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PHYTOTEST ASSESSMENT OF POTENTIAL HEALTH RISKS TO CHILDREN FROM USING SECOND-HAND AND STOCK CLOTHING WASHED WITH SYNTHETIC DETERGENTS

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ОЦІНКА ЗА ФІТОТЕСТОМ ПОТЕНЦІЙНИХ РИЗИКІВ ДЛЯ ЗДОРОВ'Я ДІТЕЙ ПРИ ВИКОРИСТАННІ ОДЯГУ «СЕКОНД ХЕНД» ТА СТОКОВОГО ОДЯГУ, ВИПРАНОГО СИНТЕТИЧНИМИ МИЮЧИМИ ЗАСОБАМИ

ABSTRACT

Second-hand clothing, for the treatment of which formaldehyde is used, as well as stock clothing, are widely used in Ukraine. The toxicity of such clothing can be assessed by phytotesting using *Lepidium sativum* as a test plant. It is proposed to solve the problem of clothing toxicity by washing with synthetic detergents, which include compounds with toxic properties.

The aim of this work was to study the toxicity of reusable clothing ("second-hand") and stock clothing using *L. sativum* phytotest in different washing options with children's laundry detergents and to assess the potential health risks to children when using such clothing.

Methodology. The study used the method of questioning students about their use of second-hand clothing, as well as the method of phytotesting the toxicity of second-hand clothing and stock clothing washed with synthetic detergents, using *Lepidium sativum* as a test plant. During the study, 3 series of experiments were carried out. The results were statistically processed.

Scientific novelty. For the first time, the toxicity of second-hand children's clothing and stock clothing after washing with synthetic detergents has been shown in the growth test with *Lepidium sativum*, which may be associated with residual compounds of these detergents and is potentially dangerous for children's health.

Conclusions. Phytotesting has established a slight toxicity of second-hand and stock cotton clothing, which may be associated with residual compounds used to treat such clothing. The presence of water-soluble and water-insoluble residual compounds after washing such clothing with synthetic detergents ensures its toxicity (from weak to extreme), which is potentially dangerous for the health of children. Elimination of toxicity of second-hand and stock cotton clothing is achieved by washing them with laundry soap.

Key words: children's health, *Lepidium sativum*, residual compounds, second-hand clothing, stock clothing, synthetic detergents, toxicity

АНОТАЦІЯ

Одяг «секонд хенд», для обробки якого використовується формальдегід, а також стоковий одяг знаходять широкий вжиток в Україні. Токсичність такого одягу можна оцінити за фітотестуванням з використанням *Lepidium sativum* як тест-рослини. Вирішити проблему токсичності одягу пропонується шляхом прання синтетичними миючими засобами, до складу яких входять сполуки з токсичними властивостями.

Метою даної роботи було дослідження за фітотестом з крес-салатом токсичності одягу повторного використання («секонд хенд») та стокового одягу при різних варіантах прання засобами для дитячої білизни та оцінка потенційних ризиків для здоров'я дітей при використанні такого одягу.

Методологія. В ході дослідження використано метод анкетування учнів щодо використання ними одягу «секонд хенд», а також метод фітотестування токсичності одягу «секонд хенд» та стокового одягу, випраного синтетичними миючими засобами, з використанням *Lepidium sativum* як тест-рослини. В ході дослідження здійснено 3 серії експериментів. Результати оброблено статистично.

Наукова новизна. Вперше показано токсичність за ростовим тестом з *Lepidium sativum* дитячого одягу «секонд хенд» та стокового одягу після прання синтетичними миючими засобами, що може бути пов'язано з залишковими сполуками цих миючих засобів та має потенційну небезпеку для здоров'я дітей.

Висновки. Фітотестуванням встановлено незначну токсичність бавовняного одягу «секонд-хенд» та стокового одягу, що може бути пов'язане із залишковими сполуками, що використовуються для обробки такого одягу. Наявність водорозчинних та нерозчинних у воді залишкових сполук після прання такого одягу синтетичними мийними засобами забезпечує його токсичність (від слабкої до екстремальної), що потенційно небезпечно для здоров'я дітей. Усунення токсичності бавовняного одягу «секонд-хенд» та стокового одягу досягається шляхом його прання з господарським милом.

