Enhanced removal of ciprofloxacin with sludge-based catalysts by catalytic wet air oxidation processes

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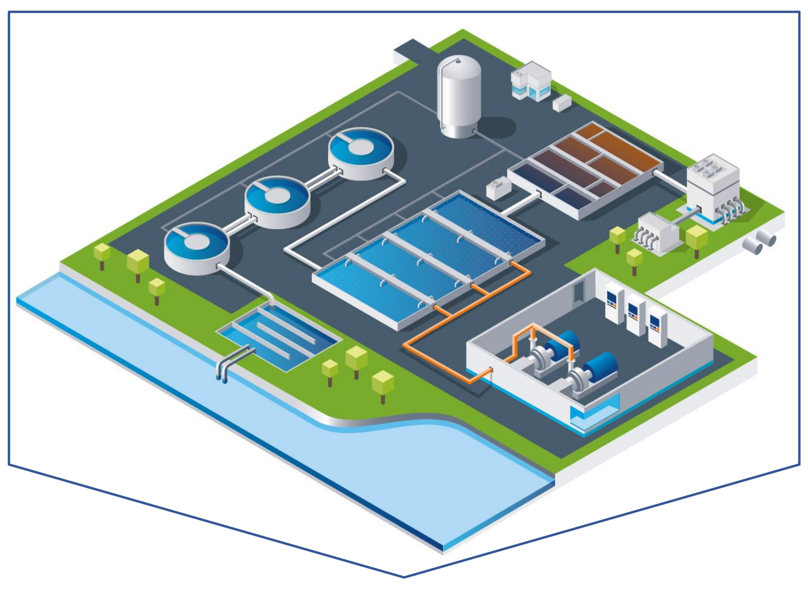
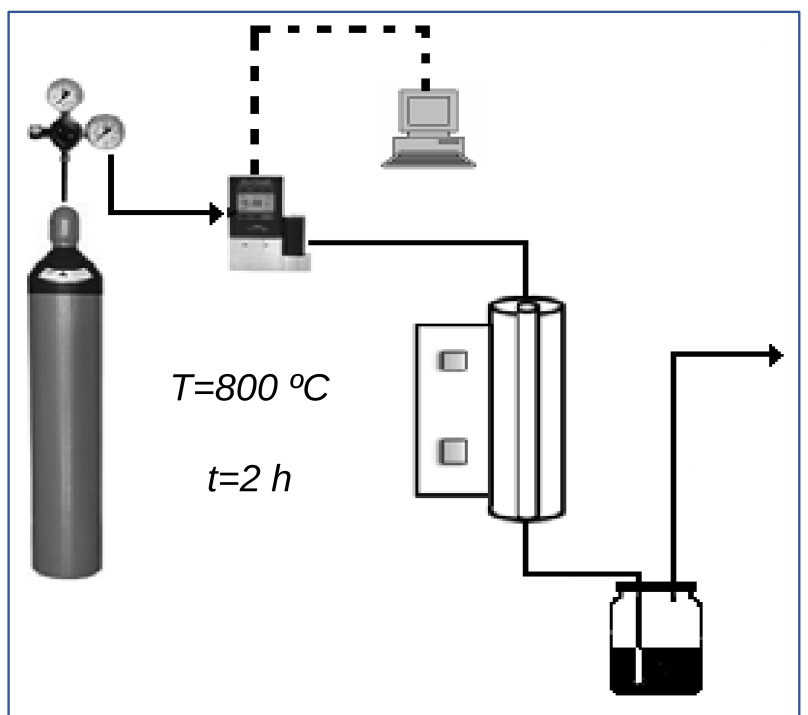
Materials and methods

