BioCompWaterClean Workshop

New applications in wastewater treatment on the way to zero-waste technology

20-21 October, 2025, Novi Sad, Serbia

BOOK OF PROCEEDINGS

Science Fund of the Republic of Serbia

Title: Book of Proceedings of BioCompWaterClean Workshop “New Applications in Wastewater Treatment on the Way to Zero-Waste Technology”

Published by: University of Novi Sad, Faculty of Technology Novi Sad, Bulevar cara Lazara 1, Novi Sad, Serbia

For publisher: Prof. Dr. Zita Šereš, Dean,
University of Novi Sad, Faculty of Technology Novi Sad, Novi Sad, Serbia

Editors: Dr. Sanja Panić, Prof. Dr. Slavica Ražić

This publication is financially supported by: Science Fund of the Republic of Serbia

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

628.3/4(082)
628.16(082)

BIO Comp Water Clean Workshop "New applications in wastewater treatment on the way to zero-waste technology" (1 ; 2025 ; Novi Sad)

Book of proceedings [Elektronski izvor] / Bio Comp Water Clean Workshop "New applications in wastewater treatment on the way to zero-waste technology", 20-21st October 2025, Novi Sad ; [editors Sanja Panić, Slavica Ražić]. - Novi Sad : Faculty of Technology, 2025

Način pristupa (URL): https://biocompwaterclean.org/. - Opis zasnovan na stanju na dan 10.12.2025. - Nasl. sa naslovnog ekrana. - Bibliografija uz svaki rad.

ISBN 978-86-6253-198-8

a) Третман воде -- Иновативна решења -- Зборници b) Отпадне воде -- Третман -- Иновативна решења -- Зборници

COBISS.SR-ID 182033673

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PRISMA

WELCOME

On behalf of the Scientific and Organizing Committee, it is our great pleasure to warmly welcome you to the BioCompWaterClean Workshop, "New applications in wastewater treatment on the way to zero-waste technology".

In a world facing the greatest challenges of current and future generations, innovation in water treatment and clean water is not just a scientific and professional task—it is also a social responsibility. In this context, and in line with current global demands and the UN Sustainable Development Goals (SDGs), the BioCompWaterClean Workshop aims to add value by providing high-quality knowledge exchange that contributes particularly to SDG 4 (quality education) and SDG 6 (clean water and sanitation).

Multidisciplinary teams of researchers and experts in various fields of chemistry and technology will present at this two-day international workshop, sharing innovative methodologies and advances in processes for wastewater treatment, pollutant removal, new materials, and potential solutions for zero-waste technologies or waste material utilization and valorization. These efforts generate new resources to ensure the sustainable management of water and improve water quality.

Furthermore, the exchange of knowledge, best practices, and problem-solving ideas may drive new initiatives for further cooperation and joint projects.

Enjoy sharing your valuable time with us!

Prof. Dr. Slavica Ražić
BioCompWaterClean Project Leader

REUSABILITY OF BIOCHAR AS A CATALYST IN PERSULFATE SYSTEMS FOR ATRAZINE AND SIMAZINE DEGRADATION

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Abstract

The reusability of biochar (BC) in persulfate (PS) activation remains insufficiently explored, although it is one of the key factors for the potential practical application of this process in wastewater treatment. In this work, BC prepared at 700 °C from hardwood, corn cob, and wheat straw was tested through five consecutive degradation cycles for the triazine herbicides atrazine and simazine. In previous experiments, degradation efficiencies were monitored for up to 48 h, confirming that equilibrium was reached after 4 h. Based on this, all reusability experiments were conducted within this time frame, with degradation efficiencies determined at 0.5, 1, 2, and 4 h. After each cycle, the recovered BC was rinsed, dried, and reused under identical conditions (100 µg/L initial pesticide concentration, PS 3.0 mM, BC 0.2 g/L, pH 7.02, 180 rpm). The results revealed clear differences between the two triazine herbicides. Atrazine removal depended on the BC source: hardwood-derived BC retained >85% degradation efficiency after five cycles (4 h), while corn cob and wheat straw BC showed moderate declines. In contrast, simazine degradation remained consistently >90% across all BC and cycles, showing that simazine maintained stable degradation efficiency in this system over multiple cycles. These results suggest that both the pesticide type and the BC feedstock significantly influence the reusability of BC/PS systems, in which BC functions as a catalyst, indicating their potential in water treatment.

