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AVALIAÇÃO DE IMPACTE AMBIENTAL DA GESTÃO DE RESÍDUOS DA PRODUÇÃO DE UMA BANCADA COM BASE NA ABORDAGEM DE ACV


ENVIRONMENTAL IMPACT ASSESSMENT OF THE WASTE MANAGEMENT IN A COUNTERTOP PRODUCTION BASED ON LCA APPROACH


EVALUACIÓN DE IMPACTO AMBIENTAL DE LA GESTIÓN DE RESIDUOS EN UNA PRODUCCIÓN DE MOSTRADOR BASADO EN EL ENFOQUE ECV

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RESUMO

Introdução: O consumismo tem levado a um aumento dos problemas ambientais e, por isso, as soluções sustentáveis devem ser a prioridade na hora de projetar novos produtos ou serviços. A Avaliação do Ciclo de Vida (ACV) é uma das ferramentas analíticas mais importantes disponíveis para escolher a melhor decisão quando se trata de sustentabilidade.

Objetivo: O foco deste estudo foi aplicar a ACV para a gestão de resíduos resultantes de uma produção de um painel para bancadas de cozinhas e casas de banho. Os cenários de gestão de resíduos estudados foram o aterro (prática atual) e a reciclagem de resíduos. O painel é constituído por uma camada de cerâmica sobre um substrato de painel lamelar, formado por glassliner e PVC, que se destina a ser resistente à água, a riscos e a impactos. Os resíduos resultantes da produção do painel são plásticos *glassliner* e PVC e cerâmica.

Métodos: A metodologia ACV foi seguida e o método EPD 2018 disponível no software SimaPro foi escolhido para quantificar os impactos ambientais da gestão de resíduos. As categorias de impacto ambiental estudadas foram eutrofização, aquecimento global, oxidação fotoquímica, depleção da camada de ozono, depleção abiótica e acidificação.

Resultados: Os resultados mostraram que os dois resíduos plásticos são os principais contribuintes para a acidificação, eutrofização e aquecimento global. No entanto, para a oxidação fotoquímica e escassez de água, o resíduo do componente cerâmico é o principal contribuinte. Comparando os dois cenários, a reciclagem de resíduos diminui todas as categorias de impactos ambientais analisadas em comparação com o aterro.

Conclusão: A reciclagem dos resíduos da produção dos painéis acarreta diminuição nos impactos ambientais em todas as categorias analisadas.

Palavras-chave: economia circular; mobiliário; avaliação do ciclo de vida; reciclagem

ABSTRACT

Introduction: Consumerism has led to an increase in environmental problems, and for this reason, sustainable solutions must be the priority when designing new products or services. Life Cycle Assessment (LCA) is one of the most important analytical tools available for choosing the best decision when it comes to sustainability.

Objective: The focus of this study was to apply an LCA to the management of wastes from a kitchen/bathroom countertop production. The waste management scenarios studied were landfill (current practice) and waste recycling. The panel consists of a ceramic layer on a lamellar panel substrate, formed by glassliner and PVC, which is intended to be resistant to water, scratches and impacts. The residues generated from the panel production are glassliner and PVC plastics and ceramics.

Methods: The LCA methodology was followed and the EPD 2018 method available in the SimaPro software was chosen to quantify the environmental impacts of waste management. The environmental impact categories studied were eutrophication, global warming, photochemical oxidation, ozone layer depletion, abiotic depletion and acidification.

Results: The results showed that the two plastic wastes are the main contributors to acidification, eutrophication and global warming. However, for photochemical oxidation and water scarcity, the ceramic component residue is the main contributor. Comparing the two scenarios, waste recycling reduces the impacts in all environmental impact categories, in comparison with landfill.

Conclusion: Recycling the residues from the production of panels brings improvements in environmental impacts in all categories analyzed.

Keywords: circular economy; furniture; life cycle assessment; recycling

RESUMEN

Introducción: El consumismo ha provocado un aumento de los problemas ambientales y, por tanto, como soluciones sostenibles, deben ser la prioridad a la hora de diseñar nuevos productos o servicios. La evaluación del ciclo de vida (ECV) es una de las herramientas analíticas más importantes disponibles para elegir la mejor decisión en lo que respecta a la sostenibilidad.

