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ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT MODELS IN MUNICIPALITIES OF THE TIETÊ-JACARÉ HYDROGRAPHIC BASIN, SÃO PAULO, BRAZIL

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RESUMO
O presente estudo tem como objetivo avaliar os modelos de gestão de resíduos sólidos urbanos dos municípios pertencentes à Bacia Hidrográfica Tietê-Jacaré, São Paulo, Brasil. A crescente geração de resíduos sólidos urbanos (RSU) no Brasil, que atingiu 79 milhões de toneladas em 2019 e deve chegar a 120 milhões de toneladas em 2050, reforça a necessidade de estratégias sustentáveis de gestão de resíduos. Em meio a essa urgência, o discurso em torno da economia circular ganhou força, oferecendo uma mudança de paradigma para o desenvolvimento sustentável, priorizando a redução, reutilização, reciclagem e recuperação. No Brasil, embora a Política Nacional de Resíduos Sólidos estabeleça uma ordem de prioridade na gestão de resíduos, enfatizando a minimização e a disposição adequada, vários desafios impedem sua plena implementação. Através da coleta de documentos e planos de gestão publicados em sites de instituições públicas e posterior análise de dados secundários sobre saneamento e resíduos sólidos, realizou-se o diagnóstico dos modelos de gestão de resíduos sólidos urbanos vigentes nos municípios pertencentes à Bacia Hidrográfica Tietê-Jacaré. Os resultados mostram que o início da transição de um modelo linear de produção, consumo e descarte para um modelo circular na bacia envolve a superação de obstáculos em termos de gestão, especialmente no que diz respeito a campanhas educativas para a destinação final correta; a implantação de programas de coleta seletiva; o apoio e financiamento a projetos e obras de sistemas de coleta, tratamento e destinação final ou outras ações de gestão; a destinação adequada de resíduos perigosos; e a logística reversa.

PALAVRAS-CHAVE: avaliação, gestão resíduos sólidos, países em desenvolvimento, sustentabilidade, bacia Tietê-Jacaré.

ABSTRACT
The aim of this study is to evaluate the urban solid waste management models of the municipalities belonging to the Tietê-Jacaré Hydrographic Basin, São Paulo, Brazil. The escalating generation of municipal solid waste (MSW) in Brazil, reaching 79 million tons in 2019 and projected to reach 120 million tons by 2050, underscores the imperative for sustainable waste management strategies. Amidst this urgency, the discourse surrounding the circular economy has gained traction, offering a paradigm shift towards sustainable development by prioritizing reduction, reuse, recycling, and recovery. In Brazil, although the National Solid Waste Policy establishes a priority order in waste management, emphasizing minimization and proper disposal, various challenges hinder its full implementation. Through the collection of documents and management plans published on the websites of public institutions and subsequent analysis of secondary data on sanitation and solid waste, a diagnosis was made of the urban solid waste management models in force in the municipalities belonging to the Tietê-Jacaré Hydrographic Basin. Results show that the beginning of the transition from a linear model of production, consumption and disposal to a circular model in the basin involves overcoming obstacles in terms of management, especially with regard to educational campaigns for correct final disposal; the implementation of selective collection programs; support and funding for projects and works on collection, treatment and final disposal systems or other management actions; the proper disposal of hazardous waste; and reverse logistics.

KEY WORDS: assessment, solid waste management, developing countries, sustainability, Tietê-Jacaré basin.

INTRODUCTION

In Brazil, between 2010 and 2019, there was an 18% increase in the annual generation of municipal solid waste (MSW), which increased from 67 million to 79 million tons and it is projected that the annual generation will continue to increase over the coming decades, reaching 120 million tons by 2050 (ABRELPE, 2020). Furthermore, the amount of waste recovered in the country is very low and most of the total generated is sent for final disposal (BRASIL, 2023). This indicates the urgency for public administrations to adapt their solid waste management models to a more circular and sustainable design.

