ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 12, Issue 2, February 2025

Mathematical Optimization of the Process of Thermal Treatment of Intermediate Products for Producing Activated Carbon from Secondary Raw Materials of Textile and Spinning Production

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ABSTRACT: This article presents the results of mathematical planning of experiments on thermal treatment of intermediate products for obtaining activated carbons from secondary raw materials. The 3×3 Latin squares method was used to perform the optimization. As a result, the significance of the coefficients influencing the efficiency of the technological cycle during the process of carbonization of organic raw materials was revealed.

I. INTRODUCTION

The textile industry is an industry that uses and depletes water resources in large quantities. In addition, textile wastewater is mainly discharged contaminated with dyes. To purify this type of wastewater from coloring substances, many technological methods have been proposed, one of which is the use of adsorbents based on activated carbon. Considering that the discharge of water contaminated with dyes into natural reservoirs or into nature may have a negative impact on environmental safety. Taking into account these factors, expanding the scope of research on the development of new brands of activated carbon based on local secondary raw materials is an urgent task. The use of higher mathematics methods in planning laboratory experiments allows identifying the most optimal conditions of the technological cycle, which subsequently simplifies the management of technological processes of production processes.

II. LITERATURE SURVEY

In the production of activated carbon from organic structures, a carbonization process is carried out before the activation of the raw materials [1]. The carbonization process is carried out in a pyrolysis unit [2]. Complete and high-quality execution of technological operations during carbonization has a positive effect on the adsorption, physical-chemical, technological and other properties of the final product - activated carbon, as well as on its commercial properties, which are at the highest possible level [3-5]. In this work, the process of heat treatment of raw materials is also carried out. The stage has 3 factors that are related to temperature. Maximum process temperature, rate of temperature increase and holding time at maximum temperature. For experiments with three influencing factors, the 3x3 Latin squares method is suitable [6-7]. We have chosen this method as a mathematical tool.

III. RESEARCH METHODOLOGY

The research was carried out using waste fibres and fabric trimmings generated in primary fibre processing, yarn spinning, fabric weaving and similar workshops of textile enterprises operating in the Fergana region, as well as Angren brown coal powder. The mass was prepared by adding a binder solution to carbon powder and waste cotton fiber or fabric

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International Journal of AdvancedResearch in Science, Engineering and Technology
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scraps in a 1:1 ratio (by weight) and mixing in a laboratory mixer. The obtained masses were subjected to heat treatment in a laboratory pyrolysis unit under a vacuum of -0.9 kg/cm2 at temperatures of 450-550ºC for different periods of time.

The following factors were investigated:

1) A – maximum temperature, ºC;
2) B – holding time at maximum temperature, min;
3) C – rate of temperature increase, min/ºC.

Each factor has three values:

1) A_1 = 450ºC, A_2 = 500ºC, A_3 = 550ºC;
2) B_1 = 25 min, B_2 = 30 min, B_3 = 35 min/
3) C_1 = 7 min/ºC, C_2 = 10 min/ºC, C_3 = 13 min/ºC.

To conduct the experiment, the pre-prepared raw material was loaded into a laboratory pyrolysis unit. Temperatures were gradually increased, the rate of which was different in each individual experiment. Once a certain maximum temperature was reached, the raw material was kept at this temperature value.

The experiments were planned according to the scheme given in Table 1.

Table 1. Scheme of the experimental plan.

A	***B***		
	B_1	B_2	B_3
A_1	C_1	C_3	C_2
A_2	C_3	C_2	C_1
A_3	C_2	C_1	C_3

IV. EXPERIMENTAL RESULTS

The results of the experiments are collected in a table (Table 2), and their total and average values are also revealed.

