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ELECTRONIC WASTE MANAGEMENT IN CONTAGEM: CHALLENGES AND PROPOSALS FOR A SUSTAINABLE FUTURE

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ABSTRACT

This study analyzes the management of electronic waste in Contagem, Minas Gerais, focusing on innovative reverse logistics actions through public-private partnerships. The research adopts a qualitative approach, based on documentary analysis of federal, state, and municipal legislation, as well as data collected from the Contagem City Hall and the Rotary Club Cidade Industrial. The objectives include outlining the current panorama of electronics management in the municipality, identifying key determining partnerships, and evaluating the effectiveness of reverse logistics initiatives. Methodologically, we conducted a comprehensive literature review, complemented by documentary research and direct contacts with municipal managers and involved partners. The results reveal a management structure based on agreements between the city hall and waste picker associations, as well as an innovative Rotary Club project that combines electronics recycling with professional training for young people. It is concluded that the determining partnerships have the potential to significantly improve electronic waste management in Contagem, although challenges remain regarding the expansion and sustainability of these initiatives. This study contributes to the understanding of electronic waste management practices at the municipal level, providing important insights for public managers and researchers in the field.

Keywords: Electronic Waste, Reverse Logistics, Public-Private Partnerships, Environmental Management, Contagem-MG.

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INTRODUCTION

The technological revolution of the 20th century brought extraordinary advances to humanity, profoundly transforming society in various aspects, from communication to the automation of industrial processes. However, with these advances, new challenges emerged, among them, the growing generation of electronic waste (E-waste), also known as E-scrap. This type of waste, which includes everything from small devices such as cell phones and batteries to large equipment such as televisions and computers, represents one of the greatest environmental and public health challenges of our time (Alhaij, 2007; Catão, 2019; Mansuy et al., 2020; Kanta et al., 2024).

The global scenario of E-waste generation is alarming. According to estimates by Jabbour et al. (2023), about 55.5 million metric tons of E-waste were generated globally in 2020, with projections pointing to an increase to 74.7 million tons by 2030. This exponential growth is directly related to the rapid technological advancement and the increasing accessibility of electronic devices to a larger portion of the global population.

In Brazil, the situation is equally concerning. Approximately 500 thousand tons of E-waste are improperly discarded annually, compromising the environment and public health (Aguiar, 2017; PR, 2024). This inadequate management of E-waste is a growing concern, especially in developing countries. The improper disposal in open-air dumps can release toxic substances such as lead, mercury, and cadmium, which are harmful to both the environment and human health (Panda et al., 2021; 2023). Furthermore, the incineration of these materials results in the generation of toxic gases and fine dust particles, presenting potential risks of air and soil pollution (Bagwan, 2024; Jabbour et al., 2023).

The issue of E-waste is closely linked to the phenomenon of planned obsolescence, a strategy adopted by the industry to limit the useful life of products and stimulate continuous consumption. This practice, associated with the exponential growth of the electronics market, results in an ever-increasing volume of waste (International Labour Organization, 2024; Ahirwar & Tripathi, 2021).

Given this scenario, the present study aims to: 1. Analyze the management of E-waste in Contagem, Minas Gerais, focusing on innovative reverse logistics actions through public-private partnerships. 2. Outline the current panorama of electronics management in the municipality. 3. Identify the main determining partnerships in the management of E-waste in Contagem. Evaluate the effectiveness of reverse logistics initiatives implemented in the municipality. Contribute to the understanding of E-waste management practices at

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the municipal level, providing important insights for public managers and researchers in the field.

This study adopts a qualitative approach, based on documentary analysis of federal, state, and municipal legislation, as well as data collected from the Contagem City Hall and the Rotary Club Cidade Industrial. Through a comprehensive literature review and analysis of local initiatives, we aim to provide a comprehensive view of the challenges and opportunities in E-waste management in Contagem, contributing to the development of more effective and sustainable public policies in this sector.

THEORETICAL FOUNDATION

EVOLUTION OF LEGISLATION ON SOLID WASTE

The management of solid waste, including E-waste, has been a subject of increasing concern and regulation over the past decades, both internationally and nationally. The initial milestone of this legislative evolution can be attributed to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, adopted in 1989. This convention established guidelines for controlling the transport and disposal of hazardous waste, especially in developing countries, which often became destinations for E-waste produced by industrialized nations (Beck, 2010; Kanta et al., 2024; Bilesan et al., 2021; Blumbergs et al., 2022).

In the Brazilian context, the legislative evolution on solid waste began to take shape with the creation of the National Environmental Policy (NEP) by Law No. 6,938/81, which established general guidelines for environmental protection in the country (Brasil, 1981). The Federal Constitution of 1988 consolidated the right to an ecologically balanced environment in its Article 225, introducing shared responsibility between the government and society in environmental preservation (Brasil, 1988).

