Obtaining granular activated carbon using a binder gelatin in the joint processing of rice and oil waste

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Received: October 27, 2021; Accepted: November 12, 2021

In this article, the effect of gelatin as a binder to obtain granular activated carbon by joint processing of rice waste (husk and straw) and oil sludge was studied. Carbonation and activation of the granules were carried out in a high-temperature vacuum tube furnace of the BR-12 NFT series with a length of 200 mm, in a heating tube made of quartz glass with a length of 300 mm and a diameter of 60 mm. Carbonation was carried out at a temperature of 500°C, activation-by water vapor at a temperature of 850°C, at a ratio of water and carbonizate 2:1. The effect of the ratio of gelatin binder, rice waste and oil sludge on the properties of the activated carbon was studied. The optimal ratio of the joint processing of the mixture is rice husk: oil sludge: gelatin = 9:1:2 (by weight). The studies were carried out according to the following indicators: adsorption activity for iodine, total pore volume for water, mass fraction of moisture, adsorption activity for methylene blue, and bulk density. Granulated activated carbon corresponds to the BAU-MF brand.

Keywords: activated carbon, rice husk, rice straw, oil sludge, gelatin, granules.

INTRODUCTION

The adsorption process is widely used as an effective physical method to eliminate or reduce the concentration of dissolved pollutants (organic and inorganic) in wastewater. Adsorption is recognized as a more advanced method compared to other methods due to its simplicity, cost-effectiveness and wide application. Granular activated carbon, powdered activated carbon, carbon fiber, black coal, and other activated carbon materials are widely used as adsorbents in water treatment [1, 2].

Activated carbon is the best adsorbent that is effectively used to remove a wide range of pollutants from air, soil, and liquids [3, 4]. The resource base of activated carbon is diverse - from plant residues to brown carbon and carbon. Activated carbon is obtained from chestnut peels, watermelon peels, rice peels, mango seeds, banana peels, orange peels, bean peels, nut shells, and agricultural waste [5, 6]. These agricultural waste products are relatively cheap, affordable, biodegradable, environmentally friendly, and contain lignocellulosic material that can improve the adsorption properties of activated carbon.

The characteristics of activated carbon depend on the physical and chemical properties of the raw material, as well as on the activation methods [7, 8]. For the production of activated carbon, in most cases, two approaches are chosen. The first is grinding of the initial lignite, followed by carbonation and activation. By the second method, after the process of carbonization, granulation, and grinding of raw materials, an activation process is carried out.

Granulation is an effective method of recycling waste from carbon-containing chemical industries [9, 10]. The use of this processing method in theory allows you to obtain activated carbon of high strength and density. In addition, some sources use the co-thermolysis process to produce activated carbon.

Co-thermolysis is a process in which two or more raw materials are processed in one operating system of conventional thermolysis [11, 12]. Thus, it can effectively combine the favorable properties of the raw materials and improve the characteristics of activated carbon [13, 14]. In our research works, the optimal ratios for obtaining activated carbon by carrying out the processes of co-thermolization of rice straw and oil sludge, oil sludge with rice husk have been determined [15-17].

The purpose of this experimental research work is to determine the optimal ratio for obtaining granular activated carbon by adding a binder gelatin in oil sludge with rice waste to increase the sorption and mechanical strength of activated carbon.

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EXPERIMENTAL

Rice waste was ground in a laboratory mill to a size of 0.25 mm. The granules were obtained by adding a binder to crushed rice waste (husk and straw) and oil sludge in the proportions indicated in Table 1. Carbonization was carried out in nitrogen atmosphere at a temperature of 500°C, and activation in a high-temperature vacuum tube furnace of the BR-12 NFT series with water vapor at a temperature of 850°C.

To determine the mass fraction of moisture, 1 g of granular activated carbon was weighed and was placed in a pre-weighed bottle. The latter was placed with an open lid in an oven for 1 h at a temperature of 105-110°C. After the specified time had elapsed, the weighing bottle was removed from the drying cabinet and cooled in a desiccator for 15 minutes. Then the mass of the dried granular activated carbon was measured and calculations were made [18].

