Selective recovery of plastics from WEEE treatment residue using LARCODEMS Dense Media Separator

H. Muñiz Sierra[1], M. Šyc[1], A. Šperlich[1], J. McCulloch[2]

[1]Research Group of Waste Management and Sustainable Technologies, Institute of Chemical Process Fundamentals of the CAS, v.v.i., Prague, 165 02, Czech Republic
[2]JMC Engineering (UK) Ltd., P.O. Box 36, Alfreton, Derbyshire DE55 1NG, UK
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Presenting author email: muniz@icpf.cas.cz

In the year 2021, approximately 13.5 million tonnes of electrical and electronic equipment (EEE) were introduced to the market in the European Union. This amount represents an increase of more than 75% compared to what was placed on the market in 2012. Similarly, the 4.9 million tonnes of waste electrical and electronic equipment (WEEE) collected in 2021 represent an increase of over 60% compared to that was collected 10 years ago (Eurostat, 2023). WEEE includes hundreds of elements and compounds that can mostly be classified into three categories: metals, glass, and plastics, with the last category constituting almost 30% by weight of WEEE production (Chaine et al., 2022).

The plastic fraction of WEEE is a heterogeneous mixture of different types, among which acrylonitrile-butadiene-styrene (ABS), high-impact polystyrene (HIPS), polycarbonate (PC), polypropylene (PP), poly(vinyl chloride) (PVC), and poly(butylene terephthalate) (PBT) stand out due to their high proportion (Achilias & Antonakou, 2015). Additionally, other compositions such as polyvinyl fluoride (PVF) or poly-1,1-difluoroethene (PVDF), or additives in some plastics such as brominated flame retardants (BFRs) that exist in lower proportions, must be taken into account due to their different environmental issues (Chaine et al., 2022). The high proportion of plastic in WEEE, its high heterogeneity in formulation, and the presence of environmental pollutants make its management a critical issue for recyclability and to comply with the circular economy policy of the EU.

Recycling plants for WEEE are based on a series of stages developed to separate and classify materials for subsequent use in recycling, reuse, or energy recovery processes. In the case of plastic products, this fraction can be obtained from two treatments: plastics pieces from the manual dismantling of large EEE and plastic-rich fractions as a by-product from physical concentration treatments, which are mostly focused on metals recovery (Haarman et al., 2020). This plastic-rich product, consisting mostly of plastic compounds and minor fractions of glass and metals, is then managed downstream by recycling, reuse, or energy recovery processes and ultimately sent to landfill, with recycling being the most preferred option.

Recycling treatments of these plastic-rich fractions must comply with the following objectives: creating homogeneous or complementary plastic formulation output products, controlling the existing additives in the stream through concentration or dilution, and isolating plastic formulations that, due to their composition, could be considered pollutants for subsequent treatments such as energy recovery treatment.

Among the different physical concentration treatments widely used in the plastics recycling industry such as manual sorting, optical sensor-based separators, froth flotation technologies, electrostatic separators, density-based technology has been demonstrated as a suitable method for its classification (Yuan et al., 2015). Among the different density-based suitable technologies, dense medium separators (DMS) have been shown to be more accurate than typical sink-float treatments, and cylindrical cyclones have demonstrated higher efficiency than conical or cono-cylindrical cyclones (Gent et al., 2018).

Of the three most common versions of cylindrical-based cyclones—tri-flo, Dyna-Whirlpool, and LARCODEMS—the latter appears to be the most versatile cyclone dense separator. LARCODEMS is based on a cylindrical vessel inclined at 30º in which the dense media is introduced tangentially at the bottom of the vessel. Part of the media exits the vessel tangentially at the top, while the rest exits through a central diaphragm at the bottom. A separation vortex is formed at the core of the vessel between the feed diaphragm partially introduced in the vessel and the central bottom exit. Dense particles leave the device through the upper tangential outlet, while light particles exit through the bottom central exit (Gent et al., 2018). Additionally, the choice of dense media is crucial to optimizing this separation. Brines are the most common dense media for separating low-density materials due to their easy stabilization and low cost; however, the choice of the type of salt used to create the brine could be a critical factor in the separation yield.

