ENVIRONMENTAL STUDY OF BIOCOMPOSITES INTENDED FOR PASSENGER CARS

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Abstract

The aim of this project is to realize an environmental study on technical textiles and more particularly on biocomposites. These materials are obtained by thermal compressing nonwovens made from natural fibers (short or long fibres of flax) and polymeric matrix (polypropylene [PP], polylactic acid [PLA] and polyamide 11 [PA11]). The development of such materials could be an interesting solution for replacing the traditional glass fibers/PP composites used actually into the automotive sector. We used the Life Cycle Assessment (LCA) to compare biocomposites with glass fibres/PP composite.

Contrary to the most of studies made on composites structures which focus only on the weight reduction, we take into account a function bring by this material. For this study, the flexural property has been chosen. Based on this study, it can be concluded that this change of methodology impacts the results, i.e: biocomposites become not so interesting. Furthermore, due to the modelization of the use phase, this latter is the more polluting step of the life cycle. In contrast, the production of composites is one the less polluting step.

Key words: LCA, biocomposites, flexural modulus, flax, automotive

1. INTRODUCTION

Biocomposites, which are composed of at least one biosourced component, are new materials which are developed for 20 years and are notably used for automotive sector. Nowadays, European, American and Japanese recycling regulations encourage the use of biomass in automotive materials. Thus, the substitution of glass fibres for vegetable fibres is particularly supported by European automotive manufacturers, dealing with the construction of vehicles using 95% recyclable materials by 2015 [1][2]. The driving forces justifying the use of natural fibre composites in automotive industry are: low-cost raw materials/products and associated manufacturing processes, and lightweight composite materials leading to a better environmental impact.

The aim of this study is also to compare the environmental impacts of biocomposites made of flax with glass/PP composite thanks to LCA according to their flexural property.

Four different biocomposites have been produced depending on the type of flax, scutched long fibre and scutching tow (short fibre), and the polymer. Thus we have composites made of flax short fibers with PP, and with PLA, and two others made of flax long fibers with PP and with PA11. These composites are produced from a nonwoven, obtain with a classic carding/needlepunching nonwoven line, which is then thermo-compressed (to melt the synthetic fibres).

On the one hand, the environmental impacts of the biocomposites and the glass/PP composite are compared for the different steps of the life cycle. On the other hand, we propose to compare the environmental impacts with or without taking into account a mechanical property (flexural property).

2. MATERIALS AND METHODS

The Life Cycle Assessment is realized thanks to the software GaBi 4 (software and database for Life Cycle Engineering, PE INTERNATIONAL AG, Stuttgart). The CML2001 (Nov. 09) method is used to calculate the environmental impacts. The data comes from the GaBi software and EcoInvent databases in general. For more specific processes like composite manufacturing, data comes from machines manufacturers. The functional unit chosen for this study is: “a composite of 25 m² used into a car passenger for 12 years". The systems boundaries include: raw materials production, composites manufacturing, transport between each steps, use phase and end of life (incineration).

In a first time, the flexural modulus has been measured to compare all the materials. Then, the theoretical thickness of biocomposites has been calculated to get the same flexural modulus than the reference (glass/PP composite) according to the equation 1 (Table 1).

$$e2^3 = \frac{N2}{N1} e1^3 \qquad (1)$$

e1 biocomposite thickness, e2 theoretical thickness, N1 and N2 respectively flexural modulus of biocomposite and of the reference glass fibres/PP

Thanks to the density we are able to calculate the weight of biocomposite in a car to replace the 25 m² of glass/PP. This leads to an abatement or increment of the weight, which reflects back to the fuel consumption of the car (Table 1). According to Eberle and Franze, there is 8,4L fuel saving for each kilogram of weight reduction for the lifetime of a car (considering that the lifetime of a car is 12 years which corresponds to 175 000 km) [1].

