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Characteristic analysis for odor gas emitted from food waste anaerobic fermentation in the pretreatment workshop

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Gas chromatography–mass spectrometry, olfactometry, and other related methods were applied for the qualitative and quantitative analysis of the characteristics of odorous gases in the pretreatment workshop. The composition of odorous gases emitted from municipal food waste was also investigated in this study. The results showed that the tested gases are mainly composed of aromatic gases, which account for 49% of the total volatile organic compounds (VOC) concentrations. The nitrogenous compounds comprise 15% of the total concentration and the other gases comprise the remaining 36%. The level of odor concentration ranged from 2523 odor units (OU) m⁻³ to 3577 OU m⁻³. The variation of the total chemical composition ranged from 19,725 µg m⁻³ to 24,184 µg m⁻³. Among the selected four sampling points, the discharge outlet was detected to have the highest concentration in terms of odor, total chemical, sulfur compounds, and aromatics. The correlation analysis showed that the odor concentrations were evidently related to the total chemical composition, sulfur compounds, and aromatics ($P < 0.05$, $n = 5$). The odor activity value analysis identified the top three compounds, hydrogen sulfide (91.8), ethyl sulfide (35.8), and trimethylamine (70.6), which contribute to air pollution complaint of waste materials.

Implications: Currently, the amount of food waste has rapidly increased, which leads to difficulty in waste management and more odorous gases released as air pollution. In processing of food wastes by anaerobic fermentation, odorous gases are generated, which significantly affect the workers and occupants in the plant. In the pretreatment workshop for anaerobic decomposition, the odorous gases are generated because of the stacking and decomposition of food wastes. The gases emitted mainly consist of organic gases because the food wastes are mainly organic materials. The other odors that comprise 1% of the gases are S-compounds, aromatics, esters, alkanes, and limonene, which result in unpleasant odors that are harmful to the health.

Introduction

To date, the amount of food waste disposal has rapidly increased, which leads to difficulty in waste management and more odorous gases being released as air pollution (Kim et al., 2008; Wu et al., 2010). The key methods for food waste management are landfill, compost, and anaerobic decomposition to produce biogas (Filippi et al., 2002; Mao et al., 2006; Levis et al., 2010; Das et al., 2003). Biogas fermentation is a new treatment process that is gradually applied in most cities in China. Unlike landfill and compost treatment processes, food waste should be pretreated, such as by separation and beating, before entering the anaerobic fermentation tank. Odorous gases are generated during the processing of food wastes, which come in direct contact with the workers and occupants in the plant. Therefore, the composition of these odorous gases and their adverse effect on human health should be investigated.

Odorous gases are generated in the pretreatment workshop due to the stacking and decomposition of food wastes. The gases emitted mainly consist of organic gases because of the organic content of food wastes. Currently, there are no reports published for the chemical composition of odorant. The existing research studies have imitated the main contents of gases from the studies of landfill, that is, methane and carbon dioxide. The odor compounds like S-compounds, aromatics, esters, alkanes, and limonene comprise only 1% of the emitted gases (Dincer et al., 2006). However, these minority-content odorants make a great contribution to the unpleasant sensing that may be harmful to the health (ATDSR, 2007; Hurst et al., 2005; Leong et al., 2002; Sarkar et al., 2003; Zou et al., 2003).

There are basically two types of method used for odor detection: olfactometry and instrumental chemical detection. Olfactometry is the most commonly used measurement (ASTM, 1997; CEN, 2003; Japan Ministry of the Environment, 2003; Taiwan EPA, 1994). It employs a panel of sensory-trained

experts to determine the concentration of diluted odor gases. However, this method is not able to quantify and qualify the composition and content of gases. The gas chromatography–mass spectrometry (GC-MS) technique is considered one of the most effective chemical detection methods and produces a list of substances involved and their concentration. Dincer and Davoli monitored the composition of odor gases in a landfill with the GC-MS technique (e.g., Dincer et al., 2006; Davoli et al., 2003). Both solid-phase extraction and GC-MS techniques were adopted in the Defoer and Tsai et al. studies to investigate the composition of odor gases in a composting plant (Defoer et al., 2002; Tsai et al., 2008).

