Materials Research Proceedings **24** (2022) 301-308 https://doi.org/10.21741/9781644902059-44

The Assessment of the Environmental Impact of Textile Cleaning Processes in the Aquatic Environment on Human Health

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Keywords: Textile Cleaning Processes, Wet Cleaning, Biosurfactants, Life Cycle Assessment, Environmental Impact

Abstract. This article analyzes the technological process of textile product cleaning in the aquatic environment from the point of view of identified sources of hazard. It is established at what particular stages of cleaning of the products, the negative affects on the environment, workers and consumers occur. According to Life Cycle Assessment (LCA), detailed information was received at an enterprise about the technological processes and the impact of their individual factors on the environment and human health. Creating closed water cycles will reduce the impact on the environment and human health. The use of new types of biosurfactants in detergent compositions will allow reducing the duration of technological operations, and the number of cycles of textile product processing, to increase their exploitation life and improve the quality of textile product cleaning.

Introduction

In modern conditions, the activity of the garment care industry involves finding opportunities to reduce costs, minimize risks, and increase business stability and competitive advantages [1 – 3]. In order to improve the efficiency of textile cleaning technologies in the aquatic environment, the quality of services provided to consumers, and the environmental safety of the processes, it is necessary to take into account the social, economic, and environmental impacts of technologies throughout the life cycle of textile products [2, 4, 5]. The implementation of the Life Cycle Assessment (LCA) procedure allows us to determine the interaction between energy, material costs, and technology over the life cycle of textiles, as well as in the long run – to determine the impact of these interactions on the environment and society (from raw materials production through processing, manufacturing, distribution, use, disposal or recycling).

According to [1, 2, 5], the implementation of the LCA method is one of the leading tools for sustainable business development, which allows for increasing the efficiency of the enterprise activity by studying the environmental impact while the exportation of textile products/services.

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The use of the LCA method is driven by the desire to increase the market value of products/services by disclosing information about their safety. In addition, the LCA allows you to set and optimize the most energy and resource-intensive stages of technological processes, as well as to create the preconditions for cost reduction through the rational use of raw materials, resources, and energy. Information obtained from LCA is important in making strategic business development decisions and innovating when cleaning textiles at an enterprise.

The implementation of LCA in the process of textile products cleaning allows us to create new, environmentally friendly auxiliaries and technologies; introduce eco-labeling and certification; an increase production efficiency; the identification of cost reduction opportunities; make decisions based on sustainable development goals; compare alternative opportunities for sustainable development of the enterprise; improving the quality of service provision, extending the life of textile products.

Methodology

The LCA method is a part of the integrated Life Cycle Sustainability Assessment method in accordance with ISO 14000 series standards, in particular ISO 14040: 2006 Environmental management – Life Cycle Assessment – Principles and framework, ISO 14044: 2006 Environmental management – Life Cycle Assessment – Requirements and guidelines. This method also includes Life Cycle Costing and Social Life Cycle Assessment [6, 7]. Other similar tools include Environmental Impact Assessment (EIA), Ecological Risk Assessment (ERA), Material Flows Analysis (MFA), and Cost-Benefit Analysis (CBA). The LCA is a multilateral and multifactorial environmental management tool aimed at assessing environmental impacts.

The sequence of LCA conducting [6, 7]:

– Preparatory stage – determining the purpose and scope: determining the purpose of the study, the circle of persons to whom the results of the study will be communicated; description of the technology life cycle system under study, and determination of boundaries and functions.
– The main stage:
    - life cycle inventory analysis: data collection, data calculation, flow, and emission distribution.
    - life cycle impact assessment: selection of impact categories and their indicators, distribution of inventory results, calculation of results of category indicators.
– Final stage:
    - interpretation of the results of the analysis: consideration of the results of the inventory analysis and impact assessment, preparation of the report on the results of the conducted assessment, formation of conclusions and recommendations.
    - environmental indicators of the study: waste generation during operation, consumption of water resources, wastewater discharge, emissions into the atmosphere, greenhouse gas emissions, physical factors (noise, vibration, radiation, thermal pollution), and impact on soils.

In the LCA study of the technological process of textile products cleaning in the aquatic environment at the company LLC TPP "Universal" (Ukraine) [8] estimation techniques were used. The analysis of the use and utilization of the main solvents (water) and means, without production and extraction of raw materials for their production. Thus, cleaning technologies for environmental and human health impacts and the effectiveness of the removal of contamination from textiles were analyzed.

Results and Discussion

In the technological processes of textile products cleaning in the aquatic environment, they use detergents and auxiliaries, which can remain on the products, affect the health of workers and consumers, as well as the environment [3, 9-11]. Modern washing machines and water purifiers [3, 8] using the latest technologies consume less electricity when cleaning clothes, but energy production can cause air pollution after a while. Therefore, when choosing professional equipment, first of all, pay attention to the technical and economic indicators of the equipment. It should be borne in mind that washing machines and water purifiers consume a large amount of water as a cleaning medium.

