CHARACTERIZATION OF MUNICIPAL SOLID WASTE LANDFILL FOR SECONDARY RAW MATERIALS

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Landfill mining for secondary raw material recovery has received growing interest in recent years. Metsäsairila municipal solid waste (MSW) landfill was investigated as part of the Smart ground project to find out its material content (e.g. metals, plastics, wood, paper, and cardboard) as well as composition of fine fraction (<20 mm). Sampling wells were core drilled by a hydraulic piling rig and samples collected by excavator and sorted to different waste fractions manually. Results showed that the amount of critical raw materials was not high enough from an economical point of view to recover these metals from MSW landfill. However, the economic viability of landfill mining could be increased by utilizing additional materials fraction (e.g. plastics, paper and wood) and biogas collected from the landfill for energy production.

Introduction

Landfill mining is a rather new area of science connecting all the essential elements of the effective implementation of circular economy; however, there are between 150,000 and 500,000 historic and still active landfills in the EU (Hogland et al. 2011), which can deliver a significant stream of secondary materials and energy. The number of landfills has decreased in the early 2000s from the numbers of the late 1970s. Similarly, the average size of the landfills has increased notably. The smaller landfills have been closed or removed and integrated to larger landfill entities.

Municipal landfills consist of about 50–60 per cent by weight of a soil-type material, 20–30 per cent by weight of material suitable for incineration (e.g. plastic, paper and wood), 10 per cent by weight of inorganic materials (e.g. concrete, stones, and glass) and a few weight per cent of metals (Kaartinen et al. 2013a). In old landfills, the particularly high proportions of mineral content but also the metallic components (e.g. aluminum and electronic equipment waste) could be recycled (Franke and Mocker 2013). From the energy point of view, the high calorific waste components such as wood, plastics, or paper/cardboard could act as substitute fuel. Estimations show that 178 million Mg of plastics, 83 million Mg of iron and 13 million Mg of nonferrous metals have been disposed of in landfills since 1975 (Franke and Mocker 2013). However, when the full potential in MSW landfills are included, the magnitude is notably higher. For example, in Germany alone the estimated total energy potential stored within the landfills during the decades is around 7700 PJ (Franke and Mocker 2013). The annual global methane emission from landfills is estimated at between 14–40 Tg (Humer and Lechner 2003; Bogner and Matthews 2003) when world's annual total methane emission is around 550 Tg (Bogner and Matthews 2003).

Currently, the active Smart Ground project is receiving funding from European Union's Horizon 2020 research and innovation program. The project intends to foster resource recovery in landfills by improving the availability and accessibility of data and information on secondary raw materials (SRM) in the EU area, while creating synergies among the different stakeholders involved in the SRM value chain. One important part of the project is in-depth characterization of the target pilot landfills. It will take into account the type of the material dumped into the landfills (e.g. metals/ores in municipal and industry landfills and in mining landfills, aggregates, and industrial minerals from mining and industrial dumps or organic material and SRMs suitable for incineration). Each partner country involved in project has selected at least three target pilot landfills from two main categories: municipal (e.g. community and local industry wastes) and industry landfills (e.g. mining industry). The project team has used existing information sources, e.g. databanks with waste information, scientific publications, and information gathered from dedicated networks to identify the most potential pilot sites. This information was complemented, for example, with water analyses and/or spatial analysis using aerogeophysical and lidar data.

Materials and methods

Metsäsairila was selected as a municipal solid waste (MSW) landfill under more detailed investigation in Finland. It is located in the south-eastern region in Finland, more precisely at the City of Mikkeli. It has both active and old closed parts and it has been operating since the beginning of 1970s. The surface area of the closed landfill area is around 8 ha and currently active area around 3 ha.

FIGURE 1. Sampling wells in landfill area (Photo by Ramboll Finland Oy)

The most promising sampling points were selected based on the geophysical measurements implemented in the landfill area by the Geological Survey of Finland (GTK). After this, five research (sampling) wells were drilled by hydraulic piling rig in the landfill area (Figure 1). Samples with codes DH1, DH2a, and DH3 were from the old, closed landfill area and samples with codes DH6 and DH7 were from the currently active area. Waste material collected from sampling well DH2a is shown in Figure 2.

