

Reducing the Indoor Odorous Charge in Waste Treatment Facilities

E Gallego^{1*}, FJ Roca¹, JF Perales¹ and G Sánchez²

¹Laboratory Centre for Environment, Polytechnic University of Catalonia (LCMA-UPC), Spain

²Department of Prevention and Waste Management of Greater Barcelona, Spain

Abstract

Characterising and determining the odorous charge of indoor air through Odour Units (OU) is an advantageous approach to evaluate indoor air quality and discomfort inside municipal solid waste facilities. The assessment of the OU can be done through the determination of Volatile Organic Compounds (VOC) concentrations and their odour thresholds. The aim of the study was to evaluate the differences in the odorous charge in the organic matter pit of a mechanical-biological waste treatment plant with a processing capacity of 287,500 tons year⁻¹. The sampling was carried out during the months of September 2012 (original situation) and October 2012 (after emptying the organic matter pit drain pipe). 150 chemical compounds were determined qualitatively in the studied location, from which 102 were quantified due to their odorous characteristics as well as their potentiality of having negative health effects. The results obtained demonstrated that after a maintenance cleaning operation such as draining the organic matter pit pipe, the odorous charge inside the facility can be diminished in a great way, up to a 95%.

Keywords: Indoor air quality; Maintenance cleaning; Municipal solid waste (MSW); Odour units; TD GC/MS; Volatile organic compounds (VOC)

Introduction

Perceptible malodours in the indoor air of waste treatment plants have a considerable impact on occupational comfort, hygiene, health and safety [1,2]. Volatile organic compounds (VOC) are the main causes of odorous nuisances [3], being formed and released to the indoor environment of waste treatment facilities either from degradation processes of the organic matter or by degradation and volatilization of other materials treated. Hence, determining the odorous contribution of each VOC or family to the total odorous charge in the indoor air is a helpful method to identify, characterize and evaluate the most annoying chemicals in order to prevent their generation during the waste treatment processes, as well as to find solutions to suppress them [3]. The working thesis assumes the superposition of the individual odorous concentrations calculated through VOC concentrations and their concrete odour thresholds [3,4]. It has to be taken into account that possible effects derived from masking or synergies between the evaluated compounds are not considered, and that the total odour units (OU) determined by olfactometry could differ in a certain way [5-8]. However, it has also to be considered that OU calculated using the presented methodology in a previous study were in the range of 1200-28,000 OU [3], in accordance with OU calculated using dynamic olfactometry (5000-30,000 OU m⁻³) in similar facilities [9,10]. Additionally, several studies have demonstrated good correlations between olfactometrically determined OU and VOC concentrations [5,10,11]. The use of the presented procedure is advisable to be used when comparing differences in the odorous charge when changes in the processes developed into the facility are implemented [3]. The aim of this short report is to exemplify the effects of maintenance cleaning operations, such as draining the organic matter pit pipe, in the odorous charge of indoor air in a waste treatment facility.

Materials and Methods

Sampling strategy

The evaluation of the odorous charge in two scenarios (before and after a cleaning maintenance operation, i.e. draining the organic matter pit pipe) was done in the organic matter pit building of a mechanical-

biological waste treatment (MBT) plant located in the metropolitan area of Barcelona, which has a processing capacity of 287,500 tons year⁻¹ of municipal residues: selected organic fraction (100,000 tons year⁻¹), waste fraction (160,000 tons year⁻¹) and light packaging (27,500 tons year⁻¹). The selected organic matter fraction is discharged from the garbage trucks in a waste reception pit in a closed building. Organic matter is disposed in a conveyor belt by a bridge crane, led through a pre-treatment section, and eventually anaerobically digested to obtain biogas.

The organic matter pit building platform is cleaned twice a week according to a maintenance program consisting in the application of pressurized water. However, the organic matter pit pipeline is cleaned when lixiviates do not drain, without following a regular planification. Two samples from the organic matter pit indoor air were taken between 17th and 25th of September 2012 in the original conditions of the facility, without having emptied the lixivate pipe of the pit for 2-3 weeks, respectively. Additionally, on the 1st of October 2012 a sample was taken after 4 days of having purged the lixivate pipeline. VOC and VSC were dynamically sampled by connecting custom packed glass multi-sorbent cartridge tubes (Carbotrap 20/40, 70 mg; Carbopack X 40/60, 100 mg and Carboxen 569 20/45, 90 mg) and Tenax TA (60/80, 200 mg) tubes, respectively, to AirChek 2000 SKC pumps [12,13].

