

ÁREA TEMÁTICA: AVALIAÇÃO DO CICLO DE VIDA

**LIFE CYCLE ASSESSMENT OF ORGANIC WASTE MANAGEMENT IN
FOOD DISTRIBUTION CENTERS: A CASE STUDY IN SÃO PAULO,
BRAZIL**

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ABSTRACT

This paper focuses on the Life Cycle Assessment (LCA) of the organic waste fraction (OF) management generated by the food distribution center CEAGESP located in São Paulo, Brazil. Currently the organic waste is sent to landfill, without any specific treatment. Following the LCA method, several impact categories were assessed. The results show that most of the processes examined cause impacts into the categories global warming potential, particular matter formation potential, photochemical oxidant formation potential, terrestrial acidification potential and fossil depletion potential. The more important sources of pollutant are methane emissions from waste degradation in landfill, leachate production and emissions to air from the steps of waste collection and transport. It is suggested replacing the old vehicle models with new models that have better emission standards and, mainly, a reduction of the waste generated by CEAGESP.

Keywords: Ceagesp; LCA; Organic waste.

**AVALIAÇÃO DO CICLO DE VIDA DA GESTÃO DE RESÍDUOS
ORGÂNICOS EM CENTROS DE DISTRIBUIÇÃO DE ALIMENTOS: UM
ESTUDO DE CASO EM SÃO PAULO, BRASIL**

RESUMO

Este trabalho foca na avaliação do ciclo de vida (ACV) sobre a gestão da fração orgânica (FO) dos resíduos gerados pelo centro de distribuição de alimentos 'CEAGESP' localizado em São Paulo, Brasil. Atualmente, os resíduos são enviados para o aterro sanitário de 'Caieiras', sem tratamento específico. Várias categorias de impacto foram avaliadas considerando a ACV. Os resultados mostram que a maioria dos processos examinados causam impactos nas categorias potencial de aquecimento global, potencial de formação de matéria particulada, potencial de formação de oxidantes fotoquímicos, potencial de acidificação terrestre e potencial de depleção fóssil. As fontes mais importantes de poluentes são as emissões de metano da degradação de resíduos em aterros, a produção de lixiviados e as emissões para a atmosfera das etapas de coleta e transporte de resíduos. Sugere-se a substituição de modelos antigos de veículos por novos modos com melhores padrões de emissão e, principalmente, uma redução da quantidade de resíduos gerados pela CEAGESP.

Palavras-chave: ACV; Ceagesp; Resíduo orgânico.

1. INTRODUCTION

During the last few decades, the exponential growth of human population and the technological development has generated an increasing amount of waste. The environmental issues associated with this waste production have become more critical than ever (RIPA et al., 2017). In this context, municipal solid waste (MSW) generation plays a key role, causing environmental impacts at different scales, directly correlated with the final disposal system. In most countries, including Brazil, landfills

(sanitary or controlled) or open dumps are still a common way to dispose MSW (COSTA et al., 2019). The main impacts related to landfill disposal of MSW are methane emissions to air (THEMELIS; ULLOA, 2007) and leachate generation (COSTA et al., 2019). These impacts are mainly caused by degradation of waste organic fraction (OF) in anaerobic conditions, highlighting the need for new tools and strategies for OF waste management.

In São Paulo city, almost 50% of MSW are organic (LIIKANEN et al., 2018), in which among the numerous sources of organic waste, the local food distribution center plays an important role, due to the high organic waste concentration. Food distribution centers (FDC) are companies that provide an efficient circulation of products in highly populated cities, allowing the products transfer between agricultural areas and the urban centers. Considering that cities, mainly the highly populated ones, does not produce their own food and needs importing it from other regions, it becomes important a market centralization through FDC to reach better logistic conditions. FDCs are concentrated wholesale market for products (usually horticultural), where sellers and buyers directly perform market agreements. As usual in any concentrated production system, large amounts of waste (organic in this specific case) are generated. They are damaged or not edible products, but also still edible low-quality products that have not met the minimum standard quality of the buyers.

