Waste Management 174 (2024) 568–574

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Research Paper

Lab-scale engineered hydrochar production and techno-economic scaling-up analysis

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ARTICLE INFO

Keywords:
Hydrochar
Engineered hydrochar
Adsorption
Congo red
Techno-economic analysis

ABSTRACT

Despite the extensive use of engineered hydrochar (EHC) for contaminants adsorption in water, little is known about the scaling-up of EHC production which has kept the technology at a low readiness level (TRL). Full-scale EHC production was simulated to help bridge this knowledge gap. A systematic analysis was performed where EHC was produced from rice straw using hydrothermal carbonization (HTC) at 200 °C with iron addition. A techno-economic evaluation model was employed to simulate the production process and to estimate energy requirements, configuration, and cost scenarios for the HTC process. The minimum selling price (MSP) analysis of the engineered hydrochar was found to be almost half compared to the market price for other similar sorbents ($ 76/t vs. $136/t) suggesting that EHC production is feasible for scaling up. Finally, as a trial, the resulting material was tested for its efficacy in the adsorption of an anionic organic contaminant (e.g., Congo Red, $C_{32}H_{22}N_6Na_2O_6S_2$) in water to identify its potential for water treatment. Experimental results showed that EHC adsorbed > 95% CR suggesting significant adsorption capability and feasibility for production scale-up.

1. Introduction

Among the various thermally produced carbon-based materials, hydrochar has attracted interest due to its low cost and the potential diverse range of applications as a contaminant adsorbent (Zhang et al., 2019b). However, due to its surface physical and chemical characteristics, hydrochar (HC) is considered a weak adsorbent (Fang et al., 2018; Shyam et al., 2022). To enhance its adsorption capacity, engineered hydrochar (EHC) with improved chemical and physical characteristics is preferred (Nadarajah et al., 2021; Rocha et al., 2020; Rodriguez-Narvaez et al., 2023). Although EHC production and application as an adsorbent has been reported, few studies have focused on process scaling-up and/or cost of production, which in turn has maintained EHC at a low technology readiness level (TRL) (Azzaz et al., 2020; Rodríguez-Narvaez et al., 2022; Zhang et al., 2019a; Zhang et al., 2019c). Due to the increasing interest in EHC for environmental applications, bridging the scaling-up knowledge gap has become an essential research need entailing techno-economic analysis (TEA) (Kumar et al., 2020; Mahmood et al., 2016). TEA determines process feasibility through an economic analysis of industrial processes, products, or services to estimate capital cost, operating cost, and revenue using technical and financial input parameters (Contreras-Zarazúa et al., 2021). Specialized software such as ASPEN can be employed for this purpose. As few hydrothermal carbonization (HTC) plants are currently in operation, very little is known about operational conditions/efficiency that can help in designing state-of-the-art plants (Sangaré et al., 2022). Available studies have evaluated HTC performance using HC mass and energy yield as indices. However, very few studies have investigated further HC modifications (i.e., EHC) to understand the effect on TEA and the viability of scale-up.

This study aimed to produce, characterize and test unmodified and modified HC (i.e., EHC) as an adsorbent to test organic anionic pollutant

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https://doi.org/10.1016/j.wasman.2023.12.024
Received 31 May 2023; Received in revised form 16 November 2023; Accepted 11 December 2023