Objetivo: El enfoque de este estudio fue aplicar un ECV a la gestión de una producción de un panel para bancos. Los escenarios de gestión de residuos estudiados fueron vertedero (práctica actual) y reciclaje de residuos. El panel está formado por una capa cerámica sobre un sustrato de panel laminar, formado por glassliner y PVC, que está destinado a ser resistente al agua, arañazos e impactos. Los residuos generados por la producción de paneles son revestimientos de vidrio y plásticos y cerámicas de PVC. El estudio actual del escenario de gestión de residuos fue el vertido (práctica) y el reciclaje de residuos.

Métodos: Se siguió la metodología LCA y se eligió el método EPD 2018 disponible en el software SimaPro para cuantificar los impactos ambientales de la gestión de residuos. Las categorías de impacto ambiental estudiadas fueron eutrofización, calentamiento global, oxidación fotoquímica, agotamiento de la capa de ozono, agotamiento abiótico y acidificación.

Resultados: Nuestros resultados indujeron a que los dos desechos plásticos son los principales contribuyentes a la acidificación,

la eutrofización y el calentamiento global. Sin embargo, para la oxidación fotoquímica y la escasez de agua, el residuo del componente cerámico es el principal contribuyente. Comparando los dos escenarios, reciclaje de residuos en todas las categorías de impacto ambiental, analizados en comparación con vertedero.

Conclusión: Se pudo observar que el reciclaje de los residuos de la producción de paneles trae mejoras en los impactos ambientales en todas las categorías analizadas.

Palabras Clave: economía circular; mobiliario; evaluación del ciclo de vida; reciclaje

INTRODUCTION

Being aware of our world's environmental problems, today's consumers are more interested in knowing the impact that products have on the environment. Sustainable products development related to this production is needed and very important to minimize environmental impacts and contribute to circular economy.

More than ever, the world is focused on consumption. Unprecedented levels of material output are being registered, and those create unprecedented levels of environmental challenges.

As the current society is much more aware of the environment there are an increasing number of environmental regulations which very often challenge the waste management and this makes the recycling as means of reducing waste to the landfill (Kassim *et al* 2012). Recycling is seen as an important way to mitigate the environmental impacts from the ever-increasing production and use of commodity materials. For some materials, such as many metals, recycling is already a vital part of the supply chain (Geyer *et al* 2016).

As people strive to understand what is sustainable from an environmental perspective, credible, comprehensive scientific tools are necessary to understand the system that needs changes. Life Cycle Assessment (LCA) is a powerful tool that allows us to study the system, measure impacts, and understand tradeoffs (Laurin *et al* 2017). Having this kind of information allow people in charge to make better decisions. With the application of LCA, is possible to optimize the production aspects, from the material's extraction to the waste disposal (Heijungs *et al* 2010). The focus of this study was to apply LCA to the management of wastes resulted from a countertop production following the ISO 14040:2006 (ISO a) (Environmental management – Life cycle assessment–principles and framework) and ISO 14044:2006 (ISO b) (Environmental management - Life cycle assessment-requirements and guidelines) standards, which are the main standards for LCA. The goal is to assess the potential life cycle environmental impacts associated with the waste generated by the manufacturing of a countertop product intended to be used in bathrooms and kitchens, produced by a company from Portugal, comparing two different waste management scenarios, where the waste generated is landfilled and recycled. The countertop panel is made of a ceramic sheet on a panel substrate, formed by glassliner (glass fiber reinforced polyester) and Polyvinyl Chloride (PVC), which is intended to be water, scratch, and impact resistant. The product produces three main types of waste: PVC, glassliner and ceramic waste, and research shows that those types of waste can be recycled. Studies suggested that PVC can be successfully recycled into a variety of products such as bottles, various pipes, pipe fittings and other profiles with good appearance and properties. They also claimed that the profiles properties were unaffected when virgin PVC was replaced by PVC recyclates (Sadat-Shojai *et al* 2011). Another example is window frames, as shown by Stichnote *et al* (2013). When it comes to the glass reinforced polyester waste, Job (2013) states that it can be added to cement kilns, and Asokan *et al* (2009) stated that it can be used as replacement for fine aggregate in foamed concrete. As for the ceramic component, it can be reused in the construction sector, as part of concrete mixtures (Campos *et al* 2013).