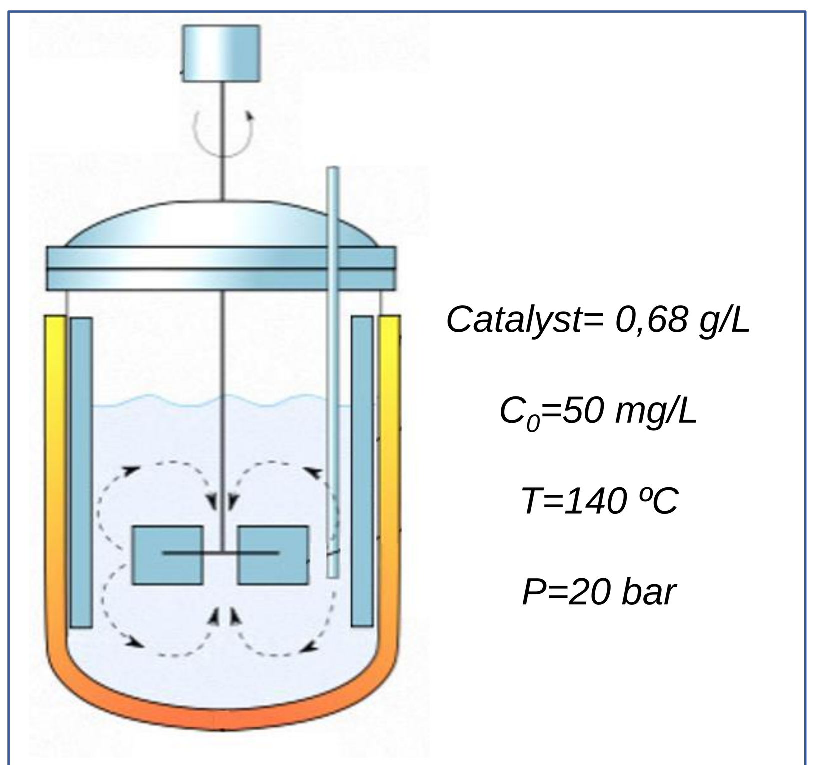


Industrial sludge



Catalyst synthesis:
Chemical activation

Fe and Ni catalysts



WAO/CWAO:
Removal of ciprofloxacin

Introduction

Sewage sludge is increasingly produced in municipal and industrial wastewater treatment plants. It is a very difficult waste to manage due to its variable composition, its contamination with pathogenic micro-organisms and micropollutants, and its high organic matter and water content.

Current sludge management practices have changed significantly over the last twenty years. Improved biogas production, advanced sludge dewatering processes, controlled landfilling and thermal processes are increasingly implemented. These developments are accompanied by an increase in the cost of sludge management. These costs often represent more than fifty percent of the total cost of wastewater treatment. Due to the high costs, but also the urgent need to develop more sustainable sludge treatment scenarios, research on innovative and more sustainable sludge treatment processes is increasing (Domini et al., 2022).

In this context, an industrial sludge was proposed as promising biomass precursor of chemically activated carbons for catalytic applications. The aim of this work is to characterize and test the efficiency of these green and sustainable iron- and nickel-based catalysts, proposing the mentioned sludge valorization technique as a feasible approach to solid waste management.

Discussion

Among the main macroscopic properties of the industrial sludge, the total solid content was 3.4 wt.%. The high COD and VS values indicated an important organic matter content. This is convenient for the synthesis of biomass derived catalysts as the more organic matter in the precursor, the higher the efficiency. In this regard, VS of 80% and COD of 35.0 g/L was obtained for the sludge.

The characterization of iron- and nickel-based catalysts showed favorable properties, as relatively high BET surface area.

The adsorption-desorption isotherms, Figure 1, confirmed that the carbonaceous catalysts are essentially mesoporous, presenting a IVa type isotherms. As observed in Figures 2 and 3, the supported Fe and Ni particles in the pores of activated carbon were needle shaped.

Promising results were obtained when iron- and nickel-based catalysts were applied to wet air oxidation processes. Figure 4 shows ciprofloxacin conversion for sludge derived catalysts synthesized. An initial removal of the pollutant was observed before the reaction started (zero-time reaction), which is related to the adsorption process until the system reaches the desired temperature. The iron-based catalyst seemed to present considerably higher conversions than the nickel one, oxidizing the emerging pollutant almost completely within 2 h at 140 ºC and 20 bar.

