Gas release and ventilation in a dry toilet – comparison between different models (I)
Methods

Pui Ki Tsang, Hilda Marta Szabo*, Eeva-Liisa Viskari

Tampere University of Applied Sciences, School of Industrial Engineering, Environmental Engineering, Kuntokatu 3, 33520, Tampere, Finland
*corresponding author:hilda.szabo@tamk.fi

Abstract

The aim of the study was to understand the composting process in dry toilets from the composition of the gas mixture emitted during composting. In this article we present our methods of study. Two dry toilet models were used: Naturum, where urine is separated from the faecal matter; and Dual-layer dry toilet with a mixed composter. The measurement time was of three months, divided into four periods in which the ventilation and/or the moisture content of the compost were changed. We followed the CO_2, H_2S, NH_3 and CH_4 emissions, temperature and relative humidity from composting under different conditions.

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

Introduction

Aerobic composting is the most favorable method for treating the human waste (feces and urine) in a dry toilet system. The end-product of the aerobic degradation of feces is an organic fertilizer or soil enrichment material, rich in nutrients such as N, P and K. The quality of compost depends on the amount of nutrients left in the end product. Meanwhile P and K remain in the solid compost, N can be lost as volatilized NH_3 during composting (Szanto G.L. et al., 2006; Sanchez-Monedero, 2000; Hotta and Funamizu, 2006b). In general, for a dry toilet to function properly the proper control of water balance (about 60% moisture content), temperature, C/N ratio as well as pH of the toilet compost is needed. These parameters affect directly or indirectly the biodegradation performance and the quality of the resulting compost (Jenkins, 1999; Lopez Zavala and Funamizu, 2006.).

The objective of this study was to examine the gas emissions from the composting in real dry toilets installed in TAMK premises, under variable air ventilation and moisture conditions by using an automatic gas control system and manual gas detector. The results of this study could help to evaluate the optimum conditions for "humanure" composting and eventually to improve the design of the particular dry toilet types based on operation performance and compost quality.

Dry Toilets

Two dry toilets with different capacities were chosen to be the study targets; Naturum is a urine-diverting toilet (UDDT) with 30 L composting capacity and Dual-layer dry toilet is a urine-mixed system (UMDT) with 400L composter. Both of the toilets were manufactured by a Finnish Company BIOLAN Oy., which sells wide range of dry toilets, compost and water purifying related products and services. The toilets were installed indoors and got used in TAMK in 2009. After a year of usage, both toilets seemed to have poor composting performance under a visual study because of the significant air ventilations, leading to heat and moisture losses. The moisture contents of the composts from both toilets were relatively low, about 40% for Naturum, and only about 20% for Dual-layer dry toilet.

In the Dual-layer dry toilet UMDT urine was mixed with the compost to provide it with moisture and nitrogen that otherwise might have been lacking due to limited amount of users (about 15 using times/month). BIOLAN peat was employed to be the bulking material for balancing the C/N ratio. The toilet seat is connected with the 400L composter underneath (Picture 1). The whole composter is surrounded by insulator, to prevent heat loss. The low-temperature composting assured by this composter with low-maintenance requirement is expected to yield relatively pathogen-free compost after a period of time.

Picture 1. Dual-layer dry toilet composter

Picture 2. Naturum dry toilet

The Naturum dry toilet is a urine-diverting dry toilet (UDDT) (Picture 2). Its key part is the rotary drum composter set up right at the back of the toilet, having an emptying container in it. It requires no electricity, water or chemicals to operate. It is designed for four persons in continuous use. Operation of Naturum is based on the composting of solid waste and separation of liquid in the toilet seat. When solid waste, including toilet paper and bulking material, drops into the drum through the seat opening, it is transferred to the composter by depressing mechanically the foot pedal a few times. The fresh waste will be covered to avoid creating any odour, and in the meantime, the compost is mixed by rotating the drum. The excess compost gradually drops into the emptying receptacle with the growing mass, and then the amount of the mass in the drum remains constant. The urine is diverted into the urine tank at the basement, through the urine hole at the toilet bowl. It is recommended to ‘flush’ the urine with small amount of water after every single use to prevent crystallization of struvite. In Naturum, a specific bulking material is used, its required amount is only half of the normal ground peat, which is normally used in dry toilet. The Naturum bulking material had about 97% of moisture content and the granule is completely decomposed in the compost (Biolan Oy., 2010).

Measurement periods

The whole study and the measurement period were divided into four periods, according to the adjustment of air ventilation and moisture content (Table 1). The first period worked as a ‘blank sample’ without any changes or modifications, so to give a reference for comparing the results. In the second period the air ventilation was fixed to raise the relative humidity (RH) of the composting environments in both dry toilets. At the middle of the second period, compost samples from both dry toilets were taken for total Kjeldahl nitrogen (TKN) test. In the third period, a one week time was used to increase the moisture content of the compost by adding tap water from time to time. In the last period, the dry toilets were closed for observation and monitoring.

