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Technical regulation of hygienic properties of infant clothing

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Abstract. Hygienic properties for children's clothing are a significant factor in quality and safety and require careful study and control. However, the technical regulation of safety and hygiene standards for children's clothing remains a significant challenge in the global market. The mechanism for ensuring the safety of children's clothing requires new solutions from governments. Key aspects of protecting children's health in clothing manufacturing include controlling the quality of raw materials, monitoring production processes, and regulating the use of chemical bleaches and dyes. The aim of this work was to examine the hygienic properties of infant clothing entering the Ukrainian market. The assessment of hygienic authorities was carried out using standard methods, including atomic absorption and chromatographic methods. Odorimetric studies revealed that the sample of the "Sova Kids" body suit does not meet the regulatory standards for odour intensity. The results of the study on hygienic properties showed that all samples meet the established requirements, but the "Sova Kids" body suit exhibited the best hygroscopicity. Chemical analysis for heavy metals revealed that in Sample No. 2, the "SMIL" body suit, the copper content exceeds both international and Ukrainian standards by 0.6 μg/kg. A very high concentration of dichlorodiphenyl trichloromethylmethane (DDT) was found in all three samples of infant clothing. These values are 12 to 17 times higher than the established Ukrainian and international standards (permissible limit: up to 0.5 μg/kg). Meanwhile, Sample No. 3 does not include any labeling data or manufacturer information. The results of this study hold practical significance for retail chains selling infant clothing and can be utilised by wholesale and retail entrepreneurs, as well as clothing manufacturers. They also serve as a basis for regulatory authorities, especially certification bodies, to implement stricter measures"

Keywords: environmental safety; heavy metals; pesticides; assessment of substance content; hygroscopicity

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Introduction

Infants and toddlers represent a unique group of textile users. The distinct nature of this group lies in the fact that the requirements for their clothing are not determined by the consumers themselves, but by adults – such as parents or nannies – who observe the children's reactions to clothing and personal hygiene items. Long-term experience shows that the most suitable fabrics for children's underwear and clothing are those made from cellulose-based fibers. Globally, there is also a growing trend towards using fabrics and knitwear that contain linen and cotton fibers.

Focusing on these issues is linked to the frequent use of chemical, especially synthetic, fibers and threads in the production of fabrics for children's clothing and personal hygiene products. Some manufacturers prioritise commercial interests over children's needs and hygiene standards. Therefore, ensuring the quality of children's products is a pressing issue that requires a systematic solution. The safety of clothing, particularly in terms of hygienic and environmental properties, is an ongoing global concern being studied by scientists not only in Ukraine but around the world. For instance, V. Afanasyeva & Z. Karpenko (2020) dedicated her research to addressing the regulatory and technical challenges surrounding children's clothing.

In a study by O.V. Domanova (2019), the issues of labeling Ukrainian-made children's clothing were examined. Similarly, O. Zavorotna & L. Halavska (2022) conducted experimental research on the consumer properties of children's clothing in her works. P. Dewangan & R. Kumar (2023) also focused his scientific research on the standarts for children's clothing. They underscore the critical importance of safety regulations for children's wear in India, given the anticipated growth in the market. Despite the absence of specific regulations, the study reveals the potential risks associated with children's clothing, emphasising the need for comprehensive safety standards. D. Sanjeevana & R. Thenmozhi (2022) explored methods to improve the wear resistance and hygiene of children's clothing by using fabrics with enhanced functional properties. The work D. Santiago *et al.* (2024) studied the dependence of the functional properties of children's clothing on the composition of the fabric. In review article F. Burks *et al.* (2021), the potential negative effects of improper textiles for children's wear, fabric dyestuffs, and common textile wet processing were covered. Y. Sorumlu *et al.* (2022) dedicated their work to the issues of safe use of fittings for children's clothing