The composition of food waste varies by season and region, which results in uncertainty of the chemical composition of odorous gases emitted by food waste during the pretreatment processes. This study aims to detect the composition of odorous gases and to characterize the pollutant content using human sensing technologies and GC-MS. The main pollution factors and rules are also analyzed. Moreover, this study would provide basic guidelines for the reduction of odorous gases during the recycling process of food wastes and the prevention of air pollution.

Materials and Methods

Site description

The food waste disposal plant in this study is one of earliest established plants in Beijing. It was first utilized in 2010 and disposes of 200 tons of wastes per day. Moreover, this plant uses anaerobic decomposition technology for food waste treatment and utilizes biogas as an energy source to generate electricity. Given the chemical complexity of food waste (Table 1), pretreatment is necessary before anaerobic decomposition to eliminate the dopants that cannot be fermented. Figure 1 shows the procedure of the technological process; the discharge inlet, crusher, beater, solid–liquid separator, and discharge outlet are located in the pretreatment plant, whereas the anaerobic fermentation tank is positioned outside the plant. The fermentable components were filtered, crushed, and beaten in the pretreatment plant before being sent to the anaerobic fermentation tank. The pretreatment plant is a relatively enclosed space and the odorous smell accumulates during the processing of waste.

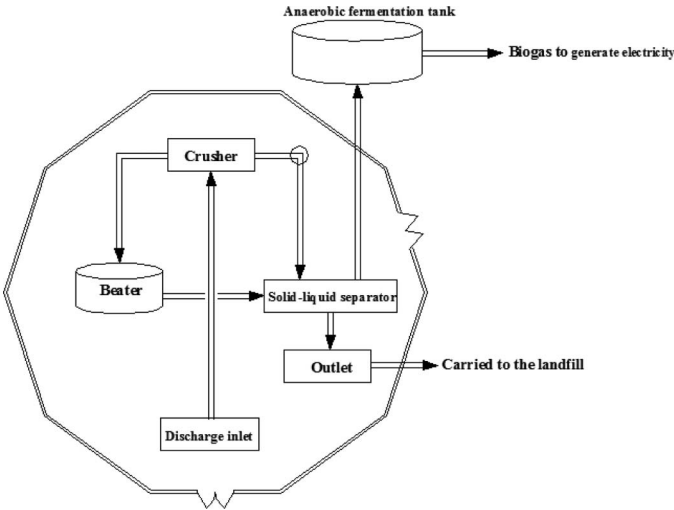


Figure 1. Production process layout of food waste anaerobic fermentation to produce biogas.

Sampling and analysis method

Olfactometry and solid-phase microextraction (SPME), followed by GC-MS, were used to determine the odor and VOC concentrations of the collected samples.

Sampling method. The sampling points were set at the discharge outlet, inlet, belt openings, and waste accumulation compartments. These four points were selected because they are exposed during the food waste disposal and become the critical pollution sources that emit odorous smells. Furthermore, the sampling points were set at 1.5 m above the floor, which is the average height of an adult’s inhaling level when standing. Sampling was carried out once in every month from March to July 2012. The food waste source, composition, and ambient environmental conditions were recorded for the corresponding sampling. The air in the sampling points was taken by an atmospheric sampling instrument (HL-1, Eesonline, China) and collected in 5-L Tedlar sampling bags (S-5L, PL Company, USA) for both GC-MS and olfactometry analyses. To avoid the contamination of samples,

Table 1. Main composition of food waste and weather condition survey during sampling

