COMMODITY BULLETIN
Journal homepage: https://c-bulletin.com.ua/en
DOI: 10.62763/ef/1.2024.146

Article's History: Received: 06.11.2024 Revised: 17.01.2024 Accepted: 26.04.2024

Vol. 17, No. 1, 2024, 146-153

UDC 678.046:687

Research on the safety level of special-purpose knitwear products

Irina Martirosyan*

PhD in Technical Sciences, Associate Professor
Odesa National University of Technology
65023, 112 Kanatna Str., Odesa, Ukraine
https://orcid.org/0000-0003-3733-3004

Kateryna Garbazhiy

PhD in Agricultural Sciences, Associate Professor
Odesa National University of Technology
65023, 112 Kanatna Str., Odesa, Ukraine
https://orcid.org/0000-0001-8696-8810

Volodymyr Voitsekhivskyi

PhD in Agricultural Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-3568-0985

Larisa Nikolaichuk

PhD in Technical Sciences, Associate Professor
Hetman Petro Sahaidachnyi National Army Academy
79026, 32 Heroiv Maidan Str., Lviv, Ukraine
https://orcid.org/0000-0003-2693-6635

Abstract. Environmental consciousness has become an essential component of human life in 2015-2024. Therefore, innovative textile and knitwear products made from environmentally-friendly fibers are becoming popular. Such products are safe for health and have less negative impact on the environment. The safety research problem of special-purpose knitwear products remains relevant, as they are used in special conditions, in direct contact with human skin. The aim of the study was to assess the safety indicators of textile products for the manufacture of workwear entering the Ukrainian market. The study used the method of atomic absorption spectrometry to determine the presence of heavy metals and pesticides in the products. The study determined the gross content of heavy metals that are harmful to human health: cobalt, chromium, copper, nickel, tin, cadmium, arsenic, and mercury. Three knitwear fabrics made in China, Ukraine and the Netherlands were selected as samples. The pesticide content was found to be inconsistent with the regulated requirements of Oeko-Tex-100. In the fabric made in China, the level of dieldrin exceeds the permitted limit and reaches 46 μg/kg, while the norm is 0.2 μg/kg. The fabric made in Ukraine contains an unacceptable amount of heptachlor (0.75 μg/kg at a norm of 0.5 μg/kg) and lindane (β-GCG) – 3.68 μg/kg at a norm of 1.0 μg/kg. The highest level of pesticides exceeding the established norms was found in the fabric made in the Netherlands. DDE exceeded almost 4 times – 3.75 μg/kg at the norm of 1.0 μg/kg; heptachlor almost 7 times – 3.19 μg/kg at the norm of 0.5 μg/kg, lindane γ-GCG – 1.51 μg/kg at the norm of 1.0 μg/kg and β-GCG – 15.7 μg/kg at the norm of 1.0 μg/kg. It is proposed to increase the level of control of environmental certification and standardisation with the introduction of mandatory eco-labeling of workwear, and to strengthen control by customs authorities when

Suggested Citation:
Martirosyan, I., Garbazhiy, K., Voitsekhivskyi, V., & Nikolaichuk, L. (2024). Research on the safety level of special-purpose knitwear products. *Commodity Bulletin*, 17(1), 146-153. doi: 10.62763/ef/1.2024.146

*Corresponding author

importing special-purpose products into the customs territory of Ukraine. The results of the study can be used by customers of workwear, wholesale and retail trade entrepreneurs, and can serve as a basis for strengthening control by customs authorities and certifying bodies over the entry of special-purpose knitwear of inadequate quality and safety level into the Ukrainian market

Keywords: heavy metals; hygiene requirements; pesticides; knitwear production; environmental safety

