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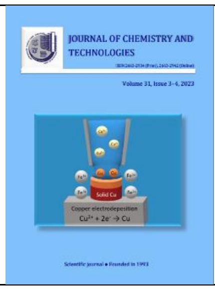

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RESULTS OF EXPERIMENTAL STUDIES ON THE REUSE OF CONCENTRATED WASTEWATER IN THE PROCESS OF DYEING COTTON FABRICS WITH DIRECT DYES

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Abstract

The wastewater from the dyeing and finishing industry contains dyes and auxiliary substances. Concentrated wastewater obtained after the dyeing process from batch equipment as a result of salvo discharges can be a high-quality secondary raw material for reuse. The paper presents the results of experimental studies of the reuse of concentrated wastewater in the technology of dyeing cotton fabrics (calico and viscose) with direct dyes. It was found that the physicochemical properties of the dye solution and the resulting concentrated wastewater are practically unchanged. To ensure the technological parameters of optimal conditions for dye sorption by fibre and dye concentration in the dye solution, a hypothesis was first put forward to create a new composition of the dye bath: concentrated waste water and the added amount of dye, calculated mathematically on the basis of the light absorption spectra of the studied water systems. It has been determined that dyeing cotton fabrics with direct dyes according to this formulation is effective and ensures the quality of dyed fabrics at the level of 95-99% compared to the standard (100%), the colour difference is of the lowest value (DE < 2), and the qualitative indicators of colour fastness are within the numerical limits of the standard. The cost savings of direct dyes using concentrated wastewater is an average of 21.93 % for every 1200 running meters (RMTs) of fabric. Laboratory studies are confirmed by the production conditions of the active dyeing and finishing production of the Private Joint Stock Company Cherkasy Silk Plant (PJSC CSP) (Cherkasy, Ukraine).

Keywords: dyeing and finishing production; direct dyes; coarse calico; viscose; concentrated wastewater.

РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ПОВТОРНОГО ВИКОРИСТАННЯ КОНЦЕНТРОВАНОЇ СТІЧНОЇ ВОДИ В ПРОЦЕСІ ФАРБУВАННЯ БАВОВНЯНИХ ТКАНИН ПРЯМИМИ БАРВНИКАМИ

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Анотація

Відходами фарбувально-опоряджувального виробництва є стічні води, які в своєму складі містять барвники та допоміжні речовини. Концентровані стічні води, одержані після процесу фарбування з обладнання періодичної дії внаслідок залпових скидів, можуть бути якісною вторинною сировиною для повторного використання. У роботі представлені результати експериментальних досліджень повторного використання концентрованої стічної води в технології фарбування бавовняних тканин (бязь та віскоза) прямими барвниками. Досліджено, що фізико-хімічні властивості фарбувального розчину і одержаної концентрованої стічної води, практично незмінні. Для забезпечення технологічних параметрів оптимальних умов сорбції барвника волокном і концентрації барвника у фарбувальному розчині вперше висунуто гіпотезу щодо створення нового складу фарбувальної ванни: концентрована стічна вода та додана кількість барвника, обчислена математично на основі спектрів світлопоглинання досліджуваних водних систем. Визначено, що фарбування бавовняних тканин прямими барвниками за такою рецептурою є ефективним та забезпечує якість пофарбованих тканин на рівні 95–99 % по відношенню до еталону (100 %), кольорова відмінність має найменше значення (DE < 2), а якісні показники стійкості забарвлень знаходяться в числових межах до еталонних. Економія витрат прямих барвників з використанням концентрованої стічної води складає в середньому 21.93 % на кожні 1200 п.м. тканини. Лабораторні дослідження підтверджені виробничими умовами фарбувально-опоряджувального виробництва ПрАТ «Черкаський шовковий комбінат» (м. Черкаси, Україна).

Ключові слова: фарбувально-опоряджувальне виробництво; прямі барвники; бязь; віскоза; концентрована стічна вода.

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Introduction

The most important place in the structure of the textile industry belongs to the cotton branch. By the way, dyeing and finishing production is one of its sub-branches. The produced textile products are characterized by high cost and significant consumption of such resources as water, dyes, auxiliary substances, thermal, and electrical energy. Large quantities of water are used in the fabric production, pretreatment, bleaching, dyeing and printing stages. Every year, 60 billion kg of textiles are produced worldwide, using up to 9 trillion gallons of water [1]. These processes require about 100–200 litres of quality water per 1 kg of textile product [2; 3], and processing fabrics weighing 8,000 kg requires 1.6–106 litres of water in total, which is the second largest volume of water consumed by all industries [4].

Water is a highly valuable natural resource and asset and cannot be treated as a mere consumable. Global water scarcity necessitates the recycling and use of wastewater. Water recycling is an important economic and environmental factor that should be implemented to improve product quality and sustainability of the dyeing and finishing industry [5–7].