In this context, the debate is growing around the circular economy, which can be understood as a new economic system that replaced the idea of the end-of-life of materials, with alternatives such as reduction, reuse, recycling, and recovery, towards sustainable development (KIRCHHERR et al., 2017). In waste management, promoting the circular economy would involve, for example, environmental education of the population to reduce generation, and the implementation of selective collection and recovery of organic waste, which would also contribute to sustainability.

The relationship between circular economy and sustainability can be seen in several of the Sustainable Development Goals (SDGs) and is largely explored in the literature (ROSA et al., 2023). For example, SDG 12 - Responsible Consumption and Production has goals such as reducing waste generation through prevention, reduction, recycling, and reuse and promoting environmentally healthy waste management (UNITED NATIONS, 2024). Furthermore, organic waste recycling processes such as composting and anaerobic digestion can contribute to SDG 2 (zero hunger and sustainable agriculture) and SDG 7 (clean and affordable energy), for example. In this sense, public managers need to change waste management in their cities by moving toward sustainability and circularity, and implementing better management models.

A management model is understood as managing through a preexisting structure, making the relevant modifications for each organization (FERREIRA et al., 2005). Although the Brazilian National Solid Waste Policy (PNRS) indicates the order of priority in management (non-generation, reduction, reuse, recycling, energy recovery, treatment, environmentally appropriate final disposal of waste), numerous legal, political-administrative, sociocultural, economic and environmental challenges prevent Brazilian municipalities from complying with it (MARTINS, 2017).

The state of São Paulo, despite having municipalities with more structured management models compared to other regions of the country, needs to improve them towards sustainability, given the high daily volume generated in households and the low rates of reuse of solid urban waste, especially the lack of treatment of organic matter (ABRELPE, 2020). Therefore, we chose the Tietê-Jacaré Hydrographic Basin within this state as a case study, considering the authors' experience in this region and access to information as criteria for selection.

Through the collection and analysis of secondary data on sanitation and solid waste from documents and management plans published on the websites of public institutions, we aimed to study the urban solid waste management models of the municipalities that belong to the Tietê-Jacaré Hydrographic Basin, in order to later examine the circularity of these models.

OBJECTIVE

This study aims to evaluate waste management models in municipalities within the Tietê-Jacaré hydrographic basin, São Paulo, Brazil.

METHODOLOGY

Study Area

The Tietê-Jacaré hydrographic basin, also referred to as Water Resources Management Unit (UGRHI) number 13, is located in the central region of the State of São Paulo. It covers a total area of 11,779 km² and includes 34 municipalities, with a population of 1,462,855 residents (IBGE, 2022). The geographical location of the Tietê-Jacaré hydrographic basin and its 34 municipalities (Agudos, Araraquara, Arealva, Areiópolis, Bariri, Barra Bonita, Bauru, Boa Esperança do Sul, Bocaina, Boracéia, Borebi, Brotas, Dois Córregos, Dourado, Gavião Peixoto, Iacanga, Ibaté,

Ibitinga, Iguaraçu do Tietê, Itaju, Itapuí, Itirapina, Jaú, Lençóis Paulista, Macatuba, Mineiros do Tietê, Nova Europa, Pederneiras, Ribeirão Bonito, São Carlos, São Manuel, Tabatinga, Torrinha and Trabiju) is shown in Figure 1.

