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Circular management of solid urban waste in Brazil: an analysis of government documents and reports

Gerenciamento circular de resíduos sólidos urbanos no Brasil: uma análise dos documentos governamentais e relatórios

Gestión circular de residuos sólidos urbanos en Brasil: un análisis de documentos e informes del gobierno

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KEYWORDS

Urban Solid Waste
Management. Circular
Economy. Sustainability.

Abstract: The circular economy is an economic model designed to move away from the approach of extracting, using, and discarding to ensure that products are reintroduced into the production chain, at the end of their life cycle, for better use of natural resources. Urban Solid Waste Management is essential for implementing the circular economy model. It can adequately dispose of solid waste discarded in urban areas, enabling reuse, recycling, or recovery strategies, among other alternatives. Despite the importance of urban solid waste management for the circular economy model, the literature surrounding the situation in Brazil is still incipient. In this scenario, this work aimed to diagnose Brazil's situation in managing urban solid waste, given the perspectives for adopting the circular economy model. Thus, we sought to highlight points for improvement and opportunities, briefly studying the adopted urban solid waste management policies and practices. The methods used for the research were bibliographic research and documentary research. As a result, it was identified that the insufficient coverage of waste collection, the lack of selective collection, and the existence of dumps and controlled landfills, among other problems, make

it challenging to develop actions for implementing a Circular Economy model. The data revealed that the Brazilian structure still presents several problems that must be solved to make the circular model viable.

PALAVRAS-CHAVE

Gestão de Resíduos Sólidos Urbanos.
Economia Circular.
Sustentabilidade.

Resumo: A economia circular é um modelo econômico que tem como objetivo abandonar a ideia de extrair, usar e descartar, de modo a garantir que os produtos sejam reintroduzidos na cadeia produtiva, ao final do seu ciclo de vida, para um melhor aproveitamento de recursos naturais. A gestão de Resíduos Sólidos Urbanos é uma parte importante para a implantação do modelo de economia circular, uma vez que pode viabilizar a destinação adequada dos resíduos sólidos descartados em áreas urbanas, possibilitando estratégias de reutilização, reciclagem ou recuperação, entre outras alternativas. Apesar da importância da gestão dos resíduos sólidos urbanos para o modelo de economia circular, a literatura que envolve a situação do Brasil ainda é incipiente. Neste cenário, este trabalho teve o objetivo de diagnosticar a situação do Brasil na gestão dos resíduos sólidos urbanos, frente às perspectivas para a adoção do modelo de economia circular. Assim, buscou-se evidenciar os pontos de melhoria e as oportunidades, fazendo um breve estudo das políticas e práticas de gestão de resíduos sólidos urbanos adotados. Os métodos empregados para a pesquisa foram a pesquisa bibliográfica, seguida de uma pesquisa documental. Como resultados, identificou-se que a insuficiência da cobertura da coleta de resíduos, a falta da coleta seletiva, a existência de lixões e aterros controlados, entre outros problemas, são fatores que atrapalham o desenvolvimento de ações para a implantação de um modelo de economia circular. De modo geral, os dados revelaram que a estrutura brasileira ainda apresenta diversos problemas que precisam ser solucionados a fim de viabilizar o modelo circular.

PALABRAS CLAVE

Gestión de Residuos Sólidos Urbanos.
Economía circular.
Sostenibilidad.

Resumen: La economía circular es un modelo económico que pretende abandonar la idea de extraer, usar y desechar, para asegurar que los productos se reincorporen a la cadena productiva, al final de su ciclo de vida, para un mejor aprovechamiento de los recursos naturales. La Gestión de Residuos Sólidos Urbanos es una parte esencial de la implementación del modelo de economía circular. Puede disponer adecuadamente los residuos sólidos desechados en áreas urbanas, posibilitando estrategias de reutilización, reciclaje o valorización, entre otras alternativas. A pesar de la importancia de la gestión de residuos sólidos urbanos para el modelo de economía circular, la literatura sobre la situación en Brasil es aún incipiente. En ese escenario, el objetivo de este trabajo fue diagnosticar la situación de Brasil en la gestión de residuos sólidos urbanos, dadas las perspectivas para la adopción del modelo de economía circular. Por lo tanto, buscamos resaltar los puntos de mejora y las oportunidades, haciendo un breve estudio de las políticas y prácticas de gestión de residuos sólidos urbanos adoptadas. Los métodos utilizados para la investigación fueron la investigación bibliográfica, seguida de la investigación documental. Como resultado, se identificó que la insuficiente cobertura de recolección de residuos, la falta de recolección selectiva, la existencia de desechos y vertederos controlados, entre otros problemas, son factores que dificultan el desarrollo de acciones para la implementación de un modelo de economía Circular. En general, los datos revelaron que la estructura brasileña todavía tiene varios problemas que necesitan ser resueltos para que el modelo circular sea viable.

Introduction

The circular economy is an economic model based on reducing, reusing, recycling, and recovering materials in production, distribution, and consumption processes (Kirchherr et al., 2017). According to Cerqueira-Streit et al. (2021), the circular economy is an alternative to the current economic model (linear), which has proven harmful to natural resources and has led to negative societal consequences.

However, in addition to the depletion of natural resources, there are other environmental and socioeconomic challenges related to the impact of waste treatment (Zeller et al., 2019). According to Khan and Ali (2022), increasing levels of pollution and waste generation have driven organisations worldwide to adopt circular economy principles. Suárez-Eiroa et al. (2019) emphasise that the circular economy proposes a regenerative production-consumption system that aims not only to maintain resource extraction rates below values suitable for planetary boundaries but also to keep waste generation and emissions below levels appropriate to those boundaries. Thus, the circular economy encompasses strategies such as reuse, reduction, recycling, and transforming waste into something that can be reintegrated into society. Nevertheless, any discussion about the circular economy must also consider adequate solid waste disposal to prevent serious negative impacts on the environment and public health.

