Reducing the Indoor Odorous Charge in Waste Treatment Facilities

E Gallego1*, 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 evaluated compounds are not considered, and that the total odour units (OU) determined by olfactometry could differ in a certain way [5-8].

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 odour 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 odoriferous contribution of each VOC or family to the total odoriferous 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 odoriferous concentrations calculated through VOC concentrations and their concrete odor 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 odoriferous charge 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\(^{-2}\)) 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 odoriferous 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 odoriferous charge of indoor air in a waste treatment facility.

Materials and Methods

Sampling strategy

The evaluation of the odoriferous 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 lixiviate 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 lixiviate pipeline. VOC and VSC were dynamically sampled by connecting custom packed glass multisorbent cartridge tubes (Carbotrap 20/40, 70 mg; Carbopack X 40/60, 100 mg and Carbobox 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, USA).
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) ≤ 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 main 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 | 17th September | 25th September | 1st October | Increase (%)a | 25th September | 1st October | 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 | -67c | 11 | 76 |
| Aldehydes | 290 | 795 | 174 | 802 | -1d |
| Esters | 2964 | 3664 | 23 | 178 | 95 |
| Acids | 3250 | 9884 | 204 | 163 | 98 |
| Terpenoids | 15,896 | 24,953 | 57 | 27,339 | -10d |
| 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 | -40d | 1.0 | 70 |
| Total VOC (mg m⁻³) | 118 | 170 | 45 | 51 | 70 |

Table 1: Indoor familial concentrations (μg m⁻³) in the organic matter pit.
| Compound                  | 17th September | 25th September | 1st October  | Increase (%) | Decrease (%) |
|---------------------------|----------------|----------------|--------------|--------------|--------------|
| 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**            |                |                |              |              |              |              |
| L-α-Limonene              | 14,600         | 22,851         | 15,798       | 1700         | 110,000f     | 0.3          |
| p-Cymene                  | 840            | 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 thresholds 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 25ºC (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 (μg m⁻³) of selected relevant odorous VOC in the organic matter pit. Concentrations with grey shading exceed the odour threshold of the compound.
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 μgm^{-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%. Programming a purging procedure instead of purging when the pipeline lixiviates 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.

**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 lixiviates 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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| 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* |
| | α-Pinene | <1 | 1.2 | - | <1 | 100 |
| | β-Myrcene | <1 | 1.3 | - | <1 | 100 |
| Total OU Terpenoids | 12 | 20 | 67 | 66 | -230* |
| 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 |

*Increase in OU (%) from 17th September to 26th September

*Decrease in OU (%) from 25th September to 1st October

*Concentration of the compound below the odour threshold, hence, odour units below the unity.

*Increase not calculated due to the absence of OU from this compound the 17th September.

*Increase in OU.

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