Introduction

In 2015-2023, the issue of ecologising the textile industry has become an urgent problem being addressed by scientists and specialists from different countries. This trend is driven by increasing requirements for the safety and hygiene of clothing, including special-purpose clothing. Scientists face new challenges in shaping and optimising the range of workwear and products. Each year, materials and fabrics with special types of processing and properties emerge, and scientists continue to work on the environmental safety of clothing and products. Among them, nanotechnologies occupy a significant place. The study by L. Nikolaichuk *et al.* (2020) substantiated the criteria for assessing the level of safety of nanotextiles and proposed a methodology for testing textiles for various purposes in the Ukrainian commodity market. The author investigated the role of nanotextiles and the issues of environmental friendliness and safety of military clothing. The work of I.A. Martyrosian *et al.* (2022) mentions eco-friendly textiles with antimicrobial properties. The research aimed to obtain a resource-saving method of applying biocidal preparations of thiosulfonate structure, which increases the wear resistance and microbiological resistance of overalls. H.E. Emam (2019) directed his research to improve the durability and mechanical properties of cellulose-containing textiles through biocidal treatment. The author also studied the interaction between cellulose and organometallic reagents, the mechanisms of biological action and the factors affecting biocidal action. In work I. Perelshtein *et al.* (2019) presented studies on the functionalisation of textiles with inorganic CuO, ZnO, MgO nanoparticles and a new Zn-CuO by sonochemical method. This mechanism makes sonochemistry a promising tool for highly stable and environmentally friendly textiles. The author also outlined the role of nanotechnology in the development of antibacterial textiles.

The importance of the environmental safety issue of textile materials is confirmed by the increased interest of scientists and is reflected in many scientific publications for 2018-2023. In scientific articles by S. Yasin & D. Sun (2019) and S. Velusamy *et al.* (2021) various types of textile dyes, including metal-containing ones, are considered. They also present studies on heavy metal pollution in wastewater and the overall environmental impact of technical and conventional textile waste.

Prior to 2018, the environmental safety of textile products in Ukraine was regulated by the Resolution of the Cabinet of Ministers of Ukraine No. 529 "On Approval of the Technical Regulation on Environmental Criteria for Eco-Labeling of Textile Products" (2011). However, by the Resolution of the Cabinet of Ministers of Ukraine No. 3 of January 11, 2018, the Technical Regulation on Ecolabeling lost its validity (Resolution of the Cabinet of Ministers of Ukraine No. 3, 2018). In 2013, the State Sanitary Norms and Rules "Materials and Products of Textile, Leather and Fur. Basic Hygienic Requirements" (Order of the Ministry of Health of Ukraine No. 1138, 2012), have been in effect. These norms and rules were developed as part of the harmonisation of Ukrainian standards with the standards of the International Association for Research and Testing in the Field of Textile Ecology (Oeko-Tex Standard 100, 1992). According to regulatory documents, the content of chemicals in the products is regulated; the content of harmful substances and their migration from the products to the human body and the environment (the content of free and partially releasable formaldehyde; residues of heavy metals that can be extracted, pesticides; the content of pentachlorophenol, azo dyes and organochlorine carriers; the presence of odour, etc.), and the absence of allergic effects is also controlled. After all, textile and knitwear production is associated with various sources of hazards. Harmful chemical dyes, which may contain heavy metals, pose a danger, as these substances migrate from the fabrics and accumulate in the human body. Azo dyes, on the other hand, cause skin diseases and allergic reactions. Moreover, raw materials and products of natural origin are treated with fungicides and insecticides to protect them from microorganisms, moths, and rodents. Natural fibers may also contain pesticides or harmful chemicals that get into the raw material through the soil. Even plant-based dust generated during cotton processing can cause bronchopulmonary pathology. There is also the fact that metals can accumulate in bones and various organs, causing their dysfunction; lead to cancer, acute and chronic kidney failure, diseases of the cardiovascular and nervous systems, autism, fetal death, metabolic disorders, etc. The mechanism of toxic effects of metals and semi-metals, as well as their consequences, varies. In the work of W. Zhou *et al.* (2023) describes the impact of various metals on human health. For example, arsenic (As) harms the liver and hearing, and has carcinogenic effects (including skin, liver, prostate, and Kupffer's cell cancers). Prolonged inhalation of cadmium (Cd) vapours leads to chronic bronchitis, emphysema,

and even lung cancer. Contact with chromium (Cr) can contribute to eczema and allergies. In case of chronic poisoning (occupational exposure), changes in the kidneys, digestive system and circulatory system can be observed. Skin itching and dermatitis can result from exposure to copper (Cu) compounds, which also cause conjunctivitis, ulcers and clouding of the cornea or throat, and also damage liver function. Lead (Pb) leads to anemia, which is more common in children. In addition to disorders of the hematopoietic system, this metal damages the nervous system and negatively affects the digestive system and kidneys. An excess of Zn leads to reduced iron absorption and, at the same time, prolonged excretion of this element from the body.