In 2013, State sanitary standards and regulations (2012) came into force in Ukraine, based on research conducted at the L.I. Medved Institute of Ecohygiene and Toxicology, the Research Institute of Transport Medicine, and various regional sanitary and epidemiological stations as part of the harmonisation of Ukrainian standards with those of the International Association for Research and Testing in the Field of Textile and Leather Ecology (Oeko-Tex Standard 100, 1992). Children's clothing must not cause skin irritation, allergic reactions, or long-term harmful effects (such as carcinogenic, mutagenic, or teratogenic activity), nor should it disrupt the skin's natural flora. In other words, textile materials and products must be safe for health, comfortable, and accompanied by a positive conclusion from the state sanitary and epidemiological inspection. This is particularly important due to children's heightened sensitivity to external factors caused by the dynamic conditions in which children's products are used. The hygienic and safety standards for children's clothing must meet the highest requirements and be recognised by all sectors (production, distribution, and ecology) as the first level of structural approach, especially with Ukraine integrating into the European Union.

The aim of study was to analyse the hygienic properties of children's clothing to ensure they meet modern safety standards.

Materials and Methods

An analysis of the children's clothing market in Ukraine identified key trends and growth prospects in individual segments, revealing that the market has been steadily expanding since 2018, despite the accerelated cyclicity of economic crises. For the study of hygienic properties of children's clothing sold in Odesa, three retail chains were selected: "Antoshka" ("Betis"), "SMIL", and "Sova Kids" (the latter representing a more affordable option). The characteristics of the research samples are summarised in Table 1 and presented as follows: Sample No. 1: TM "Betis"; Sample No. 2: TM "SMIL"; Sample No. 3: TM "Sova Kids".

Table 1. *Research objects*

Sample number	Product name	Regulatory document	Producer	Sample image
1	Bodysuit "Princess" TM "Betis"	DSTU GOST 31407:2014 (2014)	TM "Betis" 57500, Mykolaiv region, Ochakov, Ukraine	

Table 1. Continued

2	Red bodysuit TM "SMIL"	DSTU GOST 31410:2014	UNL LLC "Baltskaya Road 5", Odessa, Ukraine	
3	Bodysuit TM "Sova Kids"	Not indicated	Not indicated	

Source: *developed by the authors*

Experimental studies were conducted using standard methods. The mass fraction of fibers was determined in accordance with DSTU 4057-2001 (2001), while the combustion characteristic was assessed using the combustion method. Hygroscopicity was determined according to DSTU GOST 3816:2009 (ISO 811) (2009), each elementary fabric sample, measuring 50x200 mm, was placed in a separate cup for weighing and then transferred to a desiccator with an air humidity of 97-99%. After 4 hours, the samples were weighed, dried at a temperature of 105-109°C, and weighed again. Hygroscopicity (*H*), expressed as a percentage, was determined using the following formula:

$$H = \frac{(mh-md)}{md} * 100, \quad (1)$$

where m_h – mass of the hydrated aliquot, g; m_d – mass of the aliquot after drying to the constant mass, g.

Fabric water absorption is defined by the amount of water that the fabric can absorb within a specified time period. Water absorption (Wa) is calculated by the formula, %:

$$W_a = \frac{g_{ad}-g_h}{g_{ad}} \times 100, \quad (2)$$

where W_a – water absorption; g_{ad} – mass of the air-dried fabric; g_h – mass of the hydrated fabric.

To determine water absorption, a fabric sample measuring 4x4 cm is submerged in a vessel with distilled water for 10 minutes. The samples are then removed and pressed for 30 seconds. For this, the wet fabric is placed between three sheets of filter paper, covered with three additional sheets, and a load of 10 g/cm² is applied. Odorimetric studies include:

- assessment of the external condition of the products (packaging integrity, product aesthetics, compliance with intended use and age group);
- evaluation of the quality and intensity of the odour.

The determination of the quality and intensity of product odour is conducted with the involvement of volunteers (at least 6), all of whom must have no impairments in their olfactory organs or nasal cavity. The study is performed in a well-lit, well-ventilated room. When evaluating odour quality, attention is given to the presence or absence of any foreign, unpleasant, or unusual smells for the product in question. The intensity of the odour is assessed using a five-point scale (Wright, 1966) as shown in Table 2.

