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Improvement of Textile Materials Processing Techniques by Applying Aqueous Dispersions of Polymers

Luidmila Petrova, Rodion Grishin, Anvar Zimnurov, Olga Kozlova *, Olga Odintsova * and Elena Sangeeva

Department of Chemical Technology of Fibrous Materials, Organic Faculty, Ivanovo State University of Chemistry and Technology, Sheremetevsky Ave., 7, 153000 Ivanovo, Russia

* Correspondence: kozlova_ov@isuct.ru (O.K.); odintsova_oi@isuct.ru (O.O.)

Abstract: This paper presents the results of studies in the field of polymer materials application for fabric modification. The aim of the study is to identify the most effective technique of deposition of Russian-made formulations of an acryl and urethane nature with pigment compositions in the processes of functional fabric production. The authors analyze the efficiency of three processing solutions: the technology of uniform dyeing with pigments consisting of coating the fabric surface with a pigment–polymer composition, the technology of obtaining "camouflage" fabrics based on a conceptually new approach to creating the IR-remission effect on printed fabrics, and the technology of creating a stable retro-reflective effect on a fabric through the use of polymers produced in Russia. The paper also shows the conceptual differences in the pigment distribution mechanisms in the fiber or in the polymer matrix depending on the technique of fabric coating. The cheapest and safest technique for the environment is the squeegee method of pigment application, which provides fabrics with both oil- and water-repellent properties. An innovative technology has been developed based on the squeegee method for achieving the IR-remission effect on fabrics with "camouflage" patterns. A series of physico–chemical tests (spectrophotometry, electron microscopy), as well as assessment of the consumer properties of the obtained textile materials confirmed the efficiency of using aqueous dispersions of acrylic polymers made in Russia for producing competitive functional fabrics.

Keywords: synthetic materials; acrylic polymers; urethane polymers; surface modification; coating; pigment coloring; IR remission; camouflage; retro-reflective materials

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1. Introduction

The latest advances in science-intensive technologies have made it possible to expand the range of functional properties given to textile materials. Innovative developments are being actively introduced in the production of textile materials, and the goods made from them. Special types of textile materials with optimized characteristics are being developed based on the use of methods of physical and chemical modification with polymers [1–3].

The advent of new-generation polymers (copolymers of an acrylic and urethane nature, hybrid polymer preparations) has enabled a wide variety of color and other special effects to be created on textile materials [4,5]. Fibers, yarns, and fabrics modified in various ways with polymers are being produced for engineering applications, such as rubber product reinforcement and the production of fire retardant and ion exchange goods for medicinal and other purposes. Other applications include signaling; protective; water-, oil-, and soil-repellent coatings; and retro-reflective fabrics, which have been growing in demand lately.

The market of textile materials (TM) has been conquered by polymer-modified "human-friendly" ("Shin gosen") fabrics with improved characteristics [6,7]. For example, the Russian company "Tchaikovsky Textile" developed a series of innovative fabrics: FRall (with a fire-retardant finish), Premier Standard 250i (with a "wash and wear" soil-, oil-, and water-repellent finish), Premier Standard 180 AntiBacterial, and Panacea Cotton Rich

150 AntiBacterial (with an antimicrobial finish). The technology of their production is based on the use of new-generation chemicals, which leads to the formation of water-insoluble polymer coatings on the fiber and, at the same time, of strong chemical bonds between the polymer and the fiber.

Polymers are increasingly used in the pigment coloring of textile materials as binders [8–10]. Acting as auxiliary substances, polymers are applied as surface modifiers for textile materials, as well as primers in inkjet and transfer printing [11,12]. Fabric pre-treatment with polymers allows pigments to be fixed on textile materials of different fibrous compositions. The advantages of the inkjet printing technology include full-color transfer of a pattern to a fabric with high photographic quality and the achievement of improved color and strength characteristics of colors [5,13,14].

The primer choice depends on the chemical composition of the fabric being processed and on the requirements of the final print result. By changing the recipe and the technological mode of fabric preparation for printing, it is possible to achieve the required degree of diffusion and depth of dye penetration into the material, print clarity, and fabric stiffness, as well as color fastness to washing [15,16].

Papers [17,18] describe a method for treating the surface of mixed fabrics with an emulsion based on a foamed polymer, which provides stable colors for operating conditions and good compatibility with most inkjet inks. The disadvantage of this method, which limits its application in mass production, is the use of special equipment and careful observance of fire and explosion safety measures.

Companies, such as Kornit Digital, EPSON, HP, PrinteXcom, DuPont, and Lectra offer a large number of materials for inkjet printing, including primers [19–21]. The FIREBIRD™ FBX primer (Universal DTG Pretreatment, US) is applied with professional spray guns, airbrushes, and automatic devices, with subsequent drying of the textile material [22]. A number of companies produce equipment for optimized technological processes, where priming is integrated in a complex and is automatically carried out before printing, which is then performed on the wet material [23].

