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Effect of Synthesis Parameters on Tire Waste-Derived Carbon Adsorbents for Arsenic Removal from Aqueous Solution

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1. ABSTRACT

In recent years, the concentration of toxic and hazardous elements in water, especially arsenic ions, has increased. This study investigates the appropriate conditions for dry carbonization for arsenic removal using waste automobile tires by examining the parameters of temperature, residence time, and pressure for arsenic ion removal from water.The experiment involved residence times of 0.5, 1, 2, and 4 hours, temperatures of 400, 550, 700, and 850 °C, pressures of -0.6, -0.3, 1, 5, and 10 bar. The optimum conditions for arsenic ion removal were found to be 700°C, 3mm particle size, 2hr residence time, and -0.3 bar pressure. Finally, the study of arsenic adsorption using char prepared under optimal conditions showed that the involved adsorption process is chemical in nature.

Keywords: Rubber Tire, Functionalized Carbon Nanostructured Materials, Arsenic, Dry Carbonization, Char.

2. INTRODUCTION

As the global population increases, demands for agriculture and industry have led to the dissolution of arsenic into groundwater [1]. Among the methods for removing these materials, adsorption is considered the most effective physicochemical method for heavy metal removal due to its simplicity of operation, cost-effectiveness, and regenerative nature of the adsorbents [2].

The operational conditions of char preparation from waste tires have a significant impact on its properties. This paper focuses on investigating the effects of residence time, temperature, pressure, and particle size on char properties.Temperature is the main variable affecting the dry pyrolysis process of waste tires. This parameter determines the amount of input energy and affects the extent of molecular bond breakage. Particle size is also an important factor influencing the yield and properties of dry pyrolysis products of waste tires.To ensure complete dry pyrolysis of waste tires and complete removal of volatiles, the residence time of the tire in the pyrolysis reactor should be increased as much as possible. However, with a long residence time, the yield of the obtained tire char will be lower than that with a short residence time. And if the residence time is too short, no matter how high the dry pyrolysis temperature is, the waste tire cannot be completely decomposed.The pressure involved in the dry pyrolysis process plays a role in the product yield, quality, and affects the movement of volatiles. In other words, pressure changes not only affect the char yield but also the specific surface area and pore size distribution of tire char.

3. MATERIALS AND METHODS

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The materials used in this study include rubber waste, rhodamine B (C□□H□□ClN□O□) with 99% purity from Merck, Germany, arsenic trioxide (As□O□) is German Merck brand and nitrogen gas (N_2).

3.1 Effect of carbonization parameters

In this study, a dry carbonization furnace was used to produce char from rubber waste. Three parameters that have the most significant impact on the structural and adsorptive properties of the resulting char—residence time, process temperature, pressure, and particle size—were investigated as the effective parameters in the dry carbonization process. For the carbonization process, crushed samples with an average size of 3 millimeters from the sidewall of waste vehicle tires were used. The char produced at each stage was exposed to a solution with a specific volume and concentration of arsenic ions. After the appropriate time for determining the remaining arsenic concentration in the solution had passed, a specific reagent was used to measure the arsenic concentration at a specific wavelength.

3.2 Adsorption study

Through adsorption kinetics modeling, it is possible to estimate the amount of adsorbed ions and the type of adsorption over time, which can be used in the design of larger systems. To study the kinetics of arsenic ion adsorption, the pseudo-first-order and pseudo-second-order models were used.

4. RESULTS AND DISCUSSION

4.1 Effect of Carbonization Parameters

Figure 1 shows the results of investigating the effect of residence time, temperature and pressure on arsenic ion absorption in the dry carbonization process.The study investigates the effects of various parameters on the dry carbonization process of rubber waste for arsenic adsorption from aqueous solutions. Results indicate that a residence time of 2 hours yields optimal adsorption capacity with a higher mass yield compared to longer times. Increasing the carbonization temperature up to 700°C enhances adsorption capacity, but higher temperatures reduce reactivity and surface area due to pore collapse and structural changes. Pressure also plays a significant role; at -0.3 bar, the carbonized char achieves the highest adsorption capacity by preventing volatile material deposition and enhancing the char's porous structure. Thus, -0.3 bar pressure, 3 mm particle size, 2-hour residence time, and 700°C temperature are deemed optimal for arsenic removal.

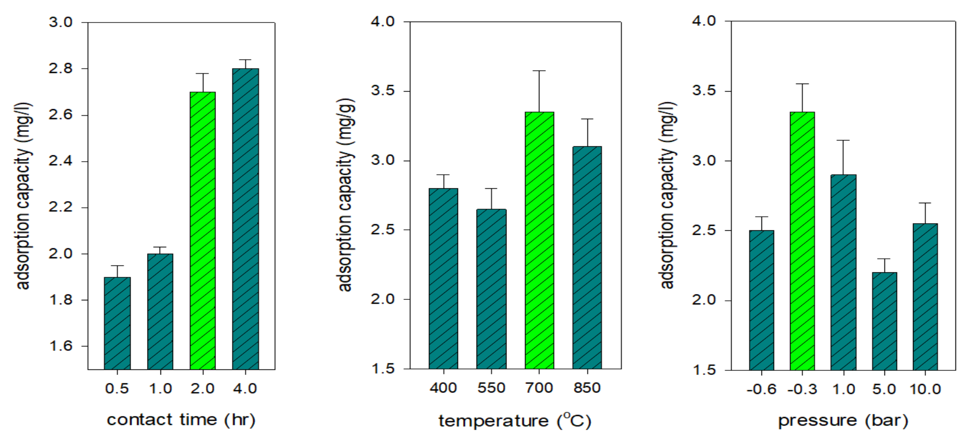

Fig1. results of investigating the effect of residence time, temperature and pressure on arsenic ion absorption in the dry carbonization process

4.2 Adsorption study

Table 1 shows the results of the kinetic study of arsenic ion adsorption from water using linear pseudo-first-order and pseudo-second-order models. It was observed that for the synthesized char, the coefficient of determination R^2 for the pseudo-second-order model is higher, indicating a better fit with this model. Therefore, it can be concluded that the adsorption is of a chemical nature, and the rate-limiting step of the process involves chemical adsorption or a chemical reaction between the adsorbent surface and the adsorbate.

Table 1. The data obtained from the investigation of the first and second order pseudo model

	R^2	$K(\frac{L}{mg})$	$q_e(\frac{mg}{g})$
Pseudo-first-order model	0.9895	0.3785	1.472
Pseudo second order model	0.9999	0.684	3.349

5. CONCLUSION

This study demonstrates that optimizing the dry carbonization process of rubber waste can significantly enhance arsenic ion adsorption from aqueous solutions. The optimal conditions identified include a residence time of 2 hours, a temperature of 700°C, a pressure of -0.3 bar. These parameters result in the highest adsorption capacity. Additionally, kinetic modeling using the pseudo-second-order model showed a better fit, indicating that the adsorption process is primarily chemical, involving a chemical reaction between the adsorbent surface and the arsenic ions. These findings can guide the design of more effective systems for arsenic removal using carbonized rubber waste.

6. REFERENCES

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