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Research article

Influence of input waste feedstock on solid recovered fuel production in a mechanical treatment plant

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ABSTRACT

In solid recovered fuel (SRF) production, type and nature of input waste stream influences the quality of fuel product. This paper presents the influence of input waste stream on SRF production in a mechanical treatment (MT) plant. The SRF was produced at industrial scale from three different types of waste streams: commercial and industrial waste (C&IW), construction and demolition waste (C&DW) and municipal solid waste (MSW). Here, the stream of MSW used for SRF production was energy waste collected from households. In the SRF production from MSW, higher yields of material were recovered in the form of SRF as compared with that of recovered from C&IW and C&DW. Of the input MSW to the MT plant, 72 wt% was recovered as SRF, equivalent to 86% energy recovery. The energy consumed to produce unit tonne of SRF from C&IW, C&DW and MSW was 1153 MJ, 1246 MJ and 1626 MJ, respectively. In the SRF production, removal of chlorine (Cl), lead (Pb) and mercury (Hg) from C&IW feedstock was worse than from C&DW and MSW feedstocks. In the SRF production from C&IW, of the input mass of chlorine, lead and mercury to the MT process 60%, 58% and 45%, respectively was found in the SRF. The SRF produced from C&DW contained the lowest mass fraction of the input chlorine, lead and mercury in comparison with the SRF produced from C&IW and MSW, namely 34%, 8% and 30%, respectively. Among the waste components rubber, plastic (hard) and textile (synthetic) were identified as potential sources of polluting and toxic elements, whereas wood, paper & cardboard and plastic (soft) were found to contain the lowest content of polluting and toxic elements. The pollutant and toxic elements investigated in this research work were chlorine, lead, cadmium, mercury and arsenic.

1. Introduction

Solid recovered fuel (SRF) is prepared from non-hazardous waste to be utilized for energy recovery in incineration/co-incineration plants and meeting the classification and specifications requirements set by European standards for SRF [1]. Here, 'preparation' refers to processing, homogenizing and upgrading to a quality that can be traded among producers and users. CEN (European Committee for Standardization) TC 343 developed standards and technical specifications for solid recovered fuels for European markets. The standardization process took around a decade in which a lot of information on SRF was generated to establish European standards for SRF [2–4]. SRF is distinguished from refuse derived fuel (RDF) as SRF is manufactured in compliance with CEN standards [1], whereas RDF does not. SRF is subject to stringent quality standards. SRF production from waste provides an alternative fuel to fossil fuels and also generates material for recycling.

SRF is used industrially in gasification and combustion processes as fuel/co-fuel for the production of electricity and heat. Currently, in the EU, approximately 13.5 Mt/year SRF/RDF are used, out of which 12 Mt/year is used in cement plants and dedicated waste-to-energy plants and, a further 1.5 Mt/year are used in other applications. In the EU, market for SRF could amount to 53 Mt/year [4].

In Europe, SRF is produced from various common waste feedstocks; municipal solid waste (MSW), commercial and industrial waste (C&IW), construction and demolition waste (C&DW), and from some other waste streams such as sewage sludge, reject from manufacturing, scrap tyres or waste textiles [5–10]. Generally, SRF is produced in mechanical treatment (MT) plant, mechanical biological treatment plant (MBT) [11–14], and in material recovery facility (MRF) [15]. In MRF, the focus is on recovery of recyclable material, and producing SRF/RDF as a by-product. SRF is a promising fuel that can be utilized for energy recovery in industries [16]. Major commercial scale uses of SRF as fuel/co-fuel are in cement kilns, lime kilns, coal-fired power plants, industrial boilers and gasification and combustion based combined heat and power (CHP) plants for the production of heat and power [5,17,18].

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Quality of SRF is a key factor for its future demand and utilization, especially in power production sector. In power production industry for SRF to be accepted as a replacement of fossil fuels, it is critically important to achieve the required or demanded quality [19]. Generally, SRF quality is defined in terms of homogeneity (composition), energy efficiency (heating value) and technical and environmental parameters (i.e. concentration of chlorine and mercury). In SRF, heating value, concentration of chlorine (Cl) and mercury (Hg) are required to be as per given in CEN standards for SRF [1] and the concentration of heavy metals is to be kept low [20,21].

SRF quality depends on the input waste material and the type of waste treatment [22]. In SRF production, type of input waste material and configuration of plant in terms of arrangements of unit operations/sorting techniques used have profound effect on the quality of product. Type of input waste stream influences the quantity, quality and composition of output streams in SRF production. Input waste stream's properties such as moisture content, particle size, composition and physical nature (in terms how mixed, hard or soft to break/open etc.) play critical role on the performance of sorting operations of unit operations/sorting techniques which ultimately affect the properties of output streams, especially of SRF [23]. For instance, in commercial scale SRF production, output streams produced form C&IW, C&DW and MSW varied considerably in terms of their quantity and quality (heating value, concentration of elements) [24–26]. The composition of SRF affects the chlorine content and other fuel properties [27]. The understandings of effect of input waste stream on the quality and yield of output streams, especially, of product stream, is very important in order to configure some pre-treatment of input waste stream and the arrangements of unit operations of plant, which can ensure to produce SRF with specified quality.

