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ENVIRONMENTAL IMPACT ANALYSIS OF HYGIENE AND CLEANING PRODUCTS PACKAGING WASTE

Abstract: *Hygiene and cleaning products are used for personal hygiene, household, workspace, and public area cleaning. However, since hygiene and cleaning products may contain substances with specific toxicological and eco-toxicological properties, they can negatively affect human and environmental health. Direct human health impact of hygiene and cleaning products is the result of their manipulation during their manufacture and their use for washing, cleaning, and other forms of hygiene maintenance. Indirect human health impact of these products is manifested through environmental pollution, e.g. through drinking water extracted from eutrophic areas. Negative environmental impact of these products and their packaging is manifested through anthropogenic eutrophication, increased water and energy consumption, ambient degradation, and generation of large amounts of packaging waste. Consequently, the aim of this paper is to highlight the negative environmental impact, which depends on the type, composition, and quantity of hygiene and cleaning products and their packaging waste. The paper presents results obtained within the research project Environmental Impact of Hygiene and Cleaning Products and Their Packaging, conducted at the recycling centre of the Public Utility Company “Mediana” in Niš, Serbia in 2014 and 2015.*

Key words: hygiene and cleaning products, environment, environmental impact, hygiene and cleaning products waste.

INTRODUCTION

Increasing amount of waste from hygienic and cleaning product in the environment is a result of higher standard of living and fast pace of life of modern man, which is confirmed by the data on the manufactured quantities of soaps, detergents, and toiletries (Figure 1), as well as their wholesale and retail trade in Serbia from 2008 to 2014 (Figure 2).

Usage of these products and their increased production result in increased amount of waste, which is a significant factor of the negative environmental impact of such waste. Namely, economic growth linearly entails an increase in the amount of waste from hygienic and cleaning products. Likewise, improper hygienic product waste management poses an additional health and environmental risk. The negative environmental impact affects impoverished people around the globe, women and children, as well as other vulnerable groups (disabled persons, persons with special needs, persons with chronic illnesses, elderly persons, parentless children, etc.) the most [1].

The aim of this paper is to determine the quantity and morphological composition of hygienic and cleaning products waste based on the research results. Waste from cleaning products consists of product packaging and chemicals that constitute the packaging, which can be found in all three states of matter (solid, liquid, and

gas). This fact additionally complicates the management of this type of waste.

Based on the obtained data on the properties of hygienic and cleaning products waste, we analyzed the environmental impact of such waste in order to establish pollution sources and the mechanisms how the waste affects specific environmental mediums (water, soil, and air) and human health. That would allow proper measures and actions that can be taken in order to minimize or eliminate the negative environmental impact of hygienic and cleaning products waste.

Methodology for determining the quantity and morphological composition of hygienic and cleaning products waste

During the month of June 2014, hygienic and cleaning products waste was collected from 600 households from larger urban (Niš, Pirot, Knjaževac, Kruševac, Jagodina, and Vranje) and rural areas in Central Serbia. The collected waste, with specialized vehicles for packaging waste collection and transport was transported to the recycling centre of the Public Utility Company “Mediana” Niš (Figure 1) [8].



Figure 1 Collected samples of hygienic and cleaning products waste

The recycling centre of PUC “Mediana” Niš (Figure 2) was open in 2014 with the capacity of 15 tonnes of waste per day. The centre does not process waste, but separates different types of waste and packaging, and employs 20 workers.



Figure 2 Recycling centre of PUC “Mediana” Niš

The recycling centre realized several projects aimed to improve waste management system in urban areas. One such project is *Waste*, which was founded by the EU via the IPA cross-border cooperation programme between Serbia and Bulgaria. The goal of the project was to provide adequate infrastructure for recyclable waste collection in the City of Niš.

We conducted the research portion of the project *Model of Environmental Impact Assessment for Hygienic and Cleaning Products Waste* at the recycling centre and analyzed the total amount of 345.52 kg of hygienic waste collected from 600 households. After measuring the waste mass, we learned that it ranged from 0.26 to 6.92 kg per sample. Such variations are due to the following:

- number of household members,
- economic conditions,
- hygiene culture, and
- household needs for specific products.