1. METHODS

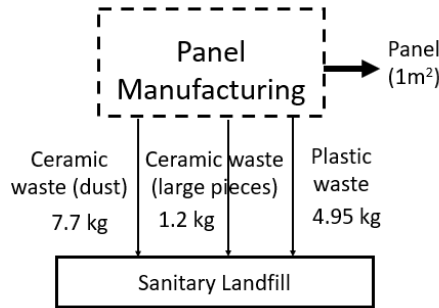
The LCA methodology following the ISO 14040:2006 (ISO a) and ISO 14044:2006 (ISO b) standards was used to quantify the environmental impacts of wastes management.

1.1 Functional unit and system description

The functional unit chosen for this study was the waste generated in the production of 1 m² of finished panel (countertop). This panel has 24 mm thickness and 34.54 Kg weight.

The system studied is presented in Figure 1. In Figure 1a, the first scenario is represented, and it can be observed that all the waste generated in the panel's production is sent to landfill. In Figure 1b, the second scenario is represented, considering that all the wastes are recycled. PVC waste is recycled into PVC production avoid the same quantity of PVC suspension polymerized. glassliner and ceramic waste are recycled into concrete production avoid the same quantity of gravel and sand respectively.

a)



b)

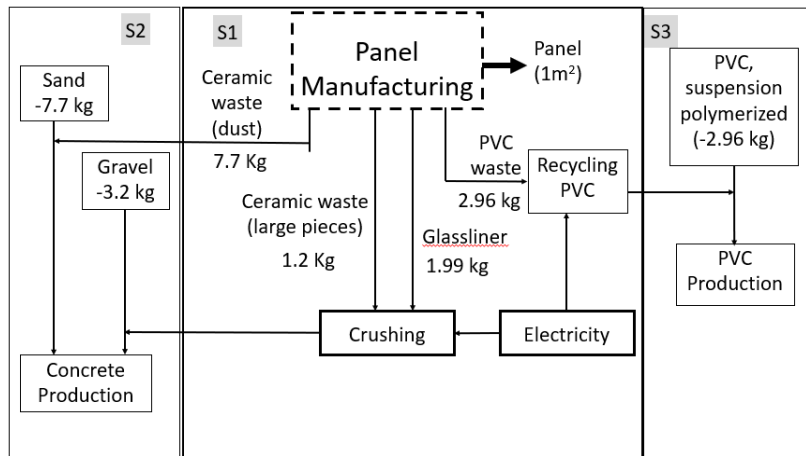


Figure 1 - System Description: a) Landfill Scenario and b) Recycling Scenario

1. 2 Inventory analysis

Data on waste production was provided by the panels manufacturer and relate to the year 2020. The data for the background processes were obtained on the Ecoinvent 3 databases. Transport of the waste to the recycling facilities and recycling methods for the PVC are considered in the equivalent process chosen and not specified.

Table 1 – Waste data for both scenarios considered.

Waste	Equivalent process in the Ecoinvent database		Unit	Quantity
	Landfill Scenario	Recycling Scenario		
Glassliner waste	Waste plastic, mixture {GLO} treatment of waste plastic, mixture, unsanitary landfill, dry infiltration class (100mm) APOS, U	Mixed plastics (waste treatment) {GLO} recycling of mixed plastics APOS, U	[kg]	1.99
PVC waste	Waste polyvinylchloride {GLO} treatment of waste polyvinylchloride, unsanitary landfill, dry infiltration class (100 mm) APOS, U	PVC (waste treatment) {GLO} recycling of PVC APOS, U	[kg]	2.96
Ceramic waste – dust	Inert waste, for final disposal {RoW} treatment of inert waste, inert material landfill APOS, U	Sand {RoW} market for sand APOS, U (avoided)	[kg]	7.7
Ceramic waste – larger pieces	Inert waste, for final disposal {RoW} treatment of inert waste, inert material landfill APOS, U	Gravel, crushed {RoW} market for gravel, crushed APOS, U (avoided)	[kg]	1.2

1. 3 Lifecy cleimp act assessment (LCIA)

The method chosen for impact assessment was EPD (2018) ready to use in SimaPro PhD software (PRé Consultants 2020). EPD is one of the many available methods for impact assessment, and considers the categories that must be evaluated in an Environmental Product Declaration. All impact categories are taken directly from CML-IA baseline method (eutrophication, global warming, photochemical oxidation, ozone layer depletion and abiotic depletion) and CML-IA non baseline method (acidification).