In Sao Paulo city, about 120 tons/day of organic waste are generated by its main FDC named 'CEAGESP', and directly sent to landfill (CEAGESP, 2019), which claims for methods in quantifying the social, economic and environmental related impacts. There are several methods available in the scientific literature that aim to estimate the environmental impacts of products or services. Among them, the life cycle assessment (LCA) is one of the most commonly used. LCA is a structured, comprehensive and internationally standardized method. It quantifies all relevant emissions and resources consumed, their related environmental and human health impacts, and resource depletion, issues that are associated with any good or service delivered by a process (ISO 140040, ISO 14044). It is a useful method previously used in several studies about MSW management. For example, some papers have focused on OF management in Italy (BURATTI et al., 2015) and Brazil (OLIVEIRA et al., 2017), while Soares et al. (2017) assessed the environmental impacts of MSW management in the 'Caieras' landfill, São Paulo.

Due to the large amount of organic waste annually generated by 'CEAGESP' FDC in São Paulo and its sustainability related issues, it becomes important to assess this specific productive sector to better understand how it works and pursue alternative managements towards a more sustainable OF waste management.

2. OBJECTIVE

This work aims to apply the life cycle assessment perspective to assess the environmental impacts of organic waste management of 'CEAGESP' food distribution center in São Paulo.

3. METHOD

3.1 Case study description

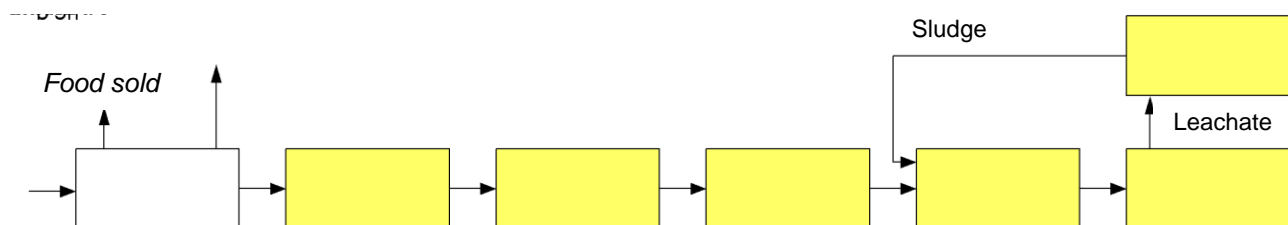
3.1.1 The food distribution center

The food distribution center (FDC) of São Paulo 'CEAGESP' is the largest in the Latin America with more than three millions food tons traded every year, where horticultural products play a key role. With about 50.000 tons per year of waste generation (80% of organic fraction; OF) and the lack of a continue and effective waste recycling strategy, between 2007 and 2018 about 77% of organic waste was sent to landfills (CEAGESP, 2019). The main steps of 'CEAGESP' internal organization includes a preliminary weighing and checking at the arrival of new products, the trading phase, the output of sold products, and the management of not saleable products, that, if still edible, are sent to charity institutions, otherwise are sent to landfill together with the organic and inorganic fraction (mainly paper, plastic, glass and wood).

3.1.2 The management of the organic fraction

The process comprehends five steps: internal collection, waste transfer, transport to landfill, waste disposal and waste degradation (Fig. 1). The first step is the internal waste collection, performed by 8 compactor trucks of 15 m³ per 1815 hrs/yr, that collect the waste generated from the trading activity and bring them to a specific area inside CEAGESP. Then, using an excavator, waste are transferred to a truck with 30 tons capacity. The third step is the waste transport from CEAGESP to 'Caieiras' Landfill located ~24,2 km distance. This process is performed by two trucks with 1569 trips/yr. The fourth step is the waste disposal inside 'Caieiras' landfill, and finally the last step is the waste degradation that releases biogas and leachate. The leachate is not treated inside the landfill, instead it is sent to the SABESP wastewater treatment plant located in Barueri city, where it receives the same treatment of sanitary sewage. After the treatment, the purified water is released into the Tietê river, while the residual sludge is sent back to 'Caieiras' Landfill.

Figure 1. Scope of this study (yellow boxes) – WWTP, wastewater treatment plant



1.1 3.2 Goal definition

The goal of this study is to evaluate the environmental impacts of the OF generated by CEAGESP in 2018. The work is performed in compliance with the guidelines of the international standard organization (ISO 14040, ISO 14044). The LCA was developed using Microsoft Visio® for the diagrams, Microsoft Excel® for the quantitative analysis, and ECOINVENT database as a source of conversion factors. LCA impacts were analyzed using the Recipe Midpoint (H) v1.13 method (GOETKOOOP et al., 2008).

3.3 Scope definition

The functional unit of this study is 1 ton of OF. The function is the treatment of this amount of waste, and all the input and output flows related to all steps considered are referred to the year 2018. Were considered all the materials used to fabricate the vehicles of each step and the related diesel consumption. About the landfill materials were considered the materials used during the construction and operational steps, while in the wastewater treatment plant (WWTP) was considered the consumption of electricity and the chemicals used.

