LIFE CYCLE ASSESSMENT OF CORRUGATED BOARD PACKAGING

EVALUAREA CICLULUI DE VIAŢĂ A AMBALAJELOR DE CARTON ONDULAT

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Abstract. *In this paper corrugated board packaging life cycle was evaluated with life cycle assessment (LCA) methodology. Two LCA methods were considered for the evaluation: CML 2001-Jan.2016 and ReCiPe 1.08, both included in GaBi software. Results showed that corrugated board packaging has negative impacts on the environment even if there were registered low values. Elimination methods like landfilling and incineration of corrugated board packaging waste are increasing the negative impacts on the environment, while recovery of packaging waste and their use in the corrugated board production leads to the reduction of these impacts and natural resources conservation.*
Key words: corrugated board, environmental impacts, life cycle, packaging

Rezumat. *În această lucrare a fost evaluat ciclul de viaţă al ambalajelor din carton ondulat cu ajutorul metodologiei de evaluare a ciclului de viaţă (ECV). Pentru evaluare au fost luate în considerare două metode ECV: CML 2001-Ian.2016 şi ReCiPe 1.08, ambele incluse în instrumentul software GaBi. Rezultatele au arătat că ambalajele din carton ondulat au un impact negativ asupra mediului, chiar dacă s-au înregistrat valori scăzute. Metodele de eliminare, precum depozitarea şi incinerarea deşeurilor de ambalaje din carton ondulat, sporesc impactul negativ asupra mediului, în timp ce recuperarea deşeurilor de ambalaje şi utilizarea acestora în producţia de carton ondulat conduce la reducerea acestor impacturi şi conservarea resurselor naturale.*
Cuvinte cheie: carton ondulat, impacturi de mediu, ciclul de viaţă, ambalaje

INTRODUCTION

The pulp, paper and cardboard industry has gone through the past 200 years through periods of growth and decline in its various segments. At the beginning of mechanized production, the paper industry was dominated by countries such as France, Great Britain and Germany. Then in the 19th century the dominance was taken over by Northern American and Northern European countries and later by countries from the Southern hemisphere and the Far East (Ojala *et. al.*, 2013). The main production process of paper is unchanged for nearly 2000 years. The fibers are mainly obtained from wood and it is considered that twentieth full-grown trees

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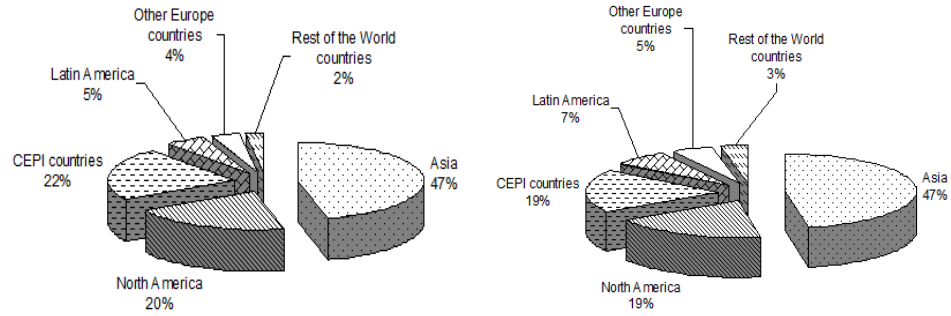
are necessary for the production of one tonne of paper (Clean Up Australia, 2009). According to Statista (2017) the quantities of paper and board produced and consumed in the world has increased from 392.7 million metric tons (mmt) in 2008 to over 410 mmt in 2015. China is the largest producer of paper and cardboard (over 107 mmt in 2015) followed by US (approximate 73 mmt), Japan (with 26 mmt) and Germany (22 mmt) (FAO, 2016). In Europe, the Confederation of European Paper Industries (CEPI) which was founded in 1992 includes 18 countries (Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and United Kingdom) with 623 number of companies in 2016 (153 pulp mills and 750 paper and board mills) having a production capacity for paper and board of 100,374,000 tonnes (CEPI, 2017). The paper and cardboard consumption according to CEPI (2017) in the member countries of this organization was of 77.4 million tonnes (newsprint, other graphic papers, case materials, other packaging (including board), sanitary and household, other paper and board). Production and consumption of paper and board in different regions in 2015 are illustrated in figure 1.



a) b)

Fig. 1 Paper and cardboard a) production, b) consumption in different regions of the world according to CEPI (2017)

CEPI (2017) declared that the raw materials consumed in paper and board production are: woodpulp (39.4%), pulp other than wood (0.4%), paper for recycling (46.2%) and non-fibrous materials (13.7%). A wood volume of 147.3 million m^3 was consumed by CEPI countries in 2016: hardwood (27.6%) such as birch, eucalyptus, beech, aspen, others, and softwood (72.4%) like pine and spruce. It is important to emphasize that almost 50% of raw materials comes from recovered paper and cardboard (EPRS, 2015). According to ERPC (2016) the paper fibre is reused 3.5 times on average in Europe. The recovered paper is used manly to produce newspapers and packaging and is collected from industry, households and offices. EPRS (2015) affirms that one tonne of paper and board can substitute three tonnes of wood. The amount of packaging waste generated in 2014 in the EU countries was 162.9 kg per capita and includes paper and cardboard with the highest percentage, followed by plastic and others (fig. 2).

