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Investigations of sorption capacity of biochars obtained from organic waste materials

Magdalena Zięzio*[1], Barbara Charmas [1], Karolina Kucio [1]

[1] *Department of Chromatography, Faculty of Chemistry, Maria Curie-Sklodowska University, Maria Curie-Sklodowska Sq. 3, 20-031 Lublin, Poland*

**corresponding author: magdalena.ziezio@ poczta.umcs.lublin.pl*

Introduction

The discharge of wastewater containing dyes into the environment, and in particular into aquatic ecosystems, is becoming a serious problem due to their toxicity. These dyes come commonly from industries such as the textile industry, dye manufacturing, dyeing and printing. These compounds can consume oxygen dissolved in water necessary for life of aquatic organisms. Moreover, some of them are toxic and even carcinogenic. Dye contamination problems can be reduced or minimized through physical, chemical and biological processes, such as microbial degradation, chemical oxidation, coagulation or filtration. However, these processes have their drawbacks and limitations such as high cost, generation of secondary contaminants, and poor removal efficiency. Thus, it was adsorption that was proved to be the most effective and economical alternative with a high ability to remove and recover dyes from wastewater. One of the most commonly used adsorbents for this purpose are activated carbons or biochars produced from various types of organic waste materials.

Aim

The main aim of the research was to investigate the sorption capacity of the biochars obtained from waste coffee grounds impregnated with phosphoric acid(V) at different impregnation ratios.

Methods

As a precursor for obtaining biochars spent coffee grounds were used. Before the pyrolysis the initial material was impregnated with phosphoric acid at the impregnation ratios: 0.5, 1.5, 2. The heating (10°C/min with 1-hour isothermal stage at 400°C) and cooling stages were conducted in the nitrogen atmosphere (150 ml/min). In the annealing stage at 800°C (3h), CO_2 was introduced as an additional oxidizing agent. In the adsorption studies, methylene blue (MB) was used as a model pollutant. Adsorption kinetics was carried out at 30°C for the MB concentrations of 60 mg/L (sample: AC-0.5) and 70 mg/L (samples: AC-1.5 and AC-2). A series of dye solutions with the concentrations ranging from 30 to 100 mg/L was prepared to obtain the adsorption isotherms. The studies were carried out at the temperature of 30°C at 130 rpm. After the adsorption process, the studied dye solutions were measured spectrophotometrically at a wavelength of 664 nm.

