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FUNCTIONALITY OF SURFACTANTS IN ANTIBACTERIAL TREATMENT PROCESSES OF TEXTILE MATERIALS BASED ON COTTON-POLYESTER FIBERS

Purpose. *Theoretical justification of the use of textile auxiliarie compounds in the creation of dye nanosystems for antibacterial treatment of cotton-polyester fabrics, establishment of the influence of surfactants on the dimensional characteristics of the dye and the efficiency of dyeing textile materials from a mixture of fibers.*

Methodology. *Developed technologies of antibacterial treatment of cotton-polyester textile materials were implemented. Surface tension of surfactant solutions was investigated by stalagmometric method. Dimensional characteristics of dye particles were determined using the NANOSIZER nanoparticle size and zeta potential analyzer. The strength indicators of developed samples to physicochemical influences were studied in accordance with standardized methods of textile materials science.*

Results. *The feasibility and experimentally proven functionality of surfactants in the processes of antibacterial treatment of mixed-type textile materials are characterized. The advantages are highlighted and the choice in favor of a nonionic surfactant is analyzed. The results of experimental studies of the specified samples and data on the analysis of the dimensional characteristics of the dye with the formation of nanosystems in the presence of surfactants for the antibacterial treatment of cotton-polyester textile materials are presented. The dimensional characteristics of the dye particles are experimentally determined for each concentration of surfactants and the influence of surfactants on the production of aggregate-stable nanodispersions is established.*

Scientific novelty. *It has been proven that nonionic surfactants contribute to the achievement of nanosized particles and effective sorption in the fiber medium of a mixed composition, taking into account the nanoscale of the dye, which is directly correlated with the uniformity, intensity, and saturation of the resulting color of the developed samples of the studied fabrics.*

Practical value. *The use of the dye-textile material nanosystem will ensure the dyeing of textile materials of various raw material composition and fiber mixtures, which will not only reduce the temperature, but also eliminate bactericidal treatment at the final finishing stage, which will simplify the technological process, obtain special properties of the textile material, and improve the technical and economic indicators of the finished antibacterial and antimicrobial textile.*

Keywords: *cotton-polyester fabric, surfactant, intensifier, dyeing, coloring.*

ФУНКЦІОНАЛЬНІСТЬ ПОВЕРХНЕВО-АКТИВНИХ РЕЧОВИН У ПРОЦЕСАХ АНТИБАКТЕРІАЛЬНОЇ ОБРОБКИ ТЕКСТИЛЬНИХ МАТЕРІАЛІВ НА ОСНОВІ БАВОВНЯНО-ПОЛІЄСТЕРНИХ ВОЛОКОН

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Мета. *Теоретичне обґрунтування застосування текстильно-допоміжних сполук при створенні наносистем барвників для антибактеріальної обробки бавовняно-поліестерних тканин,* *встановлення впливу поверхнево-активних речовин на розмірні характеристики барвника та ефективність фарбування текстильних матеріалів із суміші волокон.*

Методи. *Реалізовано розроблені технології антибактеріальної обробки бавовняно-поліестерних текстильних матеріалів. Досліджено поверхневий натяг розчинів поверхнево-активних речовин сталагмометричним методом. Визначено розмірні характеристики частинок барвника з використанням аналізатора розмірів і дзета-потенціалу наночастинок NANOSIZER. Виконано дослідження показників міцності розроблених зразків до фізико-хімічних впливів у відповідності до стандартизованих методик текстильного матеріалознавства.*

Результати. *Охарактеризовано доцільність та експериментально доведена функціональність поверхнево-активних речовин у процесах антибактеріальної обробки текстильних матеріалів змішаного типу. Висвітлено переваги та проаналізовано вибір на користь неіоногенної поверхнево-активної речовини. Подано результати експериментальних досліджень зазначених зразків і дані аналізу розмірних характеристик барвника з утворенням наносистем у присутності поверхнево-активних речовин для антибактеріальної обробки бавовняно-поліестерних текстильних матеріалів. Експериментально для кожної концентрації поверхнево-активних речовин визначено розмірні характеристики частинок барвника та встановлено вплив поверхнево-активних речовин на отримання агрегативно стійких нанодисперсій.*

