Waste Management 29 (2009) 1138–1143

Contents lists available at ScienceDirect

Waste Management

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

Application of fluidization to separate packaging waste plastics

M. Teresa Carvalho *, Célia Ferreira, Antía Portela, João Tiago Santos

CERENA, Instituto Superior Técnico, Avenida Rovisco Pais 1049-001 Lisboa, Portugal

ARTICLE INFO

Article history:
Accepted 5 August 2008
Available online 8 October 2008

ABSTRACT

The objective of the experimental work described in this paper is the study of the separation of PS (polystyrene) from PET (polyethylene terephthalate) and PVC (polyvinyl chloride) from drop-off points using a fluidized bed separator. This is a low-cost process commonly used in the hydro-classification of mineral ores. Firstly, experimental tests were carried out with artificial granulated samples with different grain sizes, types and sources of plastic ("separability tests"). The particle settling velocities were determined under different operating conditions. Then, based on the results, the laboratory tests continued with real mixtures of waste plastics ("separation tests") and the efficiency of the process was evaluated. From a PET-rich mixture, a concentrate of PS with a 75% grade in PS was produced while the underflow was quite clear from PS (grade less than 0.5% in PS).

1. Introduction

In Portugal, post-consumer packages represent almost 40% of the total domestic waste, making them an important source for the recycled materials market (Magrinho et al., 2006). Packages are made with different materials according to the desired content characteristics, price of materials, durability, storage requirements, marketing and environmental policies and many other features. Thus, for the same purpose, packages can be made, for example, of metals, glass, paper, wood or different types of plastics (Castro and Pouzada, 2003).

The recycling of materials requires the separation of the different materials. In Portugal, packaging wastes are disposed by citizens at drop-off points after being separated at home according to pre-defined sets of materials. Paper packages are placed in the paper and cardboard container (blue container), while glass vessels are placed in the glass container (green container). Packages made of different types of plastic are collected together with metals in the same container (yellow container). Municipal solid waste recovery and treatment systems are responsible for the waste collection and separation (Magrinho et al., 2006).

The contents of the containers are transported separately to sorting centers where the objects are separated (see Fig. 1). The feed to these sorting centers, especially in the case of the yellow containers, is a complex mixture of metals, various types of plastic and several other contaminants which were incorrectly placed in the containers. The sorted packaging wastes are then channelled towards the respective recycling industry by Sociedade Ponto Verde – SPV (Green Dot System), where they are usually sorted again, to eliminate the remaining contaminants, washed and generally granulated.

Currently, the separation of metals is efficiently conducted mechanically using magnetic separation for ferrous metals and electromagnetic separation (Foucault currents) for non-ferrous metals.

The separation of the different polymers by type is almost always mandatory because contamination in the recycling of one type of plastic by another type can cause serious processing problems. For example, the presence of PVC in the PET extrusion process is harmful to the equipment, due to the presence of chlorine, and lowers the product quality, namely colour and viscosity (Awaja and Pavel, 2005; Navarro et al., 2008).

In Portugal, the plastics used in packaging are mainly polyolefins, such as polyethylene, polypropylene and their copolymers, polyethylene terephthalate (PET), rigid and expanded polystyrene (PS) and polyvinyl chloride (PVC). The separation of low density materials, such as polyethylene and polypropylene, from the other plastics is not usually a problem, being currently separated by an air current.

The similarities in physical properties, such as specific gravity, make the automatic separation of some polymers a challenging task (see Table 1). There are automatic devices, based on X-ray fluorescence, used to sort out PVC objects, and optical sorting technologies, namely near infrared spectroscopy, for the separation of plastics by type. However, these technologies are very expensive and the efficiency is limited when the process feed characteristics (e.g., size and shape of objects) deviate from the pre-established ones.

An example of plastic packaging recycling is the case of PET. PET recycling plants receive a bulk load of PET packaging mostly constituted by bottles, ideally, free from PVC or other materials packaging items. Commonly, plant feed is washed and extra stages

* Corresponding author. Tel.: +351 218 417 247; fax: +351 218 417 442.
E-mail address: teresa.carvalho@ist.utl.pt (M.T. Carvalho).