Considering the escalating environmental issues, promoting the linear economy — based on extracting, transforming, and discarding — is becoming unsustainable. The vast amount of solid waste generated poses challenges for the development of businesses, families, cities, and nations. The linear economy uses natural resources in a disorderly manner, disregarding their scarcity and overlooking the need to address packaging disposal and reuse (Assunção, 2019). Consequently, in Brazil and other countries, public policies aimed at sustainability have emerged to encourage society and businesses to address the underlying issues and adopt new measures for solid waste management. In this context, the European Union can be mentioned for its efforts toward achieving a circular economy as it has been

establishing regulations and targets since 2015. It has also published reports containing data from all member countries, including waste management actions (European Commission, 2015).

In Brazil, the National Solid Waste Policy (PNRS in Portuguese) was implemented by Law No. 12.305, which outlines clear objectives for managing polluting, perishable, and toxic materials, complemented by Decree No. 10.936 to regulate the PNRS (Brasil, 2010; 2022). Despite these regulations, Andrade et al. (2018) indicate that waste separation is still inadequate in Brazil. They point out that companies in the recycling sector are geographically dispersed, which increases the cost of recovered materials. According to Assunção (2019), the shift to a circular economy in Brazil is not a straightforward transition due to various barriers and limitations. Santos et al. (2024) and de Oliveira et al. (2023) note that fewer than a quarter of Brazilian municipalities have implemented selective waste collection. This situation hampers the success of a circular model in Brazil, as large amounts of materials that could be reintegrated into the production cycle are being discarded in landfills and, in extreme cases, in open dumps.

According to Rebehy et al. (2024), the aim of implementing circular economy practices in urban solid waste management is to increase recycling rates for waste and packaging while reducing the amount of waste sent to landfills. Terranova and Biazini (2022) state that solid waste has environmental, social, and economic impacts, as it is linked to climate change, water use, land use, carbon emissions, and other issues. Effective waste management practices in Brazil have largely been isolated actions that do not cover the whole of Brazil. De Oliveira et al. (2022) explore the perspectives of recyclable material collectors in Salvador, Bahia, Brazil. Nascimento et al. (2023) indicate that despite there being open dumps in Minas Gerais, selective waste collection has been encouraged through the Recycling Grant Program (*Programa Bolsa Reciclagem*). Do Nascimento Lopes et al. (2023) emphasise actions to support selective collection in eight municipalities along the *Costa do Descobrimento* in southern Bahia.

In recent years, research on waste management in Brazil has increased (Santos et al., 2024).

However, the literature on urban solid waste management in the country, particularly regarding its integration into the circular economy model, remains limited. Searches in Scopus, Web of Science, in titles, abstracts, and keywords with the terms ("circular economy") AND ("urban solid waste") AND (Brazil), returned only 10 articles (Santos et al., 2024; Monclaro et al., 2024; Rebehy et al., 2024; Nascimento et al., 2023; Moraes et al., 2023; Do Nascimento Lopes et al., 2023; Negrete-Cardoso et al., 2022; De Oliveira et al., 2022; Ribeiro Siman et al., 2022; Terranova & Biazini, 2022), eliminating duplicates. Searches in SciELO using the same terms in both Portuguese and English did not yield any articles. Among the 10 articles found, none of them focus on Brazil regarding urban solid waste management and the circular economy model. Thus, there is a gap in the research to discuss the data presented by the country and the current government documents.

Thus, this study aimed to diagnose the state of Brazil's urban solid waste management considering the perspectives on waste management for adopting the circular economy model. The importance of this work lies in mapping Brazilian practices and regulations and assessing the country's situation regarding the implementation of a circular model in waste management. Improperly disposed waste harms the environment; therefore, it is essential to explore the possibilities for reusing, recycling, or recovering products in ways that support circular economy principles. While adopting practices aligned with the circular economy may encounter various barriers, it is crucial to analyse and disseminate the actions taken to advance this topic.

Following this introduction, the subsequent sections will cover a literature review on relevant topics. Next, the methods used in the study will be described. The main results obtained will then be discussed, and finally, the concluding remarks will be presented.

Theoretical Elements of the Research

Circular Economy

The circular economy is an important topic

that has gained increasing interest among businesses and academics in recent years (Dev et al., 2020). It emerges from a concept that links sustainable and economic development with better use of existing natural resources, adhering to the principle of using a product and then reintroducing it into the production cycle (Geissdoerfer et al., 2017). Since the early industrial revolution, the prevailing economic model has been known as the linear economy, based on the idea of extracting, using, and discarding. According to Cerqueira-Streit et al. (2021), the circular economy is an alternative to the linear economic model, which has had negative consequences for society due to its highly polluting and degrading impact on natural resources. Mishra et al. (2021) argue that the circular economy represents the latest effort to mitigate the risks associated with the linear economy, seen as a solution to issues such as excessive waste generation, resource scarcity, and the sustainability of economic advantages.

According to Stahel (2016), a circular economy aims to transform goods that are at the end of their service life into resources, closing loops in industrial ecosystems and minimising waste. The Ellen MacArthur Foundation (EMC, 2013) emphasises that economic activity under the circular model contributes to the overall health of the system. This process involves a gradual transition in which societal awareness of resource utilisation is developed, starting within households and extending to communities and businesses.

According to the Ellen MacArthur Foundation (EMC, 2013), it can be stated that using technical and biological materials is essentially the foundation of the circular economy. Biological materials are transformed into organic materials used in agriculture through processes such as composting and anaerobic decomposition. In contrast, technical materials undergo reuse, repair, remanufacturing, and even recycling processes. These actions benefit the environment as a whole, from human activities to the involuntary processes of nature.

