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Research on Flotation Technique of separating PET from plastic packaging wastes

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Abstract

Flotation, as one efficient waste plastic separation technology, is an effective method to improve the recycling rate of packaging waste. Polyethylene terephthalate (PET) widely used in packaging industry, has a large number of consumption and high recovery value. Aiming at separating PET from plastic packaging wastes, a designed flotation column was used in laboratory to investigate the effects of parameters, such as wetting agent species and wetting agent concentration, on the flotation behaviors. The results showed that the primary flotation of PET/polyvinyl chloride(PVC)/polycarbonate(PC)/ polystyrene(PS)achieved the optimal effect with PS as floating materials and PET/PC/PVC sinking materials under 70mg/L of sodium dodecyl sulfate as wetting agent. When 3mol/L sodium hydroxide used to modify the mixed plastics and 8mmol/L of dibutyl sebacate (DBS) used as wetting agent, PET/PC/PVC separation in the secondary flotation achieved the optimal effect with PET floating rate being 3.56% and PC/PVC floating rate being 97.45% and 92.91% respectively. After two stages of flotation screening, the purity of recycled PET finally reached 90.91%, which indicated that the flotation process developed could effectively separate PET from four kinds of mixed plastics.

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Keywords: packaging wastes; plastics; flotation; resource regeneration

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1. Introduction

Plastics has been widely used in the packaging industry due to its excellent performance, accounting for nearly 30% of the total materials[1]. Plastic packaging commonly are thermoplastics, including Polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), polyester (PET), polystyrene (PS), polycarbonate (PC) and so on[2]. As 80% of plastic package was discarded within a year, packing is a major source of recycled plastics[3].

Polyester (PET) plays an important role in the packaging industry. Annual consumption of PET for beverage bottles is more than 1000×10^4t all over the world, and its production and consumption is still increasing by 10% to 19% every year[4-5]. As a type of packing material, Polyester (PET) is easily recycled and has mature regeneration process[6]. Landfill is the main whereabouts of waste plastic package, and also the main source of plastic pollution. If the waste plastics were to be recovered effectively, the amount of waste packaging in municipal solid waste will be reduced by half[7].

The recycling process of plastic waste includes separation, pretreatment, smelting, granulation, molding and so on. Separation is a key link in the process[8]. Flotation is a separation method according to the different floatability of plastic particles. It can adjust or change the surface properties of plastic by physical and chemical ways, and separate mixed plastics that have little differences in charge and density. Utilizing the differences of the plastic floatability, flotation can separate the mixed plastics which have little differences in density and charge. Flotation has been a focus in the field of waste plastics separation due to its low costs, high accuracy and efficiency[9-11]. Shibata J et al. [12]separated mixture of PVC, PC, POM by flotation with lignin sulfonate, Span and emulsifiers, and the recovery rates of the three kinds of plastics were 90.17%, 83.16% and 99.12% respectively. Drelich J et al [13]preprocessed mixture of PVC and PET by NaOH, and separated them by flotation with the non-ionic surfactant, while the recovery rates of PVC and PET all reached 95%. In this paper flotation technique of PET from waste packaging was studied, and the results are important to improving the recycling rate of PET.

2. Experimental Materials and Method

2.1. Materials

The major plastics in plastic packaging wastes are PE, PP, PET, PVC, PS and PC. The density of each of them is shown in table 1. Obviously PE and PP can be directly separated by density separation method due to their lighter proportions against water. This research chose four commonly-used packaging plastics(PET, PVC, PC and PS) as flotation experimental materials. The particle size of plastics was 3-8mm.

Table 1. The density ranges of different types of plastics

Plastics	Density range(g/cm3)
Polyvinylchloride(PVC)	1.38~1.51
Polyethylene terephthalate (PET)	1.38~1.41
Polycarbonate (PC)	1.20~1.22
Polystyrene (PS)	1.04~1.08
Acrylonitrile-butadiene-styrene (ABS)	1.04~1.06
Polyethylene (PE)	0.89~0.98
Polypropylene (PP)	0.85~0.91

The wetting agents used in the research were sodium dodecyl sulfate (SDS), carboxymethyl cellulose sodium (SCMC), nonylphenolethoxylates-7(NP-7), dioctyl phthalate (DOP) and Dibutyl sebacate (DBS). Sodium hydroxide (NaOH) was used for modifying PET.

2.2. Experimental Materials

Flotation of mixed plastics is based on differences in floatability between different kinds of plastics. Little differences can be increased by modifying, which will improve the flotation rate. In the process of the flotation experiment, PS was first separated from mixture of PET/PVC/PC/PS, followed by PET from mixture of PET/PVC/PC.

