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THE WAYS TO PROVIDE TEXTILE MATERIALS WITH ANTIMICROBIAL PROPERTIES ANALYSIS

Purpose. *The purpose of the article is to analyze impregnation technology to provide biostable textiles with bacteriostatic properties and their impact on environmental safety.*

Methodology. *Analytical review and scientific information systematization in the field of biostable textiles.*

Results. *The article provides analytical review of existing impregnation methods and comparative analysis of fabric with different types of soaking. Being based upon analysis and synthesis of published data, devoted to the study of textile materials properties and their products, the article proves the expediency effects of biological stability and environmental safety through seepage technologies.*

Scientific novelty. *Biostable textiles classification was carried out and systematized in accordance with the main directions of research in rapidly developing field of biotextiles.*

Practical value. *The seepage technologies analysis allows systematizing biotextiles range and helps to determine the promising areas of research.*

Keywords: *antimicrobial properties, biostable textile, environmentally safe biotextile.*

Introduction. Our country is experiencing hybrid war now. And it has resulted in a great number of wounded people. The most necessary things in this situation are textile materials that can protect people from proliferation diseases caused by pathogenic bacteria in tense situations. Under these circumstances, it is equally important to expand the range of textiles with antimicrobial treatment of fabric for medical purposes [1].

Textile materials protective properties improvement and pathogenic factors influence upon the environment should be considered as well. On the basis of the results of research conducted by numerous authors [2, 3, 4], and in order to provide the fabric simultaneously with various effects of desired biological stability and environmental safety, it is proposed to use not only pure biocidal agents, but their combination with other processing agents.

Much more attention should be paid to greening range of groups, types of textile materials and products being in use, most sensitive to organisms harmful for humans (clothing for medical institutions staff and their patients, pharmaceutical employees and food industry workers, etc.), and other textiles and products used in similar fields.

Various fabrics' seepage technologies are often needed for this purpose. One of the most used technologies is the surface modification by means of biocidal agents. Biocides are the means of harmful organisms' destruction. Textile biocide should optimally possess a wide spectrum of antimicrobial effects upon pathogenic and damaging fiber microorganisms, small toxicity, odor absence, colorlessness, resistance biocide effect to the laundry and dry cleaning of textile products, ease of use, affordable price, and compatibility with other textile auxiliary materials (standard TPL). It should not impair physical, mechanical and chemical properties of textiles [2]. Biocidal agents seepage technology is widely used in foreign and domestic textile production practice.

Objectives. The main goal of the article is to compare the analyses of seepage technology to provide textile materials with bacteriostatic properties, knitted fabric in particular. To achieve this

goal the following objectives were set up: to study existing seepage methods and determine their influence on the final bacteriostatic properties of textile materials, taking into consideration the analysis and synthesis of published data.

Research results. The successful resolution of the issues raised, as confirmed by international experience, largely depends on the reasonable choice of modern production technologies and application of highly efficient antimicrobial drugs. They should guarantee high, stable and durable antimicrobial effects on different purpose and fiber composition textile materials, products as well as preserve their hygiene, environmental safety, durability and appropriate appearance.

The problem of textile materials and products protection from pathogenic effects of the environment and enhancement of their performance properties is based on various aspects, namely [1-10]:

- detection of pathogenic organisms on various purpose textile materials and products, and search for ways to deal with them;
- use of advanced nano, chemical and biological technologies to effectively protect people and the environment from harmful effects of particular physiological microorganism groups;
- identification of basic physiological groups, genera and species of microorganisms that participate in the processes of microbial degradation in textile materials and products of different fiber composition and purpose processing;
- disclosure of mechanisms of biodegradation in textile materials and products that have various fiber composition by fabric-damaging microorganisms;
- search for effective protection of apparel, medical and industrial textile products from fabric-damaging (especially pulp and keratin-damaging) microorganisms.

Antibacterial effects, moisture resistance, strength and durability are considered to be key indicators of textile materials. In most cases the original properties of the product rarely meet a set of performance indicators. Therefore, to provide a knitted fabric with given final chemical, physical and mechanical properties a variety of impregnations are used.

Impregnation can provide products with diverse medical properties and endow materials specified operational performance. Nowadays, pathogenic bacteria begin to show increasing resistance to widely used antibiotics [2]. Thus, the search and production of new medications has become an issue of urgent importance in the field of medical textiles development. An ability to use nanomaterials with unique physical and chemical properties makes it possible to provide new antibacterial textile solutions [2-3].