We determined the morphological composition of collected hygienic and cleaning products waste and its quantity using the direct analysis method, also known as the sample and sort method. The core of this method is the collection of a statistically predetermined amount of solid hygienic and cleaning products waste. Samples are collected, inspected, and analyzed in order to determine their morphological composition. The analyzed sample is smaller than the total amount of solid waste collected. The sample and sort method was used in many waste characterization studies in the

USA, the EU, and in other countries. Morphological composition of solid hygienic and cleaning products waste is the content of specific types of waste in the total mass of waste. It is determined based on available data obtained through research, for households or cities with the average standard of living.

The first stage involved hygienic and cleaning products waste sorting according to the purpose of their use, which yielded four categories [7]:

- personal hygiene products,
- laundry products,
- household care products, and
- auxiliary products.

Personal hygiene products include face and body skin care, hair, and nail products. Laundry products include manual and machine washing powder, liquid detergents, and fabric softeners. Household care products include products for cleaning floors and glass surfaces, kitchen cleaning products, and bathroom cleaning products. Auxiliary products include items that facilitate the use of the previous three groups of products, such as toothbrushes, razors, cleaning cloths, or washing brushes.

All 600 collected waste contents of different types of packaging were sorted into appropriate group of packaging waste according to the purpose of use of the product.

The second stage involved hygienic and cleaning products waste sorting according to the type of packaging material [3]:

- aluminium,
- glass,
- wood,
- plastic,
- paper and cardboard, and
- mixed material.

Aluminium is used as packaging for deodorants, shaving foams, and certain house cleaning products. Glass is used for perfumes, face skin products, and antiperspirants (roll-ons). Plastic packaging is the most common and it is used for a wide variety of products from soaps, softeners, and laundry detergents, through face and body care products, to household care and auxiliary products. Paper and cardboard are used for almost every hygienic and cleaning product, often as additional packaging for perfumes, sets, powders, toothpastes, and household care products. The stages of waste sorting according to purpose are shown in Figure 3 [8].



Figure 3 Stage one: separation of content from the samples; Stage two: grouping of the content according to purpose;

Analysis of physical properties of hygienic and cleaning products waste

The core physical properties of hygienic and cleaning products waste are mass and volume. In order to determine the scope of environmental impact of these products and their packaging, we measured the mass and volume of each of the 600 samples [2].

Mass measurement

To measure the mass of the samples and their content in the environment, we used electronic platform scales EPVSD with one load cell [8].



Figure 4 Electronic platform scales EPVSD

Volume measurement

We measured the volume using a graduated cylinder, a funnel, and auxiliary containers with different volumes depending on their content (we used larger containers for larger samples and vice versa). The graduated cylinder used is shown in Figure 5 [8].



Figure 5 Graduated cylinder TLS-Pula, Serbia

The procedure for volume measurement is shown in Figure 6 and it involves two stages:

- first, the fluid (water) is squeezed out of the container by buoyant force applied to each separate content,

- second, the water is displaced from the container and channeled into the graduated cylinder through a funnel for volume-reading.



Figure 6 Volume measurement procedure

Calculation of the amount of packaging

Since hygienic and cleaning products waste packaging consists of plastic, glass, metal, paper, cardboard, wood, and other materials, the calculation of the type and amount of hygienic and cleaning products wastepackaging (Q_n) is made with the following formula [10]:

$$Q_n = Q_p + Q_s + Q_m + Q_{pk} + Q_d + Q_o \quad (1)$$

where:

- Q_p - amount of plastic in the hygienic and cleaning products wastepackaging;
- Q_s - amount of glass in the hygienic and cleaning products wastepackaging;
- Q_m - amount of metal in the hygienic and cleaning products wastepackaging;
- Q_{pk} - amount of paper and cardboard in the hygienic and cleaning products wastepackaging;
- Q_d - amount of wood in the hygienic and cleaning products wastepackaging;
- Q_o - amount of other materials in the hygienic and cleaning products wastepackaging.