The works of some scientists contain research results on the raised problems. The work [8] shows the results of recovered dyes reuse in baths for coloring synthetic carpets at a large carpet factory in the USA. Adding a certain amount of dye and auxiliary substances to spent (exhausted) dyeing in baths has led to a successful restoration. Carpet samples tests for shade match and color fastness were satisfactory (compared to the reference ones). The environmental and economic benefits for the carpet factory were significant: pollutant emissions and water use were reduced by 25–50 %. According to economic calculations, the cost of upgrading the equipment could pay off in 18 months if half of the baths at the factory were converted for reuse.

Scientists Porter, J.J., and Goodman, G.A. [9] conducted research on the recovery of hot water, dyes, and auxiliary chemicals from textile wastewater. They used a recovery system and a reverse osmosis system in the experiments. Research has a high potential for recycling with the reuse of water and chemicals. It’s possible to use some drops of dye and auxiliary substances but the final amount will depend on the type of dye and the cycle times.

The researchers offer in their work [10, p. 671] a simple approach to the cost-effective reuse of water in the case of cotton pretreatment. Here you can find attempts “…to implement pretreatment processes in an environmentally and economically optimal manner by simply reusing process baths for each preliminary treatment. It is suggested that fabric washing and bleaching processes have to be carried out due to the standing bath without replenishment of water or chemicals. However, it’s essential to take care of the optimization of materials-to-liquor ratio (MLR) maintenance by appropriate adjustment of the fabric material size. The same process bath was reused until the results obtained were acceptable for further processing”.

Paper [11] investigates the possibility of reusing wastewater from Pakistan's highways in the processes of wet fabric processing (dyeing and washing). The quality and durability of the colour of the studied fabric samples dyed with reactive dyes were determined. Positive results were achieved when motorway wastewater was used instead of fresh (process) water separately at the dyeing and washing stages. The colour fastness (dE), durability and quality of the colours obtained are within the range of standard (reference samples using process water) It was determined that ".... fabric samples where water from highway wastewater was used simultaneously in the dyeing and washing stages showed unreliable results".

The authors of [12] highlight the problem of economical water consumption in the cotton and knitwear industry of Bangladesh during the dyeing of knitted fabric. It is promising to create step-by-step scenarios for water consumption, which will minimise the use of water required for each reactive dyeing process. It has been estimated that 7.80 per cent of chemical costs can be saved per 1 litre of water consumption for the production of 1 kg of fabric. In order to implement water-saving and economical use, it is necessary to introduce the latest technologies, improve dyeing processes, and take into account factors such as the design of dyeing machines, the efficiency of machine pumps, and the types and methods of wet processing of fabric (dyeing, stuffing, washing, etc.).

In order to minimise heat and energy consumption in the process of dyeing cotton fabrics with direct dyes, researchers from India [13] proposed the use of triethanolamine instead of sodium carbonate in a dye bath with low (30 °C), medium (60 °C) and high (90 °C) dyeing temperatures. As a result of the study, the dyed cotton fabric samples were compared with samples dyed using conventional technology.

According to the results of the study, the colour strength (K/S) and colour difference were acceptable compared to the traditional high temperature dyeing process with sodium carbonate (SC method). The cost of low-temperature dyeing was minimised to Rs 2.24 lakhs compared to the cost of high-temperature sodium carbonate dyeing.

It is well-known [14] that traditional textile dyeing technologies are associated with both the consumption of material and energy resources and the generation of wastewater. These technologies have a major drawback - significant volumes of wastewater containing organic and toxic chemicals that are part of fixatives, detergents, dyes, and salts are to be disposed of. Therefore, they are the most polluting of all industrial wastes [15–17].

Thus, it is necessary to solve the scientific and practical task of creating new resource-saving technologies for dyeing textile materials, which would ensure a decrease in the cost of textile products, a reduction in the consumption of dyes and water within the fabrics dyeing process, and a reduction in the environmental impact on water resources.

Concentrated wastewater obtained directly after the fabric dyeing from discontinuous equipment as a result of volley discharges can be a high-quality secondary raw material to be reused in textile dyeing technology. It has been practically investigated [18] that the average content of textile dyes in concentrated wastewater is as follows: disperse dyes - 39%, active dyes - up to 45%. Effluents obtained from the textile dyeing process are deeply colored due to the high dye content and have a complex character with high alkalinity and electrolyte concentration. Wastewater contains about 5–30 % of dye along with a significant number of electrolytes and alkalis when dyeing with direct dyes [19].

This is the basis for conducting practical research and solving scientific and practical problems.

Direct dyes are one of the leading classes of dyes for coloring textile materials from cellulose fibers. Along with the disadvantages of these coloring agents (low color fastness to washing and light exposure; insufficient brightness and purity of shades), there are also their positive qualities: economy, ease of application on fibrous material, great color range, low cost, good solubility in dyeing solution, the ability to combine with other classes of dyes, and good etchability. In this regard, they occupy one of the leading positions in the structure of world production and consumption of dyes, yielding only to sulfur and reactive dyes [20].

