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Research note

Composition of Waste at an Early EU-Landfill of Torma in Estonia

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A B S T R A C T

Landfills represent a continuous environmental threat due to the emission of different greenhouse gases, which are mainly responsible for the climate changes, and the contaminated leachate that affects the surface and ground water recipients. The circular economy approach appeared as a useful solution to reduce the depletion of the Earth's natural resources and the environmental risk effects by considering all of the lost resources like wastes including the landfills as potential secondary resources. It is well known that characterizing the composition of landfill waste is an essential step in specifying the recycling methods. In the current research the waste composition at one of the first EU regulations-compliant sanitary landfills (the Torma landfill in Estonia) was studied. The results showed that the fine fraction (<20 mm) represented 53% of the total excavated waste materials while the waste to energy fraction (plastics, woods etc.) was the highest within the coarse fraction (>20 mm). The present work emphasized that mining landfills can be a good solution either for extracting primary raw materials like metals, as a source for recovering energy, or for acquiring landfill space.

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INTRODUCTION

Nowadays the prices of raw materials are increasing due to the rising of global consumption and the economic and environmental impact of mining these materials from their primary sources. Serious concerns regarding scarcity of important natural resources have been highlighted by different researchers throughout the world [1]. As an example, about 50% of the extracted iron and copper along the industrial history are unusable due to landfilling [2]. Therefore, the landfill mining approach is of great importance to achieve a better sustainability of raw materials by returning these lost materials back to the circular economy [3].

The growing attention of energy and raw materials recovery from landfills has been witnessed due to the reduction of the harmful environmental impact of these sites [4]. Studies have been identifying the health and the environmental harmful effects of the landfill green house gases and leachates [5,6]. Consequently, the reason for mining landfills might be also to stimulate the remediation of these sites and reducing management cost [7]. In addition, mining landfills can generate spaces in the existing filled landfills to extend the life time especially in cities with dense population where no spaces are found for new landfills, which means an additional economic benefit of new business concept for waste management companies [3].

All landfill sites have been used for the disposal of different municipal and industrial wastes. These sites contain heterogeneous waste materials with a lack of information about their composition, volume and the physico-chemical properties [8,9]. The first step in the wastes characterization is a test excavation in the landfill site in order to assess the composition and the physico-chemical properties [10]. The composition and characterization data is important for the planning and development of the waste management systems and the improvement of the resource recovery technologies.

Different landfill mining characterization studies havefocused on the screening of the waste to different particle sizes followed by hand sorting of the coarse fraction [7,8,11,12]. Hogland [7] studied the characterization of the Måsalycke landfill which is located in the southeastern part of Sweden. The study aimed to explore the potential of recycling waste materials and recovery of energy through incineration. The waste materials were screened to three different

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fractions: <18 mm, 18-50 mm and >50 mm followed by hand sorting of the coarse fraction (>50 mm). The results showed that 50% of the coarse fraction (>50 mm) was wood and paper, the medium size fraction (18-50 mm) contained stones and soil like material, and the fine fraction (<18 mm) contained peat like material.

Hull et al. [11] studied the characterization of excavated waste materials from the Burlington County landfill in New Jersey in the northeastern USA. The waste material was screened to two fractions: a fine fraction and coarser oversized fraction (>25.4 mm). Then, 49 samples were hand sorted to 14 different categories. The researchers found that about 50% of the waste material was fine fraction.

Jain et al. [10] characterized 78 samples from Alachua County southwest landfill, Florida, USA were characterized to find the metal content and the properties of the waste materials. The excavated wastes were screened to 50, 12.5, 6.3 and 0.425 mm followed by hand sorting of the fractions 50, 12.5 and 6.3 mm to six different categories. The results showed that only 25% of the excavated waste samples retained on the 12.5 mm fraction and about 60% of the waste was in the fraction <0.425 mm

Quaghebeur et al. [12] characterized the REMO landfill in Belgium by studying the properties of 38 samples in detail. The wastes were first screened into two fractions.The oversize fraction >10 mm which was then hand sorted to 8 categories and the fine fraction <10 mm. The results showed that the fine fraction represents about 44% by weight of the total excavated wastes and it contains mainly mineral materials.

