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Comparative Life Cycle Assessment of High Barrier Polymer Packaging for Selecting Resource Efficient and Environmentally Low-Impact Materials

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Abstract**—**In this study tree types of multilayer gas barrier plastic packaging films were compared using life cycle assessment as a tool for resource efficient and environmentally low-impact materials selection. The first type of multilayer packaging film (PET-AlOx/LDPE) consists of polyethylene terephthalate with barrier layer AlOx (PET-AlOx) and low density polyethylene (LDPE). The second type of polymer film (PET/PE-EVOH-PE) is made of polyethylene terephthalate (PET) and co-extrusion film PE-EVOH-PE as barrier layer. And the third one type of multilayer packaging film (PET-PVOH/LDPE) is formed from polyethylene terephthalate with barrier layer PVOH (PET-PVOH) and low density polyethylene (LDPE).

All of analyzed packaging has significant impact to resource depletion, because of raw materials extraction and energy use and production of different kind of plastics. Nevertheless the impact generated during life cycle of functional unit of II type of packaging (PET/PE-EVOH-PE) was about 25% lower than impact generated by I type (PET-AlOx/LDPE) and III type (PET-PVOH/LDPE) of packaging.

Result revealed that the contribution of different gas barrier type to the overall environmental problem of packaging is not significant. The impact are mostly generated by using energy and materials during raw material extraction and production of different plastic materials as plastic polymers material as PE, LDPE and PET, but not gas barrier materials as AlOx, PVOH and EVOH.

The LCA results could be useful in different decision-making processes, for selecting resource efficient and environmentally low-impact materials.

Keywords**—**Polymer packaging, life cycle assessment, resource efficiency.

I. Introduction

THE amount of packaging is a key element when looking at resource efficiency. Packaging sector uses significant amount of natural resources, and has high eco-efficiency potential. For example, in Lithuania the total amount of packaging put in the national market reaches about 250,000 tons when only about 35% of the total amount are reused or recycled [9]. According to European Commision, each year the EU landfill of 5.25 billion euro worth of recyclable materials such as paper, glass, plastics, aluminum and steel [16]. The second important element is the material used for the packaging. Different packaging materials are associated with different environmental impacts. New materials, especially plastic and their composites (different laminates with different barrier layers) are constantly increasing, and finally they can no longer be separated for reuse or recycling, because of high cost and low resale value [3].

Researches studding environmental burdens from packaging and packaging wastes are divided into two sides. One of the sides declares that avoided consumption of packaging is better than other alternatives and even if 100% of packaging is recycled after use, from a resource perspective it is always better to avoid the initial consumption [3]. Other side of scientist argues that one of the main functions of packaging is to protect goods and reduce waste, and packaging that reduce food waste can be an important tool to reduce the total environmental impact, even if there is an increase in impact from packaging itself [1], [2]. Using gas barrier multilayer plastic packaging is one way to decrease food losses. The use of gas barrier film restricts the entry of O_2 concentration through packaging material by extending shelf-life and preserving the quality of packaged food [10]. That's is why this kind of packaging has been abundantly reported, commercialized and used in a wide range of food: exclusively used in high barrier trays for food packing, suitable for sea foods, meet, vegetables and fruits, which require high barrier ability of fresh and seal packaging. From environmental point of view to use of multilayered film including a barrier layer is not desirable with respect to poor recyclability rates and burdens to environment [11].

In order to enhance resource efficiency and minimize packaging waste, EU set out Essential Requirements which are designed to minimize the environmental impact of packaging. They focus on prevention and minimization of waste at source and ensuring that waste is recoverable, or recyclable, or reusable.

In order to find balance the product, packaging and environmental requirements packaging material industry could establish eco-design tool for packaging. Eco design is integration of environmental aspects into packaging design with the aim of improving the environmental performance of a packaging life cycle [14]. This is one of the most innovative tools for the sustainable development of the industry, to have a smaller quantity of raw materials and less harmful substances in production processes, ensuring the reduction of waste generation at the source [5], [10]. Eco-design is based on life cycle assessment (LCA) tool which is perfect instrument to evaluate how much the adopted technologies and the materials used in phase of production can negatively influence the

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environmental quality of raw material extraction, use and disposal phases [10].

The aim of the study was to compare and evaluate environmental burdens associated with raw materials extraction and production of three types of multilayer gas barrier polymer packaging used for food industry. A second objective was to assess environmental impact relation to different types of gas barrier layers.

II. Research Methodology

A comparative LCA study of the three types of multilayer polymer packaging films were carried out following the procedure and recommendations indicated in the European standards series– ISO 14040-14044 [15]. The Standards are particularly relevant in the packaging sector [7]. In accordance with the standards the LCA analyses was performed in the following main steps:

1. Definition of the goal and scope of the study; functional unit and system boundaries identification;
2. Life-cycle inventory analysis;
3. Life-cycle impact assessment;
4. Life-cycle interpretation.

