# Characterization of waste generated from discarded or end-of-life solar panels thermal delamination process for possible valorization

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The installation of solar panel in Mexico started in the 1980s in rural areas as an alternative option to supply energy (Archivo General de la Nación, 2022). Nowadays, Mexico has the fourth place in total installed capacity of photovoltaic solar energy in America surpassed only by the United States, Brazil and Chile (Hemetsberger, et al., 2023). Currently, there are worn solar panels that have reached the end of their useful life, after 25 to 30 years of service, whose waste require treatment for their correct disposal. However, there are still no specific Mexican regulations for the management of these type of waste. In addition, it is estimated that by 2045 there will be around 690,907 cubic meters of waste solar panel in Mexico, therefore the development of materials recovery treatments is an urgent task, prioritizing the delamination process (Riech, et al., 2021). Its main goal is the separation of the layers that make up the device by removing the organic layers (encapsulant and polymeric layer) from the inorganic ones (glass, filaments "ribbons" and solar cell) (Riech, et al., 2021). This treatment turns out to be a simple and, economical method without the use of potentially toxic chemical substances, but the generation of toxic gases as well as the proper management of waste must be considered, seeking to revalue this material (Negrete Hernández, et al., 2024). For this reason, the objective of this research is to carry out the characterization of the waste generated from the thermal delamination process of discarded or end-of-life solar panels for their possible valorization through the use of cutting-edge analytical techniques.

## Material and methods

For the present study, five samples of 5 x 5 cm with an average weight of 20.88 g were used, obtained from a discarded solar panel model SE-210*70-505M-150 with dimensions 2.185 m x 1.098 m x 35 mm, which was damaged during installation. The samples were subjected to thermal treatment, at 500°C for 30 min, in a Thermolyne muffle model 48000 furnace according to the methodology of Negrete Hernández *et al*. (2024). Subsequently, the components of the solar panel such as glass and filaments were separated manually while the solar cell and ashes were separated using a sieve with an opening size of 0.355 mm. Each of the components was weighed on an OHAUS balance, model PA124C and the percentage of composition of the sample after heat treatment was calculated. The ashes were characterized by two analytical techniques, X-ray Fluorescence Spectrometry with the RIGAKU equipment, model NexQc + by the rock oxide method by triplicate and X-ray Diffraction by the powder methodology with the BRUKER equipment, model D8 advance at a wavelength K$\alpha_1$Cu (1.5406 A). Once the percentage composition of each of the components of the solar panel and the characterization of the ashes were determined, a possible valorization of the recovered material was proposed.

## Results and discussion

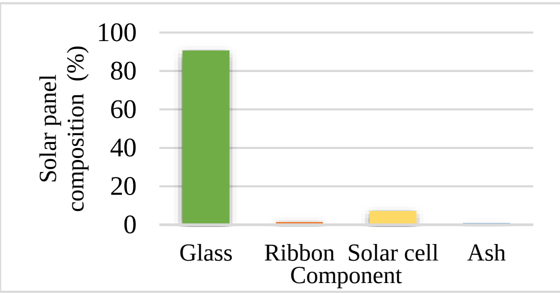


Figure 1. Average percentage composition of solar panel after heat treatment

Figure 2. Components of discarded solar panel

Table 1. Ashes characterization by XRF

| Oxide ID | Average composition (% w/w) | STD. DEV. |
|---|---|---|
| Silicon | ND | --- |
| Titanium | 8.870 | 0.0321% |
| Aluminum | 0.261 | 0.1745% |
| Iron | 0.083 | 0.0013% |
| Manganese | 0.002 | 0.0002% |
| Potassium | ND | --- |

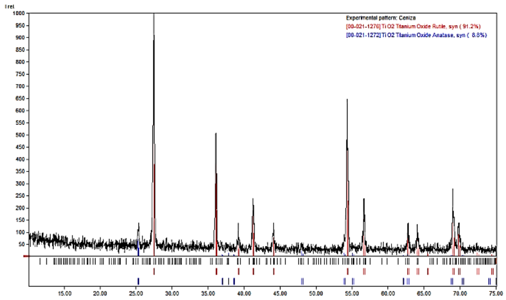
Figure 3. Ash analysis by X-ray diffraction

The predominant component in the solar panel after thermal treatment is the glass layer (90.7 %) followed by the solar cell (7.1 %), the ribbons (1.3 %) and the ashes (0.9 %). The separation of each of the layers is simple through mechanical work. In the case of the ashes, most of its composition is titanium oxide present in two mineral forms, rutile and anatase, in addition to a low concentration of metallic oxides.

## Conclusions

The three inorganic components of discarded solar panels (glass, solar cel and ribbons), can be reincorporated into the production chain. The glass layer and the cell can be recycled (reincorporate them into the assembly process) after a cleaning treatment with pressurized water. The strips or ribbons, composed mainly of a copper tin alloy can be recycled through a metallurgical treatment. Regarding the ashes, no potentially toxic compounds are detected, so it is not considered a hazardous waste, therefore, its valorization is simple and viable. Among the applications of the ashes, depending on the concentration of titanium oxide, is the treatment of wastewater for the removal of emerging organic contaminants through advanced oxidation processes using the ash as a catalyst to carry out heterogeneous photocatalysis, since $TiO_2$ is easily excited by the sun's UV radiation, chemically stable and harmless (Morales Mejia, et al., 2011).

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