Table 2. *Odour intensity of textile, leather, and fur materials*

Quantitative assessment in points	Characteristics
0	Absent; not detected by any of the volunteers
1	Barely noticeable; detectable only by the most sensitive individuals
2	Weak; noticeable and can be identified if volunteers specifically focus on detecting it
3	Expressive; easily perceptible, even without specific attention from volunteers
4	Strong; readily attracts attention
5	Unbearable; makes prolonged indoor presence intolerable
The intensity of odour in textile, leather, and fur materials and products for children should not exceed 1 point, while for adults, it should not exceed 2 points	

Source: *based on State sanitary standards and regulations (2012)*

To determine the content of heavy metals in textile materials, a comparison solution containing known quantities of elements was prepared in 100 cm³ volumes. This was analysed in accordance with DSTU GOST 22001:2008 (2008) using a ZEEN-IT 650p atomic absorption spectrometer (Germany). Both the comparison solutions and the test samples are introduced into the atomiser of the spectrometer, and the analytical signal values are recorded. The total metal content (μg/g) is then calculated using the following formula:

$$X = \frac{C1*V1}{m1*1000}, \quad (3)$$

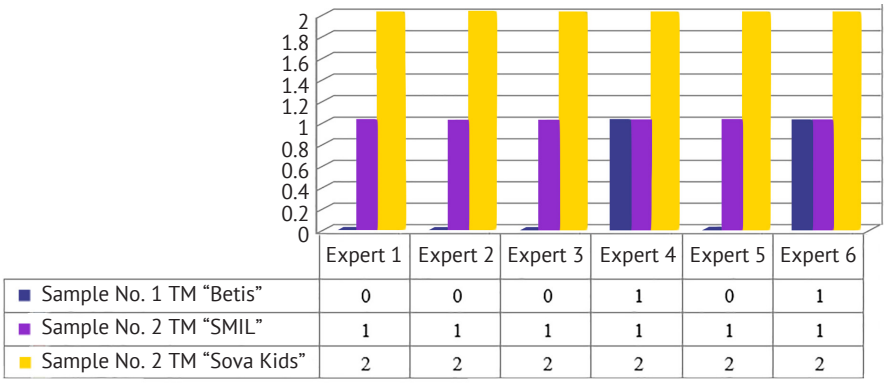
where, *C1* – mass concentration of the element being analysed in the solution, μg/cm³; V_1 – solution volume, cm³; m_1 – mass of the aliquot, g.

Pesticide content was determined using chromatographic methods. For the analysis of pesticides in textile materials, an electron capture detector was employed, with a temperature ramp rate of 1.2°C/min.

Results and Discussion

In the manufacture of clothing for newborns, cotton fabrics such as calico, flannel, and bombazine are commonly used. These fabrics are known for their diverse weaving structures, processing types, appearances, and properties. They offer high hygienic standards, durability, softness, and a pleasant feel, alongside an attractive appearance. Chemical analysis revealed that all three samples are made of 100% natural cotton. Additionally, Sample No. 3 contained a small amount of wool, with a fiber composition of 80% cotton and 20% wool.

Among the hygienic indicators, the odour of the product is also significant. The results for odour intensity are presented in Figure 1 and are normalised according to State Sanitary Rules and Regulations (based on the 5-point scale established by R.H. Wright (1966)).



	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Sample No. 1 TM "Betis"	0	0	0	1	0	1
Sample No. 2 TM "SMIL"	1	1	1	1	1	1
Sample No. 2 TM "Sova Kids"	2	2	2	2	2	2

Figure 1. *Assessment of odour intensity (point)*

Source: *developed by the authors*

According to the results of the odour intensity assessment, it was found that the sample with the least noticeable odour was Sample No. 1 (TM "Betis"), with an average score of 0.33. Sample No. 2 (TM "SMIL") ranked second, with an average score of 1. However, Sample No. 3 exceeded the permissible odour intensity, receiving a score of 2 from all experts. This violates the State sanitary standards and regulations (2012), which stipulate that odour intensity should not exceed 1 point.

For the manufacture of clothing for infants, it is necessary to select the material based not only on the indicators given in the regulatory documentation, but also to take into account the specifics of age-related use. Since not all standardised indicators of the current legislation reflect the operating conditions, it was advisable to determine the ability of materials to absorb water for this product range. Hygroscopicity of knitted fabrics is characterised by its ability to adsorb and desorb hygroscopic and capillary moisture when environmental conditions change. This indicator is of great importance for the clothing of infants. It is also known that the indicators of hygroscopicity and water absorption depend on the fibrous composition of the product, the structure of knitwear and the operating conditions of the product. The results of determining hygroscopicity and water absorption are clearly shown in Figure 2.