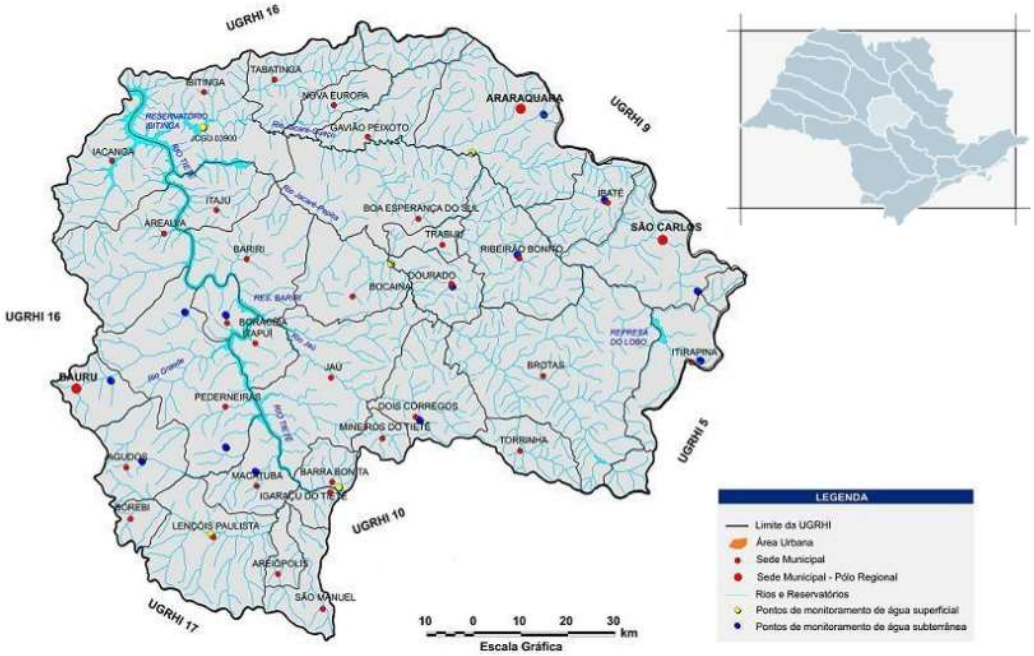

Figure 1: Geographical location of the Tietê-Jacaré hydrographic basin. Source: São Paulo (2018).

Data collection and analysis

This research adopts an exploratory approach that aims to gather qualitative and quantitative data to improve the understanding of household waste management in municipalities that belong to the Tietê-Jacaré Basin (UGRHI 13). Information collected includes identification of municipalities with approved Municipal Plans for Integrated Solid Waste Management (PMGIRS), detection of environmental education programs and initiatives, mapping of municipalities with selective collection and organic waste programmes, as well as identification of technological alternatives used by these municipalities for the environmentally safe final destination and disposal.

The data collection was carried out in 2021, based on official documents and sources such as the websites of the City Halls, Environmental Company of the State of São Paulo (CETESB), Brazilian Institute of Geography and Statistics (IBGE), Infrastructure and Environment Secretariat of São Paulo (SIMA), Integrated Water Resources Management System (SIGRH), and National Sanitation Information System (SNIS). Data from 2015 to 2019 were considered to analyse existing management models in municipalities up to that time.

RESULTS

Taking into account the order of priorities proposed by the PNRS for the management of urban solid waste, from non-generation to environmentally sound final disposal, Table 1 summarises the evaluation of urban solid waste management models in the Tietê-Jacaré Hydrographic Basin between 2015 and 2019.

Table 1. Assessment of household solid waste management in UGRHI 13 between 2015 and 2019. Source: Prepared based on data from Brasil (2021), CETESB (2021), PDEA-TJ (2017), São Paulo (2018), and São Paulo (2021).

Highlighted Points	Assessment
Municipal Plans	85.29% of municipalities have approved PMGIRS.
Management	Between 2015 and 2019: - Efficient: 0% - Inefficient: 50% or more of all municipalities depending on the year.
Environmental education and awareness	- Environmental Education Master Plan approved in 2017. - 85% of the municipalities presented some kind of environmental education initiative. - Recycling, solid waste and conscious consumption stand out among the other themes.
Household waste collection	In 2019: - 87% of municipalities → coverage between 90.1% - 100% of the territory. - 10% of municipalities → coverage between 80.1% - 90%. - 3% of municipalities → coverage between 70% - 80%. Average between 2015 and 2019: Coverage rate of the household waste collection service in relation to the total population of the municipality: 94.97% **Selective Collection:** In 2019: - 44% of the municipalities → did not provide data. - 41% of the municipalities → covered between 90.1% and 100% of the territory. - 9% of municipalities → coverage below 50%. Average between 2015 and 2019: - Rate of material collected by selective collection (except organic matter) in relation to the total amount of household waste collected: 6% - Mass recovered per capita of recyclable materials (except organic matter and waste) in relation to the urban population: 19 kg/inhab./year
Composting	In 2019: Composting Plant Quality Index - IQC evaluated only the composting plants in Andradina, Garça, Ribeirão Grande and São José do Rio Preto.
Final disposal	In 2019: - 85% dispose of within the basin; - 97.06% of final disposal in sanitary landfills with adequate IQR.