The circular economy can be seen as a combination of procedures used throughout the

supply chain, aimed at addressing environmental and social issues (Geissdoerfer et al., 2017). According to Stahel (2016), the circular economy replaces traditional economic logic with a mindset focused on reusing what can be reused; recycling what cannot be reused; repairing what is broken; and remanufacturing what cannot be repaired. From this perspective, the principles of the 3Rs — Reduce, Reuse, and Recycle—are closely associated with the concept of the circular economy (Lieder & Rashid, 2016; Gregson, 2015). By aiming to 'Reduce,' companies decrease their raw materials and energy consumption; considering 'Reuse,' organisations rethink products that are more durable and repairable; and finally, 'Recycling' ensures that materials return to the process for remanufacturing or for use in other components (Cerqueira-Streit et al., 2021). Thus, the circular economy can be linked to the three dimensions of sustainability: environmental, economic, and social.

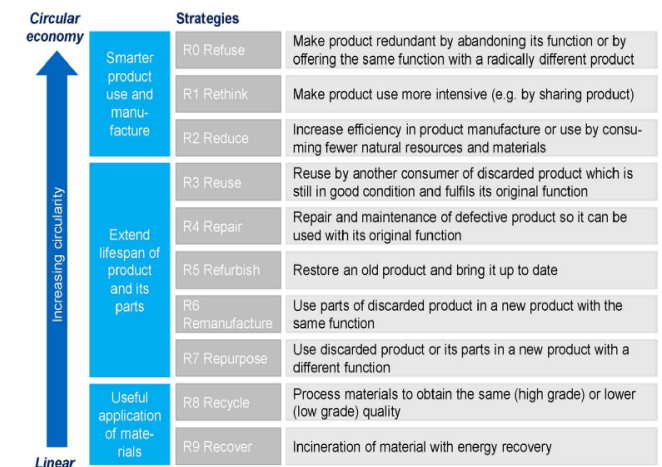
In addition to these three basic strategies, other authors have broadened the proposal of new Rs (Cerqueira-Streit et al., 2021). These proposals aim to rethink how products are designed, produced, and marketed to ensure the intelligent use and recycling of natural resources. Figure 1 presents the description of the 10 Rs proposed by Kirchherr et al. (2017).

Building on circular economy strategies, the creation and development of business models can be proposed that add value to manufactured products by designing items with multiple uses. This approach fosters a reverse logistics system that maintains quality and cost in a balanced way, thereby structuring and guiding stakeholders within and between supply chains (Azevedo et al., 2015). This model offers significant improvements to the current economic system, aiming to establish a new relationship between natural resources and their social use.

Pressure on companies is gradually increasing due to environmental consequences, prompting a shift towards more sustainable models that minimise the impact on the environment. The topic of circular economy has become progressively

more relevant, demonstrating that this concept can provide economic growth adopting a new production structure. This approach can help save on material costs, generate new jobs, mitigate price volatility, and reduce impacts and pressures (Kalmykova et al., 2018).

Figure 1
10 Rs Model



Source: Kirchherr et al. (2017).

Urban Solid Waste Management in Brazil

Since the previous decade, there has been increasing awareness of the fundamental role of waste management in ensuring the protection of health and the environment, as well as in the transition toward circular economy goals (Lombardi et al., 2021). In this context, cities in developing countries have been facing the challenges of the 21st-century environmental agenda, aiming to adapt systems for climate change mitigation, while simultaneously dealing with inherited issues from the past, such as the need to provide universal access to basic sanitation (Rio, 2015).

In Brazil, the National Solid Waste Policy (PNRS), also known as Law No. 12.305, has aimed to organise and regulate how the country manages its waste (Brasil, 2010). It proposes to form sustainable consumption habits, as well as encourage recycling, reuse, and adequate solid waste disposal in the environment, ultimately leading to eliminating open dumps (Brasil, 2010;

Santos et al., 2024). However, there are challenges in terms of the law, as inadequate disposal is still observed regarding the recovery of materials discarded in nature.

According to the PNRS, transparency in the public and private sectors regarding solid waste management is required (Brasil, 2010). According to Aguiar et al. (2021), solid waste generation, as well as its poor management, is one of the greatest environmental problems nowadays. According to Santos et al. (2024), although there has been an increase in research on waste management in Brazil, much of the literature focuses on the substantial challenges faced by municipalities in meeting the requirements outlined in the 2010 PNRS. According to Moraes et al. (2023), efficient urban solid waste management strategies are essential for promoting the circular economy at the municipal level.

To regulate Law No. 12.305, on January 12, 2022, Decree No. 10.936 was published, outlining the following priorities for solid waste management: I - solid waste non-generation; II - solid waste reduction; III - solid waste reuse; IV - solid waste recycling; V - solid waste treatment; and VI - environmentally adequate waste disposal (Brasil, 2022).

Despite the regulations, Brazil still faces obstacles, making it essential to strengthen proper solid waste management practices to enable a circular economy. Investing in new technologies for production processes is a growth opportunity and a step forward in sustainability. Similarly, raising awareness about excessive consumption, which leads to waste overabundance, is crucial. Alongside the benefits of a circular model in solid waste management, new demands are likely to be imposed on organisations, whether through market pressure or regulatory factors, to ensure proper and sustainable environmental management.

In the literature, some authors address the topics of the circular economy and urban solid waste management in Brazil. Santos et al. (2024) aimed to identify and classify indicators related to waste management in Brazilian public policies. Monclaro et al. (2024) conducted a review to

describe the valorisation of different biomass sources in the global context, focusing on Brazilian practices, while also emphasising how the use of microbial diversity is crucial for improving current technologies, such as advanced liquid fuels. Nascimento et al. (2023) discussed the challenges, opportunities, and contexts of municipal environmental management in Minas Gerais. Rebehy et al. (2024) identified the factors influencing material recovery and the best practices of the most efficient municipalities in Brazil and assessed the alignment of Brazilian legislation with European guidelines. Moraes et al. (2024) proposed to create an index to evaluate urban waste management and discussed how this issue could be better addressed in future sustainable circular cities in Brazil. Do Nascimento Lopes et al. (2023) developed an intermunicipal integrated waste management system to help implement an intermunicipal consortium among the eight municipalities of *Costa do Descobrimento* in southern Bahia. Negrete-Cardoso et al. (2022) analysed 416 articles from around the world using bibliometric techniques to compile existing knowledge on circular economy focusing on waste management between 2007 and 2020. De Oliveira et al. (2022) identified the challenges and incentives, from the perspective of recyclable material collectors, for carrying out waste collection in the city of Salvador, Bahia. Ribeiro Siman et al. (2022) sought to strengthen Brazilian collectors' organisations by applying corporate governance tools to provide conditions that would make them more efficient in the recycling market and urban solid waste management. Lastly, Terranova and Biazini (2022) discussed the National Solid Waste Plan, indicating that some concepts are partially outdated and certain indicators are questionable, suggesting that the plan is due for a new revision. Although some articles have initiated discussions on the circular economy and urban solid waste management in Brazil, it is noteworthy that none of them have addressed the data associated with the country considering the requirements outlined in government documents and a circular model.