A. Definition of the Goal and Scope of the Study

High barrier, plastic multilayer packaging film was chosen for LCA research, because of the fast growth of plastic packaging sector with consequence of significant impact to environment.

The goal of the study was to evaluate and compare environmental burdens associated with raw materials extraction and production of three types of multilayer polymer films used for food barrier packaging.

The main tasks of the study were:

- to identify environmental impact of each the individual components of the analyzed packaging types in the different environmental impact categories;
- to clarify which component of the laminate film has highest impact to environment;
- to assess environmental impact relation to different barrier layer types;

Three types of high barrier plastic packaging films, with different multilayer composition were investigated in this study. Schematic presentation of composition of analyzed multilayer films is illustrated in Fig. 1. The first type of multilayer packaging film (PET-AlOx/LDPE) consists of polyethylene terephthalate with barrier layer AlOx (PET-AlOx) and low density polyethylene (LDPE). The second type of polymer film (PET/PE-EVOH-PE) is made of polyethylene terephthalate (PET) and co-extrusion film PE-EVOH-PE as barrier layer. And the third one type of multilayer packaging film (PET-PVOH/LDPE) is formed from polyethylene terephthalate with barrier layer PVOH (PET-PVOH) and low density polyethylene (LDPE). The all three analyzed multilayer films are characterized the same high barrier value, and the same thickness.

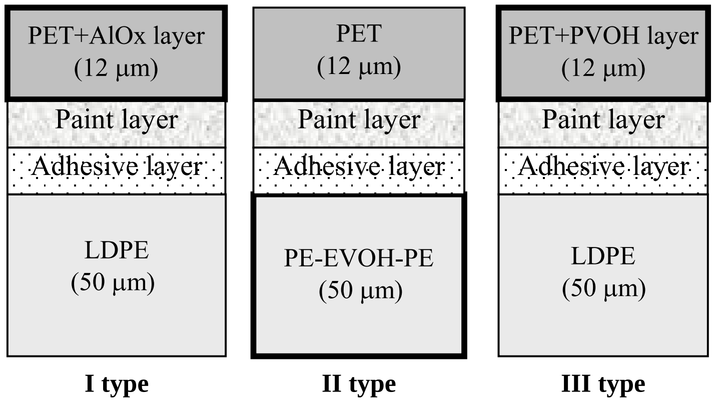

Fig. 1 Composition of analyzed multilayer high barrier polymer films (highlighting barrier layer)

B. Functional Unit and System Boundaries

Regardless the definition of the goal of the study, which was described in the introduction part, at the first phase it is very important to define the functional unit and boundaries of the system that will be included in the assessment. The functional unit defines the performance of the system. Each measure and evaluation in life cycle is performed in relation on this parameter. In comparative studies it is especially important that the systems be compared on the basis of the equivalent functions. A one square meter ($1m^2$) of the multilayer packaging film was used as functional unit in this study.

The all phases from raw material extraction to multilayer barrier packaging production have been taken into consideration in the analysis of environmental impact. Evaluated system boundaries are presented in Fig. 2.

In order to simplify the system properly and delimit research boundaries, the study deals with several stages of a life cycle of selected packing: raw materials extraction, polymers, adhesives and ink production, as well as barrier packaging production. Transportation, packaging use and waste disposal stages are excluded because they are regarded as equal.

The life cycle stages evaluated in this study do not include the food production and packaging filling as well as consumption and packaging waste management phases. Production wastes (including unused materials and defective products) were included in the LCA production model, but the waste management scenarios and alternatives were not taken into account. The energy use in multilayer film production and impact of transportation was excluded from evaluation process as well, because it was assumed that it would be the same for all three types of analyzed packaging films.

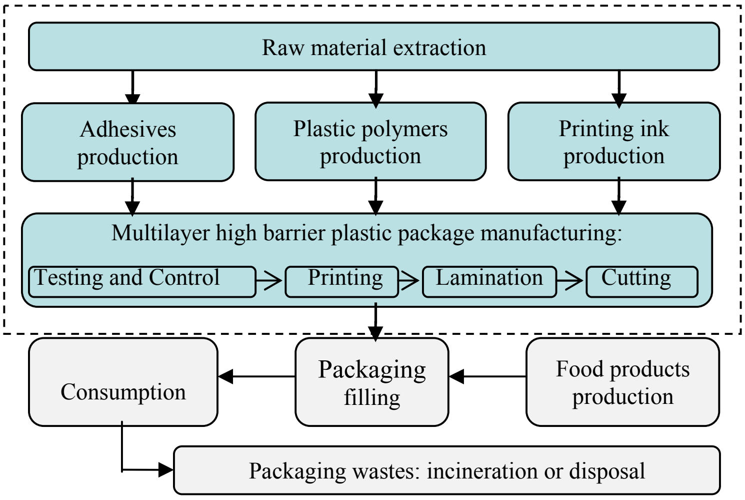

Fig. 2 Evaluated system boundaries representation, highlighting included phases

C. Inventory Analyses

The most important step in the LCA studies is to collect the inventory data for building the life cycle inventory. High quality data are essential to reliable evaluation. Data for this research were collected from different sources. The foreground system inventory data comprised average annual data that were obtained by on-site measurements in the companies. Other inventory data for the background system were obtained from the Ecoinvent database. Inventory data for production of printing ink, glue, LDPE and PET film were taken by on-site measurements in the companies.

