Waste Management 62 (2017) 101–117

Contents lists available at ScienceDirect

Waste Management

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

Energetic utilisation of refuse derived fuels from landfill mining

Martin Rotheut, Peter Quicker *

RWTH Aachen University, Unit of Technology of Fuels (TEER), Germany

ARTICLE INFO

Article history:
Received 18 August 2016
Revised 8 January 2017
Accepted 3 February 2017
Available online 20 February 2017

Keywords:
Landfill mining
Waste-to-energy
Refuse derived fuel
RDF
Solid recovered fuel
SRF
Energetic utilisation
Thermal treatment of waste

ABSTRACT

The residence of municipal solid waste within a landfill body results in a significant change of material properties. Experiences with the energetic utilisation of the burnable fractions from formerly landfilled waste are hardly documented, the influence of refuse derived fuels (RDF) from such materials on the performance of modern waste-to-energy plants is not sufficiently described in scientific literature. Therefore this study focuses on the energetic utilisation of refuse derived fuel from landfilled waste, processed in a mechanical waste treatment facility, and the impact of the material on the operation of the incineration plant. Additionally, the possibility of direct combustion of non-pre-treated excavated landfill material has been evaluated in the same facility. First, sampling and analysis of the fuel has been carried out. Based on this, a large-scale combustion experiment was planned and conducted in an industrial waste-to-energy plant. Steam mass flow rate, concentration of harmful substances in the raw gas, as well as total emissions of the facility have been monitored in detail. Furthermore, the influence of the landfilled material on the additive consumption has been determined. The combustion residues (bottom ash) were also sampled and analysed. Based on the evaluation of operating data and analysis of both fuel and residue, suitable thermal treatment approaches for the refuse-derived fuel and the non-pre-treated excavated material have been assessed.

1. Introduction

The globally rising demand for resources such as fuels and strategic metals has led to an increasing evaluation of alternative ways to provide these resources (Mocker et al., 2009). Resources in municipal waste landfills have also become the centre of discussion. In Germany for example, about 2.5 billion tons of waste have been landfilled since 1975 (Mocker et al., 2009; Rotheut and Quicker, 2015), which are currently considered to contain a noteworthy amount of resources. Some studies on the composition of different landfills have been carried out in the past (Fricke et al., 2012; Gäth and Nispel, 2011; Rettenberger, 2009). Based on these, the material in German landfills has been estimated (Mocker et al., 2009; Fricke et al., 2012). According to Fricke et al. (2012), the combustible material contained in landfilled waste is approximately 250 million tons. Considerable amounts of metal are also mentioned in the literature. An iron content of about 26 million tons is estimated (Fricke et al., 2012; Gäth and Nispel, 2011; Rettenberger, 2009; Quicker, 2014), the copper proportion is numbered between 0.85 and 1.2 million tons and also noteworthy aluminium amounts of 0.5 million tons have been reported.

1.1. State of knowledge

In the past, the reclamation of landfills was usually performed due to ecologic reasons as it primarily served the purpose of regaining land area and volume or to prevent environmental hazards. Regaining resources from landfills has therefore not been the focus of previous reclamation projects. Lately, experts have increasingly discussed the possibility of subsequent use of the contained resources (Mocker et al., 2009).

Despite this growing interest in landfill mining, the number of publications regarding this topic is still relatively small. Respective articles are addressing questions of resource potential, emissions, technical reclamation approaches, expectable mass streams and qualities, processing technologies for the excavated material as well as ecological and economical questions. Table 1 gives an overview of relevant scientific articles on the field of landfill mining and summarizes their main content.

As can be seen in the table, experimental studies on the energetic utilisation of excavated landfill material or refuse derived fuels recovered from such materials are scarce. The incineration of landfilled material in a US waste-to-energy (WtE) plant is documented in Foster (1994), and trials in a waste gasification and melting plant in Japan are described in Tanigaki (2015). All other

* Corresponding author.
E-mail address: quicker@teer.rwth-aachen.de (P. Quicker).

http://dx.doi.org/10.1016/j.wasman.2017.02.002
0956-053X/

Table 1
Literature overview of articles regarding landfill mining.