FIGURE 2. Waste material collected from the DH2a sampling well (surface part) (Photo by Ramboll Finland Oy)

More detailed information on collected waste samples is presented in Table 1. Samples were moved to a sorting point, where they were manually sorted to different particle size categories (>100 mm, 20–100 mm and <20mm) and waste fractions (metal, energy fraction (wood, paper and cardboard, plastic and textile), soil, and others). Waste fraction separation was done to fraction sizes of 20–100 mm and >100 mm. Sorted samples from each research well were transferred to separate big plastic bags. Material size of <20 mm was packed in plastic buckets. After the weighing procedure, samples were transferred to laboratories for more detailed analysis. Analysis of samples for elements, total organic carbon (TOC), dissolved organic carbon (DOC), chloride, and fluoride was implemented in an external laboratory (ALS Finland Oy).

TABLE 1. Amounts of collected samples at every sampling well

Sample ID	Sample depth (m)	Total amount of collected waste material (kg)	Amount of sorted sample (kg)
DH1	3,5-17	10 220	406,0
DH2a	3-12	4 780	192,3
DH3	2,5-10	4 220	277,4
DH6	0,2-5	1 580	282,2
DH7	0,2-5	2 140	284,4

Results and discussion

The distribution of sorted samples into different particle size categories is somewhat similar between the samples from different wells (Table 2). For example, the proportions of particle size distributions from wells DH3 and DH6 are quite similar; even DH3 was located in an old closed area and DH6 in the currently active area. Sorted fractions <100 mm and 20–100 mm, which were combined from all wells together consisted mainly of energy fraction (plastic, paper, wood, cardboard, 76%), metals (5%), soil (17%), and others 2%. Results follow a similar trend to research implemented by Kaartinen et al. (2013a) at the MSW landfill in Kuopio, Finland. They observed that the amount of fine material (<20 mm) was found to be ca. 50% (w/w), which also supports previous reports of the amount of the fines (Quaghebeur et al. 2013). Fine material consists mainly of landfilled wastes but also of the landfill cover materials (usually soil). In our study case, fine material fraction varied from 37% to 47% depending on the well (Figure 3). The fine fraction mainly included soil material but small particles of plastic, paper, and wood were also present.

TABLE 2. Weight distribution of different waste fractions

Sample ID	**DH1**	**DH2a**	**DH3**	**DH6**	**DH7**	**Average**
	kg	**kg**	**kg**	**kg**	**kg**	**kg**
Weight of the aggregate	406,02	192,33	277,39	282,21	284,38	288,5
>100 mm	**111,51**	**68,23**	**50,03**	**69,57**	**81**	**76,1**
metal	6,54	9,3	3,75	2,45	1,7	4,7
wood	8,9	11	3,4	5,06	13,6	8,4
paper and cardboard	8,15	11,92	4,27	5,52	8,8	7,7
plastic	44,2	30,4	30,96	41,2	27,8	34,9
textiles	13,92	4,38	5,73	8,99	28	12,2
soil	29,8	1,23	1,92	6,35	1,1	8,1
others	0	0	0	0	0	0
20–100 mm	**124,71**	**52,7**	**101,76**	**78,84**	**75,18**	**86,6**
metals	2,82	3,19	6,76	2,22	1,54	2,8
wood	25,49	8,02	12,6	20,9	14,52	13,6
paper and cardboard	12,37	6,77	12,5	8,7	10,5	8,5
plastic	30,2	19,8	36,4	20,5	14,44	20,2
textiles	18,11	4,07	4,41	2,8	5,2	5,8
soil	34	10,12	25	19,9	26,18	23
others	1,72	0,73	4,09	3,82	2,8	2,6
<20 mm	**169,8**	**71,4**	**125,6**	**133,8**	**128,2**	**125,8**

Chemical parameters measured from the waste fraction of <20 mm are presented in Table 3. According to analysis of metals, fine fractions of sorted samples contained primarily compounds of Ba, Cr, Cu, Zn, and Pb. Amounts of Ag, Au, and In were rather low, as expected. Concentrations of heavy metals are lower than in the study by Quaghebeur et al. (2013). This reveals a difference in the composition and the characteristics of the waste materials in different MSW landfills with regard to type, location, and the period during the waste was landfilled. The amount of organic content (TOC) was in the same range as similar studies done previously (Quaghebeur et al. 2013, Kaartinen et al. 2013a, Kaartinen et al. 2013b). Sampling points in the active landfill area (DH6 and DH7) showed higher TOC concentrations than samples from the old, closed area. This indicates that organic material has degraded with longer time.

