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Emission characteristics and variation of volatile odorous compounds in the initial decomposition stage of municipal solid waste

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ABSTRACT

The odour pollution occurring in the initial decomposition stage of municipal solid waste (MSW), including collection, transfer and transportation, has not been sufficiently emphasised. Thus the emission characteristics of and variation in odorant generation in this stage were investigated through simulation experiments at different temperatures, waste composition and processing durations. Out of 120 odorous compounds, 52 were detected in seven categories under all tested conditions, with significant variations. In the total concentration and emission rate, ethanol generally showed the largest proportion (larger than 80% on average), followed by unsaturated hydrocarbons which were dominated by propylene (13.1% on average of concentration proportion). The total emissions rapidly increased with processing duration when the temperatures were 15 °C to 30 °C. The proportion of ethanol increased significantly from 40.1% at 6 h to 82.9% at 24 h at 30 °C. By contrast, a low temperature (5 °C) resulted in low concentrations, and propylene accounted for the largest proportion instead of ethanol. With increasing temperature, biogenic compounds with large proportions increased more rapidly than xenobiotic compounds because of accelerated biological process and volatilisation. The emission rates of oxygenated compounds, saturated hydrocarbons, unsaturated hydrocarbons and halogenated compounds significantly increased (by approximately 20% to 50%) with an increase in easily biodegradable portion in the MSW. The proportions were relatively stable with the MSW composition variation, suggesting that most xenobiotic compounds were also derived from easily degradable portions. The olfactory evaluation showed that organic sulphur compounds contributed the most (approximately 75% to 95%) to odour pollution at the beginning of the stage because of their extremely low olfactory thresholds, with methanethiol as the dominant contributor (approximately 50% to 80% when detected). Results of this study can provide useful information for an improved understanding and monitoring of odorant emissions in the initial decomposition stage of MSW.

1. Introduction

The generated municipal solid waste (MSW) in every developing country has been growing exponentially alongside the promotion of urbanisation and the improvement of living standards. According to the China Statistical Yearbook (2015), the amount of MSW collected and transported in China in 2014 reached 178.60 million tons, with an annual increase rate of approximately 8–10% (Cheng et al., 2007). The huge amount of MSW results in numerous adverse environmental problems, and odour pollution is one of the most serious ones, particularly in large cities with high population densities (Capelli et al., 2011). Odour, which can refer to both pleasant and unpleasant odours, is caused by one or more volatilized chemical compounds, generally at a very low concentration, that humans or other animals perceive by the sense of olfaction (https://en.wikipedia.org/wiki/Odour). The odour pollution from MSW is mainly caused by the volatile organic compounds (VOCs) from the degradation of the biodegradable components in the waste (Scaglia et al., 2011). Particularly, in China, the high percentage of food waste in MSW results in a high organic portion and high moisture, which create favourable conditions for producing significant amounts of odorants (Kim et al., 2009). MSW management facilities, particularly those located near residential areas, often face strong opposition from urban residents because of the irritating odorants emitted by the MSW (De Feo et al., 2013; Gallego et al., 2008). In addition to odour nuisance, odorous compounds also adversely affect human activities and the surrounding environment (Nicell, 2009). Moreover, prolonged exposure to odorants could lead to undesirable mental and physiological reactions, such as headache, anxiety and depression (Ding et al., 2012).

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The issues of odour pollution and nuisance caused by MSW have been presented from different perspectives in the literature. Presenting a social perspective, De Feo et al. (2013) suggested that residents should be adequately informed about the nature and specific characteristics of MSW facilities to avoid strong opposition, protests, and conflicts. From an engineering perspective, the stabilisation of the treated organic materials in MSW was considered a key to reducing the odour impact during the anaerobic digestion of MSW (Orzi et al., 2010). Moreover, from a scientific perspective, the effects of odour were found to result from a variety of interacting factors, including frequency, intensity, duration, offensiveness and location (Nicell, 2009). The odorant emissions from landfilling, which is one of the most commonly adopted approaches to MSW disposal, have been intensively studied. The characterisation of and temporal variations of the odorants emitted by different landfills have been investigated (Duan et al., 2014; Fang et al., 2012). Some researchers have also reported odour pollution from other MSW treatment facilities, such as composting plants, and focused on the identification, quantification and impacts of trace VOCs (Komilis et al., 2004; Scaglia et al., 2011).