Наукова новизна. *Доведено, що неіоногенні поверхнево-активні речовини сприяють досягненню частинками нанорозмірів і ефективній сорбції у волоконному середовищі змішаного складу з урахуванням наностану барвника, що прямо взаємопов'язано з рівномірністю, інтенсивністю та насиченістю отриманого забарвлення розроблених зразків досліджуваних тканин.*

Практична значимість. *Застосування наносистеми барвник – текстильний матеріал забезпечить фарбування текстильних матеріалів різного сировинного складу та з сумішей волокон, що дозволить не лише знизити температуру, але й виключити бактерицидну обробку на стадії заключного опорядження, завдяки чому відбудеться спрощення технологічного процесу, отримання спеціальних властивостей текстильного матеріалу і покращення техніко-економічних показників готового антибактеріального та антимікробного текстилю.*

Ключові слова: *бавовняно-поліестерна тканина, поверхнево-активна речовина, інтенсифікатор, фарбування, забарвлення.*

Introduction. The development of technologies for providing antimicrobial protection to textile materials provides safety and durability of textile products, contributing to their widespread implementation in various industries. For example, light industry, pharmaceuticals, medicine, transport, tourism, agriculture. Antimicrobial protection of textile products reduces the spread of infections, increases hygienic properties and increases their service life.

The choice of the type of antibacterial, antifungal protection for textile materials should be based on specific operating conditions. The antimicrobial properties of materials must be stable and effective in the conditions where they will be used by the consumer [1–3].

Given the great risks posed to humanity by global pandemics and the full-scale war in Ukraine, the development of domestic production of antibacterial textile materials is extremely important. The resulting demand for personal protective equipment requires the production of competitive special-purpose products that must meet global quality standards.

The introduction of technologies for producing textile materials with antibacterial properties in Ukraine can become a strategic direction for strengthening national security. First of all, this is ensuring the safety of medical personnel, military personnel, rescuers and civilians who need constant protection from infectious threats, toxic and biological contamination. The development of technologies for producing antibacterial textile materials will reduce dependence on imported products and reduce costs [4].

Analysis of previous research. The issue of creating antibacterial textile materials is receiving special attention. Since the beginning of the coronavirus pandemic, there has been a significant increase in the number of scientific studies related to the development and improvement of textile materials with antimicrobial properties [5]. These materials are able to prevent the reproduction of bacteria, viruses and other pathogens on surfaces, which is especially important for reducing the risks of the spread of infectious diseases in various fields, including medicine, military affairs, the sports industry and everyday life [6]. Textile products with antimicrobial treatment must meet the following requirements: prevent, control and/or eliminate microbial contamination, growth and cross-infection of a wide range; reduce unpleasant odor, prevent the appearance of stains and maintain freshness for a long time; must be safe, durable and suitable for multiple use [7].

The optimal biocide for textile materials should have: a wide spectrum of antimicrobial action against pathogenic and harmful microorganisms; resistance of the biocidal effect to washing and dry cleaning of textiles; colorlessness; achievement of the effect at low concentrations; affordable cost; ease of application; not to deteriorate the physical, mechanical and chemical parameters of textile materials; compatibility with other textile auxiliary compounds (TACs). These requirements contribute to the effective use of biocides in the textile industry, while ensuring hygiene and preservation of product properties [8].

A method of processing textile material [9] is known, which is carried out in several stages: the first stage consists in treating bleached cotton fabric with triclosan in order to obtain an antibacterial textile material. The second stage consists in further processing with the action of polycarboxylic and citric acids as crosslinking agents to prolong antibacterial properties.

However, the process of treating textile materials to impart antibacterial activity to cotton fabrics treated with triclosan using 1,2,3,4-butanetetracarboxylic acid and citric acid changes the surface of the fibers of the textile material. The surface of the fibers treated with 1,2,3,4-butanetetracarboxylic acid had a larger crosslinking area, and the surface of the fabrics treated with citric acid had a larger number of deformations due to mechanical and chemical effects after 50 washes, which leads to damage to the textile material.

There is also a known method of treating fibrous materials using triclosan, where triclosan is used as an azo component in the synthesis of an azo dye in the process of finishing fibrous materials [10]. Due to this method of treatment, prolonged antimicrobial properties are achieved and the strength of dyed fibrous materials to washing is increased. However, the technological process is complicated by the fact that to ensure the implementation of this method of imparting antimicrobial properties to textile materials, the prepared cotton fabric is first impregnated with a solution of triclosan sodium salt and squeezed, then the cotton fabric is dried. The next stage is the impregnation of the fabric with a diazo compound solution at 20 °C with subsequent squeezing, which leads to additional technological operations (drying between the first and second impregnations) and causes an increase in energy consumption and labor intensity of production.

