



# Valorisation of spent tire rubber as carbon adsorbents for Pb(II) and W(VI) in the framework of a Circular Economy

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## Abstract

Spent tire rubber-derived chars and their corresponding  $\text{H}_3\text{PO}_4$  and  $\text{CO}_2$ -activated chars were used as adsorbents in the recovery of Pb(II) ion and (W(VI)) oxyanion from synthetic solutions. The developed chars (both raw and activated) were thoroughly characterized to have insight about their textural and surface chemistry properties.  $\text{H}_3\text{PO}_4$ -activated chars presented lower surface areas than the raw chars and an acidic surface chemistry which affected the performance of these samples as they showed the lowest removals of the metallic ions. On the other hand,  $\text{CO}_2$ -activated chars presented increased surface areas and increased mineral content compared to the raw chars, having presented higher uptake capacities for both Pb(II) (103–116 mg/g) and W(VI) (27–31 mg/g) ions. Cation exchange with Ca, Mg and Zn ions was appointed as a mechanism for Pb removal, as well as surface precipitation in the form of hydrocerussite ( $\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$ ). W(VI) adsorption might have been ruled by strong electrostatic attractions between the negatively charged tungstate species and the highly positively charged carbons' surface.

The results shown in this work allow concluding that the valorisation of spent tire rubber through pyrolysis and the subsequent activation of the obtained chars is an alternative and a feasible option to generate adsorbent materials with a high uptake capacity of critical metallic elements.

**Keywords** Spent Tire Rubber · Chars · Adsorption · Lead · Tungsten

## Introduction

The management of spent tires (ST) represents a challenge worldwide. Valorpneu (the Portuguese Management Company of the Integrated System for Used Tires) reported that in 2021 around 74,000 tons of ST were generated in Portugal (Valorpneu 2022), while in the European Union that value reached 3.55 million tons in 2019 (ETRMA 2021). In Europe, the rubber of 55% of the collected ST was recycled (shredded, granulated, or powdered to children's playgrounds, sports surfaces, asphalt and concrete incorporation, among other uses), mainly through mechanical recycling (ETRMA 2021). However, the problem remains at the end-of-life (EoL) of these rubber products: how to manage the spent rubber and how to separate it from the other components of the composite materials? In 2019, of the total ST generated in Europe, 40% was sent to energetic valorisation (combustion), and 5% was classified as unknown/landfill destination (ETRMA 2021), despite the European Landfill Directive (1991/31/EC) forbids the landfilling of EoL tires

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