ISSN: 2359-1048
Dezembro 2024

Validation of barriers to the reverse logistics of organic waste: a study for the individual generator in a municipality in the Metropolitan Region of Belém

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Resumo
The article investigates the barriers faced in the implementation of Reverse Logistics of Organic waste in Marituba by individual generators. Reverse Logistics is one of the means for sustainable waste management, reducing costs and environmental impacts, however, it faces significant challenges. The research used the seven barriers for the individual generator of organic waste, according to Teixeira et al. (2024), based on these barriers, data collection was carried out in the municipality of Marituba using a survey form. In the data analysis, the TOPSIS method was applied, where the barriers were ranked, analyzed and discussed. The results indicated that understanding and overcoming these barriers is essential to improve the effectiveness of waste management systems and promote sustainable practices. The research highlights the need for robust strategies and public policies to address these challenges and support the reverse logistics of organic waste in the region. This study contributes to the understanding of the barriers to reverse logistics in the context of Marituba and provides a basis for the development of sustainable solutions in the management of organic waste.

Palavras Chave
Urban Waste Management, reverse logistic barriers, Organic Waste

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1. INTRODUCTION

Reverse logistics (RL) of OSW is a set of actions undertaken by interested parties to facilitate the collection and return of solid waste to the production cycle for the purpose of reusing or properly disposing of this waste. RL of OSW includes the activities of collection, transshipment, transportation, sorting for reuse or recycling, treatment, including by composting, and final disposal of household waste, waste originating from commercial, industrial and service activities, and waste from public urban cleaning services. If properly implemented, it is an instrument to address the challenges in the reverse OSW channel (Leal et al., 2024).

The study of barriers to the Reverse Logistics of Organic Waste in is necessary to improve the effectiveness of waste management systems and promote sustainable practices in each territory. Understanding these barriers allows us to identify specific obstacles and direct actions by both the public and private authorities to overcome them. The importance of this study lies in the developments, with the identification of these barriers for the intended geographic area, making it possible to develop more robust strategies and policies that can overcome such challenges.

This study aims to answer the following research question: What are the barriers to the implementation of Reverse Logistics of Organic Solid Waste that are valid for the city of Marituba? Thus, the objective of this research is to verify whether the barriers related to the implementation of Reverse Logistics of Organic Solid Waste, identified in the literature, also apply to the reality of individual waste generators in the city of Marituba.

2. METHODOLOGICAL PROCEDURES

This research was structured in four main stages: literature review, planning and data collection, data treatment and analysis, including the classification of barriers by applying the TOPSIS method. First, the barriers to the implementation of reverse logistics and the individual stakeholders involved were considered, as outlined by Teixeira et al. (2024). The authors Teixeira et al. (2024), conducted a systematic literature review, resulting in 28 articles focused on individual stakeholders, identifying a total of seven main barriers faced by this group (Table 1). The literature review showed that these barriers are multifaceted and include challenges related to lack of technical knowledge, resistance to change, and difficulties in separating waste, among others.

Table 1- Barriers to the Reverse Logistics of Organic Solid Waste for Individual Stakeholders

BARREIRAS	REFERÊNCIAS
B1- Difficulty in separating waste to obtain good quality reuse mass	Daskal *et al*., (2022) ; Lohri *et al.*, (2017) ; Perteghella *et al.*, (2020) ; Pour *et al.*, (2018) ; Wei *et al.*, (2017) ; Xiao *et al.*, (2017) ; Xiao *et al.*, (2017)

B2- Heterogeneous composition (mixture) of waste that makes reuse/recovery difficult	Behrooznia *et al.*, (2020) ; Cerda *et al.*, (2018) ; Dell'Orto and Trois, (2022) ; Gonçalves *et al*., (2018) ; Xiao *et al.*, (2020)
B3- Social acceptance for the recovery of organic waste	Pan *et al.*, (2015); Uddin *et al.*, (2021)
B4- Limited technical expertise for waste identification and separation	Carmen-Niño *et al.*, (2023); Gonçalves *et al.*, (2018) ; Kazuva and Zhang, (2019) ; Laner *et al.*, (2015) ; Lunag *et al.*, (2021) ; Pan *et al.*, (2015)
B5- Aversion to the recovery of organic waste	Carmen-Niño *et al.*, (2023) ; Daskal *et al.*, (2022) ; Naz *et al.*, (2020) ; Pan *et al.*, (2015) ; Pour *et al.*, (2018)
B6- Understanding of biological processes for waste recovery	Lohri *et al*., (2017); Naz *et al.*, (2020)
B7- Lack of incentives to encourage waste recovery by stakeholders	Behrooznia *et al.*, (2020); Hettiarachchi *et al.*, (2018); Kazuva and Zhang, (2019); Khamkeo, (2021); Siqueira and Assad, (2015)

Source: Adapted from Teixeira *et al*., (2024)

To collect the participation of the population of Marituba, a questionnaire was prepared using the Google Forms platform. The questionnaire consists of seven statements, taken from the seven barriers identified in the literature review, evaluated through a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree". Before these statements, seven characterization questions were included, with the objective of filtering and understanding the social reality of the respondents. This approach allows for a more detailed and contextualized analysis of the participants perceptions and opinions, ensuring that the responses obtained reflect the diversity and specificities of the population studied.

