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Assessment of the possible reuse of MSW coming from landfill mining of old open dumpsites

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ABSTRACT

The present study addresses the theme of recycling potential of old open dumpsites by using landfill mining. Attention is focused on the possible reuse of the residual finer fraction (<4 mm), which constitutes more than 60% of the total mined material, sampled in the old open dumpsite of Lavello (Southern Italy). We propose a protocol of analysis of the landfill material that links chemical analyses and environmental bioassays. This protocol is used to evaluate the compatibility of the residual matrix for the disposal in temporary storages and the formation of "bio-soils" to be used in geo-environmental applications, such as the construction of barrier layers of landfills, or in environmental remediation activities. Attention is mainly focused on the presence of heavy metals and on the possible interaction with test organisms. Chemical analyses of the residual matrix and leaching tests showed that the concentration of heavy metals is always below the legislation limits. Biological acute tests (with *Lepidum sativum*, *Vicia faba* and *Lactuca sativa*) do not emphasize adverse effects to the growth of the plant species, except the bioassay with *V. faba*, which showed a dose–response effect. The new developed chronic bioassay test with *Spartium junceum* showed a good adaptation to stress conditions induced by the presence of the mined landfill material. In conclusion, the conducted experimental activities demonstrated the suitability of the material to be used for different purposes.

1. Introduction

Landfills have long been considered as a way to store waste at minimum cost. Today it is well known that this kind of waste disposal shows a series of problems related to possible contaminations caused by the degradation of organic waste, which generates methane emissions that contribute to global warming (Sormunen et al., 2008). Old dumpsites, without any sort of protection for reducing emissions, are a source of local pollution due to the leaching of hazardous substances (Krook et al., 2012). In Italy, there are more than 10,000 old open dumpsites, built and developed before current regulations were in place (before 1980), without modern environmental technologies for limiting emissions. These sites, although no longer used, still represent an important source of environmental risk, mainly for the presence of micro-pollutants, such as heavy metals. These sites can cause pollution of groundwater and surface water due to leaching and runoff. Moreover, in many parts of the world, landfilling is still the most important waste disposal method. In Italy, although more advanced systems for waste recycling and treatment have been developed, in 2011 landfilling still was the most common form of management, affecting 42.1% of municipal solid waste management (ISPRA, 2013).

The problem of environmental rehabilitation of a waste disposal site has always been one of the most delicate issues to deal with, in order to complete the phase of restitution of the site to the environment. In literature, recovery methods adopted for remediation have mainly been developed for the treatment of soils of limited size and affected by high contamination. These methodologies, with high costs, if applied to large areas with low concentrations of contaminants are useless. For the remediation of old open dumpsites, it is necessary to set up a recovery plan tailored and developed on the basis of a careful campaign of investigation. At the European level, the excavation and treatment of polluted land are now recognized as important measures to protect air, land and water resources (Hogland et al., 2004). An interesting remediation technology for the mentioned closed open dumpsites is landfill mining. Landfill mining was first introduced in Israel in 1953 as a way to obtain fertilizers for orchards. The interest in this strategy increased in the 1990s, when other studies were carried on and published (Krook et al., 2012). Landfill mining includes the extraction and processing of material buried in closed landfills, often unlined. Many of these old landfills still might be a "mine" of materials. The objectives of this type of treatment are: preservation of volume in landfills, removal of a potential source of pollution,

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mitigation of the site contamination, energy recovery, reuse of recoverable materials in landfills, reduction of management cost and redevelopment of the site (Hogland et al., 2004). Recently, the concept of Enhanced Landfill Mining (ELFM) has been receiving a lot of attention. ELFM includes the combined and integrated valorisation of waste streams as both materials and energy, while respecting ecological and social criteria (Quaghebeur et al., 2013). In addition, the volume of the old landfill site, once reclaimed, can be renovated and adapted to the standard rules and reused to store new waste (Prechthai et al., 2008b). The approach for the implementation and evaluation of landfill mining is still immature and does not use standardized rules and principles, although research has been conducted in this field (Krook et al., 2012). Four main type of uncertainties related to landfill mining projects can be listed: waste composition, processing technologies, markets for materials, environmental and health risks (Frändegård et al., 2013).

One of the most critical aspects is the destination of the residual matrix coming from landfill mining (with recovery of materials) and remediation activities on landfills and open dumps. This residual matrix represents one of the main products of the storage of waste in landfills and consists mainly of degraded organic matter, soil cover and residues of medium and large size. This material could be reused for final or daily covering of landfills, as shown by Jain et al. (2005). However, it is important to underline that landfills (as we know them) are, ideally, transformed into temporary storage places. The temporary storage is an environmentally and structurally safe storage place that permits in situ recovery of materials and energy from waste streams and allows easy future access to resources whenever needed. The temporary storage is a new concept that enables optimisation of waste recycling and will make waste disposal in landfills and incineration of valuable waste materials (potential resources) unnecessary. Moreover, it can facilitate the retrieval of materials from old and abandoned landfills, thus also creating a connection to the past and realising a delayed recycling. The temporary storage will allow creating a connection among past, present and future, and a new step towards the circular economy (Krook et al., 2013; Quaghebeur et al., 2013; Bosmans et al., 2013; Jones et al., 2013).