Kaartinen et al. [8] investigated the characterization of a landfill wastes from Kuopio, Finland by screening the materials to 4 different fractions (>100 mm, 40-100 mm, 20-40 mm and the fine fraction <20mm). All fractions, except the fine fraction, were sorted manually to seven different categories. To study the properties of the fine fraction deeply, this fraction was further screened to the following sizes 10, 4 and 1 mm. The results showed that the average mass of the fine fraction was about 45% of the total wastes. In addition, the plastic fraction was found to be the highest weight within the coarse fractions (<20 mm) with an average of 24%.

Recently Jani et al. [3] characterized excavated wastes from the Högbytorp landfill in Sweden. The results showed that the fine fraction (<10 mm) represents 38% while the organic and the moisture contents were 16.6% and 23.5% respectively. The characterization study showed that the potential of recycling the fine fraction as a waste to energy was low. However, the recycling of this fine as a waste to material was considered as a good option.

The most important conclusion from all the above reviewed studies that the potential of landfill mining differs in each studied landfill site. Different parameters play vital role in the appraisement of the waste materials inside each landfill like the geographical place of the landfill, the composition of the buried materials, the age of the landfill, the climatic conditions and the standard of living. The same parameters are important to decide which method will be used to recycle or recover these wastes as waste to energy or waste to material [3,8,10].

Therefore, the goal of the present study is to characterize the composition of the waste material inside the Torma landfill in Estonia which was one of the first landfills that followed the European Directive requirements during construction. Regaining space in a modern landfill with expensive bottom liner and fully functional infrastructure would justify excavations.

MATERIAL AND METHODS

Site description

Torma landfill is located in Jõgeva County (58°51'11.2"N, 26°52'37.9"E) in Tartu municipality (total population of about 100,000). It was established and opened in 2001. This was the first landfill in Estonia which was constructed according to the European Directive requirements. The landfill has an area of 6.2 hectares, of which municipal solid waste (MSW) represents 2.5 ha, leachate collection and treatment is 0.25 ha, waste sorting-related areas of approximately 0.5 ha and waste and hazardous waste reception and landfill service area of approximately 0.5 ha. The landfill contains three cells of different age with MSW as the main source of waste from Tartu municipality.

Sampling and analysis

The excavated cell was fresh waste of less than 5 years old and with a total weight of about 300, 000 tons. A test pit was excavated to about 4 meters in depth and samples were taken from each 1 meter to represent 4 layers of wastes by using bucket excavator. A weight of 501, 399, 260 and 575 kg of waste was taken from layers L1, L2, L3 and L4 respectively for hand sorting. Each layer was manually sorted at a conveyor belt and then the different fractions were weighted. The fine fraction was found by manually sieving the residue to < 20 mm. The metal content was found according to the EN 12457-3: 2002 by using ICP-MS analysis. However, this analysis was done in a private laboratory.

RESULTS AND DISCUSSION

Composition of the excavated wastes

Exploring the composition of landfill wastes is an essential step in finding the potential of mining any landfill and for the suggesting recycling options. Figure

1 shows the percentage of the total waste composition of the four layers. The results showed that the rejected fraction was the highest with 65% of the total excavated wastes which represents large proportion of biodegradable waste and mineral waste as landfilled. This result was higher than described in previous studies conducted by Jani et al. [3] with 27.3% and Hull et al. [12] with 17.7% but it was in corresponding with results from studies of Siddiqui et al. [14] with 58% and Quaghebeur et al. [13] with 70%. However, the plastic and textile was the dominating fraction with 25% in the sorted masses, which can be considered as a source of recovering energy by incineration.

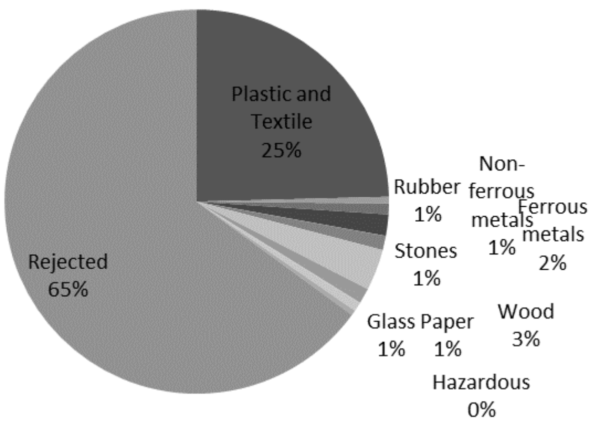

Figure 1. The waste composition of the four layers.