Although inkjet printing is easy to use, its disadvantage is the high price of foreign equipment and the need to use branded chemicals, the composition of which is not disclosed by the supplier companies.

Xie Kongliang [24] studied the process of surface modification of a dyed polyester microfiber fabric with fluoromonomers. After the surface modification, the microfiber fabrics dyed with three different dyes showed high color intensity values.

Surface modification of textile materials using polymers has become increasingly popular as a method of functional finishing. Paper [25] describes various methods of modifying textile materials, but all of these methods have a number of disadvantages: solvent-based systems are explosive, flammable, and, like most solvents, poisonous or have other undesirable side effects. Water-based adhesive systems consume a significant amount of energy to evaporate moisture and form a polymer film. Powder adhesives are of limited use as machine working areas tend to get contaminated with dust.

New types of water-dispersible preparations—Steron, Lurapret, and Texapret—based on acryl and urethane polymers are now being offered for surface modification of fabrics at the coloring and finishing stages for providing fabrics with certain functional properties [26–28].

The world market has recently seen the appearance of finely dispersed emulsions of new generation film-forming acrylic polymers capable of not only modifying the surface of a textile material, but also penetrating deeply into the fiber and interacting with its functional groups, which make it possible to create competitive fabrics with improved stable properties. The functional components of the binders (for example, the presence of epoxy groups) affect not only the pigment fixation on the textile material, but also modify the fiber surface and increase the color intensity [29–31].

Numerous studies described in the literature [3,32–35] show that such Russian acrylic and polyurethane preparations as Ruzin-14i, Lacroten-63, Emultex-5BN, Disteks, and

Aquapols can be successfully used in pigment coloring as binders and compete with foreign analogs.

Several variants of surface modification have been developed, including chemical cross-linking reactions of copolymers, plasma methods, and sol-gel processes. The introduction of new active groups into the polymer by copolymerization, as well as subsequent chemical treatment of fibers or textiles, can improve the consumer properties of textile materials and products; increase their dyeability, hydrophilicity, and sorption properties; and reduce wrinkling and contamination, as well as provide them with antistatic, fire retardant, and bactericidal properties [36–38].

All this indicates the necessity and relevance of the research in the field of the application of polymeric preparation for providing textile materials with new or improved functional properties. Further development of polymer chemistry and its application in the technology of textile materials modification will expand the range of manufactured textile products, which is technically, economically, and environmentally reasonable.

The most promising and environmentally valid dyes for mixed textile materials are pigments. They are ideal in compatibility with fibrous dyeing substrates of any composition. Pigment particles are "glued" to the surface of the substrates with the help of a polymeric binder, and this dyeing technology excludes sorption and diffusion processes.

An especially important trend in the development of technologies of obtaining fabrics with functional properties is designing techniques for the production of textile materials with properties fully satisfying the requirements of military and law enforcement agencies [39]. Fabrics of this category must meet IR-remission requirements [39]. The necessary IR-remission is normally achieved by adding a black (soot) pigment of a mineral nature to pigment dyes used to create patterns in the colors of the RGB or CMY triad. This method is more labor-consuming than the one suggested by the authors and requires careful adjustment of the colors to the standard when viewed in visible and night light.

Further development of polymer chemistry and its application in textile materials modification technologies will make it possible to broaden the range of textile goods produced, which is technically, economically, and environmentally justified.

The aim of the present work is to develop a series of technologies of textile material processing based on the application of Russian-made polymers that will improve the current methods (such as pigment dyeing), to find conceptually new processing solutions (achieving the IR-remission effect on camouflage fabrics) or to produce competitive textile materials by replacing foreign preparations with Russian ones (retro-reflective fabrics).

The relevance of the development and improvement of the technologies considered by the scientific community around the world is obvious as more and more attention is being paid to the quality of textile materials and their safe use in clothing for employees of law enforcement agencies, the Ministry of Emergency Situations, road workers, athletes, and children.

2. Materials and Methods

2.1. Materials

The object of the study was cotton–polyester and polyester fabrics with different surface density values, produced by Russian companies—OOO Nordtex (Rodniki, Russia) and OOO BTK Textile (Shakhty, Russia): polyester fabric (100%), art. 09S20-KV, with a surface density of 95 g/m^2, cotton–polyester (33/67), art. 83009, with a surface density of 255 g/m^2.

The pigments used were purchased from the Russian company Zavolzhsky Pigment (Zavolzhsk, Russia). The size of the pigment particles is 0.5–1.0 μm. The following film-forming polymers were used: Binder-21ei, Ruzin-33, and Ruzin-14i (produced by Svan LLC, Dzerzhinsk, Nizhny Novgorod, Russia), as well as acrylic thickener Printofix Ferdiker CSFN (Archroma, Austria). Binder-21ei is a new product, which does not contain ethoxylated alkylphenols (APEA-free). The polyurethanes used included Akvapols A-10, A-11, and A-21 (ZAO Makromer, Vladimir, Russia). The particle size in the polymer water

dispersions is 0.01 μm. Ruco-guard SF-8 (Rudolf GmbH&Co.KG, Geretsried, Germany), a fluorocarboxylic acid preparation, was used for oil- and water-repellent finishing.

