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Health risk assessment as an approach to manage an old landfill and to propose integrated solid waste treatment: A case study in Italy

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ABSTRACT

The aim of the present paper is to show how an approach based on human health risk analysis can be used as a decisional tool for the evaluation of impacts on population and for deciding between different waste treatment processes. The situation in which the increasing production of solid wastes cannot be confined in the old existing Municipal Solid Waste landfill (settled in Genoa, Liguria Region, Italy) is used as a case study. Risk assessment for human health due to air, surface water, groundwater and soil contamination is performed in different scenarios for the old landfill and compared with alternative Waste-to-Energy management solutions that consider thermal treatment by gasification of the total waste or gasification of the dry fraction coupled with anaerobic digestion of the wet fraction, plus biogas combustion with or without sludge and bottom ash/slag disposal in the old landfill. Hazard Index (*HI*) and Cancer Risk (*CR*) in case of operating landfill and under the suspected situation of failure of the sealing system, were respectively 1.15 and 1.1 10^{7}. Unacceptable HI were found due to groundwater contamination, while HI due to river pollution was slightly under the threshold. Vegetables ingestion was the most important pathway and ammonia the most responsible of toxic adverse effects. Fish ingestion and dermal contact with contaminated water were found to be the most important exposure pathways for carcinogenic risk, due mainly to BTEX.

HI and *CR* in the supposed scenario of total waste gasification were respectively 9.4 10^{1} and 1.1 10^{5} while they were respectively 3.2 10^{1} and 6 10^{6} in case of gasification of the dry fraction. *CR* in both scenarios was over the threshold mainly due to dioxins, where milk and meat ingestion were found to be the highest risk pathways. Inhalation resulted as the highest not-carcinogenic risk exposure pathway, mainly due to NOx.

Decision making was made by weighing up the different scenarios, and results suggested to definitively close the landfill and to eliminate gasification of the total waste as a possible waste treatment process.

1. Introduction

Typical solid waste management and related decisions include how waste can be minimized, collected, separated and treated, as well as where waste can be sent for storage, final disposal, thermal or other industrial treatment. The Directive 2008/98/EC (EC, 2008) defines the basic concepts related to waste management as reuse, recycle and recovery and classifies solid waste. Moreover it imposes to adopt managing techniques that reduce risks to air, water and soil and that prevent health risk for plants, animals and human beings. The European Union continued to encourage Governments towards waste reduction (EC, 2012; EEA, 2013). In this context the practices of landfilling and waste incineration without energy recover are not considered a good approach to municipal solid waste management.

Despite this, a lot of old landfills, in which solid waste is collected in cells and is subjected to natural processes of degradation, are present on the Italian territory.

The emissions from a MSW landfill are biogas and leachate. Biogas is often properly collected and used to produce energy, while leachate losses are frequent and pollutants contained in leachate can persist for a long period of time. Moreover, especially in old landfills, leachate is not properly collected from the bottom during operation. Leachate is the result of percolation of water initially contained into the waste, irrigation, infiltrating water and rain precipitation; it contains a variety of chemicals derived from the dissolution of the materials collected into the landfill and from chemical and biochemical reactions occurring within the landfill. The chemical composition of landfill leachate can vary from cell

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to cell within the same landfill, depending from the degradation state of waste. Many studies about risk due to leachate contamination have been carried out during the last twenty years, all demonstrating the existence of correlations between the exposition of human population to leachate and the occurence of many pathologies. (Butt et al., 2008; Butt et al., 2014; Toufexi et al., 2013; Vrijheid, 2002).

Due to both contamination risk and lack of space for disposal, current policies on waste treatment in large cities often provide for the transition from landfill to modern separation and thermal treatment facilities. Even thermal treatment of solid waste involves equally important environmental and health risk issues, mainly related to toxic chemicals contained in flue gas released during incineration, but also produced by gasification and pyrolysis: particular attention must be posed on particulate, NOx, SOx, heavy metals, PCBs and PCDDs and their adverse effect to human health, widely discussed in the literature (Lonati and Zanoni 2012; Ragazzi and Rada 2012; Ragazzi et al., 2013; Rovira et al., 2015). For these reasons Governments and Public Health Bodies have often difficulty in discussing with population (Linzalone et al., 2017) about advantages and disadvantages of a new proposed waste management practice, even if it is considered a Best Available Technique (BAT). As a consequence, since they must invest public money, Local Authorities sometimes hesitate to make decisions without data about the potential adverse health effects produced by the alternative technique proposed to replace the old one.

Risk assessment is a methodology in continuous development and it can be applied to different fields and at different levels. Techniques based on Health Risk Assessment (HRA) can help decision making during and after an accident by providing preliminary information on how waste released in the environment could be managed, but can also be used for a first evaluation of different available solutions for waste treatment, on the basis of their impact on population (Butt et al., 2016; Davoli et al. (2010); Mishra et al., 2016).

