Journal of Cleaner Production 55 (2013) 56–66

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Case study on sampling, processing and characterization of landfilled municipal solid waste in the view of landfill mining

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ARTICLE INFO

Article history:
Received 1 December 2012
Received in revised form
15 February 2013
Accepted 26 February 2013
Available online 14 March 2013

Keywords:
Landfill mining
Exploration
Manual sorting
Mechanical treatment
Waste characterization

ABSTRACT

Landfilling has been the major method for municipal solid waste (MSW) disposal during recent decades. Recently utilization of deposited materials, commonly referred to as landfill mining, has been increasingly considered due to increasing raw material costs and environmental reasons. When mining municipal solid waste (MSW) landfills, finding suitable treatment and utilization routes for different types of materials is essential because of the economic aspects and to minimize the re-landfilled fraction of the waste. This paper describes a case study to sample, characterize and process wastes of a potential landfill mining site. The study combines manual sorting with full-scale mechanical treatment to better assess the treatability of the landfilled wastes. The approach also aimed at complying with the challenges of the heterogenous nature of the landfilled MSW. An approximately 30 m high and 10-year-old Finnish landfill was sampled in connection with the drilling of three gas collections wells, producing samples from two layers of waste of slightly different ages (ca. 5–10 years). Manual sieving and sorting into seven waste fractions as well as full-scale mechanical processing was performed. Further characterization included the fuel properties of the calorific fractions and the leaching properties of the fine materials. Manual sorting of the materials yielded 40–45% (w/w) of the possible fuel fraction in the landfilled waste with a net calorific value of approximately 20 MJ/kg dry matter. The metal fractions recovered in the manual sorting amounted to 3–4% (w/w). The landfilled waste was also processable by full-scale mechanical processes, including shredding, magnetic separation, screens and a wind sieve, despite the moisture and impurities in the landfilled waste. Results from the mechanical process showed that approximately 30% (w/w) of the material could be recovered as solid recovered fuel with similar calorific values to the fuel fraction from the manual sorting. Approximately 1% (w/w) could be recovered as magnetic metals in the mechanical process. The yields of fuel and metal fractions are site-specific but could likely be improved by optimizing the mechanical process for landfill mining purposes, as is indicated by the results from the manual sorting of the materials. The amount of fine materials (<20 mm in the manual sorting and <30 mm in the mechanical process) was found to be ca. 50% (w/w) which supports previous reports of the amount of the fines. The fine materials require attention to minimize the waste remaining from landfill mining. The Fe and Al contents of the fine fraction, at approximately 5% (w/w) both in the manually sorted and mechanically treated waste, are interesting for recovery purposes. The findings from this study highlight the importance of proper exploration stage in a landfill mining project in order to plan the best applicable full-scale processes for material recovery.

1. Introduction

The rising global consumption of various materials in the past few decades has increased the costs of raw materials and the environmental impact of their extraction and use. Furthermore, concerns about the availability and sufficiency of certain materials have increased. For instance, scientific debates have taken place concerning the availability of world's copper resources in response

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http://dx.doi.org/10.1016/j.jclepro.2013.02.036

to increasing demand (Gordon et al., 2006; Tilton and Lagos, 2007). To respond to these challenges, in several countries, material efficiency and recirculation programs have been and are being developed. Recently, recovery of materials from city infrastructures and from landfills has gained growing interest (Jones et al., 2013).

Projects aimed at resource recovery from landfills are commonly referred to as landfill mining (Krook et al., 2012). In addition to the value of the recovered materials, the most commonly cited reasons for landfill excavation/mining has been the remediation of landfills to prevent local emissions, to create new volume in the existing landfill, to create space for new infrastructure, and to produce recyclable materials such as metals and waste fuels (Goeschl, 2012). Furthermore, waste management companies are looking for new business concepts due to the declining volume of solid wastes processed at landfills. (Van Der Zee et al., 2004).

Landfills have been used for the disposal of almost all municipal solid waste (MSW) and industrial waste for decades, although source segregation of materials such as metals, paper, hazardous materials, and glass has been increasingly practiced, as has waste incineration. Old MSW landfills are an especially heterogenous source of materials (Paap et al., 2011) the composition, volume and placement practices of which are not well documented (Jones et al., 2013). The importance of proper exploration in the early stages of a possible landfill mining project has been highlighted in previous papers (Goeschl, 2012; Hull et al., 2005; Quaghebeur et al., 2013). As part of the exploration stage, site specific investigations including test excavations or drillings into the landfill body are a necessity in assessing the composition of the landfilled waste (Krook et al., 2012).