Russian-made acrylic copolymer Ruzin-14i was employed to implement the technology of obtaining retro-reflective textile materials, with Al-based pigment paste and 30–60 μm Svarco micro glass beads used as the mirror substrate.

2.2. Methods

The experimental studies employed a set of physical and chemical research methods (spectrophotometry, IR spectroscopy, and scanning electron microscopy), conventional and original methods for assessing the strength and special consumer characteristics of textile materials, including color.

2.2.1. Dyeing Technologies

Classical technology of dyeing with pigments. The technology consists of impregnating a fabric with an aqueous dye composition, including, in g/L: pigment—x; binder—100; and acrylic thickener—5; water makes up the remainder. This is followed by 80% spinning, drying, and heat treatment at 140–160 °C for 2–3 min.

Option 1. A polyester textile material is colored with pigments by the classical method. Then, the fabric is coated with a polymer composition containing a water dispersion of polymers—500 g/kg and an acrylic thickener—16 g/kg by direct printing through a mesh template; the fabric is then dried and treated with hot air at a temperature of 140–160 °C for 2–3 min.

Option 2. An aqueous pigment–polymer composition is applied to the fabric prepared for dyeing using the squeegee method. The composition includes, in g/kg: a pigment—x; a water dispersion of polymers—500; an acrylic thickener—16. Drying and thermosetting are then carried out at a temperature of 140–160 °C for 2–3 min.

2.2.2. Technology of Achieving IR Remission on a Textile Material

A plain-dyed or printed "camouflage" textile material is coated with a polymer composition by the squeegee method or direct printing through a mesh template, containing, in g/kg: an aqueous dispersion of acrylic polymer Ruzin-14–300, an acrylic thickener—16, and a black pigment—0.5–5.0 This is followed by drying and fixing with hot air at a temperature of 150 °C for 3 min.

2.2.3. Technology of Obtaining a Retro-Reflective Effect on a Textile Material

A polyester fabric is coated with a layer of a pigment composition based on a fine aluminum paste, which acts as a "mirror" to ensure the efficiency of specular reflection of light. This coating can be applied either by direct printing through a mesh template (to obtain a retro-reflective effect in the form of a pattern), or by the squeegee method in the form of a continuous coating (on tapes and canvases). The fabric is then coated with a layer of a thickened Ruzin-14i-based composition by the squeegee method. Micro glass beads (GMB) are sprayed onto the wet mirror layer, and then the material is heat-treated with hot air at 150 °C, which makes the unfixed GMB blow.

2.2.4. Spectrophotometric Research Methods

The color characteristics of the dyes were determined using a YS 3010 spectrophotometer (Shenzhen, China) with standard CIE optical geometry D/8. The device measures the reflectance spectra of samples in the visible radiation region, displays color coordinates, color differences, and other colorimetric indices in accordance with the international CIELab system. The reflectance spectra were transformed into the Gurevich–Kubelka–Munk function by the formula:

$$\frac{K}{S} = \frac{(1-R)^2}{2R} - \frac{(1-R\,ref)^2}{2R\,ref}$$

where R is the dyed fabric reflection coefficient and $R\ ref$ is the original fabric reflection coefficient.

The spectral reflection curves in the operating range of 250–1100 nm, i.e., in the visible and near-IR spectrum ranges, were recorded using a Lambda spectrophotometer (company PerkinElmer Ltd. Chalfont Road Seer Green Beaconsfield BUCKS HP9 2FX, Seer Green, UK) equipped with a 150 mm Integrating sphere). During the measurements of the spectral values, light is collected by an integrating sphere, registered, processed, and displayed by the UV WinLab software V6.0.4.

2.3. Method of Achieving Color Fastness to Washing and Dry and Wet Friction

Color fastness tests were carried out to check the fabric resistance to the following factors:

To dry and wet friction according to the Russian regulatory documentation [40] on a device that makes an adjacent cotton fabric move 10 times back and forth at a working length of 100 mm for 10 s under a load of 9 N. The method consists of coloring an undyed dry or wet fabric by rubbing it against a dry test sample.

To washing—at a temperature of 95 ± 2 °C for 30 min, according to the Russian regulatory documentation [41]. The color fastness to each type of physico–chemical effects is determined by measuring the changes in the original color or changes in the original color and the shading degree of adjacent fabrics that have been subjected to joint processing. The scale for determining the degree of change in the original color consists of five or nine pairs of gray stripes, which allow color fastness to be evaluated on a scale from 1 to 5 points.