2. RESULTS AND DISCUSSION

Using the method EPD (2018) through SimaPro PhD software (PRé Consultants 2020), the results obtained for the waste management systems are discussed in this section. Firstly, the results for the Landfill Scenario are shown in Table 2 and Figure 3. Next, the results for the Recycling Scenario are shown in Table 3 and Figure 4. Finally, comparisons between the scenarios are made in Tables 4 and 5.

Table 2 - LCIA results for the waste generated, regarding the landfill scenario, for the functional unit. Acronyms: AC (acidification-fate not incl.); EU (eutrophication; GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion); NMVOC (non-methane volatile organic compounds).

Category	Unit	Total	Glassliner waste	PVC waste	Ceramic waste
AC	[g SO ₂ eq]	1.02	0.26	0.54	0.22
EU	[g PO ₄ eq]	34.19	17.14	17.01	0.04
GW	[kg CO ₂ eq]	0.34	0.15	0.16	0.03
PO	[g NMVOC]	0.53	0.12	0.15	0.27
AD	[g Sb eq]	2.65 x 10 ⁻⁴	8.06 x 10 ⁻⁶	1.20 x 10 ⁻⁵	2.44 x 10 ⁻⁴
AD(FF)	[MJ]	0.87	0.06	0.10	0.71
WS	[m ³ eq]	3.31 x 10 ⁻²	1.00 x 10 ⁻⁴	1.49 x 10 ⁻⁴	3.29 x 10 ⁻²
OD	[mg CFC-11 eq]	1.04 x 10 ⁻²	8.16 x 10 ⁻⁴	1.21 x 10 ⁻³	8.36 x 10 ⁻³

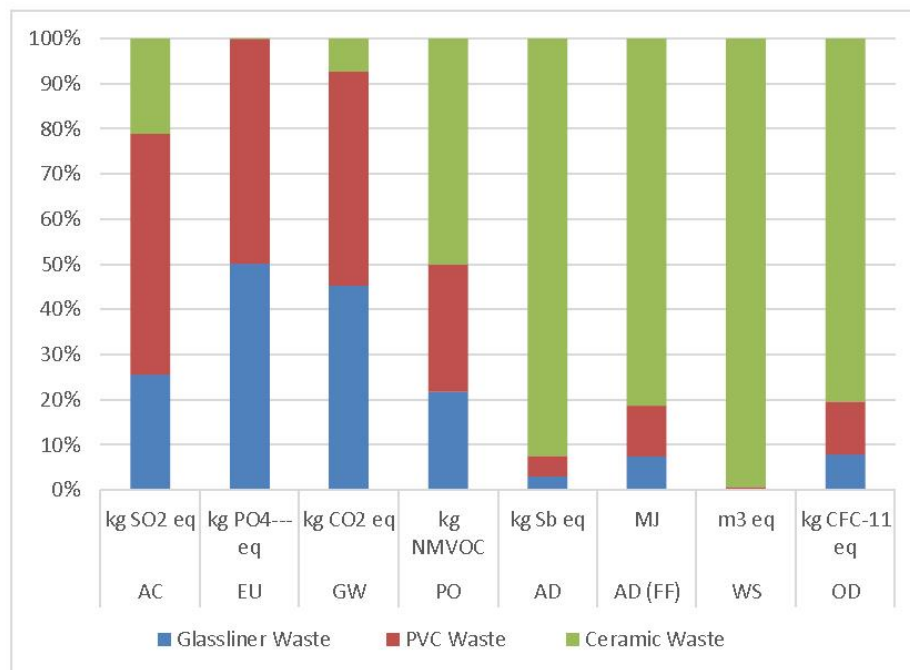


Figure 2 - LCIA results for the waste generated, regarding the landfill scenario, for the functional unit. Acronyms: AC (acidification - fate not incl.); EU (eutrophication; GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion).

Overall, considering the landfill scenario, the plastics wastes had a negative impact in all categories analyzed, ceramic waste did not show influence for the Eutrophication impact. For the first three categories (Acidification, Eutrophication and Global Warming), the wastes from the two plastic components are the main contributors. The impacts from the glassliner range from 25% on the Acidification to 50% on the Eutrophication. The impacts from the PVC range from 47% of the impact on the Global Warming to 53% of the total impact on the Acidification. However, for the other categories analyzed, the waste for the ceramic component is the main contributor, with this contribution ranging from 50% on the Photochemical Oxidation category to 99% on the Water Scarcity category.