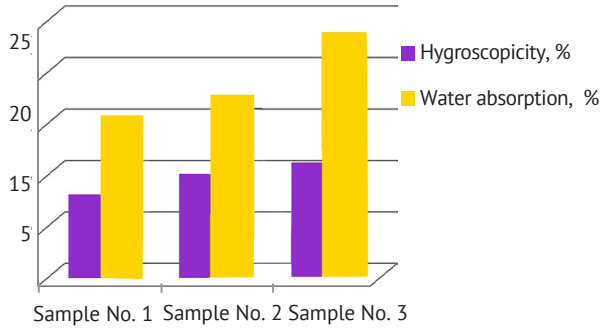


Figure 2. *Assessment of the quality of children's clothing by hygiene indicators*

Source: *developed by the authors*

Based on the results of evaluating clothing for "hygroscopicity" and "water absorption", Sample No. 3 demonstrated the best hygroscopicity. This can be attributed to the high surface density of the knitted fabric and the presence of wool fibers in its composition, which have higher hygroscopic properties compared to fabrics made solely from cotton. Ecological indicators of children's clothing also depend on the type and quantity of insecticides and fungicides used in agriculture, as only natural raw materials are intended for the production of children's fabrics. Special attention must be given to the content of heavy metals, which can enter textile materials through the use of dyes and vary depending on technological processes. The most hazardous heavy metals include cadmium, bismuth, cobalt, manganese, copper, zinc, nickel, tin, mercury, and lead. High concentrations of these metals can significantly impact the health of children, particularly infants, causing various biological effects such as allergens and skin irritants, with varying durations and detection times. Therefore, determining the presence or absence of heavy metals in fabric compositions is crucial. Tests were conducted at the Odessa branch of the Institute of Biology of the Southern Seas, National Academy of Sciences of Ukraine. The results of the heavy metal content analysis are presented in Table 3.

Table 3. *Heavy metal content in baby clothing*

Samples	Content of metals detected, µg/kg							
	Co cobalt	Cr chromium	Cu copper	Ni nickel	Pb lead	Cd cadmium	As arsenic	Hg mercury
DSTU requirements	2.0	1.0	5.0	1.0	0.2	0.1	0.2	0.02
OEKO-Tex requirements	1.0	1.0	5.0	1.0	0.2	0.1	0.2	0.02
Sample No. 1	< 0.05	0.521	< 0.1	< 0.1	< 0.05	< 0.05	< 0.05	< 0.010
Sample No. 2	< 0.05	0.400	5.6	< 0.1	< 0.05	< 0.05	< 0.05	< 0.010
Sample No. 3	< 0.05	0.310	0.4	< 0.1	< 0.05	< 0.05	< 0.05	< 0.010

Source: *developed by the authors*

Data from Table 3 show that all elements detected in the knitwear composition are within permissible limits, except for copper. In Sample No. 2, the copper content exceeds both international and Ukrainian standards by 0.6 µg/kg. This elevated level may be attributed to the use of copper-based dyes, as Sample No. 2 features a bright red colour, in contrast to the less coloured Sample No. 1 and Sample No. 3. Sample No. 1, being a bleached canvas, shows the lowest copper content but the highest chlorine content (0.521 µg/kg). This higher chlorine level is likely due to the use of hypochlorite solutions in the bleaching process; however, the chlorine content remains within acceptable limits. Sample No. 3, which is not bleached and contains minimal dye, visually exhibits the least amount of both chlorine and copper, as reflected in its product design. It is well-known that to prevent microorganisms, moths, and rodents, fungicides and insecticides are frequently applied to raw materials and products with natural origins during storage and transportation. Additionally, in traditional land cultivation, insecticides and fertilisers are used to enhance yield. Approximately 10% of all pesticides used globally are associated with cotton cultivation, and residues of these pesticides remain in the fabric after processing. Pesticides can be a source of skin diseases and allergic reactions, particularly for infants whose skin is highly sensitive to external stimuli. Table 4 presents the results of the analysis of pesticide content in the fabrics.