Table 1: Calculations of the weight of composite in a car and fuel consumption

Sample	Density (kg/m^3)	Flexural modulus (MPa)	Thickness (mm)	Theoretical thickness (mm)	Weight of composite in a car (kg)	Fuel saved (L)	Fuel consumption (L)
Glass/PP	852,00	1469,00	1,50	1,50	31,95		11200,00
Flax short fibre/PP 50/50	976,32	1944,90	1,58	1,44	35,12	-26,63	11226,63
Flax long fibre/PP 50/50	958,39	2382,40	1,55	1,32	31,61	2,86	11197,14
Flax short fibre/PLA 60/40	953,18	3674,40	1,49	1,10	26,16	48,67	11151,33
Flax long fibre/PA11 50/50	1058,73	4324,00	1,60	1,12	29,55	20,16	11179,84

In a second time, the materials are compared without taking into account the mechanical property. In that case, we consider only the density of the different materials (for a porosity of 50%). Then, the weight of biocomposites in the car and the fuel consumption are calculated.

3. RESULTS AND DISCUSSION

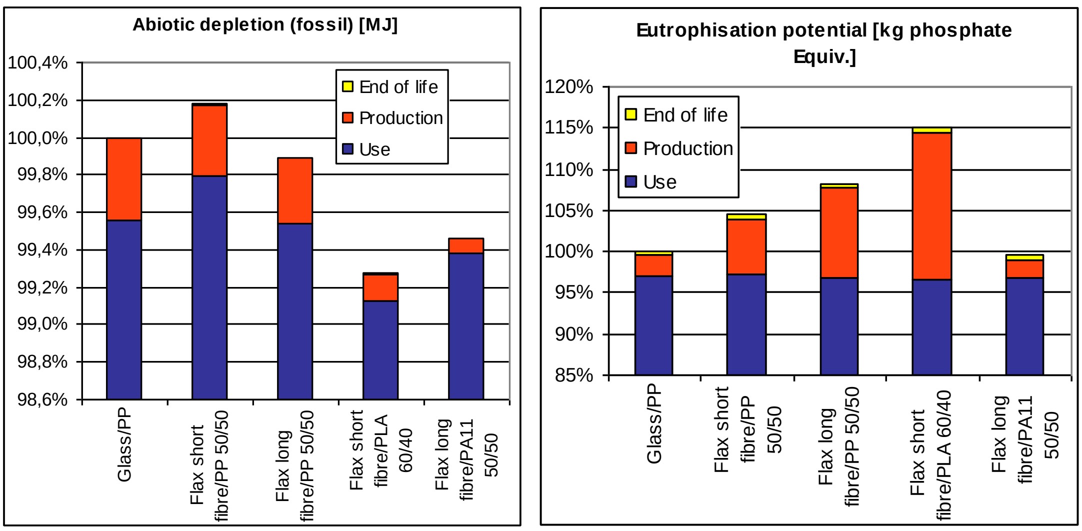

Figure 1: Abiotic depletion (a) and eutrophication potential (b) for all the life cycle

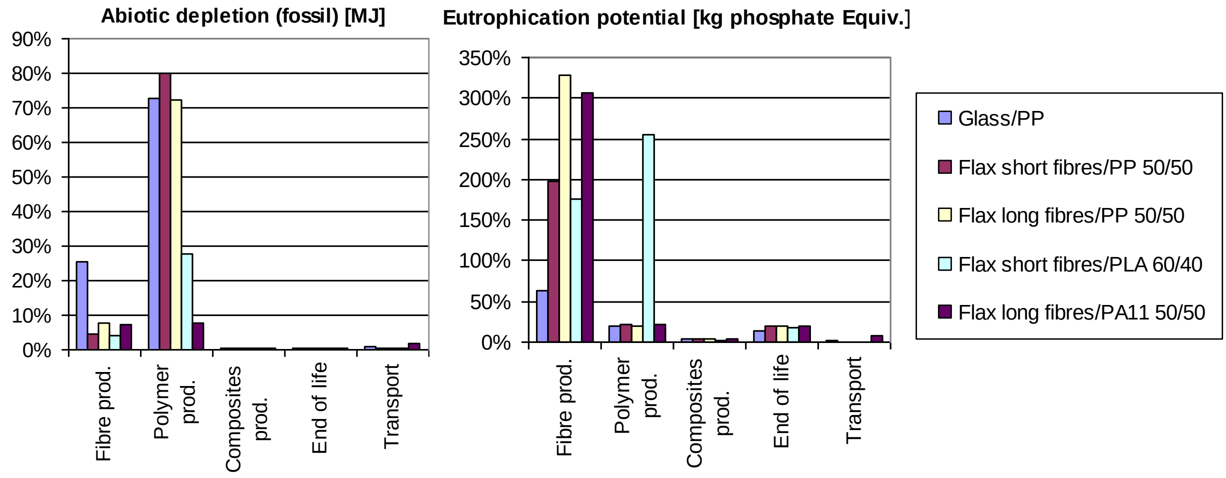

Figure 2: Abiotic depletion (a) and eutrophication potential (b) for the production phase (fibres, polymers and composites production), the transport and the end-of-life