Flotation laboratory equipment was shown as Fig. 1.
PS was the primary target plastic. Several groups of plastic mixture of PET/PVC/PC/PS with a ratio of 2:1:1:1 in net 200g was taken,and moistened in wetting agents (SDS, SCMC, NP-7) at different concentrations for 15 mins. Dissolved-air tank pressure was adjusted to stay under 0.20MPa, and flotation fluid were immitted from the bottom of the flotation column to form a homogeneous rising mixture of gas and water. After the flotation fluid circulating stably, mixed plastics after pretreatment were added to feeder and separated in the column. Then the floating plastics and sinking plastics were collected respectively and dried under 50ºC to calculate floating rates and sinking rates. After PS separated, PET, the target plastics in a high purity were to be separated from mixture of PET/PVC/PC. Firstly, the plastic mixture of PET/PVC/PC was modified in 3mol/L of NaOH solution for 15mins, and then moistened in wetting agents (DOP, DBS) at different concentrations for another 15mins. Referring to the aforementioned flotation process, after pretreatment mixed plastics were separated, and their floating and sinking rates were calculated.

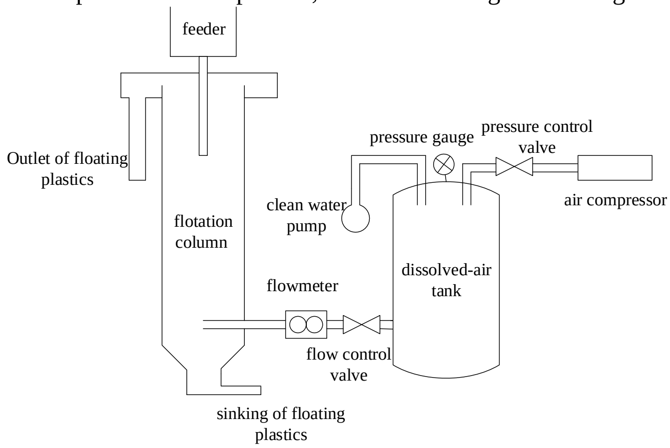

Fig.1 Schematic of flotation equipment

3. Results and Discussion

3.1. Primary flotation of PET/PVC/PC/PS and its affecting factors.

In the flotation experiments, dissolved-air tank pressure of flotation equipment remained 0.20 MPa stably to guarantee adequate flotation bubbles. Three kinds of wetting agents (SDS, SCMC, NP-7) at different concentrations were used to treat the plastic mixture for 15mins, making plastics more hydrophilic and thus more easily to sink. Flotation effects of plastic mixture as shown in Fig.2~Fig.4, floating rates of PC and PVC all reduced as the SDS concentration increased, and floating rates of PC and PVC were 0, PET floating rate were around 0, while PS floating rate remained 100%. Wetting effects of SCMC on PC and PVC were not good as SDS, and floating rates of PC and PVC remained above 20% and 10% respectively, which indicated a poor separation efficiency. The wetting agent NP-7 had a strong modifying effect on those four plastics, and when NP-7 concentration more than15mg/L, PS floating rate decreased significantly, making it difficult to separate PS effectively. Therefore, when 70mg/L of SDS used as the wetting agent, mixture of PET/PVC/PC/PS achieved an optimal flotation effect with the PS floating rate being closely 100% and sinking rates of PET, PVC and PC all being 100%. Thus PS completely separated from the mixed plastics.

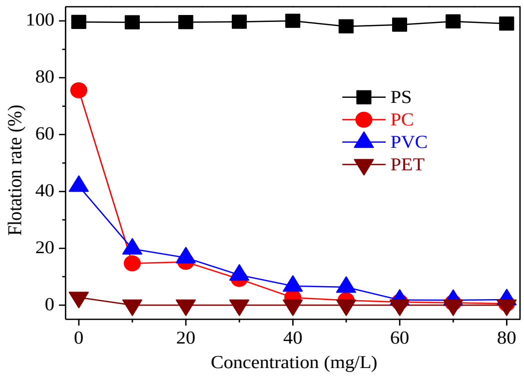

Fig.2 Effects of SDS at different concentrations on PET/PVC/PC/PS flotation efficiency