2.4. Method of Evaluation of Oil and Water Repellent Properties

The oil–water-repellent finish was evaluated in accordance with the GOST Soil-Release AA TCC-Test 130-1969. Placed face up on a smooth, flat, horizontal surface, a test fabric sample was pipetted with standard oil drops of the test liquid. The drops were observed for 30 s at an angle of 45°. If no penetration, absorption, or leakage of the liquid was observed at the point of the base contact with the liquid, a drop with the next number was applied next to it and the observation was repeated.

The oil–water repellency is a point-based value corresponding to the highest number of the test fluid that does not wet the fabric for 30 s. A fabric is identified as oil- and water-repellent if it has the value of 4, 5, or 6 points (4 for n-teradecane, 5 for n-dodecane, and 6 for n-decane).

2.5. Microscopic and Photographic Studies

Visual assessment of materials pigmented by various methods was performed microscopically using scanning electron microscopes S-4800 (Hitachi, Hitachinaka-shi, Ibaraki 312-8504, Japan) and VEGA3 SBH (Tescan, Brno, Czech Republic). To make the fabric samples under study electroconductive, before the experiment they were coated with a 10 Å carbon layer.

The number of GMB per unit area was determined by analyzing the images obtained from an MBI biological microscope (Saint Petersburg, Russia).

The images of the retro-reflective materials were obtained with a Sony photo camera in the ambient light mode with a flash.

3. Results

3.1. Options for Dyeing Cotton–Lavsan Fabrics with Pigments Using Russian Acrylic and Urethane Polymers

Comparing the results of the spectrophotometric studies of the textile materials dyed by the two methods (options 1 and 2 described in Section 2.2.1) using polymers Binder-21ei, Ruzin 33, and Akvapols (A-10, A-11, A-21) allowed us to see the differences in the coloristic properties.

Figure 1a,b show the obtained reflection spectra reduced to the Gurevich–Kubelka–Munk function, as the function that characterizes the color intensity (K/S).

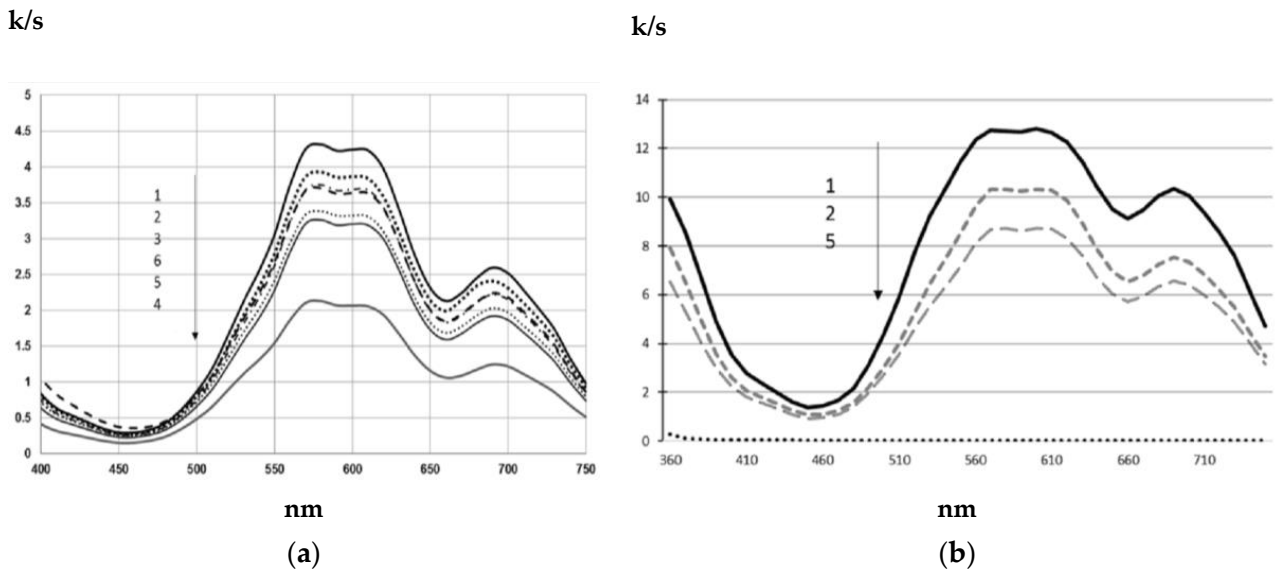


Figure 1. Intensity (k/s) of colors when dyed with the blue pigment, (**a**) followed by polymer treatment with: 1—Binder-21ei, 2—Ruzin-33, 3—Akvapol-21, 4—Akvapol-12, 5—Akvapol-10, 6—S-351; (**b**) Squeegee method of pigment–polymer composition application using: 1—Binder-21ei, 2—Ruzin-33, 5—Akvapol-10.

An analysis of the spectra (Figure 1) indicates that, in both cases (Figure 1a,b), the color intensity tends to be lower when urethane polymers (Akvapol-10 and Akvapol-21) are used and higher when acrylic ones (Ruzin-33 and Binder-21ei) are applied. Notably, the shapes of the spectral curves are similar for the two options. However, the absolute color intensity (K/S) is much higher for the second dyeing option. For option 1, the color intensity reaches a value of 4.3, whereas for option 2, it grows to 12.4.