Month	Main composition of food waste	Temperature	Relative humidity (RH, %)	Atmospheric pressure (kPa)	Weather condition
March	Cooked wheaten food, leftovers (fish, meat), oil and grease	11.5–12.3	66.9–88.0	101.3	Sunny
April	Cooked wheaten food leftovers (meat, vegetables), oil and grease	18.6–19.4	83.8–93.0	101.3	Sunny
May	Peel, leftovers (meat, vegetables), plastic bags	22.3–22.6	64.5–76.2	101.3	Sunny
June	Rice, eggshell, peel, leftovers (fish, meat, vegetables), plastic bags	23.8–24.1	85.2–94.0	101.3	Cloudy
July	Rice, fruit, leftovers (fish, vegetables), plastic bags	26.6–27.6	69.6–75.5	101.3	Sunny

the odor bag is placed inside of a sealed container evacuated by a vacuum pump. The sealed container is connected to the inlet of sampling instrument while the flow rate is set at 0 to 1 mL/min. When the sampling instrument is started, the sealing container will be pumped to vacuum, while the sampling bags will automatically absorb the gas from sampling points under the condition of negative pressure. Finally, hydrogen sulfide, ammonia, and trimethylamine were collected separately using the solution absorption method, and were analyzed via spectrophotometry. Sampling bags and glass sample tube displaced three times use nitrogen gas before sampling, to ensure the purity of the acquired gas.

Chemical analysis. SPME and GC-MS (Trace DSQ, Finnigan, USA) were used for qualitative analysis, wherein the GC detector served as a flame ionization detector (FID) and the chromatographic column was set at DB-5 (diameter = 0.25 mm, column height = 30 m). The starting temperature in the GC was 40°C and was maintained for 3 min. After this, the temperature was increased to 250°C at the rate of 20°C/min and was maintained for 5 min. The temperature at the inlet and ion sources was 250°C. Moreover, the split ratio was 1:10 and nitrogen (carrier gas) was provided at 10 mL/min. Given that the FID was unable to test the sulfide content in the sample, a flame photometric detector (FPD) was utilized. In this case, the chromatographic column used was GAS-PRO (diameter = 0.32 mm, column length = 30 m). The starting temperature inside the GC was 40°C, which was held for 1 min. The temperature was then increased to 200°C at 20°C/min, and was maintained for 10 min. Finally, the inlet temperature was 250°C, with an initial oven temperature of 250°C. Nitrogen was provided at 1.2 mL/min without split flowing. VOC was quantified by external standard method. This method uses the relationship between peak areas and five analytic concentrations. The calibration curve is constructed after multiple, identical injections of a number of standard solutions of known concentration into the GC-MS. Methylene blue spectrophotometry was used to test the concentration of hydrogen sulfide in the sample (China Ministry of Health, 1989). The hydrogen sulfide in the air was absorbed by alkaline hydrogen cadmium oxide suspension, generating cadmium sulfide precipitation. In the sulfuric acid solution, hydrogen sulfide, *p*-aminodimethyl aniline solution, and ferric chloride solution reacted to produce methylene blue. The absorbance was tested at around 665 nm based on the colors in the colorimetric analysis. The composition of hydrogen sulfide in the air was calculated using the measured absorbance. Finally, Nessler's reagent spectrophotometry was used to test the composition of ammonia (China EPA, 2009). In this study, acid spectrophotometric measurement was used to test the trimethylamine concentration (Han and Lin, 2005).

Olfactometry analysis. The odor concentration of the samples and threshold was measured using a dynamic dilution instrument (AC'SCENT, St. Croix Sensory, USA). The analysis method was based on approved standards (China EPA, 1993). Importantly, the six assessors selected to determine the odor in the samples

were all sensory-trained professionals. In the step-by-step dilution using the dynamic dilution instrument, a threshold will be reached when the odorant cannot be perceived.

Statistical analysis. Statistical evaluation of the data was performed using SPSS Version 8. In academic research, the Pearson correlation coefficient is commonly used to compare the linear correlation between two variables (Neter et al., 1996). It is adopted in this study to analyze the relationship of odor concentration and total chemical concentration, as well as the single variable or multivariate linear correlation between odor concentrations and VOCs.

