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Challenges around automotive shredder residue production and disposal

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ABSTRACT

The challenge for the automotive industry is how to ensure they adopt the circular economy when it comes to the disposal of end-of-life vehicles (ELV). According to the European Commission the UK achieved a total reuse and recovery rate of 88%. This is short of the revised ELV directive target of 95% materials recovery, which requires a minimum of 85% of materials to be recycled or reused. A significant component of the recycling process is the production of automotive shredder residue (ASR). This is currently landfilled across Europe. The additional 10% could be met by processing ASR through either waste-to-energy facilities or Post shredder technology (PST) to recover materials. The UK auto and recycling sectors claimed there would need to be a massive investment by their members in both new capacity and new technology for PST to recover additional recycle materials. It has been shown that 50% of the ASR contains valuable recoverable materials which could be used to meet the Directive target. It is expected in the next 5 years that technological innovation in car design will change the composition from easily recoverable metal to difficult polymers. This change in composition will impact on the current drive to integrate the European Circular Economy Package. A positive factor is that main driver for using ASR is coming from the metals recycling industry itself. They are looking to develop the infrastructure for energy generation from ASR and subsequent material recovery. This is driven by the economics of the process rather than meeting the Directive targets. The study undertaken has identified potential pathways and barriers for commercial thermal treatment of ASR. The results of ASR characterisation were used to assess commercial plants from around the world. Whilst there were many claiming that processing of ASR was possible none have so far shown both the technological capability and economic justification.

1. Introduction

In the UK, there is an average of 2 million vehicles reaching the end of their life every year (Government UK nd). These end-of-life vehicles (ELV) end up at metal recovery facilities (either directly deposited or via a vehicle dismantler). In order to recover useful particular materials for recycling from these ELV depollution is necessary. It is a mandatory requirement that all ELVs are fully depolluted (e.g. all fluids, oil filters, batteries, catalytic converters, airbags removed) and component dismantled (e.g. tyres, windscreen) prior to the shredding processing. This is to reduce environmental pollution and recover certain streams separately. Dismantling is a step after depollution where vehicles reusable or recyclable component parts (e.g. tyres, windscreen, bumpers) are removed.

Currently, the UK has 45 shredder sites dealing with end-of-life vehicles (BMRA Data, 2013). Each shredder site has a different layout but typically they will contain the following: a reception area; (where materials are received, inspected and validated); shredder plant and post-shredder processing/technologies. UK installations of shredders range from less than 746 kW up to 7457 kW. The ELV Directive (EC, 2000) has set targets of 85% for the recovery of materials from vehicles. The new European ELV directive (European Parliament & the European Council, Directive 2000/53/EC) (effected from January 2015) replaced the pervious target with a recycled or reused target of 95%. Within this 95% the following apply: 85% must be recycled or reused and the remaining 10% can be met through energy recovery from the combustion of none-recyclable residues. Further, new EU legislation in progress by a circular economy (CE) package that ideally seeks for a zero waste framework (EPRS, 2016). The CE model is based on sharing, leasing, reuse, repair, refurbishment, recovery and waste into a valuable resource (including energy). The aim is for an almost closed loop, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society. For a typical

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vehicle from the early 2000s it will produce after shredding between 75 and 80% metals (GHK/BioIS, 2006; Cossu and Lai, 2015). It also produces smaller fraction of between 20 and 25% of the ELV's mass, which comprises non-metallic and lower density materials. TRL (2003) estimated that 1.8 Mt of ELVs processed by UK shredders produced in a year 1.3 Mt of ferrous product (72%), 72 kt of non-ferrous product (4%) and 430 kt ASR shredder residue (24%).

A separation based on density differences allows for separating the organic (plastics) and non-organic (metals & glass) fraction in ASR. Typically, the ASR fraction contributes to between 15 and 20% of the initial ELV mass. It is expected that in the future as the composition of vehicles changes due to light weighting of materials and new material usage (polymer substitution for metal components), the amount of ASR will increase (Alonso et al., 2007; Hatzi-Hull, 2011; Davies, 2012). These changes to composition are not expected to offset the increase in vehicle weight due to safety features and increased comfort, which is being added by manufacturers. It is predicted in the next 5 years that technological innovation in car design will see the average weight per ELV from the current 900 kg to 1025 kg in 2020. This increase in mass will be at the expense of easily recoverable metal with the introduction of engineering polymers. This change in composition will impact on the current drive to integrate the European Circular Economy Package. Automobiles are often cited as examples of closed loop products but clearly ASR being sent to landfill does not support this.