Methodological elements of the research

This study aims to investigate aspects of urban solid waste management in Brazil, aiming at circular management. Thus, regarding the objectives, this research can be classified as exploratory research, according to Gil (2017), as it aims to promote a greater understanding of the problem, making it more comprehensible. Exploratory research is particularly suitable for the current study, as there is a lack of studies in the literature addressing the same topics within the Brazilian context. Thus, a wide range of sources need to be evaluated to discuss the obtained results and gain familiarity with the subject. Regarding the technical procedures, this study uses bibliographic research followed by documentary analysis according to the definitions made by Gil (2017) and Marconi and Lakatos (2010). According to Gil (2017), documentary research is developed based on prepared materials and analyses of documents related to the subject. Marconi and Lakatos (2010) state that documentary research should involve collecting data from primary source documents, such as: public records; parliamentary and administrative publications; statistics; documents from private archives; letters; and contracts. Furthermore, through bibliographic research, the analysis will also incorporate secondary data obtained from various sources, including books, journals, newspapers, theses, and other documents.

Finally, regarding the data collection and analysis approach, this research is predominantly qualitative, as it focuses on collecting data and information aiming to describe the subject matter. According to Martins (2018), qualitative research does not prioritise the measurement of variables; instead, it emphasises the object of study to gather information and/or interpret the environment in which the problem occurs. Additionally, Martins (2018) states that qualitative data are obtained through semi-structured or unstructured interviews, participant or non-participant observation, as well as document research.

Thus, for the data collection of this research, sources of evidence will include publications,

technical notes, reports, regulations, and other documents related to urban solid waste management in Brazil. In this context, documents from the 2023 Panorama of ABRELPE (Brazilian Association of Public Cleaning and Special Waste Companies) were analysed, along with national regulations, documents, and databases, including Law 12.305 (Brazil, 2010), National Decree 10.936 (Brazil, 2022), the National System of Information on Solid Waste Management (SINIR, 2024), and the National Solid Waste Plan (Ministry of the Environment, 2022).

Presentation and Discussion of Results

This section discusses the documentary analysis in three parts: the first presents an analysis of urban solid waste management decrees in Brazil. The second part highlights studies from the 2021 Panorama of ABRELPE. Finally, the third part presents federal government documents concerning waste management in the country.

Analysis of National Regulations

In 2010, Law 12.305 was enacted in Brazil, addressing the National Solid Waste Policy, which mandates integrated management and oversight of solid waste (Brazil, 2010). This law stipulates that individuals or legal entities directly or indirectly responsible for solid waste production must implement actions to manage this waste.

Concerning urban solid waste, Article 8 of Law 12.305 (Brazil, 2010) addresses the instruments of the National Solid Waste Policy and assigns the responsibility for social control of urban solid waste services to municipal collegiate bodies. Article 9 focuses on the management and oversight of solid waste, outlining a priority order: non-generation, reduction, reuse, recycling, solid waste treatment, and environmentally adequate waste disposal. The article also states that technologies may be employed to aim for the energy recovery of urban solid waste; however, these technologies must be proven effective in terms of both technical and environmental standards, and a monitoring

program for toxic gas emissions approved by the environmental authority must be established.

Further regarding urban solid waste, Article 16 of Law 12.305 (Brazil, 2010) emphasises the need to develop a state solid waste plan. In accordance with the responsibility of waste generators as outlined in this law, the microregions established under §1 encompass activities such as selective collection, recovery and recycling, treatment, and final environmentally adequate urban waste disposal, as well as construction and demolition waste management, transportation services, health services, agricultural waste, or other types of waste, according to the specific characteristics of each microregion.

The responsibility of waste generators is further highlighted in Law 12.305 (Brazil, 2010). According to the terms outlined, the formulation of the microregional solid waste plan must align with the expectations of the state plan and propose integrated solutions for selective collection, recovery and recycling, treatment, and final environmentally adequate urban waste disposal.

In January 2022, Federal Decree No. 10.936 was published to regulate the National Solid Waste Policy (PNRS). This decree introduced fundamental changes, including the establishment of the National Reverse Logistics Program. Moreover, it addresses the economic and financial sustainability of urban cleaning services and solid waste management, and it provides guidance on how to properly dispose of hazardous waste.

After establishing the National Reverse Logistics Program, Decree No. 10.936 (Brazil, 2022) mandates that manufacturers, retailers, importers, and distributors of specific products, such as batteries and cell phone batteries, ensure better traceability of the waste generated. Another important aspect of the decree is the Citizen Selective Collection Program, which makes federal public administration agencies and entities accountable for separating recyclable and reusable waste. This responsibility is assigned both directly and indirectly, ensuring adequate disposal of these materials.

Regarding urban solid waste, Federal Decree

No. 10.936 (Brazil, 2022) addresses the energy recovery of these materials in Article 31. This initiative will specifically be carried out through joint actions by the Ministers of State for the Environment, Mines and Energy, and Regional Development. However, this article does not apply to the energy recovery from landfill gas during organic matter biodigestion and decomposition in urban solid waste.

