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ORIGINAL ARTICLE

Evaluation of consumer quality parameters in environmental laundry products

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The article presents an assessment of consumer quality parameters of the products of the current "Delamark" enterprise, in particular, developed by the authors of the original formulations of washing powders.

The relevance of the work is due to the modern state of production of detergents controlled by the latest approaches to standardization and certification. This provides an enabling ground for both the improvement of the standards themselves and the development of new environmentally sound detergent formulations. The classification of detergents by composition and environmental characteristics provides for the assessment of their quality according to the corresponding consumer indicators, among which the most relevant ones are chosen. The subject of the study was qualitative indicators of organoleptic (smell, color, appearance), functional (detergency, foaming ability, reduced strength of cotton fabric, ash content of cotton fabric after 25 washing cycles) and environmental (biological folding) indicators.

It has been proved that the original formulations developed as part of the experiment for the "Delamark" enterprise, as well as the technologies for their manufacture, fully comply with the requirements of the Standard for the Organization of Ukraine SOU OEM 08.002.12.065: 2016 "Detergents and cleaning products environmental criteria for the life cycle assessment" according to the certification scheme according to ISO 14024, and the functional characteristics of the developed samples.

Keywords: indicators; formulations; components; standards; compliance with standards

Introduction

The negative effect of certain components of synthetic detergents on the human body has now become obvious and has prompted consumers to increase interest in the safety of products of various categories, and manufacturers to increase the environmental potential of enterprises and their products. With the growing popularity of a healthy lifestyle, consumer interest has increased not only in the consumer qualities of detergents, but also in their environmental characteristics.

In order to put into practice the idea of safety and stability in the production and use of detergents, it is necessary to take into account the negative impact on the environment of the production and use of detergents, identifying ways to reduce it, and to justify the methodology for conducting theoretical and experimental studies and the requirements for environmentally acceptable components; develop methods for assessing their impact on the environment and assessing functional consumer properties. This will allow conducting experimental studies to identify the optimal type and ratio of detergent components in their impact on environmental safety, to develop technological processes for their production and use.

On the other hand, a preliminary study of consumer demand for detergents showed that in conditions of high competition in the detergent market, the development of a new product requires an analysis and expert assessment of the functional properties of the product, which are the primary criteria for choosing goods by the consumer. The emergence of a wide range of new tools can be a setback for manufacturers if these tools do not meet environmental standards and demanded consumer characteristics. To solve a number of these problematic issues of expertise and assessment of the quality and competitiveness of new products, it is necessary to develop new test methods, methods of expertise, expert quality assessment, etc.

Purpose

In connection with the above, the purpose of the article is not only to substantiate the environmentally and functionally acceptable component composition of innovative detergent formulations, but also to evaluate their quality according to relevant consumer indicators and environmental standards.

Brief literature review

Since the article describes two consecutive processes (the development of innovative formulations and their functional-environmental assessment), it is worth a brief review of the literature in these two aspects. It is known that at the end of the 20th century, typical framework formulations of detergents were determined, which somehow lie in the formation of improved detergents in subsequent years (Abramzon, Zaichenko & Feingold, 1998; Bukhshtab, Melnik & Kovaliov, 1988; Nevolin, 1971; Vilkova, 2003). The functional properties of the use of enzymes, secondary alkanesulfonates, low-level surfactants and other individual components were investigated at the beginning of the 21st century in the works of V. Kasilovich, N. Divakova, Y. Novak, M. Pletnev and others (Divakova, (2006); Kasilovich,(2005); Moehle, (2007); Novak, (2006); Pletniov, (2002); Sharova, (2006).

The Eastern and Western European scientific discourse has developed numerous methodologies for the component examination of compliance of detergents with modern environmental standards (Aalto, Heiskanen, Leire, & Thidell, (2008); Backman, Lindhqvist & Thidell, 1995). Autonomous or synergistic parameters of the functional effectiveness of detergents were investigated by T.

Mukayama, S. Matsunaga, V. Makityansky, V. Ivantsova and others (Divakova, (2006); Ivantsova, (2003); Makitianskiy, Davidiuk, & Saipova, (2006); Matsunaga, Nagoh, Mukaiyama, (2004); Moehle, (2007); Vyglazov, (2006).