Each individual type of packaging (Q_i) may comprise several subtypes (Q_n). In that case, the total amount of a given type of packaging (Q_i) is calculated with the formula:

$$Q_i = Q_1 + Q_2 + Q_3 + \dots + Q_n \quad (2)$$

where:

- $Q_1, Q_2, Q_3, \dots, Q_n$ - number of subtypes in one packaging type.

Plastic packaging originates from a wide variety of hygienic and cleaning products used for personal hygiene (e.g. soaps, shampoos, or baths), clothing care, shoe care, laundry and linen (softeners and detergents), household care (floor, glass, and wall maintenance), or community hygiene (pesticides, disinfectants). Plastic packaging also includes auxiliary products used in conjunction with the cleaning products (razors, shaving brushes, toothbrushes, etc.).

The total amount of plastic packaging form used hygienic and cleaning products ($\sum Q_{AP}$) is calculated with the formula:

$$\sum Q_{AP} = Q_{pet} + Q_{hdpe} + Q_{pvc} + Q_{ldpe} + Q_{pp} + Q_{ps} + Q_{ost} \quad (3)$$

where:

- Q_{pet} - polyethylene terephthalate packaging,
- Q_{hdpe} - high-density polyethylenepackaging,
- Q_{pvc} - polyvinyl chloride packaging,
- Q_{ldpe} - low-density polyethylenepackaging,
- Q_{pp} - polypropylene packaging,
- Q_{ps} - polystyrene packaging, and
- Q_{ost} - packaging made of other plastics.

Glass packaging is the most common waste from products used for personal hygiene, such as perfumes, face skin care products, antiperspirants (roll-ons), etc.

The total amount of glass packaging form used hygienic and cleaning products ($\sum Q_{ST}$) is calculated with the formula [4]:

$$\sum Q_{ST} = Q_B + Q_Z + Q_S \quad (4)$$

where:

- Q_B - colourless glass packaging,
- Q_Z - green glass packaging,
- Q_S - amber glass packaging.

Aluminium packaging comes from personal hygiene products (deodorants, shaving foams), but also from certain household care products (floor or wall maintenance, paints) and community hygiene products (pesticides, disinfectants). This type of waste most frequently occurs as pressurized packaging for aerosol products.

The total amount of aluminium packaging form used hygienic and cleaning products ($\sum Q_{AL}$) is calculated with the formula:

$$\sum Q_{AL} = Q_m + Q_t \quad (5)$$

where:

- Q_m - soft aluminium packaging,
- Q_t - hard aluminium packaging.

Paper and cardboard packaging waste comes from all types of hygiene and cleaning products, personal hygiene, and household cleaning products, clothing, footwear, and laundry care, for additional packaging (for perfumes, sets, powders, toothpastes, air fresheners, disinfectants, pesticides, etc.), or for product descriptions and instructions for use of all types of products.

The total amount of paper and cardboard packaging form used hygienic and cleaning products ($\sum Q_{PIK}$) is calculated with the formula [10]:

$$\sum Q_{PIK} = Q_p + Q_k \quad (6)$$

where:

- Q_p - paper packaging,
- Q_k - cardboard packaging.

RESULTS AND DISCUSSION

Mass and volume of the total amount of collected hygienic and cleaning products waste

The mass and volume of the total amount of collected hygienic and cleaning products waste classified according to purpose of their use, into four categories are shown in Table 1 and in Figures 7 and 8 [8].

Table1 Mass and volume of collected hygienic and cleaning products waste classified according to purpose [Source: Model of Environmental Impact Assessment for Hygienic and Cleaning Products Waste, 2015]

No	PURPOSE	MASS (m)		VOLUME (V)	
		[kg]	%	[dm ³]	%
1.	Personal hygiene products	142.21	41	1,105.11	31
2.	Laundry products	106.87	31	1,389.15	40
3.	Household care products	73.66	21	796.32	23
4.	Auxiliary products	25.78	7	203.68	6

Analysis of the mass of hygienic and cleaning products waste showed that the packaging for personal hygiene products has the biggest mass percentage of the four categories with 41%. It is followed by laundry product packaging with 31%, household care product packaging with 21%, and auxiliary product packaging with only 7% of the total waste mass (Figure 7).