In works [8, 11, 12] the direction of deposition of nanoparticles of numerous types of nanomaterials with antimicrobial properties is shown: copper, zinc, titanium, magnesium, titanium, gold.

According to scientific works [5-7], [11], [13] the most popular biocides today is silver in various forms. Silver has a greater biocidality than copper, gold, zinc. The wide spectrum of biocidal action of silver ions, in comparison with other biocides, provides protection against Staphylococcus aureus, Pseudomonas aeruginosa and Escherichia coli, Proteus vulgaris, which are dangerous to humans. Silver ions deactivate smallpox viruses, influenza strains, inhibit other viruses dangerous to humans.

Various solutions mentioned above are used to create textile materials with antimicrobial properties. The use of nanotechnology for high-quality dyeing of synthetic textile materials with paraphenylenediamine derivatives [14] is known, as well as for obtaining conductive, magnetic and protective properties of textile materials of various raw material composition [15] using surfactants (SAS). However, the literature practically does not cover periodic methods of chemical technology of textile materials with the use of surfactants to create nanosystems with the aim of providing antibacterial properties, which will have significant advantages when treating mixed-type fabrics with triclosan.

Task statement. In this regard, it is advisable to create a method for obtaining antibacterial textile material, in which dyeing is carried out in the presence of an intensifier using sorption in the dye-textile nanosystem and at the same time provides antibacterial and antimicrobial properties of a wide spectrum of action.

The purpose of the work is to theoretically substantiate the use of surfactants in the creation of dye nanosystems for antibacterial treatment of cotton-polyester textile materials, to establish the influence of surfactants on the dimensional characteristics and dyeing efficiency of textile materials from a mixture of fibers.

Methods of research. Research, development of technologies and production of samples of antibacterial textile materials were carried out in the educational and scientific laboratory «Expertise of Textile Materials and Products» of the Kyiv National University of Technologies and Design as part of the implementation of scientific and technical work under the State Order for Scientific and Technical (Experimental) Developments for Scientific and Technical Products «Development of Technologies for Finishing Textile Materials for Individual Protection of Military Personnel» under contract No. State Order/151 – 2023 dated October 30, 2023 (State registration number: 0123U104388).

Textile materials from a mixture of fibers were used as the raw material base, namely cotton-polyester twill weave fabrics from various manufacturers.

The first stage of finishing textile materials included the preparation of textile materials. The second stage consisted of direct processing (dyeing) of textile materials using a periodic method. Bath module – 30; disperse dye (Setaprs Black CE-RN) – 2 g/l; dye concentration – 5% of the sample mass; intensifier (triclosan) – up to 4 g/l; nonionic surfactant (OP-10) – 2 g/l; ammonia – 0.5 ml/l, acetate – 2% of the sample mass; temperature – 95 0C, duration – 60 min. Treatment with soap and soda solution and then washing, drying.

The surface tension of surfactant solutions was determined by the stalagmometric method [16] according to the formula:

$$\sigma_{\div} = \sigma_0 \left(\frac{n_0 \rho_x}{n_x \rho_0}\right)$$

where ρ_0 – density of the reference liquid; ρ_x – density of the liquid being investigated.

The values of the density of the reference and investigated liquids are taken from reference tables and in the absence of data, the density of liquids is determined by a densimeter or pycnometric method. First, surfactant solutions of different concentrations in g/l are prepared: 0.01; 0.05; 0.1; 0.5; 1.0; 1.5, 2 – 20. The surface tension of all prepared solutions is measured at a constant temperature. The surface tension is calculated using the equation and a graph of the dependence of the surface tension on the concentration of the solution is constructed using the data obtained.

The NANOSIZER Malvern Nano Z ZEN2600 nano particle size and zeta potential analyzer was used to analyze the size of dye particles (Fig. 1).

Table 1 shows the characteristics of the NANOSIZER Malvern Nano Z ZEN2600 nanoparticle size and zeta potential analyzer.