Municipal Plans

Of the 34 municipalities in the Tietê-Jacaré hydrographic basin, the PMGIRS was not available for five: Areiópolis, Barra Bonita, Dourado, Mineiros do Tietê, and Trabiju. For the last two, they were still under development according to the Basin Plan (SÃO PAULO, 2018). This represents a significant percentage of approved plans in the studied region (85.3%), and an advance compared to the study conducted by Lima (2017), which identified an approval rate of 62%.

Management assessment

For the designated analysis period, the Waste Management Index (IGR) data, an indicator used to examine the management of solid waste in the cities of São Paulo, was not available for 2015. From 2016 onwards, it was observed that most of the municipalities that belong to UGRHI 13 did not provide information (Figure 2). Of the cities in the region that contributed data, it is worth noting that none of them met the criteria for efficiency according to the index. Instead, more than 50% of the cities were classified as inefficient, depending on the year (SÃO PAULO, 2021).

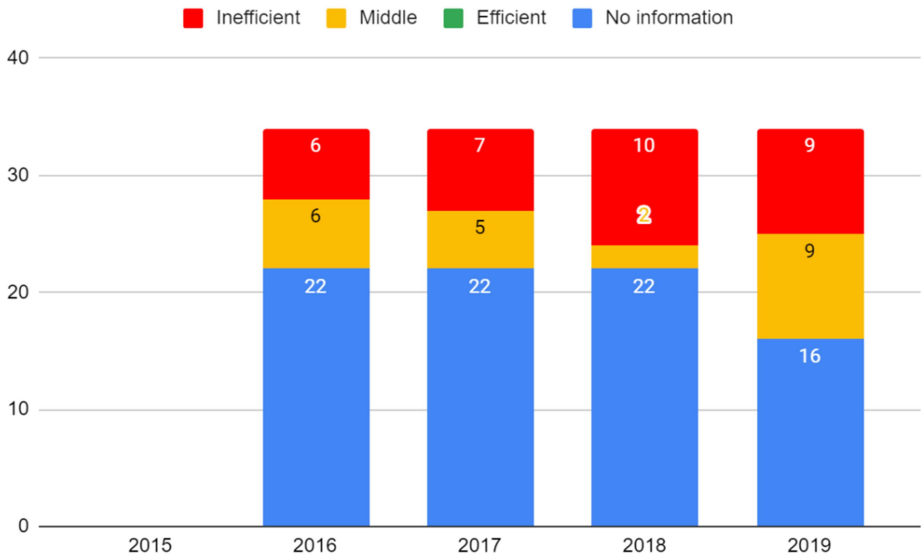

Figure 2: Waste Management Index (IGR) of the Tietê-Jacaré Basin between 2015 and 2019. Source: Prepared using data from São Paulo (2021).

Environmental education and awareness

In 2017, the Tietê-Jacaré Basin Committee approved the Environmental Education Master Plan (PDEA-TJ, 2017) in a plenary session. The objectives of the plan are related to the identification of requirements and the proposal of strategies for environmental education projects and actions.