Nanoparticles are usually perceived as very specific and important artificial molecular structures. To provide them with antimicrobial properties nanomaterials are used, which contain [1-5] copper, zinc, titanium, magnesium, gold, chitosan. Silver in various forms is considered to be the most popular kind of biocides though. Silver ions' wide action range provides protection against Staphylococcus aureus, Pseudomonas aeruginosa and E. coli, herpes zoster, influenza and Proteus vulgaris [1], and even inhibits AIDS. The methods of textile processing by means of silver nanoparticles differ in nature and depend on manufacturing operations, process regimes and types of equipment used [1, 3].

Nowadays a great amount of chemicals to impregnate materials exist. A variety of these drugs physical and mechanical properties determine appropriate technologies to perform infiltration.

The analysis of research works devoted to technology infiltration [1-6] shows their close connection with the necessity to solve all sorts of environmental problems. On the one hand, it ensures the environmental safety of the finished product in terms of its usage. On the other hand, there is a process of greening technologies for production of biocide preparations and textile materials treatment.

The work by A. Zille [1] focuses on the ways of using silver nanoparticles to provide textiles with antimicrobial properties. The optimum properties of biocides for textile materials have been found. The author justified the possibility to use textiles with silver nanoparticles for the treatment of burns, open wounds, dental materials. The work emphasizes the use of silver nanoparticles for disinfection of water and in sunscreens. The paper contains data about low toxicity of silver nanoparticles for humans.

The article [2] discloses the role of advanced nanotechnology in the production of new generation textile materials. The authors justified the necessity to introduce new nanoproducts with antibacterial properties that identify unique physical and chemical characteristics at the same time. The work as well considers antimicrobial effects of TiO2 nanoparticles and Ag2O against resistant bacteria and parasites.

The paper [3] focuses on the method of providing textile materials with antimicrobial properties by one-stage process impregnation solution containing silver salt (silver nitrites) and the reducing agent. The auxiliary components were added to strengthen the connection of silver with the surface of a fibrous material.

The article [4] deals with technology for creating textile materials with antibacterial properties. The key feature of this technology consists in combination of stages for silver nanoparticles obtaining and their sedating on material surface. The authors consider an opportunity to obtain nanoparticles of a definite size and shape that make it possible to expand medical properties of the material.

The authors [5] studied the continuous processing of material by means of antimicrobial components according to "pad-dry-cure" principle. The principle is based on the sequence of flow processes that use the fixed size, degree of extraction of silver nanoparticles dispersions, drying and heat treatment at temperatures higher than the temperature and compulsion (100 - 150 o C).

The paper [6] focuses on technology of providing textile products with antimicrobial properties by means of sol-gel. This technology is based on obtaining materials with certain physical and mechanical properties, and includes stages of sol, converting it into a gel, applying it to the textile material and drying. Nanosols are colloidal solutions of different in shape nanoscale particles of metal oxides in water or organic solutions, which aggregate in the process of coating and convert into a three-dimensional grid through evaporation.

Maillard [7] studied the usage of traditional migratory biocidal products (usually based on triclosan or zinc pyrithione) to provide textile materials with antimicrobial properties. While migrating biologically, active substances are capable of producing chemical effect upon microbes

and microfungi inhibiting their ability to reproduce or blocking their nutrition processes. The disadvantage of migrating assets is their ability to affect human skin being in contact with antimicrobial clothing. Thus, biocidal drugs have been produced to eliminate side effects.

The articles [8-10] are devoted to highlighting ways of nanotechnology use in medical textiles manufacturing. The authors overviewed the ways of effective protection for textile biodeterioration domestic textile and its adaptation to the requirements of foreign markets; also the expediency of using multifunctional silicone finishing agents for the surface modification of textiles to endow them with simultaneously several desirable effects - biological stability, watertightness, environmental safety, etc. The article [10] deals with the ways of textiles protection from the influence of biodeterioration ecotextiles cellulose-damaging pathogenic microorganisms. The authors paid attention to disclosing the mechanism of interaction between ftor- and silicon manufacturing drugs, and certain types of bacteria and cellulose-damaging fungus. The impact of biocide and silicone agents on biostable textiles was studied. Besides, the article focused on the factors that determine the effectiveness of antimicrobial treatment of textile materials.

The authors of the article [11] focused on biocidal treatment as an effective method of protecting textiles. They produced methods of evaluating the effectiveness of biocide treatment for textile materials.

