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# Influence of a municipal solid waste landfill in the surrounding environment: Toxicological risk and odor nuisance effects

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ABSTRACT

The large amounts of treated waste materials and the complex biological and physicochemical processes make the areas in the proximity of landfills vulnerable not only to emissions of potential toxic compounds but also to nuisance such as odor pollution. All these factors have a dramatic impact in the local environment producing environmental quality degradation.

Most of the human health problems come from the landfill gas, from its non-methanic volatile organic compounds and from hazardous air pollutants. In addition several odorants are released during landfill operations and uncontrolled emissions.

In this work we present an integrated risk assessment for emissions of hazard compounds and odor nuisance, to describe environmental quality in the landfill proximity. The study was based on sampling campaigns to acquire emission data for polychlorinated dibenzo-p-dioxins and dibenzofurans, dioxin-like polychlorobiphenyls, polycyclic aromatic hydrocarbons, benzene and vinyl chloride monomer and odor. All concentration values in the emissions from the landfill were measured and used in an air dispersion model to estimate maximum concentrations and depositions in correspondence to five sensitive receptors located in proximity of the landfill.

Results for the different scenarios and cancer and non-cancer effects always showed risk estimates which were orders of magnitude below those accepted from the main international agencies (WHO, US EPA). Odor pollution was significant for a limited downwind area near the landfill appearing to be a significant risk factor of the damage to the local environment.



## 1. Introduction

Waste treatment plants are now large complex realities where large amounts of waste materials are treated and where complex biological and physicochemical processes occur in a controlled environment.

The impact produced by municipal solid waste (MSW) landfills has received special social and environmental attention in recent decades. Environmental degradation, landscape appearance, heavy traffic load, noise, dusts, fumes and odor emissions, render these facilities environmental stressor with negative impact on life quality of the surrounding communities (Downey and Van Willigen, 2005). Environmental inequality studies show that waste facilities are disproportionally located in the areas where more deprived, or minority groups reside (Faber and Krieg, 2002; Forastiere et al., 2011; Martuzzi et al., 2010), with consequent unequal pollutant exposure. The scientific literature provides some indications of an association between adverse health effects and the residence distance from the landfill site but the level of epidemiological evidence is "inadequate" or "limited" (Porta et al., 2009; WHO, 2007) with a general lack of consistency in the results for cancer incidence and mortality studies (Jarup et al., 2002; Rushton, 2003). Despite the lack of univocal evidence on the health implications, people are concerned with potential toxic compounds and unpleasant odors produced by landfill gas (LFG) emissions, which include gases generated by the biodegradation of waste and those arising from chemical reactions or volatilization from waste (Environment Agency, 2004a). The LFG emissions mainly consist of methane, carbon dioxide, water vapor and trace amount on non-methane organic compounds (NMOCs) (Soltani-Ahmadi, 2000) which include volatile organic compounds (VOCs), hazardous air pollutants (HAPs) and odorous compounds, which in recent years, have been chemically characterized (Davoli et al., 2003; Fang et al., 2012).

Communities living nearby landfills are directly exposed to chemicals through inhalation of LFG released during the waste degradation, but also to the combustion products (e.g. dioxins and dioxin-like compounds) that can be generated when LFG is burned in flares or for energy recovery (Environment Agency, 2004a). Ingestion of drinking water obtained from private wells contaminated by leachates, skin absorption and ingestion of contaminated soil particles, or ingestion of home-grown products, are other possible exposure pathways to chemicals.

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Concern is also due to uncontrolled LFG emissions related to the presence of complex mixtures of odorants and irritant air pollutants (Sadowska-Rociek et al., 2009). Although odorous compounds generally represent a nuisance more than a health risk (Fransess et al., 2002), nearby residents are concerned about the potential adverse health impacts for long-term exposure (De Feo et al., 2013). Recently studies have shown that a prolonged exposure to odors can generate unpleasant reactions ranging from emotional stresses such as states of anxiety and unease to physical symptoms (Aatamila et al., 2011), including headaches, eye irritation, respiratory problems, nausea or vomiting (National Research Council Committee on Odours, 1979). All these reactions interfere with daily activities with a great impact of life quality (Heaney et al., 2011). In addition unpleasant odor is more and more often regarded as an environmental concern, that can cause impairment of the quality of the natural environment for any use, altering the ecosystem structure and function. The growing concern for human and environmental well-being, has promoted the necessity for odor impact assessment and consequent odor emission regulation (Nicell, 2009).

Many of the studies on health impact of waste treatment plant lack direct exposure information, relying only on residential distance from the site (WHO, 2007). More recently impact assessment study use air dispersion modeling and local weather information to evaluate the exposure to pollutants (Davoli et al., 2010; Forastiere et al., 2011) and to odor (Capelli et al., 2011; Chemel et al., 2012; Sironi et al., 2010) around a landfill site.

The main objective of this study was understanding the local environmental impact of a large facility like a landfill. In this work we present an integrated risk assessment study on health impact and the consequences on environmental quality of a municipal solid waste landfill. Air dispersion modeling and local weather information have been considered to estimate the exposure to hazardous pollutants and odor impact, for residents, living near the landfill, in order to evaluate both the potential health risks (carcinogenic and non-carcinogenic) and odor nuisance.