In the inventory analyses for laminate production process analyses have been used average production data for one setting and control cycle - 4150 m^2 film.

D. Environmental Impact Assessment and Interpretation

Environmental impact assessment and interpretation was performed using SimaPro software received from Pre Consultants. Impact assessment is a technical, quantitative, and qualitative process to characterize and assess the effects of the environmental burdens identified in the inventory. Impact assessment in LCA consists of the following three steps: characterization, normalization and weight. Firstly, in this study, eleven impact categories (Table III) included by the EI99 method were investigated by the following steps: characterization, normalization and weight. Eco-indicator – end-point method developed in 1995 to provide designer and design engineers with environmental information in a simple single value format.

TABLE I
GLOBAL INVENTORY FOR THE ASSESSMENT OF THREE TYPES OF MULTILAYER PACKAGING FILMS

Materials and processes	**Unit**	**I Type package film** PET-AlOx/LDPE	**II Type package film** PET/PE-EVOH-PE	**III Type package film** PET-PVOH/LDPE
Printing ink				
Testing	kg/m2	0.0048	0.0048	0.0048
Production	kg/m2	0.0180	0.0180	0.0180
Adhesives				
Testing	kg/m2	0.00054	0.00054	0.00054
Production	kg/m2	0.00193	0.00193	0.00193
PET-AlOx				
Testing	kg/m2	0.0045		
Production	kg/m2	0.0168		
PET				
Testing	kg/m2		0.0044	
Production	kg/m2		0.0157	
PET-PVOH				
Testing	kg/m2			0.0045
Production	kg/m2			0.0168
PE-EVOH-PE				
Testing	kg/m2		0.0014	
Production	kg/m2		0.0457	
LDPE				
Testing	kg/m2	0.0013		0.0013
Production	kg/m2	0.0446		0.0446
Wastes				
Plastic from production	kg/m2	0.00779	0.00767	0.00779

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TABLE II
INVENTORY ANALYSES FOR COMPOSITION OF DIFFERENT TYPES OF BARRIER LAYERS

		Testing	Production
I Type package barrier layer PET-AlOx			
PET (96%)	kg/m2	0.0043	0.0161
AlOx layer (4%)	kg/m2	0.00018	0.00068
II Type package barrier layer PE-EVOH-PE			
PE (90%)	kg/m2	0.0012	0.0411
EVOH (10%)	kg/m2	0.0046	0.0046
III Type package barrier layer PET-PVOH			
PET (96.5%)	kg/m2	0.0043	0.0162
PVOH layer (3.5%)	kg/m2	0.00018	0.00067

Damage-oriented impact assessment methodology has received attention in recent years [12]. In the present study the Eco-Indicator 99 method was used for the impact assessment step, because it is a damage-oriented and endpoint approach proceeding from the identification of areas of concern (damage categories) to determine what causes damage in these areas [13], [14]. The Eco-indicator 99 method considers three damage categories: human health (Disability Adjusted Life Years-DALYs), ecosystem quality (Potentially Disappeared of Affected Fraction-PDF of PAF, on given area during a given time period) and depletion of resources (surplus energy for future extraction). For further interpretation, the results are integrated to one indicator using standardized weighting methods to keep the integration step transparent. The Eco-indicator 99 results are integrated using the default weighting set of 40% for damage to human health, 40% for damage to ecosystems and 20% for depletion of resources. Table III shows the three damage categories and the impact categories modeled in Eco-indicator 99 [8], [11]. To provide a single environmental score impacts are characterized into damage levels. These are then combined in three categories: Human Health, Eco-systems, Resource use. These are then weighted into a single score which is measured in eco-points. 1 eco-point=1/1000th of an average Europeans yearly environmental load.

TABLE III
IMPACT CATEGORIES ANALYZED IN THIS STUDY (PRÈ CONSULTANTS, 2001)

	Impact category indicators (with their unit for kg emissions)	Grouping, reduced number of impact categories
1	Carcinogenic substances (mg C2H3CL-equivalent)	Human health, DALY*
2	Respiratory effects (organics) (kg C2H4-equivalent	
3	Respiratory effects (inorganics) (kg PM2.5-equivalent)	
4	Climate change (kg CO_2-equivalent)	
5	Ionizing radiation	
6	Ozone layer depletion (CFC11-equivalent)	
7	Ecotoxicity	Ecosystem Quality, PDF**
8	Acidification/ Eutrophication (SO2 and NO2-equivalent)	
9	Land use	
10	Depletion of minerals	Resources, MJ Surplus Energy***
11	Depletion of fossil fuels	

DALY* (Disability Adjusted Life Years) – This is a measure of the disability caused by the different environmental impacts and is therefore represents the impact on human health.