The small number of scientific publications in professional publications over the past ten years evidences about insufficient research on the problem of dyeing cotton textile materials with substantive coloring agents using wastewater from the dyeing and finishing industry. This substantiates the relevance of the work, its practical perspective, and the significance of the obtained experimental results.

The purpose of the experimental work is to study the process of dyeing cotton fabrics (Calico and Viscose) with direct dyes (Red Lightfast and Blue Direct B2RL) using concentrated wastewater obtained directly after the dyeing process from batch equipment and the possibility of its further use as a secondary material resource in the technologies of dyeing textile materials.

Materials and methods

We used substantive coloring agents that belong to disazo and trasazo dyes with disconnected groups (Table 1). These are anionic dyes with substantiality for cellulose fibers, which are selected from an aqueous dyeing bath containing an electrolyte [21].

The general formula of direct dyes can be the following: $R\text{-}SO_3Na$, where – R is an organic radical that determines the dye color, its sorption, and diffusion capacity. The presence of sulfo groups $-SO_3Na$ indicates good solubility of dyes. Coloring agents are sodium salts of sulfonic acids by chemical nature, mainly azo compounds. The chemical structure of direct dyes' -R radical ensures their high affinity to cellulose. It is caused by the presence of a long chain of connections and groups in dye molecules that are capable of forming hydrogen bonds with the fiber, as well as the linear elongated shape and planar structure of the molecule. Dyes dissociate with the formation of colored anions in aqueous solutions. These anions are capable of association: $R\text{-}SO_3Na \leftrightarrow R\text{-}SO_3^- + Na^+$. Sodium cations are compensating ones [20, p. 3].

Coarse calico and Viscose fabrics were the subjects of research. Coarse calico is a dense cotton fabric with a linen weave. It is low-cost, made of 100 % cotton, and has high density. The chemical composition of cotton is the following: α-cellulose (94.5–96 %), waxy substances (0.5–0.6 %), pectin substances (1–1.2 %), protein substances (1.2 %), minerals substances (1–2 %), and other substances (0.3–1.3 %) [24]. We used

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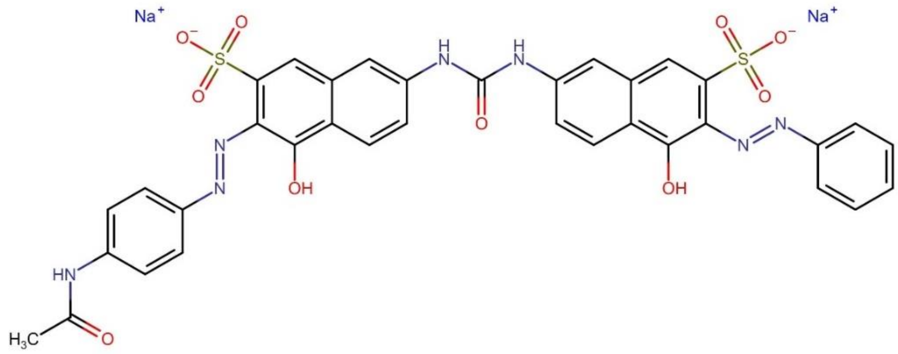
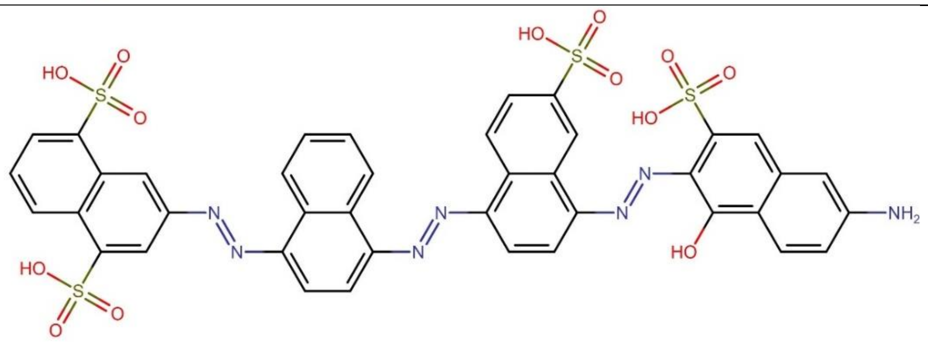
the Coarse calico fabric (art. 3461) produced by the Private Joint Stock Company Cherkasy Silk Plant (PJSC CSP) (Cherkasy, Ukraine).