Article 55 of Federal Decree No. 10.936 (Brazil, 2022) discusses the activities related to solid waste cleaning and handling, ensuring economic and financial sustainability through user fees, which help recover costs associated with providing essential and specialised services. Moreover, the decree strengthens the concept of Zero Landfill, aimed at reducing the number of landfills in Brazil by reinforcing selective collection and recycling efforts.

Thus, it is important to highlight that federal regulations are progressing towards better urban solid waste management, as various sections of Law No. 12.305 (Brazil, 2010) and Federal Decree No. 10.936 (Brazil, 2022) address issues related to the topic. However, Brazil is still in the early stages of ensuring adequate waste disposal, which also hampers implementing a circular model, as discussed in the literature review. To support these assertions, the following section presents data on urban solid waste management.

Analysis of the 2023 ABRELPE Overview

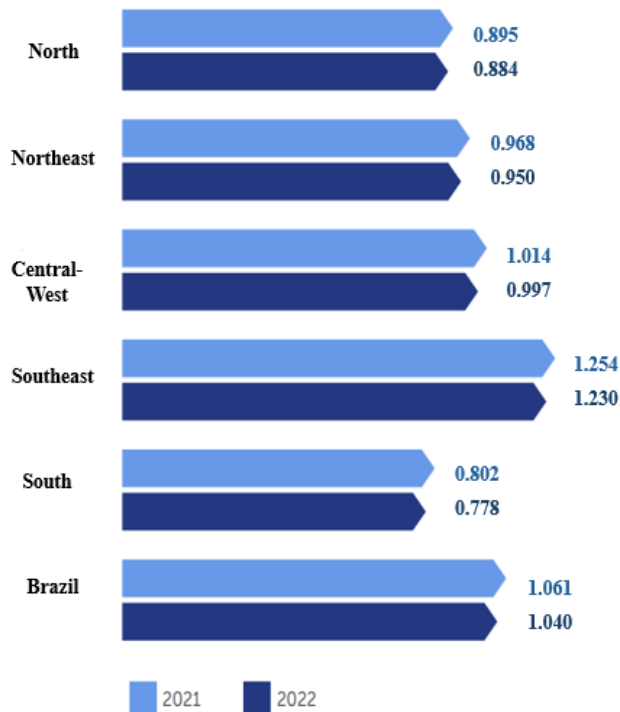
ABRELPE is an organisation focused on training and solid waste management development, in cooperation with public and private sectors, seeking suitable options for organisational activities. The association provides an overview that aims to supply data that is compiled and processed through scientific grounding, presenting the reality of waste management in Brazil.

The data presented by ABRELPE (2023) reveals that in 2022, waste generation reached a total of 77.1 million tons, equivalent to 211 thousand tons per day. This indicates that each person produced an average of 1.04 kg of waste per

day. When analysing these figures regionally, the Southeast region was the highest contributor, generating approximately 105 thousand tons daily, accounting for nearly 50% of the national total (ABRELPE, 2023).

Figure 2 illustrates how waste production occurs in Brazil, measured in kg per capita per day, distributed by region.

Figure 2
Comparative Analysis of Waste Production in Brazil (Kg/hab/day) for 2021 and 2022



Source: ABRELPE (2023).

Figure 3 shows, in percentage, the contribution of each region to waste generation.

Considering the large amount of waste generated in households, there is also a significant quantity of materials discarded for collection and cleaning services. In 2022, a total of 71.7 million tons were collected, which represents 93% of the waste generated in Brazil that year. When looking at the Brazilian regions, the Southeast accounted for the largest share, with approximately 38 million tons per year (ABRELPE, 2023).

Figure 3
Contribution of regions to waste generation (%)

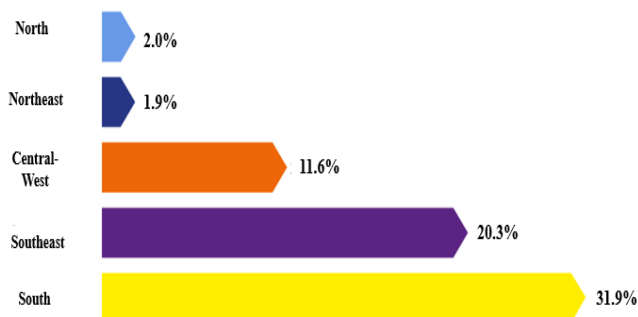


Source: ABRELPE (2023).

Selective Collection is an important procedure for waste collection, where materials are classified and separated based on their origin. According to ABRELPE, in 2022, the door-to-door selective collection service reached only 69.7 million inhabitants, meaning that, on average, 85.3% of the population in municipalities was not served by this service (ABRELPE, 2023). These data corroborate the statements made by Santos et al. (2024) and Oliveira et al. (2023), who highlight that less than a quarter of the population has access to this service. At this point, the South and Southeast regions have the highest percentages of initiatives. As pointed out by Andrade et al. (2018), this can be explained by the fact that recycling companies are geographically dispersed. Figure 4 presents the average urban population served by door-to-door selective collection, by region.

Since Law 12.305 was implemented (BRASIL, 2010), Brazil has aimed for effective urban solid waste management. However, in 2022, 38.9% of the country still lacked final adequate waste disposal, in which dumps and controlled landfills operated and received collected waste (ABRELPE, 2023).

Figure 4
Average urban population served by door-to-door selective collection by region.



Source: ABRELPE (2023).

Table 1 presents the distribution of the type of final urban solid waste disposal by region in Brazil for 2022.

Table 1
Final Urban Solid Waste Disposal in Brazil (in t/year and %)

Region	Adequate Disposal		Inadequate disposal	
	t/year	%	t/year	%
North	1,695,017	36.6%	2,939,546	63.4%
Northeast	5,844,347	37.3%	9,822,541	62.7%
Centre-West	2,453,280	43.6%	3,175,017	56.4%
Southeast	27,916,327	74.3%	9,636,432	25.7%
South	5,903,246	71.6%	2,344,088	28.4%
Brazil	43,812,217	61.1%	27,917,626	38.9%

Source: Data from ABRELPE (2023).