To determine the adsorption activity for iodine, a solution of iodine in potassium iodide at a concentration of 0.1 mol/dm^3 was added to the suspended part of the granular activated carbon and shaken in a shaking unit for 15 min at an intensity of 100-125 vibrations/min. Then the mixture was titrated with 0.1 mol/dm^3 sodium thiosulfate solution until the blue color disappeared using starch as an indicator [19].

To determine the total pore volume with respect to water, the pores were studied in the range of 0.5-104 nm by boiling in water for 15 minutes and weighing on an analytical balance after the excess amount of water was separated by a pump under a pressure of 8 kPa. Determination of the bulk density of the granular activated carbon was carried out by standardizing and measuring the mass of activated carbon of a certain volume [20, 21].

RESULTS AND DISCUSSION

From rice waste (husk and straw) and oil sludge, granules were obtained by adding a gelatin binder. The resulting granules were placed in a tubular furnace which was hermetically closed, filled with gaseous nitrogen, and the carbonization process was carried out at a rate of temperature rise of 10 °C per minute to 500 °C and kept at this temperature for 100 min. The activation was carried out at a temperature of 850 ° C. The effect of the ratio of the binder on the yield and physicochemical properties of granular activated carbon was investigated.

Table 1. Properties of granular activated carbon obtained with the addition of gelatin as a binder in the processing of rice straw and oil sludge

Indicator name	Results of experimental studies							
	Rice straw: gelatin	Rice straw: oil sludge: gelatin			Rice husk: gelatin	Rice husk: oil sludge: gelatin		
Ratio (by weight)	10:1	9:1:1.1	9:1:1.25	9:1:2	10:1	9:1:1.1	9:1:1.25	9:1:2
Carbonation temperature, °C	500							
Carbonization yield, wt. %	78.86	71.28	70.56	80.53	70.3	76.28	69.8	62.86
Activation temperature, °C	850							
Water:carbonization (mass ratio)	2:1							
Activated carbon yield, wt. %	25.06	30.07	26.07	27.41	35.9	34.23	33.8	37.08
Iodine absorption activity,%	32.8	51.5	59.9	71.2	72.24	87.63	88.45	89.72
Water total pore volume, cm^3/g	0.94	0.99	0.99	0.91	0.50	0.42	0.49	0.56
Mass fraction of moisture, %	0.70	1.09	0.50	2.30	2.65	1.99	2.18	2.21
Bulk density, g/dm^3	241.36	232.73	201.12	201.52	463.19	458.45	459.06	433.99
Adsorption activity of methylene blue, mg/g	372.29	370.12	378.78	380.74	335.82	341.56	345.51	356.01

Table 1 shows the data of granulated activated carbon obtained by adding rice waste, oil sludge and gelatin in a ratio of 10:1, 9:1:1.1, 9:1:1.25, and 9:1:2. Granulated activated carbon from rice husk: oil sludge: gelatin in a ratio of 9: 1:2 showed the highest values for the following indicators: adsorption activity for iodine – 89.72%, total pore volume for water-0.56 cm^3/g, bulk density-433.99 g/dm^3 and adsorption activity for methylene blue-356.01 mg/g.

According to the results of the research, it was found that the optimal ratio for the production of granular activated carbon is the ratio of rice husk: oil sludge: gelatin = 9:1:2. At the optimal ratio, granulated activated carbon corresponds to the BAU – MF brand. Figure 1 shows the granulated activated carbon obtained at the ratio of 9:1:2 rice husk: oil sludge: gelatin.

Figure 1. Granulated activated carbon obtained from rice husk, oil sludge and gelatin at a ratio of 9: 1: 2.

CONCLUSIONS

In conclusion, granular activated carbon was obtained with the addition of gelatin at various ratios to rice and oil waste. The physicochemical properties of the granular activated carbons were investigated and their optimal ratio was determined. Based on the adsorption activity of activated carbon at the optimal ratio, the resulting adsorbent allows water purification from inorganic and organic impurities.

Acknowledgement: *The work was carried out with the financial support of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan at the expense of grant funding AR 05134356.*

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