Table 1

Textile direct dyes

Name of the dye	Dye formula
Direct Red Light-resistant [22] disodium;7-[[6-[(4-acetamidophenyl)diazenyl]-5-hydroxy-7-sulfonatonaphthalen-2-yl]carbamoylamino]-4-hydroxy-3-phenyldiazenylnaphthalene-2-sulfonate	
Direct Fast Blue B2RL [23] 3-[[4-[[4-[(6-amino-1-hydroxy-3-sulfonaphthalen-2-yl)diazenyl]-6-sulfonaphthalen-1-yl]diazenyl]naphthalen-1-yl]diazenyl]naphthalene-1,5-disulfonic acid	

Viscose is a fabric obtained artificially from natural raw materials. Viscose fibers consist of α-cellulose (80 %) and impurities (20 %). They have a dense structure, are quite resistant to temperature, have high hygroscopicity (11–13 %), and swell in water (100–110 %), as a result of which they lose 50–60 % of their strength when wet. [25, p. 91–93]. We used the Viscose fabric (art. 3324) produced by PJSC CSP. The physical and mechanical parameters of the used fabrics are shown in Table 2.

Table 2

Physical and mechanical parameters of the finished fabric

Fabric properties		Coarse calico, art. 3461	Viscose, art. 3324
Fabric width, cm		155.7	156.1
Surface density, g/m^2		144.6	141.8
Density, number of threads per 10 cm			
	warp	270	503
	weft	196	312
Breaking load, N			
	warp	480	610
	weft	310	550
Elongation at break, %			
	warp	12	21
	weft	18	17
Resistance to the threads spreading, N		-	29.4
Thread shedding		-	
	warp		0.31
	weft		1.07
Air-tightness, dm^3/m^{2}s		321	215.0
Fabric mass (1200 RMTs of fabric), kg		270.17	265.62

Fabric samples were dyed on the AHIBA NUANCE CH-6015 (Datacolor USA) laboratory machine in real production conditions of the PJSC CSP dyeing and finishing production according to the recipe that corresponds to the enterprise's technological regulations. Technological dyeing solution with a total volume of 80 cm^3 (for an industrial laboratory machine) contains 2 g of sodium bicarbonate (Na_2CO_3 GOST 32802-2014), 3 g of table salt (NaCl GOST 4233-77), 12 cm^3 of a solution (3 %) of pre-boiled dye, 63 cm^3 of softened water (softening carried out at PJSC CSP). Electrolyte (table salt and sodium chloride) is necessary to improve the dye selection by the fiber. Sodium chloride accumulates positively charged ions in the solution by dissociating in an aqueous solution according to the following scheme: $NaCl \rightarrow Na^+ + Cl^-$, which neutralizes the negative charge of the fiber and dye. Thereby, there's a faster and more complete dye transition to the fiber, which leads to an increase in the intensity of the color agents and less contamination of wastewater with dyes. Baking soda (sodium carbonate) contributes to better dye dissolution and creates a weakly alkaline environment that serves for the dye interaction with the fiber [20].

2 g of cotton fabric is immersed in the dyeing solution according to the technological mode. Dyeing is carried out periodically at a temperature of 95 °C for 40 minutes. The samples are washed several times with tap water after dyeing and dried in a drying cabinet at a temperature of 100 °C for 5–7 minutes. The obtained dyed tissue samples are examined for the intensity and stability of the color.

The resulting wastewater (after dyeing according to the basic recipe) contains a significant number of dyes and auxiliary inorganic compounds. Therefore, the recipe for dyeing cotton fabric using concentrated wastewater is created taking into account the number of dye contained in wastewater.

A spectrophotometric method was applied using a UV-5800 PC (CHINA) spectrophotometer to study the analysis of dye solutions and produced wastewater and to determine the mass of dye in concentrated wastewater. The color characteristics of the examined tissue samples were determined using a Datacolor Spectrum 400 (automatic computer system of objective color measurement) (Datacolor USA). The quality and stability of the obtained colors were determined by comparing them with the standard used by the samples of PJSC CSP and by determining the stability of dyeing in accordance with the current state standards of Ukraine ((DSTU ((National Standard of Ukraine)) 3998-2000 [26], DSTU ISO 105-X12:2016 [27], DSTU ISO 105-A02:2005 [28], DSTU EN ISO 105-C10:2020 [29]. The Stainingtester device (Computex, Hungary) was used to measure color fastness to dry and wet crocking according to DSTU ISO 105-X12:2016 [27]. The head of the device, which is covered with a white cotton fabric, makes 10 forward and backward movements under a load of 9H (according to a sample of the tested fabric with a length of 10cm). At least three samples have to be taken for testing and the result is an arithmetic mean of all the measurements.

Results and discussion

The dye solutions' density and pH are indicators that affect the dye adsorption process by the fiber. These indicators are determined by adding the necessary amount of baking soda and NaCl electrolyte to the coloring solutions. The number of electrolyte and the acidity of the medium require strict regulation because an excess of the electrolyte leads to the situation in which dye particles deprived of a negative charge easily unite into large aggregates that are not able to take a direct part in the surface layer formation and in the redistribution of the dye from this layer into the fiber [30]. The electric potential barrier decreases sharply due to the presence of salt in the solution. The dye anions can approach the surface of the fibers close enough for mutual attraction and the dye is absorbed by the fibrous material [31].