Thus, the ABRELPE report analysis (2023) highlighted three key areas of concern regarding the current situation in Brazil concerning urban solid waste management:

- The need to reduce waste volumes, prioritising actions in regions with higher waste generation.
- The need to implement selective collection systems with 100% coverage across the country.
- Ensuring adequate disposal of all waste.

To support these analyses, the following section will present data from other governmental documents.

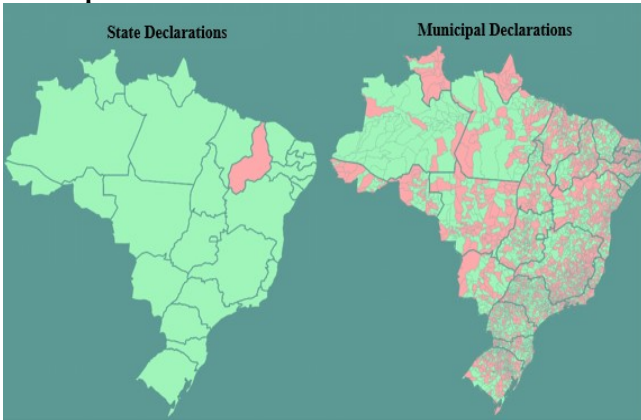
Federal Government Documents and Information

The National Solid Waste Management Information System (SINIR in Portuguese) was established by Federal Law No. 12.305 as a tool developed and managed by the Ministry of the Environment. It consists of three modules: states and municipalities; the Waste Transport Manifest (MTR in Portuguese), and the National Solid Waste Inventory. The first version of SINIR was presented by the Ministry of the Environment in 2019, with the most recent data from the system dating back to 2021 (SINIR, 2024). However, it was found that not all information for that year is available and updated, as some data still dates back to 2019 and 2020.

Federal Law No. 12.305 of the National Solid Waste Policy (Brazil, 2010) requires organisations to maintain transparency regarding their waste management practices. In 2020, 96% of the state declarations to SINIR were consolidated, reflecting the performance of public waste management services. The state and municipal governments were accountable for this module (SINIR, 2024). Figure 5 shows the states and municipalities that complied with the declaration (in green) and those that failed to do so (in pink).

Final adequate disposal is essential for reducing urban solid waste, as it contributes to the recycling, reuse, and recovery of waste materials, thereby helping to mitigate environmental impacts. According to SINIR, in 2019, only 37% of municipalities had proper waste disposal practices, while 32% had inadequate disposal, and 30% did not report their disposal methods (SINIR, 2024). As of the date of this report, data for 2020 were not available. Figure 7 illustrates the status of municipalities regarding the final urban solid waste disposal, where municipalities are shown in green indicating adequate disposal and those in red showing inadequate disposal.

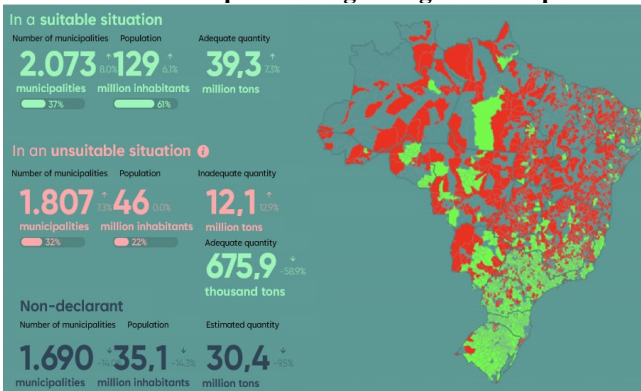
Figure 5
Municipal and State Declarations



Source: SINIR (2024).

Thus, Figure 6 not only highlights a significant number of municipalities with inadequate waste management practices but also an increase in the volume of urban solid waste disposed of inadequately compared to the previous year.

Figure 6
Situation of Municipalities Regarding Final Disposal

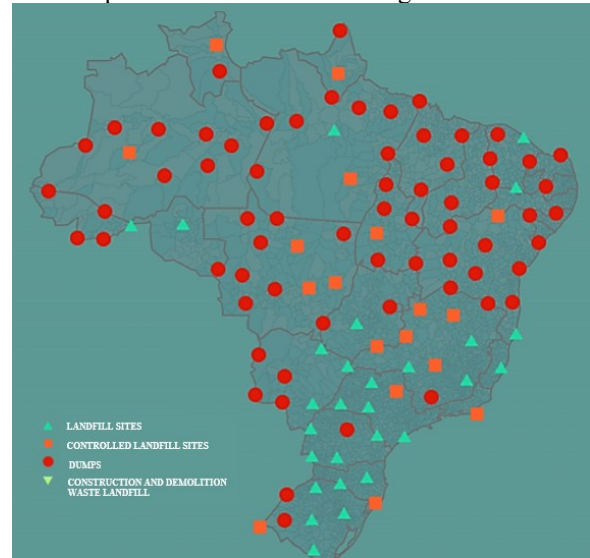


Source: SINIR (2024).

Figure 7 illustrates the various types of final urban solid waste disposal methods and their coverage areas. According to SINIR data from 2019, 54% of Brazilian municipalities have sanitary landfills, 17% operate controlled landfills, and 28% still have dumps (SINIR, 2024).

It is important to note that, in accordance with Law No. 12.305 (Brazil, 2010), all dumps in the country are required to cease operations by 2024.

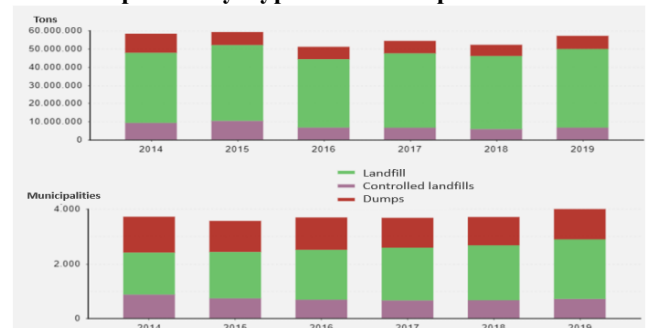
Figure 7
Final disposal units and their coverage areas.