Table 4. *Pesticide content in children's clothing*

Indicator name	OEKO-Tex -100	DSTU 4239:2003	Sample No. 1	Sample No. 2	Sample No. 3
DDT	up to 0.5	up to 0.5	12.67	12.76	16.94
DDE	up to 0.5	up to 0.5	0.00	0.00	0.00
DDD	up to 0.5	up to 0.5	0.00	0.00	0.00
Aldrin	up to 0.1	up to 0.1	0.00	0.00	0.00
Lindane	up to 0.5	up to 0.5	3.44	2.21	0.63
Heptachlor	up to 0.25	up to 0.25	0.00	0.00	0.00
Dieldrin	up to 0.1	up to 0.1	0.00	0.00	0.00

Source: *developed by the authors*

Studies on the composition of knitwear revealed very high concentrations of DDT (dichlorodiphenyltrichloroethane) in all three samples. Notably, Sample No. 2, which is marketed as eco-friendly and bears eco-labeling and safety certificates, showed a particularly high concentration of DDT. Specifically, the DDT content in Sample No. 1 from TM "Betis" was 12.67 μg/kg, while in Sample No. 2 from TM "SMIL" it was 12.76 μg/kg – both of which are approximately 12 times higher than the established norms. Sample No. 3 from TM "Sova Kids" had a DDT content of 16.94 μg/kg, exceeding both Ukrainian and international requirements by 16 times, with the permissible amount being up to 0.5 μg/kg. Additionally, non-compliance with regulatory requirements was observed for lindane content in all three samples, which also exceeded permissible norms: 3.44 μg/kg, 2.21 μg/kg, and 0.63 μg/kg, respectively, against the permissible limit of no more than 0.5 μg/kg.

Similar studies are presented in the work of M. Zhaldak *et al.* (2023), which analysed the database of current regulatory documents governing the quality and safety indicators of clothing for children and newborns. Clothing for newborns sold by the Epi-Center K retail chain (Ukraine) was examined, and it was determined that while the studied samples meet the safety requirements of regulatory documents, they do not comply with labeling standards. In the article by O. Zavorotna & L. Halavska (2022), modern knitwear materials used in the production of children's clothing are analysed. The study established a correlation between the material's component composition and the structural and technological design of children's garments. Modern decoration techniques and their safety are also discussed.

The authors L.Ye. Halavska & O.V. Gnatiuk (2019) focused on the influence of raw materials on the quality characteristics of children's clothing in their research. They propose eco-friendly linen as a material with superior hygienic properties. S. Mikhaylov & V. Mikhaylov (2010) studied the mass fraction of the components of synthetic detergents for children's clothing in textile materials after washing. M. Turdiyev & D. Yuldasheva (2021) conducted research on the effects of raw materials on the hygienic properties of children's clothing. Their experimental data showed that breathability and hygroscopicity are directly influenced by the fabric's quantitative composition, which in turn affects the thermal protection properties of the clothing. S. Sun *et al.* (2023) focused on eco-friendly clothing, referred to as "green design", in their study. The authors presented a comparative assessment of children's clothing made from traditional materials versus those of organic origin. Their experiments confirmed the absence of heavy metals and pesticides in the organic fabrics. Additionally, the study examined the environmental impact of clothing after disposal. C. Gomes *et al.* (2024) noted that the textile industry is one of the sectors with the greatest impact on the environment.

The researcher H. Chen *et al.* (2022) studied the concentration of heavy metals in children's clothing produced in four Asian regions. The research revealed particularly high levels of nickel and chromium, especially in products from Chinese manufacturers. The study also evaluated the exposure doses of heavy metals on infants' skin. M. Rahman *et al.* (2019) also highlighted the presence of heavy metals in fabric compositions, particularly in children's clothing. As an alternative, they proposed the use of a cationic fixative, which reduces the toxicity of clothing by eliminating electrolytes. The researchers also advocated for reducing wastewater production. Fundamental research conducted by P. Nyamukamba *et al.* (2020) revealed that the quality and safety of children's clothing in South African regions do not meet regulatory standards. The study found toxic substances in most samples (27 out of 34), particularly high concentrations of formaldehyde and elevated levels of all regulated heavy metals, except arsenic.