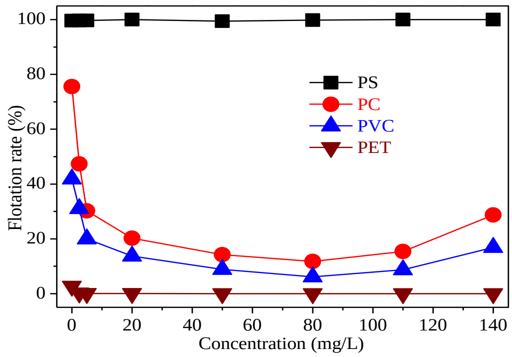

Fig.3 Effects of SCMC at different concentrations on PET/PVC/PC/PS flotation efficiency

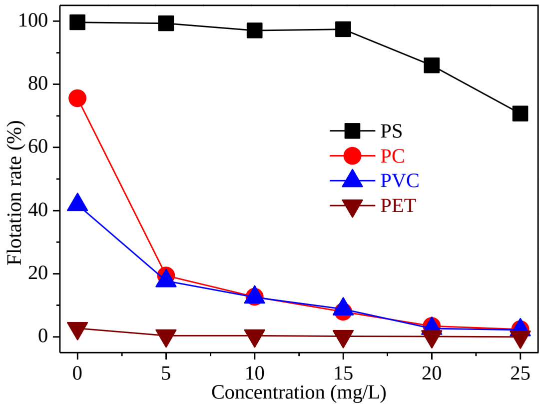

Fig.4 Effects of NP-7 at different concentrations on PET/PVC/PC/PS flotation efficiency

3.2. Secondary flotation of PET/PVC/PC and its affecting factors.

To adjust the flotation equipment to the optimum condition for Secondary flotation. DOP and DBS are highly hydrophobic compounds, which can be absorbed on the surface of plastics easily. Preprocessed the mixed plastics for15mins under different concentrations of DOP and DBS,which could make the plastics more hydrophobic and better floatability. The effects of DOP at different concentrations on flotation efficiency were shown in Fig. 5. DOP has a certain viscosity. An adsorption of too much DOP make the plastics adhering to each other, as a consequence, the flotation effects were quite irregular.

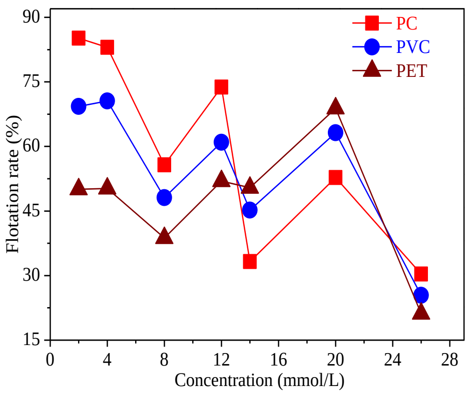

Fig.5 Effects of DOP at different concentrations on PET/PVC/PC flotation efficiency

Before treating the mixed plastics using DOP, plastics were modified with 3mol/L NaOH solution for 15mins to reduce plastic agglomeration. NaOH also can reduce the floatability of PET. After modifying the surface properties of plastics with NaOH, the effects of DOP at different concentrations on flotation efficiency was shown in Fig.6. An opimal floating rate of PET,PCandPVC were gotten with 5.21%, 88.77% and 73.90%, respectively, under 9mmol/L of DOP as wetting agent.However, the purity of PET was not high enough.

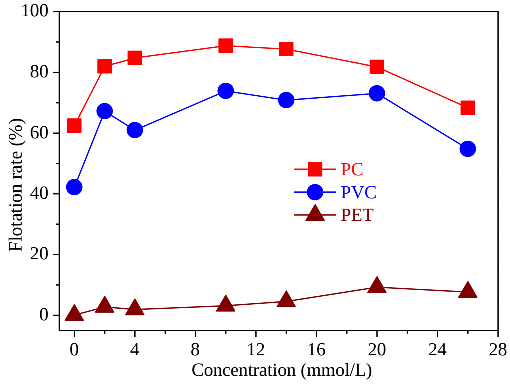

Fig.6 NaOH at 3mol/L, effects of DOP at different concentrations on PET/PVC/PC flotation efficiency

After modifying the surface properties of the mixed plastic by NaOH, the effects of DBS at different concentrations on flotation efficiency was shown in Fig.7. The flotation efficiency using DBS are much better than DOP. Under 8mmol/L of dibutyl sebacate(DBS) as wetting agent, PET/PC/PVC separation in the secondary flotation achieved the optimal effect with PET floating rate being 3.56% and PC/PVC floating rate being 97.45% and 92.91% respectively. The purpose of separating PET from four kinds of mixed packaging plastics has already achieved basically. After two stages of flotation screening, the purity of recycled PET finally reached 90.91%.