In the process of textile products cleaning in the aquatic environment at the enterprise LLC TPP "Universal" they use professional tools of different producers [8]: Alberti Angelo, Colortex (Italy), Bufa, Kreussler, Seitz (Germany), LLC "Sphere-93" (Ukraine). The volumes of use of professional means in some technological operations at the enterprise are given in Table 1.

Table 1. *The volume of use of professional means in the enterprise*

Technological operation	Consumption of preparations per year, l (kg)
stain removal	117.29
wet cleaning, laundering	149.84
finishing	113.28

According to Table 1, we can conclude that the processes of product cleaning and the preparations they use have some impact on the environment and human health. On the basis of the received information, we will analyze the activity of the textile cleaning company in accordance with the LCA methodology.

The first stage defines the scope and purpose of the research, for this purpose is established:

1. Functions of the production system – efficiency of removal of pollution from textile products.
2. Functional unit – consumption of water, energy, chemicals.

In determining the functional unit and reference flows distinguish the following steps: identification of functions; choice of functions and definition of the functional unit; identification of product performance and definition of reference flow.

The purpose of the functional unit is to quantify the function provided by the production system. Thus, the first step is to identify the goal that the production system provides, that is, to identify its function.

After determining the functional unit, it is necessary to determine the number of products required to perform the function, expressed in terms of the functional unit. Reference flow is related to product performance and is usually defined as the result of a standard measurement method. The nature of this measurement and calculation depends on the object of study. Reference flow – the number of required output streams from processes in a given production system that is required to perform a function expressed by a functional unit (ISO 14041 [12]).

In the laundering process or wet cleaning, water is used as the primary solvent for wetting the products, and in the subsequent stages, the primary solvent is used in combination with more effective means. The advantage of this technology is the easy removal of dirt from the surface of textiles.

To narrow the boundaries of the system we use the rule of "trimming" – the exclusion of flows that do not have a significant impact on the environment, as well as the corresponding individual processes. This simplifies the model of the production system.

An operational analysis of a textile cleaning service provider contains the following input and output indicators. Inputs: materials (chemicals, detergents, auxiliaries), water (drinking and technological); the amount of energy used; types of services. Outputs: clean textile products; detergent remains (waste); emission (evaporation) of washing solutions. Indicators of operational characteristics of the technological process of textile products cleaning in an aqueous environment are shown in Table 2.

To determine the boundaries of a single process, a link can be established with the sites within the given list to determine the smallest components of the production system for which data is acceptable. Due to the variability of certain technological processes carried out on a particular site, the boundaries of a single process are set in order to minimize the need for distribution procedures.

Types of effect, methods used and interpretation of results: vapors of chemicals emitted into the atmosphere, hydrosphere, water (Tables 2, 3) and affecting the environment, health of staff who remain in working space for a long time.

Table 2. *Indicators of operational characteristics of the technological process*

Operation Performance Indicators	Group	The grounds for selecting an indicator, its purpose
Materials		
Chemicals consumption per product, (l, kg, m^3)	E	Set the amount of chemicals used to reduce consumption
Water consumption per product, general use, m^3	E	Set water consumption to reduce consumption
Quality of textiles cleaning,%	E	Setting the amount of re-cleaning to reduce it
Electricity		
Calculation of electricity costs per 1 kg of textile products, total energy use, kW, UAH	E	Set electricity costs to reduce them
Calculation of electricity consumption for technological purposes, kW	E	Establishment of electricity bill
Textiles (products)		
Number of textile products that have lost their consumption properties, item	E	Establishment of the service life of textile products of different assortment, with the aim of reducing the environmental impact during the life cycle
Waste		
Waste (emissions), m^3	E	Set the amount to minimize waste
Quantity of waste per 1 kg of textile products	F	Set waste minimization characteristics in accordance with future regulations in order to reduce them
Drainage into water and soil		
Amount of wastewater in the process of cleaning 1 kg of textile products	D	Set the amount of wastewater in the process of cleaning 1 kg of textile products

Table 3. *Environmental pollution of the textile cleaning process in the aquatic environment*

Impact on the environment	Emissions
Air	- detergent, auxiliaries evaporation
Water	- wastewater after the process of water treatment - wastewater after the washing process

Inventory analysis is the basis and indispensable element of any LCA. During this phase, all material, energy, and source streams associated with the production system are collected and systematized for LCA in the environment. After the inventory analysis, the following conclusions were obtained: during the process of textile products cleaning, there are vapors of chemicals, and wastewater contaminates the remains of detergents.

Carbon dioxide emissions that affect climate change, as well as sulfur and nitrogen oxides, which affect oxidation processes, i.e. CO_2 and SO_2 equivalents, are potential impacts of the activity of the garment care industry.