Analytical instrumentation

VOC and VSC were analysed by Automatic Thermal Desorption and capillary Gas Chromatography/Mass Spectrometry Detector using a Perkin Elmer ATD 400 (Perkin Elmer, Boston, Massachusetts, USA) and a Thermo Quest Trace 2000 GC (Thermo Quest, San Jose,

***Corresponding author:** Eva Gallego, Laboratory Centre for Environment, Polytechnic University of Catalonia (LCMA-UPC), Avda Diagonal 647, 08028 Barcelona, Spain, Tel: 34934016683; Fax: 34934017150; E-mail: lcma.info@upc.edu

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California, USA) fitted with a Thermo Quest Trace Finnigan MSD. Mass spectral data were acquired over a mass range of 20-300 amu. Samples were quantified by the external standard method. The methodology is described elsewhere [12].

Limits of detection, determined with a signal-to-noise ratio of 3, ranged from 0.001 to 10 ng. Compounds showed repeatabilities (% relative standard deviation values) \leq 25%.

Results and Discussion

Indoor air VOC concentrations

150 chemical compounds were determined qualitatively in the studied location, as it had been observed in a previous study [3], from which 102 were quantified (those compounds with a low odour threshold as well as those with toxicity component or potential negative health effects). Table 1 shows the chemical familial concentrations for each sampling day. Concentrations obtained were of the same order of magnitude than the observed in previous studies regarding

organic matter waste treatment, being terpenoids, alcohols, carboxylic acids and esters the mainly emitted compounds [3,6,14]. Generally, familial concentrations increase from 23-282%, with a global value of 45% between the two first samplings. Four days after cleaning, concentrations decreased a global value of 70% in respect to the sample taken 3 weeks after the last pipeline drainage (25th September). Terpenoid and aldehyde concentrations did not vary in a substantial way after the pipeline drainage process.

In the original scenario, alcohols, terpenoids, carboxylic acids, esters and ketones showed higher concentrations in respect to the other families evaluated, as observed in a previous study [3]. However, when the pipeline was drained, the most concentrated VOC were alcohols, terpenoids, ketones and aldehydes.

VOC concentrations did not exceed the VLA-ED (Table 2), the Spanish correspondence for Threshold Limit Value (TLV)-Time Weighted Average, as it had been observed in previous studies conducted in similar facilities [3,10,15]. However, as a great number

Family	17 th September	25 th September		1 st October	
	$\mu\text{g m}^{-3}$	$\mu\text{g m}^{-3}$	Increase (%) ^a	$\mu\text{g m}^{-3}$	Decrease (%) ^b
Alkanes	218	380	74	9.4	98
Aromatic hydrocarbons	551	761	38	47	94
Alcohols	91,161	124,464	37	21,129	83
Ketones	2854	4657	63	1064	77
Halocarbons	137	45	-67 ^c	11	76
Aldehydes	290	795	174	802	-1 ^d
Esters	2984	3664	23	178	95
Acids	3250	9884	204	163	98
Terpenoids	15,896	24,953	57	27,339	-10 ^d
Organosulfurs	165	219	33	10	95
Ethers	1.7	6.5	282	5.7	12
Furans	4.5	6.2	38	0.2	97
Glycols	123	155	26	7.0	95
Organonitrogenated	5.5	3.3	-40 ^c	1.0	70
Total VOC (mg m^{-3})	118	170	45	51	70

^aIncrease in concentrations (%) from 17th September to 25th September

^bDecrease in concentrations (%) from 25th September to 1st October

^cDecrease in concentrations.

^dIncrease in concentrations.

Table 1: Indoor familial concentrations ($\mu\text{g m}^{-3}$) in the organic matter pit.

Compound	17 th September	25 th September	1 st October	Odour threshold ^a	VLA-ED ^b	Vapour pressure ^c
Aromatic hydrocarbons						
m+p-Ethyltoluene	28.1	72.0	1.1	42	- ^d	0.4
Styrene	14.0	32.2	0.3	12	86,000	0.6
Alcohols						
1-Butanol	382	2521	31.6	480	61,000	0.9
1-Hexanol	28.7	56.0	1.1	40	-	0.1
1-Propanol	1733	4042	69.1	2000	246,000	3.5
2-Butanol	5161	7619	183	400	308,000	2.4
Ethanol	82,397	106,833	20,547	2000	1,910,000 ^e	7.9
Ketones						
Biacetyl	32.8	162	1.7	0.7	-	7.6
Aldehydes						
Acetaldehyde	221	651	786	2.7	46,000 ^e	120
Benzaldehyde	9.9	26.1	4.2	10	-	0.1
Isovaleraldehyde	2.6	3.3	0.3	1.6	-	6.6
Propanal	24.3	58.9	4.5	3.6	48,300 ^f	39.9
Esters						
Ethyl butyrate	38.8	113	0.6	0.017	-	1.7