PDF** (Potentially Disappeared Fraction) – this is the influence of number of impact categories (ecotoxicity, land use) on the extinction of plant species and represents the impact on ecosystem quality.

MJ Surplus Energy* –** a measure of the amount of additional energy required to compensate for future resource depletion and represents the impact on resources. The factors used to combine different impact categories into the three damage categories

III. RESULTS

A. Environmental Impacts Characterization Phase for Individual Components of Packaging

1. I Type PET-AlOx/LDPE

The results of the functional unit per impact category of the individual components of the I type (PET-AlOx/LDPE) package are introduced in Fig. 3. The different color represents individual components of the packaging material and the length of the columns represents the seriousness of the impact. Carcinogens, Respiratory inorganics and organics, Acidification/eutrophication potential and Fossil fuels categories exhibit a percentage high contribution from the component of LDPE, because of the extraction of the raw materials and production of low-density polyethylene. Radiation, Ozone layer and Land use categories dominated from the Ink and Adhesives impacts. Component PET-AlOx represents a serious impact in Eco-toxicity category, because of heavy metals emissions and effluents, also less, but significant impact in Minerals (natural raw materials) consumption, Climate change and Fossil fuels use categories.

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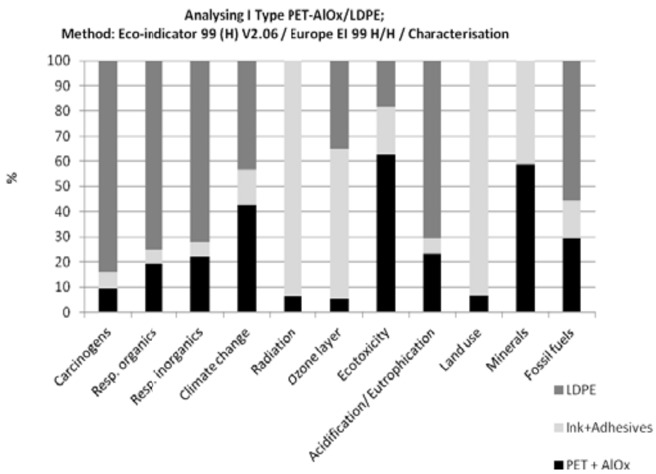

Fig. 3 Environmental impact assessment of the individual components of I type of packaging in different impact categories

In order to indicate, the most significant impact categories, which was effected by the life-cycle of individual components of I type of packaging, each impact category was integrated into one score (Fig. 4.). Single score Fig. 4 shows that the most significant environmental impact of packaging I type components were for Fossil fuels, Respiratory inorganic emissions and Climate change impact categories. Comparing the environmental impact of different components, it was identified that the total impact of LDPE (57.5%) exceeds the other components total impacts (PET-AlOx (28.8%) and Ink and Adhesives (13.6%)) on environment. Fig. 5 supports that the largest environmental problems are generated in Fossil fuels, Respiratory inorganic emissions and Climate change categories.

The fossil fuels category presents the largest contribution by the raw material from crude oil, respiratory inorganics and climate change categories are associated with energy consumption. Thus, Climate change category is remarkably affected by the airborne emissions from the extraction of polyethylene and from electricity generation.

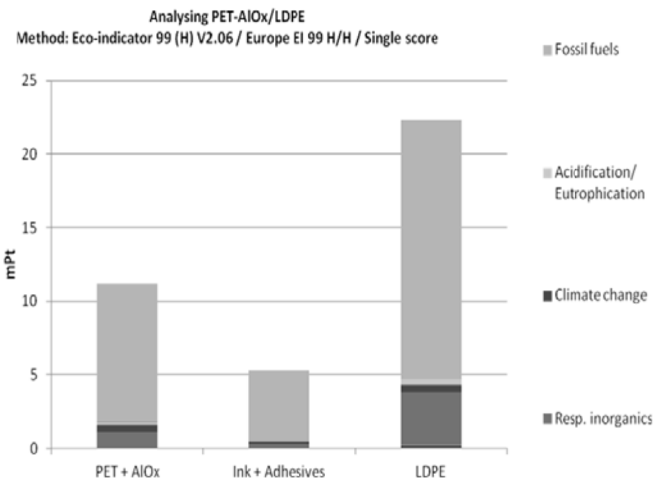

Fig. 4 Environmental impacts categories comparison of individual components of I type of packaging

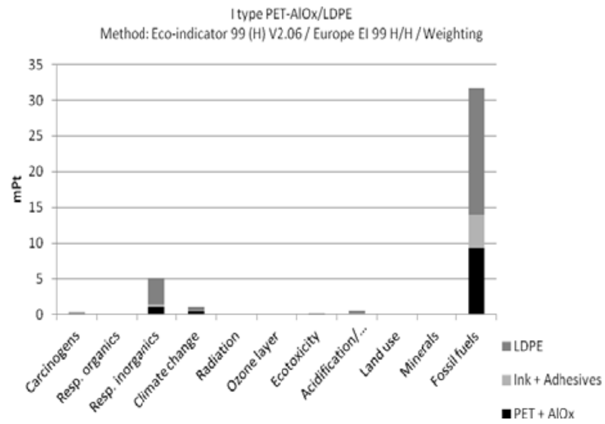

Fig. 5 The most significant impact categories effected by the I type of packaging components

