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Measurement of Odour Concentration of Immissions using a New Field Olfactometer and Markers' Chemical Analysis

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A novel field olfactometer, Scentroid SM110 (IDES Canada Inc., 2012), based on a new technology, has been tested in comparison with another portable olfactometer, Nasal Ranger (St. Croix Sensory Inc., 2003). Responses of both devices during a measurement campaign were compared with odour predicted values by a dispersion model and with chemical data of emission marker's analysis.
The measurement test was performed in an anaerobic digestion plant located near Vicenza (Italy) and one typical odour source was a biofilter with an emission of 350 ou_E/m^3. The objective of this study is to compare different techniques (field olfactometry, marker's analysis, dispersion model) for assessing the concentration of odour in ambient air. The analysis of results shows a clear and measurable influence of background odour in ambient air, resulting in higher odour levels when measured using field olfactometry than is predicted using chemical analysis or dispersion modeling. Furthermore, a good agreement was found between chemical data and predicted values from CALPUFF dispersion model.

1. Introduction

Assessment of odour in ambient air is a very demanding task: sensorial analysis of field collected samples using dynamic olfactometry according to EN 13725 (2003) is not suitable for ambient air analysis, because the presence of a variable odour background in the field may strongly affect panel response.
Field measurement with portable olfactometers seems more effective, but the use of field olfactometers is not regulated in Europe so far, while it is popular in the U.S. and Canada, where several States set limits at the receptor sites or along the perimeter of odour emitting plants, expressed in units of dilution to threshold (D/T).
A field olfactometer is a portable device with a source of clean filtered air and a dilution system based on several calibrated orifices: the assessor may gradually reduce the dilution of external air until he perceives its odour, obtaining its D/T value, which can be easily compared with odour concentration expressed in ou_E/m^3.
The goal of this work is to compare different techniques for assessing odour concentration in ambient air. The results of portable olfactometers were compared with markers' chemical analysis: GC/MS analysis of pre-concentrated emission samples on Tenax tube (using Selected Ion Monitoring technique) may be helpful to determinate marker compounds at level as low as 0.01 $\mu g/m^3$.
In this field test we studied the dispersion of odour from the biofilter of an anaerobic digestion plant for Municipal Waste: the biofilter treats the exhausted air from the composting shed, releasing

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continuously the flow into the ambient air. In this paper we didn't take into account odour from other sources than the biofilter. So the Field inspections with portable olfactometers have been done around the biofilter: assessors stopped at different sites for odour field measurement and for sampling of ambient air at the same time. At the same sites, we sampled the ambient air; the samples were then analyzed at the olfactometric laboratory at Pavia University (Department of Pharmaceutical Sciences). The same samples were analyzed after preconcentration with GC/MS SIM (at the same laboratory in Pavia), for the determination of the marker compounds in the biofilter emission. Previously an approximate odour calibration curve versus marker concentration was built performing at the same time chemical and sensorial analysis of source samples at different dilution, with GC/MS SIM and with dynamic olfactometry respectively: odour concentration and marker concentration only for the biofilter emission were compared.
Then another comparison was made: an odour dispersion model (CALPUFF) simulated the odour plume around the biofilter; the odour concentration values predicted from the model were compared with D/T values from field olfactometry and with odour concentration values calculated by the marker calibration curve. In the past, the odour impact of the plant was already studied through several field inspections according to VDI 3940 (2006a; 2006b; Benzo et al., 2010) and their results were used to validate an odour dispersion model implemented to study the dispersion of the biofilter odour (Mantovani et al., 2011).

