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From gray water to green solutions: Life Cycle Sustainability Assessment of heavy metals removal using inactive yeast

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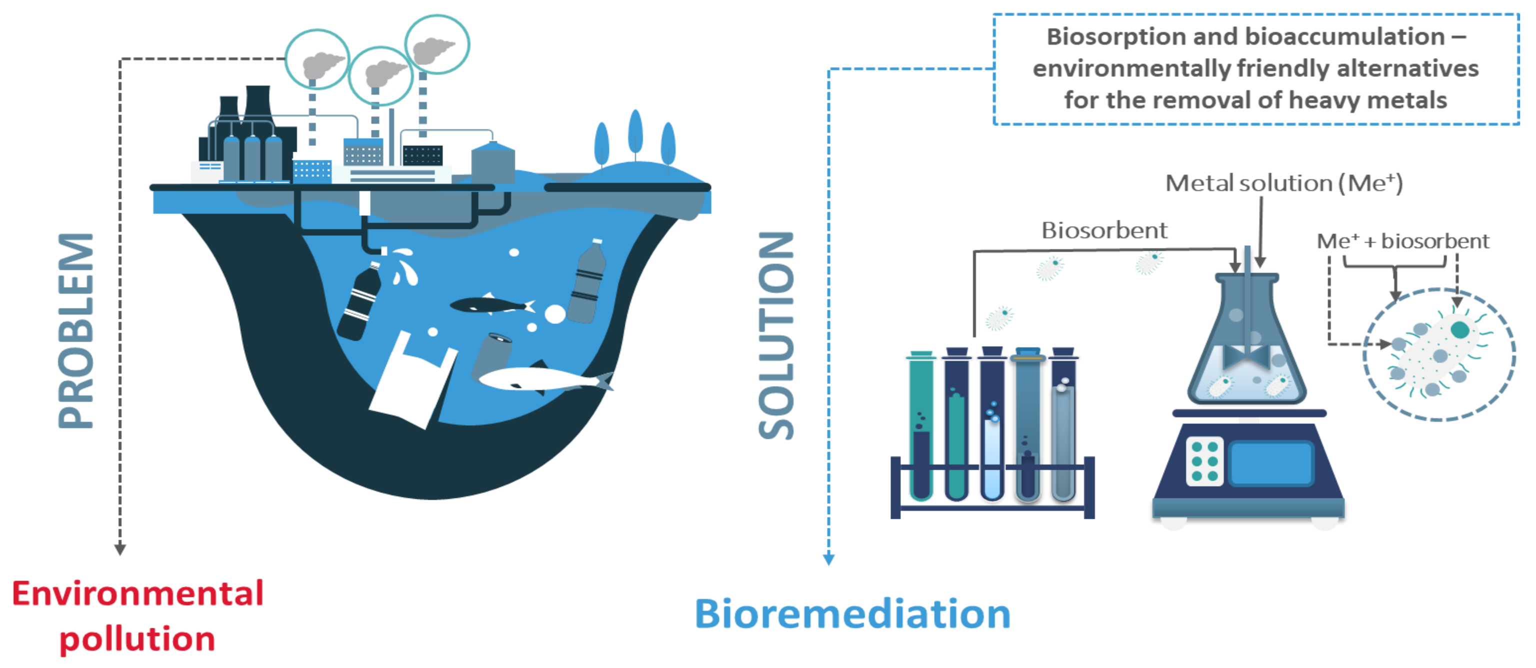
INTRODUCTION & AIM