2. II Type PET/PE-EVOH-PE

The environmental impact characterization phase analysis (Fig. 6) on the II type of packaging showed there is no clear differentiation of impact category for different packaging components. Nevertheless it could be noted that the Land use, Organic and Innorganic emissions, Radiation potential, Acidification potential carcinogenic category and fossil fuel energy consumption carcinogenic categories were more affected by packaging component PE/EVOH/PE. While Ecotoxicity (heavy metals in airborne and liquid), Climate changes impact categories were significantly affected by the PET component.

Ink and Adhesives components of packaging Type II dominates in up to 4 categories of exposure - Ozone potential, Radiation potential, Minerals and Carcinogens.

Environmental impacts categories comparison of individual components of II type of packaging (Fig. 7) indicates that the most significant environmental impact of packaging II type components were for Fossil fuels, Respiratory inorganic emissions and Climate change impact categories (the same as for I type of packaging). Comparing the environmental impact of different components, it was identified that the total impact of PE/EVOH/PE (53.3%) exceeds the other components total impacts (PET (32%) and Ink and Adhesives (14.7%)) on environment. Fig. 8 supports that the largest environmental problems are generated in Fossil fuels, Respiratory inorganic emissions and Climate change categories.

The fossil fuels category presents the largest contribution by the raw material from crude oil, respiratory inorganics and climate change categories are associated with energy consumption. Thus, the respiratory inorganics category is remarkably affected by the airborne emissions from the extraction of polyethylene and from electricity generation.

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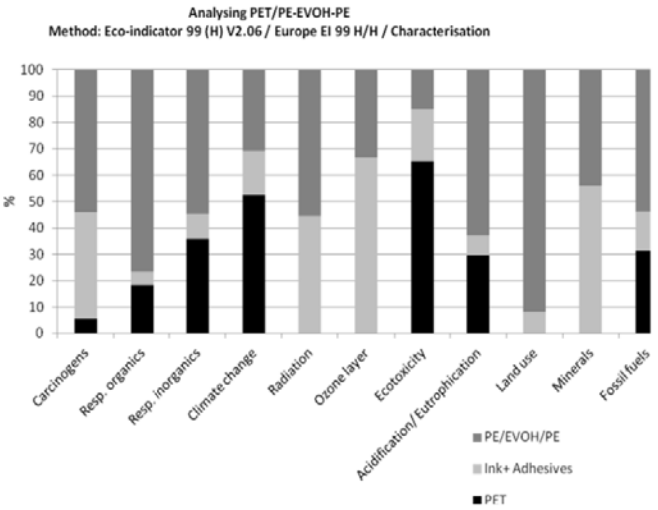

Fig. 6 Environmental impacts categories comparison of individual components of II type of packaging

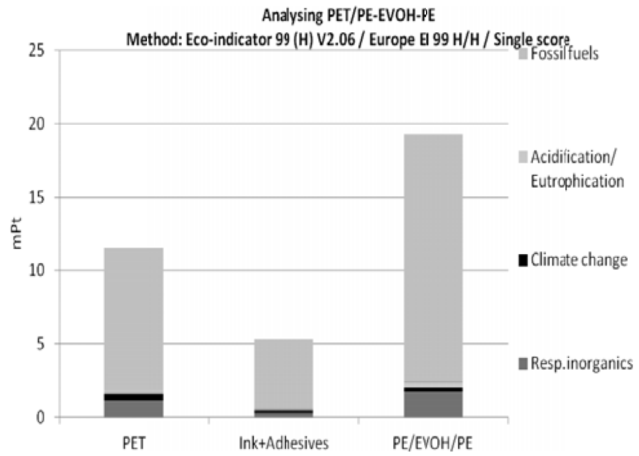

Fig. 7 Environmental impacts categories comparison of individual components of II type of packaging

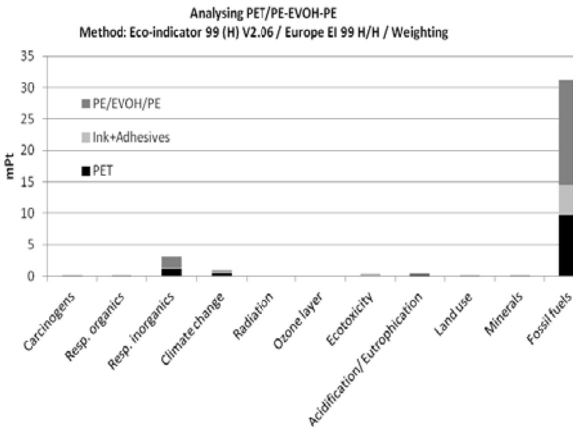

Fig. 8 The most significant impact categories affected by the II type of packaging components

3. III Type PET-PVOH/LDPE

Results are very similar to I type of packaging. It means that different kind of barrier material doesn't have different significant impact to packaging impact to environment.