2. Instrumentation and Methods

2.1 Field Olfactometers

Two field olfactometers have been used: Nasal Ranger (St. Croix Sensory Inc., 2003) and Scentroid SM110 (IDES Canada Inc., 2012).
Field olfactometers are portable devices with a source of clean filtered air and a dilution system based on several calibrated orifices: the assessor may gradually reduce the dilution of external air until he perceives its odour, obtaining its D/T value (dilution to threshold), according to ASTM E679-04 (2011).
The Scentroid SM110 Field Olfactometer (IDES Canada Inc., 2012) allows accurate quantification of ambient odour strength using the same basic theory of lab based olfactometers. The SM110 draws a sample of ambient air via venturi vacuum pump and dilutes it using carbon filtered air from a high pressure compressed air tank. The mixed air is sent through a flexible hose to a disposable face mask.
Dilution ratio of clean air to sample air is controlled via Scentroid's patented flow regulator valve: the operator slowly increases concentration of the mix until the odour of ambient air is detected. When measuring odour concentration in ambient air, the operator may select between 15 dilution ratios (Table 1). The flow is regulated to provide a flow of diluted sample air at 20 lpm (in compliance to international standards EN 13725 (2003) and ASTM E679-4 (2011)), thus ensuring a positive pressure inside the mask to prevent ambient air from entering.
The Nasal Ranger Field Olfactometer in contrast uses carbon filters to directly clean ambient air to be used as the odour-free diluting gas. The filtered air is mixed with odourous ambient air at discrete volume ratios (McGinley et al., 2000).
The Nasal Ranger consists of a barrel with a nasal mask at the edge; two carbon filters are attached to the opposite sides of the Nasal Ranger housing. Dilution ratio of clean air to sample air is controlled via the D/T Dial, which contains six D/T positions (six orifices with traceable calibration), alternating with six blank positions for the user to inhale only odour-free filtered air (Table 1). The operator place his nose firmly inside the nasal mask, sets the D/T ratio turning the D/T dial, and inhales through the Nasal Mask; then the operator turns the dial, slowly increasing concentration of the mix, until the odour of ambient air is detected.
An electronic flow-meter built into the Nasal Ranger barrel measures the total volume of mixed airflow that is inhaled by the user and is travelling down the barrel on the way to the nasal mask: the inhalation flow rate should be within the factory calibration flow rate of 16-20 lpm.

Table 1: Dilution ratios of both olfactometers in D/T

Step	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Scentroid SM 110	100	59	44	34	27	23	18	12	10	8	6	5	4	3	2
Nasal Ranger	60	30	15	7	4	2									

2.2 Markers' Chemical Analysis

The chemical marker of an odourous emission should be chosen based on its high concentration in the emission, on its representativeness of the emission, on its absence in the background air, and on the ease of chemical analysis. It's not essential that the substance is odourous and that the substance is the one responsible for the odour. On the basis of these considerations we have chosen 1-methyl-4-(1-methylethyl)-benzene (common name p-cymene) as the marker: it is an aromatic hydrocarbon, produced by biological reduction of limonene, and it has been found in biofilter emission at concentration level as high as 2 mg/m^3.

P-cymene is a good choice as marker for the emission from the biofilter of an anaerobic digestion plant. In fact, it's one of the main substances in the emission, and it is not present in other sources or in the background ambient air in any significant concentration (lower than a few micrograms). Moreover, p-cymene is easily trapped in Tenax tube and adsorbed for GC/MS analysis (Benzo and Gilardoni, 2008).

For determination of p-cymene concentration, ambient air and biofilter emission were sampled in Nalophan bags through a vacuum pump; the samples were analyzed in a GC/MS system model 5973N (Agilent Technologies, USA) after preconcentration on a Tenax tube, deuterated internal standard addition and thermal desorption on TDS-2 (Gerstel, Germany), according to US EPA TO-15 method.

Odour concentration of biofilter emission was measured by dynamic olfactometry, with a TO7 olfactometer (Ecoma, Germany) and panel of selected assessors according to EN 13725:2003.

Odour concentration of ambient air samples were calculated multiplying their p-cymene concentration by the ratio between odour concentration and p-cymene content of averaged biofilter emission.

In Table 2 we show the concentration of p-cymene sampled with Nalophan bags in eight different measuring points and analyzed by GC/MS. The result of sample no. 1 is the average value obtained from the analysis of the biofilter emission: this is to conform to Italian standards such as DGR no. IX/3018, 2012 ("Guidelines for odour measuring", Lombardy Region).

