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Volatile trace compounds released from municipal solid waste at the transfer stage: Evaluation of environmental impacts and odour pollution

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HIGHLIGHTS

- Volatile trace compounds released from a waste transfer station were evaluated.
- Contributions were compared in terms of concentration, impact potential and olfaction.
- As an oxygenated compound, ethanol presented the highest releasing rate and ratio.
- The impacts to different categories of environment and health were revealed by LCA.
- Odour pollution evaluation revealed methane thiol as a dominant sulphur compound.

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ABSTRACT

Odour pollution caused by municipal solid waste is a public concern. This study quantitatively evaluated the concentration, environmental impacts, and olfaction of volatile trace compounds released from a waste transfer station. Seventy-six compounds were detected, and ethanol presented the highest releasing rate and ratio of 14.76 kg/d and 12.30 g/t of waste, respectively. Life cycle assessment showed that trichlorofluoromethane and dichlorodifluoromethane accounted for more than 99% of impact potentials to global warming and approximately 70% to human toxicity (non-carcinogenic). The major contributor for both photochemical ozone formation and ecotoxicity was ethanol. A detection threshold method was also used to evaluate odour pollution. Five compounds including methane thiol, hydrogen sulphide, ethanol, dimethyl disulphide, and dimethyl sulphide, with dilution multiples above one, were considered the critical compounds. Methane thiol showed the highest contribution to odour pollution of more than 90%, as indicated by its low threshold. Comparison of the contributions of the compounds to different environmental aspects indicated that typical pollutants varied based on specific evaluation targets and therefore should be comprehensively considered. This study provides important information and scientific methodology to elucidate the impacts of odourant compounds to the environment and odour pollution.

1. Introduction

Odour pollution caused by volatile trace compounds released from municipal solid waste (MSW) has been one of the most critical public concerns, and the potential negative effects of these odourants on human health remains a debated issue [4]. As such, odour pollution is generally considered a nuisance, particularly in developing countries afflicted by rapidly increasing waste generation [21]. For instance, the daily generation of MSW in Beijing, the capital of China, is more than 18,400 t, and the total design capacity of all the treatment facilities increased from 10,350 t/d in 2006 to more than 20,000 t/d in 2013. Despite the significantly inadequate treatment capacities, planning and building new facilities have been contradicted because of the public concern on odour nuisance. Odour pollution has been a limiting factor in MSW management for both existing and developing facilities in cities [31].

Most odourant compounds emitted by MSW facilities are present at very low concentrations; as such, these odourants are considered volatile trace compounds. These odourants typically include sulphur compounds, oxygenated compounds (alcohols,

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aldehydes, ketones, acids and esters), aromatics, terpenes, halogenated compounds and saturated and unsaturated hydrocarbons [10,30]. Some of these trace compounds, including chlorofluorocarbons (CFCs), affect the environment through global warming, ozone depletion and photochemical ozone formation; similarly, carbon disulphide and toluene may cause human toxicity [16,5]. Despite the limited epidemiological evidence on the adverse health effects of MSW sites [29], the potential toxicity of related compounds to the environment and humans has been a concern of residents near the facilities [9]. These compounds generally cause varied levels of nuisance odour, which is more than a health risk because of the direct olfactory sensation of humans [15].

Odour pollution should be quantitatively evaluated to assess the impacts of volatile trace compounds and provide basis for the establishment of health protection zone [26]. Many studies have demonstrated the advantages and disadvantages of chemical, sensorial and senso-instrumental analyses. Gas chromatography coupled with mass spectrometry (GC/MS) is the most accurate and widely used chemical method for detecting and analyzing the concentrations of substances in the air [8]. Nevertheless, direct odour assessment through chemical analysis is complicated because of the interaction among the compounds and several uncertain factors [3,34]. The olfactory sensorial method using human noses as detectors, which can deal with the complexity of smells, has been one of the main odour assessment tools. In this regard, a dynamic olfactometer equipped with a dilution instrument was developed to determine odour concentration [2]. Senso-instrumental method,involving GC–MS coupled with olfactometric detection (GC–MS/O), is an improved odour determination technique, which offers a comprehensive understanding of the chemical nature and perceived smell of odourants [23]. However, most analytical methods, especially sensorial methods, are difficult to utilise for evaluation or prediction because they require actual measured data. Life cycle assessment (LCA), which is an efficient method for evaluating the environmental impacts of emissions, normally excludes odour pollution evaluation, given its spatial and temporal scales. Therefore, a convenient and objective method, similar to environmental impact assessment with life cycle thinking must be developed to determine the effects of odour pollution.

