Gas release and ventilation in a dry toilet – comparison between different models (II) Results

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The scope of the work was to evaluate the gas emissions, temperature and relative humidity from composting in two dry toilets: Naturum, and Dual-layer dry toilet. The moisture content of the compost was improved by reducing air ventilation. In Dual-layer dry toilet gas emissions followed the same pattern as the moisture content. The composting performance of Naturum tended to be better than in Daul-layer dry toilet. For Dual-layer dry-toilet, the cumulative emissions were 2.9±28 mg of H_2S, 2508±20g for CH_4, and in last three periods 12g±193mg for NH_3. In Naturum, only the H_2S emissions could be quantified, being about 418±148mg. A moisture content of 35-40%, and air ventilation rate of only 5L/s for Dual-layer dry toilet and 2-3L/s for Naturum are recommended for a proper composting.

Keywords: air ventilation, dry toilet, moisture, NH_3, composting

Air flow measurement and gas emissions

The air flow measurement data is shown in Table 1. In Dual-layer dry toilet, the relative humidity (RH) was remarkably increased by nearly 80% with the reduction of air flow and was kept over 40% on average for the rest of the observation periods.

TABLE 1. Air ventilation adjustment details

Period	Air Flow		RH	Moisture Content
	Ventilation pipe(L/s)	Inside composter (m/s)	(%)	(%)
(a) Dual-layer dry-toilet				
1	30	5	24	20.49
2	5	0.5	43	30.05
3	5	0.5	43	35.32
4	5	0.5	48	28.13
(b) Naturum dry-toilet				
Period	Air Flow (L/s)	Moisture Content (%)		
1	4.5	40		
2	3	64		
3	3	77		
4	3	46		

The moisture content of the composts was improved with the increased RH, and it was further enhanced by 5% in the third period by adding extra 8L of tap water to the composter. In Naturum, a high moisture content of compost was obtained immediately after the reduction of air ventilation.

Table 2 shows the average concentrations of gas emissions. The O_2 contents were kept at a constant level which was close to ambient (20.8%). H_2S was detected from both toilets, whereas CH_4 was detected only in Dual-layer dry toilet and gave out the largest emissions among other gas measurements.

Table 2. Average gas emission concentrations

	Dual-layer Dry-toilet				Naturum			
Period	1	2	3	4	1	2	3	4
O_2 (%)	20.8	20.8	20.8	20.8	19.7	20.8	20.8	20.8
CO_2 (%)	0	0	0	0	0.02	0.2	0.25	0.12
H_2S (ppm)	0.14	1.15	0.14	0.15	0	0.38	0	0.25
CH_4 (ppm)	234	410	431	305	0	0	0	0
NH_3(ppm)	*Nil	8.8	9.9	5.0	(**Nil)			

*NH3 was not measured in the first period due to calibration accuracy
**MX iBird gas detector cannot measure NH_3

The concentrations of H_2S, CH_4 and NH_3 were calculated as mg/s by taking the air flow factor into account. The results are given in Table 3.

Table 3. Gas emission rates

Period	Air Flow (L/s)	RH (%) (%)	Temperature (□)	NH_3 (mg/s)	CH_4 (mg/s)	H_2S (mg/s)
(a) Dual-layer dry-toilet						
1	30	24.00%	22	Nil	0.46	5.9×10^{-4}
2	5	43.00%	22	3.1×10^{-3}	0.13	1×10^{-4}
3	5	43.00%	21	3.4×10^{-3}	0.14	9.7×10^{-5}
4	5	48.00%	21	1.7×10^{-3}	0.1	1×10^{-4}

(b) Naturum dry toilet

Period	Air Flow (L/s)	H_2S (mg/s)
1	4.5	0
2	3	1.25×10^{-4}
3	3	0
4	3	1.05×10^{-4}

The air temperature inside the composters of both toilets remained constant at about 21^0C.

The cumulative emissions of the gases in the 3 month period were calculated with the data in Table 2. For Dual-layer dry toilet, the cumulative emissions in four periods are 2.9±28 mg of H_2S, 2508±20g for CH_4, and in last three periods 12g±193mg for NH_3. In Naturum, only the H_2S emissions could be quantified, being about 418±148mg.

The TN value of Dual-layer dry toilet from the bottom and upper layer was about 1.41% and 0.89% respectively. Naturum contained similar concentrations as the lower part of Dual-layer dry toilet. The input nitrogen value of the Dual-layer dry toilet was higher than in the Naturum because of the urine input. TN in Naturum's compost had a similar value with the Dual-layer dry toilet's compost in the lower part.