Table 2: Marker concentration converted in odour concentration

Measurement Point N	1	2	3	4	5	6	7	8
p-cymene [µg/m^3]	1,987	185.9	229	72.5	130.4	68.7	6.4	3.7
ou_E/m^3	345	32	40	13	23	12	1	<1

2.3 Dispersion Modelling

Dispersion models are a useful tool for evaluating the impact of odour sources on the surrounding areas, as they can estimate the odour transport depending on the site weather conditions. In the model simulation used here (CALPUFF, Scire et al., 2000) the odours are treated as unreactive gaseous pollutants, released by the source as a series of packets of mass (puffs), at regular time steps. CALPUFF is a Gaussian-puff model, 3D and not steady-state: puff models are proved to be effective for the simulation of the dispersion of odours at local scale, in domains with complex terrain and meteorology issues. In addition, CALPUFF belongs to the class of regulatory models approved by US

EPA.

3. Experimental

The test was carried out during one day. A weather station was located near the biofilter for instantaneous data acquisition of wind direction and velocity, and meteorological variables were measured on-site to implement the preprocessor of dispersion model (CALMET).
Odour flowrate from the source was measured by dynamic olfactometry, sampling the emission with a hood on four different points of the biofilter surface. The emission was calculated as the average of the four samples. In the map, point 1 indicates the center of the biofilter emitting surface.
Two trained assessors equipped with portable olfactometers walked downwind to the biofilter avoiding to inhale ambient air, and stopped for measuring the odour in ambient air when the third assessor set the starting time: at that time they started operating the field olfactometers and measured odour concentration as D/T value. Two consecutive measurements were made for each chosen site, with portable olfactometers, meanwhile the third assessor sampled ambient air in Nalophan bag for analysis of chemical marker (Bokowa, 2010).
During the campaign, the prevailing wind came from north-east and had an average speed of 0.5÷1.3 m/s. Situations of calm winds occurred for 25% of the monitoring period (mostly at the end of the monitoring) and alternated with wind coming from north-east; calm winds are critical for odour dispersion, since they cause odour stagnation.
In this work, CALPUFF model was applied to evaluate the odour dispersion around the biofilter. The biofilter was simulated as an areal source, releasing odour with forced flux: the odour emission rate was assumed to be stationary and equal to 9583 ou_E/s (as measured by dynamic olfactometry).
At the end of the campaign, we measured odour concentration at seven sites, downwind the odour source: points 2 to 8 are placed at different distances from the biofilter, along the wind direction (Figure 1). The model calculated the odour concentration on the same sites, at the same time when the field olfactometry measurements were performed.

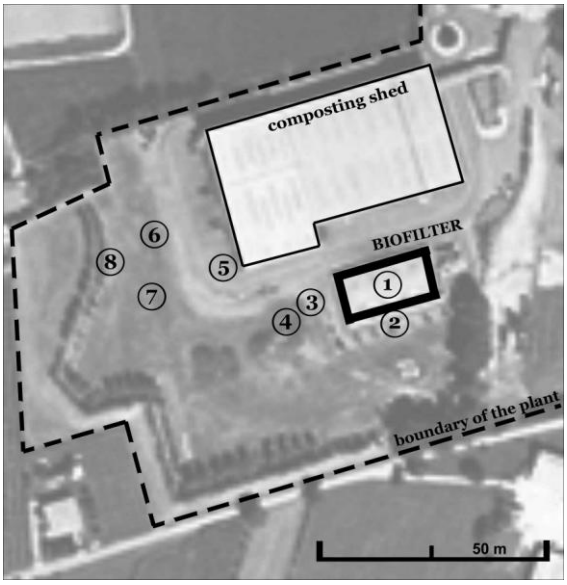

Figure 1: Sampling points

4. Results and Discussion

Results of this first test are summarized in the histogram of Figure 2, where D/T values are converted into ou_E/m^3 values for better comparison of results.
P-cymene strictly represents biofilter emission without any other contribution, taking no account of odours from other sources and of background odour in the field; the p-cymene concentration in ambient air typically decreases, as the distance from the biofilter increases (see points 3 to 8).
Both field olfactometers show similar values, always higher than p-cymene concentration, because the field olfactometers might sometimes be strongly affected by background odour in the field. For this reason, their results should be compared to the results obtained using dynamic olfactometry.
In fact, some background odour was perceived on sites 7 and 8 without any contribution of the biofilter (p-cymene < 10 $\mu g/m^3$, which is the background concentration). A different situation occurred at measurement sites 3 and 5, where the high perceived value may be explained by a second source of