Since the landfill and WWTP treat, respectively, waste fraction other than the OF generated by 'Ceagesp' and the leachate and wastewater from other sources, the input and outputs flows were calculated evaluating by allocation procedures considering the mass percentage related to the original CEAGESP's OF.

Among the impact categories available in Recipe Midpoint (H) V1.13 method (GOETKOOOP et al., 2008), the following ones were considered due to their close relation to waste management systems: global warming potential (GWP); human toxicity potential (HTP); fossil depletion potential (FDP); metal depletion potential (MDP); water depletion potential (WDP); fresh water eutrophication potential (FEP); terrestrial acidification potential (TAP); terrestrial ecotoxicity potential (TETP); particular matter formation potential (PMFP); and photochemical oxidants formation potential (POFP).

Other assumptions related to LCA were: (1) diesel consumption of the operations of collection, waste transfer, transport and landfilling was all assigned to the OF despite the organic content of the waste

generated by CEAGESP is only 80%, consistently with the work of Buratti et al. (2015) who affirms that “the not separated collection of the OF requires the management of a not separable fraction of inorganic waste”. (2) CO₂ from the OF decomposition, directly produced or originated by the combustion of methane, was not accounted for because it comes from biogenic origin according to IPCC (2006).

3.4 Data Collection

Data were collected from CEAGESP annual management reports, during technical visits and information exchange with the technical staff of CEAGESP and ‘Caieiras’ Landfill. In case of lack of direct data, values from literature were considered. The indirect impacts, as the fuel production, vehicles and landfill materials, chemical products and electricity were modelled using the Ecoinvent database (Ecoinvent, 2019), considering Brazilian values when possible and global values in the rest of cases. About diesel fuel consumption and direct emissions from vehicles, it was assessed the emission of CO₂, CO, N₂O, NMVOC, CH₄, NO_x, SO₂ and PM₁₀. Due to the variation along the years in emission standards, to estimate more precise emissions, when the vehicle models were not available, it was considered an average value using the weighted average per year of the circulating truck fleet in 2018, considering the report of vehicular emissions of Sao Paulo State in 2018 (CETESB, 2019).

3.5 Life cycle inventory analysis

In the first step, waste collection is carried out by eight diesel fuelled compactors of 15 m³ capacity. The average fuel consumption of 8 L/hr was estimated considering information from ZAND et al. (2019) and CETESB (2019). A specific fuel consumption of 3,09 L / ton was estimated; this value is in between the range from 1.4 to 10.4 L / ton as found by LARSEN et al. (2009) about diesel consumption in waste collection and transport. For the waste transfer, a consumption of 0.68 L/ton was directly calculated from the excavator model. In the third step, waste transport to Caieiras Landfill, the consumption calculated was 0,56 L / ton of organic waste, which is consistent with LARSEN et al. (2009) results. The fourth step of waste disposal in Caieiras landfill involves several vehicles and materials, but due to the unavailability of some data, it was considered average values from the works of YANG et al. (2014), BROADGARD et al. (2013), CHERUBINI et al. (2009) and MENARD et al. (2004). About diesel consumption, the work of Yang et al. (2014) was considered, because the other ones do not include all landfilling process steps. A fuel consumption of 1,65 L / ton OF was estimated. In the last step, waste degradation, direct biogas emissions from Caieiras landfill were measured. It was found a 50% of methane and an annual methane production of 47,29 Nm³ / ton OF (33,76 kg/t OF). These values are consistent with CANDIANI & DA SILVA (2011) who analyzed the biogas of Caieiras Landfill in 2011, but below the average values found by Themelis (THEMELIS; ULLOA, 2007). Because 80% of this methane is burned, only 20% was considered as direct emission.

Regarding the generated leachate, it was measured a BOD of 500 mg/l and a COD of 27500 mg/L. The leachate is not treated in Caieiras landfill, but it is sent to the WWTP Sabesp in Barueri and treated together with wastewater with a process of sludge activated in two phases. Thus, it was considered the transport of leachate from landfill to WWTP and input of chemicals and electricity used by the WWTP, as well as methane emissions from anaerobic sludge degradation. Due to incomplete data, missing values were obtained from literature (SOUTO; POVINELLI, 2007). It was found an electricity consumption of 0,4 kWh/ t OF, and consumption of ferric chloride and calcium hydroxide of 0,62 kg / t OF and 1.26 kg / t OF, respectively.