Fig. 1. **Malvern Nano Z NANOSIZER Malvern Nano Z ZEN2600 nanoparticle size and zeta potential analyzer**

Table 1

Characteristics of the NANOSIZER Malvern Nano Z ZEN2600 nanoparticle size and zeta potential analyzer

Particle size measurement	0.3 nm – 10 µm (diameter)
Measurement principle	dynamic light scattering
Minimum sample volume	12 µl
Accuracy	Better than +/- 2% when using NIST-traceable reference materials
Accuracy / repeatability	Better than +/- 2% when using NIST-traceable standard samples
Sensitivity	0.1 mg/ml (lysozyme)
Concentration range	0.1 mg/ml – 40% vol.

The resistance of treatments to physical and chemical influences was determined according to the methods provided for by the current State Standards of Ukraine (DSTU ISO 105-A02 DSTU ISO 105-A03). Namely, resistance to washing at 30 °C (change in sample color/staining of adjacent fabric) DSTU ISO 105-S06:2009 – 4/4 points, to dry and wet rubbing (change in sample color/staining of adjacent fabric) DSTU ISO 105-X12:2009 – 4/4 points.

Research results and discussion. A large part of the range of textile auxiliary compounds in terms of use, and especially in terms of the nomenclature list, is occupied by surfactants [17]. Therefore, it is important to know their properties and how they are affected by the parameters of the technological process. Surfactants are products that, when dissolved in water, even in very small concentrations, significantly reduce the surface tension of water in relation to air or at the interface with other substances. Due to the peculiarities of their molecular structure, surfactants are located on the interface of aqueous solutions and thus reduce their surface tension.

Surfactants are divided into three main groups by the nature of their ions, depending on the peculiarities of the structure of molecules: anionic, cationic, non-ionic. Surfactants in the textile industry are mainly used as: detergents, antistatics, leveling agents, dispersants, emulsifiers, wetting agents.

The use of nonionic surfactants in the antibacterial treatment of mixed-type fabrics is due to the fact that both anionic and cationic surfactants dissociate in water, forming negatively or positively charged surface-active ions. Anions or cations are adsorbed by the surface from solutions of such surfactants, as a result of which it becomes negatively or positively charged. Thus, negatively or positively charged particles of the dispersed phase stabilized by such surfactants will be selectively absorbed from the treatment bath by negatively charged plant fiber much more intensively and completely than negatively charged particles stabilized by anionic surfactants. But the ability to dissolve in water can be given to the molecule by another group of atoms that does not form ions, that is, nonionic. In many cases, this is of practical importance, especially in the case of the formation of a nanosystem.

The introduction of surfactants into the treatment bath must meet the following requirements: 1) reduce the interfacial tension (in some cases to a minimum); 2) provide the particles with a larger electrical charge, counteracting the reverse fusion of the particles; 3) envelop the particles due to the adsorption of highly hydrated molecular layers.

That is, in this case, the functionality of nonionic surfactants is of great importance. Dyeing of mixed cotton-polyester textile materials is complicated by the hydrophobicity and dense structure of polyester fibers, which do not swell sufficiently in water and make it difficult for the dye to penetrate the fiber. This significantly slows down diffusion processes, therefore, when dyeing such mixed textile materials, it is advisable to carry out dyeing in the presence of intensifiers (carriers) [18] and to use nano-sized dye dispersions, which will significantly affect the efficiency of dyeing with high-quality fixation of dyes inside polyester fibers.

In the course of research, considerable attention was paid to ensuring the maximum yield of dye in the textile material during its absorption from the processing solution. For this, favorable conditions were created for the diffusion of the dye into the textile material by increasing the gradient of dye concentrations. To increase the amount of dye in cotton-polyester textile material, nanotechnological approaches were used to achieve nanosize dye using surfactants [15]. Ideally, the maximum interaction with the textile material should belong to nanosize particles of the dispersed phase. The number of dye particles can be commensurate with the number of surfactant micelles (nanosize), as a result, the number of surfactant molecules spent on adsorption filling of the surface of dye particles can lead to an increase in the total surfactant concentration at which micelle formation occurs. In this case, the total number of surfactant molecules is determined by their number in the solution itself, the number of molecules adsorbed on the dye particles and on the textile material.

The proposed assumption can be tested experimentally: 1) by determining the size of the dye particles in the dispersion; 2) by determining the surface tension of the dye baths after dispersing the dye in the presence of a surfactant.