Introduction

Biochar (BC) is a carbon-rich material produced through the pyrolysis of various biomass sources [1]. A wide variety of organic wastes, including agricultural residues, forestry by-products, industrial sludge, and municipal solid waste, can serve as feedstocks for its production [2-3]. The use of waste biomass to produce BC not only reduces waste but also promotes resource reuse and supports sustainable environmental management [3]. Depending on the feedstock type and pyrolysis conditions, the physicochemical properties of BC, including surface area, porosity, elemental composition, and functional groups, vary significantly, directly affecting its adsorption and catalytic performance [4-6]. To enhance these characteristics, numerous modification and activation methods have been developed, including physical, chemical, and composite-based treatments [7-13]. Such modifications improve its surface reactivity, functional group density, and overall stability, making BC suitable for various environmental applications [10,13]. However, while numerous studies have addressed the modification and activation of BC, its long-term catalytic stability and reusability in advanced oxidation processes remain insufficiently explored.

BC has been successfully applied in several environmental fields, including soil remediation, pollutant adsorption, and water treatment, as well as in climate change mitigation through carbon sequestration and reduced greenhouse gas emissions [14-16]. Its effectiveness in removing both inorganic and organic contaminants mainly relies on functional surface groups such as carboxyl and hydroxyl, which enable ion exchange and surface complexation mechanisms [17]. Although BC demonstrates great potential as an adsorbent and catalyst, further research is required to fully evaluate its reusability and stability in practical applications.

This study therefore aims to evaluate the reusability of BC derived from hardwood, corn cob, and wheat straw (pyrolyzed at 700 °C) as a PS activator for the degradation of triazine herbicides, atrazine and simazine. By examining its performance over multiple degradation cycles, the work provides new insights into the long-term stability and practical potential of BC/PS systems in wastewater treatment.

Materials and methods

BC samples were produced via pyrolysis of hardwood, corn cob, and wheat straw at 700 °C and subsequently applied as catalysts in persulfate (PS) systems for the degradation of triazine herbicides (atrazine and simazine) over five consecutive reuse cycles. All experiments were performed under previously optimized conditions: PS concentration of 3.0 mM, BC dosage of 0.2 g/L and an initial pesticide concentration of 100 µg/L. The degradation experiments were carried out at pH 7.02 with a stirring rate of 180 rpm. The contact time was 4 h, and samples were collected at 0.5, 1, 2, and 4 h for analysis. After each degradation cycle, the reaction mixture was filtered through a 0.45 µm membrane, and the recovered BC was thoroughly rinsed with Milli-Q water, dried, and reused under identical conditions in the subsequent run. All experiments were carried out in duplicate.

The concentrations of atrazine and simazine were determined using gas chromatography coupled with mass spectrometry (GC-MS, Agilent Technologies 7890A Gas Chromatograph/5975C Mass Spectrometer, Santa Clara, CA, USA). The samples were prepared by liquid-liquid extraction prior to analysis. Separation was carried out on a DB-5MS capillary column (30 m × 0.25 mm × 0.25 µm; J&W Scientific, Santa Clara, CA, USA).

Results and discussion

The reusability of BC in PS systems was evaluated through five consecutive degradation cycles performed under identical experimental conditions. The obtained results for atrazine and simazine degradation are shown in Figure 1 and Figure 2, respectively. In both figures, part a) refers to hardwood BC, b) to corn cob BC, and c) to wheat straw BC. The results illustrate how degradation efficiency evolves across reuse cycles, offering insight into the long-term catalytic stability of BCs derived from different feedstocks. Comparison of the two triazine herbicides further reveals the combined influence of BC origin and pesticide type on the overall performance of the BC/PS system. All experiments were carried out in duplicate, and the data are presented as mean values with standard deviations below 5%.

As shown in Figure 1, the degradation efficiency of atrazine decreased gradually with successive reuse cycles for all BC, indicating partial deactivation of active surface sites. However, the extent of this decline varied depending on the BC type.