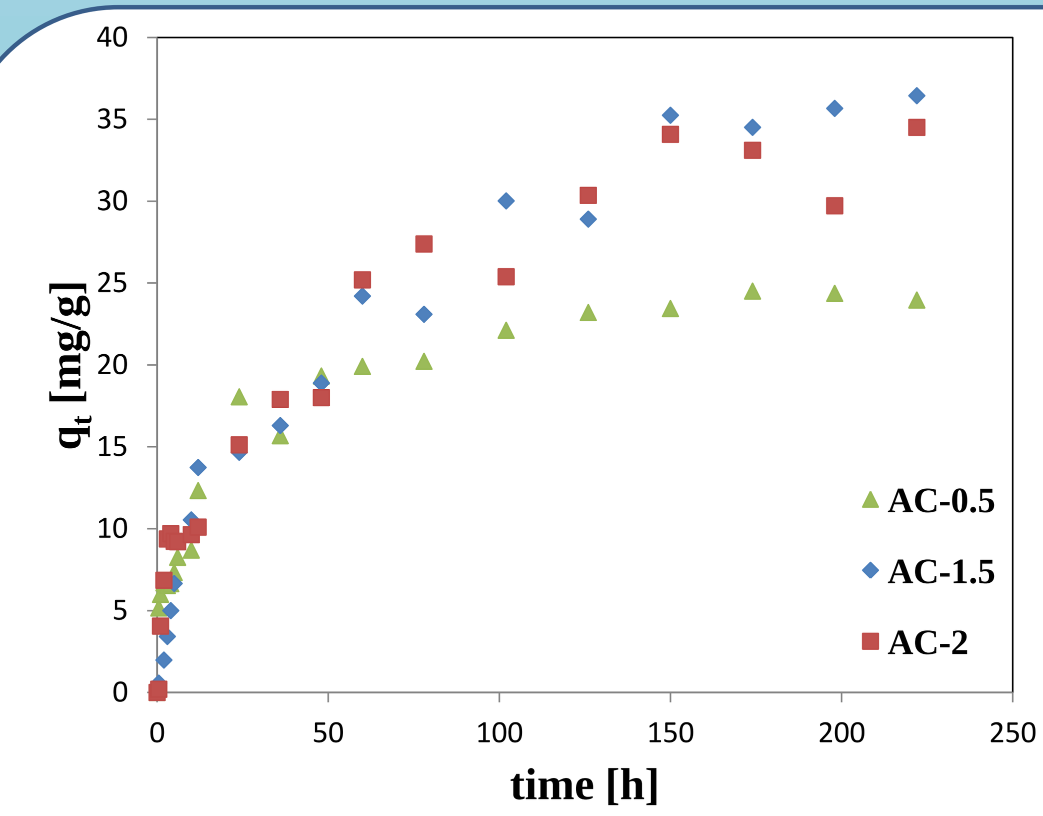

Fig. 1. Adsorption kinetics of MB on the studied adsorbents.

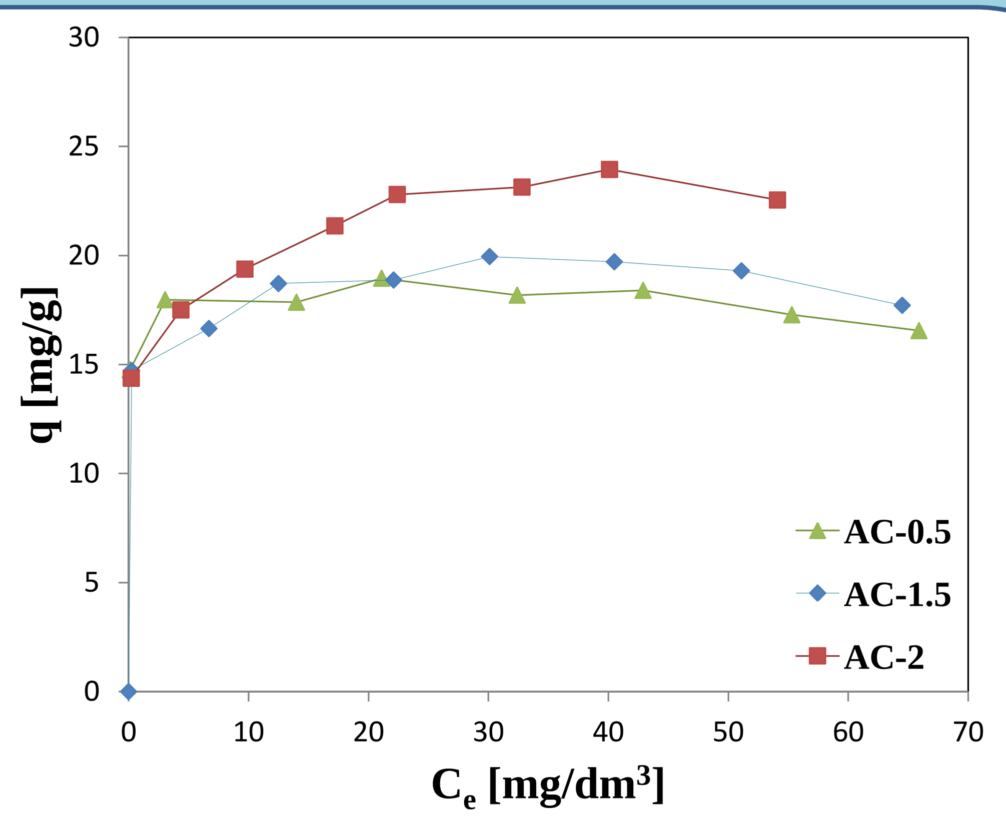

Fig 2. Adsorption isotherms of MB on the studied adsorbents.