Ключові слова: залишкові сполуки, здоров'я дітей, одяг секонд-хенд, стоковий одяг, синтетичні миючі засоби, токсичність, *Lepidium sativum*

Introduction

Today, a significant part of the population (80%) uses reusable clothing, in particular, they dress in "second-hand" stores (Kratik, n.d.). In Ukraine, second-hand clothing stores ("second-hand") have gained significant importance, which is caused by both the low solvency of citizens and the lack of provision of the population with basic wardrobe items (Kuchma, 2010). 60-80% of Ukrainians buy clothes in "second-hand" stores (Bazik & Gayova, 2019). Stock stores are also popular in Ukraine, where branded remnants of clothing or shoes that were not sold in time in branded stores are sold (Dankeeva, 2016).

According to some researchers, the reuse of clothing solves a number of environmental, economic and social problems of a person and society as a whole (Filho et al., 2019). Other researchers hold the opposite opinion, noting that new problems also appear: environmental – accumulation of garbage in countries with a low level of socio-economic development, economic – decline of the textile industry; social – deterioration of human health (Kratik, n.d.; Kyrychenko, 2021). Risks to human health arise when sanitary standards for processing reusable clothing with formaldehyde are not observed (Kratik, n.d.; Mala, 2017). High doses of formaldehyde may also contain new cotton items due to the peculiarities of the technology for manufacturing cotton fabric (Herrero et al., 2022; Reitz et al., 2022). It is proposed to solve the problem of clothing toxicity by washing (Herrero et al., 2022). However, washing with synthetic detergents (SDs), which are toxic to living organisms (Nyder et al., 1964; Lal et al., 1983; Han & Jung, 2021; Tkachuk & Zelena, 2023) and may have negative effects on human health due to residual amounts on the fabric after washing (Meesters et al., 2018; Wang et al., 2019). Children are most sensitive to toxicants (Au, 2002), so special attention should be paid to the potential health risks to children when using second-hand and stock clothing after washing with synthetic detergents.

One of the easy and accessible biological methods for assessing environmental pollution, the toxicity of various compounds, and their impact on living organisms is phytotesting (Gálvez et al., 2018; Hart, 2019). In phytotesting of toxicants, a sensitive plant model is *Lepidium sativum* (Galli et al., 2019; Bożym, 2020; Tkachuk et al., 2022).

Therefore, the purpose of this work was to study the toxicity of reusable ("second-hand") and stock clothing using *L. sativum* phytotest in different washing options with children's laundry detergents and to assess the potential health risks to children when using such clothing.

Materials and methods

Student survey on the use of second-hand and off-the-shelf clothing

A student survey on the use of second-hand clothing was conducted in November 2023 for students of Chernihiv Lyceum No. 32 (Chernihiv, Ukraine). The survey was anonymous. 103 children (58 girls and 45 boys) aged 13 to 17 years participated in the survey. The questionnaire contained 7 questions, including questions with different answer options:

Question 1. How old are you?

Question 2. Your gender.

Question 3. How often do you (or do your parents for you) buy second-hand clothing?

a) once a week
b) once a month
c) once a year
d) never
e) other

Question 4. How do you (or do your parents for you) process second-hand clothing?

a) only by washing without additional treatments
b) before washing, we treat with ammonia
c) before washing, we use a vinegar solution
d) other

Question 5. What material do you prefer?

a) synthetics
b) cotton
c) wool
d) does not matter
e) other

Question 6. What means for washing clothes of the "second-hand" category do you (or your parents for you) use?

a) washing powder for children's underwear

b) washing powder not recommended for children

c) washing powder for children's underwear with additional treatment with conditioner for children's underwear

d) washing powder not recommended for children with additional treatment with conditioner (not for children's underwear)

e) other

Question 7. Have you had allergic reactions to second-hand clothing?

a) yes

b) no

c) other

Selection of samples of second-hand and stock clothing and their preparation for research

For the study, children's clothing made of 100% cotton (T-shirts) of white color was selected, which was purchased: April 2023 – from a well-known network of second-hand stores in Chernihiv – 3 pieces (to study the toxicity of water-insoluble components contained in the fabric not treated by washing and in the fabric after washing with children's laundry detergents – experiment I), as well as in a stock clothing store (May 2024) – 3 pieces (to study the toxicity of residual water-insoluble and water-soluble complexes of detergents when washing samples by hand (h) and using a washing machine (m) – experiment II). Samples of material 9 cm in diameter (total 18 samples – experiment I; 39 samples – experiment II) were cut from each T-shirt. In experiments I and II, 3 samples (one from different T-shirts) were not treated (options 2-I, 2-II, respectively), and the other samples were washed by hand (and by machine – in experiment II) using different detergents, dried in the fresh air and ironed. Filter paper moistened with distilled water (option 1) served as a control. Washing was carried out with the amount of detergent recommended by the manufacturer. The following washing options were used:

