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Odour emission rates from a waste treatment plant: results from a multi year follow-up study.

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Results from a multi-year follow-up of a municipal solid waste treatment plant are presented. The plant has available both a landfill and a composting site. The study was focused on non-methane volatile organic compounds and other hazardous air pollutants emissions. Odour emission rates are presented as well. With a multi-disciplinary approach, emissions were characterized both chemically, with a gas chromatographic-mass spectrometry approach, and by dynamic olfactometry. Samples were collected in the last 8 years in different lots, from the biogas piping collection network as well as from the composting plant bio-oxidation and curing heaps. Chemical characterization is important to monitor emissions from toxicological aspects, while sensorial analysis, dynamic olfactometry, has been used to assess odour emission rates. Results show that in an operating landfill, total odour emission rate, due to uncollected landfill gas vertical extraction pipes, represent only 3.6% of the total theoretical emission rate of the capped landfill.

1. Introduction

The 99/31 EU landfill directive imposes strict targets for the reduction of biodegradable municipal waste that may be disposed of to landfill, namely a reduction to 35 % by 2016 of the total amount, starting from 1995. In 1995, about 107 M tons of biodegradable municipal waste were generated in the EU and Norway, being 66% landfilled. Source separation, separate collection, incineration, composting as well as limitations and bans on landfilling, are among the key instruments needed to reach this target.

Waste treatment plants are now large, complex realities where different biological processes take place under controlled conditions. Still the results are, mainly due to the large amounts of waste material treated, that landfills and composting plants face several environmental problems. Most of the problems come from the landfill gas (LFG), from its non-methanic volatile organic compounds (NMOCs). Among NMOCs, the volatile compounds, VOC, comprise about 39% of the total in a MSW landfill gas (EPA AP-42, Section 2.4, 1997). LFG composition is influenced from several factors like solid waste in landfill, but also stage of decomposition, oxygen availability, moisture and rain infiltration, pH, organic amount and microorganism population. It is

clear that LFG composition is not fixed but changes in time. Also the total amount of VOCs released from landfilling is significative for the environment. In the United States solid waste management contributes for 10% of the total VOC release in the atmosphere (EPA 1995). But problems come also for population living near landfills as they are exposed to LFG emissions. Several hazardous air pollutants (HAP) are present in LFG, some of these being carcinogen for humans. Studies have assessed the health risk near landfills (ATSDR 1992) but findings seem not to demonstrate an increased risk for the exposed population, possibly because evidence is not sufficient to establish the causality of the association (WHO Report, 2007). Still, as the exposed population

Odour is another commonly present problem that is more and more felt, by the general population, especially in its offensiveness, and its control is becoming a key issue for the plant management. Most of NMOC are almost odourless, with a high olfactory threshold (OT), but some are potent osmogens, with very low OTs, and they can be felt from long distances, eventually causing annoyance to the general population. Often odour is also associated with an health risk resulting in complaints. Recently UK Environment Agency (EA) released guidance for environmental odour, the IPPC-H4, for regulating and permitting odour emissions from industrial and agricultural activities. Here methods are proposed not only to measure or to predict odour emissions and environmental odour assessment, but also to determine if the exposure to odour is acceptable and if there is " no reasonable cause for annoyance"

We have been monitoring VOC emissions in the atmosphere from a MSW and non toxic special waste (B2 code waste) treatment plant, before its final capping, since 2001, focusing the attention mainly to direct atmospheric emissions that could not be prevented during this stage. Odour emission factors for landfills have been recently described (Sironi 2005, Sironi 2006) from different surfaces, with and without final capping. But, as the landfill grows up, the piping network grows with it and the LFG that is formed before its completion is lost in the atmosphere through the vertical extraction pipes. The most practiced control technologies for landfill gas are flares, but in the very early stages LFG methane concentration is too low to burn efficiently in flares, and cannot be used in engines for energy generation. Also piping network, before the landfill reaches its final level, is not complete and transport pipes emit directly in the atmosphere or are capped with temporary covers, possibly with adsorbing material, that are difficult to handle and to maintain efficient. The result is that during landfill operation, direct LFG emissions occur in the atmosphere that are difficult to control and have not been previously described in term of quantitative emissions.

