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A RESOURCE-SAVING PROCESS OF EXTRACTING INDUSTRIAL CONTAMINATS FROM FIBROUS MATERIAL

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Abstract: The study of the kinetics of extraction of unfixed dye from a colored fibrous terry flat material using a washing solution to intensify the process of magnetic processing was carried out. The possibility of reducing the duration of the process, reducing the concentration of chemicals in the formulation of the working solution, the amount of waste water and their contamination was shown.

Improving the efficiency of the process of extraction (washing) of industrial contaminants from fibrous materials due to its intensification is an urgent task, since its solution allows reducing the consumption of clean washing water and chemicals, in particular surfactants, the amount of wastewater, energy costs for the process [1 – 5].

There are some publications on the intensification of the processes of extraction of industrial contaminants from fibrous materials under the influence of electric discharges, magnetic fields, ultrasonic fields, etc. Methods for calculating the kinetics of intensified processes are proposed [4 – 12].

The design of new efficient heat and mass transfer equipment and the modernization of existing equipment require additional experimental studies of heat and mass transfer processes and methods for their calculation [1, 5, 12, 13].

The purpose of the paper is to study the process of extracting (washing) unfixed dye from terry cotton fabric to increase resource efficiency, improve production and environmental safety with a reasonable choice and use the intensifying effect - magnetization of the wash solution, study the laws of the washing process, evaluate the effectiveness of the selected method of intensification.

To achieve this goal, it is necessary to study the kinetics of the washing process of the selected object, to analyze the results of studies of the mass transfer process that occurs during the magnetization of the washing solution. Assessment of energy and resource efficiency, safety and economic efficiency of the process under study, comparison of industrial and environmental safety during the washing process under the current and intensified mode.

Intensification of washing fabrics, which is periodic and very long process that would reduce its duration, and thus the time of exposure to hazardous and harmful factors in the work area, in addition, the surfactant concentration may be reduced or complete elimination of soda ash. To solve this problem, it is necessary to use the results of experimental studies and analysis of the fabric selected for the study as an object of technological processing.

The object of study is a cotton terry fabric (100 %). Surface weight: 410 g/m^2, web width: 159 cm, weight per meter: 429 g, weight of m^2: 270 g, average fiber length ranges from 22 to 50 mm with a cross section of 18 – 25 microns. The average fiber strength is 4–5 cN, the breaking length is 24 – 34 km, and the elongation at break is 7–8 %.

Table 1 shows the characteristics of the tissue, and the values of the inner surface and specific pore volume are determined experimentally by the method of adsorption of water vapor and methanol. In Table 2 there is a characteristic of the washing process.

Table 1

Characterization of the object of study

Characteristic	Value
Internal surface area, m^2/g:	
water	94 – 137
methanol	20 – 82
Pore volume, cm^3/g:	
water	0.130
methanol	0.142
Density, g/cm^3	1.52
Volumetric swelling in water	45
Moisture absorption at 20 °C and φ = 65 %	7 – 9

Table 2

Technological features of washing process

<table>
<tr><th>Technological operation</th><th>Temperature, °C</th><th>Time, min</th></tr>
<tr><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Washing - stream. The circulation of the solution. The water valve is open at 70%</td><td rowspan="9">20</td><td rowspan="3">15</td></tr>
<tr><td>Drain of the solution</td></tr>
<tr><td>Filling the barque with soft water</td></tr>
<tr><td>Washing with a rise in temperature to 85 °C for 22 minutes. Solution circulation for 15 minutes.</td><td rowspan="4">15</td></tr>
<tr><td>Cooling the solution to a temperature of 75 °C. Solution circulation</td></tr>
<tr><td>Drain of the solution</td></tr>
<tr><td>Filling the barque with soft water</td></tr>
<tr><td>Call operator. Light signal. Preparation of chemical materials in a dosing tank:
“VIK” (synthetic detergent) – 1 g/l - 2.0 liter</td><td rowspan="2">5</td></tr>
<tr><td>Injection of chemical materials into the apparatus</td></tr>
<tr><td>Soaping at a temperature of 95 °C for 20 minutes</td><td>95</td><td>20</td></tr>
<tr><td>Cooling the solution to a temperature of 75 °C for 7 minutes. Solution circulation</td><td rowspan="2">75</td><td rowspan="2">7</td></tr>
<tr><td>Drain of the solution</td></tr>
</table>