A significant advancement occurred with the enactment of Law No. 9,605/98, which addresses criminal and administrative sanctions derived from harmful conduct and activities to the environment, also covering the improper management of solid waste (Brasil, 1998). However, the most important milestone in solid waste management in Brazil came with the creation of the National Solid Waste Policy (NSWP) by Law No. 12,305/10. This law established principles, objectives, instruments, and guidelines for integrated management and handling of solid waste, including hazardous waste, assigning responsibilities to generators and the government (Brasil, 2010; Rauber, 2011; Maiello et al., 2018).

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The NSWP introduced fundamental concepts such as shared responsibility for the product life cycle and reverse logistics, which became pillars for E-waste management in the country. Additionally, the law established a hierarchy in waste management, prioritizing non-generation, reduction, reuse, recycling, treatment of solid waste, and environmentally appropriate final disposal of waste (Guanabara et al., 2008).

REVERSE LOGISTICS AND CIRCULAR ECONOMY

Reverse logistics, one of the central concepts introduced by the NSWP, is defined as an instrument of economic and social development characterized by a set of actions, procedures, and means aimed at enabling the collection and return of solid waste to the business sector for reuse, in its cycle or other production cycles, or other environmentally appropriate final destinations (Brasil, 2010; Gurgel et al., 2024).

In the context of E-waste, reverse logistics plays a crucial role as it allows these materials to return to the production cycle, reducing environmental impact and recovering valuable resources. Effective implementation of reverse logistics for E-waste involves creating systems for collection, sorting, disassembly, and recycling, as well as developing technologies for material recovery (Neves et al., 2024).

The importance of reverse logistics was reinforced in 2022, with the inclusion of a specific chapter in Brazilian legislation, demonstrating the growing concern with the correct disposal of E-waste (Catão, 2019). This legislative advancement reflects the need to more effectively address the specific challenges associated with E-waste management.

Reverse logistics is closely linked to the concept of a circular economy, which proposes a regenerative and restorative economic model by design. In the context of E-waste, the circular economy involves designing products for durability, reparability, and recyclability, as well as establishing efficient systems for E-waste collection and processing. This model contrasts with the traditional linear approach of "take-make-dispose," seeking to maximize resource value and minimize waste (Ellen MacArthur Foundation, 2013).

The transition to a circular economy in the electronics sector involves not only changes in production and recycling processes but also a transformation in business models and consumption patterns. This includes promoting practices such as design for disassembly, offering repair and upgrade services, and developing service-based business models instead of ownership (Parajuly et al., 2024).

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E-WASTE MANAGEMENT IN BRAZIL

Despite legislative advances, the practical scenario of E-waste management in Brazil still faces significant challenges. The country is one of the largest producers of E-waste in Latin America, with approximately 500,000 tons of E-waste discarded annually (International Labour Organization, 2024). However, the collection and recycling system is still incipient and uneven, with much of this E-waste not being recycled adequately.

Challenges include the lack of adequate infrastructure for collection and processing, low public awareness about the importance of proper disposal, and the presence of an informal recycling sector that often operates under precarious and unsafe conditions (Alhaij, 2007; Catão, 2019). Furthermore, the complexity and rapid evolution of electronic products make recycling a technically challenging and economically costly process.

On the other hand, E-waste represents a potential source of valuable metals, such as copper, gold, and silver, which can be recovered through sustainable recycling processes (Nithya et al., 2018; 2021). However, recovering these materials is complex due to the heterogeneous composition of electronic equipment and the lack of adequate technologies for their separation and recycling (Marques et al., 2013; Kanta et al., 2024).

Inadequate E-waste management, especially in developing countries like Brazil, where informal recycling predominates, can lead to significant occupational and environmental risks (Xu et al., 2023). Heavy metals, such as mercury, lead, and cadmium, present in many of these devices, are highly toxic and, when improperly disposed of, can contaminate soil, water, and air, posing direct risks to workers involved in handling this waste (Beck, 2010; Alhaij, 2007; Bilbao, 2012; Neves et al., 2024).

In the face of these challenges, innovative initiatives and public-private partnerships have emerged as promising strategies to improve E-waste management in Brazil. These initiatives include creating collection points in partnership with retailers, environmental education programs, and developing more efficient and sustainable recycling technologies. Additionally, collaboration between local governments, companies, and civil society organizations has proven fundamental to the success of these initiatives (Scheren & Ferreira, 2004; Gregório et al., 2023).