Table 3 - LCIA results for the waste generated, regarding the recycling scenario, for the functional unit. Acronyms: AC (acidification-fate not incl.); EU (eutrophication; GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion) ; NMVOC (non-methane volatile organic compounds).

Category	Unit	Total	Glassliner waste	PVC waste	Ceramic waste
AC	[g SO ₂ eq]	-5.46 x 10 ⁻¹	-5.20 x 10 ⁻³	-5.18 x 10 ⁻¹	-2.29 x 10 ⁻²
EU	[g PO ₄ eq]	-2.12 x 10 ⁻¹	-1.78 x 10 ⁻³	-2.04 x 10 ⁻¹	-5.54 x 10 ⁻³
GW	[kg CO ₂ eq]	-1.40 x 10 ⁻¹	-7.97 x 10 ⁻⁴	-1.36 x 10 ⁻¹	-3.01 x 10 ⁻³
PO	[g NMVOC]	-4.31 x 10 ⁻¹	-4.63 x 10 ⁻³	-4.01 x 10 ⁻¹	-2.52 x 10 ⁻²
AD	[g Sb eq]	-4.74 x 10 ⁻³	-6.25 x 10 ⁻⁵	-4.56 x 10 ⁻³	-1.20 x 10 ⁻⁴
AD(FF)	[MJ]	-3.64	-9.82 x 10 ⁻³	-3.59	-3.95 x 10 ⁻²
WS	[m ³ eq]	-2.67 x 10 ⁻¹	-9.09 x 10 ⁻⁴	-2.55 x 10 ⁻¹	-1.10 x 10 ⁻²
OD	[mg CFC-11 eq]	-1.01 x 10 ⁻¹	-8.64 x 10 ⁻⁵	-1.01 x 10 ⁻¹	-3.87 x 10 ⁻⁴

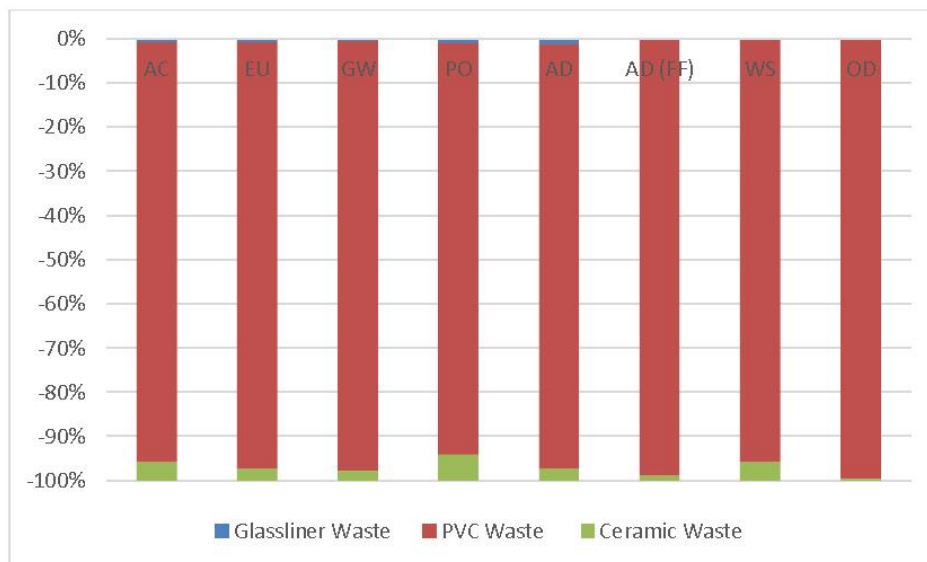


Figure 3 - LCIA results for the waste generated, regarding the recycling scenario, for the functional unit. Acronyms: AC (acidification-fate not incl.); EU (eutrophication; GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion).

When a recycling scenario is considered, all wastes registered a negative value, which means that the impacts caused are positive for the environment. The PVC component recycling had the most positive impacts. This is possibly due to the fact that for the recycling of the glassliner and ceramic components, it was necessary to consider a crushing stage, and that has high impacts. For the PVC, there was no need to consider this stage, since it is already considered in the chosen equivalent process. Adding to that, according to Stichnothe *et al* (2013), the environmental and health impacts of PVC have been under intense scrutiny over the years, largely due to the use of heavy metals and phthalates in the manufacturing process and emissions of dioxins from incineration of PVC waste. Recycling this material would avoid all these impacts associated with this polymer production.