The complexity of studying the suitability in environmental applications of the residual material originating from landfill mining operations on old landfills is mainly due to its heterogeneity (Masi et al., 2011). In literature, different studies have shown residual material recovery originating from landfill mining activities (Hogland et al., 2004; Prechthai et al., 2008b), but only in recent years papers concerning the study of the possibility of mining very old dumpsites were published (Quaghebeur et al., 2013, Kaartinen et al., 2013, Jain et al., 2013). A good characterization of the site is needed to identify the problems related to the process of reclamation (Raga and Cossu, 2013). Moreover, a qualitative and quantitative analysis of waste is essential, in order to determine the potential of waste recycling in reclamation operations (Prechthai et al., 2008a). Multiple studies showed that the chemical approach does not provide satisfactory tools to define the environmental risk associated to a mixture of pollutants (Pasini et al., 2000). Information about phytotoxicity is necessary for the evaluation of the environmental pollution risk (Wang et al., 2001; Caniani et al., 2013). The presence of toxicological agents can be detected by analysing the changes caused on a test organism. These tests are reliable, convenient, fast and simple (Valerio et al., 2007). Laboratory tests can be divided into acute and chronic (or sublethal) tests. An acute test uses increasing doses (on a logarithmic scale) for short periods, from 15 min to 96 h. Chronic tests have a duration variable from days to months and are conducted typically using low concentrations for long periods. The use of plants offers an advantage if compared to other organisms, because they may be more sensitive to environmental stress (Valerio et al., 2007). Furthermore, the use of ecotoxicological assays allows us to evaluate, on one side, the bio-available fraction of the pollutants, and, on the other hand, any synergy and/or antagonism phenomena of different substances (Pasini et al., 2000).

In this research paper, an innovative analytical protocol is designed to test the suitability of organic residues from landfill mining activities of very old closed dumpsites. There are several hypothesis of usage of the obtained material, such as: storage in temporary storages, formation of "bio-soils" to be used in geo-environmental applications, as daily and final covering in controlled landfills in substitution of the soil layer, or in environmental remediation activities. We carried out chemical and physical analyses. Moreover, we applied acute and chronic bioassays, to evaluate the toxicity of some heavy metals on vegetable species by varying the growth substrate. The analysis protocol proposed in this study is able to describe the influence of the analyzed organic matrix on soil receptors, vegetation material and groundwater resources. Vegetation tests were used to evaluate the toxicity of some heavy metals on vegetable species by varying the growth substrate. However, giving the lack in literature of chronic tests on plant species typically used in geo-environmental restoration applications, an innovative chronic test with *Spartium Junctium* was developed and carried out. The developed analytical protocol is able to verify: the main physical and chemical characteristics of the material to be tested, the possible percolation of pollutants in groundwater, the dry matter production of the aboveground biomass, in order to meet the specific needs for reuse of the material in the fields it is meant for, and the possible use of the material under study in environmental remediation activities.

2. Materials and methods

2.1. Site description and sampling

The material used in this research originates from the old closed dumpsite of Lavello (Basilicata Region-Southern Italy), which was developed before current regulations were in place. The samples were collected in the period between June and July 2009. The landfill site was object of solid waste dumping from the 1950s to the early years of the 1980s. The dumpsite does not possess any form of containment of pollutants (unlined landfill). The sampling programme was defined on the basis of a visual observation of the site and the acquired knowledge on historical information. From the studied landfill, which covers an area of about 1 ha, 7 samples were taken, following the scheme showed in Fig. 1, at a depth from the

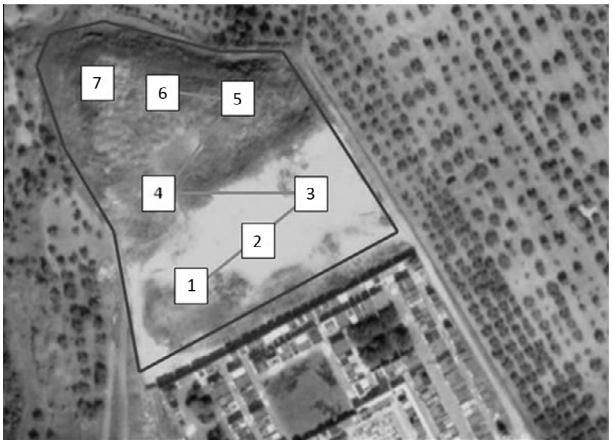

Fig. 1. Study area and samples collection points (total area of the dumpsite is approximately 10,000 m^2).