## 2. Experimental

The approach adopted for this impact assessment study involved the site characterization including an identification of the principal emission sources of pollutants and odor, the analytical measurements of the pollutants emitted, the distribution within the environmental media by an appropriate air dispersion model, the identification of sensitive receptors that might be involved, the exposure assessment for the different exposure pathways and, finally, the toxicological evaluation and risk characterization (Environment Agency, 2004b).

### 2.1. Site characterization

This study has been conducted on a hilly isolated area of central Italy that includes small municipalities located few kilometers from the municipal solid waste landfill.

The landfill is located in a deep valley completely isolated from the soil by a natural layer of clay. It consists of an exhausted site built in 1986 and closed in 2001 with a capacity of 4,329,254 $m^3$ and an operating site, built in 2001. The surface of the exhausted site is completely covered with natural vegetation while the operating site is covered daily with layers of clay. The landfill receives only non-hazardous waste and the actual volume is 8,877,447 $m^3$ with a final potentiality of 9,465,447 $m^3$. The plant has a leachate collection and removal system with uncovered leachate lagoon, a composting plant with scrubber and fabric filter and a landfill gas extraction system that conveys the LFG to four engines for electricity generation or, alternatively, to flares for burning.

### 2.2. Pollutant emissions

For this study we considered the following pollutants: benzene, vinyl chloride monomer (VCM), polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs), dioxin-like polychlorinated biphenyls (DL-PCBs) and polycyclic aromatic hydrocarbons (PAHs). They have been selected because their presence in landfill emissions has been well documented and for their toxicological properties and/or environmental persistence and bioaccumulation (WHO, 2000).

The emission sources identified were both the diffusive emissions from landfill surface and the point emissions from flares and engines. The aquifer is absent and leachate migration into underlying ground zones has been supposed to be negligible due to the adoption of high density polyethylene (HDPE) geomembranes as bottom barriers and mainly for a 200 m deep clay layer.

We considered three different diffusive emission zones (DEZ), which have been characterized by different types of capping: the first (DEZ-1) has a final capping covered by vegetation. The second and the third areas are the temporary capped surfaces of freshly tipped municipal solid waste (DEZ-2) and the landfill side slopes (DEZ-3), for an overall extension of 214,208 $m^2$ (Fig. 1).

Vinyl chloride can be formed from waste as a degradation product of chloroethylene solvents (US EPA, 2002a) whereas benzene can be released directly from the waste (IPCS, 1993). Because of their origin, they have been measured in surface emissions with a depression sampler from the LFG collection tube, which conveys all LFG formed by wastes to engines, using Nalophan™ bags (Max Ramp AG, Switzerland), in accordance with the European norm EN 13725:2003. The sample has been analyzed by solid phase micro extraction (SPME) technique and the extraction has been performed at 22 °C for 25 min with a 50/30 μm DVB/CAR/PDMS triphasic fiber (Supelco). The analysis has been carried out by gas chromatography–mass spectrometry (GC/MS) by using an Agilent 5975C Mass Spectrometer interfaced to an Agilent 7890A GC. Quantitative determinations were performed by the isotope dilution method by comparison with a calibration curve built with $^2$H-internal standard.

Benzene and VCM concentrations and LFG emission data over the landfill surface have been used to estimate benzene and VCM emissions from the landfill, assuming that the flow of pollutants emitted was directly proportional to the loss of LFG, without taking into account the possible effects of abatement from the covering layer of the landfill.

LFG diffusive emission data were obtained during a 1-week sampling campaign, performed in June 2008, during calm, sunny days. Temperature was 16.8 $\pm$ 5.3 °C and pressure 1009 $\pm$ 4.1 hPa (mean $\pm$ SD) during the sampling period. Sampling has been performed in 93 different points on the landfill, using a systematic square grid sampling scheme. A number of 75 sampling point was defined following USEPA recommendations (Winegar and Keith, 1993) for the isolation flux chamber operations and it has been adapted to the most convenient number (93 total final samples) due to landfill shape irregularities.

PCDD/Fs, DL-PCBs and PAHs have been measured in the flare and engine emissions.

For each emission source, a 16-h composite sample has been collected during standard working procedures, in two consecutive days. Flare sampling temperature was 850 °C, while engine emission has been sampled at 140 °C.

According to the UNI EN1948-1:2006 procedure, a mixture containing 0.4 ng of 1,2,3,7,8 PCDF and 1,2,3,7,8,9 HxCDF and 0.8 ng of 1,2,3,4,7,8,9 HpCDF has been added during the sampling procedure.

PCDD/F analysis in emissions has been performed by using standard official methods (UNI-EN 1948-2:2006 for PCDD/Fs in torch emissions) adding a surrogate containing 0.4 ng of $^{13}C_{12}$ tetra-, penta- and hexa-CDD/Fs and 0.8 ng of $^{13}C_{12}$ hepta- and octa-CDD/Fs.

PCB analysis has been performed by adding a surrogate containing 1 ng of each congener.