According to Eurostat (2017) the recycling rate for total packaging waste increased from 54.6 % in 2005 to 65.5 % in 2014. The recycling rates for paper and cardboard packaging in EU27 and Romania are illustrated in figure 3.

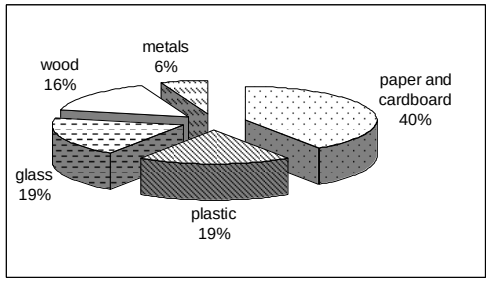


Fig. 2 Packaging waste generated by weight in EU countries in 2014 (adapted upon Eurostat, 2017)

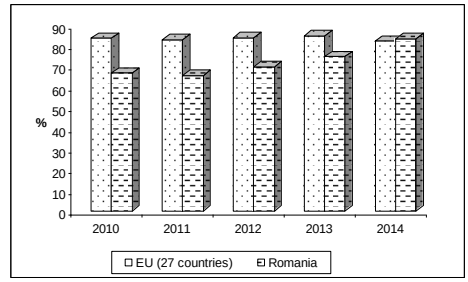


Fig. 3 Recycling rates for paper and cardboard packaging (adapted upon Eurostat, 2017)

The aim of this paper was to investigate the environmental impacts of corrugated board packaging boxes using life cycle assessment methodology.

MATERIAL AND METHOD

1. Corrugated board production using primary and recovered fibre

Cardboard is an agglomeration of cellulosic fibers resulting from the processing of vegetable raw materials such as grain straw, corn kernels, reed, fir, pine, beech, poplar etc. This is a compact paper with very little flexibility and it is mainly used for packaging. There are five types of cardboards used for packaging:

- *Flat carton* - is different from paper in that it is thicker and stiffer,
- *Duplex carton* - consists of two different layers of wet bonded fiber material by pressing,
- *Triplex carton* - is made up of three different layers of fibrous material bonded wet,
- *Corrugated cardboard* - consists of four smooth stucco and three wavy layers, joined together by an adhesive,
- *Micro-cardboard* is lightweight, has a good resistance to cracking and is a good duplex and triplex cardboard replacement.

For corrugated cardboard production different systems as Kraftliner, Testliner, Smeichemical Fluting and Wellenstoff are used (FEFCO, 2015).

In this study it was considered 1.05 t of recovered paper and 0.21 t of wood for production of 1 t of corrugated board, which means that were used 83% recycled fibre and 17% virgin fibre. According to FEFCO (2015), it can be obtained 1 t of corrugated board from 1.08 t of recovered paper. CEPI statistics mentioned that 87% of corrugated board used in Europe was collected and recycled (CEPI, 2017). Based on this fact we can assume that 0.87 t of corrugated board from 1 t of cardboard waste produced and used can be recovered and recycled in order to obtain new corrugated products. The remaining 0.13 t of corrugated board can be incinerated or landfilled. Considering that, for boxes with 650 g weight and dimensions 575 x 385 x 225 mm (L x B x H) there are necessary Kraftliner 233 g/box, Wellenstoff 267g/box, Testliner 233 g/box and Glue 13g/box, it results total losses (shavings) of 96 g/box. This means that

at 1 t of corrugated cardboard we will have 129 kg of shavings/tonne and it will be obtained approximately 1340 corrugated cardboard boxes. Figure 4 illustrates the life cycle of corrugated cardboard boxes.

