Waste Management 33 (2013) 574–584

Contents lists available at SciVerse ScienceDirect

Waste Management

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

Recycling-oriented characterization of polyolefin packaging waste

Bin Hu [a,*], Silvia Serranti [b], Norbert Fraunholcz [c], Francesco Di Maio [a], Giuseppe Bonifazi [b]

[a] Resources & Recycling, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN, Delft, The Netherlands
[b] Department of Chemical Engineering Materials & Environment, Sapienza, University of Rome, Via Eudossiana 18, 00184 Rome, Italy
[c] Recycling Avenue bv, Rotterdamseweg, 2629 HG, Delft, The Netherlands

ARTICLE INFO

Article history:
Received 10 July 2012
Accepted 13 November 2012
Available online 27 December 2012

Keywords:
Polyolefins
Density separation
Recycling
Packaging waste
Hyperspectral imaging

ABSTRACT

Packaging waste is one of the main sources of secondary polyolefins. It is essential to characterize polyolefins derived from this waste stream in such way, that not only mechanical sorting methods can effectively separate, but also that on-line sensor systems can quantitatively assess their distribution. The characterization methodology is hierarchical, relating all properties of waste particles in any phase of the processing ultimately to the input End-Of-Life products. The present paper documents a pre-concentrate obtained by hand picking of mixed Romanian household waste. Investigations have been addressed to identify the composition of this polyolefin waste stream, to study the polyolefin density distribution, to distinguish the polymer manufacturing methods (i.e. injection molding and blow molding) by flake physical properties and finally to perform all the required characterization and identification by hyperspectral imaging. On the basis of these analyses, polyolefins from packaging wastes can be recycled by density separation and their rheological properties and wall thickness indicate the molding procedures. Hyperspectral imaging based procedures have been also applied to set up quality control actions for recycled products.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Plastic, one of the most commonly used materials, has become an integral part of our lives. The amount of plastics produced has been growing almost 5% per year over the past 20 years in virtue of their low cost, light weight, high strength and design adaptability (Plastics-the Fact, 2011). There are different types of plastics with a variety of specific properties for each application. Polyolefins (PO), including polyethylene (PE) and polypropylene (PP), occupy nearly 40% in the market share. They are widely applied, in particularly in packaging which is the largest segment in plastic applications and represents 39% of the overall demand (Mustafa, 1993). Due to the high amount, the short product lifespan, the increasing price of virgin resin and legislative pressures, waste PO packaging wastes are being considered as a valuable resource that has become one of the targets of plastic recycling efforts.

Post-consumer wastes, such as Household Waste (HW), Construction and Demolition Waste (CDW), Waste from Electric and Electronic Equipment (WEEE), and Automotive Shredder Residues (ASRs), are *end-of-use anthropogenic materials* generated and/or utilized inside urban areas, and can provide a large polyolefin resource. its recovery can be assessed in the new "urban mining" concept, that is an innovative approach finalized to recycle large stocks of materials incorporated into cities, in particular in buildings and infrastructure but also in landfills (Brunner, 2011). These stocks represent, in fact, a potential resource that will eventually – at the end of the product lifetime – become available for recycling.

There is no general definition for *urban mining* yet: some researchers use the term to describe exploitation of resources from landfills, others apply it to traditional recycling schemes of waste materials, such as construction debris, scrap iron, glass and, as in this case, plastics. In this perspective it is thus fundamental, to develop a new knowledge base, specifically addressed to perform a full characterization of the waste materials to recycle, to realize their optimal processing/sorting. A general question relates to the information requirements: which information is needed for setting the right priorities, for planning and implementing appropriate measures, and for ensuring the overall cost/effectiveness of urban mining? Information requirements will extend across many materials and substances and will cover long time periods (e.g., several decades for materials in the urban stock of buildings and infrastructure). Thus, to prevent high costs and little utility, it is of utmost importance to elaborate clear goals and strategies for the new knowledge base. But, to reach this goal it is of primary importance to collect, as already outlined, comprehensive information about materials and substances (e.g. quality, quantity, relative proportion inside a product, assessment, etc.).

HW, CDW, WEEE and ASR are from five to ten times larger reservoir of polyolefins than do post-industrial wastes, but these wastes are also much more complex mixtures of materials and

* Corresponding author. Tel.: +31 152782897; fax: +31 152788162.
E-mail address: Bin.Hu@Tudelft.nl (B. Hu).

0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.wasman.2012.11.018

hence much more difficult to recycle. Although it is possible to mix different types of polymers together, the resulting physical properties are less desirable than those of the original components. Efforts to recycle plastics are mostly concentrated on sorting and separation of a single polymeric material. Near infrared (NIR) spectroscopy is widely applied industrially for sorting polymer products based on the fact that NIR spectra of different types of plastics are quite distinct. It has many advantages for sorting waste plastics, for instance, it enables rapid reliable identification. However, it is not applicable to identify black plastics (Pascoe, 2000; Siesler et al., 2002) and it has a limitation on the size of the materials as well: too big or too small objects are not favorable for NIR in practice. As a result, roughly 50% of the amount of the input ends up in residuals. Another most used mechanical method is density-based separation (e.g. conventional sink-float). The separation of different plastics is dependent on their different densities. Such separations are comparatively simple, easily automated, high-capacity process and flexible in operation. But it is a rather slow process and discharging of the separation media is expensive. Due to the low efficiency of the current separation technologies for the secondary plastics, most of the polymer resource in complex wastes is unused. In Europe the total plastic production reached 57 million tonnes from 2009, but only 6% of them were recycled, and the value of the recycled plastics was only 2% of the turnover of plastic production which was about 100 billion Euros in 2009 (Plastics-the Fact, 2011 and EEA report, 2011). It indicates that the value of the recycled polymers is low due to their poor quality, and thus high grade secondary polymers are urgently needed.