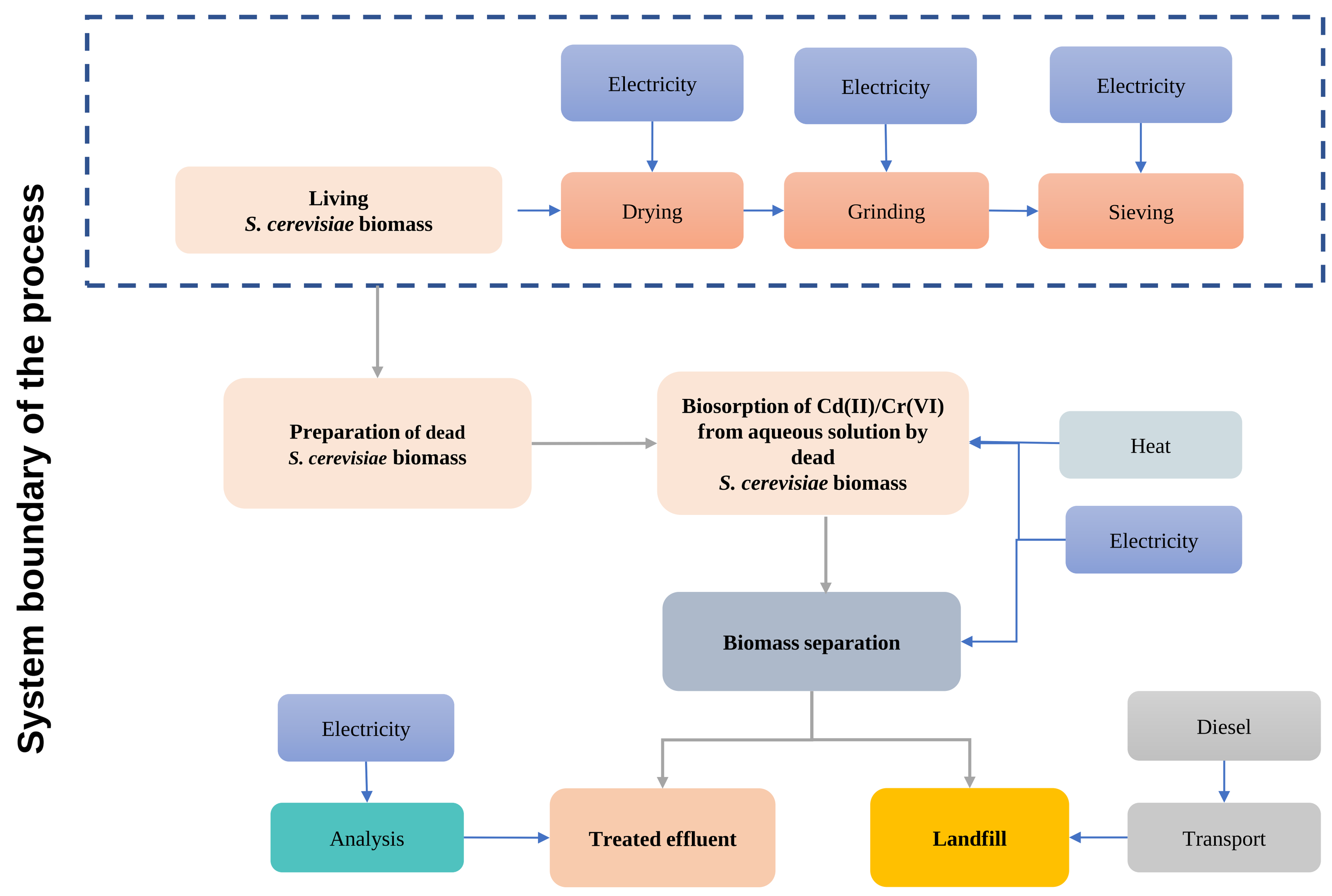
Due to increasing anthropogenic pressures, significant quantities of heavy metals are released into the environment, posing severe risks to human health because of their persistence, non-biodegradability, and long-term accumulation within ecosystems.



