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RESEARCH ARTICLE

Effect of dewatering and composting on helminth eggs removal from lagooning sludge under semi-arid climate

Bouchra El Hayany[1] · Ghizlen El Mezouari El Glaoui[1,2] · Mohammed Rihanni[2] · Amine Ezzariai[1] · Abdelouahed El Faiz[1] · Mohamed El Gharous[3] · Mohamed Hafidi[1] · Loubna El Fels[1,4]

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Abstract

In this work, we assessed the drying and composting effectiveness of helminth eggs removal from sewage sludge of a lagoon wastewater treatment plant located in Chichaoua city. The composting was run after mixing sludge with green waste in different proportions: M1 (½ sludge + ½ green waste), M2 ($^{2}/_{3}$ sludge + $^{1}/_{3}$ green waste), and M3 ($^{1}/_{3}$ sludge + $^{2}/_{3}$ green waste) for 105 days. The analysis of the dewatered sewage sludge showed a load of 8–24 helminth eggs/g of fresh matter identified as *Ascaris* spp. eggs (5–19 eggs/g) followed by *Toxocara* spp. (0.2 to 2.4 eggs/g); *Hookworm* spp. and *Capillaria* spp. (0.4–1 egg/g); *Trichuris* spp., *Taenia* spp., and *Shistosoma* spp. (< 1 egg/g) in the untreated sludge. After 105 days of treatment by composting, we noted a total reduction of helminth eggs in the order of 97.5, 97.83, and 98.37% for mixtures M1, M2, and M3, respectively. The *Ascaris* spp. eggs were reduced by 98% for M1 and M3 treatments and by 97% for M_2 Treatment. *Toxocara* spp., *Hookworm* spp., *Trichuris* spp., *Capillaria* spp., and *Shistosoma* spp. eggs were totally eliminated (100% decrease) and the *Taenia* spp. was absent from the first stage of composting. These results confirm the effectiveness of both dehydrating and composting processes on the removal of helminth eggs.

Keywords Lagooning sludge · Composting · Dewatering process · Helminth eggs

Introduction

Wastewater treatment produces significant quantities of sewage sludge. According to the national report of the Sludge Step Management Strategy in Morocco in 2009, the sludge quantity is estimated at 98,000 t/year in 2015, and the forecasts are 300,000 t/year in 2025. In general, the sludge that comes from wastewater treatment systems is known for its potential fertilizing characteristics (Hartenstein 1981; El Fels et al. 2014a; Rocha et al. 2016). However, sludge presents evident contents of a large quantity of enteric viruses, pathogenic bacteria, and helminth eggs of human or animal origin in several taxa. We distinguish Platyhelminthes (flatworms) as *Schistosoma* spp. and Nemathelminthes (roundworms) as *Ascaris* spp., *Trichuris* spp., *Capillaria* spp., *Hookworm* spp., and *Toxocara* spp.

Toxocara canis, commonly known as dog roundworm, can affect humans and cause human toxocariasis (Keffala et al. 2012). Hookworm eggs causing human hookworm occur in the stool of infected person; infection is through skin penetration by infective larvae. *Schistosoma* spp. is a parasite responsible for schistosomiasis, *Schistosoma* eggs released into the external environment through feces or urine of infected people; furthermore, *Schistosoma* can be observed in other mammals as mice and wistar rats (Sene 1994; Wang et al. 2016). *Taenia* spp. is a tapeworm of the class of Cestoda, responsible for Taeniasis disease; the usual hosts for this parasite are cattle

Responsible editor: Philippe Garrigues

✉ Loubna El Fels
loubna.elfels@gmail.com

[1] Laboratoire Ecologie et Environnement (Unité associée au CNRST, URAC 32), Faculté des Sciences Semlalia, Université Cadi Ayyad Marrakech, Marrakesh, Morocco

[2] Laboratoire Biotechnologie Marines et de l'Environnement, Faculté des Sciences El Jadida, Université Chouaib Doukkali, El Jadida, Morocco

[3] University Mohammed VI Polytechnic, Benguerir, Morocco

[4] Institut Supérieur des Professions Infirmières et Techniques de Santé, Marrakesh - Safi, Morocco

and swine, from which humans become infected with the adult tapeworm (Parkhouse and Harrison 2014). *Ascaris* spp. is the most common intestinal parasites in the world; it is responsible for the human Ascariasis. The natural habitats of adult larvae is the small intestine (Stephenson 2009), the infected individuals excrete up to 200,000 eggs per day (Bethony et al. 2006; Karkashan et al. 2015). *Capillaria* is responsible of Capillariasis disease, and *Trichuris trichiura* eggs are responsible of Trichuriasis disease, which is among the common human parasitic infection (Pullan et al. 2014).