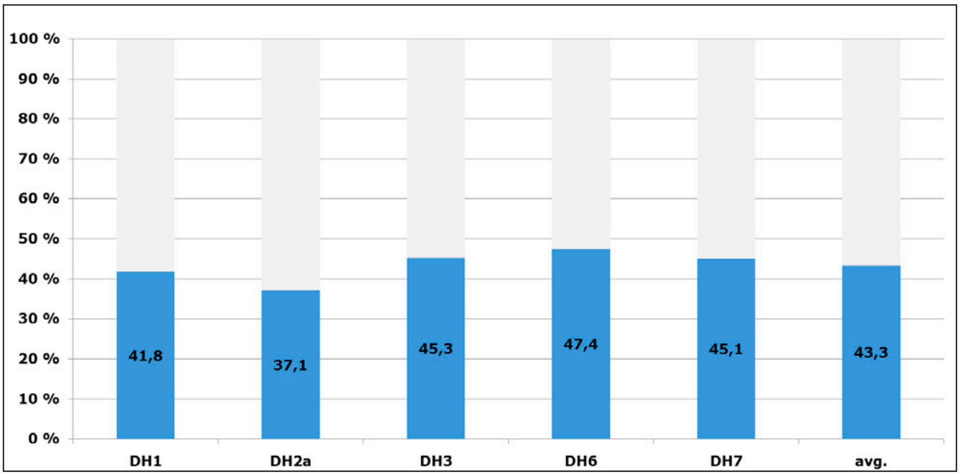

FIGURE 3. Percentage of <20 mm fraction in the wells investigated

Gutiérrez-Gutiérrez et al. (2015) reported of the critical raw material (CRM) studies from the four British MSW-based landfills. Landfills were operating between the following periods and receiving MSW, commercial, and industrial waste: 1980–1999, 2007–2013, 1998–2005, and 1992–2011. The concentration of rare earth elements (REEs: Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) was 220 ±11 mg/kg, while that of platinum group metals (PGMs: Pt, Pd, Ru) was 2,1 ±0,2 mg/kg, and 156 ±7 mg/kg for the other critical metals (Li, Ln, Sb, Co). In our study concentrations were lower, and for REEs 87±13 mg/kg. Concentrations of Pt, Pd, and Ru were lower than 0,5 mg/kg for each metal. Similarly, Ce was the most abundant rare metal in our study and the study by Gutiérrez-Gutiérrez et al. (2015).