•option 3-I – phosphonate-containing washing powder 1 for children's laundry (WP1); option 4-I – WP1 with subsequent treatment with a conditioner-rinse aid for children's laundry (CR) – WP1+CR; option 5-I – phosphate-free washing powder for children's laundry 1 (FWP1); option 6-I – FWP1 with subsequent treatment with CR (FWP1+CR); option 7-I – household soap, 72% (HS);

•option 3-IIh – WP1; option 4-IIh – WP1 with subsequent treatment with a conditioner for children's laundry (CL) – WP1+CL; option 5-IIh – phosphate-free washing powder 2 (FWP2); option 6-IIh – FWP2+CL; option 7-IIh – HS; option 8-IIh – phosphonate-containing washing powder 2 (WP2);

•option 3-IIm – WP2; option 4-IIm – WP1+CL; option 5-IIm – FWP1+CL.

The detergents used are widely available in the Ukrainian retail network. In order to prevent accusations of advertising or anti-advertising of laundry detergents, we do not provide their trade names. According to the manufacturers, the composition of the products is as follows:

•WP1: 5-10% anionic surfactants; oxygen bleaches; zeolites; < 5% nonionic surfactants; cationic surfactants; phosphonates; soap; polycarboxylates; additionally: enzymes, optical brighteners, perfume composition.

•FWP1: > 30% sodium chloride; 15-30% sodium carbonate; > 5% anionic surfactants; < 5% sodium silicate; sodium percarbonate; soap; tetraacetylethylenediamine (TAED); defoamer; fragrance.

•FWP2: > 30% sodium chloride, 15-30% sodium carbonate, 5-15% sodium silicate, < 5% TAED, fragrance.

•WP2: 5-15% anionic surfactants, oxygen bleach, < 5% nonionic surfactants, polycarboxylates, phosphonates, soap, optical brightener, enzymes, fragrance, bleach activator.

•CL: < 5% cationic surfactants, < 5% nonionic surfactants, fragrance (hexyl cinnamal), preservative (benzisothiazolinone, methylisothiazolinone), aloe vera leaf juice.

•CR: < 5% cationic surfactants; fragrance; preservative.

•HS: sodium salts of fatty acids of tropical vegetable oils and animal fats; water; glycerin; disodium EDTA; antioxidant.

In experiments I and II, after ironing, the fabric samples were placed in homemade containers made of food-grade plastic, moistened with distilled water (5 ml) and used as a basis for germination of test plant seeds.

Aqueous solutions of synthetic detergents for phytotesting

Phytotoxicity studies of aqueous solutions of the above synthetic detergents for children's underwear (experiment III) were carried out for their aqueous solutions with a concentration of 0.1%: $WP1_{0.1\%}$, $FWP1_{0.1\%}$, $CL_{0.1\%}$, $CR_{0.1\%}$, $HS_{0.1\%}$.

Test plant and phytotesting process

The test plant was watercress (*L. sativum*) produced in the Czech Republic (MoravoSeed), packaged by the Private Enterprise "Tyras", batch No. 69088-01, which, according to the information on the packaging, complies with DSTU 6006:2008. The number of seeds per container was 10 pieces, the repetition of control and each experiment was threefold. Seed germination took place in the dark at a temperature of 23 ± 2 ºC. On the 3rd day, germination energy was determined, on the 5th day – germination and length of the aerial part and roots. Control – distilled water (option 1).

Phytotoxic indices were calculated – root length index (RLI) and phytotoxic effect of solutions (PhTE) according to the formulas given in the publications of Bagur-González et al. (2011) and Mtisi and Gwenzi (2019).

To determine phytotoxicity, the toxicity scale from the publications of Bagur-González et al. (2011) and Mtisi and Gwenzi (2019) was used.

To calculate the phytotoxic effect, we used the formula given in the publication by Tkachuk and Okulovych (2021).