Table 2. Experimental results and some of their meanings

Experiments and meanings	B_1	B_2	B_3	$_ATij$ sum	Average
A_1	40,3	47,4	46,1	133,8	44,600
A_2	43,2	48,8	50,3	142,3	47,433
A_3	55,4	67,9	66,5	189,8	63,267
$_BTij$ sum	138,9	164,1	162,9	T = 465,9 N = 9 f = 2	
Average	46,300	54,700	54,300		
C factor	C_1	C_2	C_3		
$_CTij$ sum	158,5	150,3	157,100		
Average	52,833	50,100	52,367		

To establish the significance of the influence of factors, a dispersion analysis of the experimental results was carried out. Initial data for dispersion analysis:

$$T = \sum_{i=1}^{n} Tij \quad \text{(Formula 1)}$$

$$T = 133{,}8 + 142{,}3 + 189{,}8 = 465{,}9$$

An analysis of variance of the squares of all observation results was carried out using formula 2:

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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$$S^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} Yij^2 \text{ (Formula 2)}$$

$$S^2 = 40{,}3^2 + 47{,}4^2 + 46{,}1^2 + 43{,}2^2 + 48{,}8^2 + 50{,}3^2 + 55{,}4^2 + 67{,}9^2 + 66{,}5^2 = 24875{,}65$$

Then the sum of squares for each factor was determined using formula 3:

$$S_1^{\ 2} = \frac{1}{n} \sum_{i=1}^{n} T_A ij \text{ (Formula 3)}$$

what led to the results:

$$S_1^{\ 2} = \frac{1}{n} \sum_{i=1}^{n} T_A ij = 24252{,}81$$

$$S_2^{\ 2} = \frac{1}{n} \sum_{i=1}^{n} T_B ij = 24725{,}26$$

$$S_3^{\ 2} = \frac{1}{n} \sum_{i=1}^{n} T_C ij = 24130{,}92$$

The mean value of the sum of squares for the obtained results was calculated:

$$\frac{T^2}{N} = \frac{465{,}9^2}{9} = 24118{,}09$$

The values of the sums of squares were calculated using formula 4:

$$SS \ = S^2 - \frac{T^2}{N} \text{ (Formula 4)}$$

according to formula 4 the total value of the sum of squares:

$$SS_{tot.} = S^2 - \frac{T^2}{N} = 757{,}56$$

and the average value of each group of factors separately:

$$SS_A = S_1^{\ 2} - \frac{T^2}{N} = 134{,}72$$

$$SS_B = S_2^{\ 2} - \frac{T^2}{N} = 607{,}17$$

$$SS_C = S_3^{\ 2} - \frac{T^2}{N} = 12{,}83$$

The variance residual is:

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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$$SS_{rem.} = SS_{tot.} - SS_A - SS_B - SS_C = 1{,}423$$

To identify the F-values of the factors, a series of calculations were carried out:

$S_A = \frac{SS_A}{f}$	$f = n - 1;$	$S_A = \frac{67{,}36}{2}$
$S_B = \frac{SS_B}{f}$	$f = n - 1;$	$S_B = \frac{303{,}58}{2}$
$S_C = \frac{SS_C}{f}$	$f = n - 1;$	$S_C = \frac{6{,}41}{2}$
$S_{rem.} = \frac{SS_{rem.}}{f}$	$f = (n - 1)(n - 2);$	$S_{rem.} = \frac{1{,}423}{2}$

F – value of factors after calculations:

$$F_A = \frac{S_A}{S_{rem.}} = 47{,}6$$

$$F_B = \frac{S_B}{S_{rem.}} = 213{,}29$$

$$F_C = \frac{S_C}{S_{rem.}} = 4{,}51$$

To determine the significance of each factor, the F – value was compared with the Fisher table criterion. The coefficient is significant if its absolute value is greater than the Fisher criterion ($F_{tab.} = 4{,}3$).

The results are shown in Table 3.

Table 3. Significance of coefficients

$F_{exp.}$ – Fisher criterion		Icons	$F_{tab.}$ – Fisher criterion	Results
F_A	47,33	>	4,3	The coefficient is significant
F_B	213,29	>	4,3	The coefficient is significant
F_C	4,51	>	4,3	The coefficient is significant

All factors turned out to be significant, since an increase and decrease in the levels of influencing factors affect the yield of the target product.

V. CONCLUSION

The results of the research revealed the possibility of using the product in the standardization and control of technological processes in the development of a new brand of activated carbon adsorbent for adsorption purification of textile industry wastewater from dyes. This, in turn, allows not only to standardize the adsorbent, but also to use it in the preparation of regulatory and technical documentation for it. As a result, a new brand of adsorbent based on activated carbon was developed for adsorption treatment of wastewater in the textile industry. The new brand of the developed

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 12, Issue 2, February 2025

adsorbent was named "AKVT-1" and the Technical Conditions for it were approved in 2024 under number Ts 200131171-002:2024.

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