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PANELS WITH AGROINDUSTRIAL RESIDUE: LIFE CYCLE ASSESSMENT AS AN INSTRUMENT IN THE EVALUATION OF RECYCLING

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Abstract

Nowadays, the continuous growth of the paper and cellulose industrial sector has caught the attention of researchers due to the huge quantities of residue produced during processing, and the potential it presents for civil construction, using the fibers in new materials. Much research has been developed aimed at introducing this residue in constructions materials, but very little as been discussed about the real advantages for the environment if effective recycling would be implemented. In this context, the Life Cycle Assessment (LCA) of materials produced with residues appears as an important instrument in the search for answers about the best disposal of cellulose residue. The LCA consists of the quantitative and qualitative inventory of all consumed inputs and emitted residue in the environment, throughout the entire life cycle of a product, from its production to its use and disposal.

Therefore, the objective of this study is to examine the life cycle study of a material made of cellulose residue, in this case, house ceiling panels, as well as establish an evaluation of this instrument in recycling decisions.

Key-words: Cellulose residue, Bamboo, Life Cycle Assessment.

1. Introduction

All human activity causes some sort of impact on the environment to a greater or lesser degree. Every action in and of itself concludes an entire series of previous actions and at the same time triggers another series. An understanding of this basic premise is the key that can lead us to significant transformations in the environment in which we live.

Understanding a product, or an activity, outside the context in which it is inserted, is not merely an omission of its area of influence, but also a serious methodological error. When speaking of so-called “sustainable products”, it is necessary to take additional care with regard to these issues, because they should be the first to reveal concern about the reuse of residue, minimizing energy consumption in the productive process, reducing emissions, among others.

Nowadays, much is being discussed with regard to the reuse of residue in new materials, however, before a recycling system can be effectively implemented, it is fundamental for all aspects involved in this action to be understood, and most especially, what the true gains for the environment will be should such be the case.

The continuous growth of the paper and cellulose industrial sector has caught the attention of researchers due to the huge quantities of residue produced during processing, and the potential it presents for civil construction, reusing these fibers in new materials.

Along these lines, this study focuses on reusing this residue in new construction material through the production of house ceiling panels, and it aims at evaluating whether this form of final disposal of the residue is appropriate and technically, economically and environmentally feasible.

2. Development

The industrial cellulose residue used comes from Votorantin Celulose e Papel's Jacareí/SP Unit. The residual sludge (Figure 01) derived from the paper whitening process is composed of cellulose (58%), lignin and bleaches. The cellulose is the white substance, insoluble in water, highly resistant to traction, and made of carbon, hydrogen and oxygen. This residue is classified as Class II (Brazilian norm). In other words, it has the following properties: combustibility, biodegradability and solubility in water.

Figure 01: Moist cellulose residue.

Figure 02: Bamboo stalk leaves.

The bamboo straw (Figure 02) was supplied by the Agriculture Machine Laboratory at Unesp's Department of Mechanical Engineering, Bauru campus. This bamboo is grown at the campus and none of the various research projects being developed in this area use the stalk leaves.

Urea-formaldehyde resin was used to glue the composite together. This is the most economical stabilizer found on the market. A paraffin emulsion was also used with the objective of filling in the gaps between the particles in the panels in order to reduce their water absorption capacity.

For material characterization, panels were produced with different proportions of cellulose residue (Figure 03), 100%, 70%, 60%, 50%, 40% and 0% in relation to the composite's total mass, and they were analyzed in standardized tests: specific mass, moisture content, water absorption, swelling, resistance to parallel traction, perpendicular traction, static flexion and the coefficient of the material's thermal conductivity.

All tests were carried out according to the American ASTM D-1435 (1994) norm recommendations for particleboard panels.

Figure 03: Production process for particleboard panels.