Hardwood-derived BC (Figure 1a) exhibited the highest catalytic stability, maintaining over 85 % degradation efficiency even after the fifth reuse cycle. This stability can be attributed to its well-developed porous structure and the presence of persistent functional groups that remain active during repeated PS activation. In contrast, corn cob BC (Figure 1b) showed a moderate reduction in efficiency after the third cycle, likely due to partial pore blockage and a gradual loss of active sites. Wheat straw BC (Figure 1c) demonstrated the most pronounced decline in catalytic performance, which can be associated with its less stable structure and the higher content of oxygen-containing surface groups that are more susceptible to oxidation and deactivation.

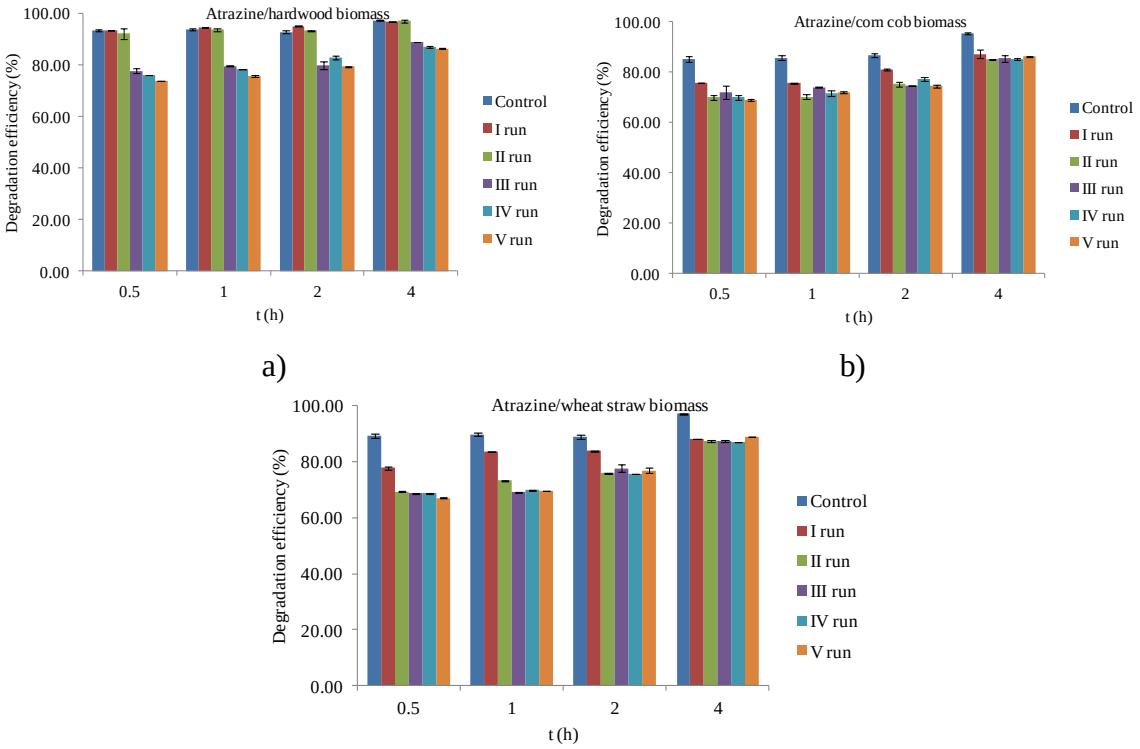

Figure 1. Degradation efficiency of atrazine (c_0=100 µg/L) over five consecutive reuse cycles: persulfate dose 3 mM; contact time: 0.5-4 h; catalyst: biochar (c=0.2 g/L), pyrolyzed at 700 °C, derived from: a) hardwood biomass, b) corn cob biomass, c) wheat straw biomass; pH 7.02

The degradation performance of simazine in the same systems is shown in Figure 2 (a-c). In contrast to atrazine, the efficiency of simazine remained highly stable across all reuse cycles for each BC type. Only negligible variations were observed between consecutive runs, confirming that no significant deactivation occurred during repeated use. Hardwood BC (Figure 2a) maintained nearly constant efficiency (> 90 %) throughout all five cycles, while corn cob (Figure 2b) and wheat straw BC (Figure 2c) also preserved similarly high and stable degradation rates. This consistent performance suggests that simazine interacts differently with the catalyst surface compared to atrazine, resulting in less fouling or blockage of active sites.

