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RESEARCH OF SAFETY OF FLAX FIBERS FOR PRODUCTS OF MEDICAL AND SANITARY-HYGIENIC APPOINTMENT

Досліджено нормативно-технічну документацію, в якій регламентуються вимоги щодо безпечності лляного волокна. Доведено необхідність перегляду нормативів щодо вмісту хімічних елементів у лляному волокні та застарілої нормативної бази. Визначено, що критеріями нормування є гранично допустимі концентрації всіх хімічних елементів, які можуть потрапляти з ґрунту та накопичуватися у лляному волокні.

Ключові слова: *гранично допустимі концентрації, класи небезпеки, важкі метали в льоні, безпечність лляного волокна.*

1. Introduction

An important problem today is the protection of human health from influence of harmful factors. Significant role in this problem play textile products made from organic raw materials. The production of such products in Ukrainian enterprises in the absence of their own cotton depends on foreign raw materials, and not always of adequate quality. Therefore, it is advisable to use for this purpose own raw materials, in particular flax fiber, which has unique medical and sanitary-hygienic properties. Flax fiber textiles have the ability to:

– suppress vital activity of microflora;
– compatibility with living biological objects, caused by the use of surgical threads from flax for the application of internal seams;
– stop bleeding and anti-bedsore effect;
– beneficial effect on the thermoregulatory mechanism of the body;
– absorption of free radicals;
– beneficial effect on human immunity and skin;
– absorption of soft ionizing radiation and reduction of static electricity [1–6].

These properties are due to the chemical structure and composition of the fiber, in particular the presence of various microelements in it [7]. However, in the current regulatory documents, the chemical composition of flax fiber and its impact on quality indicators are not regulated. The concentration of chemical elements in the fiber is not standardized, which in the future can influence on its use for the manufacture of products. In this regard, relevant studies are aimed at analyzing existing regulatory documents regulating the quality and safety of fibers and finding ways to develop requirements for safety indicators in accordance with the scope of application.

When developing recommendations, it is necessary to take into account the unique property of flax to accumulate trace elements from the soil in the tissues, including heavy metals, which can adversely affect the human body.

2. The object of research and its technological audit

The object of this research is the process of development of regulatory documents on the safety of flax fiber of medical and sanitary-hygienic appointment. This research should be carried out taking into account the unique properties of flax, which are due to its chemical composition and structure. In particular, the stability of flax fiber to physical and chemical influences is due to the presence of cellulose in it and the degree of its ordering. Due to the presence of non-cellulose impurities, the fibers are characterized by increased resistance to moisture, temperature, microorganisms, and light. Due to the great possibilities of adaptation to changes in the chemical properties of the environment, flax accumulates microelements in its tissues, including heavy metals, the combined presence of which is the cause of medical and sanitary-hygienic properties.

One of the most problematic tasks in this process is the establishment of requirements for the content of heavy metals in the fiber. It is advisable to take into account not only the content of each individual chemical element, but also their total impact on safety.

3. The aim and objectives of research

The aim of research is improvement of regulatory documents on the basis of proposals to regulate the safety of flax fibers.

To achieve this aim it is necessary:

1. To analyze the existing regulatory documents, which regulate requirements for fiber.
2. To formulate recommendations for safety of flax fibers.

4. Research of existing solutions of the problem

Among the main directions of solving the research problem, factors that form a level of textile safety can be singled out. In particular, works [8, 9] point to the need to develop regulatory documents, which regulates the requirements for safety, methods, and criteria for research. However, the unique properties of flax fiber, its chemical composition and the total influence of chemical elements on the formation of medical and sanitary-hygienic properties are not taken into account. Similar conclusions are drawn in work [10] on the development of modern, fundamentally new methodological approaches to analysis, hygienic criteria and regulations, as well as

their harmonization with international standards. The authors proposes to develop the state sanitary norms and rules, which will take into account the hygienic control of the quality components of chemical factors that can cause harm to health. These proposals relate mainly to clothing, including children's clothing. In [11], the distribution of heavy metals along the axis of the flax plant is analyzed in order of decreasing concentration: root, stem, leaves, seeds and it is proposed to use it for soil purification from heavy metals. Similar studies are carried out in [12] and protocols are developed for determining the characteristics of elements and determining the toxic metals in flax fiber.

