# Innovative techniques for plastics recovery from WEEE

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Key words: WEEE, recycling, plastics, environment

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Waste from electrical and electronic equipment (WEEE) represents the fastest-growing waste stream in the world due to technological innovation and the availability of new products on the market at affordable prices (Kaya, 2018). The largest percentage is represented by dishwashers, washing machines, ovens, hobs and electric stoves which, in the Italian context, represent the 'Great Whites' and fall into the R2 grouping.

These wastes consist of ferrous and non-ferrous metals (copper and aluminium), plastics, glass, precious materials and rare earths which, if properly treated, can be recovered and reintroduced into the economic cycle. However, some equipment contains hazardous substances (heavy metals, brominated flame retardants, etc.) that, if not properly managed in the recycling process, can cause environmental impacts and harm to human health (Kuehr, 2019).

One of the main critical issues related to the recovery of R2 WEEE is the mixed plastic fraction, which is currently mainly landfilled (Cafiero, 2021). This fraction is characterised by different types of polymers, including polypropylene (PP), polystyrene (PS), acrylonitrile butadiene styrene (ABS), polyamide (PA), polyvinyl chloride (PVC), which may contain brominated flame retardants and heavy metals, posing a risk to human health and environmental conservation. Therefore, it is necessary to promote the proper sorting and recovery of the main plastics found in household appliances to comply with the increasingly stringent directives of the European Union (Martinho, 2012).

In this study, the processing chain of an R2 WEEE treatment plant in Italy is analysed to determine the efficiencies of separating ferrous metals, non-ferrous metals, and plastics. The plastics are characterized by identifying the main polymer types and evaluating the possible presence of additives and halogenated compounds. The effectiveness of the sink-float technique in plastic separation based on density is assessed.

The results showed that the separation efficiency for ferrous metals is over 90 %, while that for non-ferrous metals and plastics is in the range of 80-85 %.

The characterization of the plastic fraction has allowed the identification that the predominant polymer is PP (approximately 55%), followed by ABS (approximately 17%); PS, PA, and PVC each represent about 9% of the total. Sliding spark technology revealed the presence of flame retardants in plastics: approximately 20% of PP and 35% of ABS contain halogen additives and compounds. Six samples (three for each polymer) were studied through SEM-EDX microanalysis. This analysis showed the presence of brominated flame retardants (BFR) at a concentration of 1.08% in ABS samples, while no significant amount of Br (%) was found in PP plastic samples. A significant amount of Titanium (Ti%) was observed in ABS plastic samples: this can be attributed to $TiO_2$ typically used as UV stabilizer (Grigorescu, 2020). Both polymers showed a high probability of the presence of calcium (Ca%), likely attributable to calcium dioxide ($CaO_2$), commonly used as an opacifying agent in plastics.

The sink float methodology has shown that 100% recovery of PP in an aqueous solution is achieved; complete separation of PS from ABS occurs in a solution of water with 18 % sugar [$C_{12}H_{22}O_{11}$ (w/v)], while complete separation of PVC from PA in a solution of water with 35 % salt [NaCl]. However, it was observed that the shape and presence of additives significantly influence the effectiveness of the separation process.

Sink float technique is effective in the polymer sorting process; however, it has limitations because the shape and the presence of additives can change the separation efficiency.

Therefore, further studies are underway in order to optimise the recycling process. For example, triboelectrostatic separation is an innovative technique that selects plastics according to their surface charge characteristics: plastic particles acquire a positive or negative surface charge as a result of collisions and friction with each other or with the inner walls of a tribo-charging device and are sorted in an electrostatic separator. Triboelectrostatic separation represents a future perspective to overcome the challenges in the management of plastics from WEEE and maximise material recovery.

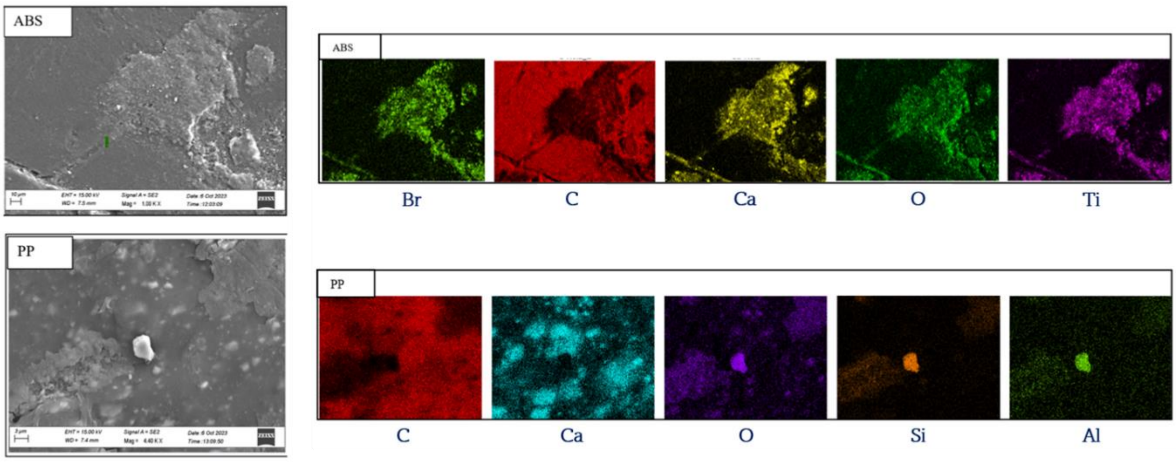


Figure 1. SEM images of ABS and PP plastic samples and distribution maps of the main chemical elements of ABS and PP samples.

| | C | O | Ti | Ca | Br | Fe | Al | Si | Mg | Zn | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % | % |
| ***ABS*** | 68,00 | 17,63 | 8,57 | 2,87 | 1,08 | 0,61 | 0,19 | 0,15 | 0,02 | - | 0,88 |
| ***PP*** | 42,86 | 29,33 | 0,01 | 11,36 | - | 1,06 | 1,78 | 7,17 | 2,69 | 1,57 | 2,17 |

Table 1. Results of SEM-EDX microanalysis related to WEEE plastics samples.

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