The purpose of the study was to investigate the presence of hazardous substances in knitwear products entering the Ukrainian market that can be harmful to the health of workers and the environment.

Materials and methods

Pure cotton knitwear products for special-purposes were chosen as the objects of study, since these products have direct contact with human skin. The selection of objects is also due to specific operating conditions, where the fabrics are more exposed to various chemical and biological factors. The characteristics of the investigated knitwear products are shown in Table 1.

Table 1. *Characteristics of investigated knitwear products*

Variant number	Name	Fiber composition, %	Type weave	Surface density, g/m2	Colour, country of origin
1	Knitted fabric taken from a short-sleeved jacket	Cotton 100	single jersey	171	Black, unknown paint brand, China
2	Knitted fabric taken from a short-sleeved jacket	Cotton 100	single jersey	150	Red, unknown paint brand, Ukraine
3	Knitted fabric taken from a short-sleeved jacket	Cotton 100	single jersey	150	Green, unknown paint brand, Netherlands

Source: *developed by the authors*

The tests were carried out in the laboratory of chemical and analytical research of the Ukrainian Scientific Center for Ecology (Odessa) under the Ministry of Ecology and Natural Resources of Ukraine. The concentrations of heavy metals were studied by atomic absorption spectrometry (AAS) using a ZEENIT 650P spectrometer (Analytik Jena AG, Germany), including division/preconcentration, solid phase extraction and co-precipitation procedures. The principle of the spectrometer is based on atomiation of the sample, measurement of the optical density of atomic vapours, and subsequent determination of the mass concentration of elements determined by calibration curves. The pesticide content was determined using an Agilent 4200 MP-AES (Agilent Technologies, USA), an electron capture detector (temperature rise of 1.2°C per min).

Results and discussion

The study took into account the fact that the main pollutants are cadmium, cobalt, bismuth, manganese, copper, nickel, mercury, zinc, lead, antimony, tin, and chromium. From this list, mercury, lead and cadmium are classified as global environmental pollutants of the first class of danger, as they can remain in the structure or on the surface of the fabric, causing various biological effects. The results of the chemical analysis of the presence of heavy metals in the knitwear products under study are shown in Table 2.

Table 2. *Heavy metal content in the investigated knitwear products*

No.	Metal name (concentration of heavy metals in the extract 0.07M HCL)	Displayed in knitted fabrics			Requirements of Oeko-Tex-100 not more than
		Variant No. 1 (black)	Variant No. 2 (red)	Variant No. 3 (green)	
1	Co (cobalt)	<0.05	<0.05	<0.05	4.0
2	Cr (chromium)	0.415	0.087	0.076	2.0
3	Cu (copper)	7.98	0.488	0.242	50.0
4	Ni (nickel)	0.672	0.326	0.068	4.0
5	Pb (tin)	0.897	0.241	0.160	1.0
6	Cd (cadmium)	0.095	0.231	0.050	0.1
7	As (arsenic)	<0.05	<0.05	<0.05	1.0
8	Hg (mercury)	<0.010	<0.010	<0.010	0.02

Source: *developed by the authors*

From the data in Table 2, it can be seen that the concentration of heavy metals in the extract is within the minimum permissible limits. It is worth noting that the content of heavy metals in the fabric of variant 1 (country of origin: China) is the highest compared to the others, while the lowest is observed in variant 3 (country of origin: Netherlands). In all three variants of the fabrics, the levels of cobalt, arsenic and mercury were significantly

lower than the norms regulated by Oeko-Tex-100. Control of pesticide content is also a prerequisite for the environmental safety of clothing and products, as these compounds are among the top priorities for ecosystem pollution. They are persistent and remain for a long time not only in the soil but also in natural raw materials, i.e. in natural fibers. The results of the tests for the presence of organochlorine pesticides are shown in Table 3.