Amahmid et al. (2002) attributed the reduction of parasite eggs during the treatment of wastewater to their accumulation in the solid phase (sludge). The sedimentation speed is estimated by Shuval (1977) at 0.65 m/h for *Ascaris* spp. eggs, 0.39 m/h of *Ankylostome*, 0.26 m/h of *Taenia*, 1.53 m/h of *Trichuris*, and 12.55 m/h of *Schistosoma*. Several authors have showed that wastewater and sewage sludge contain a large quantity of *Ascaris* spp. eggs (Amahmid et al. 2002; Sylla and Belghyti 2008; El Fels et al. 2014b), the abundance of *Ascaris* spp. eggs is explained by their resistance and their transmission mode (direct cycle). The helminth eggs contain a thick outer layer that acts as protection barriers to various environmental conditions, which explain their high resistance to inactivation (Maya et al. 2012).

According to the literature, helminth eggs can survive until 10–12 months in excretion in tropical climate (Sanguinetti et al. 2005; Koné et al. 2007). Feachem et al. (1983) explained the predominance of *Ascaris* spp. in the environment by their extremely abundant egg production and their ability to survive. 0.8 to 1.2 billion people are globally affected by Ascariasis and the most affected populations are in Sub-Saharan Africa, Latin America, and Asia (Lozano 2012). Children between 5 and 15 years old are the most vulnerable (Bundy 2004).

One of the most attractive options for sludge disposal is its use in agriculture and then specific guidelines regarding hygienic quality must be fulfilled. So, as to avert the risk of contamination, the sludge must be properly sanitized (Reilly 2001; Arthurson 2008; Rocha et al. 2016). Dehydration techniques and sludge liming are often used as ways to reduce and/or eliminate their parasite loads. Numerous studies have shown that the basic pH (higher than 10) influences the disintegration of helminth eggs in biosolids (Gaspard and Schwartzbrod 2003; Cappizzi-Banas et al. 2004). Nevertheless, treating sludge by dehydration process on drying beds was not efficient enough to eliminate all helminth eggs. The high concentration of helminth eggs contained in the fresh sludge could not be inactivated in drying beds. El Fels et al. (2014b) and Koné et al. (2007) showed the existence of significant amount of helminth eggs (*Ascaris* and *Trichuris*) after sludge dewatering. Furthermore, Gantzer et al. (2001) detected viable nematode eggs in dehydrated sludge stored for 8 months. Treatment of sludge by anaerobic or aerobic digestion and/or dewatering will reduce the number of pathogens, but significant numbers will remain (Straub et al. 1993). Several sludge treatment procedures include composting were applied; and most factors involved in pathogen inactivation are controlled by composting process (Koné et al. 2007; El Fels et al. 2014b). Haug (1993) showed that pathogen survival could occur in low temperature zones. However, Wichuk and Mc Cartney (2007) demonstrated that pathogen inactivation is expected to occur if all particles of compost maintain temperatures greater than 55 °C for at least 3 days. El Fels et al. (2016) showed that pathogens should be reduced to non-detectable levels during composting of organic matter.

Composting is a process with a low-cost and easy-to-operate, it is a widespread process used for the treatment of wastes in middle-income countries (WHO 2006; Koné et al. 2007; El Fels et al. 2014b). This aerobic biological degradation process of organic matter has developed in Morocco in recent years especially the sector of composting of green waste and sludge treatment plants. Nevertheless, composting has the benefits of reducing the environmental risks associated with waste management by reducing the volume and the destruction of pathogenic organisms (Sæbø and Ferrini 2006; El Fels et al. 2014b). Moreover, composting provides a stable, humified and hygienic amendment containing nutrients.

Many studies were interested in the effect of composting on helminthes eggs inactivation. Szabová et al. (2010) studied the influence of composting organic wastes (straw, sawdust, wood brash, and sludge) during the winter and summer seasons on the survival of non-embryonated *Ascaris suum* eggs. Other studies were conducted on activated municipal sludge (Yanko 1988; El Fels et al. 2014b). Helminth eggs inactivation in lagooning sludge is not widely discussed in the composting literature.

The objectives of this study were to assess the quantities of helminth eggs in fresh and dehydrated lagooning sludge under semi-arid climate (case of lagooning wastewater treatment plant of Chichaoua city), and then follow their inactivation during sludge composting with green waste. Moreover, to identify factors involved in the effectiveness of helminth eggs inactivation by the co-composting process of dewatered sludge mixed with green waste.