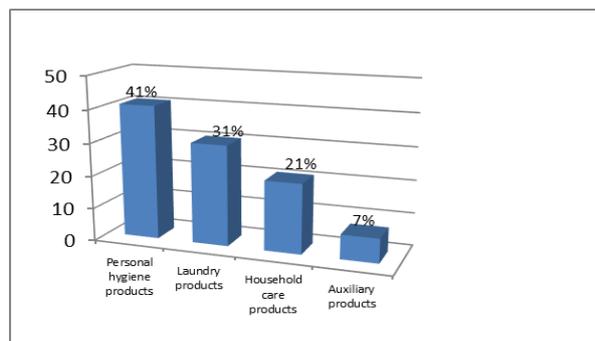


Figure 7 Percentage of the mass of specific packaging type waste in relation to the total amount of hygienic and cleaning products packaging

Analysis of the volume of hygienic and cleaning products waste showed that the laundry product packaging has the biggest mass percentage of the four categories with 40%. It is followed by the packaging for personal hygiene products with 31%, household care product packaging with 23%, and auxiliary product packaging with only 6% of the total waste mass (Figure 8).

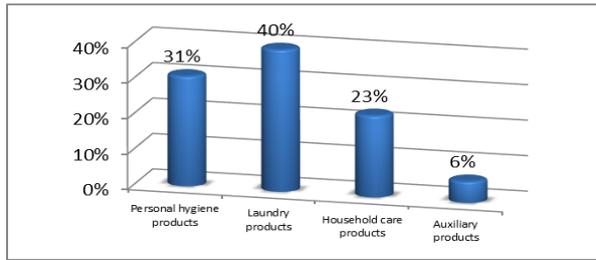


Figure 8 Percentage of the volume of hygienic and cleaning products waste according to purpose

Mass and volume of collected packaging waste according to packaging material

Data on the mass and volume of hygienic and cleaning products packaging according to packaging material are shown in Table 2 and Figure 11.

Table 2 Mass and volume of hygienic and cleaning products packaging according to material

No	PACKAGING	MASS		VOLUME	
	Unit	[kg]	%	[dm ³]	%
1.	Plastic	158.71	46	1,687.42	48
2.	Glass	118.72	34	1,107.69	32
3.	Aluminium	42.16	12	397.58	11
4.	Paper and cardboard	28.93	8	301.57	9
	TOTAL	348.52	100	3,494.26	100

Measurement of the total mass of hygienic and cleaning products packaging waste yielded the percentage of the amount of waste according to the packaging material category. Plastic packaging has the biggest mass percentage of the four categories with 46%. It is followed by glass packaging with 34%, aluminium packaging with 12%, and paper and cardboard packaging with only 8% of the total packaging waste mass (Figure 9) [4].

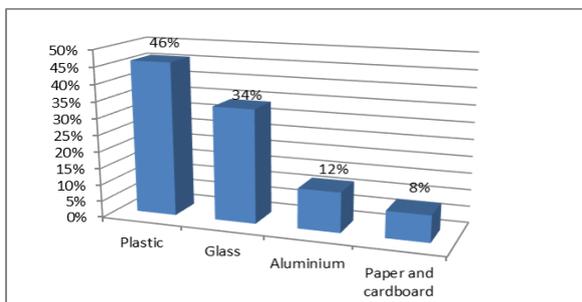


Figure 9 Percentage of the mass of hygienic and cleaning products waste according to the packaging material

Analysis of the volume of hygienic and cleaning products packaging waste, which had been classified according to the packaging material, showed that plastic packaging has the biggest volume percentage of

the four categories with 48%. It is followed by glass packaging with 33%, aluminium packaging with 11%, and paper and cardboard packaging with only 9% of the total packaging waste volume (Figure 10).