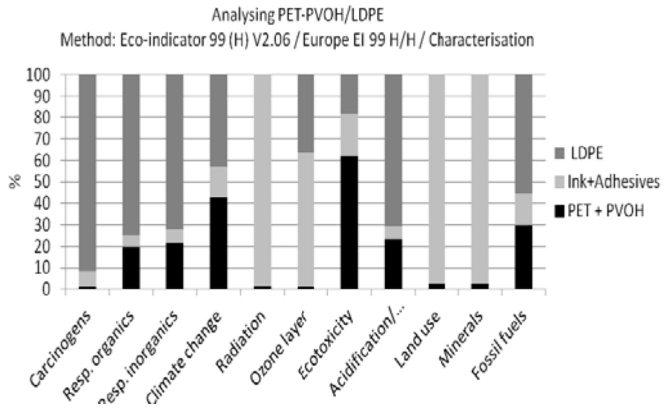

Fig. 9 Environmental impacts categories comparison of individual components of III type of packaging

B. Environmental Impact Comparison of Different Type of Packaging

Comparison results of three types of packaging impacts generated from their functional units during life cycle on different environmental categories are presented in Fig. 10. Results show relative (percentage value from the worsted case) impact contribution of analyzed packaging types on different impact categories. The comparison reveals that I and III type of packaging have similar profile of percentage impact value in most of impact categories. The exception is only impact on Minerals and relatively on Carcinogens and Ozone layer. As the composition of plastic components is the same in I and III type of packaging, this difference could be related with different barrier material and their extraction and production phases: I type packaging contains AlOx barrier, III type of packaging PVOH barrier.

Packaging type III has different profile of percentage impact value from Packaging types I and II in most of impact categories. This result is influenced by different packages individual plastic (plastics), which have different chemical properties as well as manufacturing process.

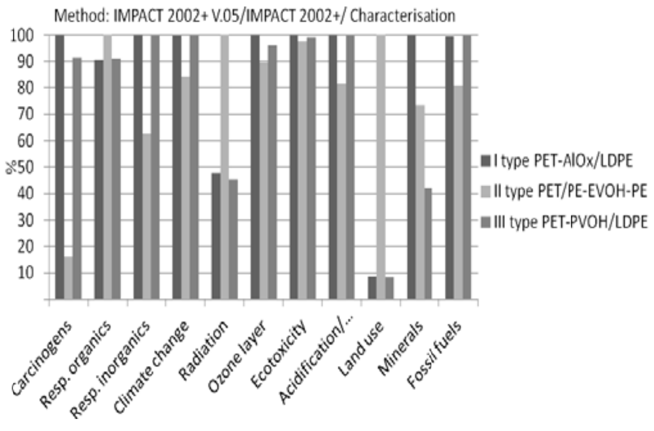

Fig. 10 Comparison of three types of packaging life cycle impacts on different environmental categories

In order to assess the most effected environmental categories, the impact values of each category were weighted. The result is briefly presented in Fig. 11. Results show that significant impact contribution from all three types of packaging goes to Fossil fuels, Climate change, Respiratory inorganic and Carcinogens categories. Other categories showed very low contribution to overall environmental problem that is why they were taken out of further impact comparison analyses (see Fig. 12). Results from Fig. 11 also reveals that the II type of packaging has lower impact on Fossil fuels (40 μPt), Climate change (20 μPt), and Respiratory inorganics (20 μPt), but higher comparing to other two packaging, impact on Carcinogens (10 μPt). The environmental impact values of other types (I and III) of packages on Fossil fuels was 48 μPt, on Global warming - 28 μPt, on Respiratory inorganics 38 μPt and on carcinogens 9 μPt.

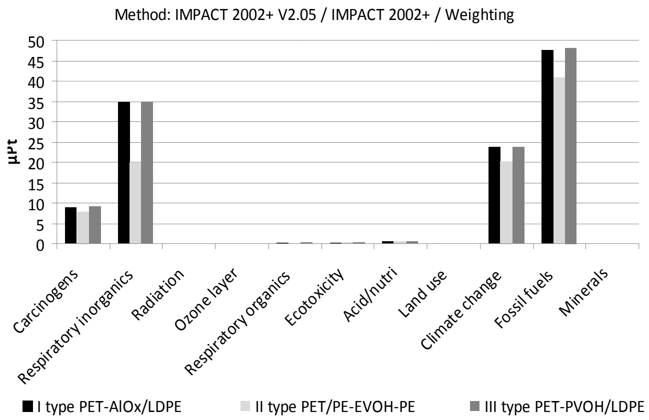

Fig. 11 Comparison of impact categories importance through weighting

The cumulative environmental impacts of analyze packages, on four main significant impact categories, is illustrated in Fig. 12. The obtained results reveal that total environmental impact generated during life cycle of II type of packaging is smaller (93 μPt) that packaging type I (115 μPt) and type III (116 μPt).