Material and methods

Sampling of sewage sludge

The sewage sludge comes from natural lagooning wastewater treatment plant of Chichaoua city. A total of 3609 m^3 of lagooning sludge was recovered by a pumping unit set on the banks of each pond. This is the first total cleaning done after 7 years of operation.

Dewatering is one of the primary processes of sludge management. A small decrease in the amount of water in the sewage sludge produces a significant reduction in its volume, which is very necessary for the following stage of sludge recycling (Kołecka et al. 2017). In our case, the sludge was dehydrated on drying beds to facilitate the preparation of mixtures for an industrial scale composting. The dehydrated sludge with 37% of water and a pH of about 7.2 was stored for about 4 months at room temperature before composting. However, samples of fresh sludge (moisture content of about 64% and a pH value of 7.80) were stored at − 20 °C until analysis.

Composting trials

Dehydrated sludge and green waste (mixed of blend of leaves, grass clippings, and shrub clipping) from the garden city were the two substrates used in composting.

The main characteristics of the different composting substrate are presented in Table 1.

The composting process was carried out as windrows for 105 days on a composting platform located in Chichaoua city. Three trials with different proportions were conducted:

- Mixture 1 (M1), 1/2 sludge + 1/2 green waste, (total volume of 4 m^3).
- Mixture 2 (M2), 2/3 sludge + 1/3 green waste, (total volume of 4 m^3).
- Mixture 3 (M3), 1/3 sludge + 2/3 green waste, (total volume of 4 m^3).

During the first 3 months of composting, a regular brewing was achieved manually and weekly to ensure aeration of windrows and to moderate the moisture by adding water to 60%. The temperature of the windrows during the process of co-composting was measured daily at different levels with special chips (PH0700115 Version 1.20 Ector Traceability).

Homogeneous composite samples were taken at T_0 (first day of composting) and during each stage of composting (T_{27}, T_{98}, and T_{105} day). Subsamples of 1 kg were taken at different points along the length and height of the windrow followed by quartering and carefully mixed. The composite samples were kept at − 20 °C until analysis.

Table 1 Main features of the substrates used for composting

Parameters	Green waste	Dehydrated sludge	Fresh sludge
pH	7.30 ± 0.18	7.22 ± 0.34	7.80 ± 0.31
Moisture (%)(FW)	35.23 ± 0.16	37 ± 0.4	64.14 ± 0.11
Ash content (%) (DW)	18.73 ± 0.04	60.28 ± 0.1	44.47 ± 0.08
TOC (%) (DW)	51.44 ± 0.35	22.06 ± 0.18	30.85 ± 0.12
TKN (%) (DW)	1.04 ± 0.028	1.06 ± 0.15	1.10 ± 0.1
C/N	49.46	20.82	28.04

FW fresh weight, *DW* dry weight, *TOC* total organic carbon, *TKN* total kjeldahl nitrogen

Physico-chemical analyses

The pH was measured on an aqueous extract of the compost as indicated in the French standard procedure AFNOR NF T90-008. The total kjeldahl nitrogen (TKN) was assayed by distillation according to the French standard procedure AFNOR T90-110 and ammonium ion content was determined by alkaline distillation. Total organic carbon (TOC) was determined according to El Fels et al.'s (2014a) procedure. Moisture contents were determined by drying a fresh sample of compost and sludge at 105 °C for 48 h (AFNOR 2000).

Decomposition rate and ash content were calculated after calcination in a muffle furnace at 600 °C for 6 h according the equation below:

Decomposition rate (%) = 100−100 [initial ash (100−final ash)]/[final ash (100−initial ash)].

Identification and quantification of helminth eggs

The analytical technique for the identification of helminth eggs was carried out on 10 g of fresh sludge and of each co-composting stage. The first step was the separation of eggs helminth from the particles by ammonium bicarbonate (11.9%); after centrifugation, the pellet was recovered and washed with water to remove the rest of ammonium bicarbonate.

The second step was the concentration of eggs based on flotation method (Bailenger method) with the presence of zinc sulfate (56.81%, specific gravity, 1.29) (Bowman et al. 2003; Schwartzbrod 2003; Koné et al. 2007; El Fels et al. 2014b). After centrifugation, the liquid supernatant was recovered.

After being located at × 100 magnification, the helminth eggs were identified at × 400 magnification using a Mac Master blade. Photomicrographs were made using a binocular microscope (camera: Moticam 1000, 1.3 M pixel USB 2.0, lens 16 MM, ø28). The total number of helminth eggs was expressed per gram of fresh sample.