The panels made of cellulose residue and bamboo fiber demonstrated satisfactory results in all tests carried out as well as good cohesion, good superficial quality and excellent esthetics. The results obtained from the testing indicate the technical feasibility of the residue used in house ceiling panels because all the tests revealed values similar to those shown in the CS 236-66 (1968) norm for future commercialization of the particleboard panels.

Through the interpolation of data, Proportion 05, with a 40% cellulose residue and 60% bamboo fiber content, was chosen as the "ideal" proportion for this type of composite. Testing results, only for the ideal proportion, are shown in Table 01 below.

Table 01: Summary of data obtained in tests for Proportion 05.

Proportion 05: 40%cellulose and 60%bamboo	
Tests	**Values**
Specific mass	1.023 g/cm^3
Moisture content	6.27 %
Water absorption	49.76 %
Swelling	24.42 %
Resistance to Traction II	42 kgf/cm^2
Resistance to Traction ⊥	2.03 kgf/cm^2
MOR	103 kgf/cm^2
MOE	15.070 kgf/cm^2
Thermal Conductivity	0.3590 W/m°k

With the technical feasibility confirmed, the next step was to prove the economic and environmental feasibility of this new process.

In this context, the Life Cycle Analysis (LCA) of the material being studied arises as an important tool in the search for answers about the best way to dispose of cellulose residue.

The LCA consists of the quantitative and qualitative inventory of all inputs consumed and the residue and other pollutants released into the environment throughout a product's life cycle (from production to use and disposal) and subsequent evaluation of the environmental impacts generated. For such, an inventory was taken based on the NBR ISO 14.040 (2001) norms and the methodology presented by MOURAD et al. (2002), with all stages of the studied composite's life cycle: obtaining the raw materials, production of the panels, transportation to the consumer, their use and subsequent disposal.

From this analysis, it is possible to understand the life cycle of the house ceiling panels made of residue, find out the critical point of its life cycle (when there is the greatest environmental impact), and consequently promote product improvements.

Since the panels being studies are only produced on a laboratory scale and their nominal measurements differ from commercial panels, the functional unit adopted was the m^2 of CBR panel – Cellulose and Bamboo Residue. Comparisons can thus be made between these panels and the commercial ones. The process unit is understood as being the production of panels at the Unesp Bauru Wood Processing Laboratory.

The entire system involving CBR panel production was studied, including: the acquisition of the raw materials, panel production (including machining), transportation to the consumer, their use (as the internal ceiling of a house) and final disposal. Since the objective of the study aims specifically at evaluating panel production, this was the phase carried out in greatest detail in order to observe the critical points of this phase and promote improvements in the final product. The following parameters and units were quantified in this phase:

(1) Input:

- power consumption (kw/m^2 of CBR);
- consumption of vehicle fuel (l/m^2 of panel);
- water consumption (l/m^2 of panel);
- natural resource consumption (kg/m^2 of panel).

(2) Output:

- pollutant emissions into the air (kg/m² of panel);
- liquid effluents (l/m² of panel);
- solid residue production (kg/m² of panel).

In order to better visualize the flows of inputs and outputs in the system being studied, a schematic for the entire life cycle of CBR panels was elaborated, from obtaining raw materials (cellulose and bamboo), transportation to the panel production unit, production, their use as a ceiling in a house and their subsequent disposal in a landfill. Figure 04 below shows this flow diagram of inputs and outputs.