Table 3. *Content of organochlorine pesticides in knitwear, (μg/kg)*

No.	Pesticide name	Variant No. 1 (black)	Variant No. 2 (red)	Variant No. 3 (green)	Requirements of Oeko-Tex-100 not more than
1	DDT	<0.10	<0.05	0.86	1.0
2	DDD	0.011	0.42	0.05	1.0
3	DDE	0.49	0.85	**3.75**	1.0
4	Heptachlor	<0.10	**0.75**	**3.19**	0.5
5	Lindane (γ-GCG)	<0.10	0.24	**1.51**	1.0
6	(α-HCCG)	<0.10	0.15	0.51	1.0
7	(β-HCCG)	<0.10	**3.68**	**15.7**	1.0
8	Aldrin	<0.10	<0.05	<0.05	0.2
9	Dieldrin	**46.2**	<0.05	<0.05	0.2

Note: *DDT – dichlorodiphenyl trichloromethylmethane; DDD – dichlorodiphenyl dichloroethane; DDE – dichlorodiphenyl dichloroethylene*
Source: *developed by the authors*

The data in Table 3 show that all three variants of knitted fabrics from different countries of origin do not meet the requirements of Oeko-Tex-100. For example, in the Chinese-made fabric (variant 1), the dieldrin value, at a norm of No more than 0.2, exceeds the established value by 46 μg/kg. In a knitted fabric made in Ukraine (variant 2), heptachlor exceeds the norms by 0.25 μg/kg, and lindane (β-GCG) by 2.68 μg/kg. Heptachlor is a highly effective insect repellent, so it is used for plants, but as of 2024, its levels are at the lowest concentrations in accordance with the Stockholm Convention on Persistent Organic Pollutants (2001). The results of the chemical analysis of Dutch-made knitted fabric (variant 3) are of particular interest, which also revealed non-compliance with the standard requirements for DDE (1.1-di(4'-chlorophenyl)-2.2-dichloroethylene), heptachlor, lindane γ-GCCH and (β-GCCH) – the content of pesticides significantly exceeds the permissible limits for all of these indicators.

Similar studies are presented in the work of E. Bielak & E. Marcinkowska (2022) to identify heavy metals in textiles and artificial leather sold on the Polish market. The objects were children's products, and the research was conducted to assess the compliance of textiles with the Oeko-Tex-100 requirements for arsenic, cadmium, chromium, copper, tin, and zinc. The results showed that all of the above heavy metals were present in the textile samples, but within the permissible limits of the standard.

M.F. Sima (2022) also dedicated a study to quantifying the content of heavy metals in knitwear products, in particular T-shirts dyed in various bright colours. In this research, the concentrations of heavy metals (Co, Cu, Cr, Cd, and Pb) were analysed in contact with the skin. The results of the research showed high levels of copper (Cu) in black, green, blue and red T-shirts ranging from 26.726-179.315 mg/kg. All T-shirt samples had low cobalt content. In this research, the concentrations of Pb, Cu and Cr in the red and green T-shirt samples exceeded Oeko-Tex.

During the research, I. Rujido-Santos *et al.* (2022) also found that the textile materials under study did not meet the requirements of European Regulation 1906/2006 (Regulation (EC) No 1906/2006, 2006) for the content of heavy metals. The determination of metals in the fabrics was carried out using inductively coupled plasma mass spectrometry (ICP-MS) after acid digestion using microwaves. The results showed that the arsenic content in one and the lead content in 3 fabric samples exceeded the maximum limits. The other 3 samples also contained high levels of mercury. Thus, the test samples of fabrics commercialised in Europe did not meet the requirements of the European Regulation.

H. Chen *et al.* (2021) selected preschool children's clothing made in four Asian regions as the object of their research, where the concentrations of Pb, Cd, Co, Zn, Cr, As, Cu and Ni were investigated. The test results showed that the children's clothing had high levels of Ni and Cr, while the levels of Pb and Cd were not significant within the normal range. Cd concentrations were higher in black garments than in white and coloured samples. Samples without cotton contained unacceptable concentrations of Co. Pb concentrations in samples made in China were significantly higher than in the other three regions. The authors also estimated the doses of skin exposure to these metals and calculated the corresponding risks. The results showed that the health risks from the impact of these metals on children's clothing were within the acceptable limits.