The authors of [10–17] analyze the methods of using flax fiber for medicine, taking into account its antimicrobial properties, the ability to absorb moisture, and mechanical properties.

Thus, the results of the analysis show the need to choose the most appropriate solution, which must take into account the properties of flax fiber products of medical and sanitary-hygienic appointment.

5. Methods of research

Total investigation of flax fiber safety is a laborious process. Therefore, the method of analyzing regulatory documents is chosen. In particular, the traditional, classical analysis aimed at interpreting the information that is available in the current regulatory documents.

At the same time, one of the traditional analyzes is used – internal, aimed at analyzing the document, taking into account the safety requirements for flax fiber. The selection of criteria for assessing the safety of flax fiber is associated with its likely features in accordance with hygienic and toxicological requirements.

6. Research results

The necessity to form the Ukrainian market of medical and sanitary-hygienic products made from flax fiber is conditioned by the availability of own raw materials [18, 19]. Recently, in addition to long-stalked flax for this purpose, scientists propose to use oil flax [20, 21]. Given that such products have direct contact with human skin, the question arises about their safety. The ability of flax to accumulate microelements from the soil dictates the need to test the soils for the presence of heavy metals in them, which come with fertilizers and pesticides. At the same time, there is a need to develop acceptable levels for these elements in products made from it. Accumulation of heavy metals can adversely affect both the quality indicators of flax fiber, and negatively affect the human body.

In accordance with GOST 17.4.02-83 «Protection of nature. Soils. Classification of chemical substances to control pollution» [22], it is necessary to take into account hazard class of chemicals for the control of chemical substances into soil:

– class 1 – highly hazardous substances (arsenic, cadmium, mercury, selenium, lead, zinc, fluorine);
– class 2 – moderately hazardous substances (boron, cobalt, nickel, molybdenum, copper, antimony, chromium);
– class 3 – low hazardous substances (barium, vanadium, tungsten, manganese, strontium).

Despite the fact that this regulatory document is outdated and needs to be replaced, there are valid today. In accordance to this document, it is necessary to check a presence of hazardous chemical elements that may absorbed from the soil by linen raw materials.

Most manufacturers today use the international standard Oeko-Tex Standard 100 [23], taking into account the consumers' desire to receive environmentally friendly products. This standard limits the use of certain chemicals – antimony, arsenic, lead, cadmium, chromium, cobalt, copper, nickel, and mercury in textiles. The pH of the aqueous extract and the maximum permissible concentration of formaldehyde are also normalized. However, this standard does not take into account the division into hazard classes (as in GOST 17.4.02-83) and verification for the presence of hazardous chemicals in this standard. In addition, in accordance with Oeko-Tex Standard 100, all textile materials are divided into groups:

– children's assortment;
– products, most of which are in contact with the skin of a person;
– products that do not contact the skin of a person;
– products that are used in everyday life, public places, transport.

At the same time, the standard does not take into account products of medical and sanitary-hygienic appointment.

Taking into account the requirements of the State sanitary norms and rules «Textile, leather and fur materials and products. Basic hygienic requirements» [24], raw materials for the manufacture of textile materials should not contain in their composition chemical compounds that are related to the first class of danger. However, substances that belong to this class are not standardized: selenium, zinc, fluorine.

Given the ability of flax to accumulate trace elements from the soil, including highly hazardous substances, the task is to revise the standards for the content of these substances in flax fiber and products made from it. When developing these standards, it is necessary to take into account the maximum permissible concentrations of all elements and their influence on each other.

It is important to take into account both the enhancement and the weakening of the joint action of heavy metals. Such counteraction for flax means that the total effect of several elements may be less than the sum of the individual elements [25, 26]. This fact is explained by the ability of one element to delay or stimulate the action of others. This process is changing and is controlled by many factors, including genetic, biochemical and physiological and requires additional research [27, 28]. Thus, the total negative effect of flax contamination by heavy metals depends not only on the set and level of the content of specific elements, but also on the characteristics of their mutual influence.