Studies by scientists who have studied the toxicological reactions of synthetic detergents to aquatic ecosystems, in particular neutralized alkylbenzene sulfonate, are important (Hazari Lal Virendra and all, 1983); contamination of the environment with bio-impermeable ingredients (Pedrazzani and all, 2012), etc. The pouring of phosphates on natural reservoirs and aqueous solutions was investigated by S. Candu, S. Raendiren P. Juver, J. Kjoler and others (Kundu, Coumar, Rajendiran, and Rao, (2015); Weaver, (т1969); Köhler, (2006).

Consider the scientific discourse trends in the study of environmentally friendly detergents of recent years. Thus, scientists pay considerable attention to the fight against eutrophication - the accumulation of excess nutrients in aquatic ecosystems as a result of the dumping of household waste into water bodies (Pal, 2020). This encourages manufacturers to produce detergents with a short lifecycle and complete biodegradation of complexing agents.

Since the component composition of environmental detergents is now more or less established, the main attention of scientists is focused on reducing the anthropogenic impact on biotic processes in nature. A complementary mechanism for reducing such effects is now not only the modification of detergent composition, but also the development of buffer systems with high absorption capacity for fertile soils (Galynkin & Gabidova, 2020).

In turn, these trends also promote the role of environmental assessment in the circular economy, in particular the total use of the Life Cycle Assessment (LCA) method in the detergent sector. In particular, recommendations on the use of regenerated vegetable oils for the production of detergents have been implemented. This replacement of the component "significantly reduces the environmental impact compared to the use of coconut oil imported from third countries" (Lucchetti, Paolotti, Rocchi & Boggia, 2019).

Another promising direction is the search for alternative components of detergents of plant origin. So, with the help of the chemometry tool, a register of bioactive phytologies used in traditional cultures as detergents is now being determined (Wisetkomolmat, Inta, Krongchai, Kittiwachana, Jantanasakulwong, Rachtanapun & Sommano, 2021) When establishing industrial extraction of extracts from such substances (the main bioactive component.

No less important are sociological studies of consumer behavior and determination of their environmental consciousness in terms of interest in the acquisition and consumption of environmentally friendly products. Such research is based on a study of awareness of eco-labelling principles, which is still voluntary in Europe. The popularity of specific environmental brands among marginal regions of the world is also being studied (Ionu & Eugenia, 2019).

Detergents are not so much a significant environmental hazard as disinfectants, which have not yet undergone sufficient regulatory and eco-certification restrictions. Thus, disinfectant compounds of ammonium alkyldimethylbenzyl chloride (ADBAC) and ammonium dialkyldimethyl chloride (DDAC) compounds are still common. Therefore, examinations are being actively conducted to identify the ecological share of such compounds and "data on acute and chronic aquatic ecotoxicity for freshwater species, including algae, invertebrates, fish and plants" are being accumulated. (DeLeo, Huynh, Pattanayek, Schmid & Pechacek, 2020). A large database of environmental safety and proportion of alkyldimethylbenzyl ammonium chloride compounds has already been concluded (ADBAC) and ammonium dialkyldimethyl chloride (DDAC), but lack generalized ecobiological studies for disinfectant quats.

Global studies of so-called "corporate sustainability" on the use of environmentally friendly components in the production of household chemicals in Europe, the Middle East and Africa are also gaining popularity. These trends have become a political objective of the United Nations and the European Union. So, since 2017, the use of phosphates has been limited in the European Union. Scientists note that "ESC Assessment (Environmental Safety Check) and Environmental Risk Assessment for MGDA of modern products show that environmental risk is now expected to decrease with its favorable environmental fate and ecotoxicological profiles" (Van Hoof, Fan & Lievens, 2017).

Finally, the problem of environmental technology for water treatment in an open natural system is still unresolved. Promising studies are those that attempt to prepare methods previously used in laboratory or closed systems to purify water from anthropogenic pollution. So, J. Zhu, G, Luo, S. Meng and others propose the purification of natural waters using a gravity-controlled biomimetic membrane (GDBM), which has so far been used only in a closed membrane reactor system (Zhu, Chen, Luo, Zhang & Meng, 2020). In the near future, industrial purification systems are expected to be prepared and scaled to filter natural waters.