Table 1 presents the color characteristics of a cotton–polyester fabric dyed with a red PV pigment, which also shows a considerable increase in the C color intensity for option 2.

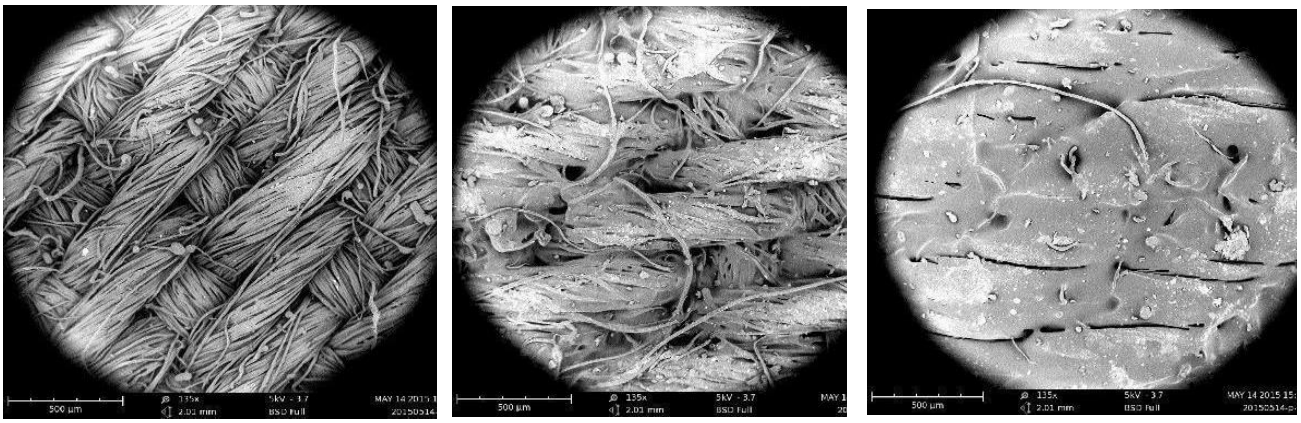
Table 1. Color characteristics of the cotton–polyester fabric dyed with the red RV pigment.

Polymers Used	Color Characteristics			Color Coordinates	
	Lightness, L	Saturation, C	Color Tone, H	a	b
Dyeing with pigments followed by processing with polymers (option 1)					
Binder-21ei	86	70	28	89	46
Ruzin-33	84	77	26	87	44
Akvapol-21	70	67	25	86	40
Akvapol-10	66	71	26	87	39
Squeegee method of pigment–polymer composition application on the fabric (option 2)					
Binder-21ei	98	105	30	87	59
Ruzin-33	95	101	33	85	55
Akvapol-21	90	106	35	88	60
Akvapol-10	88	103	36	86	57

The significant difference in the coloristic properties of the colors can be explained by the difference in the color rheology at the stage of fabric preparation, by the greater amount of the applied pigment composition, and the difference in the mechanism of pigment fixing in the polymer layer on the textile substrate.

The microphotographs of the dyed fabrics obtained using an S-4800 Scanning Electron Microscope (Figure 2) led us to the conclusion about a significant difference in the pigment–polymer layer distribution—from a thin layer that envelops the texture of the

fabric (classic dyeing option) to continuous covering with a polymer (options 1 and 2). This can be explained by the fact that the classical impregnation-based dyeing method assumes distributing a pigment with a polymer binder in the inter-fiber space, whereas in the case of the squeegee method, a thickened pigment–polymer composition is distributed over the surface of a textile material.



(**a**) (**b**) (**c**)

Figure 2. Micrographs of dyed fabrics: (**a**) shows classical dyeing impregnation pigments; (**b**) indicates dyeing followed by polymer application (option 1); (**c**) shows the squeegee method of pigment–polymer composition application (option 2).

The dyeing results and the fabric quality indicators (mechanical strength, abrasion resistance, air permeability, color fastness, and wrinkle resistance) reveal the fundamental differences in the mechanisms of pigment distribution in the fiber or in the polymer layer deposited on the textile material (Table 2).

Table 2. Results of cotton–polyester fabric dyeing by various techniques.

Indicator Name	Dye Option		
	Classical	**Option 1**	**Option 2**
Breaking load (N), not less than, warp/weft	1193/607	1210/652	1291/681
Abrasion resistance, cycles	4280	4956	5193
Air permeability, dm^3/m^2s	120	80	45
Wrinkle resistance, %, not less than	37	55	58
Dimensional change after wet processing at 40 °C, %, no more than, warp/weft	3.5/1.8	3.7/1.0	2.0/0.5
Color fastness to dry/wet friction, points	4/3	5/4	5/4

The classical pigment dyeing technique assumes fixing pigment particles on a textile material to form a thin polymer film enveloping the fibers. Because the particles in the dispersions of the polymers used are much smaller than those of the pigment, the polymer particles easily penetrate inside the fibers and the pigment particles mainly remain on the surface. This leads to poor friction fastness of the dyes.