Results and Discussion

Composition and concentration of odorous gases

Different compounds were found in the odorous samples collected from the four sampling points. 29 VOCs were measured (Table 2), which were classified as S-compounds (e.g., hydrogen sulfide and ethyl sulfide), N-compounds (e.g., ammonia and trimethylamine), aromatics (toluene and naphthalene), alkanes (e.g., tetradecane), esters (e.g., dibutyl phthalate), acids (e.g., 4-(*para*-tolyl)-butyric acid), and other compounds (e.g., decanal, phenol, and limonene). The measured concentrations of several compounds were dramatically higher than those in the landfill, especially the concentration of aromatics, which are all above 1500 $\mu\text{g m}^{-3}$, much higher than in the landfill site (Ding et al., 2012; Davoli et al., 2003; Dincer et al., 2006; Fang et al., 2012; Zou et al., 2003). This could result from the slower production with the covered landfills, wherein the odors emitted by biodegradable substances are released slowly. As compared, the food waste treatment workshop in this study was relatively open, which led to high concentrations of odorous gases in the air.

The tested compounds and their concentrations were categorized as follows: aromatics (49% of the total concentration), other compounds (28%), N-compounds (15%), volatile fatty acids (4%), alkanes (2%), S-compounds (1%), and esters (1%). The substances with highest concentrations in each category were naphthalene (1651 $\mu\text{g m}^{-3}$), limonene (3735 $\mu\text{g m}^{-3}$), dimethylacetamide (2404 $\mu\text{g m}^{-3}$), 4-(*para*-tolyl)-butyric (1581 $\mu\text{g m}^{-3}$), docosane (504.9 $\mu\text{g m}^{-3}$), ethyl sulfide (281.3 $\mu\text{g m}^{-3}$), and phthalate (157.7 $\mu\text{g m}^{-3}$). In the pretreatment workshop, the composition of the aromatic compounds was relatively higher and more varied than that of the other compounds, which could be attributed to the common use of plastic bags. The generated limonene in the test is attributed to the use of air cleaners, washing liquids, and the presence of vegetables (Zou et al., 2003).

Odor and total chemical concentrations

The results of the olfactory and chemical analyses for the four different sampling points in the pretreatment workshop are shown in Table 3. The total concentration is the sum concentration of all the tested compounds. The tested odor concentrations

Table 2. Odor gases composition and content for food waste in the pretreatment workshop ($\mu\text{g m}^{-3}$)

Category	Composition	Average concentration	Landfill concentration	Reference
S-compounds	Hydrogen sulfide	44.1 (38.8–54.6)	56.58–514.52	Ying, 2012
	Ethyl sulfide	281.3 (259.9–328.9)		
	(Methylthio)ethane	17.9 (12.6–23.7)	1.56–5.30	Ying, 2012
	Methyl mercaptan	1.4 (1.0–1.8)		
	Propyl mercaptan	5.2 (1.0–10.9)		
N-compounds	Carbon disulfide	5.4 (2.4–8.3)	0.04–5.05	Dincer et al., 2006; Ying, 2012
	Dimethyl disulfide	8.3 (5.3–9.6)		
	Ammonia	500.9 (341.1–628.6)	0.002–0.04	Ying, 2012
	Trimethylamine	340.2 (142.6–475.4)	520–4020	Ying, 2012
	Dimethylacetamide	2403.7 (2362.8–2463.3)	3.69–108.52	Fang et al., 2012
Aromatics	Styrene	1646 (1604–1698)	0.1–48	Dincer et al., 2006; Zou et al., 2003
	Toluene	1604 (1594–1614)	1.56–202	Dincer et al., 2006; Zou et al. 2003; Ying, 2012
	Ethylbenzene	1612 (1601–1624)	0.1–52	Dincer et al., 2006; Zou et al. 2003; Ying, 2012
	O-xylene	1587 (1582–1591)	0.02–72	Dincer et al., 2006; Zou et al. 2003; Ying, 2012
	Tetramethylbenzene	1564 (1555–1573)	0.60–10.77	Davoli et al., 2003
Alkane	Pentamethylbenzene	1577 (1573–1581)	0.02–27	Zou et al., 2003; Ying, 2012
	Naphthalene	1651 (1639–1666)		
	Methyl naphthalene	1612 (1581–1661)	0.1–2.1	Zou et al., 2003
	Tetradecane	496.0 (481.2–510.7)		
	Docosane	504.9 (489.8–520.0)		
Esters	Nonacosane	498.9 (493.3–504.4)	0.02–9.42	Dincer et al., 2006; Zou et al., 2003; Ying, 2012
	1,2-Benzenedicarboxylic acid, butyl octyl ester	145.5 (143.6–147.5)		
	Dibutyl phthalate	157.6 (135.1–180.2)		
Acids	3-Cyclohexen-1-ol, acetate	56.9 (50.8–62.9)	0.1–162	Zou et al., 2003; Davoli et al., 2003
	4-(<i>para</i> -Tolyl)-butyric acid	1581 (1547–1615)		
	Hexanoic acid, 2-ethyl	522.8 (507.5–548.1)		
Others	Decanal	2003 (1993–2014)		
	Phenol	1553 (1406–1737)		
	Limone	3735 (3220–5023)		