The first stage of the impact assessment is to distribute the data collected from the inventory analysis of emissions, use of natural resources, and land by impact classes. The impact class includes climate change, oxidation, ecotoxicity, and carcinogen substances.

The characterization process involves the transformation of environmental variables into a single cost system. In practice, this is done by multiplying the variable, which is obtained in the inventory analysis by the coefficient of performance.

Normalization occurs after characterization. When normalized, the impact class indicators correlate with relevant data in a particular area; also calculate the relative share of the influence of the class of action in the ratio of the reference value. Normalization is required before the final consolidation of the data into a common impact indicator. At the accenting stage, the normalized values of the impact class indicators are combined into integrated impact indicators if the action of the system under study is to be expressed by means of integrated indicators. An integrated impact indicator can be obtained by multiplying the normalized impact class indicators by the weight factor of each impact class and compiling the results obtained. In practice, only mandatory structural parts that comply with the standard are performed at the LCA stage. The results are represented as the equivalents of CO_2 and SO_2. The calculations made at this stage for different impact classes are given in Table 4.

Integrated indicators of the impact of the technological process of textile cleaning in the aquatic environment are given in Table 5.

According to the integration of the general results, it is proved that the share introduced by the processes of textile products cleaning in the aquatic environment is insignificant in comparison with other technologies. Creating closed water supply cycles, reducing the duration of technological operations, and the use of new types of biosurfactants, will reduce the contamination burden on the environment and human health, the number of product treatment cycles in operation, and improve the quality of cleaning.

Table 4. *Performance evaluation indicators for different impact classes*

Impact class	Units	Indicator	Normalization factor	Normalization
Energy	kW	2.7	201.5 kW · eq / h	0.013
Water used	l	13.3	417580 l · eq	0.000032
Materials: Preparations, Auxiliaries	kg	0.006	27.13 kg · eq	0.00022
	l	0.1		0.0037
Climate change	kg CO_2 · eq	0,25	12300 kg CO_2 · eq	0.00002
Oxidation	kg SO_2 · eq	-	58.9 kg SO_2 · eq	-
Formation photochemical oxidants	kg C_xH_y · eq	-	32.20 kg C_xH_y · eq	-
Eutrophication (wastewater)	kg PO_4 · eq	0.005	8.01 kg PO_4 · eq	0.00062
Liquid waste	kg	-	0.00719 kg · eq	-
Total	-	-	-	0.0176

Table 5. *Integrated indicators of the impact of the process of textile products cleaning*

Weight coefficient			**Integrated Impact Indicators**		
Local	Regional	Global	Local	Regional	Global
10.57	11.77	12.76	0.137	0.153	0.106
10.39	8.61	9.12	$3.3 \cdot 10^{-4}$	$2.7 \cdot 10^{-4}$	$2.9 \cdot 10^{-4}$
8.34	9.23	10.56	0.033	0.036	0.041
8.02	9.66	12.71	$1.6 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$2.5 \cdot 10^{-4}$
7.23	9.41	10.09	-	-	-
13.68	11.68	7.56	-	-	-
2.57	3.52	3.8	0.0016	0.002	0.002
14.91	11.23	8.92	-	-	-
Total					
75.71	75.11	75.52	0.172	0.19	0.149

The third step is the method of evaluating the action. In various countries in the LCA process, a great deal of effort is being made to unify and systematize the environmental factors and methods of impact on the environment [6, 7, 12]. The Eco-indicator 95 method considers energy costs for raw materials, the final disposal of waste, and related environmental impacts and harms.

The fourth stage is the interpretation of the results. At this stage, the results of inventory analysis and impact assessment according to the tasks and technologies used are brought together.

Based on the results of the LCA, detergents, and technologies [13, 14] were developed for textile products cleaning in the aquatic environment. According to [13, 14] the cost of reagents, the time of operations, the cycle of processing products, energy costs are reduced, the environmental safety of the process is improved, high quality of cleaning products is achieved, and their service life is extended.

Summary

Thus, in the process of inventory analysis, it was found that during the textile products cleaning in the aquatic environment, emissions into the air are vapors of chemicals, and the main components of wastewater are surfactants that are part of detergents.

The technological process of textile product cleaning from the point of view of the identified sources of environmental danger was analyzed, and it was determined which stages of the technological process of the products cleaning have a negative impact on the environment and employees of the enterprise as well as the most harmful preparations.

According to the integration of the results of the study, the share of textile cleaning technologies in the aquatic environment is insignificant, which makes it possible to extend the scope of their use in the process of removing contaminants from the products, restoring their consumption properties, by creating closed water supply cycles and using new types of detergents compositions with low environmental impact.

The developed methodology for conducting LCA technologies for textile product cleaning in the aquatic environment can be applied to individual technological operations of product cleaning, as well as implemented at various enterprises of the garment care industry, which will minimize the negative impact on the environment and human health, reduce the cost of water, detergents, and auxiliaries, improve the quality of removal of contamination from textile products.

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