Odour pollution from the transfer stage normally warrants increased concern because transfer stations are situated near to residential districts. This study investigated odourant compounds released from a large transfer station in Beijing through in situ sampling and chemical analysis. The characteristics, impacts and contributions of the detected volatile trace compounds were evaluated and compared based on concentration, environmental impact and olfaction. Results provide significant evidence to comprehensively understand the impacts of odourant compounds from MSW management.

2. Materials and methods

2.1. Gas emission sampling from the transfer station

2.1.1. Description of the transfer station

A large MSW transfer station in Beijing city was selected as the study site. The transfer station contains sorting and compressing facilities with a design capacity of 2000 t/d. The transfer station currently accommodates 1200 t/d of household MSW collected from the downtown areas of Beijing city. Odour pollution is a major concern in residential areas situated near the transfer station. The station is operated under negative pressure, and the municipal government is planning to construct an enclosed workshop equipped with an exhaust gas treatment facility.

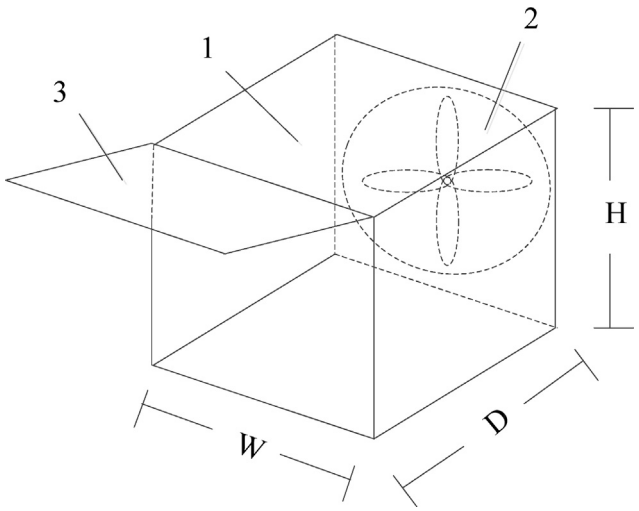

Fig. 1. Diagram of the enclosure of the exhaust outlet.
1—enclosure, 2—fan, 3—baffler, W—52 cm, H—54 cm, and D—50 cm.

2.1.2. Gas sampling method

The transfer station is operated under negative pressure, and gas is discharged from 15 fan-equipped exhaust outlets located on the roof of the facility. Each exhaust outlet is equipped with a square enclosure (52 cm width, 54 cm height and 50 cm depth) with a baffler (Fig. 1). In this study, four evenly distributed exhaust outlets were selected for sampling, with the sampling points located at the centre of the enclosures.

Gas sampling was performed during normal operation. Four points were sampled at a time interval of 5 min, and three replicate samples were collected at each point at a time interval of 20 min. Each sampling took 1 min to collect 300 mL of gas sample, and gas velocity was simultaneously measured using an anemometer to calculate the corresponding gas emission rate.

The specialised sampler system (SOC-01, National Key Laboratory of Odour Pollution Control of EPA-China) used in this study consisted of a sealed vessel containing a sampling bag, a sampling tube and a vacuum pump. The schematic of the sampler system was described in a previous study [12]. Gas samples were naturally drawn into bi-oriented polyester bags by vacuumising the sealed vessel with the pump. The disposable sampling bags were washed twice by sucking and discharging the gas in situ before sampling. The gas samples were analysed in the laboratory within 24 h.

2.2. Analysis of odour compounds

Considering most of the odourant compounds are volatile organic compounds, analysis was performed according to the methods described in US EPA TO-14 and TO-15 [39,40]. The gas samples were pre-concentrated using a three-stage cold trap concentrator (Entench 7100, USA) and then analysed through GC–MS. The GC (Agilent 7890A, USA) and the mass selective detector (Agilent 5975C, USA) were equipped with a column DB-5ms (60 m × 0.32 mm × 1.0 mm), with a temperature program of three ranges (35–150 °C with a rate of 5 °C/min, 150–220 °C at 15 °C/min and held at 220 °C for 7 min). In addition to the volatile organic compounds included in the US EPA TO-14 and TO-15, sulphur compounds and terpenes were also analysed because of their nuisance odour. As such, a comprehensive compound list was used to cover most common odourants. The standard curve for each compound was established prior to analysis by using a single standard substance or mixed standard substances (the same to the standard substances in TO-14 and TO-15). During the sample analysis, internal standard was applied to check and calibrate the accuracy of