Ethyl hexanoate	74.2	255	1.7	10	-	0.2
Ethyl isovalerate	0.8	2.2	0.04	0.1	-	1.1
Ethyl octanoate	2.8	13.4	0.2	6	-	0.03
Methyl butyrate	5.5	9.6	0.1	7.7	-	4.2
Acids						
Acetic acid	572	4070	95	90	25,000	2.1
Butanoic acid	16.0	365	1.8	0.35	-	0.2
Hexanoic acid	2653	5245	59.5	20	-	0.02
Propanoic acid	7.2	194	6.8	5.1	31,000	0.6
Terpenoids						
D-Limonene	14,600	22,851	15,798	1700	110,000 ^f	0.3
p-Cymene	640	726	11,457	200	-	0.2
α-Pinene	191	277	14.6	230	113,000	0.6
β-Myrcene	78.9	164	10.2	130	-	0.3
Organosulfurs						
Dimethyl disulfide	151	187	5.1	7	-	3.8
Dimethyl sulfide	13.3	24.2	0.3	1	25,800	86.3

^aSource: "Compilations of odour threshold values in air and water", L.J. van Gemert (TNO Nutrition and Food Research Institute). Boelens Aroma Chemicals Information Service (BACIS). The Netherlands (2003); "Odor Thresholds for Chemicals with Established Occupational Health Standards" American Industrial Hygiene Association. USA (2009); "Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990". EPA/600/R-92/047 (2009); and "Measurement of odor threshold by triangle odor bag method", Y. Nagata. Odor Measurement Review, 118-127, Japan Ministry of Environment (2003).

^bValor Límite Ambiental-Exposición Diaria: the Spanish correspondence for Threshold Limit Value-Time Weighted Average (TLV-TWA).

^cVapour pressure at 25°C (kPa)

^dNot established value

^eAs VLA-EC: Valor Límite Ambiental-Exposición de cortaduración (maximum of 15 min during the daily exposure)

^fProposed value

Table 2: Concentrations ($\mu\text{g m}^{-3}$) of selected relevant odorous VOC in the organic matter pit. Concentrations with grey shading exceed the odour threshold of the compound.

Compound	17 th September	25 th September		1 st October	
	OU	OU	Increase (%) ^a	OU	Decrease (%) ^b
Aromatic hydrocarbons					
m+p-Ethyltoluene	<1 ^c	1.7	- ^d	<1	100
Styrene	1.2	2.7	125	<1	100
Total OU Aromatic hydrocarbons	1.2	4.4	267	<1	100
Alcohols					
1-Butanol	<1	5.3	-	<1	100
1-Hexanol	<1	1.4	-	<1	100
1-Propanol	<1	2.0	-	<1	100
2-Butanol	13	19	46	<1	100
Ethanol	41	53	29	10	81
Total OU Alcohols	54	81	50	10	88
Ketones					
Biacetyl	47	232	394	2.4	99
Total OU Ketones	47	232	394	2	99
Aldehydes					
Acetaldehyde	82	241	194	291	-21 ^e
Benzaldehyde	<1	2.6	-	<1	100
Isovaleraldehyde	1.6	2.1	31	<1	100
Propanal	6.7	16	139	1.3	91
Total OU Aldehydes	90	262	191	292	-11^e
Esters					
Ethyl butyrate	2284	6654	191	34	99
Ethyl hexanoate	7.4	25	238	<1	100
Ethyl isovalerate	7.6	22	189	<1	100
Ethyl octanoate	<1	2.2	-	<1	100
Methyl butyrate	<1	1.2	-	<1	100
Total OU Esters	2299	6704	192	34	99
Acids					
Acetic acid	6.4	45	603	1.1	98
Butanoic acid	46	1041	2163	5.1	99
Hexanoic acid	133	262	97	3.0	99
Propanoic acid	1.4	38	2614	1.3	97

Total OU Acids	186	1387	646	10	99
Terpenoids					
D-Limonene	8.6	13	51	9.3	28
p-Cymene	3.2	3.6	13	57	-1483 ^e
α-Pinene	<1	1.2	-	<1	100
β-Myrcene	<1	1.3	-	<1	100
Total OU Terpenoids	12	20	67	66	-230^e
Organosulfurs					
Dimethyl disulfide	22	27	23	<1	100
Dimethyl sulfide	13	24	85	<1	100
Total OU Organosulfurs	35	51	46	<1	100
Total OU	2724	8741	221	414	95

^aIncrease in OU (%) from 17th September to 25th September

^bDecrease in OU (%) from 25th September to 1st October

^cConcentration of the compound below the odour threshold, hence, odour units below the unity.