Statistical analysis of experimental data

For statistical processing of the obtained data, the statistical module of the Microsoft Office Excel 2010 program was used. Descriptive statistics methods were used – calculation of the arithmetic mean (M) and the standard error of the arithmetic mean (m). The reliability of the differences between the control and the experiment was assessed using the Student's significance criterion (t). A 95% probability of differences ($p \leq 0.05$) was considered statistically significant.

Results and Discussion

Results of the student survey on the use of second-hand clothing

According to the results of the student survey on the use of second-hand clothing, we found that among the students who participated in the survey, the largest share was made up of children aged 16 (43.7 % of respondents), and the smallest – 13 years old (7.8 % of respondents). The distribution of respondents by gender was 56 % girls and 44 % boys. The surveyed students (or their parents for them) most often buy second-hand clothing once a year (35 % of respondents). The smallest number of respondents (1.9 %) buys such clothing once a week. 26.2 % of respondents have never bought second-hand clothing. The largest number of respondents (70.9 %) uses only washing without additional processing to process second-hand clothing. However, some respondents (or their parents) treat such clothes with ammonia (1.9 % of respondents) or vinegar solution (5.8 % of respondents) before washing. Other treatment options noted by respondents included capsules (2 % of respondents) and antiseptic or soap (0.97 % of respondents). The surveyed students noted that the material of the clothes is not important to them – 71.9 % of respondents to question 5 (What material do you prefer?) answered "It doesn't matter". 23.3 % of surveyed students noted that they prefer cotton, 2.9 % – synthetic material, 1.9 % – wool. The vast majority of respondents did not know the exact answer to which synthetic detergents are used in their family to treat "second-hand" clothes (recommended for children or not; or whether fabric conditioner is used or not) – 23.3 %. Regarding the laundry detergents of the "second-hand" category used in the respondents' families, the answers "Washing powder for children's laundry", "Washing powder not recommended for children", "Washing powder for children's laundry with additional conditioner treatment for children's laundry", "Washing powder not recommended for children with additional conditioner treatment (not for children's laundry)" were chosen by approximately the same number of surveyed students – 12.6 %, 15.5 %, 19.4 %, 16.5 %, respectively. The vast majority of surveyed students did not have allergic reactions to "second-hand" clothing (82.5 % of respondents), however, 13 students (12.6 % of respondents) had allergic reactions to clothing of this category.

Thus, the vast majority of surveyed students have "second-hand" clothing without giving preference to a specific type of material, which is washed with synthetic detergents without prior treatment and does not have allergic reactions from its use.

Toxicity of second-hand clothing washed with baby laundry detergents: the complex of water-insoluble and water-soluble residual compounds of the studied SDs

The results of the study of the toxicity of the complex of water-insoluble and water-soluble residual compounds of the studied SDs from second-hand clothing washed with baby laundry detergents according to the phytotest with watercress are presented in Tables 1-2.

Table 1

Test indicators of watercress under the influence of a complex of residual water-insoluble and water-soluble components of material from second-hand clothing under different treatment options with baby laundry detergents

Experiment option	Germination energy, % relative to control	Germination, % relative to control	Length, % relative to control	
			Roots	Aboveground part
1 (Control)	100	100	100	100
2-I (without washing)	96.7 ± 3.3	96.7 ± 3.3	63.8 ± 5.6*	69.9 ± 4.9*
3-I (WP1)	93.3 ± 7.7	96.7 ± 3.3	2.4 ± 0.3*	6.4 ± 0.5*
4-I (WP1+CR)	90.0 ± 5.8	96.7 ± 3.3	2.4 ± 0.3*	6.2 ± 0.5*
5-I (FWP1)	90.0 ± 0.0*	96.7 ± 3.3	2.4 ± 0.3*	8.8 ± 0.5*
6-I (FWP1+CR)	100	100	78.1 ± 4.0*	71.4 ± 4.4*
7-I (HS)	90.0 ± 5.8	100	51.0 ± 4.1*	95.4 ± 5.7

Note: * – differences from control are significant at $p \leq 0.05$; option 3-I – phosphonate-containing washing powder 1 for children's laundry (WP1); option 4-I – WP1 with subsequent treatment with a conditioner-rinse aid for children's laundry (CR) – WP1+CR; option 5-I – phosphate-free washing powder for children's laundry 1 (FWP1); option 6-I – FWP1 with subsequent treatment with CR (FWP1+CR); option 7-I – household soap, 72% (HS)

