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Characterization of fine fraction mined from two Finnish landfills

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ABSTRACT

A fine fraction (FF) was mined from two Finnish municipal solid waste (MSW) landfills in Kuopio (1- to 10-year-old, referred as new landfill) and Lohja (24- to 40-year-old, referred as old landfill) in order to characterize FF. In Kuopio the FF (<20 mm) was on average 45 ± 7% of the content of landfill and in Lohja 58 ± 11%. Sieving showed that 86.5 ± 5.7% of the FF was smaller than 11.2 mm and the fraction resembled soil. The total solids (TS) content was 46–82%, being lower in the bottom layers compared to the middle layers. The organic matter content (measured as volatile solids, VS) and the biochemical methane potential (BMP) of FF were lower in the old landfill (VS/TS 12.8 ± 7.1% and BMP 5.8 ± 3.4 m^3 CH_4/t TS) than in the new landfill (VS/TS 21.3 ± 4.3% and BMP 14.4 ± 9.9 m^3 CH_4/t TS), and both were lower compared with fresh MSW. In the Kuopio landfill materials were also mechanically sieved in the full scale plant in two size fraction <30 mm (VS/TS 31.1% and 32.9 m^3 CH_4/t TS) and 30–70 mm (VS/TS 50.8% and BMP 78.5 m^3 CH_4/t TS). The nitrogen (3.5 ± 2.0 g/kg TS), phosphorus (<1.0–1.5 g/kg TS) and soluble chemical oxygen demand (COD) (2.77 ± 1.77 kg/t TS) contents were low in all samples. Since FF is major fraction of the content of landfill, the characterization of FF is important to find possible methods for using or disposing FF mined from landfills.

1. Introduction

Landfilling has been the major method for disposing of municipal solid waste (MSW) in many regions of the world for decades. In 2010 in the European Union (EU-27) 38% of the MSW (96 million tons) was landfilled, while in 1995 in same countries up to 68% was landfilled (141 million tons) (Eurostat, 2011). For example, in Sweden (population 9.6 million), there are 6000 old landfills with an average size of 8000 m^2 (total 4800 ha) (Hogland et al., 2010), in the Netherlands (population 16.7 million) about 3800 abandoned landfills with total surface of 9000 ha (Paap et al., 2011) and Finland (population 5.4 million) has an estimated 1600 landfills. Usually, landfills contain MSW from households, commerce, trade and administration (Eurostat, 2011) but also from industry (Kaartinen et al., 2013). Composition of MSW depends besides waste management system also on region and season, mainly composing of food waste, paper and cardboard, plastics, metal and glass. Low-income countries have higher proportion of organic waste compared to high-income countries (IPCC, 2006).

Landfills may contain valuable materials and resources that are wasted. Landfills, especially old ones, are sources of local water, soil and air pollution and also generate long-term methane (greenhouse gas) emissions. In EU-28 in 2011, the waste management sector produced 3% of greenhouse gases, of which 84% of methane emissions (4700 Gg CH_4) derived from solid waste disposal sites (EEA, 2013). It is estimated that globally 1500 million tons of MSW is landfilled yearly having potential to produce 50 N m^3 CH_4 per ton MSW (Themelis and Ulloa, 2007). Recently, interest in landfill mining, e.g. excavating, processing, treating and recycling waste materials, has increased. Landfill mining offers possibility to recover landfilled resources and also diminishes global and local pollution, especially methane emissions. Landfill mining provides additional space for landfill or for other purposes. After processing, for example sieving, magnetic separation and size reduction, the mined waste can be used as a raw material or energy resource or safely disposed. Until now, landfill mining research has focused on recovering valuable metals and additional space for landfilling or other purposes (Krook et al., 2012). When valuable materials are mined, less valuable waste materials must be used or safely disposed. This study concentrates on the fine fraction (FF) mined from landfills.

The FF (particle size ranging between <10 mm and <25.4 mm) is 40–70% (w/w) of mined landfill waste (Kaartinen et al., 2013; Quaghebeur et al., 2013; Hull et al., 2005), and is typically considered mainly soil containing varying amounts of landfilled materials (Kaartinen et al., 2013). The FF should be characterized so that utilization methods, such as energy and material, required processing

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(e.g. sieving, stabilization) methods or final disposal methods can be identified. Although thermochemical technologies, i.e. incineration, gasification, pyrolysis, have recently been evaluated to process materials (also FF) recovered from landfills (Bosmans et al., 2013), methane production potential of FF has not been studied. The methane potential may indicate potential for methane recovery for energy utilization, or the need for stabilization of the FF material to prevent emissions. To evaluate possibility to use FF in applications for soil type materials, factors such as particle size and nutrients are important characteristics. Site specific contaminants such as heavy metals are not characterized in this study, but they also affect the utilization of FF.

The aim of this study was to characterize the FF mined from two landfill sites by analyzing the content of the FF. The characterized properties are the water content, organic content (VS) and biochemical methane potential (BMP) of the FF. Also pH, chemical oxygen demand (COD), total nitrogen and phosphorus of the FF were studied after leaching. The FF samples were further sieved to examine the organic matter content and the methane potential in smaller fractions to compare these properties in various size fractions. The results can be used in assessing the processing, use and disposal of the FF while planning landfill mining.