Statistical analyses

Principal components analysis (PCA) was applied to the correlation matrix between physical–chemical variables and abatement rate of helminth eggs for the three mixtures. The statistical treatments were studied with the software SPSS Statistics 24 Win version 10.

Results and discussion

In order to follow the evolution of composting process, the physico-chemical parameters were analyzed. Figure 1 presents temperature versus time during composting period for the three mixtures. The graphic has a classic look composting evolution; it has two main phases of temperature changes (thermophilic phase and maturation). In thermophilic phase, the temperature increases to 45, 44.6, and 50 °C, respectively, for mixtures M1, M2, and M3 resulting from the intense microbial activity by degradation of simple molecules in the substrate (Khalil et al. 2001; El Fels et al. 2016). Thereafter, the temperature decreases to reach room temperature; this second phase called maturation phase during which only compounds resistant to degradation are remaining.

Table 2 presents the physicochemical parameters values after 105 days of composting. The pH value of the three mixtures tended to stabilize at around neutrality (7.22, 7.14, and 7.09, respectively, for mixtures M1, M2, and M3) because of buffer power of humus at the maturation phase. The increasing of Carbon/Nitrogen ratio (C/N) is related to the loss of organic carbon due to the biological oxidation of organic matter, and to the augmentation of total kjeldahl nitrogen (TKN) concentration by degradation of carbon compounds and the mineralization of nitrogen-containing molecules. The decomposition rate also increased after 105 days of composting to 33.63, 39.24, and 36.41%, respectively, for mixtures M1, M2, and M3. According to the literature, the results of the physicochemical parameters after 105 days indicated that the final compost is mature and stable.

Identification and quantification of helminth eggs of raw sludge before and after dewatering

The microscopic examination of sludge samples shows a presence of parasites belonging to Nemathelminthes groups (*Ascaris* spp., *Trichuris* spp., *Capillaria* spp., *Hookworm* spp., and *Toxocara* spp.) and to Plathelminthes groups (*Taenia* spp. and *Schistosoma* spp.), a predominance of *Ascaris* spp. eggs compared to other types of helminths was noted (Fig. 2). The identified Nemathelminthes and Plathelminthes species originated from human and animal intestinal parasites.

The concentration and distribution of nematode eggs (*Ascaris* specifically) in sewage sludge have been studied (Koné et al. 2007; Konaté et al. 2013; El Fels et al. 2014b). It has been shown that the density of the helminth eggs is greater than that of the water (1.056 to 1.237), which favors their settling in sludge (Koné et al. 2007; Gantzer et al. 2001). El Fels et al. (2014b) and Koné et al. (2007) have reported that eggs of intestinal nematodes are stronger than those of tapeworms in wastewater and, therefore, in sludge. Konaté et al. (2013) have examined the vertical distribution of helminth eggs in the sewage sludge and showed that the upper layer of sludge, which is the most recently deposited, contains most of helminth eggs (3100 helminth eggs/g DW) and has the highest percentage of viability (57.2%).

The fresh sludge contains 15.4 to 37 eggs/g, with a predominance of *Ascaris* spp. (10.4–16.6 eggs/g) followed by *Capillaria* spp. (2.4–11 eggs/g), *Trichuris* spp. (0.8–6 eggs/g), *Toxocara* spp. (0.2 to 2.4 eggs/g), *Hookworm* spp. (1.2–1.4 eggs/g), and *Taenia* spp. and *Schistosoma* spp. (< 1 egg/g). After dehydrating the sludge, the concentration of helminth eggs decreased with an abatement rate of about 35 to 48%. We counted from 8 to 24 eggs/g, with a dominance of *Ascaris* spp. (5–19 eggs/g) followed by *Toxocara* spp. (0.2–2.4 eggs/g); *Hookworm* spp. and *Capillaria* spp. (0.4–1 egg/g); *Trichuris*, *Taenia*, and *Schistosoma* (< 1 egg/g). The treatment of sludge by drying beds allows the inactivation of a part of helminth eggs through the ultraviolet rays and leaching, Ayres et al. (1993) have determined that 9 to 41.5 eggs/g of nematode eggs were presented in dewatered sludge. Koné et al. (2007) showed that dewatering process on the drying beds was not efficient enough to inactivate all the helminth eggs. They isolated up to 22–38 helminth eggs/g (*Ascaris* and *Trichuris*), of which 25 to 50% are viable. Furthermore, El Fels et al. (2014b) showed that the dehydration process did not appear to be effective for the complete elimination of helminth eggs; they have counted from 4 to 27 eggs/g (*Ascaris* spp., *Trichuris* spp., and *Capillaria* spp.) in dehydrated sludge.

