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Emission of volatile organic sulfur compounds (VOSCs) during aerobic decomposition of food wastes

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A B S T R A C T

Food wastes collected from typical urban residential communities were investigated for the emission of volatile organic sulfur compounds (VOSCs) during laboratory-controlled aerobic decomposition in an incubator for a period of 41 days. Emission of VOSCs from the food wastes totaled 409.9 mg kg^{-1} (dry weight), and dimethyl disulfide (DMDS), dimethyl sulfide (DMS), methyl 2-propenyl disulfide, carbonyl sulfide and methyl 1-propenyl sulfide were the five most abundant VOSCs, with shares of 75.5%, 13.5%, 4.8%, 2.2% and 1.3% in total 15 VOSCs released, respectively. The emission fluxes of major VOSCs were very low at the beginning (day 0). They peaked at days 2–4 and then decreased sharply until they leveled off after 10 days of incubation. For most VOSCs, over 95% of their emission occurred in the first 10 days. The time series of VOSC emission fluxes, as well as their significant correlation with internal food waste temperature ($p < 0.05$) during incubation, suggested that production of VOSC species was induced mainly by microbial activities during the aerobic decomposition instead of as inherited. Released VOSCs accounted for 5.3% of sulfur content in the food wastes, implying that during aerobic decomposition considerable portion of sulfur in food wastes would be released into the atmosphere as VOSCs, primarily as DMDS, which is very short-lived in the atmosphere and thus usually less considered in the sources and sinks of reduced sulfur gases.

1. Introduction

Volatile organic sulfur compounds (VOSCs) refer to volatile organic compounds (VOCs) containing sulfur and mainly include organic reduced sulfur compounds (RSCs) like methylmercaptan (MeSH), dimethyl sulfide (DMS), dimethyl disulfide (DMDS), carbonyl sulfide (OCS) and carbon disulfide (CS_2). They have attracted great concern due to their health effects (Shuterman, 1992; Schiffman, 1998) and their roles in atmospheric chemistry (Andreae and Crutzen, 1997). As primary irritants and ubiquitous offensive odor pollutants with very low sensory thresholds (Devos et al., 1990; Table 1), VOSCs are widely regulated for their emission and presence in ambient air. For example, MeSH, DMS and DMDS have long been regulated for odor control by Ministry of the Environment of Japan (MEJ, 1971); CS_2 is a hazardous air pollutant according to the 1990 Clean Air Act Amendments (CAAA) of the United States; and the emission of MeSH, DMS, DMDS and CS_2 is limited by Ministry of Environmental Protection of China under GB 14554-1993. Apart from being odor gases, VOSCs like COS and DMS are involved in the chemical processes of atmospheric aerosol and cloud formation (Andreae and Crutzen, 1997; Faloona, 2009). Consequently their mixing ratios and fluxes, as well as their global budgets, have been widely investigated (Watts, 2000; Kesselmeier and Hubert, 2002; Geng and Mu, 2004, 2006; Yi et al., 2008; Faloona, 2009).

VOSCs can be present in food as aroma compounds (Blank, 2002) or formed during fermentation (Landaud et al., 2008) and decay of food (Kim et al., 2009). They are not only major odor compounds in waste gases from agricultural operations and food industries (Rappert and Müller, 2005; Kim et al., 2006), but also an important class of malodorous gases from various waste treatment processes including landfilling (Kim et al., 2005, 2006) and composting (Vandergheynst et al., 1998; Smet et al., 1999). Emission of VOSCs from these treatment facilities may give rise to their airborne ambient levels in the neighborhood (Leach et al., 1999), and trigger complaints of sensory irritation by local residents. Due to high contents of organic matter and moisture (Tsai et al., 2007), food waste is easily decomposed by microbes to give off various

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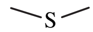
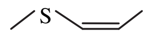
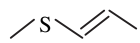
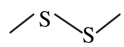
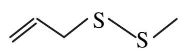
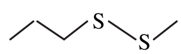
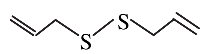
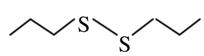
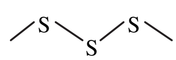
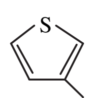
Table 1
Detected VOSCs: their chemical structures, odor threshold (μg m^{-3}), method detection limits (μg m^{-3}) and their production (mg dry kg^{-1}) based on the incubation results in the present study.

Compounds	Abbreviation	Structure	Odor threshold[a]	MS ions (m/z)	MDL	Production
Carbonyl sulfide	OCS	O=C=S		60[b]	0.26	9.11
Dimethyl sulfide	DMS		5.89	47, 62	0.16	55.29
Methyl 2-propenyl sulfide	M2-PeS			45, 73, 88	0.18	0.51
Methyl propyl sulfide	MPS			61, 90	0.20	0.53
Methyl 1-propenyl sulfide (Z)	M1-PeS(Z)			45, 73, 88	–	5.29
Methyl 1-propenyl sulfide (E)	M1-PeS(E)			45, 73, 88	–	0.26
Carbon disulfide	CS_2	S=C=S	302.00	47, 62	0.09	0.62
Dimethyl disulfide	DMDS		47.90	45, 79, 94	0.13	309.44
Methyl 2-propenyl disulfide	M2-PeDS			41, 120	0.25	18.80
Methyl propyl disulfide	MPDS			80, 122	0.19	2.28
Di-2-propenyl disulfide	D2-PeDS			41, 81, 146	0.16	1.46
Dipropyl disulfide	DPDS		446.68	43,108, 150	0.16	0.11
Dimethyl trisulfide	DMTS		8.71	45, 79, 126	0.14	3.15
Thiirane	TI			45, 60	0.12	0.07
3-Methyl thiophene	3-MT			97, 98	0.15	1.98

[a] Devos et al. (1990).
[b] Ions with underlines are target ions used for the quantitative calibration of the compounds.

volatile organic compounds (VOCs) (Komilis et al., 2004; Kim et al., 2009). VOSCs could share 35–38% of VOCs emitted during the aerobic composting processes of food wastes (Komilis et al., 2004) probably due to abundant sulfur contents in the food waste (Tian et al., 2007).

A considerable portion of annual food products is discarded as food waste particularly in developed countries like the USA and the UK (Jones, 2004; WRAP, 2008). Even in developing countries like China, food waste in recent years reached about 65,000 tons/day, accounting for approximately 43–76% of municipal solid wastes (MSWs) (Zhang et al., 2008). Food waste not only arouses great social and economical concerns (Kantor et al., 1997; WRAP, 2008), but also brings about enormous environmental problems, including the release of malodorous pollutants like VOSCs during rotting.

In China, over 80% of domestic wastes are treated mainly by the way of landfilling and composting (National Bureau of Statistics of China, 2008). As a result, odor irritation from waste transfer stations and landfills has become a major citizens' complain associated with waste disposal in recent years. Control of odor gases is therefore becoming an issue of increasing priority when treating MSWs. Since that food waste is an important component of MSWs, and that waste decomposition is initially an aerobic process in the early stage of disposal (in dustbins, transfer stations and early in landfills) by consuming oxygen from the air or remaining in the wastes (Statheropoulos et al., 2005), in the present study we collected food waste from dustbins in three residential communities in Guangzhou and conducted laboratory simulation to study the emission of VOSCs during aerobic degradation of food wastes.