However, in Ukraine there are still not enough studies that would promptly provide an expert assessment of the consumer and environmental parameters of product quality in innovative laundry products.

Methods

The article reprints two groups of methods. The first was used in the development of innovative formulations, the second - in their functional and environmental expertise.

So, when planning the development of recipes, the method of environmental certification was used, and at the very development process - the method of experimental selection of complexing agents with examination of functional and environmental indicators at each stage of selection. Theoretical and calculation methods were also used.

Methods have also been used to establish criteria for environmental and health effects of detergents during the product life cycle; Identification of key environmentally relevant physical and chemical characteristics. In the framework of experimental methods, laboratory methods have been applied: organoleptic, determination of detergent capacity and methods of aquatic toxicology to determine the safety of proposed means for aquatic ecosystems.

Functional characteristics (detergency, foaming ability, reduced strength of cotton fabric, ash content of cotton fabric) were examined after 25 cycles of washing using a pigment-oil contaminant followed by optical measurements of fabric quality.

The main method for determining the environmental friendliness of a detergent was environmental-toxicological studies of its effects on test objects (algae and crustaceans) under experimental conditions using vetlast invertebrates of Daphnia magna crustaceans and algae of Microcystis species as test objects.

Results and discussion

Based on the consumer needs of the population, as well as taking into account the environmental standard of the organization of Ukraine SOU OEM 08.002.12.065:2016 "Detergents and cleaning products environmental criteria for the life cycle assessment," which complies with the international standard ISO 14024, the authors decided to develop a number of innovative formulations

based on a framework and conduct their functional and environmental expertise on relevant indicators:organoleptic (smell, color, appearance), functional (detergency, foaming ability, reduced strength of cotton fabric, ash content of cotton fabric after 25 washing cycles) and environmentally friendly (biological folding). Components that comply with the above-mentioned Organization Standard of Ukraine shall be used. The reference sample X conforming to the National Standards of Ukraine and the Technical Specifications of Ukraine was used in the expert analysis for comparison.

The experimental process of producing detergents with improved environmental characteristics was carried out by developing original formulations of detergents based on framework. After the development of the new Standard of Ukraine SOU OEM 08.002.12.065: 2016 "Detergents and cleaning products environmental criteria for the life cycle assessment," the current project for the organization of the production of detergents under the trade "Delamark" was designed, developed and implemented. It is based on the concepts of ecological emission-free production with a closed cycle of resource turnover and minimal consumption of non-renewable resources, and the concept of "sustainable production" has been applied with constant rationalization and simplification of its stages.

By appropriately replacing the ingredients in comparison with the standard (framework) at the energy-saving and environmentally organized enterprise "Delamark," three formulations were created that correspond to the marking system of the OEM ECU 08.002.12.065: 2016 "Detergents and cleaning products environmental criteria for the life cycle assessment" according to the certification scheme according to ISO 14024. At the same time, each subsequent formulation was improved after experimental testing of the previous one by appropriately replacing the component composition.

Let us consider the main stages of expedient replacement of washing powders ingredients. The framework formulation was taken as a basis, which was developed and provided by the "VNDIHIMPROEKT" synthetic detergent laboratory.

On the basis of this framework formulation, taking into account the available raw materials and analysis of the compatibility of the components, a component composition of the washing powder "Universal" was developed, which has sufficient consumer properties. Its formulation is reoriented to Figure 1.