The research work [12] considers the current problems of producing clean and safe textiles. The methods of textile fibers identification, based on differences in their chemical and physical structures, are described. The authors highlight the use of energy efficient techniques for determining permeability performance of materials and means to prevent the harmful effects of textiles on the environment. They suggest ways to provide antimicrobial properties of textile materials based on dyeing them in onion and tutsan. The authors pay much attention to the methods of evaluating the effectiveness of fibers' biocide treatment and providing antimicrobial properties of textiles using medicinal plants.

The paper [13] deals with the problem of textile materials antibacterial activity studying. It provides the analysis of two basic principles of antibacterial activity: qualitative analysis, conducted by means of the test on an agar plate and quantitative analysis based on dynamic tests. The authors have determined antimicrobial properties of knitted cotton fibers, colored dyes, which have bactericidal effects (brilliant green, fuxin and blue methanol).

The article [14] covers the basic functions of medical clothing and defines chief properties of the material for its production. The authors selected the materials for a set of medical workers' clothes.

The author of research work [15] suggests the method of providing antibacterial properties of nonwoven fabric using silver nanoparticles. In order to insert silver nanoparticles in nonwovens based on flax fibers, he stresses upon the necessity of using silver recovery from an aqueous solution of silver nitrate reducing agent at the presence of a surfactant, followed by application of reduced silver on the fibrous material.

The work [16] focuses on the development of complex compositions to provide cotton with antimicrobial properties. The author scientifically and practically proved the feasibility of using

composite formulations based on natural polysaccharides and ethylene dichloride-1,2-bis (N, N-dimethyl-karbdetsyl oksymetyl) - ammonium and unsaturated sorbic acid.

The authors of the article [17] researched the influence of fiber's structural characteristics on the effectiveness of antimicrobial treatment, which is provided by means of use of a polymeric biocide, containing guanidine group.

It is proved that biocidal textile treatment improves the final consumer properties of textile materials and products, but priority should be given to seepage of materials, which are especially susceptible to microbiological degradation [2]. This primarily relates to gear staff of medical institutions, pharmaceutical and food industry workers. The presence of antimicrobial treatment of textile material allows achieving not only environmental and hygienic, but also economic effect. As a result of the processing the product's lifetime increases up to 10-15%.

Antimicrobial treatment of clothing textile material can be considered as multifunctional for being able to: significantly improve the product's hygiene indicators by reducing transient microorganisms access to human skin and eliminate unpleasant odors caused by the presence of bacteria's metabolic products; protect human skin from exposure of blood-sucking insects; ensure effective protection of textile materials and products of various purpose from microbiological degradation.

According to the degree of human protection from the influence of most gram-positive and gram-negative aerobic and anaerobic bacteria**,** biostable textile materials can be classified as following:

- bactericide - have the greatest degree of people’s protection; they kill bacteria using a powerful chemical agent. The main field of material application is medicine;

- antibacterial - stops the growth of microorganisms using a special agent that is added to the finished fabric. This agent is gradually washed away in the process of washing;

- bacteriostatic - stops the growth of bacteria, but doesn't kill them. The active component of this material is more resistant to leaching when washing, because the agent is added directly to the fiber and is therefore more secure.

Nowadays there are three technologies to provide textile materials with these properties: chemical leakage, finishing, late-injection and grafting. Finishing is the simplest technology. It is based on insertion of a chemical agent at the last stage of production – coloring. This method has been long criticized because it does not provide adequate resistance to washing (the agent disappears after 5-6 washings). However, recent developments have significantly improved the quality of antimicrobial agents that remain in the textile and retain their activity even after 50 washes. In the process of late insertion technology textiles are modified on the yarn level and the agent is embedded directly into the polymer fiber. The fiber is heated to a high temperature, and once it starts melting, antibacterial agent is injected (sometimes in combination with other active agents). Then it is followed by rapid cooling. Grafting technology, being tested nowadays, has shown excellent results. It is based on fabric bombarding by means of charging with antibacterial agent particles. As a result of seepage technologies analysis**,** the classification of biostable textile materials has been developed. It is presented on **fig.1**.

The analysis of scientific, technical and patent literature in the field of research makes it possible to suggest the idea that modern textiles produced due to use of traditional chemical and

mechanical technologies and high nano-, bio- and info-, cognitive (NBIC) technologies**,** can greatly expand the range of its application areas. Now we can't even imagine further technological growth typical for the developed countries without technical, emergency, medical, sports, industrial, military, transportation, space and cosmetic textiles. Depending on the properties of various appointed groups of materials**,** their consumer properties modification is determined by a various range of treatment and seepage processes.