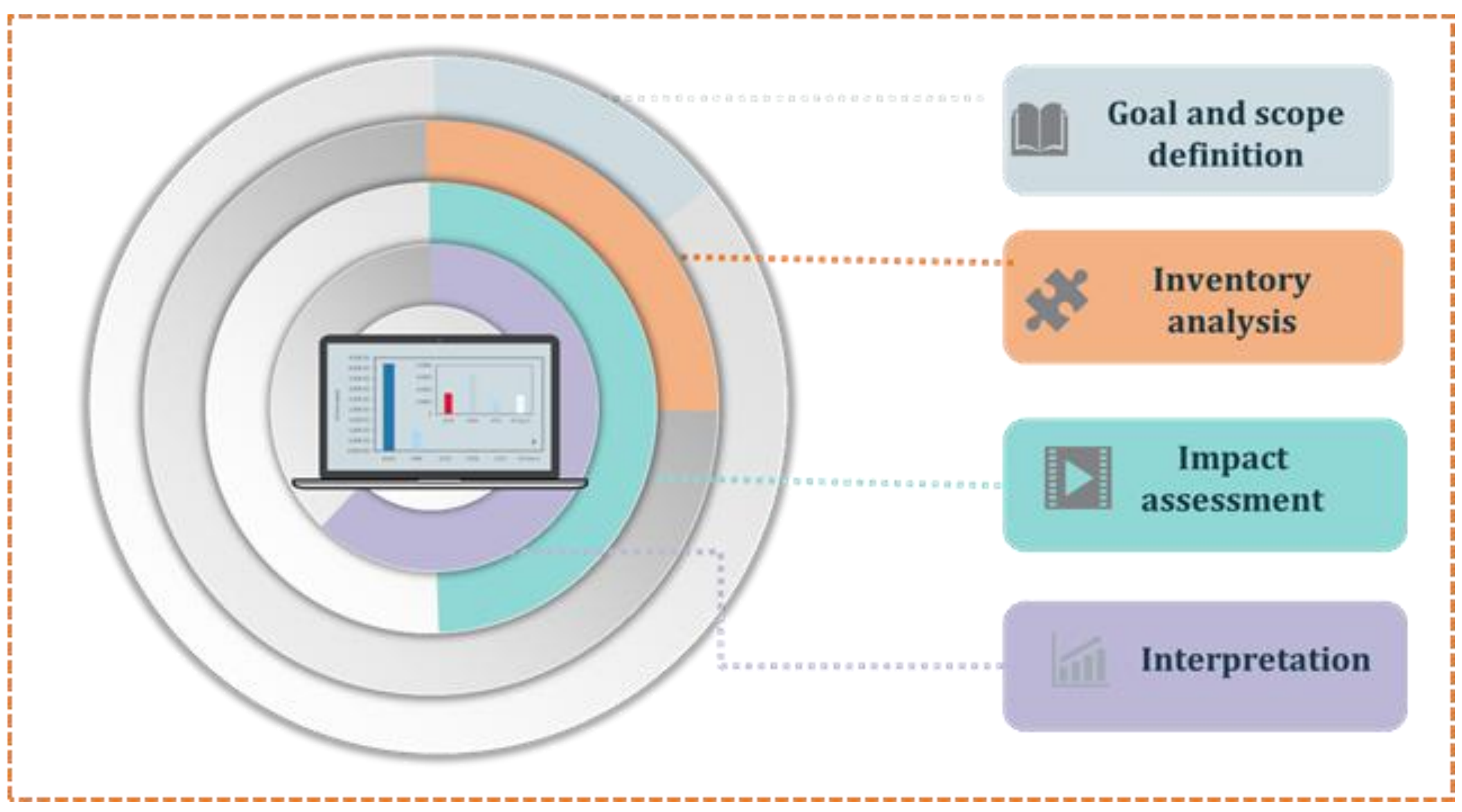
This study aimed (i) to investigate the removal efficiency of Cd(II) and Cr(VI) from aqueous solutions using *Saccharomyces cerevisiae*, an inactive yeast biomass characterized by a high surface-to-volume ratio, wide availability, and low cost, as a biosorbent; and (ii) to evaluate the environmental sustainability of the biosorption process through Life Cycle Assessment (LCA).

METHOD

Biosorption is defined as an **eco-friendly process** used for the removal of environmental pollutants such as heavy metals by biological materials, which can be organic and inorganic and are either in soluble or insoluble forms.