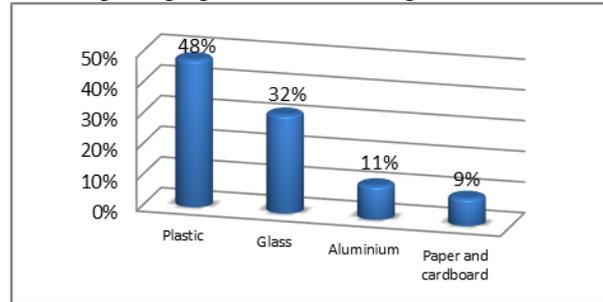


Figure 10 Percentage of the volume of hygienic and cleaning products waste according to the packaging material

Calculation of the amount of hygienic and cleaning products waste in Serbia

The average amount of hygienic and cleaning products packaging waste collected per household in Serbia (PQ_{ohs}) is calculated with the formula:

$$PQ_{ohs} = \frac{\Sigma Q_{ohs}}{NoHshlds} \text{ [kg]} \tag{7}$$

According to the data obtained during the project, we found that the total collected hygienic and cleaning products packaging waste in 600 households amounted to 348.52 kg. By entering the above values into formula (7), we obtained the average monthly amount of hygienic and cleaning products packaging waste per household:

$$PQ_{ohs} = \frac{348.52}{600} = 0.5808 \text{ [kg]} \tag{8}$$

The data on the average monthly amount of collected hygienic and cleaning products packaging waste per household (0.5808kg) and the total number of households in Serbia (2,487,886) [Source: Statistical Yearbook of Serbia, 2013] allowed us to calculate the total mass of hygienic and cleaning products packaging waste in Serbia:

$$\Sigma Q_{srb,ohs} = 0.5808 \times 2,487,886 = 1,444,964,1888 \text{ [kg]} \tag{9}$$

The obtained value in (9) indicates that ca. 1445 tonnes of hygienic and cleaning products packaging waste is generated in Serbia monthly, amounting to 17,341.56 tonnes annually. Considering the official population of Serbia – 7,186,862 (Source: Statistical Yearbook of Serbia, 2014), on average, every Serbian citizen generates 2.41 kg of hygienic and cleaning products packaging waste.

The amount of 1.92 million tonnes of waste collected and deposited by municipal public utility companies in 2013[1], and the calculated amount of 0.017 million tonnes of hygienic and cleaning products packaging waste indicate that this type of waste constitutes 0.88% of the total mass of all collected waste.

In order to better illustrate the environmental impact of hygienic and cleaning products solid waste, we chose

the example of fabric softener packaging waste (Table 3 and Figure 11).

Table 3 Structure of fabric softener plastic packaging 2 dm³ in volume

No.	Softener brand	ΣPackaging		Body		Cap		Label		Residual chemicals	
		[g]	[%]	[g]	[%]	[g]	[%]	[g]	[%]	[g]	[%]
1.	Duel	87	100	63	72.4	9	10.3	7	8.1	8	9.2
2.	Ornel	98	100	73	74.5	17	17.3	2	2.1	6	6.1
3.	Lion	66	100	53	80	8	12	2	3.5	3	4.5
	ΣTotal	251	100	189	75.29	34	13.54	11	4.38	17	6.77
	Average	83.67		63		11.34		3.67		5.67	

Table 3 shows that the average mass of a 2 dm³ fabric softener container is 83.67 g. Most of the mass goes into the body (75.29%), followed by the cap (13.54%), and the label, which is made of cellophane, thin plastic, etc. (4.38%). Additionally, measurements showed that the packaging body always contains some residual amount of liquid softener, which takes up 6.77% of the total mass of the packaging.