Source: SINIR (2024).

In 2019, Brazil's Waste Recovery Index (IRR in Portuguese) was 1.67. Among the waste treatments offered with final adequate waste disposal, only 3% was recycled, and 1% went to composting, while 94% of the waste was sent for unknown treatment (SINIR, 2024). When analysing the mass of waste by type of final disposal, 8% went to landfills, 7% to controlled landfills, 48% to sanitary landfills, and 37% remained unknown (SINIR, 2024). In Figure 8, the first graph illustrates the solid waste mass distribution by final disposal type from 2014 to 2019. The second graph in Figure 8 further analyses the distribution of municipalities by type of final disposal over the same period.

Figure 8
Solid Waste Mass by Type of Final Disposal and Number of Municipalities by Type of Final Disposal



Source: (SINIR, 2024).

In addition to the analyses provided by SINIR, Federal Law No. 12.305 (BRAZIL, 2010) stipulates in Article 15 the development of the National Solid Waste Plan, coordinated by the Ministry of the Environment. This plan must include minimum content such as diagnostics, goals, programs, projects, and actions, guidelines and standards, as well as means for control and supervision. Regarding Urban Solid Waste, the National Solid Waste Plan presented a diagnosis in 2022, with the main topics outlined in Table 2.

Regarding urban solid waste, the National

Solid Waste Plan defined nine goals to improve the control of development and actions undertaken by the stakeholders involved in the plan. Table 3 shows the goals, indicators, and descriptions outlined by the plan.

Thus, based on the goals in Table 3 and the proposed global indicators, the federal government aims to support the current regulations for adequate urban solid waste management in Brazil, ensuring solid waste management monitoring and oversight.

Table 2
Summary of the Diagnosis of the National Solid Waste Plan

Topics addressed	Diagnostic
Non-generation and reduction	Non-generation is an action presented as a priority to be undertaken by Article 9 of the PNRS (Brazil, 2010), accompanied by reduction. However, the document indicates that these practices require incentives and development and monitoring tools, as Brazil is still in the early stages of addressing these actions, lacking indicators that demonstrate the volume of waste that has not been discarded or that has been reduced.
Generation	The initial phase of solid waste management is the reduction of waste generation, and it is essential to have information about which wastes are generated, in what quantities, and in which locations. According to the document, there was an increase of almost 1% in waste generation in Brazil in 2020 compared to the previous year, generating a total of 79,069,585 tons in 2019 and 82,477,300 tons in 2020.
Collection	The collection of urban solid waste in Brazil can be classified into conventional collection (without prior segregation) and selective collection (when there is separation at the source). Regarding the coverage of the collection service, in 2018, the Southeast region had the highest coverage of urban solid waste collection services, totaling 96.2%, while the North region had the lowest coverage at 83.6%. Waste collection in Brazil is classified as a direct service, indirect service, and absence of service. According to the report, direct collection of household solid waste totals 83%, collection using containers reaches 8.1%, and 8.9% do not have regular solid waste collection services.
Final Disposal of Urban Solid Waste	Law 12.305 (Brazil, 2010) states in Article 3, Section VII, that environmentally adequate final waste disposal includes reuse, recycling, composting, recovery, energy recovery, and other destinations permitted by the competent authorities, in addition to final disposal. However, the alternative for environmentally adequate final solid waste disposal, after all possible treatment and recovery options have been implemented, often results in no option other than disposal in a landfill.
Final Disposal of Urban Solid Waste	Law No. 14.026, dated July 15, 2020, stipulated that environmentally adequate final waste disposal should be implemented by December 31, 2020. However, in 2020, approximately 39.8% of waste still did not have final adequate waste disposal.
Institutional Capacity for Urban Solid Waste Management	The report shows the vulnerability of a significant amount of municipalities concerning their institutional capacity for urban solid waste management.
Solid Waste Management Plans	Formulating plans is a fundamental requirement for states, the Federal District, and municipalities to access federal resources, which are allocated to projects and services related to urban cleaning and solid waste management, or to benefit from incentives or financing from federal credit or incentive entities for this purpose. Information related to municipal and state plans, as well as the solid waste management plan, needs to be submitted to SINIR.
Programs and actions	The report outlines the following proposals as programs and actions: National Zero Landfill Program; Implementation and Expansion of Reverse Logistics Program; National Program for Combating Marine Litter; National Clean Rivers Program; and National Program for the Recovery of Contaminated Areas.
Means of Control and Oversight	The SINIR and monitoring to be conducted by Conama (National Environment Council) will enable control through consolidated data for oversight and monitoring of implementing regulated requirements.

Source: Prepared by the authors based on the information from the National Solid Waste Plan (Ministry of the Environment, 2022).