3. RESULTS AND DISCUSSION

Therefore, it is concluded that by ranking the values of coefficient Ci*, a comparative ranking of statements related to barriers for implementing solid organic waste reverse logistics in the municipality of Marituba-PA is obtained. Thus, Table 2 presents the results of the classification of statements, correlating them with their respective barriers, with barriers B05, B03 and B04 being the most recognized by the respondents.

Tabel 2 - Ranking of claims and correspondence with barriers

Position	Ci		Affirmative		Barriers
1º	1.0000	**AF05**	I have a good level of acceptance in relation to separating organic waste so that in can be reused.	**B05**	Aversion to the recovery of organic waste

2º	0.7819	**AF03**	I am interested in using organic waste to produce fertilizer through composting, although I consider that sometimes it can be difficult to reuse waste that can be transformed into fertilizer.	**B03**	Social accpetance for organic waste recovery
3º	0.5180	**AF04**	It is necessary to have technical knowledge to transform organic waste into fertilizer through composting.	**B04**	Limited technical knowledge of waste identification and separation
4°	0.2730	**AF01**	I separate the garbage that can be turned into fertilizer from the rest of the garbage.	**B01**	Difficulty in separating waste to obtain good quality reuse mass
5º	0.2713	**AF07**	There are incentives that make it possible to separate, collect, transport, and other processes necessary to recover organic waste.	**B07**	Lack of incentives to encourage waste recovery by stakeholders
6º	0.2007	**AF02**	Sometimes it can be tricky to separate the garbage that can be turned into compost from the rest of the garbage.	**B02**	Heterogeneous composition (mixture) of waste that makes reuse/recovery difficult
7º	0.0000	**AF06**	I have knowledge about the biological processes that occur in the recovery of organic waste for fertilizer production through composting.	**B06**	Understanding of biological processes for waste recovery

Source: Authors (2024)

The results of the research demonstrate that the existence of a barrier can reinforce and even favor the existence of another barrier, suggesting the correlation between them. Also, the results for Marituba reinforce a scenario at the state and national level, where Pará, being the largest generator of MSW in the North Region (ABRELPE, 2021), collects juts over 80% of the waste generated and 63.4% of the MSW inappropriately disposed of in controlled landfills or dumps (ABRELPE, 2022). At the national level, only 0.41% of the MSW collected comes from reused organic waste, in which composting units represent 1.5% of MSW processing units in operation in Brazil, while branch management and pruning units represent only 0.9% (SNIS, 2021). Also, the research demonstrates that the barriers need to be recognized and addressed, with actions by both the public and private sectors, so that the OSW is revalued, stimulating is return to the production cycle, and is diverted from landfills.

4. CONCLUSIONS

This study aimed to identify the barriers to Reverse Logistics for OSW, considering the individual generating stakeholder, which are valid for the municipality of Marituba. Of the 7 barriers considered, three barriers are most perceived by the respondents, namely: Aversion to the recovery of organic waste (B05); Social acceptance for the recovery of organic waste (B03);

and Limited technical knowledge of waste identification and separation (B04). The barrier Understanding of biological processes for waste recovery (B06) did not reach a score, not being perceived as a barrier, especially when referring to composting as a form of recovery from OSW. The barriers Difficulty in separating waste to obtain good quality reuse mass (B01), Lack of measures to encourage waste recovery by stakeholders (B07) and Heterogeneous composition of waste that hinders reuse (B02) had lower perceptions of the respondent sample. The possible correlation between barriers due to being interconnected, such as barriers B01 and B04, was also discussed, where the lack of knowledge about waste separation may be preventing the separation of waste to obtain good mass for reuse.

This research contributes to the theoretical scope because there are few studies that deal with the barriers of the OSW management scenario in the regions (Huang *et al*., 2022) and because it is the first study that statistically tests and ranks the barriers to RL OSW for the individual generating stakeholder in Marituba. Identifying and understanding these barriers is fundamental for theoretical advancement in the field of urban solid waste management, providing a basis for future research and development in this area. It also contributes to the practice, as it brings the barriers, which for the individual generator, are hindering the operation of the RL for OSW recovery. Once addressed by both public and private managers in an integrated way, they will be able to overcome such barriers and get the OSW back into the production cycle, bringing work and income to Marituba through its recovery.

Despite the importance of this research, it has the limitation that its results cannot be considered for any territory. Additionally, the research sample corresponds to about 0.10% of the population (IBGE, 2022), bringing a 9% error to the research results at a 95% confidence level. Although we used an electronic form, the respondent's engagement was very low, which required the authors to go the streets and spaces of Marituba to obtain the answers. For future research, it is suggested to perform statistical tests (multivariate analysis) to validate the correlation between barriers. Also, to carry out this research for the municipalities of Benevides, Santa Izabel and Santa Bárbara, which together with Marituba constitute the smallest municipalities in the Metropolitan Region of Belém.

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