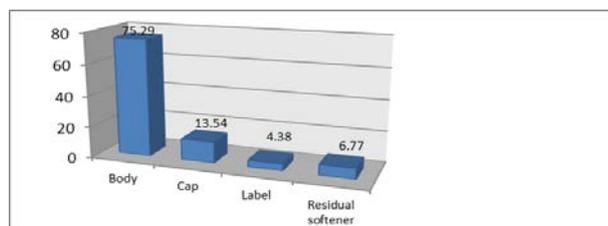


Figure 11 Structure of fabric softener plastic packaging 2 dm³ in volume

A 2 dm³ container filled with liquid fabric softener weighs 2.1 kg. Upon use, it releases 2 kg of liquid softener into the environment via wastewater from washing that goes into the sewerage and then into aquatic ecosystems. This results in negative environmental impact manifesting itself as eutrophication, altered composition or colour, etc. The example suggests a considerable load on the environment by one type of hygiene and cleaning products packaging waste - fabric softeners [5].

CONCLUSION

The analyzed data lead to a conclusion that there is an increased load placed on the environment by hygiene and cleaning product packaging waste. The data shown in this paper are the starting point for obtaining a better insight on the environmental impact. Proper management and handling of hygiene and cleaning products solid waste can significantly reduce harmful effects [6].

Today, primary waste sorting should serve the culture of housing and household hygiene. Hygienic and cleaning products waste should be separated into specially designed containers or bags for this type of waste [5]. Packaging waste from these products should also be sorted according to its material. If it is not

possible to separate hygienic and cleaning products waste according to packaging material, it is acceptable to at least sort it into separate containers or bags. Due to its specific nature, hygiene and cleaning products waste should be treated as a separate waste category, which would yield the best waste management results, reflected in the reduced negative environmental impact.

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BIOGRAPHY

Duška Pejčić was born in Niš, Serbia. She graduated from the Department of Chemistry at the Faculty of Philosophy, University of Niš. She received her Master's degree in Environmental Science from the Faculty of Occupational Safety, University of Niš in 2010. She authored several papers dedicated to occupational safety in chemical industry, sustainable development, and urban waste water published at various national and international conferences in Serbia, Bosnia and Herzegovina, Croatia, and Slovenia.



Analiza uticaja ambalažnog otpada od higijenskih sredstava na životnu sredinu

Duška Pejčić, Žarko Vranjanac

Apstrakt: Higijenska sredstva omogućavaju održavanje kako lične, tako i higijene u kući, radnom prostoru i javnim prostorijama. Međutim, s obzirom na činjenicu da se u sastavu higijenskih sredstava mogu naći supstance koje poseduju određena toksikološka i ekotoksikološka svojstva, to se mogu javiti i negativni efekti kako na stanovništvo, tako i na životnu sredinu. Direktni uticaj higijenskih sredstava na zdravlje ljudi je posledica manipulativnih operacija sa higijenskim sredstvima pri njihovoj proizvodnji, odnosno njihove upotrebe u procesima pranja, čišćenja i drugih vidova održavanja higijene. Indirektni uticaj higijenskih sredstava na zdravlje ljudi ogleda se kroz povratni uticaj zagađene životne sredine od higijenskih sredstava, kao što je na primer korišćenje vode za piće koja se ekstrahuje iz eutrofičnih oblasti. Negativne ekološke posledice uticaja higijenskih sredstava i njihove ambalaže na životnu sredinu ogledaju se kroz proces antropogene eutrofikacije, povećanu potrošnju vode i energije, degradiranje ambijenta i stvaranja velike količine ambalažnog otpada od higijenskih sredstava. Zbog toga ovaj rad ima za cilj da ukaže na ove negativne ekološke posledice a koje su u funkciji vrste, sastava i količine higijenskih sredstava, odnosno ambalažnog otpada. U radu se iznose rezultati do kojih se došlo realizacijom istraživačkog projekta Uticaj higijenskih sredstava i njihove ambalaže na životnu sredinu, koji je realizovan u reciklažnom centru Javno komunalnog preduzeća "Mediana" u Nišu u toku 2014 i 2015. godine.

Ključne reči: higijenska sredstva, životna sredine, ekološke posledice, otpad od higijenskih sredstava.