Note: The compositions of the compounds in the table are the average data for five sampling sites.

Table 3. Concentration of different type of compounds at sampling sites (odor concentration unit: OU m⁻³; chemical concentration unit: µg m⁻³)

Sampling sites	Odor concentration	Total chemical concentration	S-Compounds	N-Compounds	Aromatics	Alkane	Esters	Acids	Others
Discharge inlet	2924	19725	88.6	3412	7979	504.9	135.1	548.1	7057
Belt opening	2523	22028	343.7	3282	11285	502.4	180.2	507.6	6429
Discharge outlet	3577	24184	409.4	3050	129070	496.0	145.5	521.5	6655
Waste accumulation compartments	3295	22532	320.1	3234	11309	498.9	56.9	2095	5018

Note: OU m⁻³ is the content of odor in per cubic meter.

Table 4. Correlation coefficient analysis between compounds and odors

	Odor concentration	Total chemical concentration	S-Compounds	N-Compounds	Aromatics	Alkanes	Esters	Acids	Others
Odor concentration	1								
Total chemical concentration		0.93*							
S-compounds			0.65*	0.72*	-0.10	0.44	0.17	0.08	0.82*
N-compounds			-0.01	0.02	-0.09	0.64*	0.05	-0.27	0.67*
Aromatics				0.85*	0.01	-0.34	0.19	0.65*	0.72*
Alkanes					0.63*	0.02	0.68*	0.13	0.64*
Esters					1	0.71	0.90*	0.06	0.07
Acids						1	0.69*	-0.19	0.22
Others							1	0.42	0.33
								1	0.26
									1

Note: Asterisk indicates statistically significant ($P < 0.05$).

