Separation and Purification Technology 151 (2015) 47–56

Contents lists available at ScienceDirect

Separation and Purification Technology

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

Flotation characterization of PET and PVC in the presence of different plasticizers

Ali Güney, Cihan Özdilek, M. Olgaç Kangal, Fırat Burat *

Istanbul Technical University, Faculty of Mines, Mineral Processing Engineering Department, 34469, Maslak, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 1 April 2015
Received in revised form 30 June 2015
Accepted 15 July 2015
Available online 15 July 2015

Keywords:
Plastics
Lignin alkali
Diethylene glycol dibenzoate
Selective froth flotation

ABSTRACT

Plastic is one of the most widely used materials in our daily life and industry. Recycling is an important activity in the minimization of waste that results from human activities. Depending on plastics surface characteristics, they can be separated from each other by flotation method which is useful mineral processing technique with its low cost and simplicity. To succeed in a separation of mixed polymers based on polymer type using selective flotation, it is necessary to render one surface more hydrophilic while the others are still in a hydrophobic state. The separation could be achieved with the help of appropriate plasticizer.

In this paper, the characteristics of plastics particles and flotation behaviors of polyethylene terephthalate (PET) and polyvinyl chloride (PVC) were studied. The contact angle, liquid surface tension, zeta potential measurements and FITR analysis were performed in order to investigate the effect of plasticizer reagents and the success of froth flotation at plastic recycling. It was observed that contact angle values of PVC were smaller than PET in the presence of lignin alkali (LA) and diethylene glycol dibenzoate (DIB). Both plasticizer render PVC more hydrophilic and cause higher wettability. Therefore, PVC remains in the floatation cell while air bubbles are attaching to PET. At the end of the selective flotation experiments, PET was separated from the mixture of PET and PVC with 97% content and more than 99% recovery when using 25 g/t LA as a plasticizer at pH 8. To succeed in a separation of PET from PVC by selective flotation, 250 g/t DIB was added into the solution at pH 5 and PET particles were separated from the mixture at 90% content and 95% recovery.

1. Introduction

Plastics are used in a wide variety of products and have displaced other materials, such as wood, metal, and glass. It can be formed into polyesters for use in fabrics and textiles, polyvinylidene chloride for food packaging, and polycarbonates for eyeglasses and compact disks, among thousands of other uses. The production of plastic requires four basic steps: the acquirement of raw material, synthesizing a basic polymer, compounding the polymer into a usable fraction, and lastly, molding or shaping the plastic. In 2013, global production of plastics reached nearly 300 million metric tons, with 57 million metric tons in Europe alone (Fig. 1). China is one of the largest producers of plastics in the world, accommodating almost 25 percent of the global share [1].

In recycling of plastics material, it is often necessary to separate mixtures of plastics into individual plastics in order to get a useful recycling plastic product because some plastics are not compatible during re-melting [2]. The recycling procedure for plastic bottles normally involves three basic steps: the collection and sorting of plastic bottles, re-processing into reusable flakes or pellets, and development of market for recycled plastics [3,4].

A number of promising technologies for the separation of mixed thermoplastics are under investigation and include air classification, hydrocycloning, flotation/sedimentation, depolymerization/purification/repolymerization, selective dissolution, sorting based on infrared analysis or laser scanning of polymers, and incorporation of chemical markers into different polymers [5].

The idea to apply flotation to separate plastics was a logical step as ore flotation research has demonstrated that the surface properties of different materials can be altered selectively by surfactant adsorption [6]. The use of froth flotation for plastic separation is particularly challenging because of the similarity in the surface properties of the materials. All plastics have naturally hydrophobic surfaces and will readily float with the aid of air bubbles. The selected treatment system must render at least one plastic hydrophilic, resulting in no air attachment. The wettability of

* Corresponding author.
E-mail address: buratf@itu.edu.tr (F. Burat).

http://dx.doi.org/10.1016/j.seppur.2015.07.027
1383-5866/

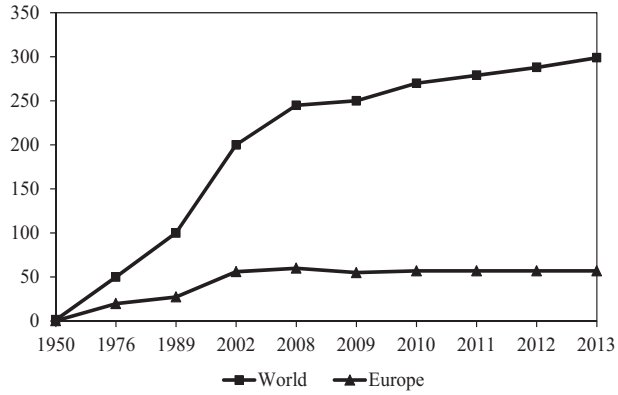

Fig. 1. World production of plastics (million tons) [1].