In this regard, the first stage was the determination of the critical micelle concentration (CMC) of surfactants by the stalagmometric method [16]. Since all surfactants are technical and multicomponent products, the properties of the preparations can vary from batch to batch depending on the composition, presence of impurities and concentration of the active substance. In this regard, for nonionic surfactants, the CMC was determined at which a further increase in the surfactant concentration does not lead to a decrease in the surface tension of the aqueous solution of the surfactant [16]. To determine the CMC, the experimental data were presented in semi-logarithmic coordinates (Fig. 2) [16]. From Fig. 2 it is seen that for OP-10 CMC = 0.1 – 0.5 g/l at surface tension values equal to 59.36 mJ/m^{2}.

As objects of research, 4 solutions of disperse dye Setaprs Black CE-RN with a concentration of 2 g/l with nonionic surfactant OP-10 were

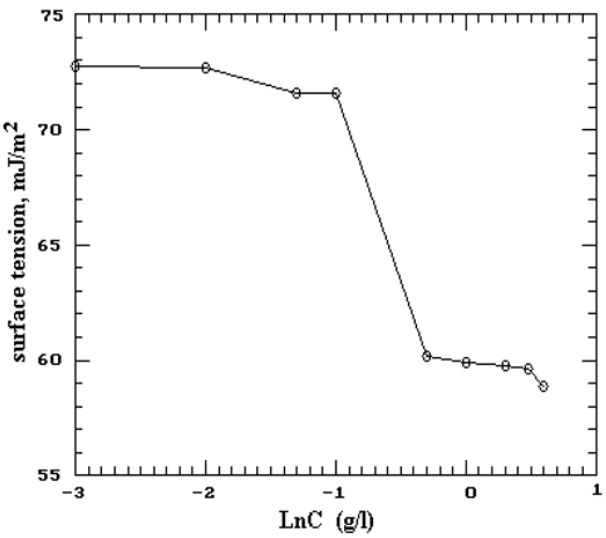

Fig. 2. **Surface tension isotherm of an aqueous solution of nonionic surfactant**

prepared. Variation of the concentration of nonionic surfactant OP-10: 0.5; 1.0; 1.5; 2 g/l (Fig. 3).

Fig. 3. **Dispersions of Setaprs Black CE-RN dye with nonionic surfactant of different concentrations**

According to the results of the study of dye solutions on the size and zeta potential of nanoparticles analyzer, the curves of the distribution of dye particle sizes depending on the concentration of nonionic surfactant were obtained (Fig. 4 – Fig. 7). The study for each solution was repeated from 10 to 15 times for the reproducibility of the result (in the figures, the curves are of different colors). It was established that the peaks recorded in the spectral analysis of the solutions are in the range of 10 – 100 nm, which indicates the presence of nanosized dye particles in the solution.

With an increase in the concentration of nonionic surfactant (OP-10), within the critical concentration of micelle formation, from 0.5 g/l to 2 g/l, the average particle size decreases.

With an increase in the amount of surfactant in the dyeing solution, the dye is absorbed by the textile material from the mixture of fibers in the nanolayer from the micellar solution, which effectively affects: the adsorption of surfactant on the surface of dye molecules, transforming and stopping its growth at the nanolevel and preventing the aggregation (agglomeration) of dye particles with each other, making it impossible to enlarge and increase the particle within 100 nm.

The results of the experiment allow us to compare the degree of influence of four different concentrations of surfactants by the magnitude