The physicochemical properties of dyeing solutions and the resulting concentrated wastewater were investigated to create optimal conditions for dyeing cotton fabric with direct dyes. The results are shown in Table 3.

Table 3

Values of pH and density of the studied water systems when dyed with substantive coloring agents

Dye	Fabric	pH		Density, g/cm³	
		technological dye solution	concentrated wastewater	technological dye solution	concentrated wastewater
Direct Red Light-resistant	Coarse calico (art. 3461)	10.12	10.09	1.004	1.003
	Viscose (art. 3324)	10.07	10.12	1.001	1.002
Direct Fast Blue B2RL	Coarse calico (art. 3461)	10.02	9.98	1.003	1.005
	Viscose (art. 3324)	10.26	10.21	1.001	1.003

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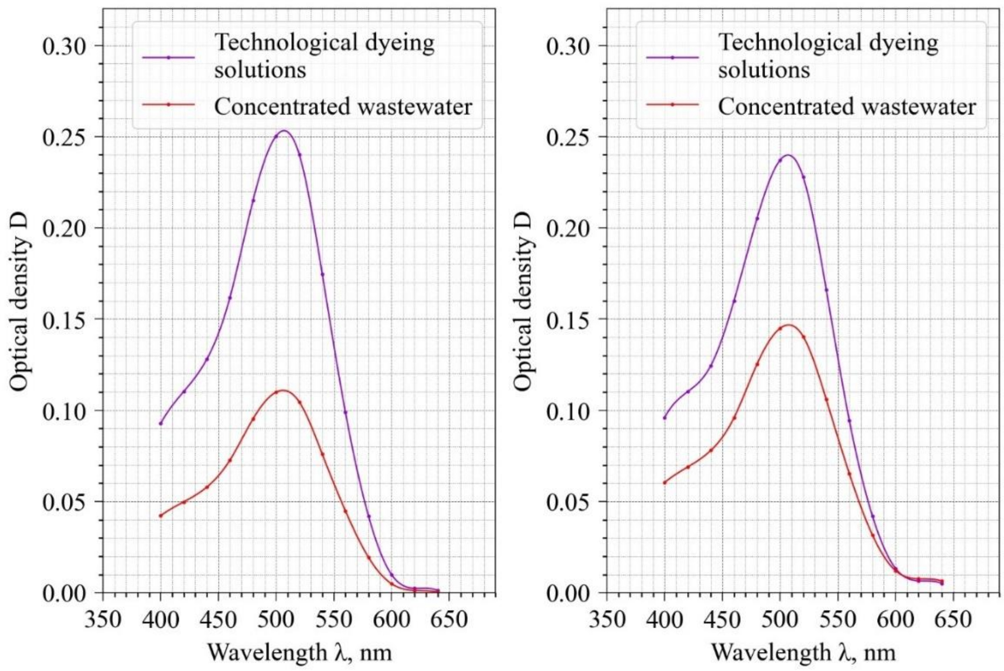
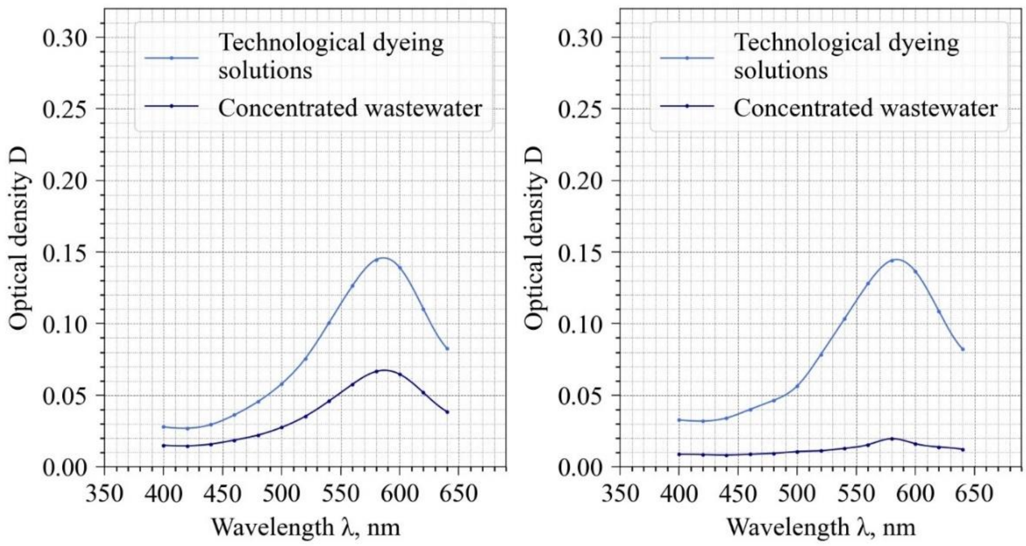
The data from the table 3 allow you to make a comparative analysis of the technological dyeing solution and the obtained concentrated wastewater according to pH and density indicators. These indicators do not differ significantly. Therefore, it's easy to conclude that the obtained concentrated wastewater contains a sufficient amount of baking soda and table salt (electrolyte) to create a new technological solution on the basis of its use in the dyeing process. Therefore, the recipe changes will concern only the amount of dye in the case of concentrated wastewater reuse and the creation of a new technological dyeing solution based on it. This will provide technological parameters of optimal conditions for dye sorption by the fiber and coloring agents' concentration in the dyeing solution. The mass of the coloring agent that was added to the concentrated wastewater was calculated mathematically was guided by the spectrophotometric studies of technological dyeing solutions and the resulting concentrated wastewater (Figures 1, 2).



