



## Viability study of automobile shredder residue as fuel



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### HIGHLIGHTS

- Four different particle size fractions from a Car Fluff sample were studied.
- Chlorine and metal content was analyzed in all samples.
- PCDD/Fs from combustion of the samples in lab scale were measured and discussed.
- The combustion of fraction smaller than 20 mm produced the highest PCDD/F emissions.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Car Fluff samples collected from a shredding plant in Italy were classified based on particle size, and three different size fractions were obtained in this way. A comparison between these size fractions and the original light fluff was made from two different points of view: (i) the properties of each size fraction as a fuel were evaluated and (ii) the pollutants evolved when each size fraction was subjected to combustion were studied. The aim was to establish which size fraction would be the most suitable for the purposes of energy recovery. The light fluff analyzed contained up to 50 wt.% fines (particle size < 20 mm). However, its low calorific value and high emissions of polychlorinated dioxins and furans (PCDD/Fs), generated during combustion, make the fines fraction inappropriate for energy recovery, and therefore, landfilling would be the best option. The 50–100 mm fraction exhibited a high calorific value and low PCDD/F emissions were generated when the sample was combusted, making it the most suitable fraction for use as refuse-derived fuel (RDF). Results obtained suggest that removing fines from the original ASR sample would lead to a material product that is more suitable for use as RDF.

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### 1. Introduction

Once vehicles are no longer useful, they are deregistered and become end-of-life vehicles (ELVs). Only in Europe, more than 9 million tons per year of ELV waste are produced. The volume of ELV waste continues to increase every year, and it is expected to rise to about 10–14 million tons by 2015 [1]. If ELV residues are

not properly managed, they can have a negative impact on the environment. In addition, ELVs are rich in valuable materials, such as metals, and possess a high calorific potential due to their high content in combustibles such as plastics.

ELVs are subjected to depolluting and dismantling; afterwards, hulks are baled and sent to a shredder plant. The main objective at a shredder plant is to recover as many metals as possible (ferrous and non-ferrous). Two material fractions are generated as by-products of the process: light and heavy fluff, which constitute *automobile shredder residue* (ASR). The light fraction, also called *car fluff*, is the fraction lifted up by a zig-zag sorter after shredding the bales, while the heavy fluff is the fraction remaining after ferrous metal separation by means of magnetic drums. The light fraction accounts

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approximately for 75 wt.% of the total ASR [2], heavily depending on the shredder mill input material. In Europe, light fluff residue is mainly landfilled. ASR has a very heterogeneous composition, which has been pointed out by a great number of studies [3,4]: it is a complex mixture of plastics (19–35%), rubber (20%), textile (10–40%), wood (2–5%), metals (8%), oils (5%) and others unidentifiable materials (10%) [4,5]. Polymers such as polyvinyl chloride (PVC), polyethylene (PE) or polypropylene (PP) [6] constitute some of the most valuable components of ASR; they provide it with a high heating value (about 21 MJ/kg [5,7]), which makes ASR suitable for energy recovery as a refuse derived fuel.

The European Directive 2000/53/CE states that by 2015, a minimum of 95% (in average weight per vehicle and year) of ELVs must be reused or recovered (including energy recovery), and that at least 85% must be reused or recycled, so as to reduce the disposal of this waste in landfills. In 2009, Spain and Italy achieved yields of 86.0% and 84.2% in reuse and recovery, and 82.6% and 81.8% in reuse and recycling, respectively [1]. The high costs associated with waste disposal in landfills, attached to meeting the required rates stipulated by the European Directive, have led to the development of new technologies focused on energy recovery from combustible fractions of ASR as well as new recovery and recycling techniques. Similarly, the European Waste Incineration Directive 2000/76/EC establishes that waste containing more than 1% of halogenated organic substances, expressed as chlorine, should comply with specific operational conditions that result in the destruction of as many organic pollutants as possible. The use of ASR as a fuel in a thermal process is a controversial issue since the combustible fraction contains chlorine. On one hand, gases evolved from the combustion process can be corrosive, which can damage the facilities. On the other hand, toxic pollutants such as polychlorinated dioxins and furans (PCDD/Fs) and polychlorinated biphenyls (PCBs) can be generated as by-products during the incineration if operational conditions and gas cleaning systems are not carefully controlled.