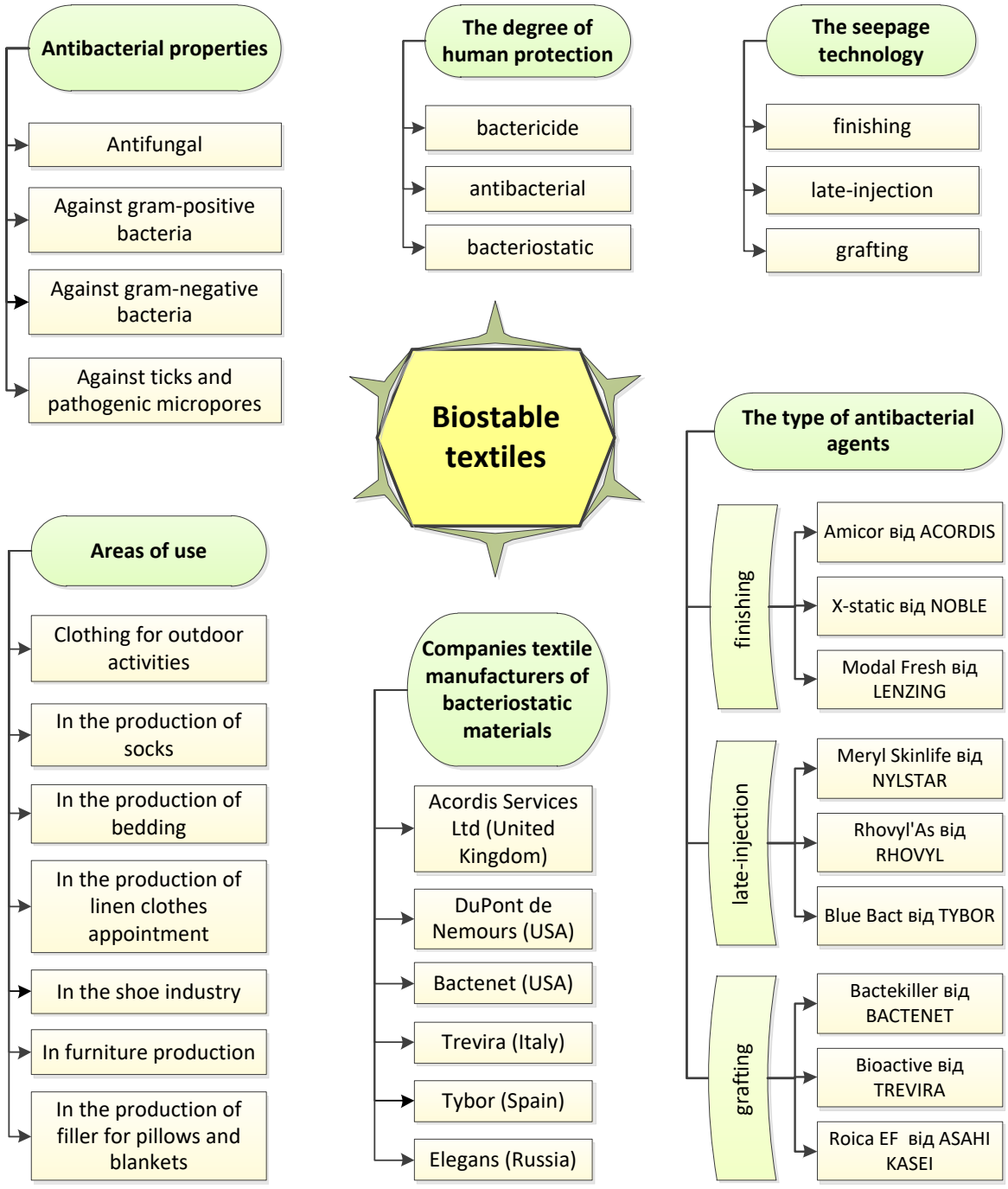

Fig. 1. **Classification of biostable textiles**

As you know, the ecological safety of textile materials consists of staff safety as well as safety of biocidal agents that vary in chemical composition, appointment and technologies of their production. Summarizing information from various literature sources as for the role of biocide treatments of textile materials and products, we can confidently say that they increase the level of environmental safety irrespective of various textile fiber compositions and products or methods for their production.

