15° ENCONTRO BRASILEIRO SOBRE ADSORÇÃO
15th Brazilian Meeting about Adsorption

Construction and demolition waste (C&D Waste), reused to Atrazine adsorption with final destination on soil.

Julia M. G. Borges[1], Giovanna K. C. de O.a Lira[1], Leonardo T. de Almeida[1], Eduardo J. S. Fonseca[2], Leonardo M. T. M. Oliveira[2]

Abstract

Construction and demolition waste (C&D Waste), often discarded as environmental pollutants, was used as an adsorbent for Atrazine, one of the most widely used herbicides, especially prominent in Alagoas due to its extensive sugarcane cultivation. This study explores the feasibility of producing a hydrochar from C&D W and coconut fiber (RCD-HC) as an adsorbent for Atrazine, aiming to remove this toxic herbicide from the environment. The CDW-HC composite repurposes materials that would otherwise be discarded, providing a sustainable solution. Batch tests with varying mass, concentration, and time were conducted, along with an assessment about the adsorbents regenerations, fixed-bed column tests and studies regarding the degree of toxicity from the disposal of the material in soil samples by evaluating the growth of tomato seeds in contact with the composites. It was observed that the addition of RCD-HC improved seed growth, with the soil showing 100% germination compared to 85% in the control sample. Overall, the RCD-HC composite demonstrated high efficiency, removing up to 70% of Atrazine in column tests.

Keywords: Pesticide removal; Environmental remediation; Fixed bed; Soil conditioning.

1. Introduction

Construction and demolition waste (C&D Waste), composed of materials such as metals, concrete, wood, and plastics, has significantly increased in Brazil, from 33.4 million tons in 2010 to 44.5 million tons in 2019[1][2]. Direct disposal in landfills is inefficient, leading to environmental challenges and loss of valuable land. Exploring the use of C&D Waste in physical adsorption highlights its cost-effectiveness, simplicity in manufacturing, and large surface area, making it a promising alternative[3].

Atrazine, a herbicide widely used in crops like corn, sorghum, and sugarcane, remains prevalent globally, with 70,000 to 90,000 tons applied annually. However, over 70% of atrazine is not absorbed by plants, leading to contamination of soil and water, where it poses risks as a category C carcinogen and endocrine disruptor[4][5][6]. Coconut husk, readily available in Brazil, offers a stable and porous structure, making it an effective biosorbent for addressing wastewater contamination.

This study aims to promote environmental remediation by synthesizing a composite of C&D Waste with coconut husk (CDW-HC) and comparing its adsorption performance to that of washed C&D Waste. Additionally, the study assesses the toxicity of these materials in soil, evaluating their potential for broader environmental applications.

2. Methodology

2.1. Material Preparation

The material used in the adsorption tests, called washed CDW, was washed with distilled water under agitation at 200 rpm for 2 hours. Then, the material was filtered and washed again under a continuous flow of distilled water, followed by being dried at 105°C for 2 hours.

The composite was produced by hydrothermal synthesis, following the method of Jung, Lee, and Lee[8]. The coconut fiber was shredded and mixed with the washed C&D Waste in a 1:1 ratio, soaked in 70 mL of distilled water, and agitated for 30 minutes. The mixture was then placed in a teflon-lined autoclave reactor and subjected to

180°C in an oven for 24 hours, followed by washing, activation at 300°C, and drying.

2.2. Fixed-Bed Adsorption

The column adsorption methodology followed the model of Olivares et al., with adaptations. The column was filled with 5cm of adsorbent material and topped off with glass microspheres. Atrazine solutions were pumped through an upward flow at 22,5 mL/min at 40 ppm through the column and collected in a final beaker after treatment. Aliquots of the treated solutions were taken at intervals to plot the breakthrough curve, and a final sample was collected to measure the removal percentage.

Additionally, a fixed-bed test with recirculation of the atrazine solution was performed, using a single beaker for the initial and treated solution, repeating the cycle for several hours.