4. RESULTS AND DISCUSSION

This section shows the analysis of the results found for all the impacts categories considered. For each category, will be considered the most important impact sources.

4.1 Global warming potential (GWP)

Were considered the emissions of CO₂, CH₄, N₂O. The results (Figure. 2) show that the main contribute to this impact category is provided by the methane directly emitted to atmosphere during the waste degradation, that is about 86% of all emissions. A similar percentage (90%) was found by Oliveira (OLIVEIRA et al, 2017), who analyzed waste collection and disposal to Landfill in Bauru, São Paulo state. The second most important source are the emissions from diesel combustion in vehicles, highlighting the not secondary role of waste transport. Figure. 3 shows the two most important greenhouse gases (GHGs) sources analyzed in a detailed way, considering their contribution as 100% and assessing the weight, in percentage, of each step. Waste degradation, due to the high characterization factor of methane, is the first contributor (about 90 %), followed by internal collection and transport (5 %) and landfilling (2.5 %). This percentages are consistent with the work of LIKANEN et al. (2018), where is highlighted the predominant role of landfill emissions where compared with collection and transport emissions. The graph confirms the necessity, along the process towards greenhouse gases reduction, to find alternatives other than landfill disposal.

Figure 2. Global warming potential of different sources

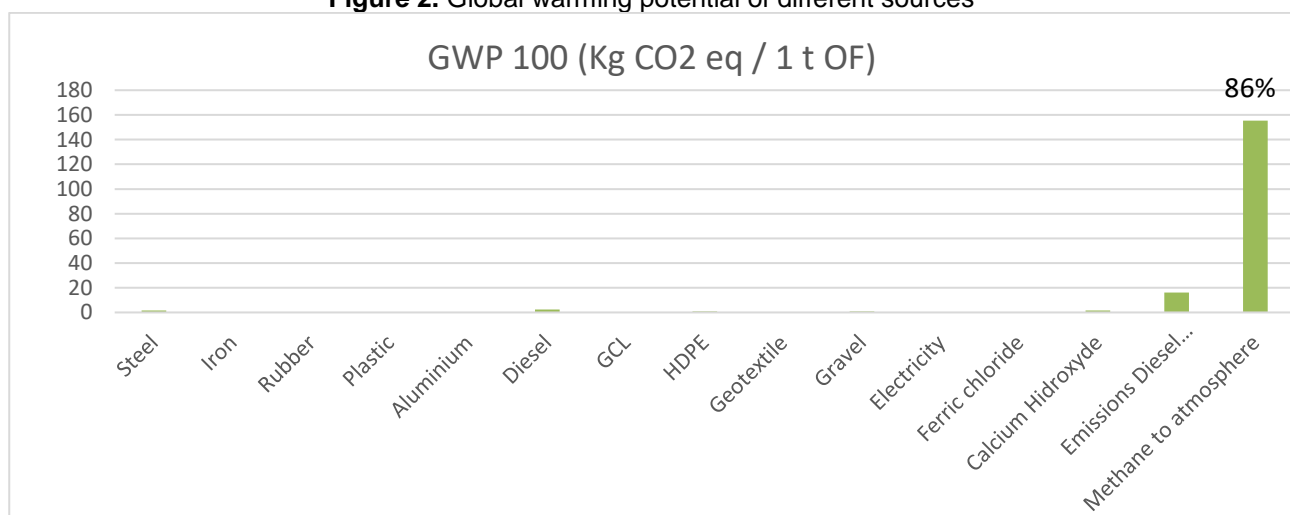


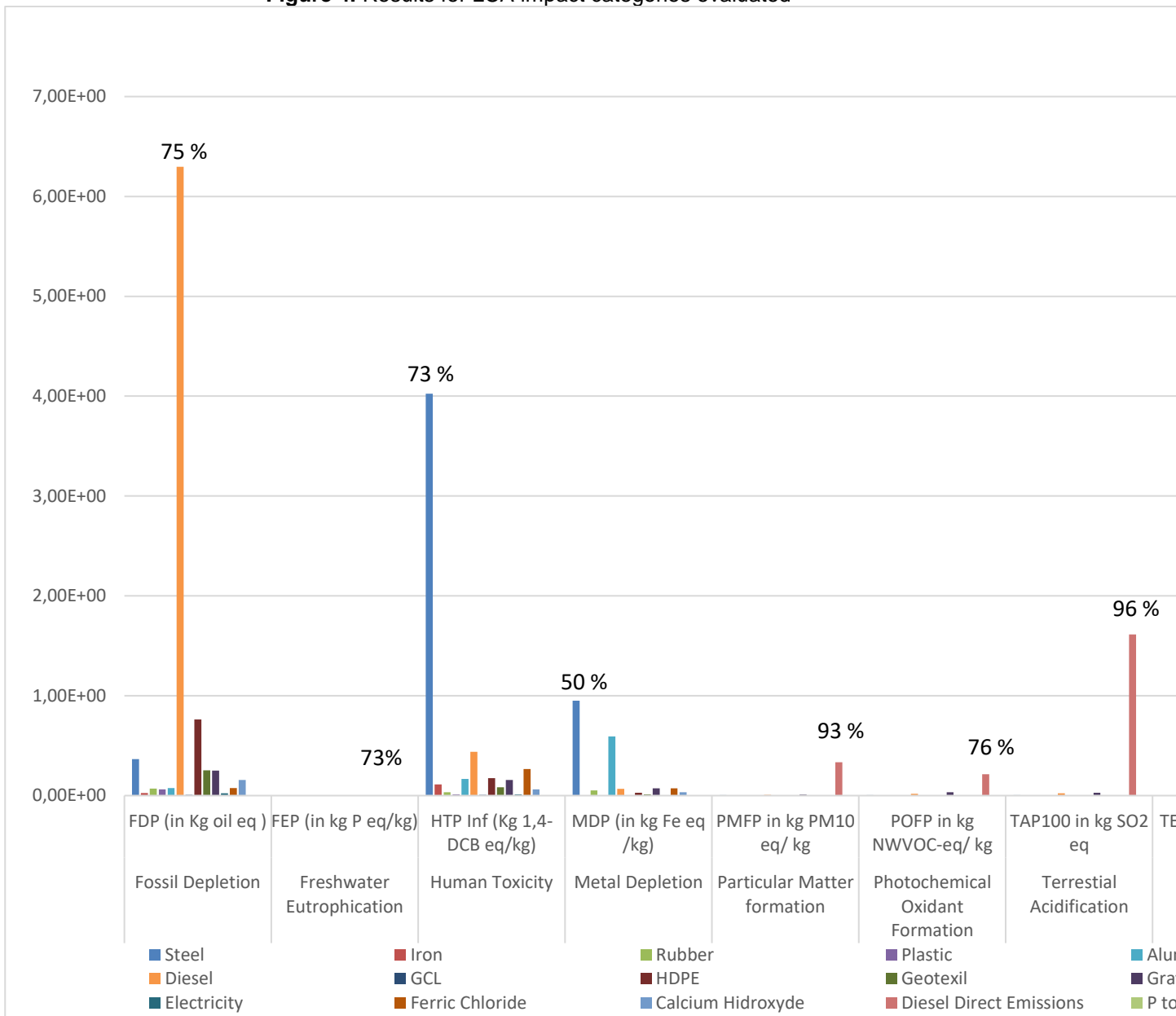
Figure 3. Global warming potential for each waste management step



4.2 Other impact categories

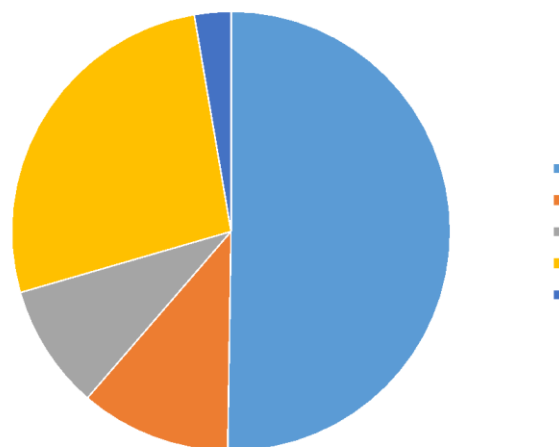
The results for the others impact categories assessed are showed in Figure 4. It is evident the role of steel in HTP and MDP, where it is the most important source with a value in percentage of 73% and 50% respectively. Being steel the most important material considered in this study for the construction of all machines and being the steel-making a process very hazard from human toxicity perspective, this could justify the important role of steel in these impact categories.