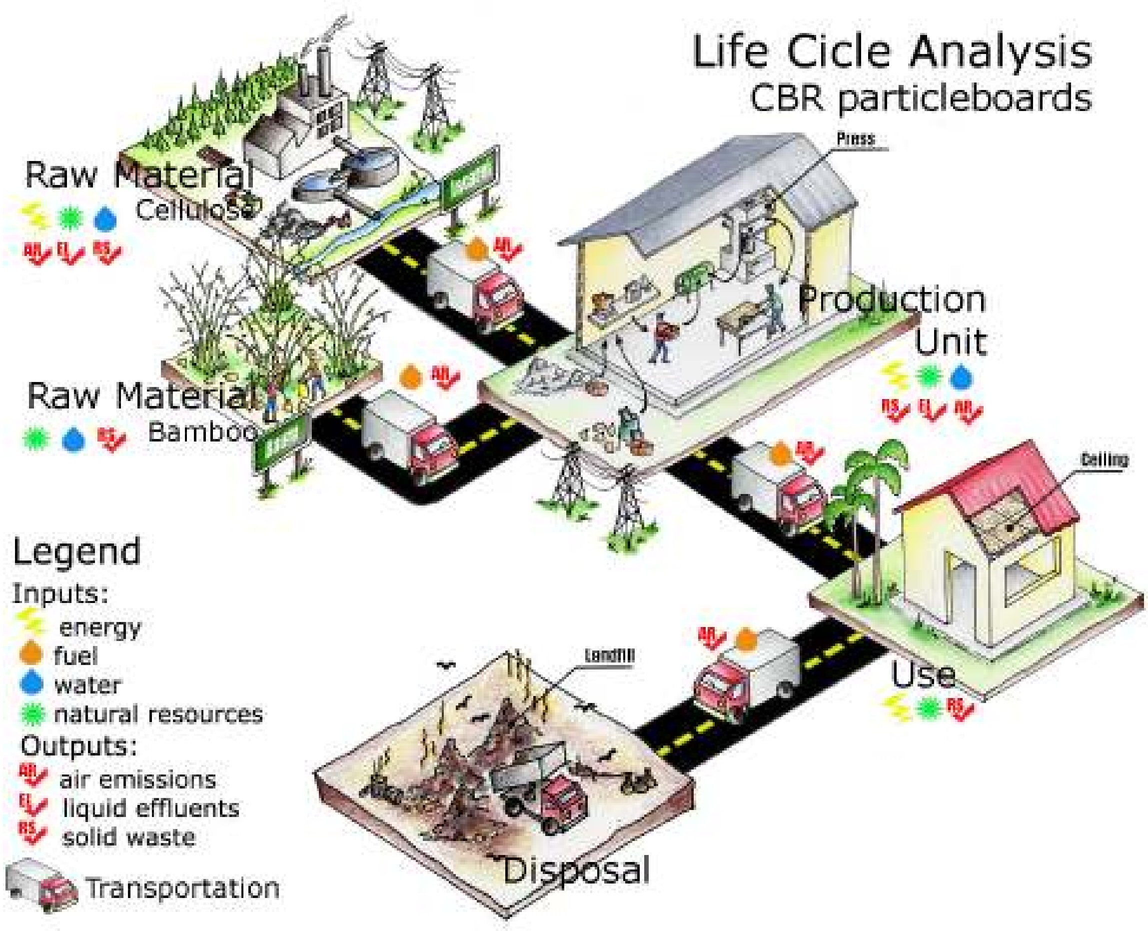


Figure 04: Schematic showing the life cycle of CBR panels.

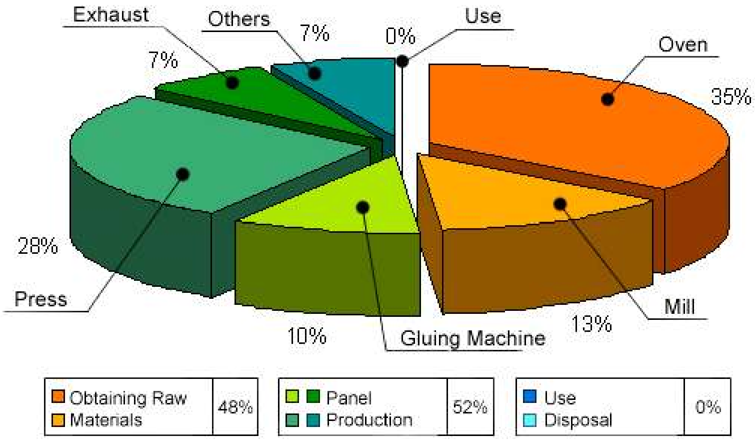
An inventory of all inputs and emissions at each phase of the panel life cycle was elaborated from this study of system inputs and outputs. The data used to elaborate the inventory were taken from practical quantifications in laboratories and bibliographic review.

