework of this project the team developed a pilot treatment scheme that allows generating biosolids from FS and producing a hygienic organic fertilizer through co-composting with municipal organic waste. The plant comprises a FS treatment step for biosolids generation and a composting unit for the organic fertilizer production. A detail description of the plant has been given by Mensah et al 2003. The co-treatment of FS with the organic solid waste appeared to be a sustainable approach to recycle organic waste generated by households as well as to reduce the amount of sludge and solids waste indiscriminately disposed off in the city.

However, in Ghana, due to the endemic situation of excreta related disease and the high level contamination among the population, an important caution must be given to the hygienic quality of organic fertilizers to avoid closing the contamination chain. In principle, all pathogens die off upon excretion except pathogens whose intermediate stages multiply in intermediate hosts. Of all excreted pathogen groups, representative of helminth eggs are the most resistant hence often used as indicator organisms.

The residual concentration of helminth eggs in the biosolids is dependent on the prevalence and intensity of infection in the population from which FS or wastewater is collected and on various factors influencing parasite survival. The main factors influencing die-off are temperature, dryness

Table 1. FS characteristics in Accra and Kumasi, Ghana – septage vs. sludges from public toilets; wastewater characteristics are included for comparison purposes (Strauss et al., 2000)

Parameters	Accra septage*	Accra public toilet sludge
TS mg/l	11,900	52,500
COD _{total} mg/l	6,400	47,000
NH ₄ -/NH ₃ -N mg/l	330	3,300
SS mg/l	3,900	49,000
Helm. Eggs no./g TS	100-150	200 - 400

and UV-light. Literature data reported that Helminth eggs can survive 10-12 months, under tropical climate, upon excretion (Feachem et al. 1983, Cross and Strauss 1985 and Schwartzbrod and Schwartzbrod 1994)). Where biosolids use in agriculture is a common practice or being aimed at, treatment or storage must be designed to reducing helminth egg counts and viability to acceptable levels. For sludge or biosolids, Xanthoulis and Strauss (1991) proposed a nematode egg standard of $\leq 3-8$ eggs/gram of dry solids. This value is based on the 1989 WHO nematode guideline of ≤ 1 egg/litre of wastewater for unrestricted irrigation.

This paper reports on a treatment scheme that allows to removing helminth eggs and the production of hygienic biosolid from FS and organic waste

Materials and methods

Biosolids generation

Faecal sludge drying/dewatering

Faecal sludge (FS) from public toilets and septic tanks was mixed in a volume ratio of 1:2 (total volume of 15 m³, total solid content 2-3%) and loaded onto two drying beds. The beds consisted of a concrete basin with a surface area of 25m² filled with 30 cm of sand on the top layer, 10 cm of fine gravel for the middle layer and 20 cm of coarse gravel as drainage layer. The percolate was discharged in a stabilization pond for further treatment. The drying process was stopped as soon as the total solid (TS) content of the sludge was higher than 20%. The dewatered sludge was then shoveled from the sand and sent for composting. The biosolids production rate on the drying beds was estimated at 0.15 m³/m³ of sludge.

Co-Composting

The composting plant consisted of a concrete platform (approx. 70 m²) equipped with a drainage system and covered by a roof. The composting process is similar to the well-known windrow process. Between June and November 2003 two composting cycles were monitored, Cycle 1 from June to October 2003, and Cycle 2 from August to November 2003. For each cycle, two compost heaps of 3 m³ each were formed using 1 m³ of dewatered fecal sludge and 2 m³ of organic waste from local markets (mixing ratio 1:2). The material was thoroughly mixed and watered if necessary before the heaps were formed.

The compost was aerated by turning the heaps inside out. In order to measure the influence of the turning frequency on the performance of the composting process, the heaps were turned with different frequencies. One of the heaps (Heap 1) was turned according to temperature. This means that during the thermophilic phase (inside temperatures higher than 55°) the heap was turned 3 times per week, and afterwards it was turned once per week. The other heap (Heap 2) was turned every 10 days, regardless of the temperature or any other factor. The moisture of the heaps was monitored and adjusted to approximately 50-60 % if necessary.

The temperature of the heap was measured daily at different

locations in the heart and in the upper layers of the heaps, using a bimetal thermometer. Mean values from inside and upper layers were reported. The "active" composting process lasted for about 60 days. During this period the heaps were turned and watered. Afterwards the maturation phase started: the heaps were left to mature without watering or turning. The temperature gradually decreases down to ambient temperature which is an indicator for its maturity. This phase lasted between 3 weeks for cycle 2 and 6 weeks for cycle 1. At the end of the maturation phase the compost was sieved (1 cm) and bagged.