Technologies that are to address post-consumer wastes need to be extremely powerful, since they must be relatively simple to be cost-effective, but also accurate enough to create high-purity products and able to valorize a substantial fraction of the materials that are present in the waste into useful products of consistent quality in order to be economical. On the other hand, the potential market for such technologies is large.

The European FP7 Project W2Plastics "*Magnetic Sorting and Ultrasound Sensor Technologies for Production of High Purity Secondary Polyolefins from Waste*" aims to develop two novel concepts, the first one an innovative separation techniques called Magnetic Density Separation (MDS) (Bakker et al., 2009) and the second an innovative quality control strategies adopting a hyperspectral imaging (HSI) based approach (Serranti et al., 2011), both aiming to recover high-purity polyolefins from complex wastes at low cost.

The MDS is a density-based technology, but the process takes much less time than the conventional sink-float separation and no polluted liquid discharge since the separation medium circulates during the process. It works on shredded flakes, and there is no limitation on size or color. The sorting principle of polyolefins is based on the fact that polypropylene especially from HW has lower densities than polyethylene. During the development of the project, it was found that in order to obtain high-valuable polyolefin products some characteristics of the plastic flow streams must be defined and assessed.

A recycling-oriented characterization, in an urban mining perspective, addressed to household plastic packaging wastes, with the aim to recover high-valuable polyolefins is discussed in this paper. Results can constitute the base to implement, at industrial level, both the innovative dense media separation (MDS) and products control (HSI). To reach these goals, investigations have been addressed: (i) to identify the composition of a polyolefin waste stream, (ii) to study the polyolefin density distribution, (iii) to distinguish the polymer manufacturing methods (i.e. injection molding (IM) and blow molding (BM)) by flake physical properties and, finally, and (iv) to perform all the required polymers characterization/identification by HSI.

The importance for the selection of the measured characteristics, such as density, rheological properties, flake's thickness and spectral signature, is highlighted and their influence on separation results evaluated and critically discussed. To obtain high grade secondary polyolefins by using density separation, it is thus essential to determine the density distributions of both PP and PE from household packaging wastes. Additionally, attention should also be paid to the same type of polymers but produced in different ways (IM or BM). In fact, the viscosity of polyolefin products varies with the molding methods, affecting the recycling production for the reason that different melt viscosity resins do not mix homogeneously. If different melt viscosity plastics are not separated, the properties will not be uniform in compounding.

2. Polyolefins density and separation strategy

The need to separate PP and PE prior to compounding arises from the fact that processing a mixture of PP and PE using standard compounding technology usually results in deterioration of physical properties of the obtained blend, in which mainly elongation and strain at break are affected, but also tensile and impact strength. In that sense, PP and PE are called incompatible despite of their very similar chemical structure. Separation of polyolefin mixtures into PP and PE usually improves the quality of the resulting compounds. The extent of loss of physical properties of the compound strongly depends on the mixing ratio of PP and PE. On the other hand, due to the wide variety of applications with their own requirements on physical properties, the threshold of acceptable mixing ratios between PP and PE is not a sharp value, but a rather wide range.

There exists a close interrelationship between (i) the molecular structure of different types of PP and PE and their densities and (ii) the degree of incompatibility of these polymer types in compounding (Fig. 1). An analysis of the chemical structures of different types of PP and of PE indicates that the degree of incompatibility between two different types of polyolefin should diminish with decreasing differences between their densities. This implies that for two different types of polyolefin with a negligible density difference of the pure polymers (i.e. without additives) the incompatibility in compounding should vanish. Our study indicates that the poor tendency of polyolefins with a large density difference (e.g. PP and HDPE) mainly stems from differences in their spatial structures, since the chemical composition of different types of PP and PE is essentially the same (Fig. 1). The material density on a macroscopic level is directly related to the distance between the molecules, i.e. the void ratio, which is, in turn, closely related to the spatial structure of the molecules. Therefore, the true density of a given polyolefin (i.e. without additives) provides a good indication of its compatibility with other types of polyolefin of known density. The above findings imply that when a mixture of polyolefins having different densities, e.g. PP and HDPE, is mixed with a polyolefin of intermediate density, e.g. LLDPE, the latter will act as a compatibilizer in compounding. As a matter of fact there are compatibilizers based on LLDPE commercially available.

Further, literature data indicate that the melt flow index (MFI) has some influence on the compatibility of PP and PE. Liang et al. found that the incompatibility between PP and LDPE increases with increasing difference of their MFI's (Liang et al., 1997).

These conclusions have great consequences for the strategy in the physical separation of PP and PE. In fact, from a compatibility point of view, it is not necessary to separate strictly between the materials PP and PE. It seems more useful to separate a mixture of PP and PE into density fractions of a pre-defined density range to obtain sufficient compatibility in compounding. In other words it appears useful to differentiate between the degree of incompat-

Download English Version:

https://daneshyari.com/en/article/6355489

Download Persian Version:

https://daneshyari.com/article/6355489

Daneshyari.com