Continuation of table 2

<table>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Washing at 75 °C for 15 minutes</td><td rowspan="5">75</td><td rowspan="3">15</td></tr>
<tr><td>Drain of the solution</td></tr>
<tr><td>Filling the barque with soft water</td></tr>
<tr><td>Call operator. Light signal. Preparation of chemical materials in a dosing tank:
“Tratskan GF” – 2,0 g/l – 4,0 kg,
Acetic acid 30% – 0.5 g/l – 1.0 l</td><td rowspan="2">5</td></tr>
<tr><td>Submission of chemical materials to the barque</td></tr>
<tr><td>Heating to 40 °C. Mellowing at a temperature of 40 °C for 20 minutes</td><td rowspan="2">40</td><td rowspan="2">20</td></tr>
<tr><td>Drain of the solution</td></tr>
</table>

At ZAO “Moskovskij shelk” (currently withdrawn from Moscow) and current similar enterprises, washing of fabric is carried out mainly with a tow.

The process of washing fabrics in an industrial environment is very lengthy. Therefore, the task of intensifying the washing process is particularly acute.

A joint analysis of the results obtained and the washing kinetics curves shows that significant intra-diffusion resistance takes place in the process.

To intensify the washing process of materials with high intradiffusion resistance, it is advisable to use ultrasonic or magnetic fields.

Studies show that the effect of ultrasound is very effective; however, the actual implementation of ultrasonic devices on existing industrial equipment is quite complicated and expensive. The use of magnetic fields is simpler and cheaper [12].

Magnetic treatment accelerates the coagulation of suspensions, wetting of solid surfaces with water, adsorption of surfactants, crystallization and dissolution processes.

Using magnetic treatment, it is possible to reduce the formation of various deposits on hard surfaces (for example, scale of various salts). In industry, thousands of magnetic devices are used for this purpose. Magnetic treatment improves the purification of water from suspensions. Treated water changes its biological properties [11, 12].

In the technological processes of the textile industry, the requirements for the quality of activation of water systems should be more stringent, as this is due to the quality of the products. Due to the fact that the effects of magnetic processing do not accumulate and are not mutually compensated, it is very important to choose the correct magnetic field parameters [11]. The mechanism of the influence of a magnetic field on water and its impurities cannot be considered sufficiently identified. Known considerations and hypotheses of various authors are mainly based on the polarizing effect of a magnetic field on ions and water molecules. Moreover, in the case of magnetic treatment of natural water in a state of thermodynamic equilibrium, there is no reason to assume the real possibility of occurrence, and even more so the long-term preservation (“magnetic memory”) of any changes in water under the influence of relatively weak magnetic fields. In this regard, it is likely that the action of a magnetic field during water treatment can manifest itself only in thermodynamically non-equilibrium systems, i.e. systems in an unstable state [11, 12].

Numerous observations and experiments show that if, during washing, water consumption is reduced by 50% using a magnetic apparatus, the quality of washing remains unchanged. If you do not reduce the water flow for washing, the use of magnetic treatment can dramatically improve the quality of washing. The objective of the study is to study the technological process of extraction (washing) of unfixed dye from terry cotton fabric to increase resource efficiency, improve production and environmental safety with a reasonable choice and use of the intensifying effect - magnetization of the wash solution.

To conduct an experimental study of the washing process, a setup was used to simulate washing baths with vertical filling of tows. The experiment was carried out in the laboratory of general chemical technology at the department of PACT of the Kosygin State University of Russia.