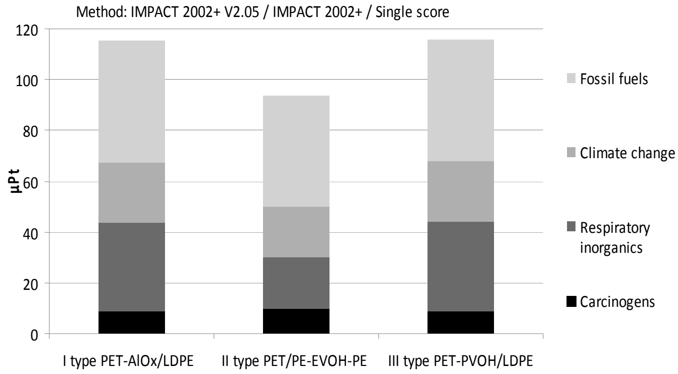

Fig. 12 Comparison of cumulative environmental impacts generated during life cycles of three types o packages

C. Damage Assessment

In the damage assessment all impact categories having the same units or measure are grouped in to one damage category: damage to Resources, damage to Ecosystem Quality, damage to Human health. Comparison of contribution of different type of packages to damage categories in percentage values is illustrated in Fig. 13. Results show that I and III type of packaging have similar profile for contribution to damage categories. The II type of packaging has less damage to Human Health and to Resources depletion that I and III type of packaging. The percentage damage value to Human health from II type of package is 64%, when from I – 100%, and from III – 99%. As well as for Resource depletion II type of packaging contributed by 83%, when I – 99% and III-100%. The damage category of Ecosystem Quality has slightly higher input from II type from packaging (100%) that from I and III – 87% and 96% respectively.

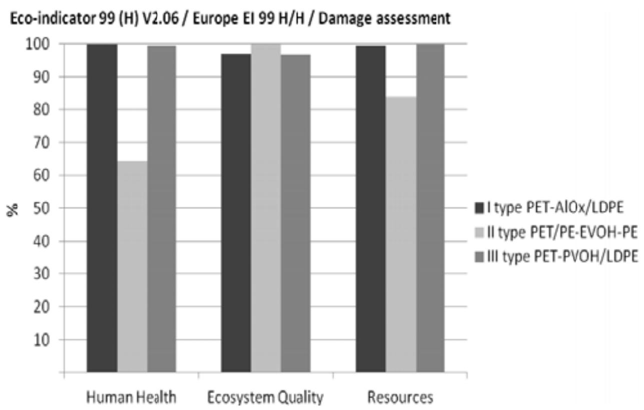

Fig. 13 Comparison of contribution of different type of packages to damage categories

Fig. 14 shows the results of damage categories importance to overall environmental problem. Results reveal that the greatest impact generated during life cycle of the plastic

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multilayer packaging is on Resource depletion (cumulative environmental impact value is varies from 27 to 32 μPt. For the damage category Human health there is damage impact value varies from 4 to 6 μPt.

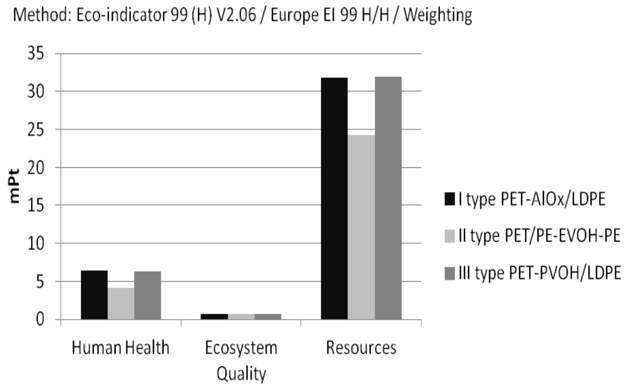

Fig. 14 Comparison of damage categories importance through weighting of impacts

In order to compare cumulative environmental impacts of the tree types of packaging, each impact category was integrated in to one score for the damage assessment. The comparison results of the damages of three types of packaging are presented in Fig. 15. The presented value of overall environmental impact looks similar- 38.8 mPt and 38.9 mPTt, respectively for I and III type of packaging. Both, I and III type of package contributed higher overall environmental impact (39 mPt) that did II type of packaging (33 mPt).