In our previous research [18], the reusability of BC produced from hardwood and wheat straw at 700 °C was investigated in PS-based systems for the degradation of organochlorine pesticides, lindane and β-endosulfan. The results revealed that the removal efficiency of lindane decreased markedly with successive cycles, particularly when wheat straw BC was used, whereas β-endosulfan exhibited much higher stability, with only a slight decline after multiple reuses. These findings, together with the present results for atrazine and simazine, demonstrate that the long-term catalytic performance of BC in PS oxidation systems is governed by the interplay between the physicochemical properties of the catalyst and the molecular characteristics of the pesticides. Differences in molecular structure, polarity, and reactivity among pesticides determine the extent of surface fouling and deactivation of active sites, thereby controlling the overall stability and reusability of BC during repeated catalytic use.

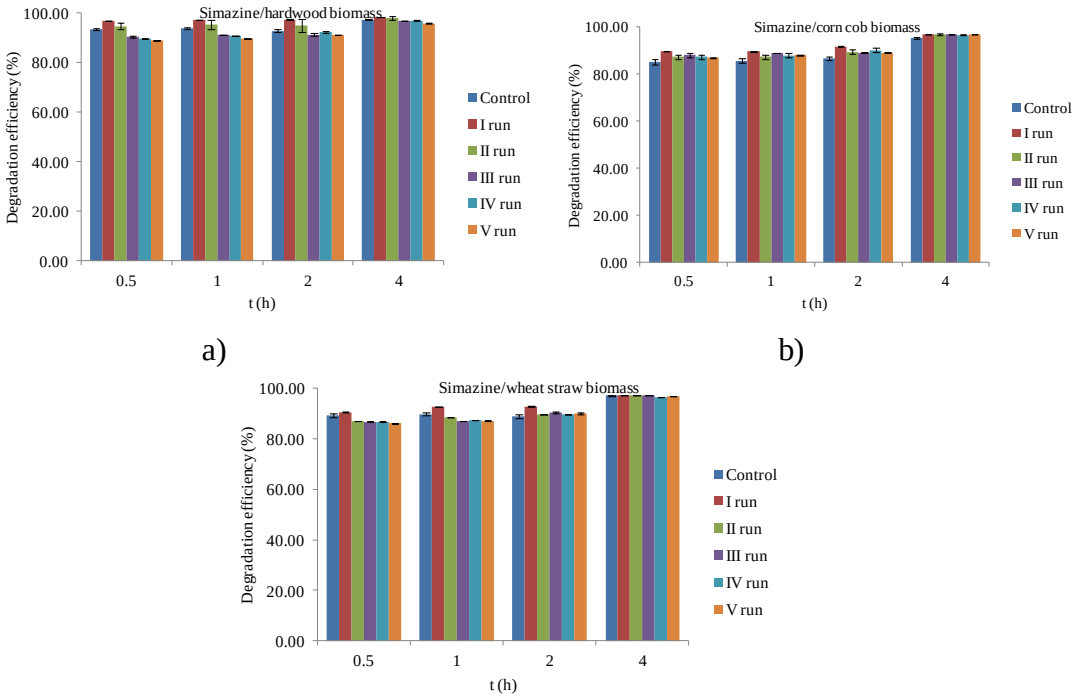

Figure 2. Degradation efficiency of simazine (c_0=100 μg/L) over five consecutive reuse cycles: persulfate dose 3 mM; contact time: 0.5-4 h; catalyst: biochar (c=0.2 g/L), pyrolyzed at 700 °C, derived from: a) hardwood biomass, b) corn cob biomass, c) wheat straw biomass; pH 7.02

Conclusion

The results of this study confirm that BC can be effectively reused over multiple pesticide degradation cycles while maintaining high catalytic activity. The stability and performance of BC were found to strongly depend on the feedstock origin and its structural features, with hardwood-derived BC exhibiting the most consistent catalytic behavior. The nature of the pesticide also influenced the preservation of activity during repeated use, as differences were observed between atrazine and simazine, with the latter showing more stable degradation throughout all cycles.

These findings highlight the strong potential of BC as a sustainable and reusable catalyst in PS-based advanced oxidation processes for water treatment. Future studies should focus on optimizing regeneration strategies and enhancing the long-term durability of the catalyst.

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Acknowledgment: *This research was supported by the Science Fund of the Republic of Serbia, #10810, Sustainable solutions in environmental chemistry: exploring biochar potential-EnviroChar*