TABLE 1. Time table of the measurement periods

Period	Duration	Date	Note
1	3 Weeks (Week 1-3)	16.1-6.3.2012	Strong air ventilation 6.3.2012 Calibration for sensors
2	4 Weeks (Week 4-7)	7.3-3.4.2012	Reduction of air ventilation 1st TKN Test
3	1 Week (Week 8)	4.4-12.4.2012	Increase moisture content of compost
4	2 Weeks (Week 9-10)	13.4-27.4.2012	Closing of dry toilet

Measurements

The gas control system used in the case of Dual Layer dry toilet, provided by a Finnish company Sensorex Oy., is an automatic gas sensor system installed inside the composter. The electrochemical measuring system is equipped with five independent gas sensors, which are O_2 (% volumic), NH_3 (ppm volumic), H_2S (ppm volumic), CO_2 (% volumic), CH_4 (ppm volumic), as well as a combined sensor of RH (%) and temperature (℃). System control and data review could be done through an intranet program that saves the measurement data. The measurement period was set to be half an hour, meaning that gas sample is taken in every 30 minutes continuously for every day. The gas measurement in the Naturun toilet was done manually by using a mobile gas detector MX6iBird detecting oxygen (O_2), ammonia (NH_3), Hydrogen sulfide (H_2S), combustible gases (LEL/CH_4), as well as carbon dioxide (CO_2). Gas measurement followed the time table of Table 1. The measurements were taken 2-3 times a week and the gas samples were directly taken from the emptying bucket of Naturum.

Air flow measurements were done by using VelociCalc 9555 Multi-Function Ventilation Meter with two different probes; thermoanemometer probe model for duet measurement and rotating vane probe model for open air cone. The former applied to the measurement of the ventilation pipes of Naturum and Dual-layer dry toilet and the latter was used to measure the air flow inside the composter of dual-layer dry toilet. In Naturum, there was a hole prepared on the ventilation pipe that the sensor can be put inside. For Dual-layer dry toilet, measurements were taken from both ventilation pipes, and inside the composter. The measurements were taken in the first and second period to provide data for air ventilation adjustment.

The moisture content of the compost was measured according to the Finnish Standard SFS-EN 13040, with moisture analyser XM 60. Moisture contents of the composts were controlled by change of ventilation in the first and second period and by water addition in the third period. In order to raise the moisture content for dual-layer dry toilet, additional tap water, 8 litres in total, was added from time to time to the composter to achieve 50-60% of moisture content.

The total nitrogen (TN) analysis was done according to European Standard SFS-EN 13342. Samples were taken from the upper and the bottom layers of the Dual-layer dry toilet, and from the emptying bucket of Naturum in the second period. The masses of the particular gases eliminated through ventilation were calculated by using the ideal gas law.

For the assessments of the gas composition, average values of the gas emission measurements were calculated for each period and for each gas. For the approximations of the cumulative gas losses the standard errors of the means were also calculated. For statistical calculations Microsoft Excel was used to calculate the standard deviation. The calculated standard errors of the means were applied also to the ideal gas law, in order to estimate the errors of the amount of gases.

The results of this study are presented in the next article.

References

Biolan Oy. (2010). Instructions for installation, use and maintenance NATURUM, http://www.biolan.fi/english/default4.asp?active_page_id=818 > [Accessed 07 June 2012

Hotta S. Funamizu N. (2006a). Biodegradability of fecal nitrogen in composting process. Bioresource Technology 98, 3412-3414

Jenkins J. (1999). The humanure handbook. Grove City: Chelsea Green

Lopez Zavala M.A., Funamizu N. (2006). Design and operation of the bio-toilet system. Water Sciences & Technology (53-9), 55-61

Sánchez-Monedero M.A., Roig A., Paredes C., Bernal M.P. (2000). Nitrogen transformation during organic waste composting by the Rutgers system and its effects on pH, EC and maturity of the composting mixtures. Bioresource Technology 78, 301-308

Szanto G.L., Hamelers H.V.M., Rulkens W.H.,Veeken A.H.M. (2007). NH3, N2O and CH4 emissions during passively aerated composting of straw-rich pig manure. Bioresource Technology 98, 2659–2670

Authors

PuiKi Tsang received the B.Eng degree in Environmental Engineering from Tampere University of Applied Sciences, Finland in 2012, and MSc degrees in environmental technology from Lappeenranta University of Technology, Finland in 2014. Her current profession is engineer working in an environmental company in Hong Kong, in a field of mobile wastewater treatment unit.

Hilda Marta Szabo has BSc degree in Chemical Engineering and MSc degree in Environmental Engineering. She worked as teacher and as researcher in the field of water, environmental engineering and related analytical chemistry. Since 2011 she is senior lecturer at TAMK Environmental Engineering Degree Programme.

Eeva-Liisa Viskari has a PhD degree in Environmental Sciences. Since 1999 she has worked at TAMK Environmental Engineering Degree Programme as a senior lecturer and head of the degree programme. She has also been involved in several RDI projects in the field of environmental engineering and science, including sustainable sanitation and dry toilet technology.