The aim of the present work is to describe an approach based on Health Risk Assessment (HRA) for deciding between different waste treatment processes. The case study is the city of Genoa, Liguria, Italy. The novelty of the work is in the complexity of the integrated scenarios analyzed, also using self-developed dispersion models. Even if Environmental Risk Assessment (ERA) is important for decision making, and in some cases it could be more relevant than HRA, in this work we used only the results of HRA for the construction of the decision matrix, since this kind of risk is most perceived at political level and by population.

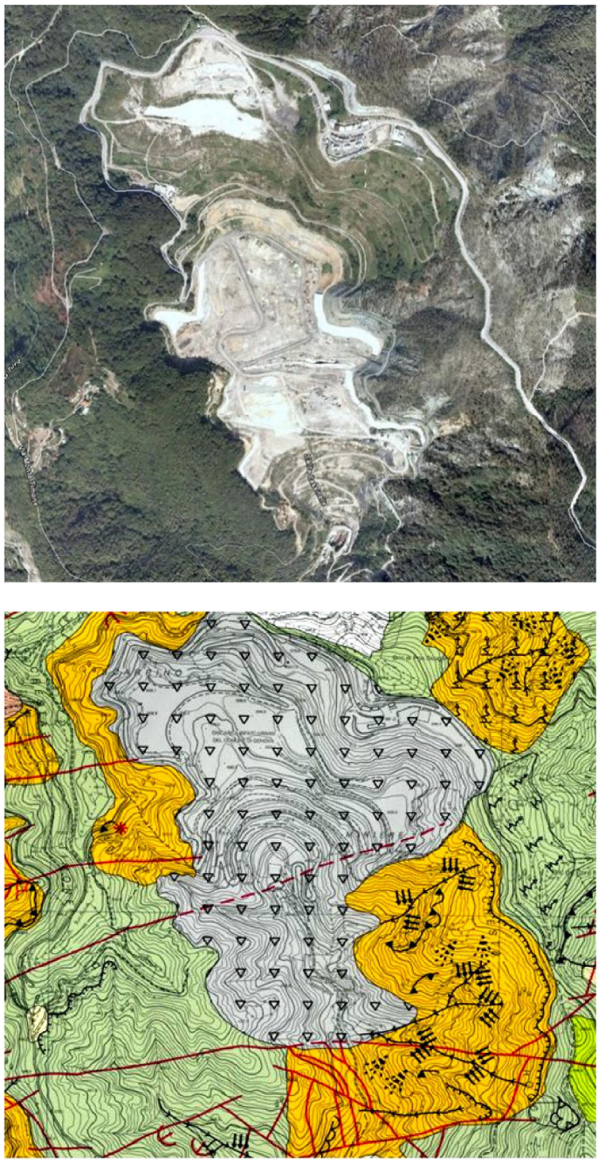

Fig. 1. (a) Satellite image of Scarpino site, operating landfill; (b) Geo-morphological Atlas of the City of Genoa, sheet 16.

2. Methods

2.1. Site description and approach

Risk assessment techniques have been applied to an existing confined Municipal Solid Waste (MSW) landfill, called Scarpino, settled in the Liguria Region, Italy, and to hypothetical scenarios involving integrated treatment solutions of the collected MSW.

The landfill is placed at an altitude of about 600 m on the sea level (Fig. 1a). It is located next to a surface water body in connection with a thin aquifer that flows from the landfill towards a small torrential river (rio Cassinelle, having a length of 18 km and flowing into the port area) and it is also connected, by a bypass, to another torrent (rio Secco). Water from both the creeks is sometimes used for human activities and irrigation of croplands even if it is seriously compromised, also because of a bordering landfill, active between the years 1960 and 1980.

The valley is set to a tectonic discontinuity that connects two distinct complexes: on the left side serpentine, on the right side to a formation of metargilliti shale, sometimes with thin intercalations of crystalline limestones. This geological scheme is known and finds reference in the geological and geomorphological mapping Atlas of the City of Genoa (Fig. 1b).

Confined landfills usually include a cover system that reduce water infiltration into the waste and a sealing system to prevent the movement of leachate to groundwater. Leachate is often collected and re-circulated. The liner system is usually composed by a drainage layer plus artificial systems with very low hydraulic permeability, as a geomembrane and a soil layer. Even good quality geomembranes are affected by flaws, due to thermal expansion of the material, initial defect density (number per unit area) and folds created during installation. So leachate losses through the geomembranes cannot be totally avoided. The landfill under study is divided into two lots, the former definitively closed and the latter in operation since 1995; the estimated losses are high and the space for waste disposal has become insufficient. For these reasons, options as increase of recycling, pre-treatment systems and thermal treatment may be a viable solution for the city of Genoa (Tornavacca et al., 2008).

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