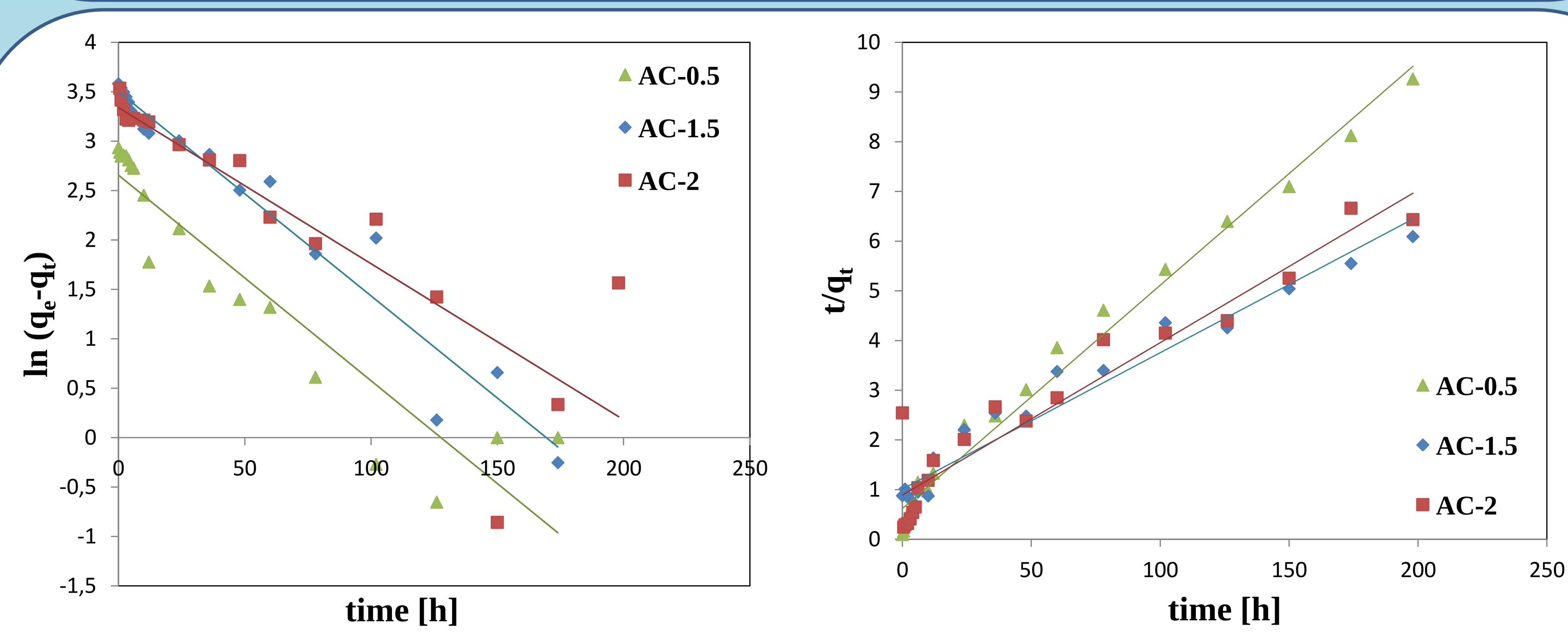

Fig. 3. Pseudo-first order (a) and pseudo-second order (b) plots of methylene blue adsorption on the studied biochars.

Results

Table 1. Parameters of the porous structure of the obtained biochars

Sample	S_{BET} [m^2/g]	V_p [cm^3/g]	R_{av} [nm]
AC-0.5	407.8	0.188	0.92
AC-1.5	614.8	0.283	0.92
AC-2	720.9	0.334	0.93

S_{BET} – the specific surface area, V_p – the total pore volume, R_{av} – the average pore radius

Table 2. Kinetic parameters of methylene blue adsorption onto the biochars.

Sample	T [°C]	Pseudo-first order		Pseudo-second order	
		k_1 [h^{-1}]	R^2	k_2 [g mg^{-1}h^{-1}]	R^2
AC-0.5	30	0.0208	0.8738	3,3*10^{-3}	0.9866
AC-1.5		0.0207	0.9498	7,4*10^{-4}	0.9571
AC-2		0.0182	0.7589	1,1*10^{-3}	0.918

k_1, k_2 – the reaction rate constants

Table 3. Langmuir and Freundlich parameters of the adsorption isotherms of methylene blue onto biochars.

Sample	T [°C]	q_e [mg/g]	Langmuir			Freundlich		
			q_m [mg/g]	K_L [L/mg]	R^2	n	K_F [mg/g]	R^2
AC-0.5	30	18.95	16.89	0.912	0.9958	39.37	16.36	0.444
AC-1.5		19.95	18.45	1.882	0.9936	20.12	15.87	0.7531
AC-2		23.94	23.53	0.957	0.9968	10.47	16.17	0.9416

q_e – the adsorption value after the equilibrium stabilization, q_m – the maximum adsorption capacity, K_L – the Langmuir adsorption equilibrium constant, K_F ,n – the Freundlich isotherm constants (describing relative intensity and adsorption ability, respectively)

Conclusions

-all studied materials are characterized by good sorption capacity, however, the sorption capacity increases with the increasing impregnation ratio. The AC-2 sample has the highest sorption capacity (q_e , q_m = ~24 mg/g);

-the study of the adsorption process speed allowed to determine the equilibrium time of the adsorption process which was about 48 hours for tested biochars;

-the adsorption process for all studied adsorbents is described by a pseudo-second order equation;

- the adsorption of methylene blue follows the Langmuir isotherm model which indicates a monolayer coverage of the adsorbent surfaces with dye particles.