Author	Year	Content	Ref.
Mocker et al.	2009	Motivation for landfill mining; short description, state of the art of landfill mining technology; economics, constraints and resource availabilities are discussed	Mocker et al. (2009)
Fricke et al.	2012	Composition of landfill material on the basis of practical investigations is described; German raw material potential is discussed	Fricke et al. (2012)
Gäth et al.	2011	Project examples (landfills Reiskirchen and Hechingen); raw material potential is discussed	Gäth and Nispel (2011)
Rettenberger et al.	2009	Rough description of process steps for landfill mining; focus on emissions during reclamation and emission reduction by removal of the landfill; example landfill Burghof; discussion of costs and economics	Rettenberger (2009)
Rettenberger et al.	2010	Process steps for landfill reclamation and following material processing; costs and German raw material potential (materials and fuels)	Rettenberger et al. (2010)
Göschl	2006	Large-scale project in the Emirate Sharjah; processing and composition of landfilled material; quantification of recovered material streams	Göschl (2006)
Wolfsberger et al.	2015	Description of a reclamation project; classification and characterisation of material from different dumping periods	Wolfsberger et al. (2015)
Tanigaki	2015	Industrial investigations on the thermal treatment of excavated material from landfills by Nippon Steel & Sumikin Engineering Co. LTD; treatment in the pilot scale gasification and melting plant with 20 t/day throughput	Tanigaki (2015)
US EPA	1991	Handout on landfill mining; detailed description of three project examples; raw material potential and availability	United States Environmental Protection Agency (1997)
Foster	1994	Detailed analysis of the Frey Farm landfill reclamation project; co-incineration of excavated material over some years in a waste-to-energy plant; material characterization; plant operation, including long-term effects; consideration of the emission situation	Foster (1994)
Johansson et al.	2016	Investigation on material composition of a Swedish landfill; excavation and processing of 600 t of landfilled waste; market potential of recovered fractions	Johansson et al. (2015)
Krook et al.	2012	Review paper on the status of landfill reclamation regarding projects in the time span from 1998 to 2008	Krook et al. (2012)
Frändegård et al.	2013	Resource potential for Sweden on the basis of literature data; processing steps for reclamation; climate gas emissions	Frändegård et al. (2013)
Bosmans et al.	2013	Theoretical overview on thermal treatment possibilities for landfill material; process classification and description; advantages and disadvantages; assessment of process suitability	Bosmans et al. (2013)
Morelli	1991	Status of landfill mining technologies on the basis of two examples; excavation and screening technologies; reclamation costs	Morelli et al. (1991)
Kurian et al.	2003	Overview on former landfill mining projects; material analysis of samples from two Indian landfills	Kurian et al. (2003)
Guerriero	1996	Status of landfill mining technology on the basis of US project examples; technical status and reclamation costs	Guerriero (1996)
Ford et al.	2013	Feasibility study for Scotland; overview of reclamation projects worldwide; resource potential, material analysis, technology, reclamation costs	Ford et al. (2013)

related papers on the energetic utilisation of landfilled material are only theoretical elaborations.

A summary of the basic results from the two documented practical investigations on energetic utilisation of landfilled material (Tanigaki, 2015; United States Environmental Protection Agency, 1997; Foster, 1994) is given in the following, subsequent to a description of the fuel characteristics of excavated material, using the example of investigations from Austria (Wolfsberger et al., 2015).

Recent research activities in Austria have focused on the characterisation of excavated material regarding its elementary composition. The samples were drilled from two different landfill sites in Austria. Samples were taken from material that had been landfilled 1979–1984, 1985–1988 and 1990–2000 and a sieve analysis was conducted. A large amount of fine fraction (<40 mm), between 68 and 84 wt%, was found. The fractions plastics, wood, leather, rubber, paper, cardboard and textiles summed up to 24.7–36.5 wt%. In total, a metal content between 2.3 and 4.7 wt% was determined. The excavated material landfilled between 1990 and 2000 was shown to have relatively high heating values between 10,750 and 10,900 kJ/kg. Samples from older material contained a comparably high amount of heavy metals, prohibiting direct incineration in Austrian facilities (Wolfsberger et al., 2015).

Large-scale experiments on thermal treatment of excavated fractions from landfilled waste were carried out in Japan by Nippon Steel & Sumikin Engineering Co. Ltd. A pilot scale gasification facility with a throughput of ca. 20 tons/day was used. Input material was excavated municipal solid waste that had been classified to a particle size <200 mm – without any other further treatment. During the experiments, a mixture of normal municipal solid waste and excavated material was used in the facility. The amount of excavated material in the mixture was about 10 wt%. No negative influence on fly ash and slag could be detected. More detailed information about the excavated material or the experiences during thermal treatment has not been published (Tanigaki, 2015).

The most detailed and comprehensive experiences on thermal treatment of excavated landfill material were gathered in the United States between 1991 and 1996 (United States Environmental Protection Agency, 1997; Foster, 1994). Waste from the Frey Farm Landfill in Lancaster County, Pennsylvania, was incinerated in a nearby waste-to-energy plant, to obtain additional landfill space and to fully load the WtE plant. The excavated waste, with an age between one and five years, was sieved in a drum screen with a mesh size of 1" (2.54 cm). The underflow (predominantly soil) was applied as a cover material on the landfill again, the overflow material was used as fuel in the waste-to-energy plant. As a result of the relatively low heating value of 7.2 MJ/kg, the material had to be enriched with fractions of higher calorific value (tire and wood chips) and was subsequently mixed with fresh municipal solid waste in a ratio of 1:4. The amount of ash was about 5–7% higher compared to normal waste. Test trials with 20 years old landfilled waste indicated much lower calorific values and even higher contents of ash.

The emission limits (CO, Cr-VI, NO_x, SO_x) of the incineration plant could be met during the entire period, but gradually a significant increase of HCl concentration in the off gas could be observed. Further impacts regarding the plant operation were the necessity of a more intensive fuel mixing in the bunker to ensure homogeneous fuel properties, and increased rates of abrasion, wear and clogging of the equipment, due to the higher ash content. The combustion of the material was stopped in 1996, when the waste-to-energy plant did not need additional fuel anymore (United States Environmental Protection Agency, 1997).