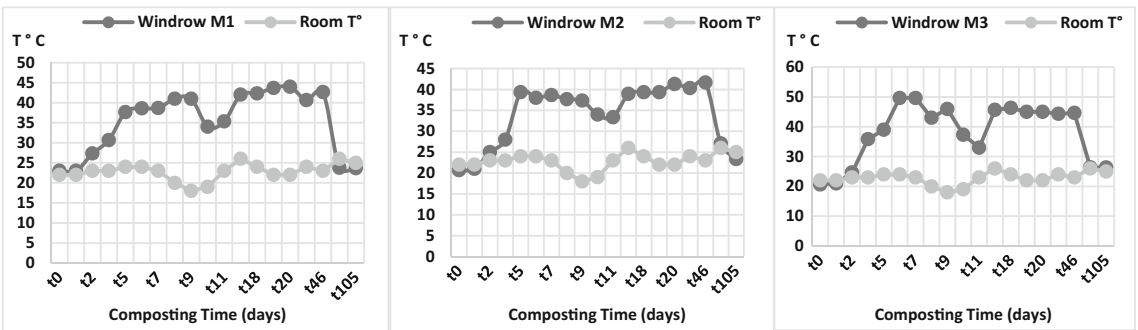

Fig. 1 Temperature versus time during the co-composting process of three mixtures

Table 2 Evolution of physicochemical parameters during composting

Mixtures	Time (days)	pH	C/N	DEC (%)	TKN (%)
1	0	7.49 ± 0.01	29	0	0.84 ± 0.028
	105	7.22 ± 0	9.47	33.63 ± 2.6	1.36 ± 0.1
2	0	7.74 ± 0.19	27.61	0	0.95 ± 0.012
	105	7.14 ± 0.075	9.24	39.24 ± 0.13	1.18 ± 0.13
3	0	*8.16 ± 0.24*	26.49	0	0.88 ± 0.008
	105	*7.09* ± 0.006	10.1	36.41 ± 2.5	1.30 ± 0.12

TKN total kjeldahl nitrogen, *DEC* decomposition rate

In accordance with the recommendations of the WHO (2006) for the reuse of sludge (1 egg/g or less), the concentration of helminth eggs remains high and exceeds the standards. Hence, the treatment of sludge by dehydration alone is insufficient.

Abatement of helminth eggs by composting process

During the co-composting, the identified helminth eggs were the same as those found initially in dehydrated sludge, such as *Ascaris* spp., *Trichuris* spp., *Capillaria* spp., *Toxocara* spp., *Hookworm* spp., and *Schistosoma* spp. At the initial stages of co-composting, we counted a lower concentration of the total helminths eggs than in the sludge only that is of about 16, 18.4, and 12.2 of the total helminth eggs/g, respectively, for mixtures M1, M2, and M3 (Fig.2). High concentration and diversity of helminth eggs was observed in mixture 2 (Fig. 2, Fig. 3a–c).

A significant difference in helminth egg numbers as well as the absence of some species at the initial stage was revealed (Fig. 3a–c). We noted the absence of *Trichuris* spp. and *Schistosoma* spp. at the initial stage of composting of mixture M1, and *Trichuris* spp., *Toxocara* spp., and *Schistosoma* spp. for mixture M3. However, the *Taenia* spp. was absent in all mixtures M1, M2, and M3.

The variability in the numbers of the helminth eggs observed at T_0 in the mixtures M1, M2, and M3 is due to the different proportions of mixed sludge with the green waste. El Fels et al. (2014b) showed that the structure of the lignocellulosic matrix onto which the helminth eggs can be adsorbed, partially explains the differences noted in helminth egg numbers during composting. Similarly, Koné et al. (2007) showed that when the material is digested and the particles are finer, the variability of egg numbers decreased because of the greater consistency of the sample. Beside the substrate structure, the initial load of helminth eggs of sludge could explain the absence of *Trichuris* spp., *Toxocara* spp., *Schistosoma* spp., and *Taenia* spp.

During composting, we observed a decrease in the concentration of total helminth eggs (Fig. 3a–c). This corresponds to a reduction of 72.5, 72.8, and 67.3%, respectively, for mixtures M1, M2, and M3 during thermophilic phase (27 days). However, after 105 days of composting, the reduction rate reached 97.5, 97.8, and 98.4%, respectively, for mixtures M1, M2, and M3.