After 2004 we have been monitoring also odour emissions both in the landfill and in the composting plant. In this work we present odour emission rates results from a three-year follow up of this a municipal waste treatment plant (MSWTP) until its completion. As the plant has available a small composting site, with static heap technology, we have been monitoring odour emissions from the landfill and the composting plant, in order to define the specific odour emission rates (SOER) from the two activities within the MSWTP, during this particular phase.

Our approach was multi-disciplinary as emissions were characterized both chemically, with a gas chromatographic-mass spectrometry approach, and by dynamic olfactometry. Samples were taken from the biogas collection network, from the leachate collection area as well as from the composting plant bio-oxidation and curing heaps. Chemical

characterization, by gas chromatography mass spectrometry was important to monitor emissions, from toxicological aspects, while sensorial analysis, with dynamic olfactometry, was used to assess total odour emission rates.

2. Experimental

2.1 Landfill site

The landfill is located in Maiolati Spontini (Ancona, Italy) and the lots studied have an extension of about 170,000 m^2. It is a hilly isolated area and the closest town is located at about 2 km. The landfill accepts both MSW and not toxic (B2) wastes. The total amount of material landfilled was about 190,000 t/year (187,500 +/- 34, mean +/- SD) while the B2 waste was about 150,000 t/year (140,500 +/- 30.5, mean +/- SD). The organic material composted is approximately 10,000 t/year (9732 +/- 573, mean +/- SD).

2.2 Sampling and analysis

LFG and environmental samples have been collected in duplicate with Nalophan bags as described in EN 13725-2003. Air samples have been collected in the landfill, in the piping system, in all open, uncollected, pipes. In each sampling point data were collected for temperature, humidity, pipe diameter and LFG emission velocity. In the composting plant samples were collected over heaps at different maturating stages (fresh, 30 days and 90 days) with a wind tunnel. Clean air was blown at 0.5 m/sec over the heap surface using a stainless steel wind tunnel and collected, as for landfill samples, in Nalophan bags. The wind tunnel is designed to simulate the parallel (without vertical mixing) airflow over the liquid surface and was developed in Australia (Jiang at al. 1995, 2001). All collected samples have been handled as from EN 13725 normative and analyzed for VOC and odour concentration within 30 hours.

Olfactometric analysis were conducted in conformity with the European Normative EN 13725 (2003) and odour concentration results have been expressed as European Odour Unit (OU_E/m^3), while VOC analysis were as from (Davoli 2003). Briefly, after addition of a deuterated internal standard, samples have been concentrated by SPME and analyzed by GC-MS with an Agilent 5971A MSD, in full scan mode. Qualitative analyses have been performed by NIST library and by authentic standards for HAP, semi-quantitative analysis by direct comparison with the internal standard, perdeuterated xylene. LFG samples were diluted before analysis by a factor of 500, with chromatographic grade nitrogen, in order to avoid SPME fiber overload.

2.3 Odour emission rate estimate

Total odour emission rate (OER) have been calculated for the landfill using the normalized LFG emission flux from all uncollected vertical extraction pipes and the odour concentration of each sampling point, while for the composting plant the odour concentration at the wind tunnel exhaust has been corrected by the clean air flux and by the tunnel covered surface in order to obtain an odour emission rate, as follows:

$$E = CQ/A$$

where E is the odour emission rate ($OU_E/m^3\ m^{-2}\ sec^{-1}$), C is the odour concentration, Q is the incoming air rate to the wind tunnel ($m^{-2}\ sec^{-1}$) and A the area covered by the wind tunnel (m^2). As the optimum air velocity inside the tunnel is 0,3 m^{s-1} but this

value was not possible to achieve precisely on field, the OER was normalized (Jing 2001).

