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Life Cycle Assessment of Magnetite Production Using Microfluidic Devices: Moving from the Laboratory to Industrial Scale

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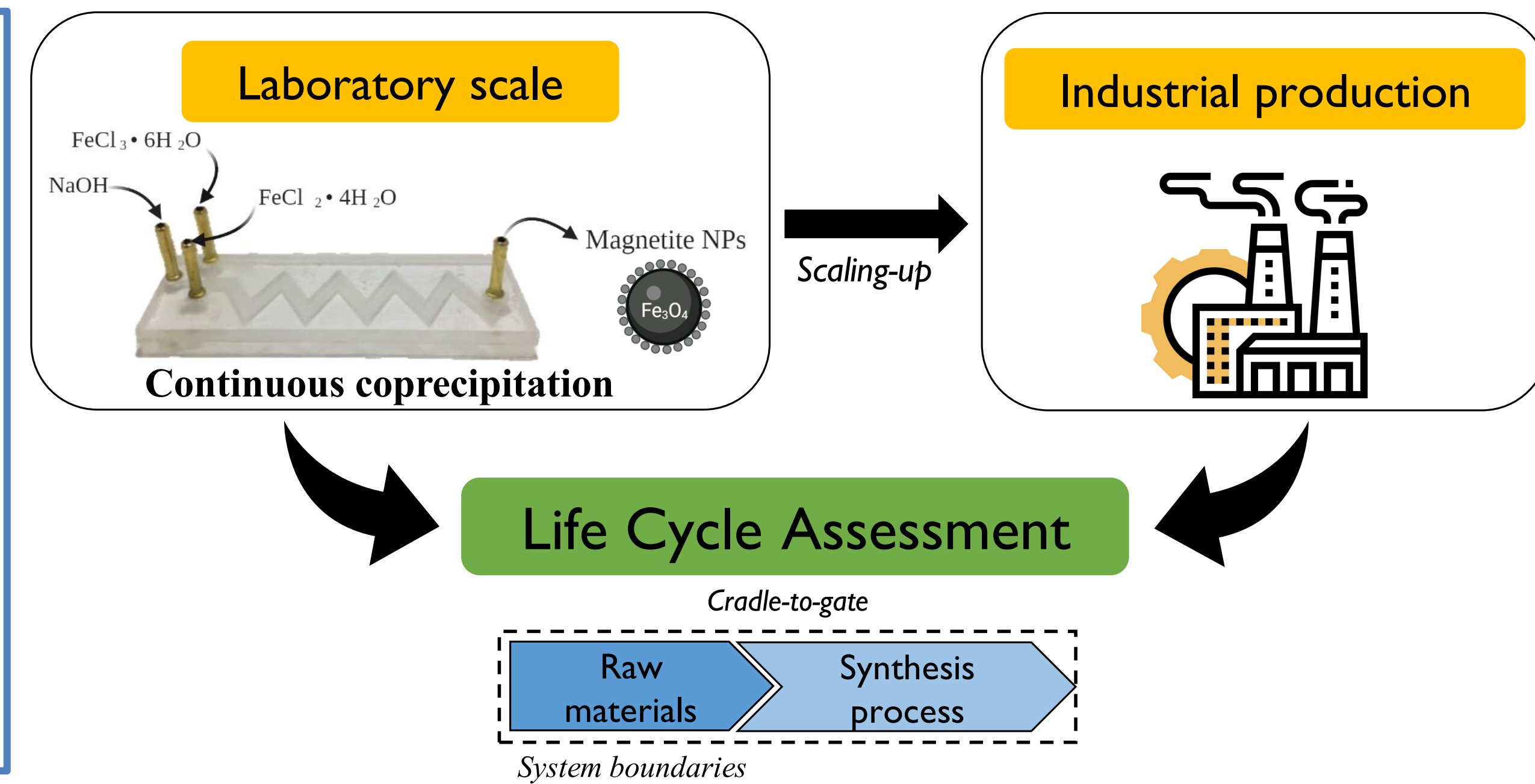
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CONTEXT AND OBJECTIVE