In terms of textile safety, one of the most important indicators is the content of heavy metals and toxic

substances that enter products from various sources. In particular, scientists E. Bielak & E. Marcinkowska (2022) conducted experimental studies on the content of heavy metals in textile materials and artificial leather. The study presents the results of verifying the compliance of the quantitative content of heavy metals with the requirements of Oeko-Tex Standard 100 (1992) by atomic absorption spectrometry. J. Kaur *et al.* (2021), A.E. Apsari & H. Purnomo (2020), Ö. Canpolat & M. Çalta (2020) dedicated their research to the assessment of heavy metal content in untreated water during textile production in the vicinity of India. N. Singh & O. Sahu (2019) studied sustainable ways to develop new textiles with improved properties. Scientists such as G.O. Odubanjo *et al.* (2021), J. Ahmed *et al.* (2021) and D. Astuti *et al.* (2023) in their works have focused on the potential risk of heavy metals to human health and the environment during textile production. Impacts on human health and the environment have been studied and discussed in D. Massella *et al.* (2019), G.A. Engwa *et al.* (2019), and W. Ahmad *et al.* (2021). However, despite the numerous available studies and scientific inventions, the issue of environmental safety remains open and requires the search for more universal, environmentally-friendly and economical solutions. In turn, the author O.V. Pakholiuk *et al.* (2019) investigated the role of vegetable dyes in improving the environmental safety of clothing fabrics and the study of low-toxic synthetic and vegetable dyes for dyeing flax-containing textiles. A. Hanczvikkel *et al.* (2019) studied the problem of microbiological safety of textiles in medical institutions, comparing the results of medical strains with multidrug resistance and antibiotic-sensitive standard strains. The research aimed to find safe and environmentally-friendly biocidal products that can inhibit the development of microorganisms.

The test results and analysis of other researchers' studies confirm the relevance of controlling the safety level of textile materials in the pre-sale period. The data shows that large volumes of textiles and clothing get into unauthorised circulation and are not properly controlled by the relevant authorities not only in the Ukrainian but also in the European and Asian markets. The research shows that hazardous substances, such as heavy metals, chemical pollutants and carcinogens, can be present in textiles in high concentrations, which can lead to harmful effects on human health through skin contact or inhalation. In addition, insufficient control over product safety in the pre-sale period contributes to the proliferation of counterfeit and fake products, which poses a threat not only to consumer health but also to economic stability and market confidence.

Conclusions

According to the results of the research on determining the content of heavy metals in special-purpose knitwear products, it has been established that all three product variants meet the established hygienic requirements of Ukrainian and European regulatory documents. All concentrations of heavy metals in the 0.07M HCL extract are within the permissible limits. The chemical analysis of pesticides showed that all the tested knitwear products did not meet the Oeko-Tex-100 requirements due to the high level of pesticides, in particular, a high content of dieldrin was found in a Chinese-made knitwear product, while variant 2 of Ukrainian production showed a slight increase in the content of heptachlor and an excess of lindane. Variant 3 (produced in the Netherlands) does not meet the safety indicators for several substances: DDE, heptachlor, γ-GCG and β-GCG lindane.

The obtained data indicate inadequate control by state authorities of both producing and exporting country. As Ukraine has been increasing its export potential of textile and knitwear products since 2018, there is a need to strengthen environmental control by customs authorities. Although Ukraine has a harmonised regulatory framework, technical regulation is at a low state level. It would be effective to increase the level of environmental certification and standardisation with the introduction of mandatory eco-labeling for certain types of products and clothing, including special-purpose clothing.

The study determined that the environmental safety of textile products is of crucial importance in shaping the Ukrainian eco-textile market. Further scientific research in this area should focus on developing clear criteria for hygiene requirements and regulatory documentation that would regulate environmental quality assessment indicators. The results of the research may serve as a basis for strengthening control over the quality and safety of textile products entering the Ukrainian market.