The plan identified 121 projects and actions related to environmental education in 29 municipalities. Most of these projects were organised by the civil society (34%), which was represented by associations, Public Interest Civil Society Organisations (OSCIP), cooperatives, labour unions and individuals, among others, followed by schools (21%), city halls (19%), public agencies (9%), companies (8%), higher education institutions (4%), conservation units (3%) and Sistema S - Senai, Sesi, Senac, Sesc, Sebrae, Senar, Sest, Senat e Sescoop (2%). The theme of recycling, solid waste, and responsible consumption stands out in contrast to other themes in the environmental education projects identified (PDEA-TJ, 2017).

The main obstacle identified for implementing environmental education actions was the lack of financial resources, as only 30% of the projects received funding. The report also highlighted several other challenges, including the need for trained personnel to work on the projects, planning and logistics related to transportation, acquisition of material resources, publicity and promotion, and ensuring continuity (PDEA-TJ, 2017).

Household waste collection

In 2019, the majority of municipalities had a household waste collection coverage rate exceeding 90.1%, as shown in Figure 3. The average coverage rate of household waste collection services for the period 2015 to 2019, relative to the total population of municipalities, is 94.9% (BRASIL, 2021).

Regarding the collection of dry recyclables, it is important to note that in 2019, data were not available for 44% of the municipalities in the basin. Meanwhile, 41% had a coverage ranging from 90.1% to 100%, and only 9% had a coverage lower than 50%.

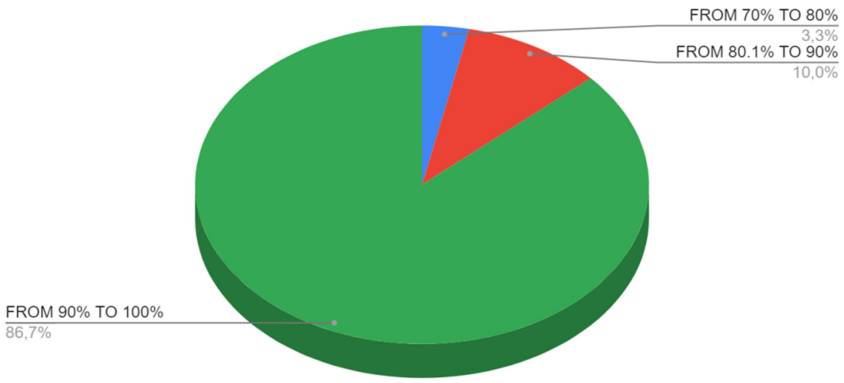

Figure 3: Coverage rate of household waste collection service in UGRHI 13 for the reference year 2019. Source: Prepared using data from Brasil (2021).

Between 2015 and 2019, only 6% of the total household waste collected was dry recyclables gathered through selective collection services (excluding organic matter and rejects). The mass per capita recovered from recyclable materials in relation to the total urban population amounts to approximately 19 kg per inhabitant per year. Figure 4 illustrates that paper and cardboard are the predominant materials recovered in the basin (BRASIL,2021).

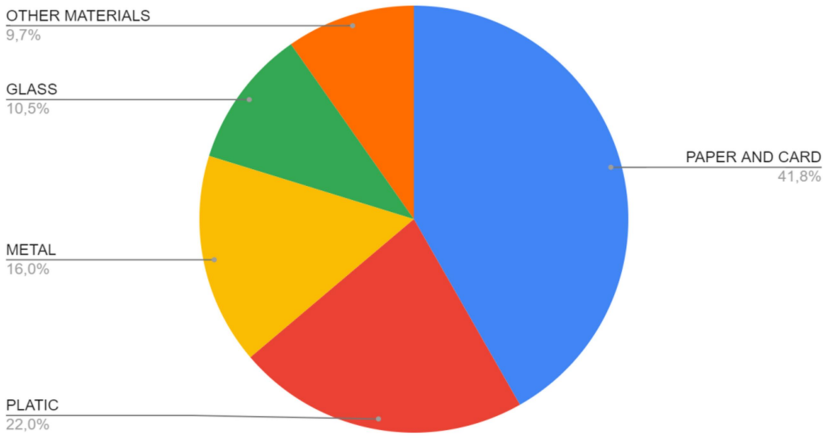

Figure 4: Materials recovered in the basin - average from 2015 to 2019. Source: Prepared using data from Brasil (2021).