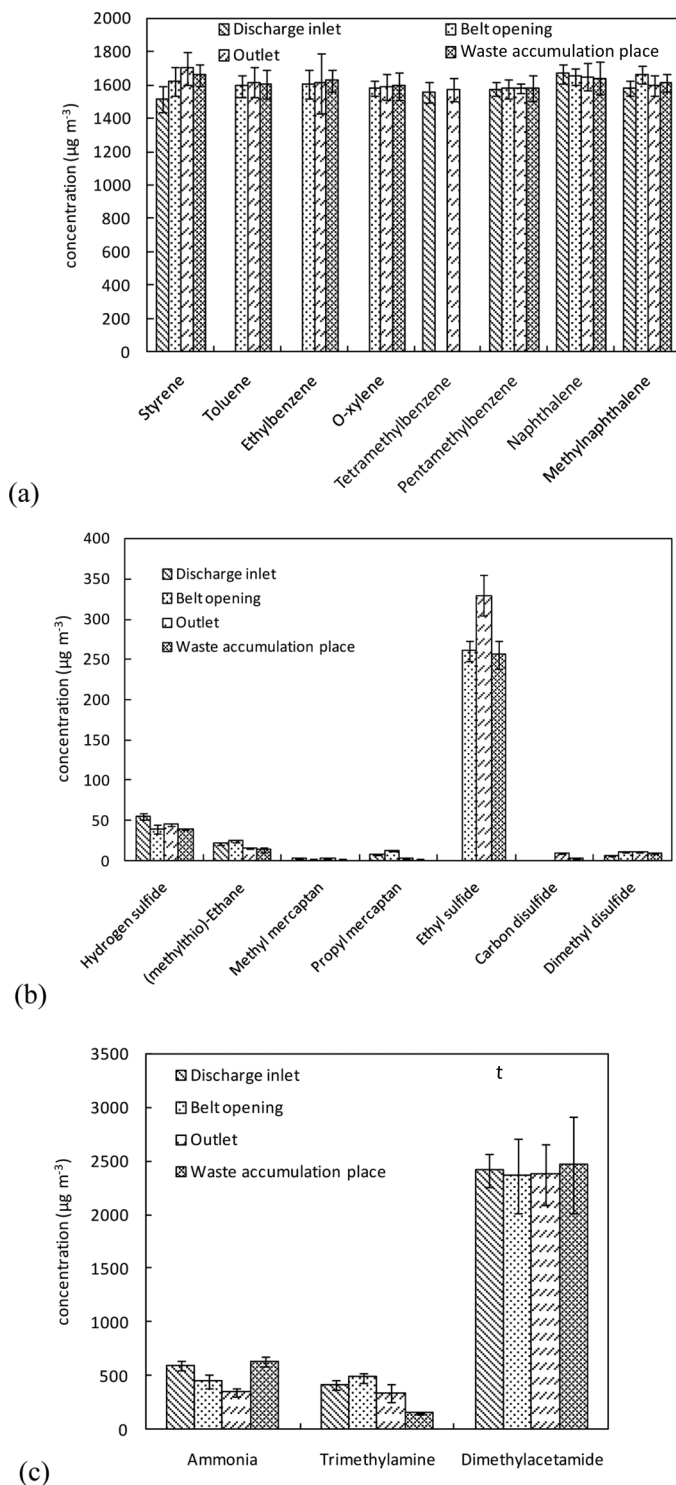


Figure 2. Chemical concentration horizontal distribution of aromatics (a), S-compounds (b), and N-compounds (c).

ranged from 2523 OU m^{-3} to 3577 OU m^{-3} , with an average of 3050 OU m^{-3} (OU m^{-3} is based on EN13725:2003-3 standard).

First, the range of total concentration fluctuated from $19,725 \mu\text{g m}^{-3}$ to $24,184 \mu\text{g m}^{-3}$, with an average of $21,954 \mu\text{g m}^{-3}$. In the four sampling points, the odor concentration, total

concentration, S-compounds, and aromatics were relatively higher at the discharge outlet, the most seriously polluted site. These might due to the increase in specific surface area after the waste materials were crushed and beaten, which led to a faster release rate of odorous gases, which increase the average concentration of the compounds. The highest concentration of acid was in the waste accumulation compartment because the accumulation of trash promoted the buildup of acid compounds.

Second, the odor concentration was tested by olfactometry. This method indicates the human perception and ranking of odors; hence, it is a suitable standard for determining the effect of odor control. The experimental measurement shows that the concentration level of odorant was highest at the charge outlet. Furthermore, among the seven tested compounds, three were concentrated at this sampling point. These three compounds were mainly S-compounds and aromatics, which had the most intense and harmful effect on the human body.

Finally, the odor concentration can be a useful and indicative standard to a certain degree. The conditions of severely polluted areas should be further evaluated in the future, particularly during ventilation design for the workshop and operation of plants or workshops, to reduce the adverse influence of high concentrations of odorous gases to human health.

This study tested eight types of aromatics (Figure 2a). The concentrations of these compounds were close to each other and were relatively high. Styrene, pentamethylbenzene, naphthalene, and methyl-naphthalene were detected at the four sites. Methyl-naphthalene was detected from the samples associated with the use of insecticides (Zou et al., 2003). Toluene, ethylbenzene, and o-xylene were not detected at the inlet, which can be attributed to the gradually emission of these compounds that occurred in the pretreatment process. The compounds in the samples can result in human poisoning and are harmful to human health after prolonged exposure. For example, styrene is a suspected carcinogen that simulates narcosis in the human body. The tested styrene concentration was higher than the threshold level of $390 \mu\text{g m}^{-3}$ in air, but lower than the limit of 50 mg m^{-3} specified in the “Workplace Harmful Factor Occupational Exposure Limit” (China Ministry of Health, 2007).