In accordance with the technological regime developed at the department of PACT and Vital Security, a mixture of anionic and nonionic surfactants in a certain ratio was used in the washing solution.

The duration of each stage was recorded by a stopwatch, the temperature of the water was monitored using a thermometer, and the volume of water was measured by a measuring cylinder.

After the washing process, the dried tissue samples were tested for color fastness to dry friction in accordance with GOST 9733.27-83 (ST SEV 5444-85) * "Textiles. Test method of colour fastness to crocking".

The magnetization of the wash water was carried out using a device for magnetic treatment CO-3, the technical characteristics of which are presented in Table 3.

Samples of fabric that were dyed were washed strictly in accordance with the technology of ZAO "Moskovskij shelk".

First, dyeing was carried out on ordinary tap water. A tissue sample was dyed with an active dye for 10 minutes at a temperature of 20 °C, and then it was dyed with a rise in temperature to 60 °C for 40 minutes. Then, soda ash 5 g/l was introduced and when the temperature rose to 90 ° C (within 15 minutes), it was painted for 40 minutes. Cooling the solution to 75 °C lasted 5 minutes. After dyeing, the samples were washed according to the technological scheme described in Table 2.

The analysis of the active dye content was carried out according to the well-known method of colorimetrication of dye solutions after washing the fabrics to 100% washing in laboratory conditions.

The amount of dye on the fabric was determined using a KFK 2 photocolorimeter and calibration curves obtained previously at the Department of PACH for various dyes.

Samples were studied by the method of the maximum amount of dye desorbed from the test sample of fabric as a result of 100 % washing solution dyed with colorimetric method after 100 % washing.

An exact weighed sample of fabric with a mass of 0.2 - 0.4 g is washed repeatedly in a solution containing 2 g/l of surfactant at a temperature of 100 °C until all unstained dye is removed from the sample.

Then, the resulting washing solutions are combined and diluted to a certain volume in a volumetric flask.

The resulting solution is colorimetric, and the concentration of the unstained dye desorbed from the sample is determined from the previously constructed calibration line. This amount is taken as 100 % washing.

Table 3

Technical characteristics of the device for magnetic treatment of water

Nomination	Parameter
The value of magnetic induction in the gates between the magnets	not less than 100 mT
Weight	no more than 0.4 kg
Dimensions	∅75x116 mm
Internal diameter of the attached hose	16 mm
Maximum allowable pressure at the inlet of the device	no more than 4 kg/cm^2

The amount of dye α (g/kg of fabric) removed from the sample is calculated by the formula (1)

$$\alpha = \frac{CV1000}{\gamma}, \quad (1)$$

where C is the dye concentration according to the calibration curve, g/l; V is the volume of the volumetric flask, l; γ – hinge of dyed fabric, g.

For analysis of the dye content on the canvas, not one sample was taken, but three from different places of the sample. The determination of the dye content on textile materials was carried out according to known methods.

The method for colorimetric acid hydrosols is described below. In accordance with this method, a piece of tissue is cut out of a stained sample, weighed, crushed and dissolved in acid. The amount of dye is determined by the optical density of the solution. In this case, it is determined not the absolute value of the amount of dye fixed by the textile material, but its change at different parameters of the magnetic treatment with respect to the control sample (painted without using magnetic fields), i.e. difference

$$\Delta G = G - G_0, \quad (2)$$

where G and G_0 are the amount of dye fixed by a unit mass of fabric, respectively, using and without magnetic treatment of solutions, g/kg.

Due to the fact that the amount of dye remaining on the fabric, even when dyeing under the same conditions in control water from experiment to experiment, does not remain constant, and also because of the desire to use a dimensionless quantity to estimate the change in the amount of dye absorbed by the fabric, it was used relative value

$$\eta = \frac{C_0 - C_i}{C_0} \cdot 100\,\%, \quad (3)$$

where C_0 is the initial concentration of the dye on the fabric, g/kg; C_i – current dye concentration on the fabric, g/kg.