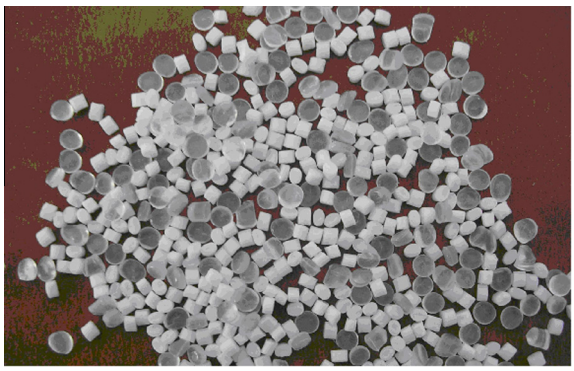

Fig. 2. The virgin PET (dull) and PVC granules (transparent).

hydrophobic (low energy) surfaces can be enhanced by depressants commonly used in ore flotation. A desired plastic can be separated from a mixture by froth flotation after treating the plastics in alkaline solution [5,7–10]. Additionally, separation of mixed plastic based on plastic type is achieved with the help of appropriate wetting agents [4,6,9,11–13]. To success an adequate separation of mixed plastic based on plastic type using selective flotation, it is necessary to render one more surface hydrophilic while the others are still in a hydrophobic state. The hydrophilic one remains in the flotation solution while air bubbles are attaching to hydrophobic one.

As well documented in literature, NaOH and lignosulfonates have been shown to be effective for PVC/PET separation [8,10,14]. It was found that NaOH caused hydrolysis of the surface of PET making it hydrophilic, whereas PVC was relatively unaffected. Lignosulfonate molecules adsorb onto the surface by physical adsorption. Depending on concentration/pH and metal ion concentrations both plastics can be rendered hydrophilic, with specific conditions allowing selectivity. Burat et al. [15] reported flotation of mixed plastics utilizing selective wetting characteristics changing the surface of specific plastics from hydrophobic to hydrophilic. According to their results, PVC particles were separated from PET particles at 100% content and 98.8% recovery rate in virgin polymer separation whereas PET particles were obtained with 99.7% content and 57.0% recovery in post-consumer polymer separation. Kounosu et al. [16] also studied flotation of plastics. Employing polyvinyl alcohol (PVA) of relatively low degree of polymerization, they reported a successful separation of PP from PE. Shibata et al. [17] separated four different types of plastics, namely polyvinyl chloride (PVC), polycarbonate (PC), polyacetal (POM) and polyphenylene (PPE), using common wetting reagents like sodium lignin sulfonate, tannic acid, Aerosol OT and saponin.

In this contribution, the selective separation of PET and PVC particles with plasticizer conditioning process followed by selective froth flotation were investigated. The mechanism of plasticizer type and amount on modification of plastic surfaces and the performance of selective flotation were examined through contact angle, surface tension, electro kinetic potential measurements and FT-IR (Fourier transform infrared spectroscopy) analysis.

2. Experimental

2.1. Materials

Samples of virgin PET and PVC (Fig. 2) less than 3 mm were received from PETKIM (Turkish Petrochemical Company) and employed to measure electro kinetic potential and FT-IR. These plastics were selected according their similar surface properties as present for common beverage bottles and windows frames.

The samples of post-consumer plastics, PET and PVC, were obtained from Fuxing-Usas, Plastic Company in Turkey. PET samples were chosen from soft drink bottles and PVC samples were selected from waste window frames (Fig. 3). Paper labels were manually removed and each plastic sample was shredded and classified into different size fractions. Coarse size fraction samples were well cleaned before performing the measurements of contact angle. Feed mixture of 25 g PET and 25 g PVC was prepared within the fraction of $-3.36 + 2$ mm and used for flotation tests as reported in our previous studies [12,15,18]. Because of difference in color and shape, the PVC and PET particles were separated from each other by hand sorting easily. The compounds of plastic samples were identified by chemical analysis and presented in Table 1.

Chemicals used for the flotation tests were NaOH and HCl as pH adjuster; methyl isobutyl carbinol (MIBC) as a frother; diethylene glycol dibenzoate (DIB) and lignin alkali (LA) (Aldrich, Munich, Germany) as plasticizers (Fig. 4). Diethylene glycol dibenzoate ($C_{18}H_{15}O_5$), a glycol benzoate ester, is a clear liquid with chemically stable properties and high boiling point. It is slightly soluble in water and very soluble in polymers. It has an excellent compatibility with polyvinyl acetates and polyvinyl chloride. It is used as a plasticizer for PVA (polyvinyl alcohol) homopolymer and copolymer emulsions and as well as for PVC coatings [19]. Lignin alkali is primary dispersing agent for dye stuffs and agricultural chemicals. It is compatible with anionic and nonionic surfactants and wetting agents [13].

Fig. 3. Post-consumer PET (transparent-blue) and PVC (white) granules. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)