At the sampling sites, seven S-compounds were tested and analyzed qualitatively and quantitatively. Figure 2b shows that the diethyl sulfide concentrations at the conveyor, outlet, and waste accumulation compartments are 59.9 , 328.9 , and $255.1 \mu\text{g m}^{-3}$, respectively. Hydrogen sulfide was the second highest compound detected at all the four sampling sites because of rich protein content in food waste (up to 15.6%), which generates hydrogen sulfide (Ting et al., 2010). Thus, hydrogen sulfide is released abundantly in pretreatment workshops.

Furthermore, although the composition of (methylthio)ethane (12.6 – $23.7 \mu\text{g m}^{-3}$) and dimethyl disulfide (5.3 – $9.6 \mu\text{g m}^{-3}$), perceived as cacosmia smell, accounts for a minority portion, these were widely distributed in the workshop and were detected at the four sampling sites. Therefore, sulfide is a key compound in the pretreatment for anaerobic decomposition of food wastes and has evident smell characteristics, while the reduction of sulfide in the workshop is as important as that in landfills.

Finally, dimethylacetamide was found to be the key component in the tested N-compounds with a measured concentration of more than 2000 $\mu\text{g m}^{-3}$ (Figure 2c). However, this compound had no significant odorous smell and has a low toxicity level, and the threshold level for dimethylacetamide is dramatically high (165 mg m^{-3}). As compared, ammonia and trimethylamine have strong smells and can stimulate human discomfort. Based on the analysis of the processes, ammonia was generated during the degradation of normal food, while trimethylamine was generated by the degradation of fish and other food items with high protein content (Wan et al., 1993). Given that food waste in this plant mainly comes from luxury restaurants where the main component of food waste sources is fish and meat, these two tested compounds are present abundantly in the samples.

Relationship between odor and total chemical concentrations

The analysis for the relationship between odor and the total chemical concentrations of different compounds using localized tests has significant benefits. Therefore, this study investigated the association between odor concentrations and the different types of compounds.

The relationship between odor and the total chemical concentrations was analyzed using the statistical method. First, the relevance metric was determined by the values of variables. The relationship was then measured based on the Pearson correlation coefficient (Table 4). The results showed that a significant relationship exists between odor concentration and total chemical concentration of the S and N compounds ($P < 0.05$, $n = 5$).

Analysis of the total associated data between odor concentration and total chemical concentration of the five samples showed that the total chemical concentration related to the odor concentration was 87% ($r^2 = 0.87$, $n = 5$, $P < 0.05$). Based on the linear regression analysis of different odors and compound

concentrations, the concentration of aromatic hydrocarbon and ester had the best estimated parameters, with an 85% correlation with odor concentrations ($r^2 = 0.85$, $n = 5$, $P < 0.05$).

Odor activity values of the typical odor gases and odor intensity analysis

The correlation analysis determines the existing relationship between odor gas concentrations and the various types of compounds. However, further studies are needed for determining the main contents of complex compounds. The odor thresholds of relatively special compounds were tested in this study (Table 5). As compared to the range of odor threshold levels tested in other studies, the monitored levels in the current study varied with the standard range of variation (Devos et al., 1990; Nagata, 2003; O'Neil, 1992; Ruth, 1986). However, the odor detection thresholds for propyl mercaptan and ethyl sulfide have not been determined in previous studies.

The odor activity value is the ratio between the compound concentration and its threshold in the environment, which elucidates the actual influence of odors to the environment. Eight typical compounds were selected to be studied, given the high environmental sensitivity and obvious threshold that can be obtained.

Table 5 shows that the odor activity levels of hydrogen sulfide, ethyl sulfide, and trimethylamine were the highest, with the values calculated at 91.77, 35.83, and 70.58, respectively, as compared with the other compounds. Therefore, hydrogen sulfide, ethyl sulfide, and trimethylamine were the main contributors to odorous smell, and play an important role in air pollution.