In summary, E-waste management in Brazil represents a complex and multifaceted challenge that requires an integrated and collaborative approach. Effective implementation of existing legislation, development of adequate infrastructure, promotion of public

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awareness, and encouragement of technological innovation are crucial elements to advance towards more sustainable and efficient E-waste management in the country.

METHODOLOGY

The methodology adopted in this study is predominantly qualitative, focusing on documentary analysis and exploratory research. Various methods were used for data collection and analysis, as described below:

The first stage of the research consisted of an extensive bibliographic review, involving books, scientific articles, technical documents, legislation, and manuals. The purpose of this review was to deepen the knowledge on the topic of E-waste management, emphasizing aspects such as reverse logistics, public-private partnerships, and environmental management policies. The review allowed for the construction of a robust theoretical framework, essential for contextualizing the study and defining the basis for subsequent analysis.

In addition to the bibliographic review, the research also relied on the collection of documentary data. These data were obtained through official documents, such as federal, state, and municipal legislation, management reports, and other unpublished materials that provide detailed information about waste management practices in Contagem. This approach allowed access to primary information that had not undergone prior analytical treatment, as described by Kripka et al. (2015).

To complement the documentary analysis, direct contacts were made with managers from the Waste Management Secretariat of the municipality of Contagem. These contacts aimed to verify where and how information about the management of non-usable items (such as debris, furniture, tires, and garden trimmings) could be collected, especially through the city's Ecopoints. It is worth noting that the Ecopoints are large sites that serve to collect various types of waste, such as furniture disposal, debris, tires, and tree trimmings.

The analysis of the collected data was conducted qualitatively, allowing for a deeper interpretation of waste management practices in the municipality of Contagem. The focus was on identifying patterns, challenges, and opportunities related to reverse logistics and the sustainability of E-waste management initiatives.

The study also considered the impact of the Global Project by the Rotary Foundation, developed by the Rotary Club Contagem, Cidade Industrial, in the context of E-waste

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management. This project combines electronics recycling with the professional training of young people, contributing to the economic and social development of the Bela Vista neighborhood community. The methodology involved analyzing documents and reports provided by the Rotary Club, as well as visits to the project's implementation sites.

Finally, the research is classified as exploratory, as defined by Gil (2017), as it sought to align familiarity with the study topic, delineating more explicitly the addressed theme and providing the possibility of formulating hypotheses for future studies.

LEGISLATION FOR SOLID AND E-WASTE MANAGEMENT IN MINAS GERAIS AND CONTAGEM

Regarding the base legislation for Urban Solid Waste (USW) management, particularly through reverse logistics at the national level, Federal Decree No. 10,936, dated January 12, 2022, was issued, revoking previous federal decrees No. 7,404/2010 and No. 9,177/2017. This decree published in 2022 regulated the NSWP (Law 12,305/2010) and incorporated the principles of isonomy, actions that were previously regulated by the mentioned revoked decrees. Previously, Decree No. 7404/2010 regulated the NSWP, established the Steering Committee for the implementation of Reverse Logistics Systems, and listed instruments for implementing reverse logistics systems, such as regulations, sectoral agreements, and terms of commitment.

In 2017, Federal Decree No. 9,177 was published, aimed at resolving issues related to those who should sign sectoral agreements on reverse logistics. This decree, through isonomy, stipulated that manufacturers, importers, distributors, and retailers of products, as well as the generated waste, packaging, subject to reverse logistics, that were not signatories of a sectoral agreement or term of commitment with the Union, would be required to structure and implement reverse logistics systems. Such obligations were also the responsibility of the signatories and adherents of sectoral agreements signed with the federal government.

On February 9, 2024, in Minas Gerais, the State Secretariat for Environment and Sustainable Development published Normative Deliberation No. 249/2024, dated January 30, 2024, a normative act that defined guidelines for the implementation, operation, and monitoring of reverse logistics systems in the state of Minas Gerais. This deliberation established the commitment of stakeholders to structure reverse logistics systems, setting goals for manufacturers, importers, distributors, and retailers of household electronic

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products, their components and packaging; portable batteries; automotive, industrial, and motorcycle lead-acid batteries; fluorescent lamps, sodium vapor, mercury vapor, and mixed light lamps; lubricant packaging; general packaging of plastic, paper, cardboard, metals, and glass; expired or unused household medications and their packaging; unusable tires.

In the municipality of Contagem, in addition to following the norms established by Law No. 12,305/2010 – NSWP and state normative rules, the municipality also delineates its activities through Law No. 18,031/2009, which brings the State Solid Waste Policy. The Municipal Law No. 3,676/2003 addresses Selective Waste Collection (Contagem, 2003). The municipality of Contagem also has Municipal Law No. 188/2014, which addresses the Policy and guidelines for Cleaning in the Municipality of Contagem (Contagem, 2014). This municipal legislation includes Chapter VII, which deals with the reverse logistics system and characterizes the following waste for management through reverse logistics: I - pesticides, their waste and packaging, as well as other products whose packaging, after use, constitutes hazardous waste; II - batteries; III - tires; IV - lubricating oils, their waste and packaging; V - fluorescent, sodium vapor, mercury vapor, and mixed light lamps; VI - electronic products and their components.