Conclusions

- The valorization of industrial sludge as catalysts has been technically proven, contributing to the circular economy in WWTPs and to the removal of emerging pollutants.
- The materials showed promising textural and chemical properties for use as catalysts.
- The iron-based catalyst presented the highest catalytic activity when applied in CWAO processes.
- Ciprofloxacin aqueous solutions could be completely oxidized within 2 hours at 140 ºC and 20 bar.

References

[1] Domini, M.; Abbà, A.; Bertanza, G. 2022. Analysis of the variation of costs for sewage sludge transport, recovery and disposal in Northern Italy: a recent survey (2015–2021). Water Sci. Technol.

Acknowledgements

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Results

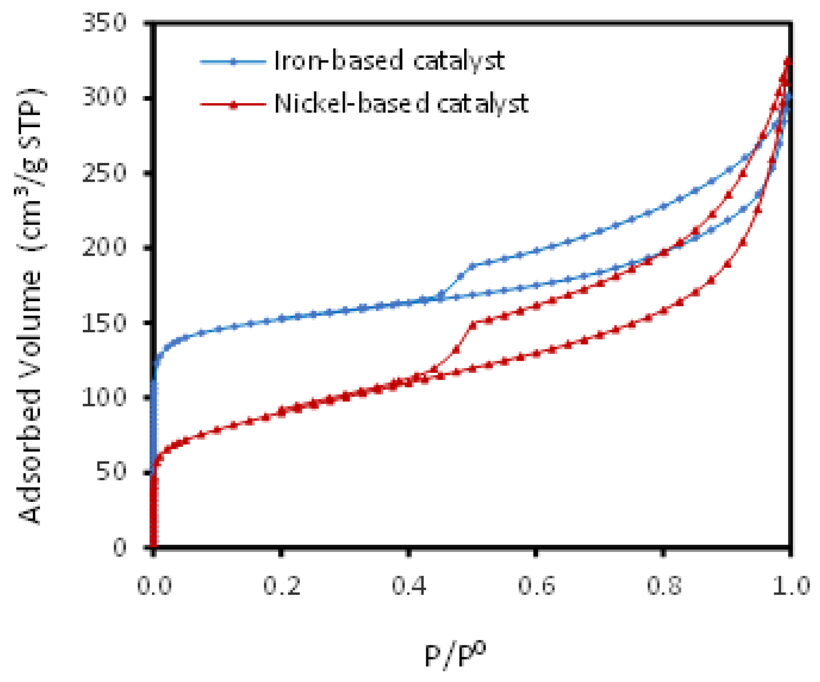

Figure 1. Adsorption–desorption isotherms of the sewage sludge-based catalysts.

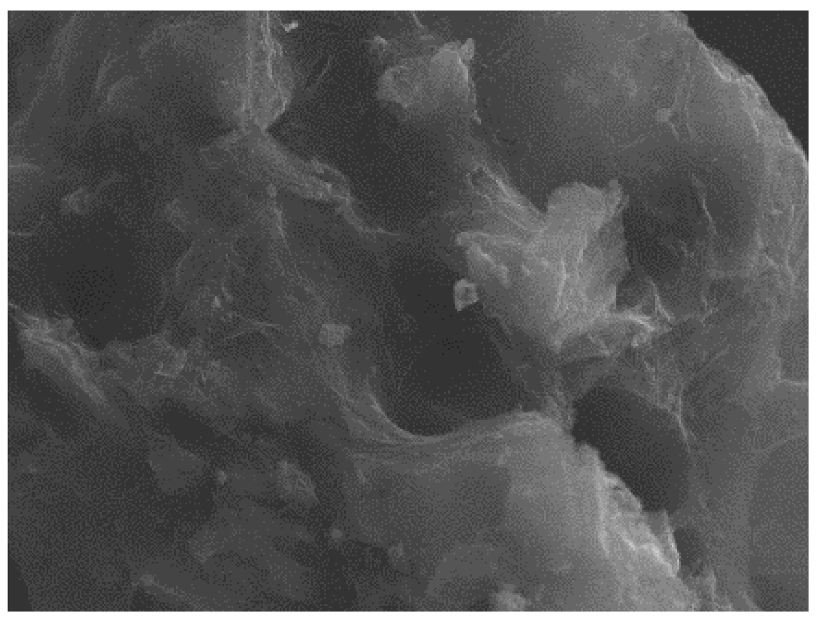

Figure 2. SEM image of the iron-based catalyst.