The current literature [21,28–31] presents work including characterization and classification of SRF production from different types of waste treatment facilities and different types of feedstocks, carrying out mass, and energy balance on waste management facilities, or element balance in waste treatment plants. However, a published work is not available presenting the influence of input waste feedstock at industrial scale SRF production with different types of waste streams and comparing the results of SRF production from different waste feedstocks in the same paper. The objective of this paper is to determine the influence of input waste feedstock on industrial scale SRF production, by comparing the major results of SRF production from C&IW, C&DW and MSW in a mechanical treatment plant.

2. Material and methods

2.1. Description of waste feedstocks and mechanical treatment plant

This research work is based on the results obtained from the three industrial scale experimental campaigns, conducted on mechanical treatment based SRF production plant. The SRF was produced from C&IW, C&DW and MSW separately. The waste materials were collected from the metropolitan area of Helsinki region, Finland. The Helsinki region includes four cities; Helsinki, Vantaa, Espoo and Kauniainen. The waste collection points were mainly located in the metropolitan areas of the region. The SRF was produced from 79 t, 74 t and 30 t of C&IW, C&DW and MSW respectively. C&IW is solid waste generated by commercial and industrial sector (i.e. shopping centers, offices, warehouses, logistical centers, manufacturing organizations' offices and retail outlets, etc.) and institutions (educational institutions, medical centers' offices and government offices, etc.). C&DW is solid waste generated during the destruction/demolition or construction/renovation of buildings. MSW: the stream of MSW used here was energy waste collected from households which was not subjected to recycling but for energy recovery. The energy waste contained major fraction of energy-related waste components, for example, paper & cardboard, plastics, textile, wood, and rubber material. In this paper MSW refers to energy waste collected from household as described here.

The three types of waste feedstocks i.e. C&IW, C&DW and MSW were treated separately in the same mechanical treatment plant having same set of unit operations/sorting techniques. The SRF produced from the said waste feedstocks was utilized as fuel/co-fuel mainly, in the dedicated waste-to-energy gasification and combustion-based power plants and in cement kilns. The SRF production plant is located in Kerava, Finland. Kerava is a town located in the Uusimaa Region located in Southern Finland. The SRF production plant consisted of various unit operations/sorting techniques: primary shredding, screening, magnetic and eddy current separation, air-classifiers, near-infrared (NIR) sorting unit and secondary shredding, as shown in Fig. 1 in the form of a simplified block diagram. In MT plant, the input waste material was classified into various output streams: fine fraction, ferrous metal, and non-ferrous metal, reject material, heavy fraction and SRF.

2.2. Sampling, sample preparation and laboratory analysis of streams

CEN standards of SRF [32,33] were used to conduct the experimental campaigns. The sampling of input and output streams was performed according to CEN standards of SRF, EN 15442 by using static lot method, static conveyor belt method and manual drop flow method [32]. As per standard method, 24 increments of each stream were taken and combined together to form their relevant combined samples. Increment size is the portion of material extracted in a single sampling operation and combined sample is the sum of 24 increments. Sampling size of streams was based on their respective top nominal size (D_{95}). The sample preparation of input and output streams' samples for their laboratory analysis was performed according to EN 15443 [33]. As per standard method, particle size reduction method and sample division (mass reduction) method were applied at each stage of sample preparation for laboratory analysis. The sample size of each stream was reduced to 0.5–5 g and 0.5 mm for the laboratory analysis. Details of process description, mechanical treatment steps involved and their functioning, sampling protocol such as lot size, sampled quantity, top nominal diameter and series of steps involved in sampling and sample preparations are published in previous papers [24–26]. Laboratory analysis of SRF was performed by using standard analysis methods. Standard methods used for laboratory analysis were: EN 15403 for ash content analysis, EN 15400 for net calorific value analysis, EN 15407 for CHNO analysis, ASTM D 4239 for S analysis, SFS-EN ISO 10304-1:2009 (mod.) for halogen analysis, SFS-EN ISO11885:2009 (mod.) for major elements/heavy metals and SFS-EN ISO 17294-2:2005 (mod.) for trace elements analysis.

2.3. Calculation methods

Composition of C&IW, C&DW and MSW was determined by the manual sorting of their respective sampled streams [24–26]. Composition of waste feedstocks, as given in Table 1 was determined in terms of the components it contained: paper & cardboard, plastics, textile, wood, rubber, metals, foam, stones, building material, glass, bio waste and fines/others. The waste material delivered to the mechanical treatment plant was collected from number of waste collecting locations of the mentioned area of Helsinki region and on different days of the week. This was done in order to make sure that the waste material arriving at the plant provides an adequate representation of waste material generated in the said area. The representativeness of the samples taken from input waste feedstocks and output streams produced in MT plant was ensured by sampling the streams according to CEN standards for SRF [32]. In order to maintain the representativeness of the original samples taken from input and output streams the further sample preparation for their laboratory analysis was performed according CEN standards for SRF [33].