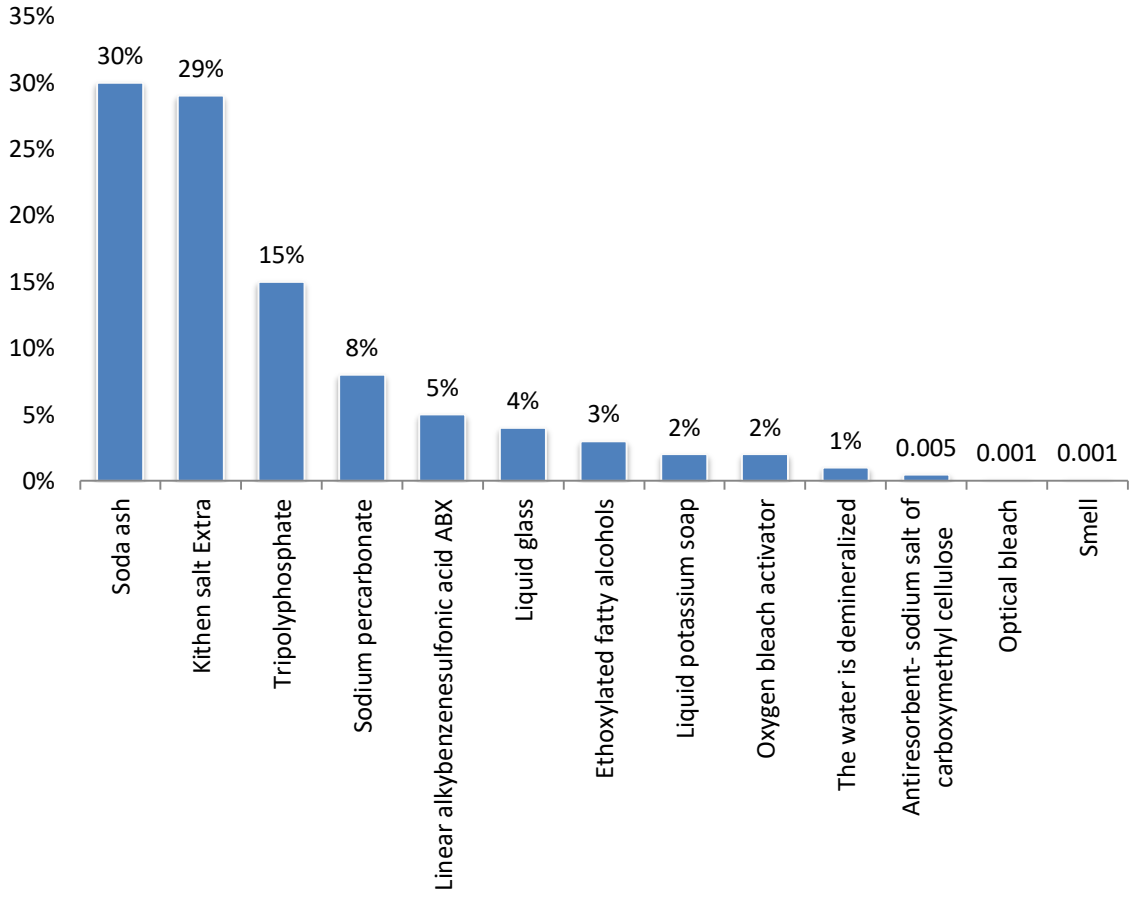

Figure 1. Recipe No. 1, Washing powder "Universal".

After studying the effect of the main and additional components on the consumer properties of the product, it was found that suitable complexing agents increase detergency and contribute to the preservation of the heating elements of washing machines and preserve the color of laundry due to a decrease in the precipitation of mineral substances.

However, environmental performance remained satisfactory due to the high phosphorus content (sodium tripolyphosphate (Na5P3O10), and its low solubility reduced consumer properties. Therefore, it was decided to replace such complexing agents with environmentally acceptable ones with a similar functional effect, namely, Trilon M (methyl glycinediacetic acid tri-sodium salt), polycarboxylates and sodium gluconate (HOCH2 (CHOH) 4COONa). The result is a formulation with improved environmental characteristics (Figure 2).