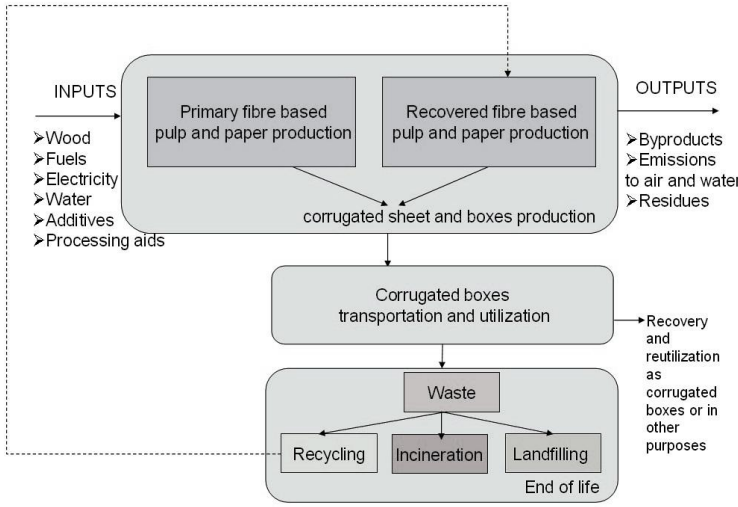


Fig. 4 System boundaries of corrugated boxes

2. Life Cycle Assessment (LCA)

LCA is a standardised tool with four main stages which can be successfully applied for environmental assessment of different product, process, systems, services etc. All LCA studies must include: goal definition and scoping, inventory analysis, impact assessment and interpretation (Ghinea *et. al.*, 2014; Petraru *et. al*., 2011). In this study we used GaBI software as an instrument which includes different LCA methods (CML, Eco-Indicator 95, Eco-Indicator 99, EDIP 1997, 2003, ReCiPe, UBP, TRACI etc.) and supports every stage of the LCA. In our case only CML 2001 and ReCiPe 1.08 LCA methods were selected for the evaluation.

Goal and scope of the study, system boundaries, functional unit:

- the scope of this study was to evaluate the environmental performance of corrugated boxes production, transport, use, landfilling and incineration;
- the system boundaries are illustrated in figure 4;
- 1 t of corrugated board production was considered as the functional unit.

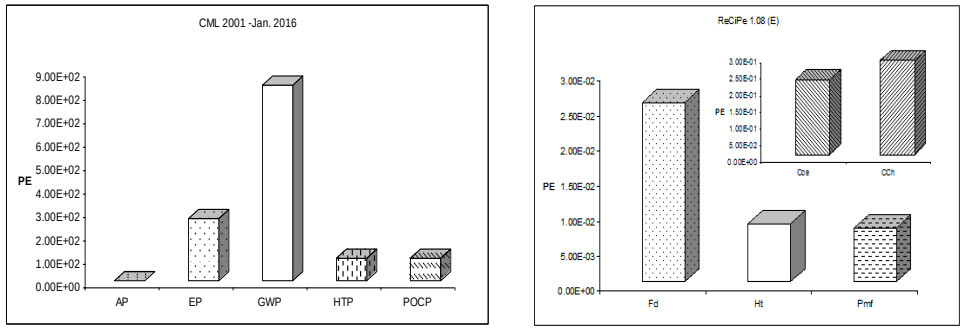
Inventory analysis: in this stage all inputs and outputs data were collected for each phase included in the analysed system. Some of the data were obtained from FEFCO, (2015) CEPI and GaBi database and others were calculated.

Impact assessment: all the data obtained in the previous stage were introduced in GaBi software in order to quantify the impacts categories associated to corrugated cardboard system considered for the analysis. The impact categories considered in this case were as follows: *Acidification Potential* (AP), *Eutrophication Potential* (EP), *Global Warming Potential* (GWP), *Human Toxicity Potential* (HTP), *Photochemical Ozone Creation Potential* (POCP) included in CML method and *Climate change Ecosystems* (CCe), *Climate change Human Health* (CCh), *Fossil depletion* (Fd), *Human toxicity* (Ht) and - *Particulate matter formation* (Pmf) which can found in ReCiPe 1.08 method.

Interpretation stage is presented in the results and discussions section.

RESULTS AND DISCUSSIONS

The results shows that the stages (production, transport, use, landfilling, incineration) included in life cycle of corrugated board generate negative impacts on the environment (the positive values mean negative impacts -fig. 5). All results are expressed in person equivalents (PE). From figure 5a it can be observed that the corrugated board (CB) production influences the *Global Warming Potential* (GWP), followed by EP, POCP and HTP. The highest contribution to the GWP is due to CB production followed by CB landfilling and CB incineration. A hierarchy of the contribution to impact categories of the evaluated processes can be made in order of decreasing contribution: for EP - CB landfilling>CB incineration>CB production; for HTP - CB landfilling>CB production>CB incineration and for POCP - CB production>CB incineration> CB landfilling. Considering the results presented in figure 5b, a hierarchy of categories of impact in order of decreasing environmental impact was performed: CCh>Cce>Fd>Ht>Pmf. It can be observed that the CCh and Cce impact categories included in ReCiPe method are the most affected by the corrugated board production and elimination steps.



a) b)

Fig. 5 Environmental impacts of corrugated board system using a) CML 2001- Jan. 2016 and b) ReCiPe 1.08 methods

CONCLUSIONS

1. The environmental impacts associated with corrugated board life cycle were determined by applying LCA methodology.

2. GaBi software was used for the evaluation and the results obtained by considering LCA methods such as CML 2001 and ReCiPe 1.08 were presented.

3. It can be concluded that corrugated board transportation, landfilling and incineration have significant negative impacts on the environment, while the impacts associated with the production stage can be reduced by using waste paper and cardboard at this stage.

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