A **B**

Fig. 1. Optical absorption spectra of aqueous solutions with Direct Red Light-resistant dye: A – fabrics Calico (art. 3461), B – fabrics Viscose (art. 3324)



A **B**

Fig. 2. Optical absorption spectra of aqueous solutions with Direct Fast Blue B2RL dye: A - fabrics Calico (art. 3461), B - fabrics Viscose (art. 3324)

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The number of investigated direct dyes in the produced concentrated wastewater is shown in Table 4.

Table 4

Content of direct dyes in process dyeing solutions and in the resulting wastewater (per solution volume of 0.08 dm³)

Dye	Fabric	Dye concentration in the process dye solution, (mol/dm³)	Concentration of dye in wastewater, (mol/dm³)
Direct Red Light-resistant	Coarse calico (art. 3461)	$9.23 \cdot 10^{-4}$	$4.05 \cdot 10^{-4}$
	Viscose (art. 3324)	$9.23 \cdot 10^{-4}$	$5.60 \cdot 10^{-4}$
Direct Fast Blue B2RL	Coarse calico (art. 3461)	$7.97 \cdot 10^{-4}$	$3.67 \cdot 10^{-4}$
	Viscose (art. 3324)	$7.97 \cdot 10^{-4}$	$1.08 \cdot 10^{-4}$

Cotton fabrics were dyed in production conditions using already created new dyeing technological solutions according to a new recipe. Fabric samples were colored via the AHIBA NUANCE CH-6015 (Datacolor, USA) laboratory dyeing machine. The recipe for the created dyeing technological solution is given in Table 5.

Table 5

Formulation of the created dyeing process solution using concentrated wastewater

Dye	Fabric	The volume of dye solution (3 %) that must be added to wastewater, cm³	Volume of concentrated wastewater, cm³ (for 80 cm³ of dyeing solution)
Direct Red Light-resistant	Coarse calico (art. 3461)	6.74	73.26
	Viscose (art. 3324)	4.72	75.28
Direct Fast Blue B2RL	Coarse calico (art. 3461)	6.48	73.52
	Viscose (art. 3324)	10.37	69.63

The quality of the obtained colors was determined by the color characteristics indicators given in Table 6.

Table 6

Color characteristics of fabrics dyed with direct dyes compared to the basic technology of PJSC CSP

Dye	Fabric	Lightness DL	Hue (red-green) Da	Hue (yellow-blue) Db	Color difference DE*	Color intensity, % according to the standard (100%)
Direct Red Light-resistant	Coarse calico (art.3461)	−0.1 lighter	+2.22 redder	−0.96 bluer	1.4	**99**
	Viscose (art.3324) [32].	+0.37 lighter	+1.07 redder	+0.43 yellower	1.92	**96.3**
Direct Fast Blue B2RL	Coarse calico (art.3461)	+0.26 lighter	−0.30 greener	−0.07 bluer	0.41	**97.4**
	Viscose (art.3324)	+0.44 lighter	−0.2 greener	−0.96 bluer	1.2	**95.6**

*Color difference is a mathematical representation that allows us to numerically express the difference between two colors in colorimetry. DE should not exceed 2, which approximately corresponds to the minimally noticeable difference between colors for the human eye [33, pp. 29–32].

Photos of the obtained dyed fabric samples are depicted in Figures 3 and 4.

Qualitative indicators of dyed fabric samples' color fastness were studied in accordance with DSTU ISO 105-A02:2005 (Gray Standards Scale), dry and wet friction (DSTU ISO 105-X12:2016), and washing with soap (DSTU EN ISO 105-C10:2020) were investigated (Table 7).