Discussion

Forced ventilation supplies sufficient oxygen to compost, therefore we expected to have aerobic composting process in both toilets. In Dual-Layer toilet however the low CO_2 level inside the composter indicated that this system had anaerobic conditions. This was confirmed by the emission of CH_4 and H_2S, gases that form under anaerobic conditions (Table 2). Oxygen is supplied mainly to the surface of the compost, the middle compaction part of the compost suffered from lack of oxygen leading to formation of anaerobic regions within the compost. The air intake holes on the composters seemed to fail in handling this large quantity of compost mass.

In Naturum, there was no CH_4 detected (Table 2) suggesting that aerobic composting was taking place in this dry toilet. Indeed, oxygen availability is ensured by turning the compost through the rotary drum. In addition, according to a previous finding, the scale of the compost also affects the volume of the anaerobic and aerobic portions (Fukumoto et al.,

2003, Tanaka et al., 2009). The composting scale of Naturum is much smaller than that of the Dual-layer dry toilet, helping to reduce the volume of anaerobic portions. However, there were H_2S emissions recorded from the manual gas detector in the second and fourth period (Table 2), suggesting that in Naturum compost anaerobic conditions might prevail from time to time.

The ventilation in the periods 2, 3 and 4 was constant, therefore we can assess the effect of moisture content on the gas emission. In Dual-layer dry toilet the gas emissions dropped when the ventilation was reduced, CH_4 dropping more than 70% in the second period. In the rest of the measuring periods, the gas emissions followed the pattern of the moisture content. The air temperature in both toilets remained at a constant level of about 21°C. Mild composting temperature slows down the biodegradation rate of compost, decreasing the gas emission rate and quantity as compared with gas emission of thermophilic composting (Lopez Zavala et al., 2004). Having mild temperature and low level of CO_2 emission in Dual-layer dry toilet, the composting process is believed to be relatively slow without any rapid aerobic degradation. The biodegradation rate of organic matter is important in dry toilets because faeces and bulking material are added daily into the composter. In the Dual-layer dry toilet, the accumulation rate of faecal matter and bulking material might excess the degrading rate even though the capacity of compost is 400L if there are a lot of users. Consequently the cumulative layer might create a larger compaction which leads to more anaerobic gas emissions and also odour problems. The large composting capacity provides a long curing period to ensure pathogen destruction since human pathogens only have a limited life time outside the human body. Additionally, longer storing time is needed in the urine mixed composting toilets, since mixing of urine with faeces might lead to possible persistence of viruses (Hotta. et al., 2007). It is, therefore, not safe to empty the composter if the compost is not sterile due to the slow biodegradation rate.

In Naturum, the biodegradation rate might be higher than in the Dual-layer due to the higher moisture content of compost, encouraging microbial activity and permitting adequate oxygen supply. About 0.25% of CO_2 emission was recorded in the third period (Table 2), showing that aerobic composting process was taking place. Due to the limited composting capacity, the number of users needs to be restricted in order to avoid a high emptying frequency.

During composting nitrogen is lost because of ammonification (Hotta and Funamizu, 2007; Lopez Zavala and Funamizu, 2006). The prevention of NH_3 emission is important in order to keep N in the compost. In the case of the Dual-layer dry toilet, the NH_3 it dropped down nearly 50% in the last period along with the decreased moisture content, this reduction is believed to be caused by the acidic environment created by the anaerobic activity. The compost from the upper part of Dual-layer dry toilet's composter only had half the amount of total nitrogen value. In other words, the Dual-layer system tends to have a greater nitrogen loss than Naturum. This is due to the hydrolysis of urea from urine that leads to formation of NH_3 (Hotta and Funamizu, 2006b). Over all, the TN value in both composts is less 3%, that is, from the fertilizing point of view, considered relatively low (Bueno et al., 2007).

Conclusions

From the results it can be concluded that the moisture content of the compost is successfully improved by reducing air ventilation. The recommended moisture content for both dry-toilets is about 35-40%, which maintains the microbial activities in compost and keeps gas emission rate still relatively low. Air ventilation rate of 5L/s for Dual-layer dry toilet and 2-3L/s for Naturum ensure the required moisture content. Additionally, the composting performances can be improved if there are more users to keep a balanced C/N ratio in Naturum and to give moisture to Dual-layer dry toilet.

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