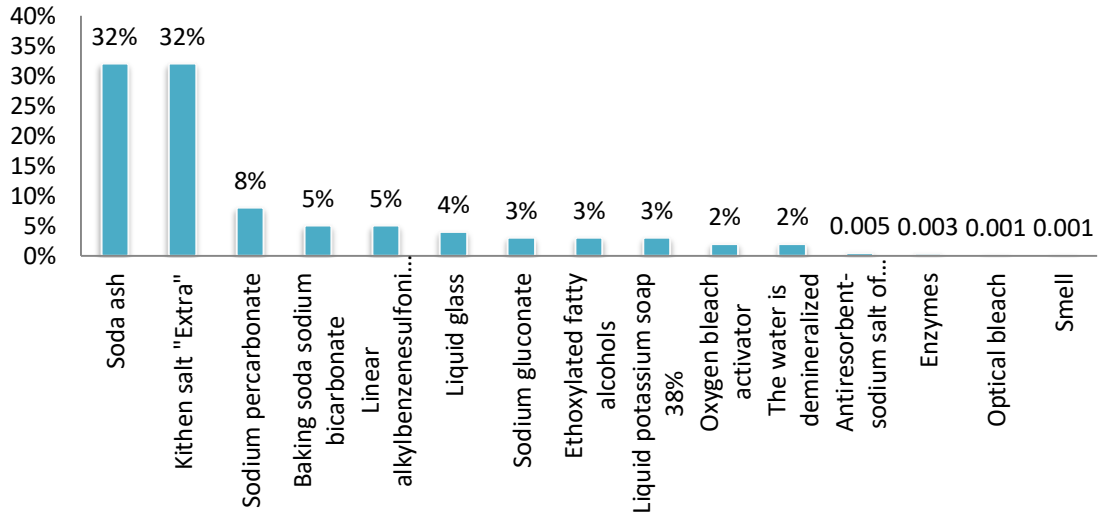

Figure 2. Formula No. 2 with replacement of tripolyphosphates with ecological complexing agents with introduction of food soda and introduction of enzymes.

The new formulation turned out to be more effective, however, an expert assessment of the functional properties of the newly created formulation found an increase in water stiffness due to the introduction of soda and ethylenediaminetetraoctic acid derivatives, as well as a decrease in the re-precipitation of dirt particles due to the active action of polycarboxylates. On the other hand, it has been found that the integrated use of components increases detergency by more than 70%. In this regard, it was decided to increase the stabilization of enzymes in order to reduce their proteolytic degradation and the possibility of long-term storage of the final product without the effect of "caking." Experimentally determined: a) the stability of enzymes depends on the level of acidity of the medium; b) effective and environmentally acceptable enzyme stabilizers are soap and nonionic surfactants; c) anionic and cationic surfactants negatively affect the stability of enzymes; d) addition of phosphate-free agents "Trilon," "Sokolan" and soap synergistically increases detergency. Also was considered the fact that, according to requirements according to requirements of SOU OEM 08.002.03.065:2016 ("Detergents and cleaning products environmental criteria for the life cycle assessment") it is necessary to avoid addition of surfactants on the basis of alkylbenzol and alkylphenols. In view of the above, it has been decided to replace the alkylbenzene sulfonic acid with environmentally acceptable enzyme components, and the antiresorbent (carboxymethyl cellulose sodium salt) with the sodium salt of the acrylic and maleic acid copolymer.
Taking into account the above-mentioned patterns, the third, final formulation was created, the component composition as a percentage of the mass fraction is given in Figure 3.