2.3. Toxicity Feasibility

The toxicity test was conducted to evaluate the feasibility of CDW disposal and its effect on real soils, considering its potential as a soil conditioner. Degraded soil from the Mata region of Alagoas and seeds of cherry tomato (Solanum lycopersicum) were used. Soil mixtures were prepared with 96% soil and 4% of each selected material: washed CDW, CDW-HC (composite with coconut fiber), and commercial charcoal. The experiment, carried out in quadruplicate, took place in an incubation room at 18°C for 15 days. The plants were watered daily with 2 mL of distilled water. At the end of the test, root length, shoot length, number of leaves, and germination rate of the plants were measured.

For the soil, moisture content, pH, organic matter, and apparent density were evaluated according to methodologies described by the Brazilian Agricultural Corporation (Embrapa, 2017) [9].

3. Results

3.1. Material Preparation

The yield of the composite synthesis was about 40%, mainly influenced by two factors: washing with hot water, which removes volatile organics from the composite, and significant thermal degradation of the coconut fiber during activation.

3.2. Fixed-Bed Adsorption

Four column tests were conducted using washed CDW as the adsorbent. The first test is shown in Figure 1(a).

Figure 1. Fixed-bed tests with washed CDW (a) and (b)

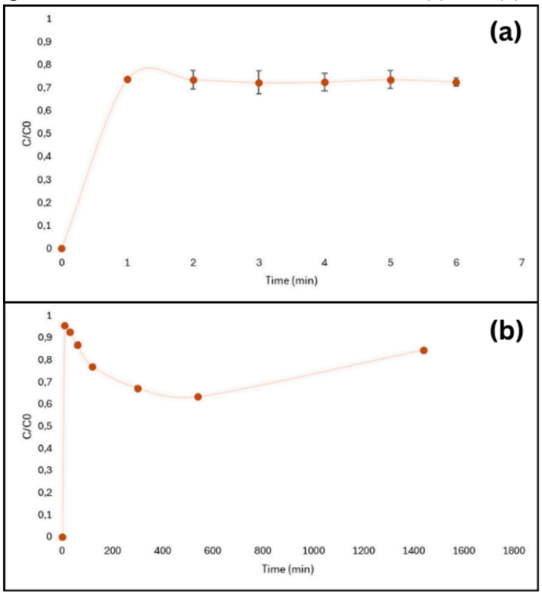
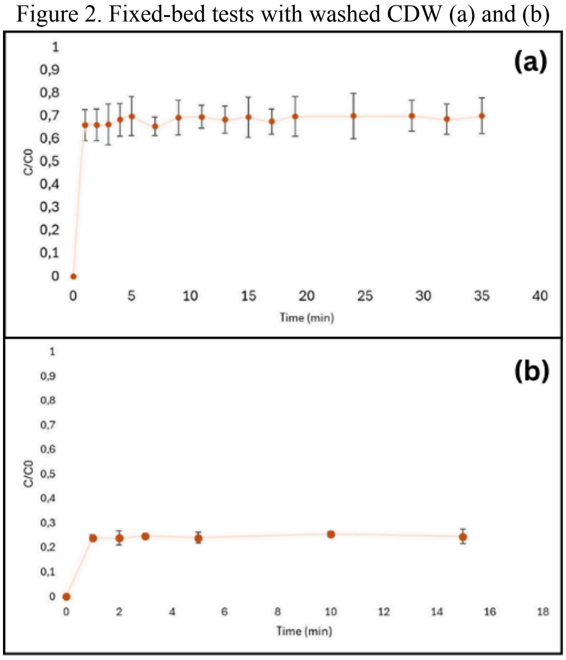


Figure 2. Fixed-bed tests with washed CDW (a) and (b)



The C/C0 ratio of the collected aliquots ranged from 0.72 to 0.79, with saturation occurring after 2 minutes, indicating high practical efficiency. The next test was conducted with a recirculation system. The breakthrough curve is shown in Figure 1(b). After 24 hours, the C/C0 value was 0.84, with a final removal of 15.60%. The subsequent test used 800 mL of solution without recirculation and under the same concentration; the breakthrough curve is in Figure 2(a). A rapid breakthrough was observed, with the adsorbent not saturating after 35 minutes. The increase in final removal performance was not proportional to the difference in volume between this test and the previous one. The following test varied the concentration to 100 ppm. The breakthrough curve is in Figure 2(b). The C/C0 values ranged from 0.23 to 0.24, achieving a final removal of 74.45%.