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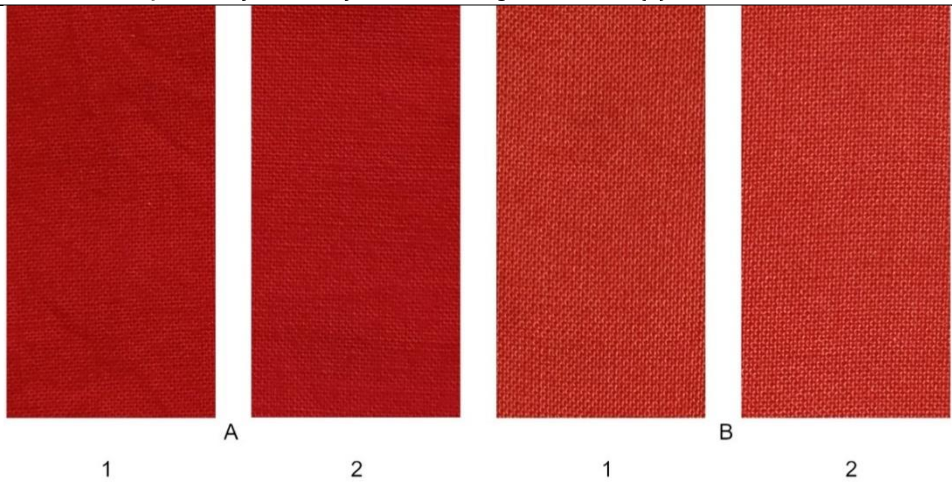

Fig. 3. Samples of cotton fabrics dyed with Direct Red Light-resistant dye: A – Coarse calico fabric (art. 3461), B – Viscose fabric (art. 3324) [32]. 1– technological solution according to the basic PJSC CSP formulation, 2 – created technological solution using concentrated wastewater

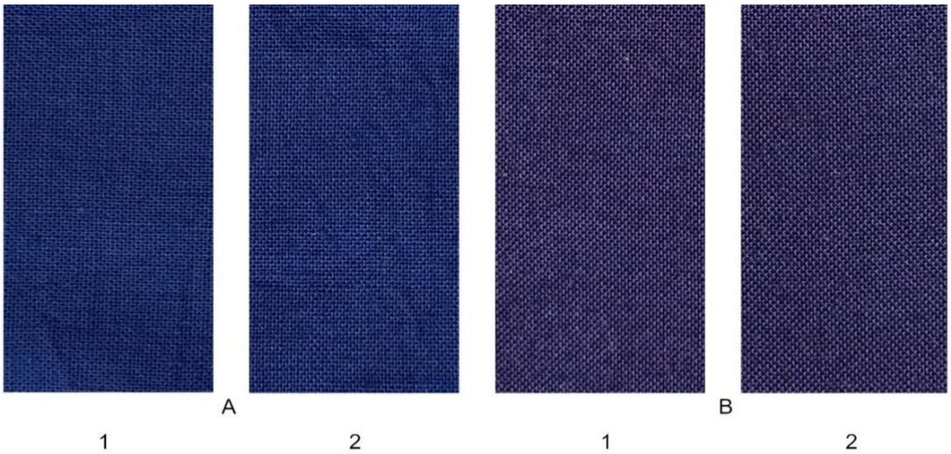

Fig. 4. Samples of cotton fabrics dyed with Direct Blue Direct B2RL dye: A – Coarse calico fabric (art. 3461), B – Viscose fabric (art. 3324). 1 – technological solution according to the basic PJSC CSP formulation, 2 – created technological solution using concentrated wastewater

Table 7

Qualitative indicators of dyed fabric samples' color fastness

Dye	Fabric	Technological dying solution	Dry friction, points	Wet friction, points	Washing with soap, points
1	2	3	4	5	6
Direct Red Light-resistant	Coarse calico (art. 3461)	according to the basic recipe	4	2	3
		according to the new recipe with wastewater	3–4	2	2–3
	Viscose (art. 3324)	according to the basic recipe	3	2	3
		according to the new recipe with wastewater	3–4	2-3	3
Direct Fast Blue B2RL	Coarse calico (art. 3461)	according to the basic recipe	4–5	2	3–4
		according to the new recipe with wastewater	4–5	2	3–4
	Viscose (art. 3324)	according to the basic recipe	3–4	2	3–4
		according to the new recipe with wastewater	3–4	2	3–4

Therefore, the results of the dye intensity values of the colored fabrics and quality indicators show that the cotton fabrics dyed according to the new recipe using concentrated wastewater correspond to the samples dyed according to the basic recipe (color intensity in the range of 95–99 % compared to the standard, colour difference value does not exceed 2).

A Jigger discontinuous roller dyeing machine (Vald. Henriksen, Netherlands) colors 1200 running meters (RMTs) of fabric during one stage (pass). The savings in consumption of direct dyes for dyeing cotton fabrics according to a new recipe using wastewater is calculated mathematically according to the formula:

$$E = C_b - C_n, \quad (1)$$

where E is the cost savings of using a direct dye when coloring cotton fabric according to a new recipe with concentrated wastewater, $/1200 RMTs of fabric.