The concentration of surfactant in the solution (a mixture of anionic and nonionic surfactants) was 0.8 g/l.

Figure 1 shows the kinetic curves for washing cotton terry cloth, where the upper curve is the average value of the dye content in the fabric when washing without magnetization, the lower curve is the average value of the dye in the fabric when washing with magnetization.

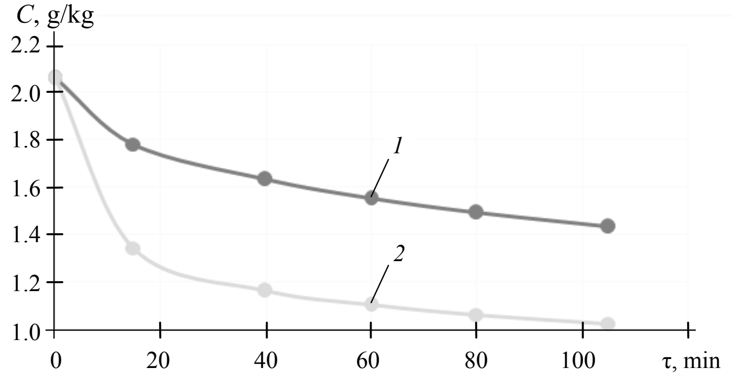

Fig. 1. Kinetic curves of washing terry cotton fabrics:
1 – without magnetization; *2* – with magnetization

Figure 2 shows the change in the degree of washing of tissue, where the upper curve is the change in the degree of washing of fabric with magnetization, the lower curve is the change in the degree of washing of fabric without magnetization.

Each point is the average value of 3 experiments when washing without the use of an intensifier and with its use.

As a comparative analysis of kinetic curves shows when using magnetic water, the duration of the process is reduced by an average of 22 %. At the same time, soda ash is completely removed, the concentration of surfactants is reduced from 1 to 0.8 g/kg due to the use of a mixture of anionic and nonionic surfactants during washing using a magnetic device, the consumption of clean water and heat for its heating is reduced.

Mathematical processing of the results of the study of the kinetics of dyed tissue was carried out using the least square method.

Equation (4) obtained

$$C' = e^{-0.006\tau+0.54}. \quad (4)$$

A comparison of experimentally obtained during the study of the kinetics of the washing process with magnetization and calculated data are given in table 4.

Table 4 shows that the discrepancy between the experimental and calculated data is significant in the first washing period. Relative errors in the second period of the process are within the limits acceptable for engineering calculations.

Research and practical development on the use of magnetization of water systems was carried out in the works of M.I. Davidzon [12].

The analysis of the environmental safety of the process under the current and intensified modes was conducted. The annual discharge of pollutants into the water resource by the example of the considered enterprise is shown in Table 5.

Based on the data in the table, it can be concluded that the charge for emissions of pollutants into water bodies will be significantly reduced.

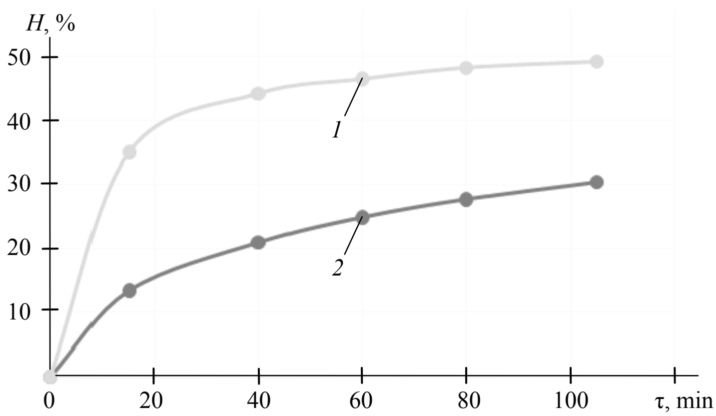

Fig. 2. Change the degree of washing terry cotton fabric:
1 – with magnetization; *2* – without magnetization