Odor intensity reflects the perception of people toward odor. Thus, odor intensity was recorded at different sites in the workplace. The average intensity of each testing site was calculated based on the collected data. The intensity contour map was produced with assistance of SURFER, as shown in Figure 3. Based on the analysis in Figure 3, the odor intensity in the workshop was relatively higher at the inlet, outlet, and belt drive areas, with

Table 5. Odor threshold levels and odor activity values of typical odor gases

Compounds	Odor threshold ($\mu\text{g/m}^3$)	Odor threshold for other researchers ($\mu\text{g/m}^3$)	Tested chemical concentration ($\mu\text{g/m}^3$)	Odor activity values
Hydrogen sulfide	0.48	0.7–0.76 (mean: 0.73), from: Devos et al., 1990; Ruth, 1986	44.05	91.77
Propyl mercaptan	5.24	—	5.18	0.99
Ethyl sulfide	7.85	—	281.30	35.83
Ammonia	250	76–4074 (mean: 2075), from: Devos et al., 1990; Nagata, 2003; O'Neil, 1992	500.90	2.00
Trimethylamine	4.82	0.26–6.32 (mean: 3.29), from: Devos et al., 1990; O'Neil, 1992	340.20	70.58
Styrene	390	139–631 (mean: 385), from: Devos et al., 1990; Nagata, 2003	1645.68	4.22
Ethylbenzene	170	13, from: Devos et al., 1990	1612.07	9.48
Limonene	455	10–2455 (mean: 1233), from: Devos et al., 1990; Nagata, 2003	3734.65	8.21

Note: Odor activity value = tested chemical concentration/ odor threshold.

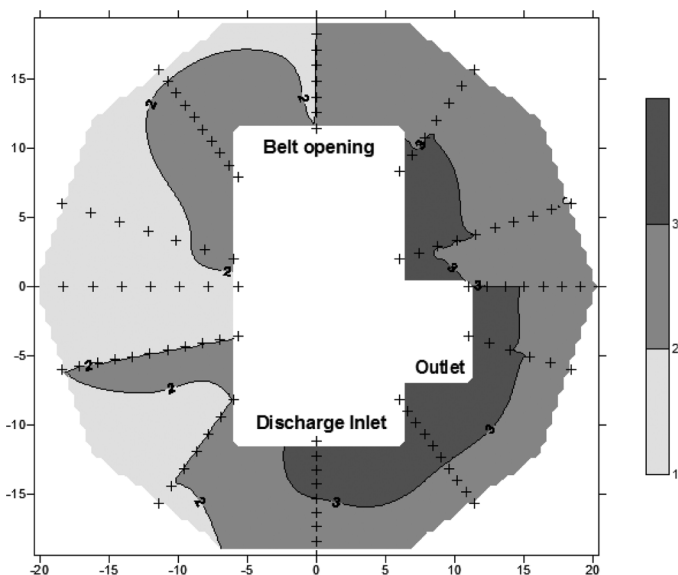


Figure 3. Odor intensity isopleth map in the pretreatment workshop of food waste anaerobic fermentation.

values higher than 3. The other areas in the workplace had values between 2 and 3. Therefore, the result was relatively similar to the total chemical concentration analysis discussed earlier.

Conclusion

This study investigated the composition, content, and distribution of odor gases emitted from the anaerobic fermentation of food waste. The tested odor concentrations can be considered as effective standards for indicative assessment, wherein the S-compounds were the main odor gases in the workplace, with significant odor characteristics. Twenty-nine volatile gases were determined, which were classified as S-compounds, N compounds, aromatics, alkanes, esters, acids, and other compounds. The correlation analysis showed that a close relationship existed between odor and total chemical concentrations. The correlation of hydrogen sulfide and aromatics had the best estimation values of approximately 85% variation with the concentration of odorous gases. Furthermore, based on the odor activity values, hydrogen sulfide, ethyl sulfide, and trimethylamine had greater contribution to air pollution, which coincided with the results of the odorous intensity analysis. Therefore, the test repeatability and reliability were relatively high for utilization in the analysis of similar studies.

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