odour: the points were located near the gates of the composting shed and assessors smelled both odours, i.e. biofilter and mature compost.
This testing verified that the new portable olfactometer Scentroid SM 110 is reliable for field measurements: the assessor, wearing the mask all the time, is usually less affected by background odour during measurement pauses and during the moves from a measurement point to another one. SM110 is provided with carbon filtered air from a high pressure compressed air tank; however, the time for odour inspection is affected by the air tank capacity.
Scentroid SM110 allows a better quality of the measurement (compared to measurement with the "Nasal Ranger" field olfactometer), because the scale from 2 to 100 (D/T) is divided in 15 steps, allowing more accurate readings. On the opposite the Nasal Ranger divides the interval from 2 to 60 (D/T) in only six steps (Table 1).
The model predicted values are very close to p-cymene concentration in ambient air, because the model strictly represents dispersion form biofilter, without any other contribution.

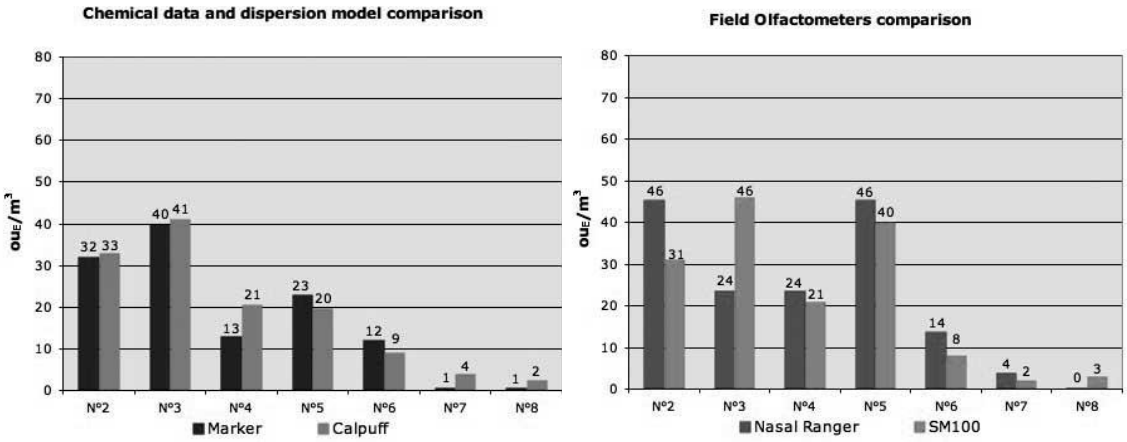

Figure 2. Comparison of results in every measurement point.

CALPUFF model calculated the odour concentration at each measurement site (points 2-8), for each sampling period; figure 3 shows plots of isoconcentration curves at ground level at points 4 and 5, during the sampling time. Point 4 and 5 lie respectively 47 m and 69 m far from the biofilter center, and 25 m and 47 m far from the nearest edge of the biofilter. Both sites were downwind during odour measurement and sampling.
Point 4 was downwind at sampling time: the wind came from east at 0.9 m/s; the plume is stretched along the wind direction. In this site the model predicted an average concentration of 21 ou_E/m^3 at ground level and the same concentration at a height of 1.7 m from the ground.
The odour concentration predicted by the model is a little higher than the odour intensity calculated by ambient air concentration of the marker p-cymene (corresponding to about 13 ou_E/m^3) in the same point at the same time. Odour concentration measured by portable olfactometers was a little higher (the operator using SM110 measured 27 ou_E/m^3, the operator using Nasal Ranger measured 24 ou_E/m^3). Chemical marker approach seems more effective for the purpose of dispersion model validation because results are not affected by background odour in the field, and single odours may be distinguished and verified separately.