Table 2

Interpretation of data obtained in experiment I

Experiment option	RLI	PhTE, %	Interpretation of phytotest results	Comments
1 (Control)	Not applicable	Not applicable	No toxicity	Growth is not inhibited
2-I (without washing)	-0.36	36	Medium toxicity	Growth inhibition of more than 30%
3-I (WP1)	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%
4-I (WP1+CR)	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%
5-I (FWP1)	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%
6-I (FWP1+CR)	-0.22	22	Low toxicity	Weak growth inhibition
7-I (HS)	-0.49	49	Medium toxicity	Growth inhibition by almost 50%

Note: option 3-I – phosphonate-containing washing powder 1 for children's laundry (WP1); option 4-I – WP1 with subsequent treatment with a conditioner-rinse aid for children's laundry (CR) – WP1+CR; option 5-I – phosphate-free washing powder for children's laundry 1 (FWP1); option 6-I – FWP1 with subsequent treatment with CR (FWP1+CR); option 7-I – household soap, 72% (HS)

It was found that in all washing options, complexes of residual water-insoluble and water-soluble compounds from second-hand fabric showed phytotoxicity, but to different degrees (Table 1). At the same time, the greatest phytotoxic properties were recorded for options 3-I (WP1), 4-I (WP1+CR) and 5-I (FWP1). For residual water-insoluble and water-soluble compounds of the indicated products, extreme toxicity was established (Table 2). Other options showed medium or weak toxicity (Table 2).

Thus, the studied SDs in order of decreasing toxicity of their residual complexes of water-insoluble and water-soluble compounds on the "second-hand" material can be

arranged as follows: washing powder for children's laundry (phosphonate-containing) 1, washing powder for children's laundry (phosphate-free) 1 and washing powder for children's laundry (phosphonate-containing) 1 + conditioner-rinse aid for children's laundry > household soap > washing powder for children's laundry (phosphate-free) 1 + conditioner-rinse aid for children's laundry.

Toxicity of stock clothing when washing SDs

The results of the study of the toxicity of stock clothing with different washing options according to the growth test with watercress are given in Tables 3-4.

It was found that unwashed used clothing exhibits phytotoxic properties – seed germination, root length and aerial part of the test plant were significantly lower than in the control. When hand washing such clothing with phosphonate-containing powder 1 for children's underwear (variant 3-IIh), a significant decrease in the length of the roots and aerial part of the seedlings of the test plant was observed (Table 3). This can be explained by the presence of residual water-insoluble and water-soluble complexes of SDs with a negative effect on watercress. Additional treatment of the used clothing fabric with conditioner for children's underwear (CL) in variant 4-IIh led to even greater inhibition of root growth – its length was 7 times shorter than in the control (Table 3).

Table 3

Test-indicators of watercress under the influence of residual water-insoluble and water-soluble complexes from used clothing under different washing options

Experiment option	Germination energy, % relative to control	Germination, % relative to control	Length, % relative to control	
			Roots	Aboveground part
1 (Control)	100	100	100	100
2-II (without washing)	91.6 ± 5.4	90.0 ± 3.7*	68.8 ± 9.5*	61.9 ± 4.6*
3-IIh (WP1)	103.6 ± 3.5	96.7 ± 3.3	29.4 ± 4.2*	52.3 ± 6.8*
4-IIIh (WP1+CL)	89.3 ± 3.5	90.0 ± 0.0*	14.0 ± 3.9*	55.1 ± 7.4*
5-IIh (FWP2)	85.8 ± 10.7	80.0 ± 10.0*	95.3 ± 10.4	109.1 ± 10.8
6-IIh (FWP2+CL)	100.0 ± 3.5	93.3 ± 3.3*	131.8 ± 8.6*	99.4 ± 9.1
7-IIh (HS)	92.9 ± 7.2	100.0 ± 0.0	105.3 ± 13.4	177.8 ± 21.6*
8-IIh (WP2)	92.9 ± 3.5	90.0 ± 0.0*	40.7 ± 8.6*	59.1 ± 8.5*
3-IIm (WP2)	89.3 ± 7.2	86.7 ± 3.3*	52.5 ± 8.3*	89.2 ± 10.2
4-IIm (WP1+CL)	85.8 ± 6.2	83.3 ± 3.3*	30.0 ± 5.9*	69.3 ± 9.1*
5-IIm (FWP1+CL)	89.3 ± 9.4	90.0 ±5.8*	61.1 ± 9.2*	73.3 ± 8.5*