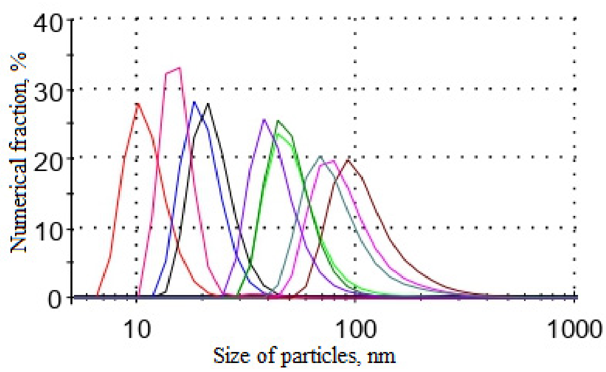

Fig. 4. **Dye particle sizes at a surfactant concentration of 0.5 g/l**

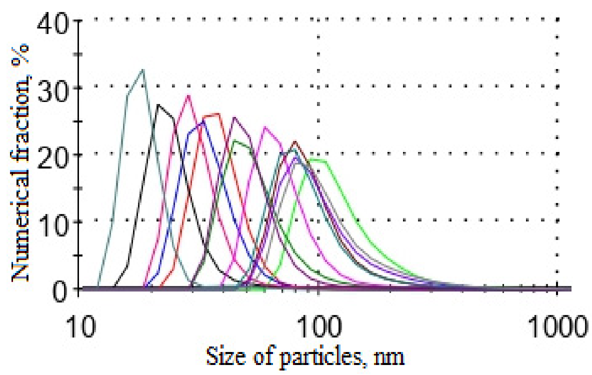

Fig. 5. **Dye particle sizes at a surfactant concentration of 1.0 g/l**

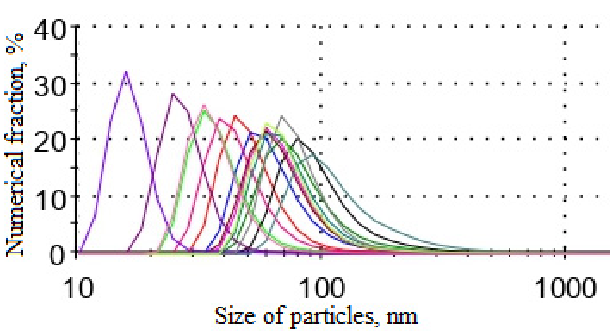

Fig. 6. **Dye particle sizes at a surfactant concentration of 1.5 g/l**

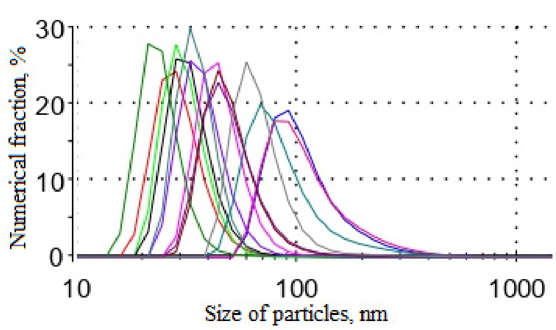

Fig. 7. **Dye particle sizes at a surfactant concentration of 2.0 g/l**

of their effective concentration. For each specific concentration of surfactant, the average size of dye particles in the nanodispersion was determined and the effect of surfactant on the efficiency of processing (dyeing) was established: surfactant concentration 0.5 g/l - average nanoparticle size 45.37 nm at a number fraction of 23.52%; surfactant concentration - 1 g/l - average dye nanoparticle size 39.19 nm at a number fraction of 17.34% in the dye nanodispersion; surfactant concentration 1.5 g/l - average dye nanoparticle size 37.88 nm at 19.59% in the dye nanodispersion; surfactant concentration 2 g/l - average lamb nanoparticle size 35.29 nm at 7.3% in the dye nanodispersion.

With increasing concentration of nonionic surfactant, the average particle size in the dye nanodispersion decreases, which has been confirmed experimentally. Analysis of dependencies (Fig. 3, Fig. 4 – Fig. 7) shows that the effective concentration of nonionic surfactant - OP-10, at which the achievement and reduction of nanosizes of the dye is observed, exceeds the critical concentration of micelle formation and is within 1 - 2 g/l. Saturation of the textile material with the dye is achieved by introducing additives of nonionic surfactant with a concentration of 2 g/l, when the surfactant exists in the form of a micellar solution.

It was found that at a concentration of the drug OP-10 within 2 g/l, the number of surfactant molecules in the surfactant micellar solution is sufficient to stabilize the dispersion with an average dye particle size of 35.29 nm, therefore, it is advisable to use a non-ionic surfactant in the processes of antibacterial treatment of textile materials from a mixture of fibers of this concentration.

The effectiveness of dyeing with nanodispersion was evaluated by the degree of fixation of the dye on the cotton-polyester textile material and the uniformity of the resulting color.

To visualize the results obtained, Table 2 shows the characteristics of the structure and appearance of the developed samples of cotton-polyester fabric dyed under different conditions, the change of which will have a significant impact on quality indicators, such as color fastness to dry and wet friction, repeated washing.