Another major change to vehicles has been the increase in electronic components units (ECU) and the corresponding presence of high value resources such as gold and rare earth metals (Restrepo et al., 2017). This will influence the recycling industry by changing the economics of processing ELVs. Several researchers (Cucchiella et al., 2016a,b; Cossu et al., 2014) have investigated the advantages of dismantling components prior to shredding. However, for ECUs to have value they need to be removed complete and this is not always practical. The compositional change of vehicles will influence the roles dismantler's and recyclers have in meeting the Directive targets (Inghels et al., 2016). The recycling sector still favours recycling over dismantling (Blume and Walther, 2013) and investment in PST would make more economic sense. The change to sustainable design for automotive products has the aim of encouraging dismantling of components (Tian and Chen, 2016). Since 2008 car manufacturers have been encouraged to make their vehicles easier to recover. However, this may not result in reuse of components as any damage of components will result in the component being shredding with the ELV. This then brings us back to the same situation that the ASR will need to processed to meet the targets and the valorisation of it PST (Fiore et al., 2012).

Recovery of rare earths from ASR and reduction of the hazardous of ASR will require thermal treatment. Sakai et al. (2014) illustrated that to meet the ELV targets ASR must be part of the recycling process. The challenge being how to recover the components in both a practical and economic manner. There are a number of high value components of ASR which could be recovered by thermal processing of ASR (Mayyas et al., 2016). The type of PST will be influences by the economics and ease of recovery of these products on a commercial scale (Cossu et al., 2014).

In order to meet the ELV Directive targets and maximize the recovery of material, post-shredder technologies (PST) will need to be employed. Studies have shown (Sakai et al., 2014) that different regions of the world place difference emphasis on recovery and the requirement to use dismantling of components to minimize ASR. This is dependent on legislation and targets. These technologies usually include mechanical separation plants and thermal recovery. The thermal treatment of ASR would alleviate some of the environmental concerns raised by Boughton and Horvath (2006). Other, solutions (Cossu and Lai, 2013) to remove leachate through PST of ASR does not offer a commercial solution and does not help to contribute towards the targets. The mechanical separation plants may or may not be attached directly to the shredder. The technologies used are: (i) magnetic separation for ferrous, (ii) eddy current magnets for non-ferrous, (iii) trommels, (iv) suction for foams and light material and (v) sink-float separation for plastics. Occasionally hand picking stations are employed to achieve the highest level of materials separation. The configuration of the mechanical separation/downstream processes is variable for companies, resulting in a variation on ASR compositions and production from one firm to another. Therefore, for ASR management, it is necessary to understand the ASR production process and to investigate its composition. Within the UK typically what is left after sorting is landfilled. Approximately, 40–50% of ASR is hydrocarbon-based: plastics, rubber, fibres, wood, paper, tar and oil. Thermal treatment of ASR reported either by pyrolysis (conversion to liquid), gasification (conversion to gaseous) or combustion (with heat recovery) technologies (Hubble et al., 1987; Zolezzi et al., 2004; Viganò et al., 2010; Cossu et al., 2014; Rey et al., 2016) will reduce the amount of material that requires final disposal. The ASR's noncombustible fraction which is made up of glass, dirt, rock, sand, moisture and residual metals can further separated and recycled.

Modelling of ELV recovery routes by several researchers (Fonseca et al., 2013; Gradin et al., 2013; Ciacci et al., 2010; Ruffino et al., 2014) concluded that energy recovery of ASR residue was a necessary part. This means that a combination of recycling and energy recovery is essential to achieve the new European ELV targets. The UK department for Business, Innovation and Skills (BIS) announced that an 88% reuse, recycling and recovery rate was achieved in 2012 meeting the previous target. However, UK Department for Environment, Food and Rural Affairs (Defra) and the, Environment Agency (and most recently British Metals Recycling Association (BMRA)) have published data which indicated that the levels of energy recovery from ASR are currently low. This is potentially an area where the UK could improve and meet the new targets. This is in contrast to the industry which is focused on reaching the higher target of 95% by applying PSTs based on mechanical separation rather than thermal treatment. This is due to the lack of any commercial off-the-shelf/small-scale solutions being available. Also, with no financial drivers to encourage investment in the necessary infrastructure to recover energy from ASR this option remains unused. The other challenge for any thermal exploitation of ASR is the amount of Polyvinyl chloride (PVC) plastics it contains. This produces acid gases which corrodes the boiler, gas duct and tubes of existing energy from waste facilities. Consequently, the preferred option for ASR has been to landfill. The heterogeneous and complex make-up means that it is difficult to separate with conventional sorting processes. Landfill disposal of ASR causes significant environmental problems (GHK/BioIS, 2006; Cossu and Lai, 2015) as it is used as daily landfill cover mixed with calcium carbonate (lime) to decrease leaching into ground water.

Due both to the changing ASR composition and its wide variability, the aim of this study is to characterise ASR produced from UK shredder plant and to identify post ASR management and treatment. The study has investigated the viability of post-shredder technologies (PST) using thermal treatment processing within the context of UK shredder plants.

2. Material and methods

2.1. Production of ASR

A shredder plant in the Northwest of the UK was used as a case study for ASR characterisation. The plant has a capacity of 416 kt

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