Note: * – differences from the control are significant at $p \leq 0.05$; h – hand wash; m – machine wash; option 3-IIh – phosphonate-containing washing powder 1 for children's laundry (WP1); option 4-IIh – WP1 with subsequent treatment with a conditioner for children's laundry (CL) – WP1+CL; option 5-IIh – phosphate-free washing powder 2 (FWP2); option 6-IIh – FWP2+CL; option 7-IIh – household soap, 72% (HS); option 8-IIh – phosphonate-containing washing powder 2 (WP2)

The length of the aerial part of the seedlings in this case was on a par with variant 3-IIh. When washing the fabric of used clothing with phosphate-free powder 2 (FWP2) (variant 5-IIh), no negative effect on the length of the roots and the above-ground part of the seedlings was observed, the difference compared to the control was statistically insignificant (Table 3). However, in this case, seed germination significantly decreased – by

1.3 times compared to the control. Therefore, residual FWP2 compounds have a different mechanism of influence on the test plant. In variant 6-IIh (FWP2+CL), a significant decrease in the germination of the seeds of the test plant and an increase in the length of the roots of the seedlings compared to the control were observed – by 1.1 times and 1.3 times, respectively. In the variant of washing the fabric of used clothing with laundry soap (variant 7-IIh), no negative effect of residual soap compounds was observed. On the contrary, a significant increase in the length of the above-ground part of the seedlings was observed – by 1.8 times compared to the control. When using another phosphonate-containing washing powder WP2 (variant 8-IIh) for hand washing, the growth of roots and aerial parts was also inhibited compared to the control, but to a lesser extent than when using WP1 – 1.9 times and 1.1 times, respectively. According to the calculated phytotoxic indices, WP1 showed high toxicity (Table 4). This fact is alarming, since the WP1 washing powder is recommended by the manufacturer for use in washing children's underwear. When machine washing, a significant decrease in seed germination, root length and aerial part was observed for all variants of the used washing powders (except for variant 3-IIm, for which the latter indicator was on a par with the control). According to the calculated phytotoxic indices, the average and high toxicity of the used washing powders is shown (Table 4).

Table 4

Interpretation of data obtained in experiment II

Experiment option	RLI	PhTE, %	Interpretation of phytotest results	Comments
1 (Control)	Not applicable	Not applicable	No toxicity	Growth is not inhibited
2-II (without washing)	-0.31	31.2	Medium toxicity	Growth inhibition of more than 30%
3-IIh (WP1)	-0.71	70.6	High toxicity	Growth inhibition by 70%
4-IIh (WP1+CL)	-0.86	86.1	Extreme toxicity	Growth inhibition by almost 90%
5-IIh (FWP2)	-0.05	4.8	Low toxicity	Weak growth inhibition
6-IIh (FWP2+CL)	0.32	-31.8	No toxicity	Growth is not inhibited
7-IIh (HS)	0.05	-5.3	No toxicity	Growth is not inhibited
8-IIh (WP2)	-0.59	59.4	High toxicity	Growth inhibition by almost 60%
3-IIm (WP2)	-0.48	47.5	Medium toxicity	Growth inhibition by almost 50%
4-IIm (WP1+CL)	-0.70	70.0	High toxicity	Growth inhibition by 70%
5-IIm (FWP1+CL)	-0.39	38.9	Medium toxicity	Growth inhibition by almost 40%

Note: h – hand wash; m – machine wash; option 3-IIh – phosphonate-containing washing powder 1 for children's laundry (WP1); option 4-IIh – WP1 with subsequent treatment with a conditioner for children's laundry (CL) – WP1+CL; option 5-IIh – phosphate-free washing powder 2 (FWP2); option 6-IIh – FWP2+CL; option 7-IIh – household soap, 72% (HS); option 8-IIh – phosphonate-containing washing powder 2 (WP2)

Therefore, the residual water-soluble and water-insoluble complexes of the studied SDs from the fabric of stock clothing both during hand washing and machine-washing show toxicity to the watercress test plant, except for phosphate-free powder 2 and laundry soap when used for hand washing.