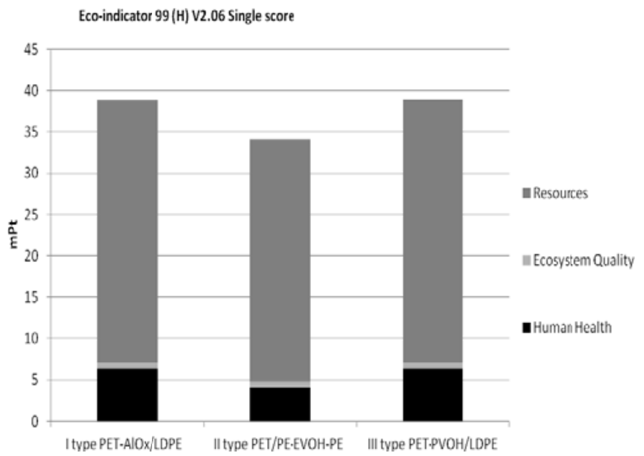

Fig. 15 Comparison of cumulative damage value of the three types of packaging

Ecosystem Quality has lowest cumulative environmental impact value, which are 0.7 μPt and equal for all types of packaging. Comparing impact of the three types of packaging to Resource damage category, it could be identified that II type of packaging has lower contribution to resource depletion (24 μPt) than other two packaging (32 μPt). The similar conclusion could be made by analyzing Human Health damage category.

IV. Discussion

All of analyzed packaging has significant impact to resource depletion, because of raw materials extraction and energy use and production of different kind of plastics. Nevertheless the impact generated during life cycle of functional unit of II type of packaging (PET/PE-EVOH-PE) was about 25% lower than impact generated by I type (PET-AlOx/LDPE) and III type (PET-PVOH/LDPE) of packaging. It seems not very big difference when comparing the functional units (1 m^2 of packaging film), but when the tons annual production is taking into account the difference make great sense, it is used less raw materials and energy during life cycle.

The II type of packaging has an advantage over the I and III type of packaging because 35% impact to human health. As it was revealed from life cycle analyses, the lower impact is related because of barrier material was consist more part – 10 %, then plastic polymer less.

Nevertheless the II type of packaging film demonstrated relatively lower impact generated through life cycle, the impact for resource depletion and human health seems still significant for all types of analyze packaging. The changes for more environmentally low impact of barrier material doesn't make sense, because the impact are mostly generated by using energy and materials during raw material extraction and production of different plastic materials as plastic polymers material as PE, LDPE and PET, but not has barrier materials as AlOx, PVOH and EVOH.

The problem still exists because all of analyzed packaging have very low recyclability rate. According to researchers blend of PE, LDPE and PET plastic materials have poor recyclability rate [4], [6].

The strategies for the improving could be:

- to use less (thinner layer) polymer material, produce thinner layer of polymer material.
- combine laminates with the compatible individual compounds for higher recyclability rate.
- to change from petro-based materials to biobased materials.

V. Conclusions

Results revealed that the most significant environmental impact of all types of packaging components were for Fossil fuels, Respiratory inorganic emissions and Climate change impact categories.

The fossil fuels category presents the largest contribution by the raw material from crude oil, respiratory inorganics and climate change categories are associated with energy consumption. Thus, Climate change category is remarkably affected by the airborne emissions from the extraction of polyethylene and from electricity generation.

Comparing the environmental impact of different components of I and III type of packaging, it was identified that the total impact of LDPE (57.5%) exceeds the other components total impacts (PET-AlOx (28.8%) and Ink and Adhesives (13.6%) on environment. When analyzing

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environmental impact of different components of II type of packaging, it was concluded that the total impact of PE/EVOH/PE (53.3%) exceeds the other components total impacts (PET (32%) and Ink and Adhesives (14.7%) on environment.

Results reveals that the II type of packaging has lower impact on Fossil fuels (40 μPt), Climate change (20 μPt), and Respiratory inorganics (20 μPt), but higher comparing to other two packaging, impact on Carcinogens (10 μPt). The environmental impact values of other types (I and III) of packages on Fossil fuels was 48 μPt, on Global warming - 28 μPt, on Respiratory inorganics 38 μPt and on carcinogens 9 μPt. The cumulative impact results indicated, that the obtained total environmental impact generated during life cycle of II type of packaging is lower (93 μPt) that for packaging type I (115 μPt) and type III (116 μPt).

Analyses of different damage categories importance to overall environmental problem revealed that the greatest impact generated during life cycle of the plastic multilayer packaging is on Resource depletion (cumulative environmental impact value is varies from 27 to 32 μPt). For the damage category Human health there is damage impact value varies from 4 to 6 μPt. The damage category Ecosystem Quality has lowest cumulative environmental impact value, which are 0.7μPt and equal for all types of packaging. Comparing impact of the three types of packaging it could be identified that I and III type of packaging have similar profile for contribution to damage categories. The II type of packaging has less damage to Human Health and contribution to Resources depletion that I and III type of packaging.

The presented value of overall environmental impact looks similar- 38.8 mPt and 38.9 mPTt, respectively for I and III type of packaging. Both, I and III type of package contributed higher overall environmental impact (39 mPt) that did II type of packaging (33 mPt).

On more important conclusion from this study could be made, that the contribution of different gas barrier type to the overall environmental problem of packaging is not significant. The impact are mostly generated by using energy and materials during raw material extraction and production of different plastic materials as plastic polymers material as PE, LDPE and PET, but not gas barrier materials as AlOx, PVOH and EVOH.

The LCA results could be useful in different decision-making processes as Environment Product Declaration (EPD) form, for selecting resource efficient and environmentally low-impact materials.

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