Of using direct dye when dyeing cotton fabrics according to a new formulation with concentrated wastewater

C_b – is the cost of direct dye according to the basic production recipe, $/1200 RMTs of fabric.

C_n – is the cost of direct dye consumption of substantive coloring agents according to the new recipe using concentrated wastewater, $/1200 RMTs of fabric.

The results of mathematical calculations are presented in Table 8. The costs of dyes were calculated based on prices as of April 2023.

Table 8

Saving costs of using direct dyes when dyeing cotton fabrics with concentrated wastewater

Dye	Fabric	Technological dying solution	The cost of dye consumption, $/1200 RMTs of fabric	Saving on dye consumption E, $/1200 RMTs of fabric	Saving on dye consumption E, %
Direct Red Light-resistant	Coarse calico (art. 3461)	according to the basic recipe	149.47	34.26	22.92
		according to the new recipe with wastewater	115.21		
	Viscose (art. 3324)	according to the basic recipe	146.98	45.62	31.04
		according to the new recipe with wastewater	101.36		
Direct Fast Blue B2RL	Coarse calico (art. 3461)	according to the basic recipe	97.76	23.97	24.52
		according to the new recipe with wastewater	73.79		
	Viscose (art. 3324)	according to the basic recipe	96.17	8.87	9.22
		according to the new recipe with wastewater	87.30		

The average indicator of the economic efficiency of direct dyes costs is 21.93 % for every 1200 RMTs of cotton fabric (Fig. 5).

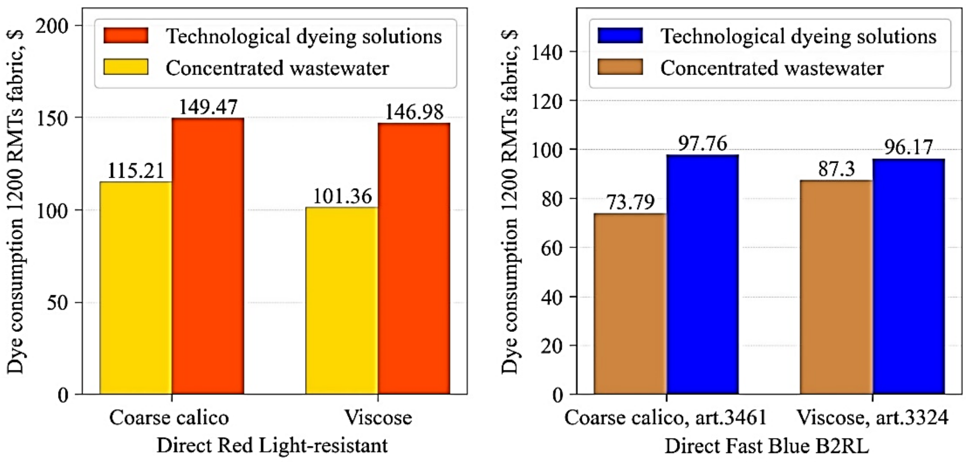

Fig. 5. Reduced consumption of direct dyes by using concentrated wastewater for every 1200 RMTs of cotton fabric

Conclusions

Concentrated wastewater is the liquid waste of the fabric dyeing process from discontinuous equipment, which contains an average of 30–40 % textile dyes. All these create prerequisites for practical research on its reuse as high-quality secondary raw material in fabric dyeing technology.

A new technological solution composition for dyeing cotton fabric Calico and Viscose with Direct Blue B2RL dye and Calico fabric with Direct Red Lightfast dye, which includes concentrated wastewater and a native solution of direct coloring agents, was proposed and tested in practice for the first time. The recipe composition was based on the research of the physical and chemical properties of the basic technological solution (real production) and the obtained concentrated wastewater. It has been practically investigated that the use of a new composition of technological dyeing solution with concentrated wastewater ensures the color intensity of the dyed cotton fabric at the level of 95–99 % compared to the standard (100 %), and the stability of the obtained color is at the level of 2–4 points on the gray standards scale. The color difference has the smallest value (DE < 2) between the reference and dyed samples. The qualitative color fastness indicators of the obtained samples are within the numerical limits of the reference ones.

For the first time, a new composition of a technological solution for dyeing cotton fabrics Calico and Viscose with Direct B2RL Direct Blue dye and Calico fabric with Direct Red Lightfast dye, which includes concentrated waste water and a native solution of direct dye, was proposed and tested in practice.

It was calculated for the first time that the cost savings of substantive coloring agents when dyeing cotton fabric according to a new recipe using concentrated wastewater is an average of 21.93 % for every 1200 RMTs of fabric.

The obtained results can serve to solve the scientific and practical task of creating new resource-saving technologies for dyeing textile materials, which would ensure a decrease in the cost of textile products and a reduction in the environmental impact on water resources.

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