The main aim of this research is to determine the feasibility of the LARCODEMS device for separating the most common plastics in WEEE. Additionally, it is proposed to investigate the influence of the dense medium used, sodium chloride and calcium chloride, on the efficiency of separating these plastic wastes.

To evaluate the separation efficiency of the LARCODEMS device and the suitability of the proposed brines, pure samples of six of the main plastics present in WEEE were used: PE with a density (d) of 0.962 g/ml, HIPS (d: 1.043 g/ml), flame retardant HIPS (d: 1.143 g/ml), PES (d: 1.175 g/ml), PVC (d: 1.216 g/ml), PBT (d: 1.303

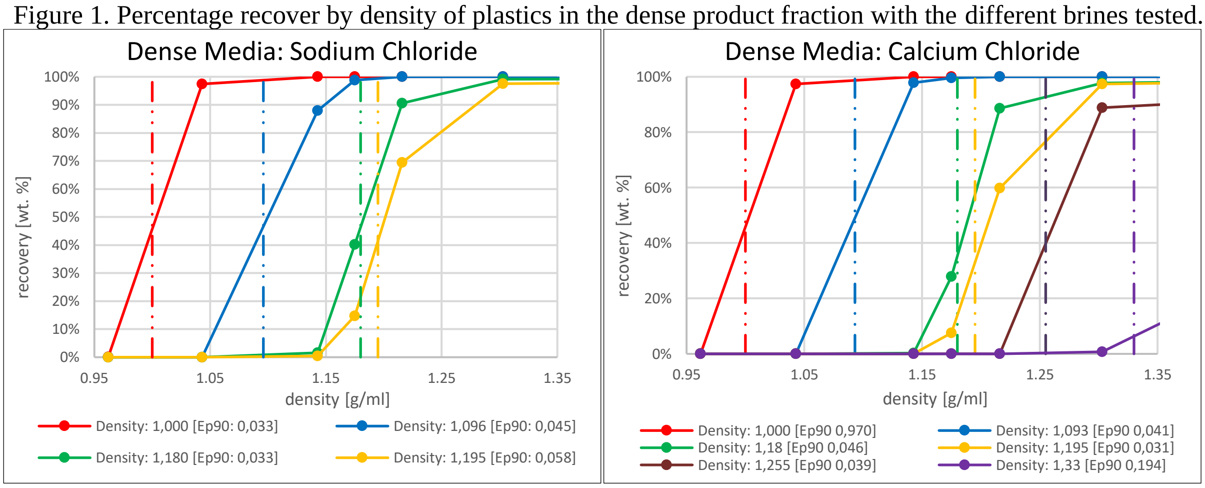
g/ml), and PVDF (d: 1.78 g/ml). Each sample consisted of approximately 25 grams of pellets with a uniform diameter and spherical shape. The suitability of the brines was assessed by conducting various plastic separation tests with densities in the dense medium intermediate between those of the selected plastics, while keeping all other parameters constant.

Figure 1 illustrates the percentage recovery of various plastic samples in each generated brine at different densities of the proposed dense media. Additionally, Ep (Ecart Probable value), the standard measure for evaluating heavy media separations, defined as the percentile recovery by weight in the dense product, was used to compare the efficiency of the separation. Ep90 is calculated as (γ90-γ10)/2, where γ represents the densities at which the 90th and 10th percentiles are recovered. A lower value indicates better efficiency. The high value of Ep was chosen due to the necessity of high purity in plastic products for the market.

The analysis conducted yields the following key results:

- The LARCODEMS concentrator has proven to be a suitable device for sorting plastics according to their density. Similarly, the use of chloride salts for formulating brines appears to be a good option for plastic separation.
- Calcium chloride brine has been proven to be the best option. Ep90 values are lower in most cases, and due to its higher solubility, it is able to achieve brines with higher densities than those produced by sodium chloride.
- By utilizing the dense calcium chloride medium, with a dense medium density of 1.18, it is possible to generate a dense concentrated product containing most of the halogenated plastics: 90% wt. of PVC and all of PVDF.

Figure 1. Percentage recover by density of plastics in the dense product fraction with the different brines tested.



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