In the future, it is planned to conduct experimental tests on the content of toxic substances in knitwear products, including formaldehyde, alcohols, hexamethylenediamine, benzene, toluene, xylene, etc. It is also planned to conduct research on the impact of biocidal treatment on the environmental safety of special-purpose knitwear products and experimental studies in production conditions.

Conflict of interest

None.

Acknowledgements

We express our gratitude to Olena Pakholiuk for fruitful cooperation.

References

[1] Ahmad, W., Alharthy, R.D., Zubair, M., Ahmed, M., Hameed, A., & Rafique, S. (2021). Toxic and heavy metals contamination assessment in soil and water to evaluate human health risk. *Scientific Reports*, 11, article number 17006. doi: 10.1038/s41598-021-94616-4.

[2] Ahmed, J., Thakur, A., & Goyal, A. (2021). Industrial wastewater and its toxic effects. In M.P. Shah (Ed.), *Biological treatment of industrial wastewater* (pp. 1-14). Cincinnati: University of Cincinnati.

[3] Apsari, A.E., & Purnomo, H. (2020). An occupational safety and health (OSH) factors identified in Indonesian batik textile small/medium enterprises. *International Research Journal of Engineering, IT & Scientific Research*, 6(2), 55-64. doi: 10.21744/irjeis.v0i0.000.

[4] Astuti, D., Awang, N., Othman, M.S.B., Kamaludin, N.F.B., Meng, C.K., & Mutalazimah, M. (2023). Analysis of heavy metals concentration in textile wastewater in batik industry center. *Journal of Science Education Research*, 9(3), 1176-1181. doi: 10.29303/jppipa.v9i3.3085.

[5] Bielak, E., & Marcinkowska, E. (2022). Heavy metals in leathers, artificial leathers, and textiles in the context of quality and safety of use. *Scientific Reports*, 12, article number 5061. doi: 10.1038/s41598-022-08911-9.

[6] Canpolat, Ö., & Çalta, M. (2020). Determination the heavy metal contents of wastewater from the leather factory. *Turkish Journal of Agriculture – Food Science and Technology*, 8(3), 752-758. doi: 10.24925/turjaf.v8i3.752-758.3306.

[7] Chen, H., Chai, M., Cheng, J., Wang, Y., & Tang, Z. (2021). Occurrence and health implications of heavy metals in preschool children's clothing manufactured in four Asian regions. *Ecotoxicology and Environmental Safety*, 245, article number 114121. doi: 10.1016/j.ecoenv.2022.114121.

[8] Emam, H.E. (2019). Antimicrobial cellulosic textiles based on organic compounds. *3 Biotech*, 9, article number 29. doi: 10.1007/s13205-018-1562-y.

[9] Engwa, G.A., Ferdinand, P.U., Nwalo, F.N., & Unachukwu, M. (2019). Mechanism and health effects of heavy metal toxicity in humans. In O. Karcioglu & B. Arslan (Eds.), *Poisoning in the modern world new tricks for an old dog* (pp. 77-99). London: IntechOpen.

[10] Hanczvikkel, A., Vig, A., & Toth, A. (2019). Survival capability of healthcare-associated, multidrug-resistant bacteria on untreated and on antimicrobial textiles. *Journal of Industrial Textiles*, 48(7), 1113-1135. doi: 10.1177/1528083718754901.

[11] Kaur, J., Bhatti, S.S., Bhat, S.A., Nagpal, A.K., Kaur, V., & Katnoria, J.K. (2021). Evaluating potential ecological risks of heavy metals of textile effluents and soil samples in vicinity of textile industries. *Soil Systems*, 5(4), article number 63. doi: 10.3390/soilsystems5040063.

[12] Martyrosian, I., Pakholiuk, O., Dzubinskyi, A., Nikolaichuk, L., Lutskova, V., Lubenets, V., & Peredriy, O. (2022). Resource-saving technology of producing textile materials with antimicrobial properties. *Fibres and Textiles*, 29(4), 3-8. doi: 10.15240/tul/008/2022-4-001.