At final stage of process, the reduction in the numbers of *Ascaris* spp. eggs was about 97.7, 97.4, and 97.9%, respectively, for mixtures M1, M2, and M3. However, a 100% of reduction was obtained for *Toxocara* spp., *Hookworm* spp., *Schistosoma* spp., *Trichuris* spp., and *Capillaria* spp.

A difference of a kinetic abatement of all identified species was noted. This abatement is linked to the variation degree of physico-chemical parameters of each mixture such as temperature. The time necessary to attain high levels of helminth inactivation (> 95%) is variable in the literature, reports varying from 2 h to 180 days, based on the temperature (Gantzer et al. 2001; Ayres et al. 1993; Ghiglietti et al. 1997).

The dominance of *Ascaris* spp. eggs in the three mixtures with low reduction rate is justified by the resistance of *Ascaris*

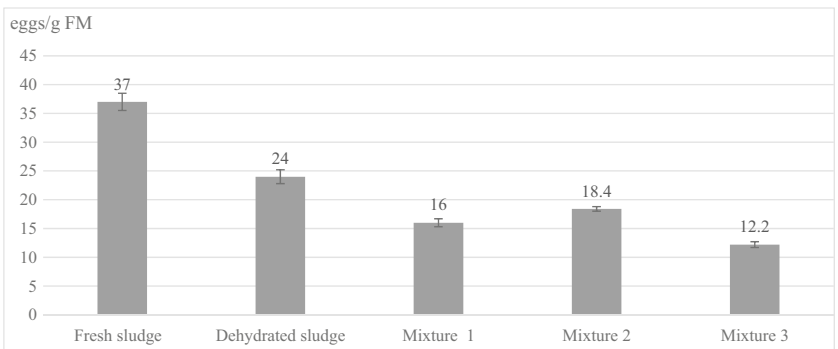

Fig. 2 Total helminth eggs per g of fresh and dewatering sludge material and initial stages (T_0) of composting of mixtures M1, M2, and M3

