Increasing the recovery of automobile shredder residue (ASR) through assimilation to a solid recovered fuel (SRF): the results of a feasibility study

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Abstract This study analyzes the possibility of assimilating some fractions extracted from the shredder light fraction (SLF) to a solid recovered fuel (SRF). Italian Ministerial Decree D.M. 22/2013 fixes the criteria for the assimilation in the compliance of three parameters (heating value and chlorine and mercury content) and a number of heavy metals with threshold values. A sample of SLF underwent a product composition analysis. The results demonstrated that polyurethane foam (PUR) and heavy textile were the most abundant fractions, with 46.0% and 23.5% by weight (b.w.) respectively. Because of their size, amounts equal to 50% b.w. of PUR and to 75% of heavy textile could be separated by using a 150 mm sieve. The mixture of the separated products had a net heating value of 25.7 kJ/g, that made it suitable to be classified as a first class SRF. The content of heavy metals was well below the threshold values fixed by D.M. 22/2013, with the only exception of nickel, the concentration of which in the mixture of the two products was 40 mg/kg, 33.3% higher than the threshold value. The results of the analyses and tests demonstrated that PUR and heavy textile were good candidates to be assimilated to a SRF and, furthermore, they could integrate the conventional fuel in cement factories, foundries or other thermal plants.

Keywords: shredder light fraction (SLF), sieving, heavy metal, net heating value, thermal valorization

1. Introduction

The proper management of end-of-life vehicles (ELVs) and of the residues that are generated from their shredding and metal separation (namely automobile shredder residue, ASR) is still an urgent issue. More than 200,000 tons of ASRs are landfilled every year in Italy (ISPRA, 2020), thus being Italy one of the EC States non-compliant with the 95% target of recovery and reuse stated by EU-Directives 2000/53/EC and 2018/849/EC. Since 2000/53/EC Directive was issued, ASR management in the EU has taken three directions: (1) intensive dismantling, involving separation and collection of materials at the dismantling stage in order to reduce the amount of ASRs in the first instance; (2) post-shredder treatments (PSTs), involving the separation of materials from ASR after the shredding stage; (3) energy recovery from ASR through different solutions (e.g. co-incineration with municipal solid waste or using it as a solid recovered fuel (SRF). A trade off among these three ways must be evaluated in order to achieve the European targets, taking into account the specific context of each Member State.

According to Directive 2000/53/EC, energy recovery is accepted up to 10%. Higher amounts of ASRs can be recycled through the thermal route provided that they assume the status of a SRF. In Italy D.M. 22/2013 fixed the conditions that allow a waste product to assume the status of a SRF. These conditions include the compliance with the threshold values of three parameters, that are related to the domains of market (heating value), combustion process (chlorine content) and environment (mercury content). Furthermore, the content of some heavy metals must be inferior to the threshold values stated by D.M. 22/2013.

This study analyzes the possibility of assimilating ASRs to a SRF, to be used in plants (namely cement factories, foundries or other) with a high need of thermal energy. The procedure for the assimilation has included a characterization of the ASR collected from a dedicated shredding test, tests for the separation of the most abundant and highest energy-content fractions, and finally the characterization of the separated products and ashes that resulted after combustion.

2. Materials and Methods

The sample of shredder light fraction (SLF) used in this study was collected during a shredding test carried out in May 2020 at the Centro Recuperi e Servizi ELV authorized treatment facility (ATF) of Settimo Torinese (Metropolitan Turin Area, NW Italy). The depollution, shredding and sorting operations currently carried out on ELVs at the ATF were described in Ruffino et al. (2020). The shredding test involved approx. 435 ELVs that were previously subjected to depollution and removal of tires, bumpers and fluid tanks.

The sample underwent a product composition analysis aimed at separating and quantifying the fractions of which the SLF was made up. The products found most abundant in the sample were subjected to a particle size analysis. Polyurethane foam and heavy textile underwent CHNS, chlorine, net heating value and heavy metals analyses after particle size reduction. The size reduction process involved a first manual shredding by using steel shears to 50-80 mm sizes, a subsequent grinding to a size of 4 mm in a SM 1000 Retsch mill and a final grinding to a size of 1 mm carried out in the same apparatus. The net heating value was determined in a calorimeter by using benzoic acid as a reference material. Metals (Cd, Cr, Cu, Pb, Fe, Mn, Zn, Ni, Co) were determined with a Perkin Elmer Optima 2000 ICP-OES after a two-stage microwave (Milestone MLS 1200 Mega) digestion.

3. Results and Discussion

The SLF accounted for 23.1% by weight (b.w.) of the total weight of involved in the shredding test. The results of the product composition analysis (Figure 1) show that the sample of SLF was made up, for approx. 80%, of the three main products namely polyurethane foam (46%), heavy textile (24%) and plastic (12%). The abundance of polyurethane foam and the reduced amounts of miscellaneous (4-10 mm) and fine (< 4 mm) fractions made this sample very different from SLF samples collected from the same ATF in previous sampling campaigns (Fiore et al., 2012 and Ruffino et al., 2020).