Sampling

During each composting process two samples were taken while turning; one from the inside of the heap and one from the outside of the heap. For each sample material from different locations inside or outside of the heap was taken and thoroughly mixed with a shovel. About 2 liters of this mixture was filled into a polyethylene bag to make the inside or the upper layer sample. During the maturation phase no samples were taken. Only the final product was analyzed before and after sieving. All samples were immediately transported to the lab (about 1 hour away from the plant) and then stored in the fridge at 4°C until analyzed.

Analytical methods

Total solids

About 60g of each sample was weighed into a Petri dish and then dried for 24h at 105°C. Thereafter the sample was weighted again, and the % of total solids was determined was estimated by the dividing the weight after drying by the initial weight.

Helminth egg concentration

For each sample the concentration of *Ascaris* and *Trichuris* eggs was determined using the method developed by Schwartzbrod et al. (2003) which was based on the US EPA Protocol (1999).

Viability tests

Two methods were used for the viability test, to overcome specific difficulty related to each: The Safranine dying method developed by de Victorica and Galván (2003) and the incubation at 37°C for 24 days where positive sample shows larvae development.

Results

Prevalence of *Ascaris* eggs in fresh and dewatered sludge

Mainly *Ascaris* and *Trichuris* eggs were enumerated in faecal sludges samples examined, *Schistosoma* eggs were seldom and low (Table 2). The number of *Ascaris* was much higher than *Trichuris* eggs; 22-150 and 3-92 respectively. There is no obvious connection between the type of sample source (public toilet or septic tank) and the degree of contamination. The lower number of *Trichuris* is mainly due to the

Table 2. Helminth egg concentration and total solids in several fresh sludge samples collected in Kumasi

Sample Source	% Total Solids (TS)	Number of eggs /g TS			Total helminth eggs /gTS	% Viable Ascaris
		Ascaris	Trichuris	Schistos- omia		
Public Toilet 1	5.6%	83	0	0	83	82%
Public Toilet 2	5.5%	15	3	0	18	40%
Public Toilet 3	1.7%	114	42	6	162	68%
Public Toilet 4	4.5%	80	20	0	100	-
Septic Tank	2.8%	30	5	0	35	50%
Public Toilet/ Septic Tank (1:2)	2.8%	150	92	0	242	48%
Public Toilet / Septic Tank (2:1)	2.6%	32	3	0	35	75%
Dewatered FS 1*	53.6	23	2	1	26	50%
Dewatered FS 2*	58.9	38	45	0	83	57%

* Dewatered FS obtain from dewatering of mixture of Public Toilet / Septic Tank sludge in a ratio (1:2)

smaller egg production of the females and also to the fact, that in Ghana less people are infected with them (P. Hotez in prep). The female *A. lumbricoides* worms produce 200'000 eggs per day, compared to the 2'000-10'000 produced by *T. trichiura*, and only some hundreds produced by *S. mansoni* (Feachem et al. 1983).

It is shown in Table 2 that the viability of *Ascaris* in fresh FS sludge ranges from 40% to 82%, while in the dewatered sludge it ranges from 50% to 57%. In most of the cases, more than half of the *Ascaris* eggs are still alive and infective.

Temperature pattern during the co-composting

The temperature pattern was similar in both experimental setups, independently of the turning frequency (Figure 1). The inside temperature of the heaps, in both cases indicate that the active composting period last between 30 and 40 days (temperature beyond 45°C), for cycle 1 and 2 respectively. According to Scott (1953) and Vinneras et al (2002) helminth eggs are inactivated at this temperature if they are exposed to this condition for at least 5 days. From this experiment, we can assume that the high temperature maintained over 1.5 months allows to expose all parts of the compost heaps to the lethal temperature and for the required exposure time, regardless the turning frequency.

Helminth eggs removal efficiency

Table 3 shows that all species of helminth eggs are drastically reduced during the composting process. After 30-40 days exposure at temperature beyond 45 °C, the removal efficiency was similar for both setups, independently to the turning frequency (Figure 1 and 2). After 2 month of

composting, the removal efficiency of the Helminth eggs reached 72-88%, where initial concentration was high. During the maturation phase the Helminth eggs die-off efficiency improved to 98-100 %. This additional yield was probably due to the positive consequence of damages cause by previous higher temperature (Feachem et al., 1983). This is also consistent with the findings of Scott (1952) who found that *Ascaris* egg destruction was 95 % complete after 22 days and 100 % complete after 36 days in a stack whose contents were turned every 5-14 days and reached 60 °C after each turning.