Table 2

Samples of cotton-polyester fabrics dyed under different conditions

No.	Dyeing conditions	Article number, raw material composition, %, producing country	Surface density, g/m^2	Sample appearance
1	Without intensifier. Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 170663 Composition, %: polyester – 77, cotton – 20, elastane – 3 China	120,0	
2	With intensifier: - intensifier (5-chloro-2-(2,4-dichlorophenoxy) phenol) – 2 g/l; Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 170663 Composition, %: polyester – 77, cotton – 20, elastane – 3 China	120,0	
3	Without intensifier. Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 148065 Composition, %: cotton – 52, polyester – 48 Turkey	110,0	
4	With intensifier: - intensifier (5-chloro-2-(2,4-dichlorophenoxy) phenol) – 2 g/l; Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 148065 Composition, %: cotton – 52, polyester – 48 Turkey	110,0	
5	Without intensifier. Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 100883 Composition, %: cotton – 55, polyester – 45 Turkey	116,0	
6	With intensifier: - intensifier (5-chloro-2-(2,4-dichlorophenoxy) phenol) – 2 g/l; Dyeing: disperse dye (Setaprs Black CE-RN) – 5% of the sample weight; Surfactant (OP-10) – 2 g/l	Article 100883 Composition, %: cotton – 55, polyester – 45 Turkey	116,0	

As objects of research, 6 samples of fabrics of the same raw material composition, differing in the content of the synthetic component, and dyed with the dye Setaprs Black CE-RN with surfactant OP-10 of a constant concentration (2 g/l), which are considered promising for implementation in the development of means for individual protection of the military and civilians of Ukraine, were selected.

The images of the specified samples presented in Table 2 demonstrate changes in appearance depending on the finishing conditions associated with the introduction or absence of an intensifier at the dyeing stage with the simultaneous provision of antibacterial properties to textile of a particular raw material composition for individual protection of military personnel.

The obtained results make it possible to establish the influence of conditions on the effectiveness of dyeing cotton-polyester fabrics with dispersed dyes with an intensifier and nonionic surfactants, the introduction of which significantly affects the sorption of the dye by the fiber medium and, as a result, facilitates its diffusion (penetration) into polyester fibers. This is confirmed by the intensity, leveling and uniformity of coloring, the overall noticeably pronounced and saturated color difference of the obtained samples, which indicates greater penetration and fixation of dye nanoparticles inside the textile material from a mixture of fibers.

Thus, the above allows us to summarize that:

- the functionality of non-ionic surfactants consists in dispersing (grinding) and stabilizing the dispersion, determining the dimensional characteristics of the dye and in influencing the strength of the interaction of nanoparticles with the textile material due to sorption in the textile material, which ensures uniform coloring of textile materials from a mixture of fibers;

- dyeing of cotton-polyester fabrics is advisable to be carried out using both an intensifier (providing antibacterial properties) and a nonionic surfactant (achieving nano-size dye particles), which also provides high indicators of strength to physico-chemical influences (table 3, for sample 2).

Conclusions. The functionality of surfactants in the processes of antibacterial treatment of mixed-type textile materials is theoretically substantiated and experimentally proven. The advantages are highlighted and the choice in favor of nonionic surfactants is analyzed. The results of experimental studies of the specified materials and data on the analysis of the dimensional characteristics of the dye with the formation of nanosystems in the presence of surfactants for the antibacterial treatment of cotton-polyester materials are presented.

Experimentally, for each concentration of surfactant in dispersion with the dye, its dimensional characteristics are determined and the influence of the surfactant on obtaining aggregate-stable dispersions with dye nanoparticles is established. It is proven that nonionic surfactants contribute to the achievement of nanosize particles by particles and effective sorption in the fiber medium of the mixed composition taking into account the nanostate of the dye, which is directly interrelated with the uniformity, intensity and saturation of the obtained color of the developed samples of the studied fabrics. The use of the dye-textile material nanosystem will ensure the dyeing of textile of various raw material composition and fiber mixtures, which will not only reduce the temperature, but also eliminate bactericidal treatment at the final finishing stage, which will simplify the technological process, obtain special properties of the textile material, and improve the technical and economic indicators of the finished antibacterial textile.

Table 3

Properties indicators of a sample of antibacterial textile material

No.	Indicator titles	Measurement units	Indicatori	Measuring tools
1.	Durability of treatments before washing (washing No. 1-5), not less	Points	5/5/5 – 4/4/5	DSTU ISO 105-C06:2009 Scale of gray standards
2.	Friction resistance of treatments: - dry, not less - wet, not less	points points	5 4–5	DSTU ISO 105-X12:2009 Gray scale standards

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