Table 3

National Solid Waste Plan Goals

Goal	Global Indicator	Description
Goal 1: Increase the economic-financial sustainability of waste management by municipalities.	Indicator 1.1: Percentage of municipalities that charge for urban cleaning and urban solid waste management services through a specific remuneration instrument.	The objective to be achieved is that by 2024, 100% of municipalities must have some form of charge for the provision of urban solid waste management services.
	Indicator 1.2: Percentage of municipalities with financial balance in funding urban cleaning services and solid waste management.	In 2040, 68% of municipalities in the national territory have a commitment to ensuring an economic-financial balance of at least 75% between the revenue collected and the expenses for urban cleaning services and solid waste management.
Goal 2: Increase management capacity of municipalities.	Indicator 2: Percentage of municipalities with intermunicipal, micro-regional, or municipal waste management plans.	By 2040, 100% of municipalities will have their integrated waste management plans developed.
Goal 3: Eliminate inadequate final disposal practices and close uncontrolled landfills and controlled dumps.	Indicator 3: Number of uncontrolled landfills and controlled dumps that still receive waste.	Closure of uncontrolled landfills and controlled dumps by 2024.
Goal 4: Reduce the amount of waste and rejects sent to environmentally safe final disposal.	Indicator 4: Percentage of total mass recovered.	Recover 48.1% of the total mass of MSW (municipal solid waste) nationwide by 2040.
Goal 5: Promote social inclusion and economic empowerment of reusable and recyclable materials collectors.	Indicator 5: Percentage of municipalities with collectors who have formal contracts to provide recyclable material management services by collectors' cooperatives and associations.	By 2040, 95% of municipalities that utilize services from collectors and cooperatives should formalize contracts with collectors' cooperatives and associations to provide recyclable material management services.
Goal 6: Increase the recovery of the dry fraction of MSW (municipal solid waste).	Indicator 6: Percentage of recovery of recyclable materials.	Ensure that 72.6% of the population has access to selective collection systems by 2040.
Goal 7: Increase the recycling of the organic fraction of MSW (municipal solid waste).	Indicator 7: Percentage of the total mass allocated for biological treatment.	Recover 13.5% of the organic fraction, in relation to the total mass of MSW (municipal solid waste), by 2040.
Goal 8: Increase the recovery and energy of biogas use from MSW (municipal solid waste).	Indicator 8: Percentage of biogas generated from the organic fraction of MSW (municipal solid waste) that is utilized for energy.	By 2040, over 60% of the biogas generated from anaerobic digestion processes and landfills will be utilized for energy, with the potential to supply electricity to 9.5 million households.
Goal 9: Increase the recovery and energy utilisation through thermal treatment of MSW (municipal solid waste).	Indicator 9: Installed capacity (in MW) in thermal treatment units for MSW (municipal solid waste).	By 2040, the country will have an installed capacity of 994 MW, which would be sufficient to supply electricity to 27 million households.

Source: Prepared by the authors based on information from the National Solid Waste Plan (Ministry of the Environment, 2022).

Final Discussion of Results, Diagnosis, and Recommendations

The National Solid Waste Policy (PNRS) established by Law No. 12.305 (Brazil, 2010), sets specific goals and objectives for individuals and legal entities involved in urban solid waste management. Some of its key purposes include aligning waste management practices with existing laws and regulations, preserving the environment by reducing the use of landfills, and promoting “post-consumer waste reverse logistics.” This law was considered a landmark in environmental legislation, aiming to close sanitary landfills by 2014. However, this target was not met and was extended until 2023. Yet, by 2022, many Brazilian municipalities had not even initiated projects to eliminate the use of dumps and controlled landfills.

This situation is described in the report by the

Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE, 2023), which indicates that areas of inadequate disposal (in dumps, controlled landfills, ditches, waste dumps, among others) received almost 38.9% of the total waste collected in Brazil.

Law 12.305/2010 holds the states, the Federal District, and municipalities account for providing the National Solid Waste Management Information System (SINIR) with essential data about the waste under their jurisdiction. However, a small percentage of states had not submitted their declarations in 2020, which was the last year of SINIR's update. A total of 96.30% of states provided declarations, but only 44.74% of municipalities submitted the required data.

Law No. 14.026 (Brazil, 2010) mandated that the environmentally adequate final waste disposal

should have been implemented by December 31, 2020. However, according to the 2023 ABRELPE Report, 38.9% of urban solid waste still does not have adequate final disposal. Given that Brazil still lacks an adequate waste management system for urban solid waste, it is challenging to plan alternatives that could help reduce or reuse waste, such as recycling, reusing, and other strategies. This also includes incinerating non-recyclable materials to generate energy or using biodigestion to treat organic waste.

When diagnosing Brazil's current urban solid waste management situation, considering adopting a circular economy model, the country's strengths lie in the guidelines provided by laws, decrees, the SINIR, and the National Solid Waste Plan. However, there are still weaknesses that hinder the shift away from the linear model. As pointed out by Assunção (2019), the transition to a circular economy in Brazil faces several barriers and limitations. These include inadequate waste collection coverage, the lack of selective collection, and the persistence of landfills and controlled dumps. These factors obstruct the development of circular economy actions. Therefore, it is crucial to apply control and oversight over the actions and goals established by laws, decrees, and the National Solid Waste Plan to ensure the stakeholders' commitment. The data analysed for the research are not yet updated with the most recent year for this study, 2023. While the ABRELPE Panorama provides data from 2023, the National Solid Waste Information System (SINIR) has only been updated until 2020, highlighting the need to demand transparency and accountability from municipal and state governments regarding these data.

Taking all the facts into consideration, a strategy to promote the circular economy model in Brazil would be to reinforce its concept and importance for the country, as well as for state and municipal governments, businesses, and, primarily, the population. Factors that contribute to the development of a culture for the circular economy include new regulations, plans with goals, effective oversight, and, above all, transparency with data.

Adequate planning is necessary to reduce waste generation, as data from research indicates that Brazil has not been able to decrease the production of these wastes; rather, this generation has been increasing. It is essential to commit to complying with regulations, to oversee, and strengthen actions that involve all stakeholders, as responsibility is shared.

Final considerations

This article aimed to understand the perspective for urban solid waste management in Brazil, considering adopting circular economy models to ensure control and reduction of environmental impacts caused by waste. The objective of diagnosing the current situation of Brazil regarding urban solid waste management was achieved, highlighting that Brazil still faces several problems that need to be addressed to enable the adoption of a circular model.

The diagnosis was carried out based on National Law 12.305 (BRAZIL, 2010) and National Decree 10.936 (BRAZIL, 2022), as well as other data sources such as the ABRELPE Panorama (2023), SINIR data (2024), and the National Urban Solid Waste Plan (Ministry of the Environment, 2022). Thus, the defined specific objectives were achieved by analysing these documents. Following the mentioned analyses, the factors were determined that facilitate and hinder implementing the circular model in Brazil.

For future research, it is recommended to analyse the studies further in the states and municipalities of Brazil to better understand how urban solid waste management is functioning and how each region could enhance this management. Additionally, future studies may consider analysing new data to diagnose whether the goals and regulations are being met, controlled, and supervised.

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