The significant impacts of the collection and transportation of MSW on the environment should not be neglected (Pisoni et al., 2009). However, the odour pollution that occurs in the initial decomposition stage of MSW has not been sufficiently investigated. This stage normally includes the processes of dumping, collection, transfer (if any) and transportation of MSW and releases odorous compounds from organic decomposition and substance volatilisation. The corresponding waste bins, collection and transportation trucks and transfer stations play important roles in MSW management. These facilities are normally near population centres or residential zones; as a result, odour pollution and its direct impact on nearby communities have become a growing concern. Different strategies of waste collection and transportation have been implemented in different countries and regions to control the odour pollution caused by MSW facilities. For example, the MSW management principle of 'the day generates, the day disposes' has been adopted in Beijing. This scheme is different from the MSW management strategies of the countries or cities with relatively low population densities, such as Denmark and UK, where residual household waste is usually collected once a week or every fortnight (Gladding and Gwyther, 2016; Larsen et al., 2009). Some researchers have studied the emitted VOCs and their contributions to the pollution in the initial MSW stage of collection, transportation or transfer (Li et al., 2013). For example, more than 150 VOCs were identified, and the 30 most abundant VOCs from urban waste disposal bins were quantified (Statheropoulos et al., 2005). In the previous study of the current authors, the concentrations, environmental impacts, and olfactory impacts of different VOCs emitted from a waste transfer station were also quantitatively evaluated (Zhao et al., 2015).

Furthermore, the odorant emissions in the initial decomposition stage of MSW are affected by many environmental and operational factors, including temperature, MSW composition and processing duration. To reveal the characteristics of and variations in odorant generation at different temperatures, waste compositions and processing duration, this initial stage was simulated in a laboratory and the gas samples at different conditions were analysed in this study, with all the detected volatile compounds causing the sense of olfaction involved. The simulation was based on the MSW management strategy in Beijing, China; because of the different climate conditions, waste compositions, management strategies and activities, it should be very cautious to generalize the results and conclusions in other MSW systems. The odour pollution was further investigated in terms of the olfactory impacts and concentrations and emission rates of odorants. Subsequently, the typical odorants in the initial decomposition stage of MSW were identified. The results of the present study could provide an improved understanding of odorant generation in the initial decomposition stage of MSW and useful information for the monitoring and assessment of the odour pollution resulting from MSW management.

2. Materials and methods

2.1. Simulation scheme for waste fractions

The MSW simulated in this study was divided into three portions according to their biodegradability, namely easily biodegradable, biodegradable and non-biodegradable portions, to control their fractions in the simulation experiments. MSW fractions extensively vary; thus, the three portions were prepared in certain fractions based on the average of the MSW in Beijing (Yang et al., 2015). The fractions of the MSW for simulation are presented in Table 1.

During the material preparation, wastepaper, fruit waste, wood and yard waste and textiles were cut into small pieces to homogenise the materials. This preparation method allowed for the use of the materials in all the trials and facilitated their sampling for the measurement of the total solid (TS) and volatile solid (VS) contents. Food and fruit wastes were collected an hour before the experiments and sampled immediately for TS and VS content measurement. The water content was calculated by measuring the weight loss after drying at 105 °C to a constant weight. VS was calculated using the weight loss after further furnace ignition at 600 °C for 1 h. The data are shown in Table 2.

2.2. Experimental apparatus and design

Three customized reactors made from Plexiglas were used in this study. As shown in Fig. 1, each reactor has an effective volume of 3 L and an inner diameter of 15 cm; its screw thread at the top is 5 cm in height, and it has a corresponding thread cap. The insulation device comprises a constant temperature box and a refrigerator. The reactors with such a scale were capable of controlling temperature uniformly, containing distinguishing waste compositions, and simulating the whole process of waste dumping, collection, transfer and transportation by operated according to the duration strategy.

As mentioned in Section 2.1, the easily biodegradable, biodegradable and non-biodegradable portions were mixed in certain fractions in accordance with the actual MSW compositions in Beijing to study the key factors and their influences on the VOCs emitted during the initial decomposition stage of MSW. Consequently, the mass ratio of the non-biodegradable portion was fixed

Table 1
Fractions of simulated MSW.

Portion	Fraction	Percentage in portion (%)	Source
Easily biodegradable	Food waste	80	Obtained from a canteen
	Fruit waste	20	Obtained from a fruit shop
Biodegradable	Wastepaper	90	Waste newspaper
	Wood and yard waste	10	Woodchips from branches
Nonbiodegradable	Plastics	50	Commercial polyethylene particles
	Metals	1	Iron powder
	Glass	7	Small glass bead
	Textiles	12	Waste clothes
	Ash	30	Commercial quartz sand