The classification of light fluff based on its particle size consists of an easy and cheap physical separation that can be carried out at shredding plants. The aim of this work is to discuss which one of these size fractions would be more suitable for use in an energy recovery treatment than the original light fluff; this would allow shredding plants to achieve the ELV targets in a suitable way, since some recent studies have concluded that the option of energy recovery combined with recycling is the most sustainable alternative for this kind of waste [8]. Each size fraction was analyzed from two perspectives: as a solid fuel and as a source of pollutants when subjected to a combustion process.

## 2. Materials and methods

### 2.1. Raw material

A sample of about 50 kg was collected from the light fluff output flow of a shredder plant located in the North of Italy. This plant produces about 175 tons per day of ASR, so the light fluff production is about 131 tons per day. Hereinafter, this material will be referred to as *raw material* or RM. The RM sample was stored in suitable containers to avoid humidity loss and contamination. Because of the heterogeneity of the ASR, a quartering procedure following the Italian standardized methodology [9] was performed to ensure that the sample was representative. An extensive characterization of the sample was carried out, and the results are interpreted in terms of the composition of the sample; this is useful when the composition of the residue obtained varies.

Particle sizes were classified according to three different-sized sieves: 20 mm, 50 mm and 100 mm. The fraction with particulate size lower than 20 mm was called *finest* although, some authors refer

to samples of particulate size smaller than 2 mm as *finest fraction* in the literature [10].

Afterwards, each size fraction was separately ground using a Pulverisette 19 (Fristch) laboratory mill and passed through a 1 mm sieve, thereby obtaining homogeneous samples. Finally, samples were stored until they were needed for analysis. Four different size fractions were studied: the RM and the other three obtained after sieving.

### 2.2. Chemical analyses

Humidity and ash content were measured and calculated according to Italian standard UNI 9903-7:2004 [11]. The humidity was determined by drying homogeneous samples of about 1 g at 105 °C for 2 h and measuring the weight loss. Ash content was calculated from the weight loss of 1 g dried and homogenized sample after combustion in a muffle for 4 h at 550 °C.

Elemental analysis was conducted in a TruSpec Microanalyzer (LECO), and 3–5 mg samples were combusted at 1000 °C during each run. Sulfur was determined by means of a TruSpec Analyzer (LECO), which required samples of about 100 mg each per analysis.

For the heating value determination, the combustion of 0.5–1 g samples was performed in a LECO AC-350 bomb calorimeter.

Finally, IR analysis was carried out in a Bruker IFS 66/S spectrometer in ATR mode.

### 2.3. Thermal analyses

Each size fraction sample underwent thermal decomposition in an oxidative atmosphere. Thermogravimetric (TG) runs were carried out in a STA 6000 Perkin-Elmer thermobalance. The total gas flow was 100 mL/min air, and a two-step temperature program was used: (1) heating from 25 °C to 800 °C at 10 °C/min; (2) constant heating for 5 min at 800 °C. A sample of about 5 mg was used for each run.

A blank experiment was performed and used to correct for the buoyancy effect caused by the gas flow in the sample runs; the reproducibility of the runs was also tested. Apart from this, an experiment suggested by the literature [12] was carried out with Avicel cellulose to test that the equipment worked properly. Results were in agreement with those in the literature [12].

### 2.4. Total chlorine analyses

Sample preparation was carried out following the US EPA Method 5050 [13]. Hydrogen chloride evolved from chlorine in complete combustion was collected over a NaHCO<sub>3</sub>/Na<sub>2</sub>CO<sub>3</sub> solution which was later analyzed by ion chromatography. The instrument used was a Dionex DX-500 with an AS9HC (Dionex) column. Operational conditions were 9 mM Na<sub>2</sub>CO<sub>3</sub>, 1 mL/min flow rate and ASRS 300 suppressor (Dionex).

### 2.5. Heavy metal analyses

Samples were subjected to complete decomposition by microwave digestion with HNO<sub>3</sub> and H<sub>2</sub>O<sub>2</sub> prior to the determination of the heavy metal content. Two different analytical techniques were used depending on the targeted metal: inductively coupled plasma optical emission spectrometry (ICP-OES) was employed to determine Al, Mn, Fe, Ni, Cu, Zn, Pb and total Cr content—a 7300DV dual vision (Perkin Elmer) was the instrument used for this. On the other hand, volatile metals such as As, Cd and Hg were analyzed by inductively coupled plasma mass spectrometry (ICP-MS) using a 7700x (Agilent) instrument.

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