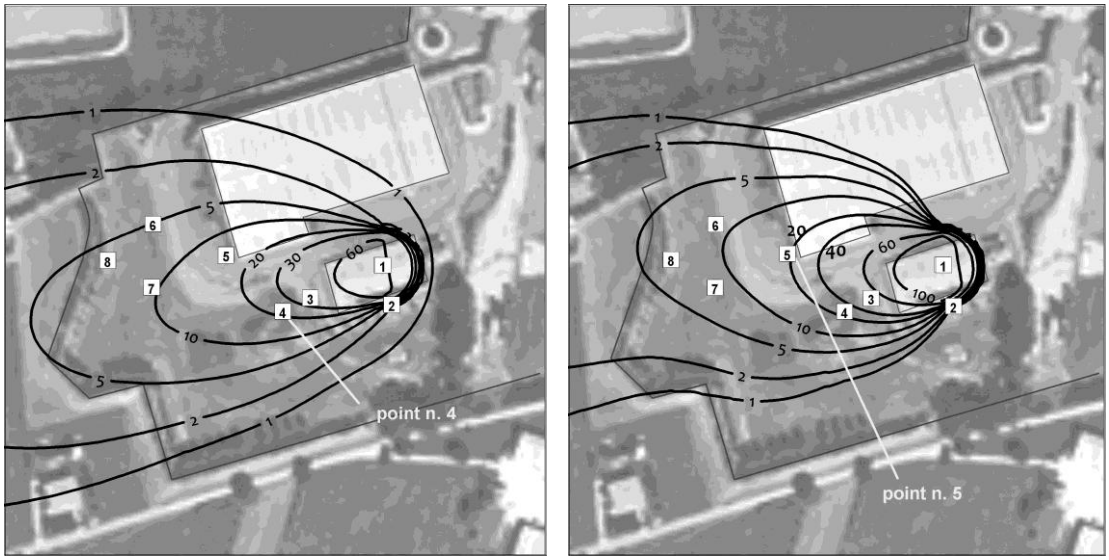

Figure 3. Isoconcentration curves during the sampling at point 4 and 5.

References

ASTM E679-04, 2011. Standard Practice for Determination of Odour and Taste Threshold by a Forced-Choice Ascending Concentration Series Method of Limits, USA.

Benzo M., Gilardoni G., 2008, Successful application of thermal desorption – GC/MS - olfactometry technique to the identification of main odorants in complex mixtures of volatile compounds, Chemical Engineering Transactions, 15, 199-206.

Benzo M., Pittarello A., Giacetti W., Gandini C., Caccialanza G., 2010, Full Application of Odour Field Inspection According to VDI 3940 in Italy: Odour Impact Evaluation of an Anaerobic Digestion Plant, Chemical Engineering Transactions, 23, 219-224, DOI: 10.3303/CET1023037.

Bokowa A.H., 2010, The Effect of Sampling on the Measured Odour Concentration, 23, 43-48, DOI: 10.3303/CET1023008.

EN 13725, 2003. Air quality and determination of odour concentration by dynamic olfactometry.

IDES CANADA INC, 2012, <www.scentroid.com>, accessed 29.3.2012.

Mantovani A., Pittarello A., Benzo M., Palmeri L., Ranzato L., 2011,

Odorigeno impact assessment of an installation of anaerobic digestion: comparison between a technical sense (Odour Field Inspection) and an atmospheric dispersion model (CALPUFF) (in Italian), Sardinia Symposium 2011.

McGinley C., Enforceable Permit Odour Limits, 2000, The Air and Waste Management Association Environmental Permitting Symposium II Chicago, USA.

Scire J. S., Strimaitis D. G., Yamartino R. J., 2000, A User's Guide for the CALPUFF Dispersion Model. Earth Tech, Inc., USA.

ST. CROIX SENSORY INC, 2003, <www.fivesenses.com/Prod_NasalRanger.cfm>, accessed 29.3.2012

VDI 3940, 2006a, Part 1: Measurement of odour impact by Field Inspection – Measurement of the impact frequency of recognizable odours - Grid measurement, Germany.

VDI 3940, 2006b, Part 2: "Measurement of odour impact by field inspection – Measurement of the impact frequency of recognizable odours - Plume measurement", Germany.