- Magnetite nanoparticles (MNPs) have important applications in several industrial and scientific fields for the remediation of contaminated soil and water, for instance.¹
- Emerging technologies such as microfluidic techniques have been adapted to continuously synthesize MNPs.
- This technique has showed appealing results, such as its high portability, the possibility of particle size control, and applicability on a large scale.²
- Therefore, this approach might become important for producing MNPs to meet industrial requirements.
- The life cycle assessment (LCA) methodology has been widely used to assess the environmental sustainability of new products and emerging technologies in the early stages.³
- In this study, a LCA is conducted to analyze and evaluate the impacts of the synthesis of MNPs performed in microfluidic devices considering all of the steps required for MNPs production at a laboratory and possible industrial scales.



MATERIAL AND METHODS

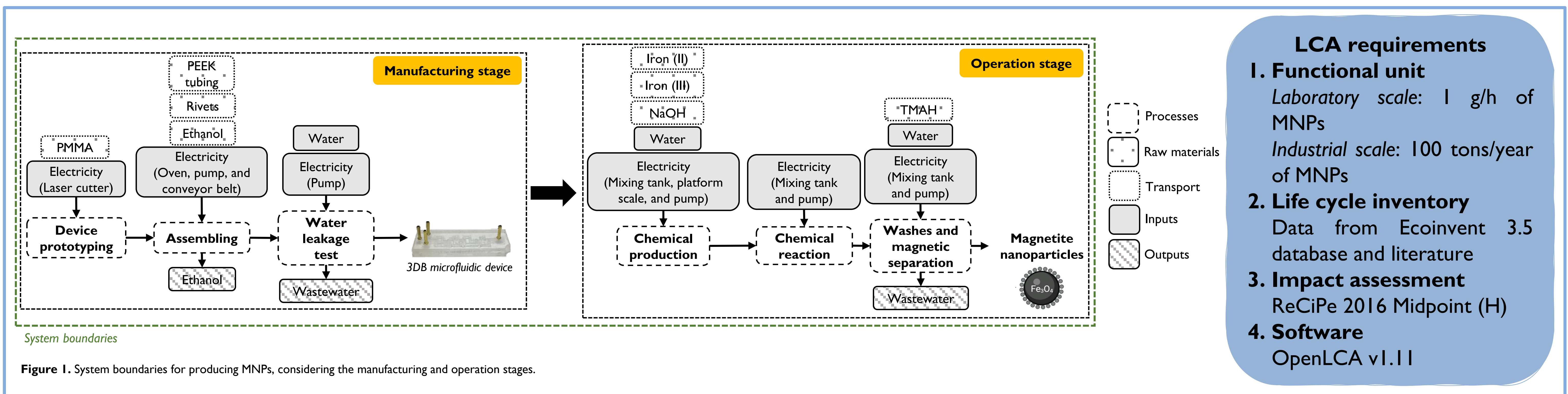


Figure 1. System boundaries for producing MNPs, considering the manufacturing and operation stages.

RESULTS

Alternatives to Reduce the Environmental Hotspots

- Replacement or rivets with another type of fitting made of a more sustainable material might be appealing as an eco-design strategy.
- To decrease the thickness of the PMMA sheets to reduce the impacts of global warming and fossil resource scarcity categories
- To mitigate the high contribution of NaOH (above 40%) to the impacts in most categories along the operation stage.

Sensitivity Analysis

- Two alternatives as a replacement for rivets, such as polyether ketone (PEEK) and PDMS fittings were evaluated.
- PEEK fittings were the best alternative for replacing rivets because it might reduce environmental burdens by around ~99.9% compared to the use of rivets.