0956-053X/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.wasman.2008.08.009

Fig. 1. Manual sorting of plastics in sorting centers (Tratolixo courtesy).

Table 1
Tabled specific weight of plastics appearing in drop-off points and measured density of the plastics used in the "separability tests"

Polymer	Specific weight range (g/cm^3)*	Measured density (g/cm^3)
PE	0.910–0.965	
PP	0.902–0.906	
PS_{vy}	1.05–1.10	1.05
PS_{us}		1.05
PET_{vy}	1.34–1.39	1.38
PET_{gr}		1.33
PET_{bl}		1.32
PVC_{vy}	1.35–1.45	1.38

* Source: Billmeyer, 1984.

of optical and/or manual sorting are used to eliminate items made of other materials. PET bottles, in general, contain parts, like caps and labels, made of other materials like polyolefins or paper. They are typically shredded and immersed in water where polyolefin particles float while particles of plastics with specific gravity higher than water sink. It should be emphasized that, due to the high hydrophobicity (or low surface wettability) of plastics, even plastics denser than water can float if air bubbles are present. Usually, an anti-frothing agent and other reagents must be used to prevent the flotation of denser particles and special care must be taken as well with the equipment design, namely residence time and operational conditions. If appropriate conditions are guaranteed, for a typical mixture of polyolefins, PET, PVC and PS, the material that sinks is composed of PET, PVC and PS particles.

The research on adequate and low-cost technologies that can be applied to the separation of different polymers is being made by several teams worldwide. Gravity separation, electrostatic separation and froth flotation have been studied. However, the separation of PS from PET and PVC has not yet been addressed by many authors. Recently, Pongstabodee et al. (2008) used sink-float separation in a calcium chloride aqueous solution to separate PS and ABS from PET and PVC.

In the present paper, the experimental work carried out to study the separability of PS from PET and PVC in tap water, using a fluidized bed separator, is described. This study is part of a wider study of the team in the search for a low-cost method to separate the different polymers received at drop-off points. This study is included in the project "*SEMEC*", financed by *Sociedade Ponto Verde* (Carvalho et al., 2007a and Carvalho et al., 2007b). The partners of the project are *CERENA*, a research center of *Instituto Superior Técnico*, *PIEP*, a research center of *Minho University*, *Tratolixo*, a solid waste management system, responsible for the collection of solid wastes in an area nearby Lisbon (corresponding to almost one million people), and *Selenis–Ambiente*, a Portuguese PET recycling company.

2. Can PS, PET and PVC be separated by gravity concentration methods?

In mineral processing, the suitability of the application of gravity concentration processes to the separation of a particular set of minerals is generally evaluated by the use of a parameter, the "concentration criteria"

$$CC = (d_h - d_f)/(d_l - d_f) \quad (1)$$

where d_h, d_l and d_f are, respectively, the specific gravity of the "heavy" and "light" species, and fluid. The fluid, usually water, can also be air, another liquid or fluid, or even a suspension of solid particles in water.

According to this criterion, for instance, the separation should be easy for CC > 2.5, for a particle size down to 75 μm but impossible at any size when CC < 1.25 (Wills, 1998).

The application of this criteria to mixtures of PS, PET and PVC, by direct use of the densities included in Table 1, shows that the separation between PS and PET and between PS and PVC should be easy (3.4 < CC < 7.8 and 3.5 < CC < 9, respectively) and impossible in the case of the separation of PET from PVC (1.03 < CC < 1.32).

However, this criterion should be considered only as a guideline because, besides specific gravity and size, other factors such as particle shape can have a strong effect on the separation.

Among the multiple separation methods and devices used in classification and gravity concentration, the hydraulic or fluidized bed classification is the simplest and theoretically most effi-

Fig. 2. The fluidized bed classifier used.