The planning of suitable treatment processes for recoverable waste fractions in a landfill mining project – in MSW, recoverable waste fractions are primarily metals, waste fuel and possibly soil - requires detailed knowledge not only of the composition but also of the treatability of the landfilled wastes. Previous waste characterization studies of landfilled wastes have addressed the issue of waste characterization primarily by screening the waste into different particle size categories and subsequently manually sorting at least the coarsest particle size categories into different waste categories (Hogland, 2002; Hull et al., 2005; Kurian et al., 2003; Quaghebeur et al., 2013; Stessel and Murphy, 1992). Hogland (2002) performed extensive waste characterization of samples excavated from two Swedish MSW landfills to address the potential for recycling and energy recovery of excavated waste. Their studies included screening (18 and 50 mm) and manual sorting of the waste samples and characterization of the different categories with regard to e.g. composition, calorific value and concentrations of contaminants. Hull et al. (2005) screened (25.4 mm) and hand-sorted the oversized fractions of 98 samples drilled from a MSW landfill in New Jersey, USA. Characterization of the samples included the determination of the calorific value of calorific fractions (paper, cardboard, food and yard waste, wood and plastics) and concentrations of both inorganic and organic contaminants in the fine fractions. Kurian et al. (2003) characterized samples from two MSW landfills in India by first separating the $<$20 mm size fraction by sieving and manually sorting the oversized material. In a recent study, Quaghebeur et al. (2013) also started with screening (10 mm) after drying the samples and continued with manual sorting of the oversized fractions. The fractions were then characterized for e.g. properties related to energy utilization potential and concentrations of contaminants.

One essential finding of previous waste characterization studies (Hogland, 2002; Hull et al., 2005; Quaghebeur et al., 2013) of landfilled wastes is the strong presence of the fine fraction. This fraction may amount to more than 50% of total mass of an MSW landfill body (Quaghebeur et al., 2013), consisting not only of the landfilled wastes but also of the landfill (daily) cover materials (usually soil). Generally speaking, the ratio between the amounts of waste and soil at a landfill may vary significantly and depends on factors such as local operating practices, compacting, the age of the landfill and the degree of decomposition of organic waste (Møller Rosendal, 2009). The quantity of recyclable metals, such as Al and Fe, has been found to be quite low in fine fractions excavated from MSW landfills (Quaghebeur et al., 2013). On the other hand the heating value of the fine fraction has been reported to be low as well (Hogland et al., 1995; Quaghebeur et al., 2013) thus limiting the possible utilization scenarios for this fraction. The fate of the fine fraction may be crucial for the economics of a landfill mining project. In some studies the fine soil type fraction has been considered to be a potential substrate for the intermediate or final covers of current landfilling operations, thus even creating revenues (Hogland et al., 2010; Jennings et al., 2007). Another alternative is that the fine fraction is classified as waste that must be re-landfilled, which obviously creates costs and may render a landfill mining project economically unfeasible.

Few studies have examined the treatability of excavated MSW and the effectiveness of unit processes (Hull et al., 2005; Stessel and Murphy, 1992). In most full-scale landfill mining projects material recovery has been a secondary objective; thus, simple soil excavation and screening techniques have been the primary methods applied in previous landfill mining work (Krook et al., 2012), with the exception of a few projects which utilized magnetic or air separation (Goeschl, 2012).

The objective of the present study was to assess the treatability, material recovery potential and material mass balances of landfilled MSW. Sorting efficiency was examined through a comparison of manual sorting (material recovery potential) and full scale mechanical pre-treatment (treatability) of wastes sampled from a MSW landfill. The full-scale process was able to treat multiple amounts of material compared to manual sorting, which helps tackling issues relating to heterogeneity of landfilled MSW. In addition the fuel properties of some of the recovered waste fractions were assessed to evaluate their potential usability as solid recovered fuel. In contrast to previous studies, the fine MSW material recovered from the landfill was also assessed with regard to its landfill acceptability.

2. Materials and methods

2.1. Site description

The landfill studied is established according to European Union (EU) requirements for sealed bottom structure. The landfill is located in Kuopio, Finland. It has a land area of approximately 32 000 square meters and a peak area of approximately 18 000 square meters. The maximum filling height is approximately 30 m. The landfill contains primarily mixed MSW landfilled between 2001 and 2011. From 2001 to 2003, source separation of biowaste was not practiced in the area. Between 2004 and 2009, the landfill received MSW with source separation of biowaste taking place. Mechanical pre-treatment of all the received waste to produce refuse-derived fuel began in 2009, and thus the uppermost layers of the landfill contain mostly rejects (sieve underflow) from the mechanical pre-treatment. These layers were seen to produce little interest with regard to landfill mining, because the fuel fractions and magnetic metals were previously recovered via a mechanical process (see 2.3.2). The uppermost layers were thus discarded from this study. In addition to the landfilled wastes, the landfill contains layers of soil used as intermediate covers during the filling. The amount of the intermediate cover materials was not known.