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Green solutions to reduce the carbon footprint of resource-intensive industries

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Abstract

The textile industry is crucial for many countries and their economies due to the social, economic, cultural, and environmental impact. The textile industry and its different sectors employ more the 60 million people and consume yearly close to 1 trillion kWh and 9 trillion liters of water. Water consumption in the textile industry depends on the type of fiber, the productive stage, the operation mode of the process, and the availability of the region. For example, during the processing of fibers like wool (100-300 L H_2O/kg) and cotton (80-200 L H_2O/kg) more water is consumed than during nylon processing (50-120 L H_2O/kg) or acrylic (30-80 L H_2O/kg) [1,2]. Although the staining stage consumes only a fraction of the water (20-30%) that goes into the process, the amount of used process auxiliaries makes the generated effluents to be considered as recalcitrant and, therefore, hard to treat by conventional biological processes [3]. In this work, we analyzed the impact of chemical and thermal intensification on the performance of Fenton and photo-Fenton processes during the treatment of a staining bath. The intensifying agents used were temperature (40, 50 °C) for the Fenton process and sodium oxalate ($Na_2C_2O_4$) for the photo-Fenton one. All processes were modelled in continuous mode in Simulink-MATLAB 2020 (MathWorks). The cost analysis considered the fixed and operational costs. The analysis of environmental performance of the process was done through a life cycle analysis using the openLCA (v1.9, database: ecoinvent v3.4) software and the ReCiPe-2016 v1.1 impact analysis method. It is feasible to attain a higher than 98% discoloration with the Fenton technologies; the consumption of electricity, due to the long treatment times, 12 h, leads the carbon footprint to reach a maximal of 6 (kg CO_2 Eqv./m^3 treated water). Thermal intensification reduces the reaction time, operational costs, and environmental footprints of the Fenton process in 58% (5 h), 28% (US\$1.8/m^3), and 25% (4.5 kg CO_2 Eqv./m^3 treated water), respectively. On the other hand, the use of Na_2CO_3 allows operating at a neutral pH and intensifies the Fenton reaction without affecting the efficiency of the treatment, the operational cost of the process, and the environmental footprint associated to the use of reagents. A process assisted with Na_2CO_3-solar radiation reduces the treatment time (75%, 3 h) and the environmental footprint of the process (57%, 2.6 kg CO_2Eqv./m^3 treated water). The thermal and/or chemical intensification is a key element to improve the sustainability of Fenton

processes because it impacts directly and significantly the reaction time. Transport of materials was not significant for the environmental footprint of the process (< 2%), whereas the consumption of reagents like NaOH, H_2SO_4, and H_2O_2 constitute less than 20% of the environmental footprint of the Fenton processes. The use of Na_2CO_3-solar radiation leads to a more sustainable process, but its main disadvantage is the availability or not of local solar radiation. The emission of contaminants that lead to the formation of particulate matter, acidification, eutrophication, and marine and terrestrial ecotoxicity was significantly reduced (40-70%).

Keywords: Carbon footprint, intensification, life cycle assessment, textile industry,

References

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