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The potential for self-sanitisation of faecal sludge by intrinsic ammonia

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ABSTRACT

Faecal sludge has the potential to be used as a sustainable fertiliser in agriculture, but the sludge must be sanitised due to its content of pathogenic microorganisms. The intrinsic ammonia from the urine may be sufficient for sanitisation of the sludge if it is not too diluted by flush water or lost by ventilation. To evaluate the potential for this sanitisation method, inactivation of *Enterococcus faecalis*, *Salmonella typhimurium* and *Ascaris suum* eggs during treatment were assessed. The inactivation was studied at different storage temperatures (10–28 °C) and in several sludge mixes with different contents of urine, faeces and flush water, and with ammonia concentrations from 40 to 400 mM. All pathogens were inactivated by the ammonia, and ascaris eggs were the most persistent. Lower flush water volume and higher urine content favoured inactivation, mainly due to increased uncharged ammonia (NH_3) concentration. The lag phase in ascaris inactivation was shortened by increasing temperature and NH_3 concentration, while post-lag phase inactivation was not influenced by NH_3 concentration. Faecal sludge can be sanitised by airtight storage without the use of additives when flush water volumes are sufficiently low. For temperatures of 23–28 °C, a 3 log reduction of ascaris egg viability can be achieved within 1–6 months depending on ammonia concentration and temperature.

1. Introduction

Lack of proper sanitation and access to safe water, combined with poor hygiene, cause 0.3 million deaths worldwide annually, and 0.9% of the global Disability Adjusted Life Years (DALY) losses (Lopez et al., 2006) (Lim et al., 2012). According to data from the Joint Monitoring Program (JMP), around 1.2 billion people defecate in the open (JMP, 2012). However, the construction of toilets is not enough to avoid transmission of diseases. It is estimated that the sewage from 4.1 billion people is not treated before discharge into water bodies and onto fields (Baum et al., 2013), exposing downstream and surrounding

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populations of humans and animals to the pathogens from the faecal sludge (Opel, 2012). In order to improve health conditions in exposed populations, it is crucial not only to build toilets but also to find sustainable methods for treating faecal sludge (Rijsberman and Zwane, 2012). Conventional sewage treatment is not desirable, as it requires expensive infrastructure, expertise management and a stable electricity supply. Furthermore, the possibility for agricultural reuse of the nutrients is limited, as the sludge is normally low in nutrients and high in heavy metals compared with faecal sludge.

Faecal sludge contains all the macro- and micro-nutrients required for plant growth, in addition to organic matter, and could thus be used as a combined fertiliser and soil conditioner. However, its pathogen content can lead to occupational risks and to an increased risk of food- and feed-borne disease transmission if it is not managed properly (Do Thuy et al., 2007; Jimenez et al., 2006). The reuse of human excreta is often strongly linked with increased prevalence of endemic diseases (Ling et al., 1993; Xu et al., 1995). Sanitisation of the sludge is thus required to avoid unacceptable health risks associated with handling and agricultural use of the sludge. The WHO guidelines (2006) for agricultural reuse of human excreta recommend more than one year of storage of faecal sludge at ambient temperatures above 20 °C. However, in low and mid income countries most farmers do not follow these recommendations, as the cropping seasons and the need for fertiliser often determine the storage times (Jensen et al., 2008).

An interesting alternative treatment option for faecal sludge is to utilise the pathogen-inactivating effect of uncharged ammonia, NH_3 (Warren, 1962), which has been shown to be efficient to inactivate bacteria (Vinnerås et al., 2008), viruses (Emmoth et al., 2011), protozoa (Jenkins et al., 1998) and helminth eggs (Nordin et al., 2009a; Pecson and Nelson, 2005). Urine contains urea, which degrades rapidly into ammonia and carbonate, both of which have a sanitising effect (Park and Diez-Gonzalez, 2003), making it potentially self-sanitising. This has been observed in some composting toilets, where sanitisation by ammonia from urine was been found to be the most important mechanism for pathogen inactivation (Hill et al., 2013; Jensen et al., 2009).

The sanitising effect of ammonia is strongly linked to the NH_3 concentration, which depends on flush water volume, faeces/urine ratio, infiltration and ventilation. According to Joint Monitoring Program {JMP, 2012 #384}, around 1.7 billion people world-wide use pit latrines without flush water. The faecal sludge from these toilets may have rather high ammonia concentrations, although a large proportion of the ammonia is probably lost as ammonia is volatile and many pits are well-ventilated. In pour flush latrines, which are used by around 0.3 billion people globally, the amount of flush water will, to a large extent, determine the ammonia concentration. Vacuum toilets are becoming increasingly popular as a high-cost alternative in water-scarce regions, as the water use is very low (0.5–1.5 L/flush). The faecal sludge from pour flush latrines and vacuum toilets can possibly be suitable for ammonia treatment due to the low flush water volumes. For successful ammonia treatment, an airtight storage should be used to avoid ammonia losses. If the pit is lined and an alternating pit is available for use during the treatment period, the storage can be done in the pit itself. Otherwise, the sludge can be transported to a storage facility.

The objective of this study was to evaluate self-sanitisation of faecal sludge utilising the effect of intrinsic ammonia, and to determine how the sludge composition and ambient temperature affect pathogen inactivation. *Salmonella* spp. and *Enterococcus faecalis* were used as indicators of inactivation of bacteria, while *Ascaris suum* was used as an indicator of helminth egg inactivation.

2. Method

2.1. Experimental setup

Different mixes of faeces, urine and water were made according to Table 1. Faeces and urine were collected from healthy volunteers and stored cold (<5 °C) until use. The dry matter content of faeces was adjusted to 17% using tap water (Vinnerås et al., 2006). Inactivation of ascaris eggs, *Salmonella* spp, and enterococci were studied at three different occasions and hence with different characteristics of urine and faeces. The study of ascaris egg inactivation was performed in 50-mL centrifuge tubes sealed with a rubber O-ring to avoid ammonia emissions. Each tube contained one permeable nylon bag (mesh: 35 μm) with ~10,000 *Ascaris suum* eggs obtained from adult *Ascaris suum* worms, which were collected from the intestines of slaughterhouse pigs. The eggs were harvested by

Table 1 – Faecal sludge compositions used in the study, with treatment name, type of toilet system delivering this composition of faeces, urine and flushwater and treatment indicators used.

Code	Sanitation system	Flush water [L/day]	Faeces [kg/day]	Urine [L/day]	Dry matter	Treatment indicators
PL1	Pit latrine	0	0.2	1	2.8%	*Ascaris*
PL2	Pit latrine	0	0.2	0.5	4.9%	*Salmonella*; *Enterococcus*
V1	Vacuum toilet	1.5	0.2	1	1.3%	*Salmonella*; *Enterococcus*
V2	Vacuum toilet	1.5	0.2	2	0.9%	*Salmonella*; *Enterococcus*
V3	Vacuum toilet	2	0.2	1	1.1%	*Salmonella*; *Enterococcus*
V4	Vacuum toilet	2	0.2	2	0.8%	*Ascaris*; *Salmonella*; *Enterococcus*
V5	Vacuum toilet	2	0.2	3	0.7%	*Ascaris*; *Salmonella*; *Enterococcus*
PF1	Pour-flush latrine	6	0.2	1	0.5%	*Ascaris*; *Salmonella*; *Enterococcus*
PF2	Pour-flush latrine	6	0.2	2	0.4%	*Ascaris*; *Salmonella*; *Enterococcus*