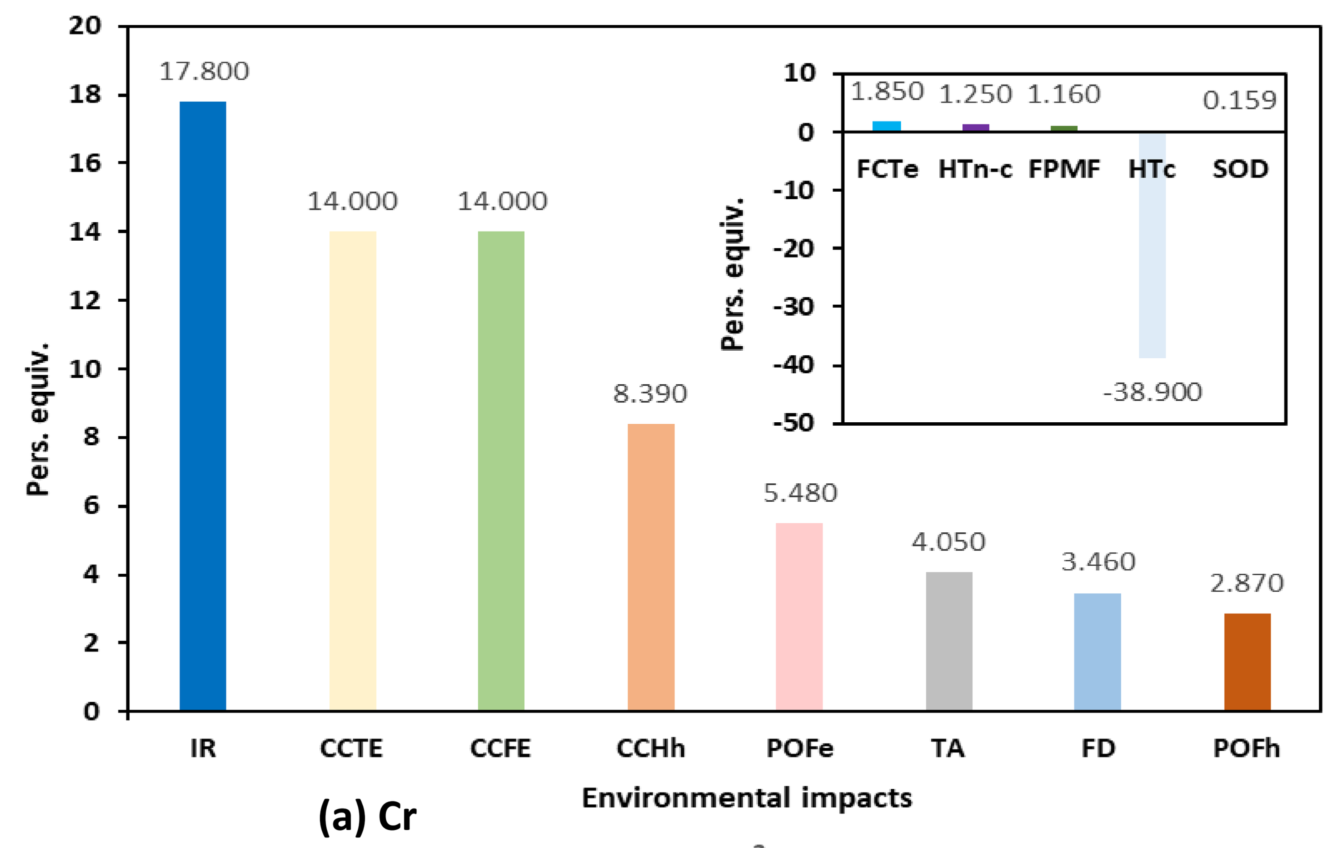
The environmental impacts associated with the removal of heavy metals from aqueous solutions were quantified across the four phases of the LCA methodology, conducted using Sphera Product Sustainability Solutions Software.