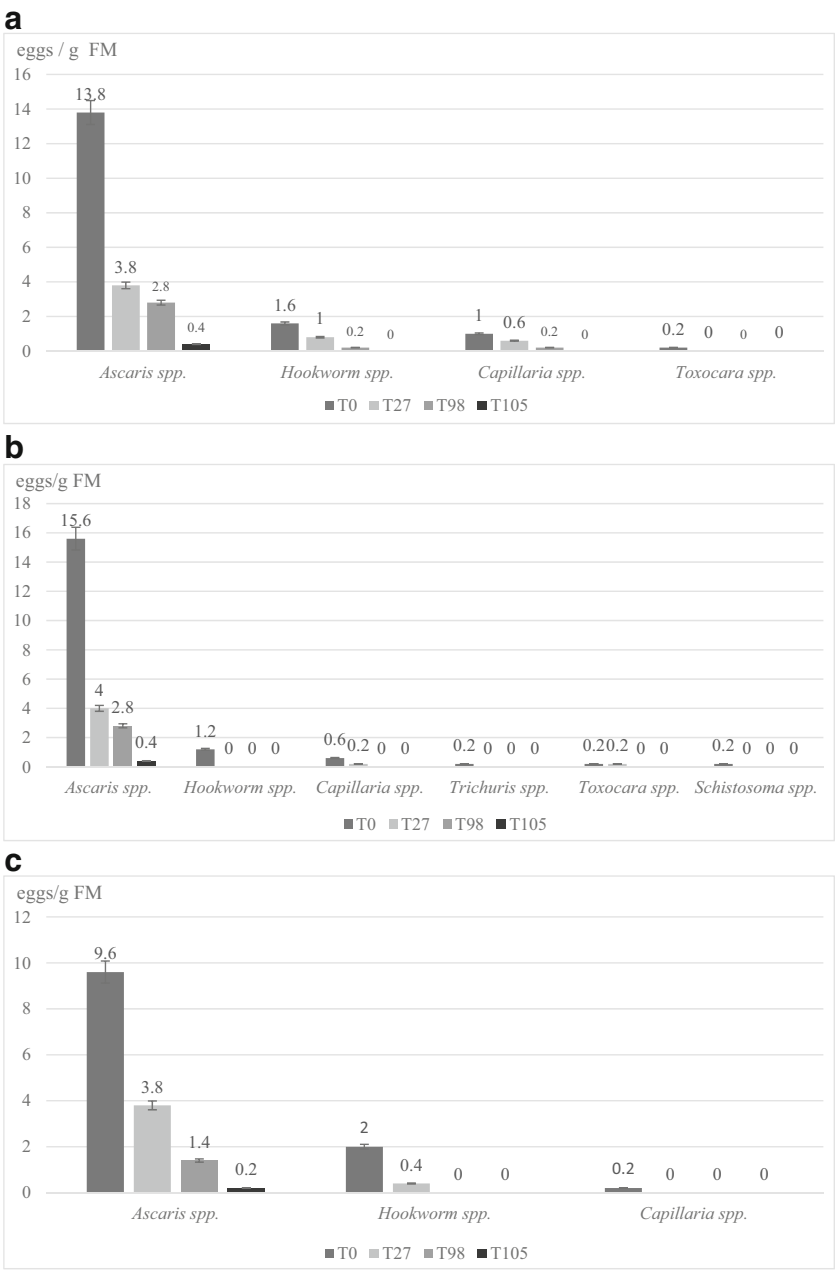

Fig. 3 **a** Evolution of helminth eggs in the mixture M1 during composting. **b** Evolution of helminth eggs in the mixture M2 during composting. **c** Evolution of helminth eggs in the mixture M3 during composting

spp. eggs compared to other helminth eggs. The helminth eggs are more resistant to attack by the environmental factors.

This resistance is due to the presence of thick cuticles that prevent the passage of certain substances (strong acids and bases, oxidants, reducing agents and detergents…etc.). The permeability of the helminth eggs is limited to the passage of water, some solvents and some gas (Keffala et al. 2012).

In our case, the helminth eggs reduction is explained by the temperature increasing which reached 45, 44.6, and 50 °C, respectively, for mixtures M1, M2, and M3. Gaspard and Schwartzbrod (2003), and Cappizzi-Banas et al. (2004) showed that high temperatures accelerate the rate of desiccation of *Ascaris* cells. El Fels et al. (2014b) showed that a high temperature is damaging the cells of the helminths and their capacity to survive after their exposal for several days. The temperature increase to 45 °C can enhance to increase the rate of chemical reactions and enzymatic processes, which involve an increase of the eggs membrane permeability (Maya et al. 2012). Vinneras et al. (2003) showed that the inactivation of all *Ascaris* spp. eggs will take place if the temperature in the composting windrows remains above 45 °C for at least 5 days. The same result can be obtained with 8 days at 44 °C.

Furthermore, other factors may contribute to the inactivation of helminth eggs such as the duration of exposure and the concentration of ammonia (El Fels et al. 2014b). The production of ammonia in the thermophilic phase of composting contributes to