Power consumption is one of the most important aspects of a product's "environmental cost" because it is associated with loss of many natural resources and the release of many emissions into the air and water. Thus, the power consumed during each phase of the panel life cycle was quantified in the laboratory by means of measurements at each machine used in the panel production process. The SAGA 4000 Power Analyzer was used to carry out these measurements (Figure 05). It measures: Voltage, Current, Active Power, Reactive Power, Apparent Power and the Power Factor.

Figure 05: SAGA 4000.

The results obtained for energy consumption are shown in Graph 01. Percentages are shown for energy consumption in the various machines employed in the panel production process.

Graph 01: Percentage of Energy Consumption.



From these measurements it was possible to observe that the phase that consumes most power is the “panel production” phase, which consumes 9.3 KW/h per m^2 of ready panel. However, it was also observed that the “obtaining raw materials” phase also had high energy consumption, almost the same as in the “production” phase, at 8.9 KW/h per m^2 of ready panel. The “use” and “disposal” phases had the lowest energy consumption rates, without influencing the final evaluation.

The “obtaining raw materials” phase also stood out with regard to fuel consumption, revealing an excessive expense of 6.5 liters of gasoline per m^2 of ready panel. As a result of this, emissions into the air also reached their critical point in this phase, with about 0.24 kg of CO (Carbon Monoxide) and 1.07 kg of CO2 (Carbon Dioxide) released per m^2 of ready panel. These excessively high rates are the result of the distance between the factory where the residue is generated, Jacareí, and the panel production unit, Bauru.

Natural resources were another aspect that was evaluated. The “production” phase had an expense of 18.76 kg in raw materials per m^2 of panel. However, this was also the phase with the greatest generation of solid waste: 4.6 kg of waste per m^2 of panel, followed by the “obtaining raw materials” phase, with 2.5 kg of waste per m^2 of panel, and last of all, the “use” phase, with 1.5 kg of waste per m^2 of already installed panel. The part of the process with the greatest generation of waste occurs during gluing, when the residue is mixed with the glue, because the existing opening does not permit removal of all the composite and approximately 200 g remain inside the machine.

The only phase that revealed liquid effluent emissions was “production”, with 32 liters per m^2 of panel. The effluent comes from cleaning the material used in manufacturing panels and is characterized as a liquid waste because of the presence of resin, detergents, paraffin, and particles suspended in water.

3. Conclusions

From the analysis of the above data it is possible to identify the critical points of the process and to promote improvements in material, making it more feasible economically with less impact on the environment. The following suggestions were thus made:

- Seek the cellulose residue at an industry located closer to the panel production unit. In this case, the residue should be acquired from a factory in Lençóis Paulista (44 km from Bauru), providing for a 99% reduction in fuel consumption and consequently the emission of CO, CO2 and NOx gases;
- The cellulose residue should be dried in the open air since the oven used for this purpose is the device that consumes most power throughout the entire life cycle of the panels. This results in a 35% reduction in energy consumed during production;
- The gluing machine (horizontal mixer) should be replaced with a beater because this would result in a 40% reduction in solid waste generated during panel production and 29% of total time spent on panel manufacturing;
- The urea-formaldehyde resin should be replaced with a castor oil-based resin, thus eliminating the emission of formaldehyde, which is toxic to human health, during the compressing process.

By simply modifying these aspects in the panel production process, it is possible to obtain a significant reduction in final cost of around 60%. This would bring the cost for the ready panel to about R$ 15.00 the m^2, a price very near the one found for panels currently on the market.

With the LCA, it is possible to clearly see the process points where there is great waste of material, power and the unnecessary emission of pollutants, making the process very costly and financially unfeasible.

4. Acknowledgements

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