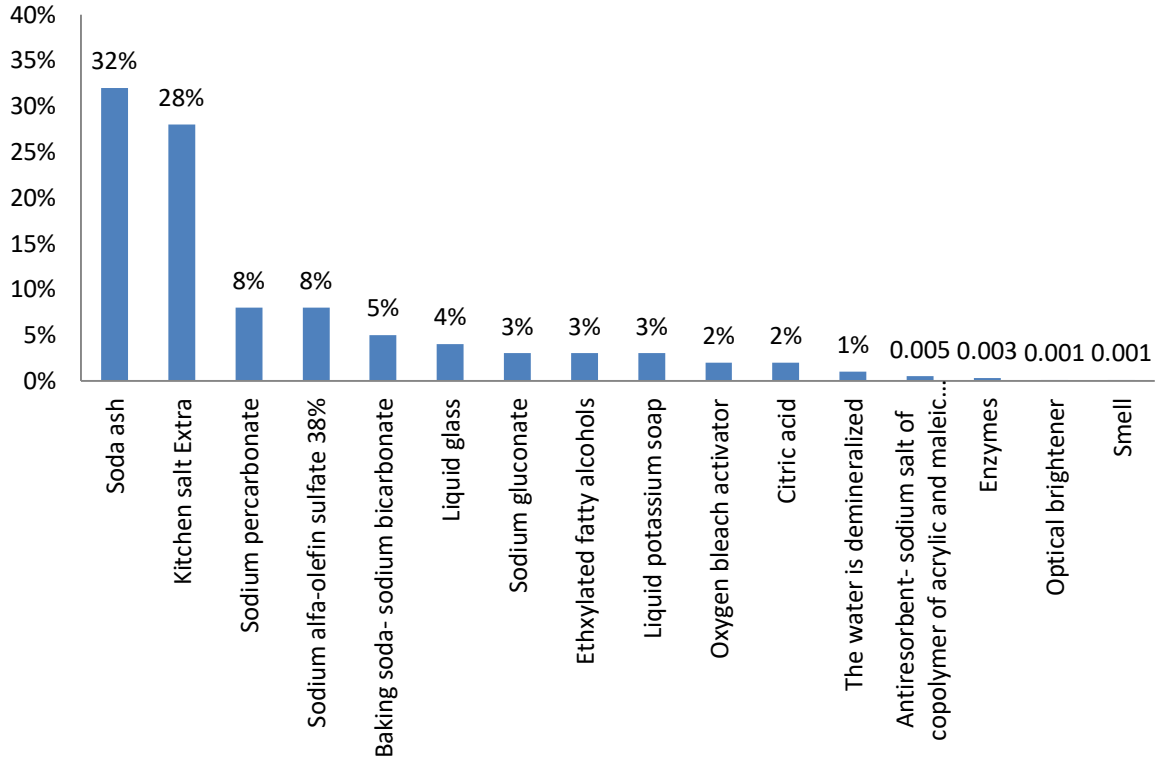

Figure 3. Formulation No. 3 replacing alkynbenzenes and alkynphenols with environmentally acceptable enzyme components (mass fraction,%).

It is now worth considering the assessment of the environmental and functional indicators of the formulations developed and presented above, therefore, we further give the results of the analysis of the compliance of functional and environmental indicators with the accepted norms of the National Standard of Ukraine (DST) and the technical conditions of Ukraine (TSS) for each of the formulated formulations (Tables 1-3), noting that the presented characteristics are determined by means of multi-decomposable formulations.

Table 1. Quality indicators according to DSTU and TUU 24.5-36385435-001: 2011 (Recipe № 1 Washing powder "Universal").

Indicator	**Normative value**	**Actual value**
Appearance	Granules or powder	Answers
Color	Compliance with the control sample	Answers
Smell	Fragrances used	Answers
The concentration of hydrogen ions in 1% aqueous solution, units pH	9, 5-10, 5	10, 1
Detergent (%)	85, 0	96
Mass fraction of dust, %	3, 0	2, 8
Ash content of cotton fabric after 25 washing cycles, %	2, 0	2, 0
The decrease in durability of cotton fabric after 25 cycles of washing, %	18	18
Foaming ability: foam height, (cm)	20	20
Biodegradability of surfactants, %	80	90

As can be seen from the table, as well as from the results of the test reports, most of the indicators meet or exceed those permitted by the existing standard. So, after 25 washing cycles, the decrease in the strength of the cotton fabric and the ash content of the cotton fabric remained at the level with the reference sample X. At the same time, the washing capacity increased by 11%, the mass fraction of dust decreased by 0.2%, and the biological folding reached 90%.
Consider quality indicators in accordance with the Relevant National Standards of Ukraine and Technical Conditions of Ukraine regarding recipe No. 2, in which alkynbenzenols and alkynphenols were replaced with an ecological complexing agent with the introduction of food soda and enzymes (Table 2).

Table 2. Formula No. 2 (replacement of alkynbenzenols and alkynfenols with ecological complexing agent, introduction of food soda, introduction of enzymes).