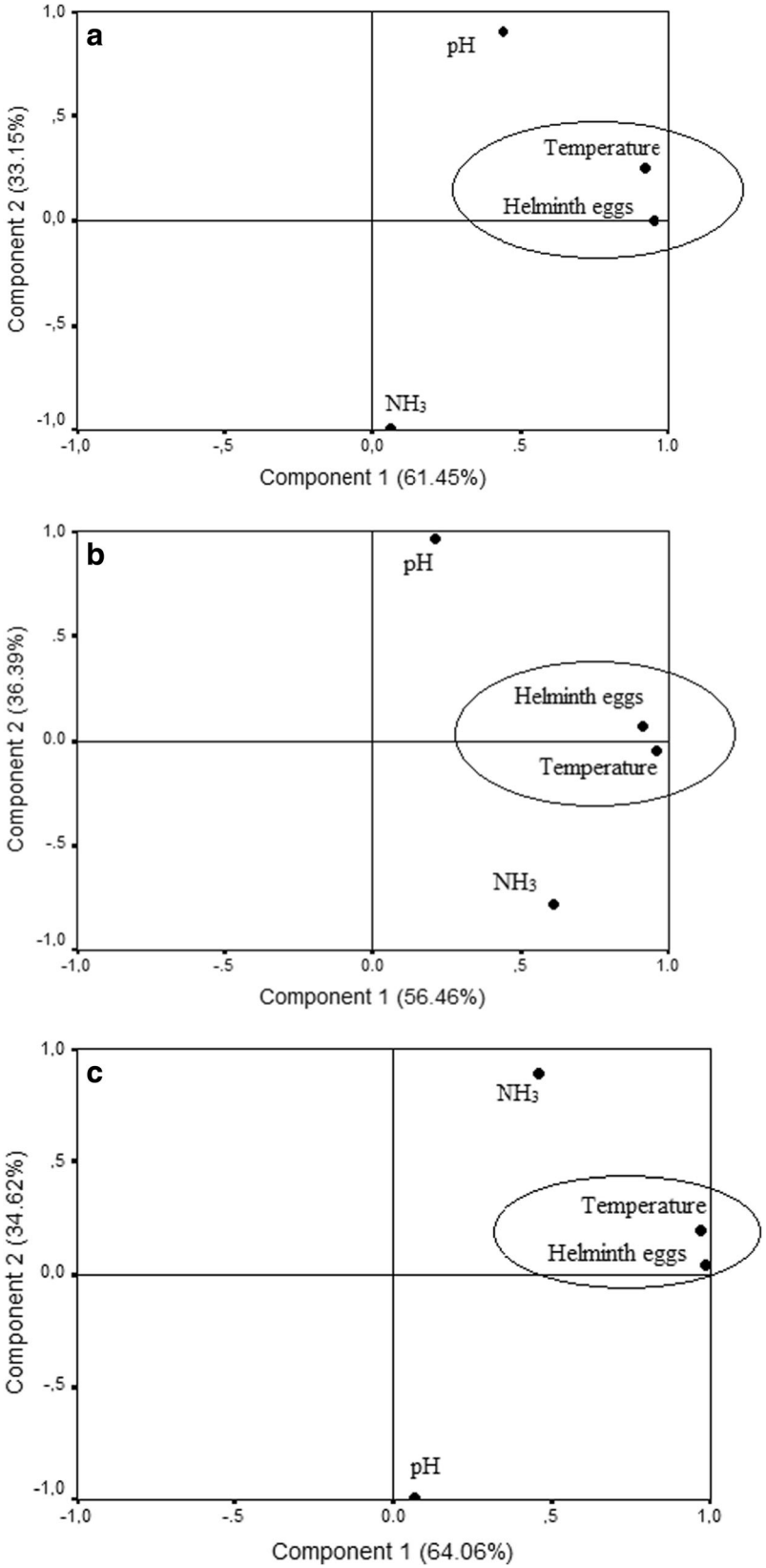

Fig. 4 PCA components of composting parameters and helminth eggs abatement of mixtures M1 (**a**), M2 (**b**), and M3 (**c**)

the reduction of helminth eggs. Ammonia exists naturally in wastewater from the hydrolysis of urea and the degradation of proteins and other compounds containing nitrogen. Thus, the inactivation mechanism of pathogenic microorganisms by ammonia may be due to an alteration of the membrane potential, to the cytoplasmic pH increase and to the loss of potassium ions (El Fels et al. 2014b; Pecson et al. 2007).

Carbonate ions and volatile fatty acids are also known for their ability to inactivate pathogens. Sanguinetti et al. (2005) showed that the decrease in the concentration of water in the environment could promote the inactivation of helminth eggs.

Other authors have studied the pH factor in biosolids disinfection; they showed that pH between 12 and 12.6 for 20 to 60 days is effective for nematode egg inactivation (Gaspard et al. 1997; Reimers et al. 1998). Schuh et al. (1985) have observed inactivation of *Ascaris suum* eggs after 2–4 months of sewage sludge storage at pH 12.5. Gantzer et al. (2001) showed significant influence of temperature and pH on the inactivation of parasite eggs during sludge treatment.

The results obtained in our study reveal that the combination of dewatering of sludge and physico-chemical factors during composting (combination of temperature pH, NH_3, and moisture) provides hygienic compost safe for agricultural reuse.

Statistical analysis

The results of the PCA of composting parameters and reduction rate of helminth eggs for the three mixtures are reported in Fig. 4.

The projection on the plane of variables composting parameters (temperature, pH, and NH_3) and Helminth eggs removal for the three mixtures in terms of two main components (I and II).

Figure 4a–c shows the strong correlation between temperature and the reduction of helminth eggs for mixtures M1, M2, and M3. These results confirm that the temperature is the main factor in the removal of helminth eggs. Ammonia and pH, which are positively correlated with helminth eggs abatement, could also contribute to the helminth inactivation during composting.

Conclusion

The sludge was initially loaded with various species (*Ascaris* spp., *Hookworm* spp., *Capillaria* spp., *Trichuris* spp., *Toxocara* spp., *Taenia* spp., and *Schistosomas* spp.). The concentration of identified helminth eggs decreased after sludge dewatering reduction rate were 35 to 48%. The helminth eggs concentration remained high and exceeded the standards.

Nevertheless, the stabilization of dewatered lagooning sludge by composting during 105 days led to reductions of helminth eggs by approximately 98%. A strong correlation was shown between temperature and helminth eggs abatement. Besides, various parameters were involved in helminth eggs inactivation such as substrate structure, moisture, ammonium content, and pH.

The concentration of helminth eggs decreased to levels meeting the WHO (2006) guidelines, set at 1 egg/g or less.

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