Currently the issue of creating textile materials with antibacterial properties, especially for medicine, is considered to be both interesting and important in the modern world. It is caused by the need to protect humans from exposure to pathogens and improve their immune status. Due to their qualities**,** bacteriostatic textile materials prevent microorganisms from interference into the human body.

Several authors focused upon economic feasibility of knitted fabrics biocide treatment for domestic textile industry [8-10]. Various kinds of antimicrobial seepage treatment can extend range, increase ecomaterial products competitiveness and raise the level of their production. The use of seepage in knitting industry in the field of underwear manufacturing can be of great preventive value, especially as concerning women's health, and a wide range of skin diseases (dermatitis of different origins, herpes, psoriasis). Impregnation of elastic bandages and tires can significantly accelerate the recovery of disturbances in the loco motor apparatus.

Unfortunately in recent years the environmental condition of the modern world has deteriorated. Thus, people face a health threat. They want to be more protected from harmful effects of the environment. Bacteriostatic textile materials should be used not only for medical purposes, but also in everyday life. Therefore, knitted fabrics treatment by bacteriostatic agent is an important and popular area of research that needs to be studied profoundly. Moreover, new ways to improve the aforesaid technology should be found.

Conclusion. The analysis of existing technologies for conducting textile seepage aimed at giving textile materials (including knitted fabrics) bacteriostatic properties disclosed the fact that the seepage impact on textile materials' physical and mechanical properties, and environmental safety had not yet been studied profoundly. The development of environmentally friendly technology for knitted fabrics with antimicrobial properties is of urgent importance nowadays. It will provide an opportunity to start domestic manufacturing of knitted fabrics for the needs of defense and industry complex, including military underwear.

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АНАЛІЗ СПОСОБІВ НАДАННЯ АНТИМІКРОБНИХ ВЛАСТИВОСТЕЙ ТЕКСТИЛЬНИМ МАТЕРІАЛАМ

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Мета. *Провести аналіз технологій просочування для надання бактеріостатичних властивостей біостійкому текстилю та їх впливу на екологічну безпечність.*

Методика. *Аналітичний огляд та систематизація наукової інформації у сфері біостійкого текстилю.*

Результати. *У статті проведено аналітичний огляд існуючих способів просочування та здійснено порівняльний аналіз текстильних матеріалів, в яких використовуються різні види просочувань. На основі аналізу та узагальнення літературних даних, присвячених дослідженню властивостей текстильних матеріалів і виробів з них, обґрунтовано доцільність надання їм ефектів біостійкості та екологічної безпечності шляхом просочування.*

Наукова новизна. *Проведено класифікацію біостійких текстильних матеріалів та систематизовано основні напрями досліджень у сфері біотекстилю, яка в останні роки розвивається випереджальними темпами.*

Практична значимість. *Проведений аналіз технологій просочення дозволяє систематизувати асортимент біотекстилю та сприяє визначенню перспективних напрямків досліджень.*

Ключові слова: *антимікробні властивості, біостійкий текстиль, екологічна безпечність біотекстилю.*

АНАЛИЗ СПОСОБОВ ПРИДАНИЯ АНТИМИКРОБНЫХ СВОЙСТВ ТЕКСТИЛЬНЫМ МАТЕРИАЛАМ

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Цель. *Анализ технологий пропитки для придания бактериостатических свойств биологически устойчивому текстилю и их влияния на экологическую безопасность.*

Методика. *Аналитический обзор и систематизация научной информации в сфере биологически устойчивого текстиля.*

Результаты. *В статье проведен аналитический обзор существующих способов пропитки и осуществлен сравнительный анализ текстильных материалов, в которых используются различные виды пропиток. На основе анализа и обобщения литературных данных, посвященных исследованию свойств текстильных материалов и изделий из них, обоснована целесообразность придания им эффектов биологической устойчивости и экологической безопасности путем пропитки.*

Научная новизна. *Проведена классификация биологически устойчивых текстильных материалов и систематизированы основные направления исследований в области биотекстиля, которая в последние годы развивается опережающими темпами.*

Практическая значимость. *Проведенный анализ технологий пропитки позволяет систематизировать ассортимент биотекстиля и способствует определению перспективных направлений исследований.*

Ключевые слова: *антимикробные свойства, биологически устойчивый текстиль, экологическая безопасность биотекстиля.*