For a better understanding of the effect of the wastes recycling effect comparing with landfilling, the respective proportion was calculated (Table 4).

Table 4 – Comparison of LCIA results for two waste scenarios. Acronyms: AC (acidification-fate not incl.); EU (eutrophication); GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion);); NMVOC (non-methane volatile organic compounds).

Category	Unit	Landfill Scenario	Recycling Scenario	Environmental Gain	%
AC	[kg SO ₂ eq]	1.02×10^{-3}	-5.46×10^{-4}	1.57×10^{-3}	154
EU	[kg PO ₄ eq]	3.42×10^{-2}	-2.12×10^{-4}	3.44×10^{-2}	101
GW	[kg CO ₂ eq]	3.39×10^{-1}	-1.40×10^{-1}	4.79×10^{-1}	141
PO	[kg NMVOC]	5.33×10^{-4}	-4.31×10^{-4}	9.64×10^{-4}	181
AD	[kg Sb eq]	2.65×10^{-7}	-4.74×10^{-6}	5.01×10^{-6}	1894
AD (FF)	[MJ]	8.68×10^{-1}	-3.64	4.51	519
WS	[m ³] eq	3.31×10^{-2}	-2.67×10^{-1}	3.00×10^{-1}	905
OD	[kg CFC-11eq]	1.04×10^{-8}	-1.01×10^{-7}	1.12×10^{-7}	1076

When the two scenarios are compared, is noticeable recycling the waste reduces the impacts in every category. The difference ranges from 101% on the Eutrophication category to 1894% on the Abiotic Depletion category. These results concern only the impacts caused by the waste generated in the production.

In the table 5 are presented the results obtained in previous studies by the authors regarding the environmental profile for the panel production, considering the landfilling of the wastes (Silva *et al*, 2020), as well as the environmental gain achieved by recycling the waste.

Table 5 – Comparison of between environmental profile results and the environmental gain. Acronyms: AC (acidification-fate not incl.); EU (eutrophication); GW (global warming - GWP100a); PO (photochemical oxidation); AD (abiotic depletion); AD(FF) (abiotic depletion - fossil fuels); WS (water scarcity); OD (ozone layer depletion).

Category	Unit	Environmental Profile f 1m panel2 production (Silva <i>et al</i> 2021)	Environmental Gain (from Table 4)	%
AC	[kg SO ₂ eq]	0.30	1.57×10^{-3}	0.52
EU	[kg PO ₄ eq]	0.13	3.44×10^{-2}	27.09
GW	[kg CO ₂ eq]	69.56	4.79×10^{-1}	0.69
PO	[kg NMVOC]	0.26	9.64×10^{-4}	0.37
AD	[kg Sb eq]	1.7×10^{-3}	5.01×10^{-6}	0.29
AD (FF)	[MJ]	1206.60	4.51	0.37
WS	[m ³] eq	13.84	3.00×10^{-1}	2.17
OD	[kg CFC-11 eq]	1.7×10^{-5}	1.12×10^{-7}	0.66

It is possible to observe that recycling of the waste generated in the panel's production positive effect would not be very significative, with the exception of the Eutrophication category, where the difference was of 27.09%. For all the other categories, the difference ranges from 0.29% on the Abiotic Depletion category to 2.17% on the Water Scarcity category.

Observing these results, the Eutrophication category stands out. In an attempt to understand the reason for this considerable environmental gain, the results on this category for both scenarios were further analyzed. It was noticed that the levels of Phosphates, Chemical Oxygen Demands, Nitrogen Oxides and Nitrates emissions were considerably larger in the Landfill Scenario. According to Chislock (2013), the presence of Nitrogen and Phosphorus, along with Nitrates and Phosphates are known causes of Eutrophication, and according to Benson *et al* (2007) these elements are found as components of landfills leachate.

CONCLUSION

On this paper, a LCA study on a countertop material has been conducted and the results obtained for the waste generated in the panels manufacturing have been presented, considering two different waste scenarios. The results were compared, and it was observed that recycling the waste generated by the panel's production decreases the environmental impacts in every category, with the variation ranging from 101% to 1894%. However, when the total impacts on the 1 m² of panel production are observed, this reduction is not very significative, ranging from 0.29% to 27.09%.

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