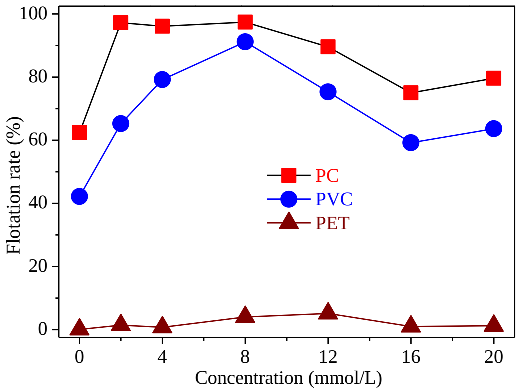

Fig.7 Effects of DBS at different concentrations on PET/PVC/PC flotation efficiency

4. Flotation Technique Process

Combined with the results of the research, this paper established the separation system of waste plastic mixtures involving four waste packaging plastics shown in Fig.8. PET was separated from mixed plastics in descending order according to the floatability of different plastics. Compared with other separation techniques of plastics, like manual separation and electrostatic separation, the separation system in this research is more suitable for the current status of the environmental protection industry in China due to its low costs and high efficiency.

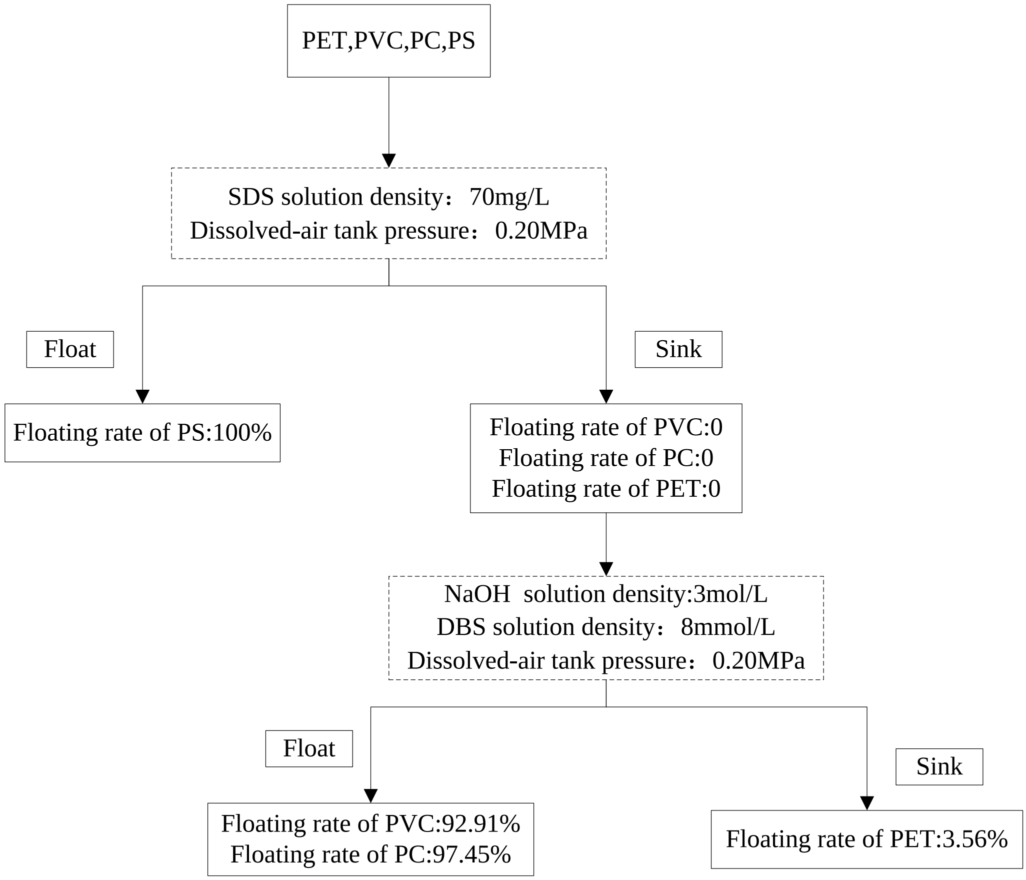

Fig.8 Flotation technique flowchart

5. Summary

This research studied the flotation technique of PET and effects of parameters based on a designed flotation column in laboratory. The species and concentrations of wetting agents have a great influence on flotation separation of mixed plastics. The two stages of flotation screening achieved the optimal effect when using 70mg/L sodium dodecyl sulfate and 8mmol/L dibutyl sebacate as wetting agents, respectively. According to the flotation process established by experiments, 90.91% of PET in purity can be efficiently separated from the mixture of PET/PVC/PC/PS.

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