[13] Massella, D., Giraud, S., Guan, J., Ferri, A., & Salaün, F. (2019). Textiles for health: A review of textile fabrics treated with chitosan microcapsules. *Environmental Chemistry Letters*, 17, 1787-1800. doi: 10.1007/s10311-019-00913-w.

[14] Nikolaichuk, L., Galyk, I., Semak, B., & Shapoval, O. (2020). The role of nanotextile in the formation of the domestic market of special clothing and application in logistic provision of military units. *Herald of Lviv University of Trade and Economics*, 23, 49-57. doi: 10.36477/2522-1221-2020-23-06.

[15] Odubanjo, G.O., Oyetibo, G.O., & Ilori, M.O. (2021). Ecological risks of heavy metals and microbiome taxonomic profile of a freshwater stream receiving wastewater of textile industry. *Frontiers in Environmental Science*, 9, article number 554490. doi: 10.3389/fenvs.2021.554490.

[16] Oeko-Tex Standard 100 - Textiles Vertrauen – Weltweit. Opens Unlimited Textile Markets. (1992). Retrieved from https://www.oeko-tex.com/en/our-standards/oeko-tex-standard-100.

[17] Order of the Ministry of Health of Ukraine No. 1138 "On Approval of the State Sanitary Norms and Rules "Materials and Products of Textile, Leather and Fur. Basic hygienic requirements". (2012, December). Retrieved from https://zakon.rada.gov.ua/laws/show/z0086-13#Text.

[18] Pakholiuk, O.V., Pushkar, G.O., Halyk, I.S., & Semak, B.D. (2019). Use of some polyfunctional protective preparations for protection the textile cellulose-based materials from microbiological damages. *Herald of Khmelnytskyi National University*, 1, 100-104. doi: 10.31891/2307-5732-2019-269-1-100-104.

[19] Perelshtein, I., Perkas, N., & Gedanken, A. (2019). The sonochemical functionalization of textiles. In *The impact and prospects of green chemistry for textile technology* (pp. 161-198). Sawston: Woodhead Publishing. doi: 10.1016/B978-0-08-102491-1.00007-1.
[20] Regulation (EC) No. 1906/2006 of the European Parliament and of the Council. (2006, December). Retrieved from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32006R1906.
[21] Resolution of the Cabinet of Ministers of Ukraine No. 529 "On Approval of the Technical Regulations on Environmental Labelling". (2011, May). Retrieved from https://zakon.rada.gov.ua/laws/show/529-2011-%D0%BF#Text.
[22] Resolution of the Cabinet of Ministers of Ukraine No. 3 "On Amendments to and Cancellation of Certain Resolutions of the Cabinet of Ministers of Ukraine". (2018, January). Retrieved from https://zakon.rada.gov.ua/laws/show/3-2018-%D0%BF#Text.
[23] Rujido-Santos, I., Herbello-Hermelo, P., Barciela-Alonso, M.C., Bermejo-Barrera, P., & Moreda-Piñeiro, A. (2022). Metal content in textile and (nano)textile products. *International Journal of Environmental Research and Public Health*, 19(2), 944. doi: 10.3390/ ijerph19020944.
[24] Sima, M.F. (2022) Determination of some heavy metals and their health risk in T-shirts printed for a special program. *PLoS One*, 17(9), article number e0274952. doi: 10.1371/journal. pone.0274952.
[25] Singh, N., & Sahu, O. (2019). Sustainable cyclodextrin in textile applications. In *The impact and prospects of green chemistry for textile technology* (pp. 83-105). Sawston: Woodhead Publishing. doi: 10.1016/B978-0-08-102491-1.00004-6.
[26] Stockholm Convention on Persistent Organic Pollutants. (2004). Retrieved from https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/stockholm-convention-on-persistent-organic-pollutants/.
[27] Velusamy, S., Roy, A., Sundaram, S., & Mallick, T.K. (2021). A review on heavy metal ions and containing dyes removal through graphene oxide-based adsorption strategies for textile wastewater treatment. *The Chemical Record*, 21(7), 1570-1610. doi: 10.1002/tcr.202000153.
[28] Yasin, S., & Sun, D. (2019). Propelling textile waste to ascend the ladder of sustainability: EOL study on probing environmental parity in technical textiles. *Journal of Cleaner Production*, 233, 1451-1464. doi: 10.1016/j.jclepro.2019.06.009.
[29] Zhou, W., Dan, Z., Meng, D., Zhou, P., Chang, K., Zhuoma, Q., Wang, J., Xu, F., & Chen, G. (2023). Distribution characteristics and potential ecological risk assessment of heavy metals in soils around Shannan landfill site, Tibet. *Environmental Geochemistry and Health*, 45, 393-407. doi 10.1007/s10653-022 -01349 - y.