Indicator	**Normative value**	**Actual value**
Appearance	Granules or powder	Answers
Color	Compliance with the control sample	Answers
Smell	Fragrances used	Answers
The concentration of hydrogen ions in 1% aqueous solution, units pH	9, 5-10, 5	10, 1
Detergent (%)	85, 0	98
Mass fraction of dust, %	3, 0	2, 0
Ash content of cotton fabric after 25 washing cycles, %	2, 0	1, 6
Decrease in durability of cotton fabric after 25 cycles of washing,%, no more than	18	18
Foaming ability: foam height, cm, not more than	20	20
Biodegradability of surfactants,%, not less than	80	90

As can be seen from the data of the table, the replacement of raw materials did not cause a deterioration in the consumer properties of the powder, on the contrary, the ash content of the fabric decreased, which, accordingly, improves the functional characteristics of the agent. At the same time, the detergent capacity, compared to the reference sample, increased by 12%, the mass dust fraction decreased by 33%, and the values of the Decrease in strength of cotton fabric and foaming ability correspond to the reference ones. As in the previous formulation, there is a 10% increase in bio-complexity.
According to the requirements of SOU OEM 08.002.12.065: 2016, environmental household chemicals should not contain surfactants based on alkylbenzenes and alkylphenols. Their replacement with more efficient and environmentally friendly (recipe No.

3) changed the indicators of quality and environmental friendliness (according to quality indicators according to the National Standard of Ukraine and Technical Conditions of Ukraine 24.5-36385435-001: 2011) (Table 3):

Table 3. Evaluation of the quality of detergents according to formula No. 3 (final, with the replacement of alkylbenzenes and alkylphenols with more efficient and environmentally friendly).

Indicator	Normative value	Actual value
Appearance	Granules or powder	Answers
Color	Compliance with the control sample	Answers
Smell	Fragrances used	Answers
The concentration of hydrogen ions in 1% aqueous solution, units pH, not more than	9, 5-10, 5	10, 2
Detergent %, not less than	85, 0	98
Mass fraction of dust, %, not more	3, 0	1, 3
Ash content of cotton fabric after 25 washing cycles, %, not more than	2, 0	1, 6
The decrease in durability of cotton fabric after 25 cycles of washing, %, no more than	18	18
Foaming ability: foam height, (cm), not more than	20	absent
Biodegradability of surfactants,%, not less than	80	98

As can be seen from the table, the replacement of raw materials did not cause a deterioration in the consumer properties of the powder, on the contrary, the foaming capacity, which is practically absent, was reduced. At the same time, a further decrease in the mass fraction of dust and ash (by 1.7 and 0.4%, respectively) was observed, and the detergency and biological folding of surfactants reached a maximum of 98%.

Conclusions

Thus, the development of a formulation of detergents (detergents) with improved environmental properties was carried out by appropriately replacing the ingredients compared to the standard (framework) components, as a result of which three formulations were created, each of which did not only comply with environmental standards corresponding to the SOU OEM marking system 08.002.12.065:2016 "Detergents and cleaning products environmental criteria for the life cycle assessment," but also increased individual or interdependent (synergistic) functional effects.

So, optimization of the system of complexing agents increased the washing ability, reduced drawdown of mineral substances, and use of a gluconate of sodium, polycarboxylate and ethylenediaminetetraacetic acid derivatives instead of phosphorus-containing complexing agents promoted the binding of inorganic compounds that increase water hardness and stimulate re-sedimentation of dirt particles on the cleaned surface. Also application the phosphate-free of components in combination with soap was reached synergy effect of substantial increase of the washing ability at the level of 98% and stabilization of enzymes, than their proteolytic decomposition was reduced. The proportion of auxiliary components of all formulations (dye, flavouring agent, optical bleach, preservative) was less than 1%. Organic substances (citric acid, sodium gluconate, etc.) have proven to be effective detergent catalysts for anionic surfactants. An assessment of the environmental acceptability of the developed detergent formulations and the experimental technology for their manufacture revealed the following practical aspects: a) experimental flood formulations comply with the requirements of the SOU OEM standards 08.002.12.065: 2016 "Detergents and cleaning products environmental criteria for the life cycle assessment" according to the certification scheme according to ISO 14024;

b) almost all functional characteristics of the developed samples are similar or higher than those of the reference samples.

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