The authors J. Rovira & J.L. Domingo (2019) focused their research on identifying harmful chemicals in materials used for manufacturing children's clothing, and experimentally demonstrated the toxic-allergic effects of these components. High levels of flame retardants, quinoline, formaldehyde, and benzothiazoles were detected. Similar studies were conducted by M. Herrero *et al.* (2023), where 120 samples of children's clothing (for ages under 3) and maternity clothing were tested in Spain. The authors investigated the potential dermal health effects on children. During the research, high concentrations of heavy metals, including aluminum, zinc, and titanium, were detected.

Conclusions

The evaluation of the labeling on children's clothing for infants available on the Ukrainian market revealed several issues. Specifically, Sample No. 3 from TM "Sova Kids" lacks essential marking information. This sample only displays the trademark and does not provide mandatory details such as the manufacturer's name, country of origin, or component composition. Furthermore, based on odorimetric analysis, this sample also fails to meet the requirements outlined in State Sanitary Rules and Regulations. According to the results of the water absorption and hygroscopicity tests, all samples met the established requirements. However, Sample No. 3 from TM "Sova Kids" exhibited the highest hygroscopicity. This is attributed to the presence of up to 20% wool fibers in its composition, which contributes to its superior moisture-absorbing properties.

According to the results of the safety studies, it was found that all three samples did not meet the established Ukrainian and international standards for pesticide content. However, the levels of heavy metals in the

infant clothing samples were within the permissible limits. In summary, there is a pressing issue concerning the control of dangerous and low-quality infant clothing entering the Ukrainian market. Notably, the presence of eco-labeling and hygiene reports on clothing does not align with the high concentrations of pesticides detected. This research underscores the critical need to examine the hygienic properties of infant clothing more rigorously and highlights the necessity for constructive actions by state and regulatory authorities.

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Conflict of Interest

None.

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Технічне регулювання гігієнічних властивостей дитячого одягу

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Анотація. Гігієнічні властивості дитячого одягу є важливим фактором якості та безпечності і потребують ретельного вивчення та контролю. Однак технічне регулювання стандартів безпеки та гігієни дитячого одягу залишається значним викликом на світовому ринку. Механізм забезпечення безпечності дитячого одягу вимагає від урядів нових рішень. Ключовими аспектами захисту здоров'я дітей при виробництві одягу є контроль якості сировини, моніторинг виробничих процесів та регулювання використання хімічних відбілювачів і барвників. Метою цієї роботи було дослідити гігієнічні властивості дитячого одягу, що надходить на український ринок. Оцінка гігієнічних показників проводилася за допомогою стандартних методів, включаючи атомно-абсорбційний та хроматографічний методи. Одориметричні дослідження показали, що зразок боді «Sova Kids» не відповідає нормативним показникам за інтенсивністю запаху. Результати дослідження гігієнічних властивостей показали, що всі зразки відповідають встановленим вимогам, але найкращу гігроскопічність продемонстрував боді «Sova Kids». Хімічний аналіз на вміст важких металів показав, що у зразку № 2, боді «SMIL», вміст міді перевищує як міжнародні, так і українські стандарти на 0,6 мкг/кг. У всіх трьох зразках дитячого одягу було виявлено дуже високу концентрацію дихлордифенілтрихлорметилметану (ДДТ). Ці показники в 12-17 разів перевищують встановлені українські та міжнародні норми (допустима межа – до 0,5 мкг/кг). При цьому зразок № 3 не містить жодних маркувальних даних або інформації про виробника. Результати дослідження мають практичне значення для торговельних мереж, що реалізують дитячий одяг, і можуть бути використані підприємцями оптової та роздрібної торгівлі, а також виробниками одягу. Вони також слугують основою для регуляторних органів, особливо органів сертифікації, для впровадження більш суворих заходів

Ключові слова: екологічна безпека; важкі метали; пестициди; оцінка вмісту речовин; гігроскопічність