Дослідження рівня безпеки трикотажних виробів спеціального призначення

Ірина Мартиросян

Кандидат технічних наук, доцент
Одеський національний технологічний університет
65023, вул. Канатна, 112, м. Одеса, Україна
https://orcid.org/0000-0003-3733-3004

Катерина Гарбажій

Кандидат сільськогосподарських наук, доцент
Одеський національний технологічний університет
65023, вул. Канатна, 112, м. Одеса, Україна
https://orcid.org/0000-0001-8696-8810

Володимир Войцехівський

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-3568-0985

Лариса Ніколайчук

Кандидат технічних наук, доцент
Національна академія сухопутних військ імені Гетьмана Петра Сагайдачного
79012, вул. Героїв Майдану, 32, м. Львів, Україна
https://orcid.org/0000-0003-2693-6635

Анотація. Екологічна свідомість за 2015-2024 роки стала важливою складовою життя людини, тому інноваційні текстильні та трикотажні вироби, створені з екологічно чистих волокон, стають популярними. Такі вироби безпечні для здоров'я та мають менший негативний вплив на довкілля. Проблема дослідження безпечності трикотажних виробів спеціального призначення залишається актуальною, оскільки вони експлуатуються в особливих умовах, безпосередньо контактуючи зі шкірою людини. Метою роботи була оцінка показників безпечності текстильних виробів для виготовлення спецодягу, що надходить на український ринок. У дослідженні був використаний метод атомно-абсорбційної спектрометрії щодо наявності важких металів та пестицидів у складі виробів. В роботі визначено валовий вміст важких металів, які шкідливі для здоров'я людини: кобальт, хром, мідь, нікель, олово, кадмій, миш'як, ртуть. Досліджено наявність пестицидів у складі виробів. В ролі зразків обрано 3 трикотажних полотна китайського, українського та голландського виробництва. Встановлено невідповідність за вмістом пестицидів регламентованим нормативним вимогам Oeko-Tex-100. У полотні китайського виробництва показник дилдрину перевищує дозволену межу і досягає 46 мкг/кг при нормі 0,2 мкг/кг. Полотно українського виробництва містить недопустиму кількість гептахлору (0,75 мкг/кг при нормі 0,5 мкг/кг) та линдану (β-ГХЦГ) – 3,68 мкг/кг при нормі 1,0 мкг/кг. У полотні голландського виробництва виявлено найбільший рівень пестицидів, що перевищують встановлені норми. ДДЕ перевищений майже в 4 рази – 3,75 мкг/кг при нормі 1,0 мкг/кг; гептахлор майже в 7 разів – 3,19 мкг/кг при нормі 0,5 мкг/кг, линдан γ-ГХЦГ – 1,51 мкг/кг при нормі 1,0 мкг/кг та β-ГХЦГ – 15,7 мкг/кг при нормі 1,0 мкг/кг. Запропоновано підвищити рівень контролю екологічної сертифікації та стандартизації із введенням обов'язкового еко-маркування спецодягу, посилити контроль з боку митних органів під час імпорту на митну територію України виробів спеціального призначення. Результати дослідження можуть бути використані замовниками спецодягу, підприємцями оптової та роздрібної торгівлі, бути підставою для посилення контролю з боку митних органів та органів сертифікації щодо надходження на ринок України трикотажних виробів спеціального призначення неналежної якості та рівня безпечності

Ключові слова: важкі метали; вимоги до гігієни; пестициди; трикотажне виробництво; екологічна безпека