The rejected fraction was studied further through sieving manually the wastes for two fractions a coarse fraction >20 mm and a fine fraction <20 mm. As shown in Figure 2, the fine fraction dominating the waste materials with an average of 53% and increased with increasing the waste age which can be due to the decomposition of the organic wastes in the older layers, considering that the L1 is the newest while the L4 is the oldest. This result was comparable with that of different studies which emphasized that the fine fraction at any landfill could represent 40-70% [3,8]. In addition, the percentage of the fine fraction depends on different parameters like the chosen particle size, the landfill age and excavation method [13].

According to Figure 3, the excavated waste showed a high potential of recovering energy (waste to energy) as a burnable materials with 77% within the coarse fraction (plastics, textile, paper and wood) while recycling the waste as material was only 11% (rubber, metals and stones). However, this result was higher than that of Jani et al. [3], Quaghebeur et al. [13] and Kaartinen et al. [8] and might be explained by that landfilled materials within this landfilled was accepted according to the European Landfill Directive requirements.

Composition of the fine fraction

The fine fraction <20 mm was studied further by hand sorting the waste materials from all the 4 layers. The results are presented in Figure 4, which show that the plastic and textile fraction has the highest weight percentage with 27% followed by the fine <10 mm and the fine >10 mm fractions with 24% and 22% respectively. However, even with this fine fraction <20 mm the Waste to Energy aspect is recommended due to the high percentage of the burnable fractions (plastic and textile, wood and paper) with a total percentage of 37%.

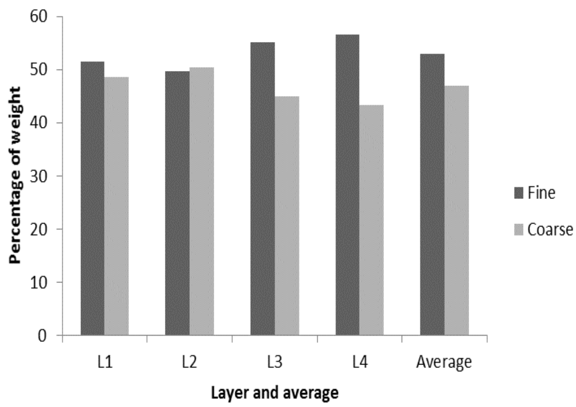

Figure 2. The weight percentage of the fine and coarse fractions.

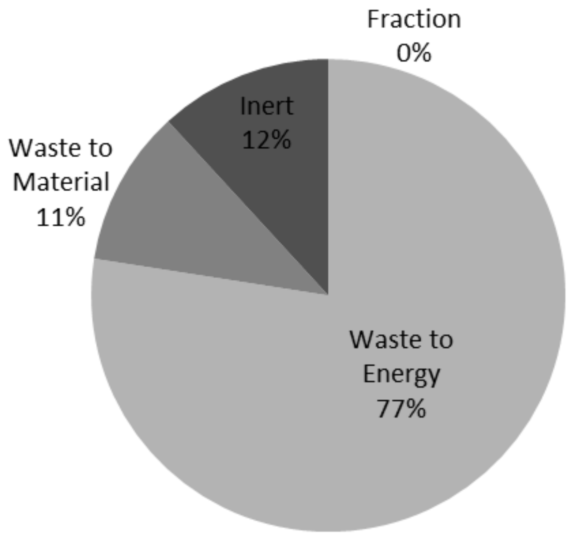

Figure 3. Recycling potential of the coarse fraction >20 mm.

Metal content of the fine fraction

Table 1 shows the metals content of the fine fraction compared to that of REMO landfill in Belgium [13] and Högbytorp landfill in Sweden [3]. The results showed that high concentrations of Al, Fe and Mn were found compared to Quaghebeur et al. [13] and Jani et al. [3], which can be due to the differences in source of the deposited wastes. The high concentration of Al could be indicated as a good prospective of metal extraction. However, the prices of the recycled metals are usually low compared to the mined metals from primary sources which can be as a consequent of poor quality [8]. Low concentrations of As, Cd, Ni, Co and Pb were found compared to that of Quaghebeur et al. [13] and Jani et al. [3] which can be due to the variation of the wastes streams in these countries. However, the composition of the landfilled waste at any landfill is based on different parameters such as society, culture, standard of living, waste management system and landfill legislations [3]. The low concentrations of these metals might be also considered as environmental and economic benefits due to the expectation of low metals content in the leachate. In addition, the concentration of Cu was corresponding to that of Quaghebeur et al. [13] results and less than that of Jani et al. [3]. While the Zn concentration was higher than that of Quaghebeur et al. [13] and in agreement with reported data by Jani et al. [3].