The results of the particle size analysis carried out on the four more abundant fractions, namely polyurethane foam, heavy textile, plastics and metals, are shown in Table 1.

Table 1. Results of the particle size analysis carried out on the four most abundant fractions of SLF.

Product	D_{10} (mm)	D_{50} (mm)	D_{90} (mm)
PUR	78	150	250
Heavy textile	105	220	500
Plastic	50	120	230
Metals	58	160	210

It was seen that amounts equal to 50% b.w. of polyurethane foam and to 75% of heavy textile had sizes of more than 150 mm. That outcome suggested the possibility of separating the two most abundant fractions from the whole SLF by a sieving operation and, subsequently, testing their suitability so as to be used as a SRF. The mixture of the two waste products separated with the sieving process was characterized by 56.6% b.w. of polyurethane foam and 43.4% b.w. of heavy textile.

According to Italian D.M. 22, 14/02/2013, a waste product can assume the status of a SRF if its characteristics satisfy the requirements for net heating value, and chlorine, mercury and heavy metal content listed in Table 1 and Table 2 of the law. The higher heating value found for polyurethane foam and heavy textile was of 28.04±0.60 kJ/g and 22.64±0.51 kJ/g respectively. On the basis of the net heating values, polyurethane foam could be placed in class I and the heavy textile in class II. The mixture of the two products had a net heating value of 25.7 kJ/g, that made it suitable to be classified as a first class SRF.

Table 2 reports the content of heavy metals of the two products. It can be seen that in both products the metal content was well below the threshold values fixed by D.M. 22/2013, with the exception of nickel. Nickel concentrations were 43.7% and 21.7% higher than the threshold values for heavy textile and polyurethane foam, respectively.

Table 2. Content of heavy metals of heavy textile and PUR

Metal	Heavy textile	Polyurethane foam	Threshold values 22/2013
	mg/kg	mg/kg	mg/kg
Cd	1.40 ± 0.17	1.75 ± 0.18	4
Cr	51.3 ± 2.6	33.3 ± 0.6	100
Cu	259 ± 30	270 ± 10	500
Pb	24.7 ± 6.0	29.8 ± 6.2	240
Fe	5668 ± 180	2549 ± 112	-
Mn	93.9 ± 4.3	58.6 ± 0.8	250
Zn	1974 ± 39	908 ± 15	-
Ni	**43.1 ± 6.8**	**36.5 ± 2.0**	30
Co	6.76 ± 0.60	3.54 ± 1.64	18

The compliance with the threshold values fixed by D.M. 22/2013 concerning the concentration of heavy metals depended on the amount of the fine fraction that can be embedded into the matrix of the polymeric or textile product. In the SLF sample used for this study the content of the fine fraction (< 4 mm) was only in the order of 2% b.w.

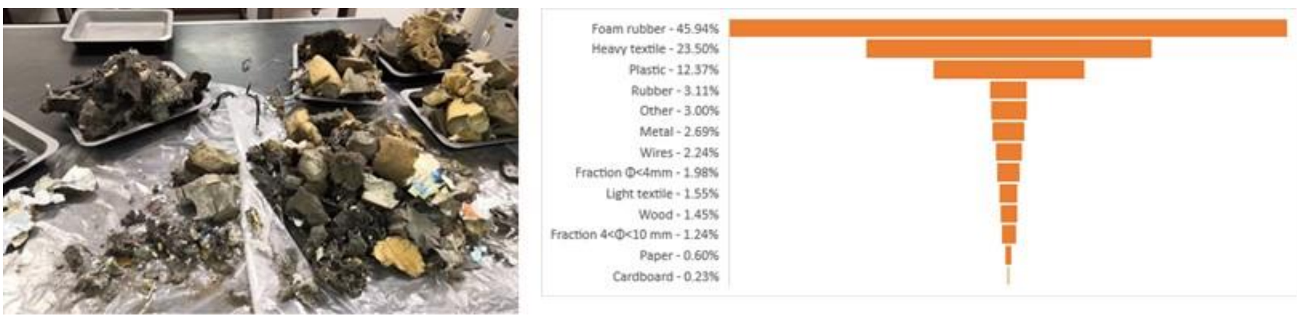

Figure 1. Picture of the sample of light ASR (left side) and results of the product composition analysis (right side)

The correct regulation of the power of the hammer mill used for ELV shredding is a critical issue to maintain the amount of the fine fraction low and, consequently, the polymeric or textile products free from heavy metals

4. Conclusions

Post shredder treatments are currently used to separate the steel hulk and the main metallic parts from shredder residues. The valorization of the remaining waste products with the aim of complying with the statements of EU-Directives 2000/53/EC and 2018/849/EC is still a challenge. The aim of this study was testing a process able to recover some waste products from ASRs that could be assimilated to a SRF. The results of the sieving test and characterization of the separated products demonstrated that polyurethane foam and heavy textile had the characteristics to be assimilated to a SRF and, furthermore, they were promising candidates to integrate the conventional fuel in cement factories, foundries or other thermal plants.

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