Figure 3. Fixed-bed tests with CDW-HC (a) and (b)

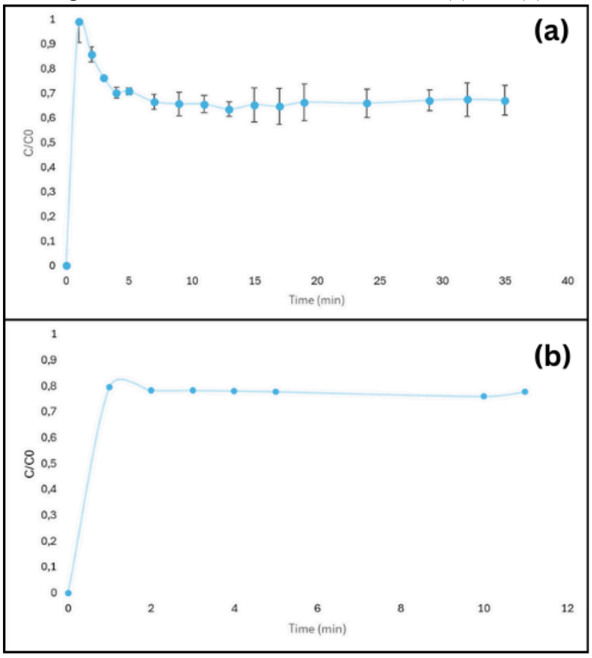
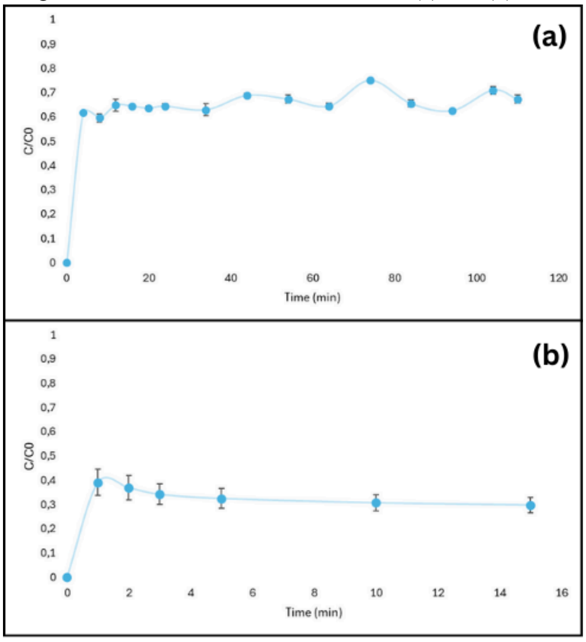


Figure 4. Fixed-bed tests with CDW-HC (a) and (b).



The first test, with the breakthrough curve shown in Figure 3(a), was analogous to the washed CDW but with slightly better performance; the final treatment was 28.40%. Following this, two experiments were conducted with different flow rates while keeping the concentration constant. The first flow rate was 45 mL/min. Its breakthrough curve is shown in Figure 3(b). Breakthrough occurred rapidly, with a removal fraction of 0.79 in the first minute. The final treatment was 38.63%. The next test was conducted with a flow rate of 12 mL/min, lasting 1 hour and 50 minutes. The breakthrough curve is shown in Figure 4(a). The C/C0 fraction varied in the final minutes, indicating saturation; the final treatment was 43.15%; a longer residence time of the pollutant in the column allows for more extensive treatment, but the effect is small. The last test contained 300 mL of solution at 100 ppm and a flow rate of 22.5 mL/min. The breakthrough curve is shown in Figure 4(b). Immediate breakthrough was observed, with a residual fraction of 0.39 in the first minute and a peak removal of 0.29 at 15 minutes. The treated solution showed a 68.98% reduction in the pollutant.