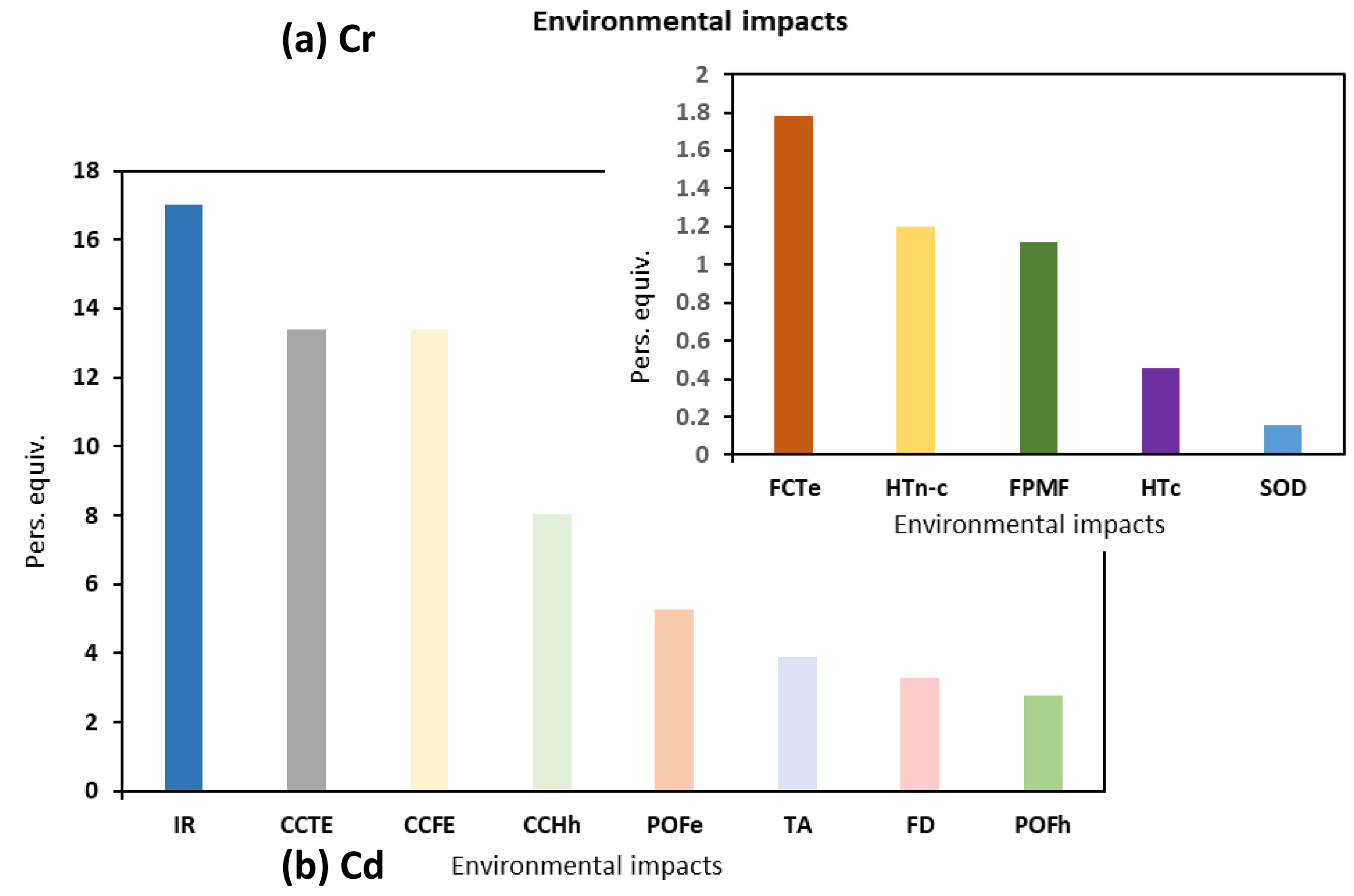
RESULTS & DISCUSSION

Results revealed that the highest environmental burdens, for both Cr(VI) and Cd(II) removal, were recorded in the impact category *Ionizing Radiation*, according with Recipe method, with values of 17.8 person equivalents for Cd(II) and 17 person equivalents for Cr(VI), primarily due to the energy-intensive processes and electricity mix linked to biosorption system operation and LCA modeling.

A negative value was identified for *Human Toxicity*, cancer effects (–38.9 person equivalents) in the case of Cr(VI) removal, indicating an apparent environmental benefit in this category employing *S. cerevisiae*. Conversely, Cd(II) biosorption showed a positive value to potential human toxicity (0.458 person equivalents), reflecting a measurable burden on the environment.



(a) Cr



(b) Cd

CONCLUSION

The application of life cycle assessment (LCA) provided a comprehensive and systemic **perspective on the environmental impact generated** at each stage of the process, clearly identifying the **biosorption phase as the main factor contributing to overall environmental performance**. At the same time, the biosorption process demonstrates strong performance in removing heavy metals, dyes, and other pollutants, even at low concentrations. This efficiency can reduce the need for multiple treatment steps, thereby diminishing the overall environmental impact of the treatment system.

We can conclude that identifying biosorption as the main factor contributing to the LCA framework does not diminish its importance; on the contrary, it highlights its central role in the system. By focusing optimization strategies on this stage, significant improvements in overall environmental performance can be achieved. Biosorption remains a highly promising, sustainable, and adaptable technology for wastewater treatment, especially when integrated into circular and resource-efficient process designs.

FUTURE WORK

Future research will focus on developing sustainable management strategies for heavy metal-loaded biosorbents in general. We intend to pay particular attention to post-treatment options that minimize secondary environmental impacts. Instead of conventional storage, which poses risks of metal leakage and long-term contamination of soil and groundwater, alternative routes such as metal recovery and controlled biomass incineration need to be investigated.

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