3. Results

As the fully VOC concentration description goes beyond the scope of this work, detailed data will not be presented. In fig. 1 a typical composition of VOC in LFG and in fresh and cured compost is presented. While in LFG the main components are hydrocarbons, either aromatics or aliphatics, in compost are terpenes (in fresh material) and oxygen compounds (in cured compost).

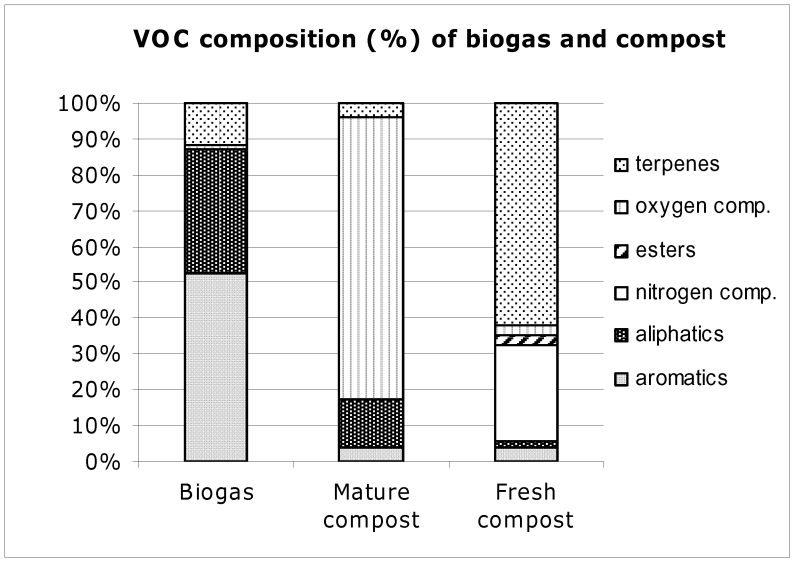

Fig.1. Chemical composition of VOCs in LFG and in compost emissions.

In fig. 2 and 3 percentages of aromatic compounds vs. total VOC is presented in LFG and in compost emissions respectively. It can be noted that B2 waste, during the years, presents a consistent higher concentration of aromatic compounds than MSW, possibly to highlight their different composition. In compost the aromatics are present in low percentage.

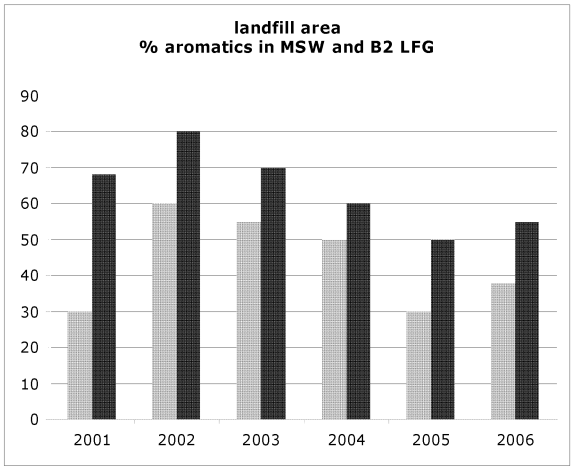

Fig.2. Chemical composition of VOCs in LFG. The aromatics percentage vs. total VOCs in landfill gas is represented in MSW (light grey) and B2 wastes LFG (dark grey).