One-stage dyeing of a textile material with a pigment–polymer composition by the squeegee method makes it possible to dye the material intensively and permanently. Furthermore, in such case, coloring can be combined with finishing.

Compatibility tests of the polymer composition with fluorocarboxylic acid water-repellent finishes and the finishing results confirmed the effectiveness of combining these operations. Figure 3 shows the results of an oil–water-repellent finish on cotton–polyester

fabric dyes by the option 2 technique. The oil drops corresponding to n-tetradecane, n-dodecane, and n-decane were round in shape, which indicated that the fabric became oil- and water-repellent. This corresponds to 4, 5, and 6 points.

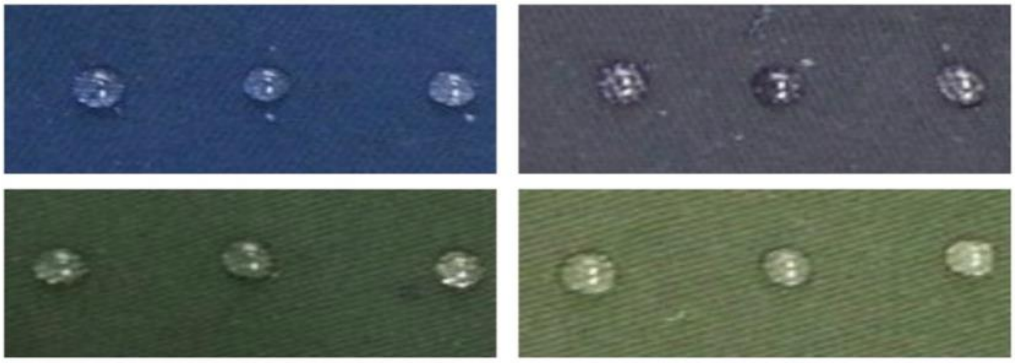


Figure 3. Soil-Release AA TCC-Test 130-1969 Oil Repellency Finish Evaluation Results.

An important advantage of the squeegee method of dyeing composition application is that it can significantly reduce (or eliminate) the use of water in the technological process of coloring, and, consequently, solve the environmental problem associated with resource saving. The developed composition for TM dyeing with pigments received the patent protection of the Russian Federation in the form of a patent for an invention [42].

3.2. Modification of "Camouflage" Cotton–Polyester Fabrics with a Pigment–Polymer Composition to Create an IR Remission Effect

It is proposed to modify a "camouflage-patterned" cotton–polyester fabric for outerwear in order to give it additional properties that fully meet the requirements of law enforcement agencies. Fabrics of this category must meet the requirements for the level of remission in the IR region of the spectrum [41]. For this purpose, pigment inks used to create a pattern from the colors of the RGB or CMY triad are usually supplemented with mineral black pigment additives (soot) to achieve the required level of reflection in the IR region. This option is time-consuming and requires careful refinement of the resulting colors in accordance with the standard, both when viewed in visible and night light.

The variant proposed by the authors for obtaining the IR remission effect on fabrics is achieved by introducing a black pigment into the polymer composition in the form of additive (see Section 2.2.2). A plain-dyed or camouflage-patterned textile material is coated with a thickened polymer composition containing a black pigment using the squeegee method or direct printing method through a mesh template. Both methods of pigment–polymer composition application are effective. However, the authors showed that the choice of the method of pigment–polymer coating is made based on economic and technological considerations; when achieving the camouflage effect on a smoothly dyed fabric, it is more expedient to use the squeegee method, and when reducing the remission of camouflage patterns, the method of direct printing through a mesh template is more effective. The difference lies only in the specially selected working viscosity of the composition.

The polymer base of the composition is the acrylic thermosetting polymer Ruzin-14i, which, as was shown in the earlier works of the department [33–35], provides strong fixation of pigments with improved physical and mechanical color properties.

The reflection curves of the printed samples were obtained in the spectral working range of 250–1100 nm (i.e., in the visible and near-IR ranges zone), taken from printed samples. As can be seen in Figure 4, the reflection curves in the near IR region of the spectrum are reduced by 20% compared to the untreated samples, which indicates the acquisition of IR remission colors.