As the use phase takes into account the utilization of a car during its whole life, this step is very polluting (Figure 1). As the abiotic depletion (fossil) is mainly linked to the use phase of the composite, this impact is a function of the weight of the composite. That is why the flax short fibres/PP, which is heaviest, is more polluting; whereas the flax short fibres/PLA, which is the lowest, is less polluting. Contrary to the abiotic depletion impact it can be seen on the Figure 1b that it is the production phase which determine the eutrophication impact.

Among the production steps (fibres, polymer and composite), the transport and the end-of-life, we can see that the production of polymers represents more or less 70% of the abiotic depletion impact (Figure 2a). However, considering the eutrophication impact, the production of the natural fibres is the most polluting (Figure 2b). Nevertheless PLA production shows equivalent impacts to the production of flax fibres due to the origin of PLA (culture of corn). For the two impacts studied, we can see that the production of the composites, the transport and the end-of-life are the steps the less polluting.

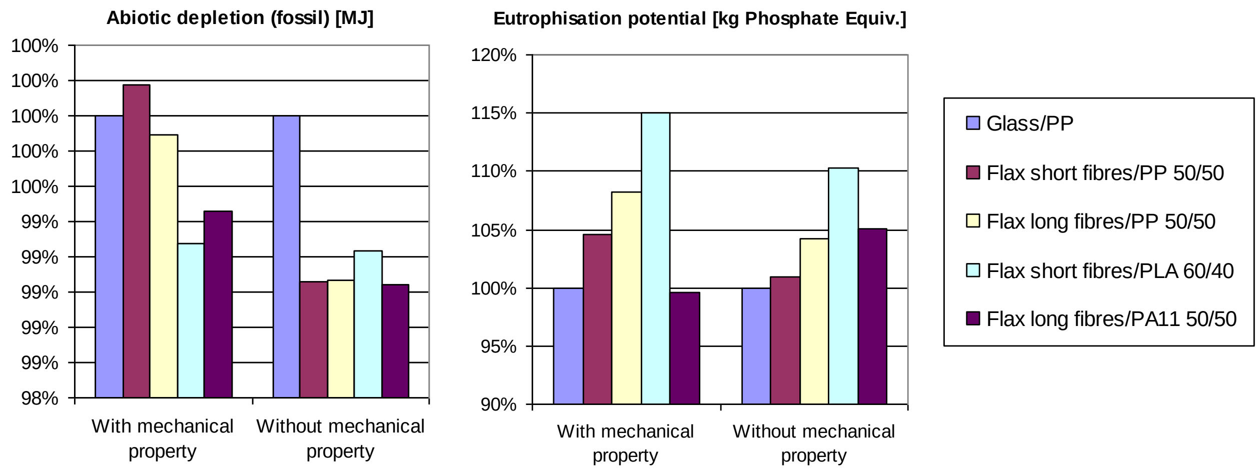

Figure 3: Abiotic depletion (a) and eutrophication potential (b) for the life cycle of the composites with and without the mechanical property

When we compare the composites without taking into account the mechanical property, we obtain different results than those obtain by considering the flexural modulus in particular for the abiotic depletion impact. In this case, the biocomposites are always less polluting than the glass fibres/PP composite.

4. CONCLUSION

In this study, the environmental impacts of composites made from textile structures (nonwovens) have been compared by considering a mechanical property. With this methodology, it can be pointed out that biocomposites are not necessarily better than glass fibres/PP composites. However, it should be interesting to evaluate others environmental impacts and/or to consider other properties such as acoustic behavior or impact property. Furthermore, it has been demonstrated that the use phase is the more polluting step of the life cycle due to the choice of its modelization and that the production of the composites is one of the less polluting step of the life cycle.

For this assessment an incineration process was considered for the end of fife. However, it could be interesting to study recycling processes which could be more interesting in an environmental point of view.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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