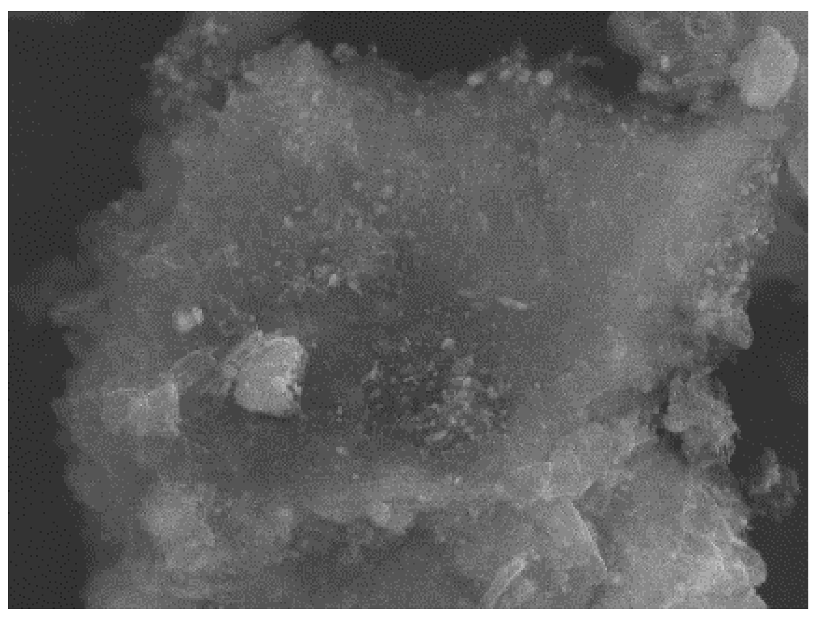

Figure 3. SEM image of the nickel-based catalyst.

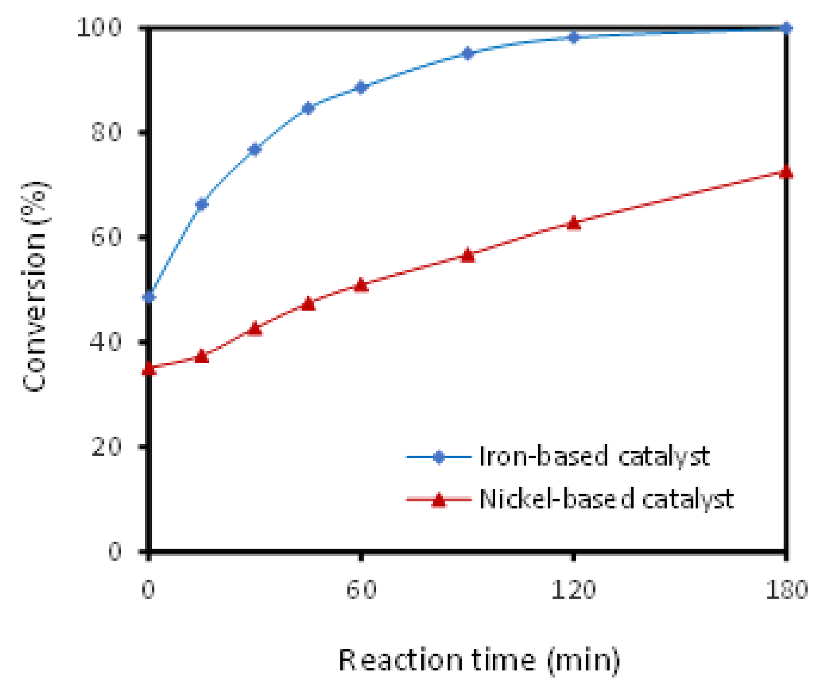

Figure 4. Ciprofloxacin conversion with iron- nickel-based catalysts by catalytic wet air oxidation