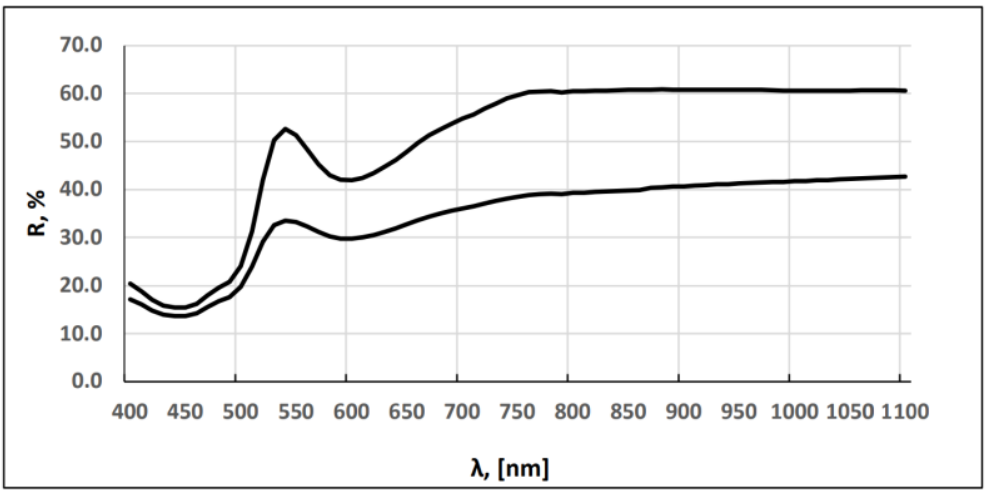
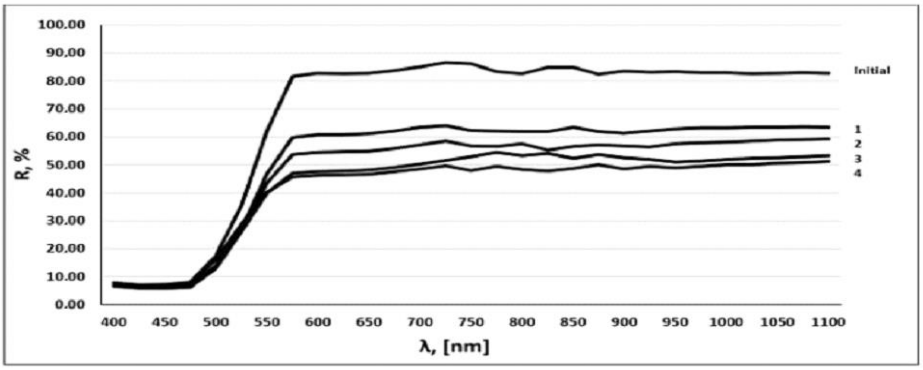
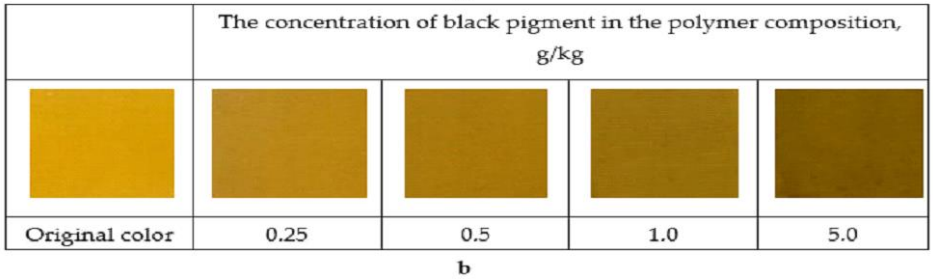


Figure 4. Spectral characteristics of colors printed on a mixed fabric with a yellow P-R pigment without (upper curve) and with subsequent modification of the fabric (lower curve) with a thickened polymer composition containing a black pigment.

As a result of studying the spectral curves, the permissible ranges of black pigment concentrations in the polymer composition were verified. Figure 5 shows the patterns of changes in the optical properties of colors when changing the black pigment concentration in the polymer composition from 0.25 to 5 g/kg. The reflectance of the original color is at the level of 80% for the yellow pigment, whereas with an increase in the black pigment concentration in the modifier from 0.25 to 5 g/kg, the reflection level decreases to 64, 59, 52, and 50%, respectively.



a



b

Figure 5. Spectral reflection curves (**a**) and appearance of the samples (**b**) printed with golden yellow pigment 2K without modification (the upper curve) and with black pigment concentrations from 0.25 to 5.0 g/kg in the polymer composition.

As a result of studying the spectral curves, the permissible concentration ranges of PrinteX black in the modifying polymer composition were verified. The results obtained

are of great practical importance, which means research needs to be continued to expand the range of colors obtained for the color of a particular landscape.

3.3. Use of Aqueous Dispersions of Acrylic Polymers to Create a Retro-Reflective Effect on a Fabric

The technology of producing a retro-reflective coating is described in Section 2.2.3.

We earlier determined the GMB concentrations per unit area of fabric sufficient for obtaining retro-reflective materials that are almost identical in their quality to the analogs widely used for this purpose [43].

Figure 6 shows images of the samples that clearly show the difference in the GMB consumption per unit area of fabric. The authors show that the maximum retro-reflective effect is produced when 80–98% of the fabric surface is covered with micro glass beads.

