Recycling of plastic tube shelters: characterization of the degradation and contamination of the used tubes

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Introduction

Tube shelters are widely used to improve the development and survival rates of young seedlings, both in afforestation processes (Figure 1a) and in agriculture, in vineyard plantations, for example. Among the main advantages derived from the use of these tubes are the protection of the seedlings against the wind and against predators, such as rabbits or deer, and a certain control of the light that reaches the plants and the microclimate in which they develop (Oliet et al., 2007; Puértolas et al., 2010).

These tubes are made of different materials, including plastic, metal, and, more recently, some biomaterials (Arnold & Alston, 2012). The manufacture of tubes from recycled plastics of agricultural origin has also been proposed (Martínez Urreaga et al., 2020). The main materials are plastics, especially polypropylene (PP) and polyethylene (PE). The amounts used are high, several thousand tons each year in a country like Spain, which indicates the importance of the issues related to the destination of these tubes when they become residues.

At present, the plastic tubes used in agriculture, in accessible environments, can be collected and, at least in part, valorized, for example by recovering their energy value as fuel. In the case of afforestation processes carried out in environments with difficult access, it is usual that plastic tubes are not collected, being abandoned forever in the environment. In all cases, the recycling of the plastics used in this application is practically non-existent.

In this way, the incorrect management of waste from plastic tube shelters becomes a serious environmental problem. On the one hand, these plastics undergo slow degradation over many years, in which certain additives used in their manufacture are gradually released, together with micro and nanoplastics formed in the degradation processes. The full effects of these additives on the environment are still not well understood. On the other hand, the problem derived from the loss of significant amounts of raw material is becoming more important every day, in a planet where the scarcity of raw materials is becoming increasingly evident.

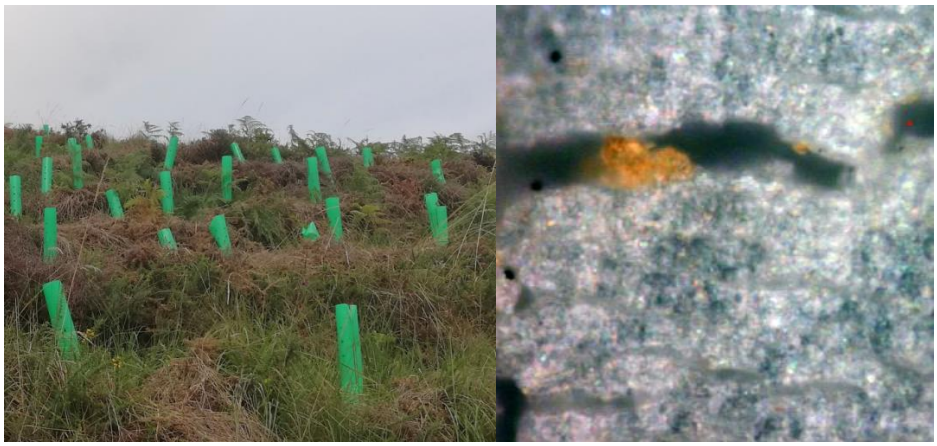

Fig. 1. a) (left) PP tubeshelters used in a recent afforestation process in Spain. b) Optical micrography (100x) of the outer surface of a PP tube used for 10 years.

From an environmental point of view, and especially considering the recommendations of the European Union, (European Commission, 2018), mechanical recycling would be the best End of Life scenario for tube

shelters made of PP or PE. This kind of recycling would greatly reduce both the loss of raw materials and the release of potential pollutants into the environment, thus contributing to the development of a more circular economy. However, some issues can limit the viability of mechanical recycling, in addition to the cost of waste collection, such as:

- The thermo-oxidative and photochemical degradation suffered by the plastic, despite the use of stabilizing additives, which could reduce the performance of recycled plastic.
- The presence of contamination in the waste, which could affect the machinery used in recycling and the properties of the recycled material.

Therefore, it is essential to know the levels of degradation and contamination present in the waste to assess the interest in its collection and recycling. This is the main objective of this work.

Experimental

PP tubes with different time of use, between 2 and 20 years, were collected from vineyard plantations in Castilla-La Mancha, Spain. The degradation and contamination of the aged tubes was studied by using infrared (IR) and Raman spectroscopy, thermogravimetric analysis (TGA), and microscopy.

Results and discussion

Although the tubes used for more than 10 years in the studied plantations are too brittle, the tubes with less aging time can still be easily collected. The results indicate that the external surface, more exposed, shows degradation and the presence of different types of impurities. Figure 1b, which corresponds to the external surface of a tube aged for 10 years and washed, shows the degradation, which results in the appearance of cracks, and the presence of a mineral impurity. IR confirms the degradation and shows the appearance on the surface of different carbonyl compounds formed during the thermos-oxidative and photochemical degradation of the polymer. Raman spectroscopy allows to determine the nature of the contaminants, showing the presence of a silicate in this case.

However, it should be noted that results also show that degradation and the presence of impurities are much lower in the internal parts of the tubes. Furthermore, most impurities, which could damage reprocessing equipment, can be effectively removed by simple washing procedures. These results support the viability of mechanical recycling.

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