Composting

No composting initiatives were identified in the region studied. From 2015 to 2019, the Composting Plant Quality Index (ICQ) only assessed composting plants in the cities of Andradina, Garça, Ribeirão Grande and São José do Rio Preto (CETESB, 2021). This finding is consistent with the broader Brazilian framework, where data from SNIS also show limited efforts to recover organic waste.

Final disposal

According to CETESB (2021), in 2017 and 2018, all the municipalities in the basin disposed of their waste in sanitary landfills with an adequate Landfill Quality Index (IQR). However, this scenario changed in 2019, when the municipality of Boa Esperança do Sul began to have inadequate disposal. The variation of the IQR over the years in the basin is illustrated in Figure 5.

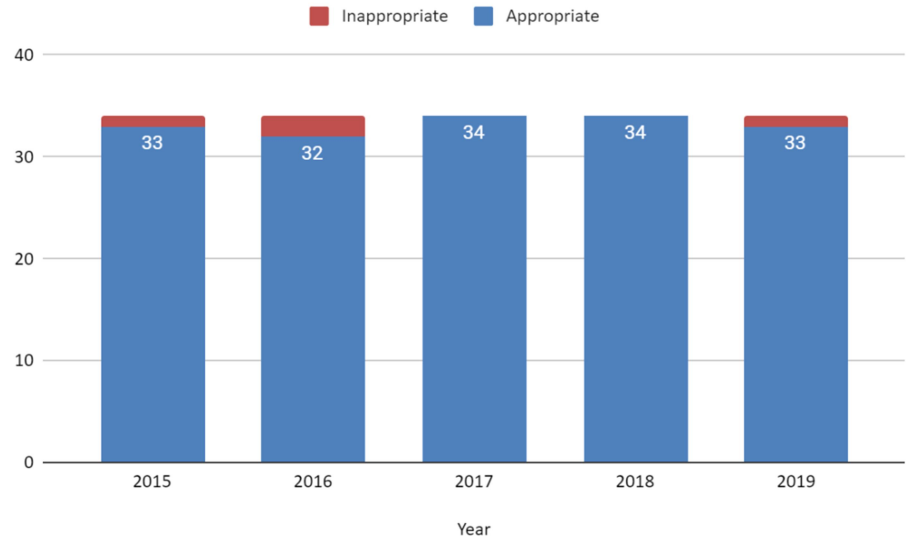

Figure 5: Landfill Quality Index (IQR) for UGRHI 13 between 2015 and 2019. Source: Prepared using data from CETESB (2021).

The rate of municipalities that dispose of waste internally in the basin was 85%. The main challenge in this area was related to the illegal disposal and the management of hazardous waste (SÃO PAULO, 2020). Furthermore, it is important to emphasise that disposing of waste in a licenced landfill does not fully align with the National Solid Waste Policy, which prioritises other methods over landfilling in waste management. Unfortunately, the region studied lacks organic waste recovery initiatives. Consequently, these landfills are receiving waste that should have been directed elsewhere according to legislation.

FINAL CONSIDERATIONS

The analysis of municipal waste management in the Tietê-Jacaré hydrographic basin has revealed significant advances, such as the increase in the number of Municipal Integrated Solid Waste Management Plans (PMGIRS) and the implementation of environmental education projects. However, challenges persist, particularly due to inconsistent data for assessments and the requirement for financial resources to support environmental initiatives. The coverage of household waste collection is substantial; however, the efficiency of the management of these wastes is insufficient. This is evidenced by the low recovery rate of dry recyclable waste in relation to the total amount of household waste collected, as well as the early stage of composting initiatives. Based on the results of the assessment, we conclude that it is essential to allocate resources for environmental education, improve the selective waste collection infrastructure, and implement composting programmes to manage household waste in a sustainable way in the Tietê-Jacaré hydrographic basin.

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