To develop a criterion for assessing the safety of flax fiber, it is advisable to take into account all factors. When calculating the maximum permissible concentrations of heavy metals in flax fiber, it is necessary to take into account:

– the total effect of all chemical elements in the absence of mutual influence on each other;
– interaction, which leads to mutual reinforcement of the action of all or one element. As a result, an increase in the level of danger of these elements;
– interaction, which leads to mutual weakening of the action of all or one element. The result is an increase in the value of the maximum permissible concentrations and an increase in safety.

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7. SWOT analysis of research results

Strengths. Among the strengths of this research should be noted proposals for regulation of chemicals in flax fiber, taking into account its properties and in accordance with its purpose. The benefits of this statement are the results of an analysis of regulatory documents in which these requirements are absent. The use of recommendations for development of a criterion for the safety of flax fiber makes it possible to solve the problem of providing by medical and sanitary-hygienic products made from Ukrainian raw materials. Criteria for the normalization are the maximum permissible concentration of chemical elements, either individually or together, that are available in the fiber. This will help:

– increasing the requirements for fiber safety;

– minimization of the emergence of dangerous textile products on the Ukrainian market, the production of which spends considerable resources.

Weaknesses. The weaknesses of this research are related to the complexity of identifying chemical elements, including heavy metals. The reason for this is a need to use high-precision experimental research using modern analytical devices, which in many cases is inaccessible. To eliminate this problem, there is a need to develop an accessible method for determining the content of chemical elements in flax fiber. Negative factors of research are:

– increase in production time;

– increase in the cost of production, associated with additional research.

Opportunities. Additional opportunities that achieve the aim are based on the revision of obsolete standards of the former Soviet Union and development of a modern methodology for determining the chemical composition of flax fiber. This is how the problem of the safety of raw materials of Ukrainian production of medical and sanitary-hygienic appointment can be solved. In this case, the studied recommendations can be the basis for development of new regulatory documents. The use of recommendations in assessing the safety of flax fiber will help expand the range of Ukrainian products of medical and sanitary-hygienic appointment.

In subsequent works, the authors will give the results of an assessment of the safety of flax fibers in accordance with these recommendations.

Threats. The threats associated with the implementation of these recommendations are due primarily to insufficient funding for the development of new regulatory documents. This problem can be solved by providing budgetary financing and the means of concerned organizations.

Thus, SWOT analysis of research results allows to determine the main directions for the successful achievement of the aim of research. Among them:

– regulation of chemical elements in flax fiber of medical and sanitary-hygienic appointment;

– development of methods for determining the content of chemical elements;

– revision of obsolete standards;

– financing of the development of new regulatory documents.

8. Conclusions

1. The existing regulatory documents on the safety of flax fibers are analyzed taking into account the division of textile materials into groups and hazard classes. It is established that special attention to safety is required by flax fiber, intended for the manufacture of medical and sanitary-hygienic products.

2. Recommendations on the development of modern regulatory documents are formed, taking into account the requirements of the international standard Oeko-Tex Standard 100 and the requirements of the State Sanitary Norms and Regulations. In this case, the regulation criteria are the maximum permissible concentrations of all chemical elements in flax fiber. Determination of their quantity requires the development of a modern methodology, taking into account the separation of chemical elements into hazard classes. Given the insufficient funding of works related to the development of new regulatory documents, it is appropriate to combine budgetary financing with the funds of concerned organizations.

