Life Cycle Assessment of purification and regeneration plating bath technologies with Magnetic Nanoparticles

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The targets for circular economy announced in the Action plan of the European Commission, as well as the Sustainable Development Goals from United Nations (namely number 12 – Responsible consumption and production and 13 – Climate action), have pursued the development of new sustainable strategies in the electroplating industry.

In fact, one of the environmental burdens of the plating process within the electroplating industry is related to the spend bath End-of-Life (EoL), i.e., the total discard of the aqueous solutions used in the process. In this context, to boost sustainability and circular economy, innovative technologies concerning a safe plating bath recirculation are being developed in the PureNano Horizon 2020 Project.

Furthermore, the top priority of the project is focused on the in-situ purification and/or regeneration process of plating baths from pollutants and other undesired chemical compounds. The main purposes of a novel purification/regeneration pilot line are (1) to extend the lifetime of baths by removing the undesired species and (2) to recover metal ions, that are pollutants from the electroplating process, to be used as secondary raw materials.

To allow the in-place purification and regeneration of the baths, different strategies have been tested, involving functionalized magnetic nanoparticles (MNPs). The application of MNPs in the processing lines are a key factor to extend the lifetime of the baths, and, consequently, an important factor to increase economic and environmental performance of this industry. The MNPs produced can be adapted according to the needs of the end users to enhance their efficiencies in removing specific pollutants. In addition, depending on the nature of the pollutants to be removed from the spent bath, different MNPs coatings could be applied.

The present work aims to evaluate the environmental performance, within a life cycle perspective, of the purification/regeneration pilot lines developed. A comprehensive assessment is carried out to support the decision-making process regarding innovative technological solutions. Thus, the environmental sustainability of the processing lines and the benefits in relation to conventional disposal procedures (e.g., landfill) are evaluated.

Additionally, in this work, the main environmental hot-spots and strategies to overcome the potential impacts of these new technologies are assessed. The LCA (ISO 14040/ 14044) was applied to assess the potential environmental impacts of novel purification/regeneration pilot lines. For this study, the SimaPro software was used to determine the impacts, according to the ReCiPe method. In addition, the inventory data used in this study was supported by the PureNano Project in-situ quantifications, as well as data from peer-reviewed scientific research works and international databases, such as ecoinvent.

The results from the comparison of the plating baths purification/regeneration through innovative technological solutions with business-as-usual options, as direct disposal in landfill, have demonstrated promising results for the mitigation of the EoL environmental impacts. Additionally, the possibility of recovering and reusing the MNPs applied in the purification/regeneration process for different uses (e.g., concrete production and wastewater treatment) may represent an important benefit for the entire system.

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