Contribution Analysis

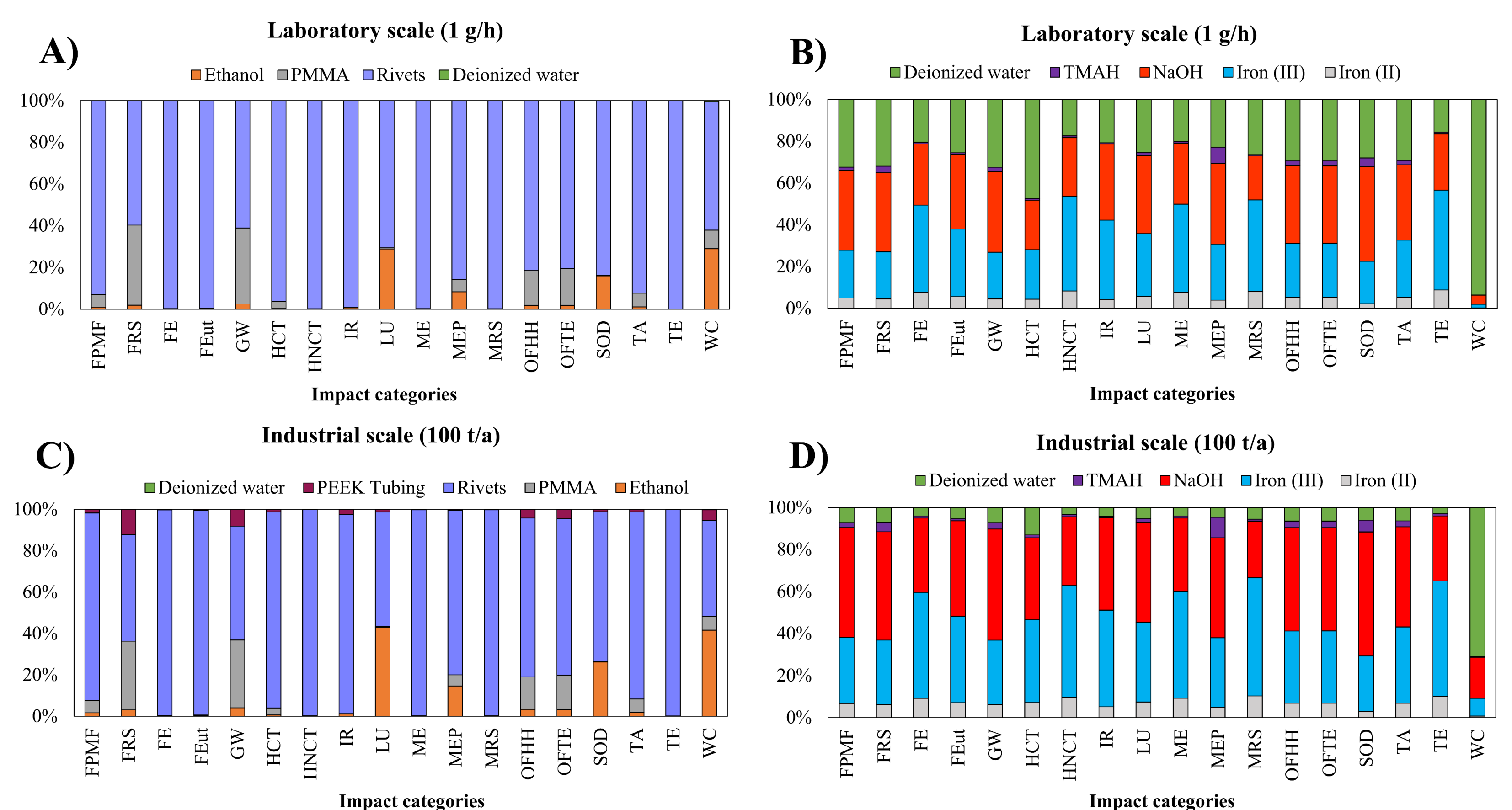


Figure 2. Environmental hotspot analysis of chemicals used for the synthesis of MNPs: at the laboratory scale: (A) manufacturing stage and (B) operation stage; and at the industrial scale: (C) manufacturing stage and (D) operation stage.

CONCLUSIONS

- First LCA study of microfluidic devices, which we are aware of, that consider scaling-up calculations.
- The industrial production of the MNPs introduced here is an innovative process whose environmental impact, to our knowledge, had not been analyzed previously.
- This study contributes to studying this process' overall feasibility by providing detailed information on the implementation of the LCA methodology to assess comprehensively emerging technologies such as microfluidics.
- This work represents a holistic understanding of the potential environmental impacts of MNP synthesis processes.
- Finally, this work is expected to help future environmental impact studies of nanomaterial production at the laboratory and industrial scales.

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