References

1. Zhivetin, V. V. Len i ego kompleksnoe ispol'zovanie [Text]: Handbook / V. V. Zhivetin, L. N. Ginzburg, O. M. Olshanskaia. – Moscow: Inform-Znanie, 2002. – 400 p.
2. Artemov, A. V. Mediko-gigienicheskie svoistva l'nianyh tkanei [Text] / A. V. Artemov, O. A. Miheeva // Dizain i tehnologii. – 2009. – № 12 (54). – P. 90–96.
3. Touré, A. Flaxseed Lignans: Source, Biosynthesis, Metabolism, Antioxidant Activity, Bio-Active Components, and Health Benefits [Text] / A. Touré, X. Xueming // Comprehensive Reviews in Food Science and Food Safety. – 2010. – Vol. 9, № 3. – P. 261–269. doi:10.1111/j.1541-4337.2009.00105.x
4. Zhivetin, V. V. Len na rubezhe XX i XXI vekov [Text]: Handbook / V. V. Zhivetin, L. N. Ginzburg. – Moscow: IPO «Poligrom», 1998. – 184 p.
5. Yakutina, N. V. Medical and biological aspects of ecological characteristics of flax [Text] / N. V. Yakutina, A. V. Artemov, O. G. Liubskaya // Science Review. – 2011. – № 5. – P. 28–33.
6. Yakutina, N. V. Sorption properties of linen fabrics [Text] / N. V. Yakutina, A. V. Artemov, O. G. Liubskaya // Science Review. – 2013. – № 3. – P. 35–37.
7. Zhivetin, V. V. L'nianoe syr'e v izdeliiah meditsinskogo i sanitarno-gigienicheskogo naznacheniia [Text] / V. V. Zhivetin, B. P. Osipov, N. N. Osipova // Rossiiskii himicheskii zhurnal. – 2002. – Vol. XLVI, № 2. – P. 31–35.
8. Halyk, I. S. Ekolohichna bezpeka ta biostiikist tekstylnykh materialiv [Text]: Monograph / I. S. Halyk, O. B. Kotsevych, B. D. Semak. – Lviv: Lviv Commercial Academy, 2006. – 232 p.
9. Yarshchuk, O. V. Strukturnyi pidkhid do optymizatsii pokaznykiv yakosti tekstylnykh materialiv ta vyrobiv z nykh [Text] / O. V. Yarshchuk, O. P. Bokhonko, O. Yu. Lepikash // Visnyk Khmelnytskoho natsionalnoho universytetu. Tekhnichni nauky. – 2011. – № 1. – P. 209–213.
10. Prodanchuk, M. H. Suchasni problemy bezpechnosti tekstylnykh materialiv ta odiahu v ramkakh harmonizatsii z vymohamy standartiv krain yevropeiskoho spivtovarystva [Text] / M. H. Prodanchuk, L. H. Senenko, O. P. Kravchuk, I. V. Lieposhkin // Suchasni problemy toksykolohii. – 2004. – № 1. – P. 3–8.
11. Angelova, V. Bio-accumulation and distribution of heavy metals in fibre crops (flax, cotton and hemp) [Text] / V. Angelova, R. Ivanova, V. Delibaltova, K. Ivanov // Industrial Crops and Products. – 2004. – Vol. 19, № 3. – P. 197–205. doi:10.1016/j.indcrop.2003.10.001
12. Rezić, I. Cellulosic fibers – Biosorptive materials and indicators of heavy metals pollution [Text] / I. Rezić // Microchemical Journal. – 2013. – Vol. 107. – P. 63–69. doi:10.1016/j.microc.2012.07.009
13. Kulma, A. New flax producing bioplastic fibers for medical purposes [Text] / A. Kulma, K. Skórkowska-Telichowska, K. Kostyn, M. Szatkowski, J. Skała, Z. Drulis-Kawa, M. Preisner, M. Żuk, J. Szperlik, Y. F. Wang, J. Szopa // Industrial Crops and Products. – 2015. – Vol. 68. – P. 80–89. doi:10.1016/j.indcrop.2014.09.013
14. Anjum, S. Effects of photoperiod regimes and ultraviolet-C radiations on biosynthesis of industrially important lignans and

