Application of dissolution recycling on agricultural film for recovery of pure LDPE, EVA and TiO_2

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Plastics have turned into essential goods in the industrialized world, reaching a global production of 400.3 Mt in 2022 (PlasticsEurope, 2023). It was estimated that in 2018, at least 12.5 Mt of plastics were used in agriculture, counting for the 3.5% of the global plastic production (FAO, 2021). More recent data show a similar trend for Europe, where 4% of the total plastic production (54 Mt) was converted in agriculture, farming and gardening products (PlasticsEurope, 2023). The reason why such large quantities of plastics are used in this filed is that they ensure higher yields, reduction of the use of herbicides and pesticides and a more efficient water consumption. All this is achieved due to the property of plastics to mitigate extreme weather conditions, extend the growing season and reduce plant diseases. Unavoidably, the high production volumes mentioned earlier, translate in high volumes of plastic waste that have to be managed. Agricultural plastic waste (APW) is considered as industrial waste, from non-hazardous economic activities, hence it cannot be managed in the same way as household waste. Looking at the APW generation, 0.7Mt/y of waste are produced in Europe, where around 0.5 Mt/y[1] are produced by the four main consumers of agricultural plastic products (Spain, Italy, France and Greece) (Briassoulis et al., 2013b). These data, compared to the 0.5 Mt/y of total APW generated in Europe in 1992 (Jachia, 1992), prove the increasing importance of the management of this waste.

Depending on the application, films can be based on different polymers, have different types of additives and different thickness. Polyethylene (PE) is the main polymer used for agricultural films, with its different grades: low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high density polyethylene (HDPE). As for any plastic in any application, basic properties given by the main polymer, need to be complemented by the inclusion of different additives in the formulation. UV light stabilizers are one of the main additive types used in agricultural films, since they are typically exposed to harsh outdoor conditions, thus there is a need of improving the durability and resistance to UV light. Pigments as carbon black (CB) and titanium dioxide (TiO_2) are also typically added for a double purpose: the typical color aim and to modify the UV radiation interaction with the film (e.g. carbon black absorbs UV radiation, reducing the heat absorption).

In this study, we investigated an alternative recycling route for agricultural films respect to the well-established mechanical recycling: dissolution based recycling. With this technique the polymer is first dissolved in a suitable solvent, then the obtained polymer solution, containing also additives and contaminants originally present in the plastic, undergoes a solid-liquid separation step to remove insoluble matter. Afterwards the polymer is recovered through precipitation, typically achieved by means of antisolvent addition. Finally, the precipitated polymer is separated from the liquid solution via filtration. The polymers used in this study are LDPE and EVA. LDPE films alone account for approximately 60% of the production of all agricultural plastic (approximately 502,000 t) (Briassoulis et al., 2013b) and more than 80% LDPE products have a life time of less than 2 years (Papaspyrides et al., 1994), so our work can have an important impact on agricultural film recycling. EVA was chosen as second polymer to test the selective recovery of different polymer, seen the extensive use of this other polymer in agricultural films. Besides polymers, this paper evaluates the possibility of recover a valuable additive used in this application: titanium dioxide (TiO_2). TiO_2 is a white inorganic pigment, widely used in agricultural films in high concentrations (up to 15w%). With 59% of world pigments consumption, TiO_2 is the most used pigment (Postle et al., 2018), thus its recovery would significantly increase the economic added value of the recycling chain. Next to TiO_2, the most used pigment in agricultural films is carbon black. It is designed to absorb UV radiation and reduce heat absorption, to improve the performance of the film and increase its lifespan.

Firstly, a characterization of solutions of LDPE and EVA was performed, in order to determine cloud

[1] Including: protected cultivation plastic films, silage films, bale wraps, PP twine, micro-irrigation systems, fertilizer sacks, agrochemical containers and agricultural nets.

point, dissolution temperature and viscosity at different concentrations, in two different solvents. Secondly, dead-end filtration was investigated as solid-liquid separation technique to remove the two pigments from the polymeric solution. Flux, turbidity reduction (respect to the original solution) and polymer content (measured via TGA) of the permeate were chosen as parameters to evaluate filtration performance. As conclusion of the process, reclaimed polymers were recovered through precipitation, without addition of antisolvent, but based on the cloud point curves.

To summarize, our work assesses the recycling of LDPE and EVA from agricultural films trough dissolution based process, with particular focus on solid-liquid separation of TiO_2 and carbon black pigments via filtration and the reclaim of the white pigment. An alternative precipitation step respect to the antisolvent addition is tested in this process, where polymer are selectively precipitated by temperature.

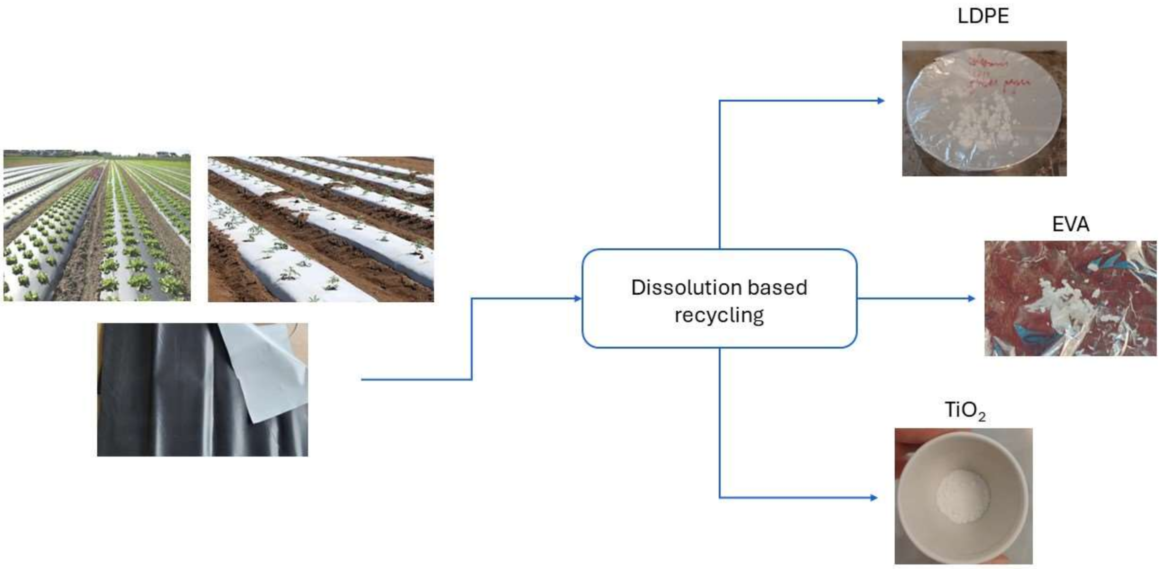

Figure 1. Conceptual scheme of the solvent-based recycling process studied in the present work.

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