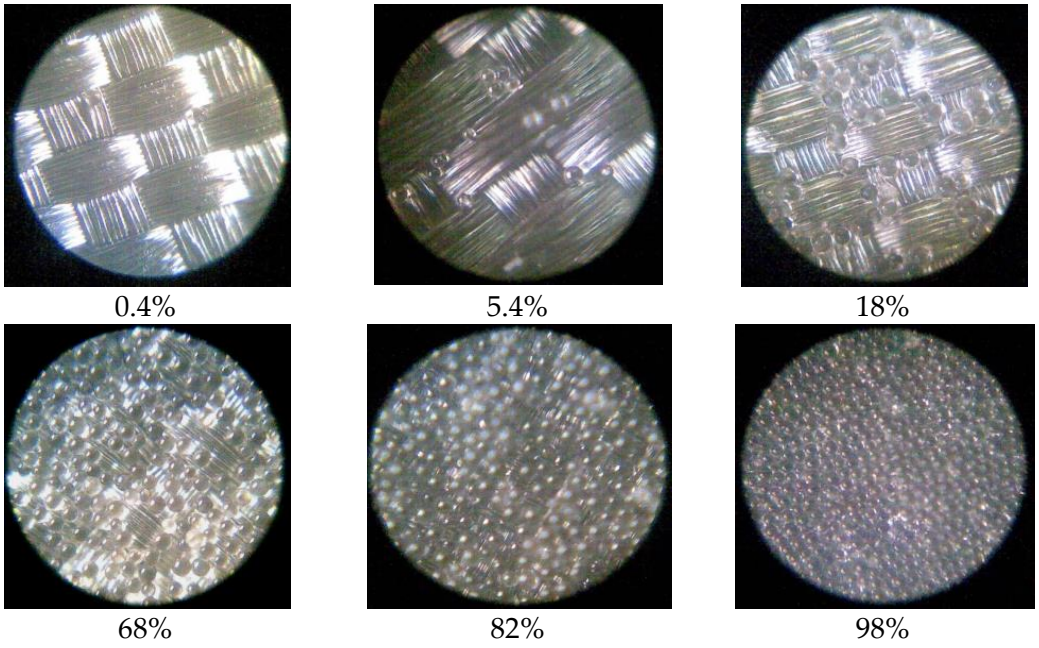


Figure 6. Microscope image of the coating on the fabric surface.

The maximum retro-reflective effect can be reached when the depth of the penetration of glass beads into the polymer layer is 40–60% [43]. For visual assessment of the depth of GMB penetration into the polymer, we analyzed the folds of the obtained materials. Figure 7 shows a fragment of the GMB surface, where the depth of the sphere penetration into the polymer is approximately 60%.

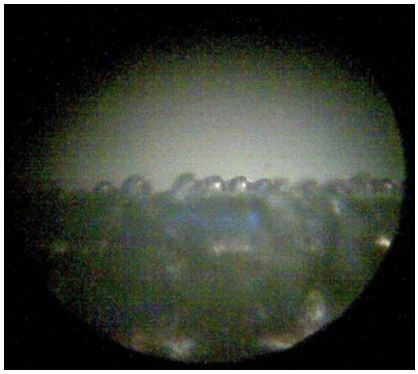


Figure 7. Microscope image of the coating on the fabric fold.

The required degree of immersion of GMB in the polymer, which ensures effective retroreflection, was achieved by changing the polymer concentration in the thickened water–polymer composition.

The express method (see Section 2.5) that was used to check the retro-reflective (RR) properties of the obtained materials was the photographic shooting at night with a flash, which showed the complete identity of the achieved effect in comparison with the foreign counterpart shown in Table 3.

Table 3. Images of the patterns obtained.

Photo Shooting Option	Foreign Samples from the 3M Catalog	Samples Prepared by the Domestic Technology
Daytime photography without flash		
Photographic images taken at night		

The washing and friction tests of the obtained samples testify to the high resistance of the created RR materials to these types of influences [44].

4. Conclusions

A technology has been developed for dyeing cellulose–polyester fabrics by squeegee deposition of a pigment–polymer composition onto a textile material. The effectiveness of this dyeing method in comparison with the traditional impregnation technique is shown, both in terms of obtaining high strength and color intensity, and providing the possibility of combining the dyeing process and the final water-repellent finish.

It is shown that to achieve the IR remission effect on dyed or printed patterns, it is most expedient to use the squeegee method of polymer coating application, including a black pigment, for processing plain-dyed fabrics and the method of direct printing through a mesh pattern when processing "camouflage" patterns.

A technology has been proposed for obtaining textile materials with a retro-reflective effect using Russian components. Depending on the color effect, it is suggested to use the following methods of polymer coating application to fix GMB: the squeegee method to obtain a continuous retro-reflective effect on tapes or canvases and direct printing method through a mesh template to obtain retro-reflective patterns or logos on fabrics or products.

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