Toxicity of aqueous solutions of SDs according to watercress test indicators

The results of the study of the toxicity of aqueous solutions of SDs for children's underwear according to the phytotest with watercress are presented in Tables 5-6.

Table 5

Toxicity of aqueous solutions of SDs according to the phytotest with watercress

Experiment option	Germination energy, % relative to control	Germination, % relative to control	Length, % relative to control	
			Roots	Aboveground part
1 (Control)	100	100	100	100
$WP1_{0.1\%}$	86.7 ± 3.3	96.7 ± 3.3	1.6 ± 0.1*	7.2 ± 0.7*
$FWP1_{0.1\%}$	90.0 ± 0.0	96.7 ± 3.3	1.7 ± 0.2*	7.0 ± 0.5*
$CL_{0.1\%}$	92.6 ± 3.7	89.3 ± 3.5	101.6 ± 9.6	118.0 ± 8.9
$CR_{0.1\%}$	100 ± 0.0	100 ± 0.0	90.9 ± 2.9*	85.8 ± 7.0
$HS_{0.1\%}$	96.7 ± 3.3	96.7 ± 3.3	1.5 ± 0.1*	7.5 ± 0.2*

Note: * – differences from control are significant at $p \leq 0.05$; WP1 – phosphonate-containing washing powder 1 for children's laundry; FWP1 – phosphate-free washing powder 1; CL – conditioner for children's laundry; CR – a conditioner-rinse aid for children's laundry; HS – household soap, 72%

Table 6

Interpretation of data from the study of the toxicity of aqueous solutions of SDs (experiment III)

Experiment option	RLI	PhTE, %	Interpretation of phytotest results	Comments
1 (Control)	Not applicable	Not applicable	No toxicity	Growth is not inhibited
$WP1_{0.1\%}$	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%
$FWP1_{0.1\%}$	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%
$CL_{0.1\%}$	0.02	-11	No toxicity	Growth is not inhibited
$CR_{0.1\%}$	-0.09	9	Low toxicity	Weak growth inhibition
$HS_{0.1\%}$	-0.98	98	Extreme toxicity	Growth inhibition by almost 100%

Note: WP1 – phosphonate-containing washing powder 1 for children's laundry; FWP1 – phosphate-free washing powder 1; CL – conditioner for children's laundry; CR – a conditioner-rinse aid for children's laundry; HS – household soap, 72%

It was found that aqueous solutions of the studied SDs do not affect the germination energy and seed germination (Table 5). However, they had a suppressive effect on the length of the roots and the above-ground part of the seedlings of the test plant, except for the conditioner for children's laundry ($CL_{0.1\%}$), the differences recorded for which, compared to the control, are statistically insignificant. An aqueous solution of another studied conditioner-rinse aid for children's laundry ($CR_{0.1\%}$) significantly reduced the length of the roots compared to the control and showed weak toxicity, but did not affect the length of the above-ground part (Tables 5 and 6). Aqueous solutions of phosphonate-containing powders 1 and phosphate-free 1, as well as laundry soap, showed extreme toxicity, significantly reducing the length of the roots by 64, 61 and 69 times, respectively (Tables 5 and 6).

Thus, aqueous solutions of the studied detergents for children's laundry can be arranged in the following order of decreasing toxicity: washing powder for children's laundry (phosphonate-containing 1), washing powder for children's laundry (phosphate-free 1), laundry soap > fabric softener for children's laundry ($CR_{0.1\%}$) > fabric softener for children's laundry ($CL_{0.1\%}$).