The final product showed helminth egg concentrations of 1-6 eggs/g TS. According to laboratory analysis showed that the viability of *Ascaris* was reduced to 30%, after 45-60 days of composting. Therefore, it can be conclude that the quality the compost obtained in this study meet the WHO guidelines for agricultural reuse without restriction. Indeed, the WHO guidelines adapted by Xanthoulis and Strauss (1991) from wastewater reuse for the quality of biosolids applied in agriculture without restrictions are $\leq 3-8$ helminth eggs/gTS.

Conclusion

From this study, we can derive the following conclusion:

- The turning frequency during the active composting period does not to influence the Helminth eggs removal efficiency; hence a less frequent turning is sufficient
- The heat generated by the composting process exposed the helminth eggs at temperature beyond 45°C for more than one month. Hence, high removal rate (90 to 100%) was achieved after 80 days.

Table 3. The reduction of the different helminth egg species (*Ascaris* and *Trichuris*) during the composting process. Compared are the amounts of eggs in the starting material, in the compost before the start of the maturation phase, and in the final product.

Cycle	Heap	Species	Beginning Composting [Eggs/gTS]	Beginning Maturation ** [Eggs/gTS]	End product *** [Eggs/gTS]	Reduction until Maturation	Total Reduction
Cycle 1	Heap 1*	<i>Ascaris</i>	23	6.5	0.0	72%	100%
		<i>Trichuris</i>	2	1.5	0.5	25%	75%
	Heap 2	<i>Ascaris</i>	23	4.4	0.5	81%	98%
		<i>Trichuris</i>	2	1.9	1.5	6%	25%
Cycle 2	Heap 1*	<i>Ascaris</i>	38	2.4	0.4	94%	99%
		<i>Trichuris</i>	45	8.5	2.9	81%	94%
	Heap 2	<i>Ascaris</i>	38	5.0	1.7	87%	96%
		<i>Trichuris</i>	45	5.4	4.3	88%	91%

* heap 1 turned each 3 day during the active composting period and heap2 turned each 10.

** during the maturation phase (which last 6 weeks for Cycle 5 and 3 weeks for Cycle 6) the compost is not turned anymore. This phase starts 60 days after the beginning of composting.

*** this refers to end of maturation phase.

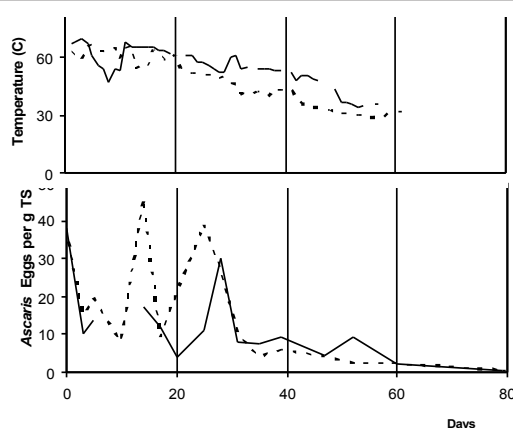


Figure 1. Temperature evolution and *Ascaris* eggs reduction in upper layer (dashed line) and in the heart (full line) of co-compost made of faecal sludge and market solid waste. Heaps turned each 3 days in the active composting period

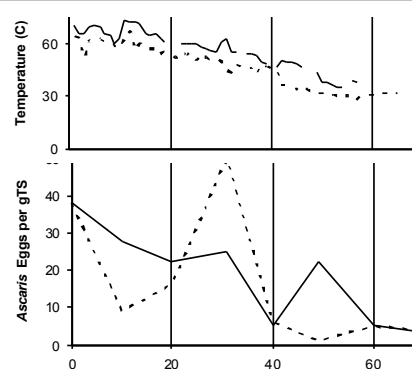


Figure 2. Temperature evolution and *Ascaris* eggs reduction in upper layer (dashed line) and in the heart (full line) of co-compost made of faecal sludge and market solid waste. Heaps turned each 10 days in the active composting period

Figures 1 and 2.

- The optimal duration of the composting process (60 + 30 days) is longer enough for the reduction of all helminth eggs. Hence co-composting of dewatered faecal sludge with organic solid waste seems to be an adequate low-cost method for FS biosolids hygienisation.

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