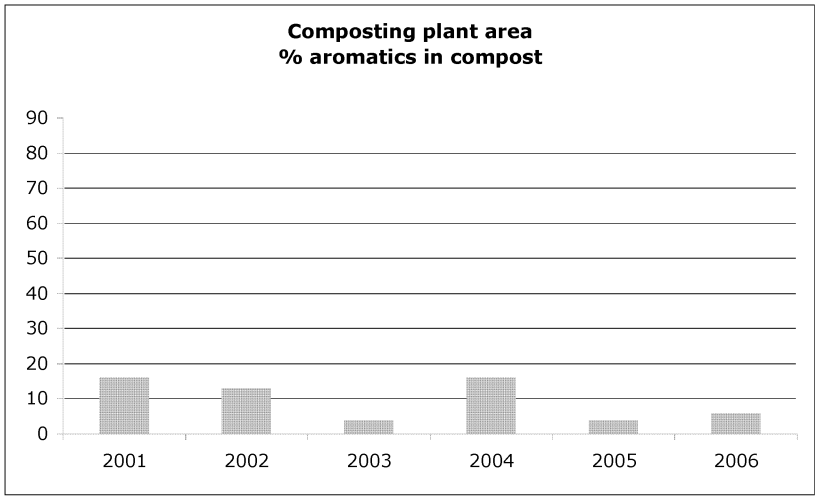

Fig.3. Chemical composition of VOCs in compost emissions. The aromatics percentage vs. total VOCs is presented.

Estimated OER from the landfill piping system is presented in fig. 4. Here the different waste material (MSW and special, non toxic waste, B2) are reported. During year 2006, B2 lots were completed and all pipes were almost finished and airtight sealed to the LFG collection blower.

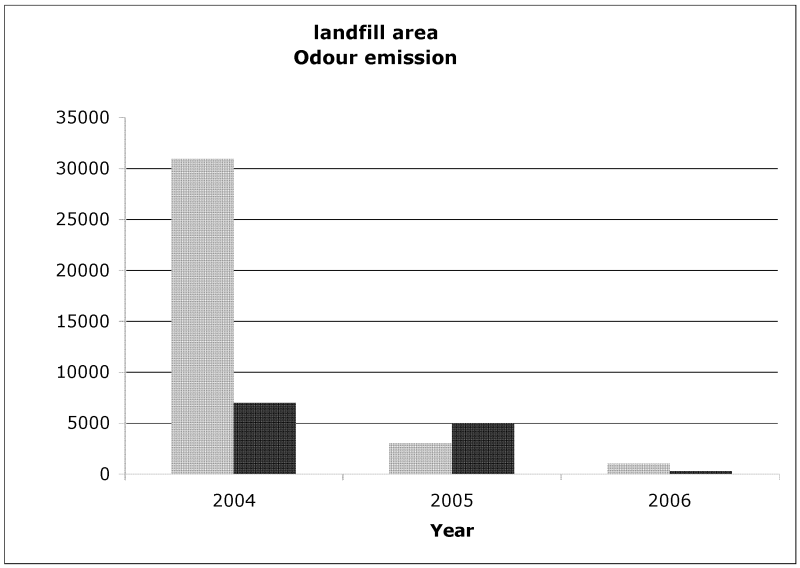

Fig.4. Odour emission rate (OER) from the piping system of the landfill, during its completion. MSW lots are in grey while B2 wastes are in black. In year 2006 B2 lots were completed.

The negative trend is observed for OER in 2004-2006 years is obviously due to the increased number of extraction pipes that are terminated and sealed. In fig. 5 the measured LFG flux lost in the atmosphere through the uncollected pipes is reported