2. Materials and methods

2.1. Sampling sites

The two studied landfills are located in Kuopio in central Finland and in Lohja in southern Finland. The Kuopio landfill contains MSW landfilled between 2001 and 2011. The landfilled waste was affected by changes in the local waste management system, as biowaste source segregation was initiated in 2004. Since 2009, MSW has been mechanically pre-treated, and only sieved underflow (<70 mm) has been landfilled. Regional paper, glass, hazardous waste, and metal collection systems were used during the landfill's history. The Kuopio landfill has a sealed bottom structure according to the EU requirements. For this study, the landfill was sampled when the vertical gas collection system was built in July 2012. The Lohja landfill was landfilled between 1967 and 1989 with MSW, construction waste and soil. The area is closed with a top cover but has no bottom structure; the gas collection system was built in 2000. The site was sampled in June 2013.

2.2. Sampling

In both sites, samples were taken from wells (0.9 m borehole) drilled with a hydraulic piling rig Casagrande B 170. In the Kuopio landfill, the samples (six in total) were taken from three wells at two depths (referred to as the bottom layer and the middle layer). The cutting points of the layers were chosen so that layers would present approximately same years of landfilling. Wells are referred as KU1, KU2 and KU4, while middle layer samples are named with number 1 (e.g. KU1.1) and bottom layer samples with 2 (e.g. KU1.2). In the Lohja landfill, vertical samples (altogether seven samples) were taken from four wells, of which two wells were studied as single samples, one well was divided into a three-layer samples and one well into a two-layer sample. One sample was not studied further, because it contained only soil without any waste materials. Depth of wells was determined so that layer between soil and waste would not be affected by sampling. Wells were referred as LO1, LO2, LO3 and LO4. Different layers were numbered starting from the top layer (LO1.1, LO1.2, LO1.3, LO4.1 and LO4.2). Samples, sampling depths and masses are presented in Table 1. Due to technical failure in transporting the sample KU4.2 from auger to skip, sample mass was less than that of other samples.

Table 1
Sampling points, sample depths, masses and portion of fine fraction in two studied landfills.

Sampling point	Depth (m)	Sample mass (t)	<20 mm (% (w/w))
Kuopio landfill			
KU1.1	2–10	3.4	38.0
KU1.2	10–22	7.2	49.8
KU2.1	2–14	8.2	50.2
KU2.2	14–26	9.9	38.0
KU4.1	2–15	11.0	41.2
KU4.2	15–31	3.3	53.9
Lohja landfill			
LO1.1	2–5	8.8	39.8
LO1.2	5–9	1.9	58.3
LO1.3	9–13	3.5	61.6
LO2	2–10	3.0	59.4
LO3	2–10	4.7	56.5
LO4.1	2–9.3	10.7	Not studied[a]
LO4.2	9.3–10	1.0	73.6

[a] Sample contained only soil and not waste materials.

Immediately after the materials were drilled from landfill, the samples were stored for 1–2 weeks in ambient conditions in dumpsters. During sampling and storing, water may have evaporated or poured off the samples since the water was not collected and the dumpsters were not closed. The samples were sieved and sorted at the site manually from approximately 600 L of sub-samples collected from the dumpsters. Samples were manually sieved in the Kuopio landfill to separate four particle size categories (>100 mm, 40–100 mm, 20–40 mm and <20 mm) and in the Lohja landfill three particle size categories the (>100 mm, 20–100 mm and <20 mm). Size categories 20–40 mm and 40–100 mm were combined in the Lohja landfill because 20–40 mm was very small fraction of the Kuopio landfill (6%). Samples were weighed before and after sieving. Particles smaller than 20 mm were referred as FF. In the Kuopio landfill, the rest of the sampled material (which was not manually sieved) was mechanically pre-treated using the same full-scale machinery that processed the MSW (since 2009). Three middle layer samples and three bottom layer samples were combined before mechanical treatment (middle layer referred as KUMTP1 and bottom layer as KUMTP2). The mechanical pre-treatment plant consisted of a shredder, a magnetic separator, a drum sieve (<30 mm and 30–70 mm) and a wind sieve as described in Kaartinen et al. (2013). The fractions examined were the <30 mm and 30–70 mm drum-sieved fractions.

The sieved and sorted samples were packed in 10 L buckets and transferred to the laboratory where they were stored at 7 °C. Maximum storage time was 6 months.

2.3. Batch assays

BMP was determined in duplicate or triplicate in 1 L glass bottles, which contained 500 mL (Kuopio samples) or 350 mL (Lohja samples) inoculum and waste samples at a ratio of 0.5 g $VS_{inoculum}$/g VS_{waste}. The inoculum was digested mesophilic municipal sewage sludge from the Viinikanlahti sewage treatment plant (Tampere, Finland). The inoculum was assayed alone, and its gas production was excluded from that of the samples. 50 mL of 42 g/L $NaHCO_3$ was added each bottle to adjust and buffer pH. Deionized water was added so that the total liquid volume in all bottles was 700 mL. Bottles were flushed 2–3 min with N_2 gas before sealing. The samples were incubated at 35 °C in a water bath. The biogas produced was collected in aluminum gas bags. The BMPs were continued until methane production became negligible (<5 mL CH_4/d) after 130–160 days.