^dIncrease not calculated due to the absence of OU from this compound the 17th September.

^eIncrease in OU.

Table 3: Odour units (OU) in the organic matter pit.

of VOC exceed their odour thresholds, they can lead to a lower employee satisfaction and productivity in the workplace, as well as to an increase of discomfort and personnel health hazards [15-17]. High VOC concentrations, even presenting lower values than TLV, can cause direct reactions such as sensory irritation of mucous membranes (eyes, nose and throat), and other individual's subjective symptoms like weakness, confusion, difficulty in making decisions, headache and memory loss [2,18]. In a previous study conducted in the same facility evaluated in the present paper, the total carcinogenic and non-carcinogenic risks (sum of selected VOC) were obtained in the ranges of 10^{-5} - 10^{-4} and 10^{-2} -6, respectively [15]. Even though, long term epidemiological occupational health studies in municipal waste management plants are scarce. Additionally, major differences exist among developed and developing countries in relation to health and safety management in this kind of facilities. More research in this field has to be promoted before long, and the use of biomarkers can be a crucial step in order to detect biological effects in the exposed workers before the illnesses are diagnosed [1].

Odorous charge

The OU, calculated by dividing the concentration of a specific compound by its odour threshold limit, indicate how many times the threshold limit has been exceeded [3]. The OU in the organic matter pit are presented in Table 3. Familial OU increase from 46 to 646%, with a global value of 221% between the two first samplings, a higher increase than in concentrations, mainly due to the low odour thresholds that present several compounds. Additionally, some compounds only generate OU on the 25th of September, when their concentrations are relatively high (e.g. certain alcohols, aldehydes, esters and terpenes). These compounds present odour thresholds between 6 and 2000 $\mu\text{g}\cdot\text{m}^{-3}$. The above mentioned compounds present the lower vapour pressures, between 0.03-4.2 kPa at 25°C, being less volatile than the other evaluated compounds, and only present in concentrations that generate OU when their accumulation due to lack of cleaning is produced. Carboxylic acids, p-cymene and α-pinene also present similar vapour pressures, yet they are the main released compounds from organic matter degradation processes [3,19]. Once the pipeline was drained, OU in the organic matter pit decreased a global value of 95%. Previously to the draining process, esters were the family that contributed most to total OU (Figure 1), as already observed in a preceding study [3]. After the pipe was drained, ketones, esters, carboxylic acids and organosulfurs decreased in a relevant way their

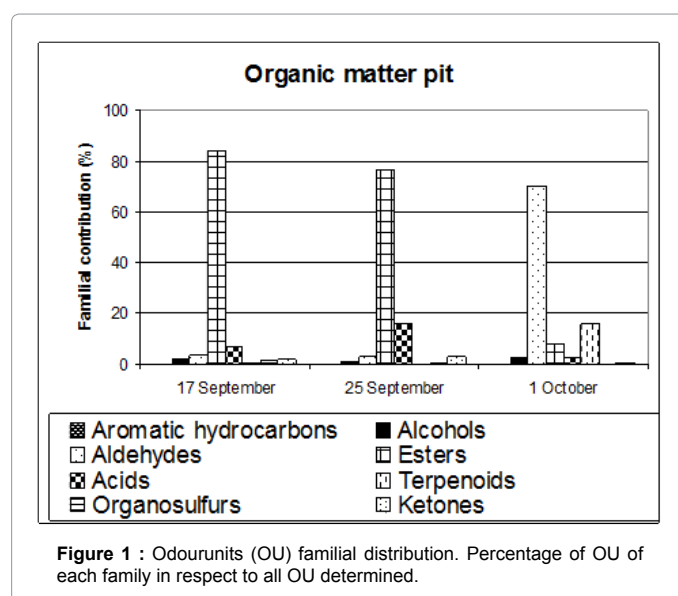


Figure 1 : Odourunits (OU) familial distribution. Percentage of OU of each family in respect to all OU determined.

contribution to the total OU. Hence, the main contributors to total OU in this second scenario were aldehydes and terpenoids.

Conclusions

The best way to avoid the nuisance produced by odours in a waste treatment plant is not generating them, reducing at a minimum the presence of VOC in the indoor air of the facility. The present study has demonstrated that with a simple maintenance operation odours can be reduced up to 95%. Programming a purging procedure instead of purging when the pipeline lixivates do not drain would decrease indoor discomfort related to odours. This work is a preliminary approach to the effects of cleaning maintenance programs in respect to ambient VOC. Deeper evaluations and more research are needed in this field.

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