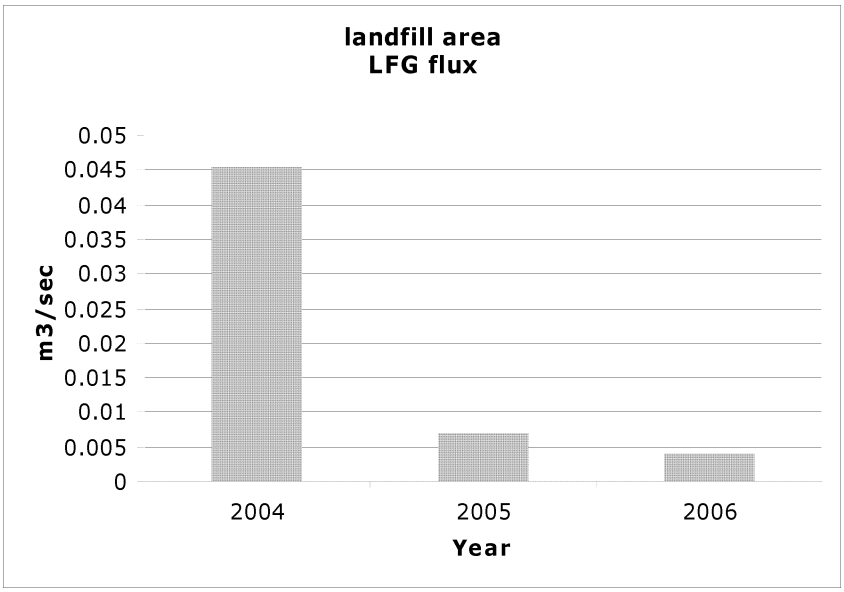

Fig.5. LFG flux emissions measured from the uncollected piping system of the landfill

The composting plant area, as a comparison, maintains fairly constant odour emission rates in the years, as the treated amounts and the process do not change much. In fig. 6 data are reported for specific OERs, of the composting plant, for fresh, 30 and 90 days old compost as well as the total emissions.

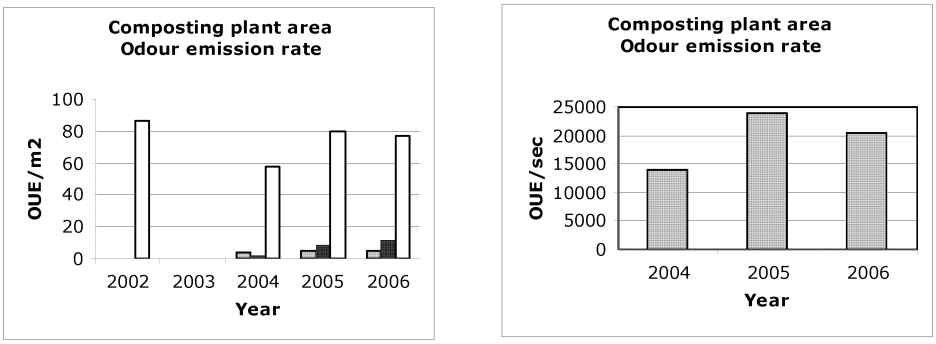

Fig. 6. OERs from the composting plant. Specific emissions are reported for fresh, 30 and 90 days old (on the left, white, grey and black respectively) and total area emissions (on the right, 2002 data not available).

4. Conclusions

Experimental data, obtained in this multi-year follow up, allowed odour emissions rate to be estimated both from the landfill gas piping network and from the composting plant. As landfill area emissions were measured during landfill operation and were due to uncollected vertical extraction pipes only, they are correlated with this specific activity and total emissions rate decreased as the extraction pipes were terminated and sealed towards the collection system. On the contrary the composting area did not change significantly emissions rate as the process and the amount of organic material did not change significantly in the last years.

Measured LFG emissions are due to the landfill development and are limited to the first years of new plant. However as there is large attention from the general population to landfill emissions, is useful to have a quantitative assessment of this specific activity emission. The higher measured SOER was 34,000 OU_E sec^{-1} in 2004. Using odour emission factors (OEFs) specific for small landfills (Sironi 2005, US EPA 1995), proposed for two landfills in Italy, of 5.5 OU_E m^{-2} sec^{-1} is possible to have a rough estimate of the theoretical total odour emission of this landfill, once completed as follows:

$$5{,}5\ OU_E\ m^{-2}\ sec^{-1} * 170{,}000\ m^2 = 935{,}000\ OU_E\ sec^{-1}$$

The SOER due to uncollected extraction pipes in this case would be only 3.6% of the total, being in line (Sironi 2003) with recently presented evidence.

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