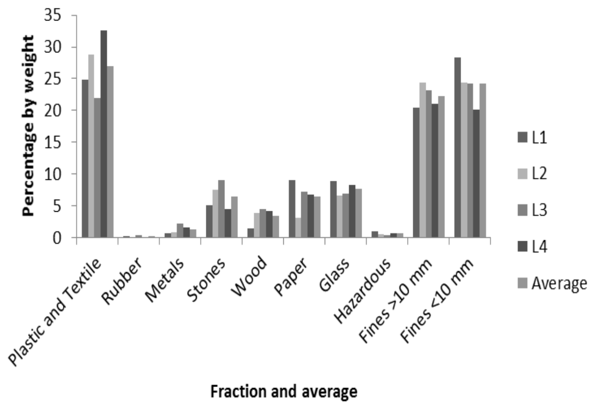

Figure 4. Waste composition of the fine fraction <20 mm.

TABLE 1. The metals content of the studied fine fraction at Torma landfill in mg/kg compared to that in REMO landfill in Belgium and Högbytorp landfill in Sweden.

Element mg/kg	REMO, Belgium Fine < 10 mm Quaghebeur et al. (2013)	Högbytorp, Sweden Fine < 10 mm Jani et al. (2016)	Torma, Estonia Fine < 20 mm Present study
Al	ND	ND	10684(6144)
As	27(15)	5(2)	ND
Fe	27000(750)	28724(8108)	49390(35791)
Cr	496(118)	254(54)	260(193)
Mn	ND	ND	356(204)
Co	ND	23(6)	7(4)
Ni	176(61)	111(34)	34(19)
Cu	339(55)	1460(684)	321(181)
Zn	667(211)	1848(488)	1046(572)
Cd	6(4)	2(0.6)	0.5(0.8)
Pb	ND	240(65)	141(97)

Note values between brackets represent standard deviation and ND means not detected.

CONCLUSION

The present work focused on studying the waste composition at one of the early landfills that was constructed in compliance with European Landfill Directive requirements the Torma landfill which is located in Estonia. According to the manual sieving results of the four layers the fine fraction <20 mm was higher than the coarse fraction with 53% by weight. It was found that the waste to energy is the best recovery option for the excavated wastes due to the high concentrations of the burnable fractions (plastic and textile, wood and paper) in the coarse (>20 mm) and the fine (<20 mm) fractions with 77% and 37% by weight, respectively. Mining landfills might be a potential solution for the shortage of industrial raw materials if methods of extraction and recycling can be developed to offer quality standards for industrial use. However, energy recovery can be considered as a good solution for reducing the occupied places in the operating landfills and hence increasing the lifetime of these sites. Waste characterization is essential for any landfill mining project because specifying the waste properties will help to find the most suitable recycling, recovery or even re-disposal option for each landfilled fraction.

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Persian Abstract

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چکیده

محل دفن زباله با متساعد کردن گازهای گلخانه‌ای گوناگون به عنوان خطری جدی برای محیط زیست شناخته می‌شود که باعث تغییرات آب و هوایی، آلودگی آب‌های سطحی و آب‌های پذیرنده می‌شود. دیدگاه اقتصاد چرخه ای به عنوان راهکاری کارآمد در جهت جلوگیری از اتمام منابع طبیعی و کاهش خطرات و تاثیر پذیری محیط زیست از آلاینده ها با در نظر گرفتن ضایعات به عنوان مواد با ارزش قابل بازیافت مطرح است. شناخت خصوصیات مواد موجود در محل دفن زباله به عنوان مرحله اول نقشی تعیین کننده در انتخاب روش بازیافت دارد. در این تحقیق خصوصیات یکی از محل‌های دفن زباله در استونی مورد مطالعه قرار گرفته است. نتایج حاکی از آ« است که بیش از نیمی از مواد موجود را مواد با سایز کمتر از ۲۰ میلی متر تشکیل داده اند. نتیجه تحقیق حاضر نشان داد که استخراج این مواد راهی مناسب برای بازیافت مواد قابل بازیافت در این مناطق است.