3.1. Toxicity Test

As an alternative for disposal and final disposition of materials, a toxicity study was conducted on soil to observe the effects of possible disposal and how it would affect the flora. The study was carried out in a seed laboratory using tomato seeds in soils containing 4% of the produced charcoal used in the adsorption tests. Knowing that atrazine is harmful to flora, regeneration of the charcoal was performed through high temperatures, thus eliminating all the pollutant.

In the tests conducted, the average germination rate of plants in soil with the charcoal was 100%, higher than in pure soil, which was 85%, as well as the average number of leaves in soils with composites, which was 4, higher than the average number of leaves in the control soil, which was 3.5. The average total plant size (sum of root and stem size) was also greater in soils with composites. Tests for pH, organic matter percentage, and soil moisture were also performed after the test. The pH study indicated that the control sample had a value of 5.57; the values for raw CDW, washed CDW, and CDW-HC ranged between 7.11 and 7.18, and commercial charcoal was 6.08; it is noted that the composites maintain the soil pH near neutral, which has a positive impact on the soil.

In moisture and organic matter tests, other results were also favorable for soils containing the composite. The apparent density test showed that the change in soil density was practically null. This result is positive as density is not a limiting factor for the soil's utility.

4. Conclusion

As observed, both washed CDW and CDW-HC represent promising options for atrazine removal in water bodies, especially with high concentrations. The evaluation of composites as soil fertilizers was especially promising for hydrochar, which exhibited a range of results comparable to or even exceeding the commercial charcoal used in the tests. Thus, it provides a material capable of reducing the pollutant mass of local waste, offering effective treatment of a concerning agricultural pollutant, and potentially being applied, upon disposal, as a booster for planting a widely consumed crop.

5. Acknowledgments

The authors thank Braskem S.A., the project funder, and the Federal University of Alagoas for structural support.

References

[1] United States Environmental Protection Agency: Construction and Demolition Debris: Material-Specific Data. Available at: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/construction-and-demolition-debris-material. Accessed on December 21, 2023.

[2] Brazilian Association for Recycling of Construction and Demolition Waste: Sectorial Research 2017/2018. Available at: https://abrecon.org.br/documentos-e-informa/pesquisa-setorial-2017-2018. Accessed on December 21, 2023.

[3] Pallewatta, S.; Weerasooriyagedara, M.; Bordoloi, S.; Sarmah, A.; Vithanage, M. Reprocessed construction and demolition waste as an adsorbent: An appraisal. Science of The Total Environment, v. 882, 2023.

[4] Contreras, M.; Camacho, J.; Fernández-Morales, F.; Cañizares, P.; Rodrigo, M. Biodegradability improvement and toxicity reduction of soil washing effluents polluted with atrazine by means of electrochemical pre-treatment: Influence of the anode material. Journal of Environmental Management, v. 255, 2020.

[5] Liu, Z.; Han, L.; Zhang, X.; Chen, S.; Wang, X.; Fang, H. Core bacteria carrying the genes associated with the degradation of atrazine in different soils. Environment International, v. 181, 2023.

[6] Singh, S.; Narasimhappa, P.; Uppara, B.; Behera, S.; Varshney, R.; Naik, T.; Khan, N.; Singh, J.; Ramamurthy, R. Bio-engineered sensing of Atrazine by green CdS quantum dots: Evidence from electrochemical studies and DFT simulations. Chemosphere, v. 345, 2023.

[7] Nascimento, P.; Neto, E.; Bezerra, D.; Silva, A. Anionic Surfactant Impregnation in Solid Waste for Cu2+ Adsorption: Study of Kinetics, Equilibrium Isotherms, and Thermodynamic Parameters. Journal of Surfactants and Detergents, v. 23, p. 781-795, 2020.

[8] Jung, H.; Lee, S.; Lee, J. Synthesis and characterization of hydrothermal composites. Journal of Composite Materials, v. 52, n. 10, p. 1234-1245, 2018.

[9] Teixeira, H.; Donzelli, J.; Silva, M. Soil Analysis Methods. 2017. Brazilian Agricultural Research Corporatio