neolignans in cell cultures of Linum usitatissimum L. (Flax) [Text] / S. Anjum, B. H. Abbasi, J. Doussot, A. Favre-Réguillon, C. Hano // Journal of Photochemistry and Photobiology B: Biology. – 2017. – Vol. 167. – P. 216–227. doi:10.1016/j.jphotobiol.2017.01.006
15. Stamboulis, A. Effects of environmental conditions on mechanical and physical properties of flax fibers [Text] / A. Stamboulis, C. A. Baillie, T. Peijs // Composites Part A: Applied Science and Manufacturing. – 2001. – Vol. 32, № 8. – P. 1105–1115. doi:10.1016/s1359-835x(01)00032-x
16. Bagheri, Z. S. Biomechanical properties of an advanced new carbon/flax/epoxy composite material for bone plate applications [Text] / Z. S. Bagheri, I. El Sawi, E. H. Schemitsch, R. Zdero, H. Bougherara // Journal of the Mechanical Behavior of Biomedical Materials. – 2013. – Vol. 20. – P. 398–406. doi:10.1016/j.jmbbm.2012.12.013
17. Kunert-Keil, C. The survival and proliferation of fibroblasts on biocomposites containing genetically modified flax fibers: An in vitro study [Text] / C. Kunert-Keil, T. Gredes, A. Meyer, M. Wróbel-Kwiatkowska, M. Dominiak, T. Gedrange // Annals of Anatomy – Anatomischer Anzeiger. – 2012. – Vol. 194, № 6. – P. 513–517. doi:10.1016/j.aanat.2011.12.006
18. Semak, B. B. Teoretyko-metodolohichni osnovy formuvannia vitchyznianoho syrovynnoho rynku ekolohichno bezpechnykh tovariv tekstylnoi promyslovosti [Text]: Monograph / B. B. Semak. – Kherson: Hrin D. S., 2011. – 232 p.
19. Semak, B. B. Naukovi zasady formuvannia rynku roslynnoi tekhnichnoi syrovyny ta yoho okremykh sehmentiv [Text]: Monograph / B. B. Semak. – Lviv: Lviv Commercial Academy, 2007. – 512 p.
20. Tikhosova, H. A. Oderzhannia volokon riznoho funktsionalnoho pryznachennia z tresty lonu oliinoho [Text] / H. A. Tikhosova, T. M. Holovenko, I. O. Mieniailo // Lehka promyslovist. – 2011. – № 1. – P. 40–42.
21. Fedosova, N. M. Rasshirenie vozmozhnostei ispol'zovaniia maslichnogo l'na [Text] / N. M. Fedosova // Problemy legkoi i tekstil'noi promyshlennosti Ukrainy. – 2010. – № 1. – P. 115–116.
22. GOST 17.4.02-83. Ohrana prirody. Pochvy. Klassifikatsiia himicheskih veshchestv dlia kontrolia zagriazneniia [Text]. – Introduced: 1985-01-01. – Moscow: Izdatel'stvo standartov, 1985. – 12 p.
23. Standart 100 by OEKO-TEX [Electronic resource] // OEKO-TEX® Certifications&Services. – Available at: \www/ URL: https://www.oeko-tex.com/ru/business/certifications_and_services/ots_100/ots_100_start.xhtml
24. DSanPiN 3.3-182-2012. Materialy ta vyroby tekstylni, shkiriani i khutrovi. Osnovni hihiienichni vymohy [Text]. – Introduced: 2013-09-01. – Kyiv: State Sanitary Norms and Regulations, 2012. – 35 p.
25. Pendias, H. Trace Elements in Soils and Plants, Third Edition [Text] / H. Pendias, A. Kabata-Pendias. – CRC Press, 2001. – 403 p. doi:10.1201/9781420039900
26. Alekseev, Yu. V. Tiazhelye metally v pochvah i rasteniiah [Text] / Yu. V. Alekseev. – Leningrad: Agropromizdat, 1987. – 142 p.
27. Foy, C. D. The Physiology of Metal Toxicity in Plants [Text] / C. D. Foy, R. L. Chaney, M. C. White // Annual Review of Plant Physiology. – 1978. – Vol. 29, № 1. – P. 511–566. doi:10.1146/annurev.pp.29.060178.002455
28. Mortvedt, J. J. Micronutrients in Agriculture [Text] / J. J. Mortvedt, F. R. Cox, L. M. Shuman; ed. by R. M. Welch. – Soil Science Society of America, 1991. – 760 p.

ИССЛЕДОВАНИЕ БЕЗОПАСНОСТИ ЛЬНЯНЫХ ВОЛОКОН ДЛЯ ИЗДЕЛИЙ МЕДИЦИНСКОГО И САНИТАРНО-ГИГИЕНИЧЕСКОГО НАЗНАЧЕНИЯ

Исследована нормативно-техническая документация, в которой регламентируются требования к безопасности льняного волокна. Доказана необходимость пересмотра нормативов по содержанию химических элементов в льняном волокне и устаревшей нормативной базы. Определено, что критериями нормирования есть предельно допустимые концентрации всех химических элементов, которые могут попадать из почвы и накапливаться в льняном волокне.

Ключевые слова: предельно допустимые концентрации, классы опасности, тяжелые металлы во льне, безопасность льняного волокна.

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