Figure 4. Results for LCA impact categories evaluated



The categories FDP, PMFP, POFP and TAP have as predominant source of impact Diesel consumption. In particular, in PMFP, POFP and TAP the direct emissions from diesel combustion are responsible of 93 %, 76 % and 96 % of total emissions respectively, while in FDP, the indirect emissions caused by the use of Diesel are the 75 % of all impacts assessed in this category. This role of Diesel suggests the importance of vehicles use in different steps of our process. In fact, analyzing the contributions of each step in the impacts caused by diesel fuel, for example about PMFP, it is evident the main contribution of internal waste collection & transport in CEAGESP (50.24%), followed by landfilling (26%) and waste transfer (11.07%) (Figure 5). The impact categories POFP, TAP and FDP present similar trend about the single step contributions, because they are different impacts generated by the same amount of diesel consumed. As highlighted above, collection and transport steps are the most important source of emissions related to diesel consumption. A way to reduce these emissions could be the reduction of total kilometers traveled, or the substitution of the vehicles used with new models. In São Paulo state, the circulating truck fleet in 2018 had an average (weighted) age of about 10 years (CETESB, 2019). It means that there are many old vehicles with old emissions standards and high pollution levels. As suggested by LARSEN et al. (2009), replacing the old vehicles models with the new ones, it is possible to obtain a reduction of potential impact of 60 % for terrestrial acidification and 40% for POFP. About the last three impact categories assessed, a predominant role of the phosphorus released into the water (73%), originated by leachate production into the landfill, is the main information obtained from the category FEP, while in TETP end WDP the gravel, used during the construction and operation steps in landfilling processes, has the biggest weight, with a percentage of 52% and 24 % respectively.

Figure 5. Contribution of each evaluated step in the PMFP impact category



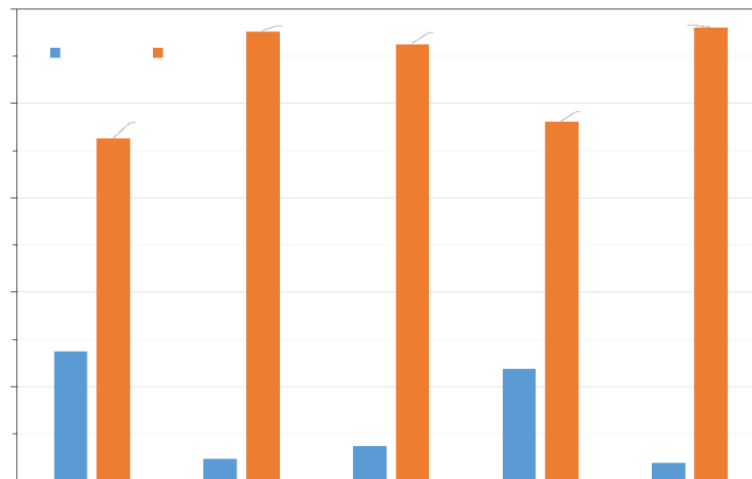
Another interesting information is provided by the comparison between indirect and direct impacts. (Figure 6). FEP, GWP, PMFP, POFP and TAP include both, and it is evident the role of direct impacts compared with total impacts. The direct impacts have a weight from about 73% in freshwater eutrophication potential to the 96 % related to the terrestrial acidification potential.

In conclusion, it is evident the role of several steps and processes as main sources of environmental problems, that vary according to the impact category assessed. This work confirms the role of landfill methane generation as one of the most important impacts in OF management, as showed by BURATTI et al. (2015) and OLIVEIRA et al. (2019).

The contribution of direct diesel emissions and diesel consumption, typical of the steps waste collection and transport, is also fundamental, as confirmed by LIIKANEN et al. (2018).

These results show that internal collection & transport in “CEAGESP” and waste degradation in Caieiras landfill are the most pollutant steps of the OF generated by CEAGESP, and therefore, new approaches towards a more sustainable management have to start from a better collection system, seeking for an alternative to landfilling, about the final waste disposal.

Figure 6. Comparison between direct and indirect impacts into selected impact categories



5. CONCLUSIONS

Landfilling is still the predominant treatment method for MSW in Brazil. Among the different waste types, the OF has a crucial role in leachate generation and methane emissions. This work has assessed the environmental impacts of MSW OF generated by the food distribution center CEAGESP in 2018, by applying a LCA perspective. The results have shown that methane emissions from landfill and direct emissions from diesel combustion during the transport steps are the main sources, as highlighted by GWP, FDP, PMFP, POFP and TAP impact categories. The substitution of old vehicles with new models and finding another option other than landfilling could be appropriate actions towards a more sustainable waste management.

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