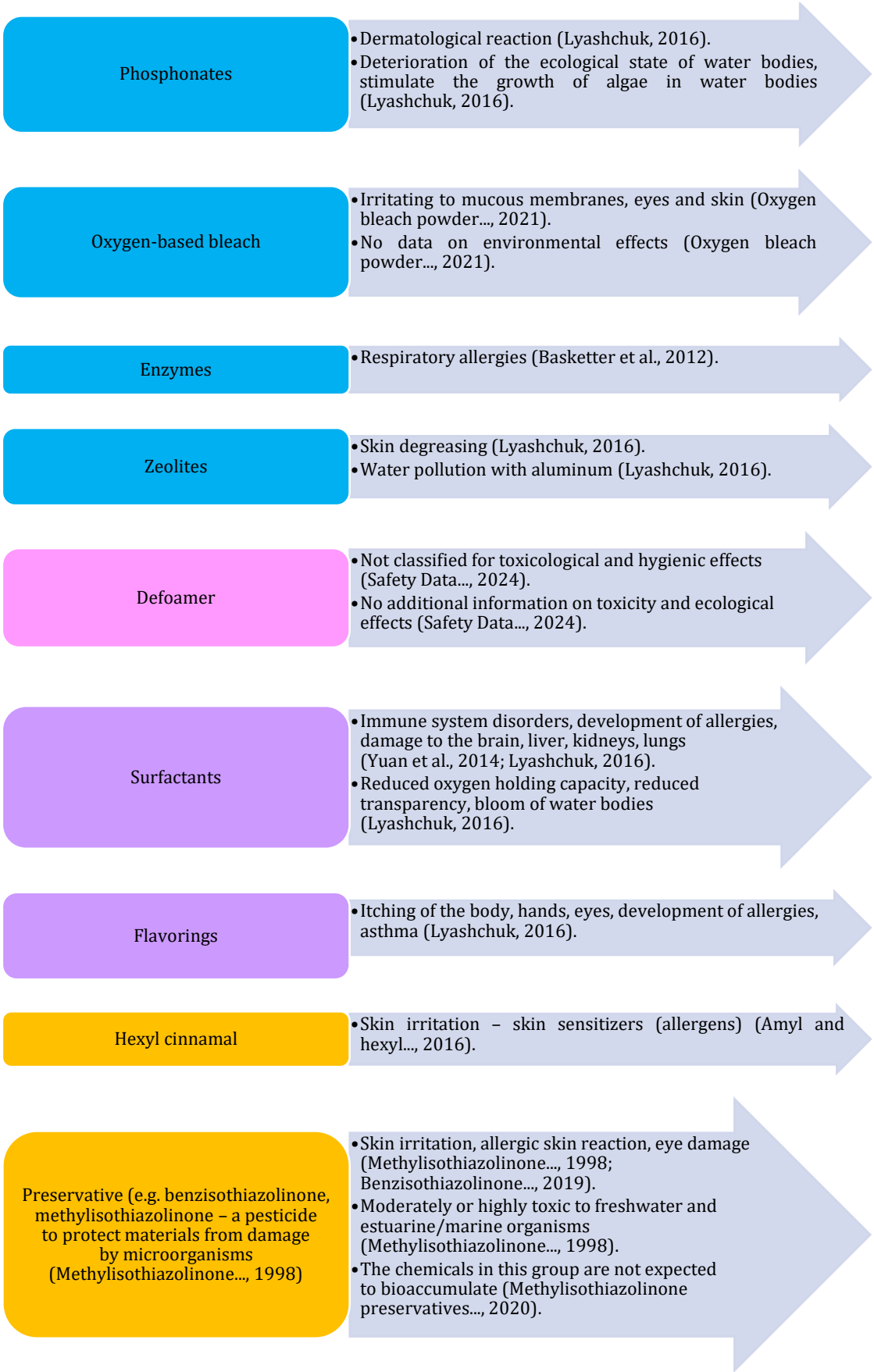

Fig. 1. Toxic components of the studied products and the risks to human health and the environment associated with them (blue color – component of the phosphonate-containing product; pink color – component of the phosphate-free product; purple color – component of both products (phosphonate-containing and phosphate-free); orange color – component of the conditioner for children's laundry)

Toxic compounds in the composition of the studied synthetic detergents and their impact on human health and the environment

A summary of the results of the theoretical analysis of the composition of the detergents used in the study and their impact on the human body and the environment is presented in the form of a diagram (Fig. 1).

Conclusions

Phytotesting has established a slight toxicity of second-hand and stock cotton clothing, which may be associated with residual compounds used to treat such clothing. The presence of water-soluble and water-insoluble residual compounds after washing such clothing with synthetic detergents ensures its toxicity (from weak to extreme), which is potentially dangerous for the health of children. Elimination of toxicity of second-hand and stock cotton clothing is achieved by washing them with laundry soap.

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У цьому дослідженні не використовувався генеративний штучний інтелект або технології штучного інтелекту для збору, аналізу чи інтерпретації даних / This study did not use generative artificial intelligence or AI-enabled technologies to collect, analyze, or interpret data.

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