Table 4

Comparison of experimental and calculated data during the study of the kinetics of the washing process with magnetization

τ, s	0	15	40	60	80	105
C′ experimental	2.06	1.34	1.29	1.21	1.06	1.02
C′ calculated	1.33	1.27	1.17	1.10	1.03	0.95

Table 5

Characteristics of pollutant discharges

Characteristics	Surfactant, t/year	Soda ash, t/year
Under the current technological regime	4.40	1.1
With intensified technological mode	2.46	0
Permissible Norm	6.40	2.0

Savings will be achieved by reducing emissions into the air. A rough estimate suggests that the savings could be at least 5 rubles per linear meter of flat fibrous material.

Conclusions. An assessment of energy saving and safety issues in the finishing production of a textile enterprise was carried out using the example of ZAO "Moskovskij shelk", which showed that one of the important tasks of improving working conditions and safety is to improve the technology of batch processes, in particular, the washing process, since this process is resource-intensive a source of negative impact on workers in the finishing industry and on the environment.

An experimental study was carried out of the kinetics of tissue washing, article 13592, dyed with an active dye without the use of an intensifier and using magnetic treatment of water to prepare a washing solution. The result of the study is the fact that when using magnetic water, the duration of the process is reduced by an average of 22 % (from 1 hour 45 minutes to 1 hour 20 minutes). It was shown that it is possible to completely eliminate soda ash from the wash solution formulation, reduce the concentration of surfactants from 1 g/l to 0.8 g/l through the use of a mixture of anionic and nonionic surfactants, and reduce the amount of wastewater and its pollution. Practical recommendations were developed to intensify the washing process, a device for magnetic treatment of water was selected, and a scheme for its installation with technological equipment was proposed.

An approximate economic assessment shows that the use of magnetization of the working solution can lead to a reduction in the cost of electricity, clean water, by reducing the time of the washing process. Perhaps a decrease in the concentration of surfactants and the elimination of soda ash.

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Ресурсосберегающий процесс экстрагирования технологических загрязнений из волокнистого материала

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Ключевые слова: кинетика; магнитное поле; ресурсосбережение; хлопчатобумажный волокнистый плоский материал; экстрагирование.

Аннотация: Проведено изучение кинетики экстрагирования незафиксированного красителя из окрашенного волокнистого махрового плоского материала с использованием для интенсификации процесса магнитной обработки промывного раствора. Показана возможность сокращения продолжительности процесса, снижения концентрации химических реагентов в рецептуре рабочего раствора, количества сточных вод и их загрязненности.

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Ressourcenschonender Extraktionsprozess der technologischen Verunreinigungen aus Fasermaterial

Zusammenfassung: Die Untersuchung der Kinetik der Extraktion eines nicht fixierten Farbstoffs aus einem gefärbten faserigen Frottee-Flachmaterial unter Verwendung einer Waschlösung zur Intensivierung des Magnetbehandlungsprozesses ist durchgeführt worden. Die Möglichkeit, die Dauer des Prozesses zu verringern, die Konzentration chemischer Reagenzien in der Formulierung der Arbeitslösung, die Abwassermenge und deren Verunreinigung zu verringern, ist gezeigt.

Processus d'extraction économe en resources des pollutions technologiques des matériaux fibreux

Résumé: Est étudiée la cinétique de l'extraction d'un colorant non fixé à partir d'un matériau plat éponge fibreux coloré avec une utilisation d’une solution de lavage pour intensifier le processus du traitement magnétique. Est montrée la possibilité de réduire la durée du processus, de réduire la concentration des réactifs chimiques dans la formulation de la solution de travail, la quantité d'eaux usées et leur pollution.

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