TABLE 3. Chemical parameters measured from the waste fraction of < 20 mm

		DH1	DH2A	DH3	DH6	DH7
Dry content 105° C	%	68,5	64,8	62,6	74,2	69,2
TOC	% k.a.	3,69	4,56	5,8	5,99	9,57
DOC	mg/l	24,7	6,24	74,7	27,6	27,9
As	mg/kg	5,64	17,2	11,1	3,1	2,9
Ag	mg/kg	0,62	1,41	<0,50	<0,50	<0,50
Ba	mg/kg	146	285	232	132	173
Cd	mg/kg	0,45	0,98	0,93	<0,40	<0,40
Cr	mg/kg	55,7	65,1	79,7	51	73,9
Cu	mg/kg	113	174	144	97,1	61,7
Mo	mg/kg	1,82	2,4	2,7	1,96	2,11
Ni	mg/kg	23	42,2	25	25,5	33,2
Pb	mg/kg	54,7	29,2	120	34,1	31,2
Sb	mg/kg	<0,50	<0,50	<0,50	<0,50	<0,50
Zn	mg/kg	387	496	794	359	286
Hg	mg/kg	<0,20	<0,20	<0,20	<0,20	<0,20
Se	mg/kg	<2,0	<2,0	<2,0	<2,0	<2,0
Fluoride	% k.a.	0,002	<0,002	<0,002	<0,002	<0,002
Chloride	% k.a.	0,0334	0,0365	0,112	0,0348	0,105
Er	mg/kg	0,632	1,00	0,692	0,654	0,556
Eu	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Au	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Pd	mg/kg	<0,50	<0,50	<0,50	<0,50	<0,50
La	mg/kg	16,9	19,2	21,2	13,8	15
Y	mg/kg	6,24	9,43	6,69	6,53	5,55
Pt	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Ce	mg/kg	33,8	38,6	42	28,7	31,2
Nd	mg/kg	13,1	15,7	18,5	11,8	10,9
Pr	mg/kg	3,57	4,13	3,52	3,15	2,93
Ru	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Sm	mg/kg	2,29	2,82	2,19	2,2	1,93
Gd	mg/kg	1,75	2,28	1,67	1,74	1,51
Tb	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Dy	mg/kg	1,28	1,89	1,87	1,34	1,16
Ho	mg/kg	<0,500	<0,500	<0,500	<0,500	<0,500
Yb	mg/kg	0,543	0,898	0,579	0,546	<0,500
Sc	mg/kg	3,68	4,46	2,85	3,99	4,93
In	mg/kg	1,34	2,47	2,44	0,88	0,55

Conclusions

Sorted size fractions <100 mm and 20–100 mm from every well followed similar waste distribution as MSW landfills previously investigated. Drilled well samples consisted mainly of energy fraction and the fine material (<20 mm). Amounts of critical raw materials were rather low. This was expectable for municipal solid waste landfill. Even though landfills have the potential for both energy and material valorization, the development of a treatment plant with high resource recovery remains one of the technological challenges for further development of enhanced landfill mining. It is most likely that recovery of critical raw materials from MSW landfills is not economically profitable. On the contrary, biogas (methane) produced during anaerobic degradation of organic material is worth collecting. The biggest recovery potential in MSW landfills is in energy fraction which could be used for energy production (incineration). However, this is not currently profitable in old landfills. All secondary raw material information collected from different landfills will be useful in the future when there will probably be a cost-efficient way to utilize these materials.

References

Bogner, J., Matthews, E., 2003. Global methane emissions from landfills: New methodology and annual estimates 1980-1996. Global Biogeochemical Cycles, doi:10.1029/2002GB001913.

Franke, M., Mocker, M., 2013. Resource Potential of Landfill Mining – A National and Regional Evaluation. ATZ Entwicklungszentrum, Institute of Resource and Energy Technology, Technische Universität München, Germany.

Gutiérrez-Gutiérrez, S.C., Coulon, F., Jiang, Y., Wagland, S., 2015. Rare earth elements and critical metal content of extracted landfilled material and potential recovery opportunities. Waste Management, 42, 128-136.

Hogland, W., Hogland, M., Marques, M., 2011. Enhanced landfill mining: material recovery, energy utilization and economics in the EU (Directive) perspective. In: Proceedings International Academic Symposium on Enhanced Landfill Mining. Houthalen-Helchteren, Belgium, 233-247.

Humer, M.H., Lechner, P., 2003. Effect of methane oxidation on the water balance of the landfill cover and the vegetation layer. In: T.H. Christensen et al. (eds.), Proc. Eleventh International Waste Management and Landfill Symposium, Sardinia, Italy.

Kaartinen, T., Sormunen, K., Rintala, J., 2013a. Case study on sampling, processing and characterization of landfilled municipal solid waste in the view of landfill mining. Journal of Cleaner Production, 55, 56-66.

Kaartinen, T., Sormunen, K., Rintala, J., 2013b. Studies on material composition of closed Finnish landfills: Potential for landfill mining? In: ELFM Consortium (Ed.), 2nd International Academic Symposium on Enhanced Landfill Mining, 14–16 October 2013, Houthalen-Helchteren, Belgium, 1–11.

Quaghebeur, M., Laenen, B., Geysen, D., Nielsen, P., Pontikes, Y., Van Gerven, T., Spooren, J., 2013. Characterization of landfilled materials: screening of the enhanced landfill mining potential. Journal of Cleaner Production, 55, 72-83.