In addition to Law 12,305/2010, which addresses the National Solid Waste Policy, relevant norms can be cited that intertwine through definitions of means of final disposal and management by waste categories and common specificities that each possesses. Thus, some norms can be mentioned, such as National Environmental Council (NEC) Resolution No. 416, dated September 30, 2009, which deals with the Disposal of Unusable Tires. NEC Resolution No. 362, dated June 23, 2005, addresses the Collection and final disposal of used or contaminated lubricating oil. Interministerial Ordinance (Ministry of Mines and Energy and Ministry of Environment and Climate Change) No. 4, dated December 28, 2023, defines minimum collection percentages for used or contaminated lubricating oils collected, for the four-year period 2024-2027.

On the other hand, NEC Resolution No. 401, dated November 4, 2008, establishes criteria and standards for the environmentally appropriate management of batteries. Similarly, (Brazilian Institute of Environment and Renewable Natural Resources) Normative Instruction No. 8, dated September 30, 2012, lists procedures related to the control of receipt and final disposal of batteries.

Federal Law No. 14,785, dated December 27, 2023, addresses research, experimentation, production, packaging, labeling, transportation, storage, marketing, use,

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import, export, final disposal of waste and packaging, registration, classification, control, inspection, and monitoring of pesticides, environmental control products, their technical products, and related products. NEC Resolution No. 465, dated December 5, 2014, provides criteria for the environmental licensing of establishments receiving pesticide packaging and related products.

The Resolution of the National Council of Metrology, Standardization and Industrial Quality No. 01, dated July 5, 2016, provides for the approval of lamp imports. Federal Decree No. 10240, dated February 12, 2020, addresses the Reverse logistics of household electronic products and their components. Federal Decree No. 10388, dated June 5, 2020, addresses the Reverse logistics of expired or unused household medications, for human use, industrialized and compounded, and their packaging. Normative Instruction No. 8, dated July 20, 2021, specifies the cases of mandatory issuance of the Environmental Authorization for the Transportation of Hazardous Products for interstate transportation of E-waste.

Decree No. 11,043, dated April 13, 2022, approved the National Solid Waste Plan. Decree No. 11,300, dated December 21, 2022, instituted the glass packaging reverse logistics system. Federal Decree No. 11413, dated February 13, 2023, instituted the Reverse Logistics Recycling Credit Certificate, the Packaging Structuring and Recycling Certificate, and the Future Mass Credit Certificate, within the scope of reverse logistics systems referred to in Article 33 of Law No. 12,305, of 2010. Ministry of Environment and Climate Change (MECC) Ordinance No. 1,011, dated March 11, 2024, established the standard model of the annual results report, within the scope of reverse logistics systems according to Article 33 of Law No. 12,305, of 2010.

MECC Ordinance No. 1,018, dated March 19, 2024, provides for the procedures for the registration and qualification of cooperatives and associations of recyclable and reusable material collectors in the National Information System on Solid Waste Management (SINIR). Law No. 14,260, dated December 8, 2021, establishes incentives for the recycling industry; and creates the Support Fund for Recycling Actions and Investment Funds for Recycling Projects. Decree No. 12,106, dated July 10, 2024, regulated the tax incentive for the recycling production chain established in Law No. 14,260, dated December 8, 2021. Finally, MECC Ordinance No. 1,102, dated July 12, 2024, regulated provisions of Decree No. 11,413, of 2023, within the scope of general packaging reverse logistics systems, and the criteria for qualifying managing and generating entities.

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The next section presents relevant data and facts that align with the justifications for choosing the analysis region of this research in Minas Gerais.

MESORREGION MINAS GERAIS

To clarify the choice of the analysis region for this research, it is important to describe relevant data that align with the objectives of this research. Thus, it can be mentioned that the Brazilian Institute of Geography and Statistics (IBGE), made the geographical division of the state of Minas Gerais into 12 mesoregions, which encompass 66 microregions since 1989. In 2017, the IBGE created a new Brazilian regional framework, with new geographical divisions called intermediate and immediate geographical regions, IBGE (2024).

The Mesoregion of Belo Horizonte in Minas Gerais is composed of 24 municipalities, namely: Belo Horizonte, Betim, Brumadinho, Caeté, Confins, Contagem, Esmeraldas, Ibirité, Igarapé, Juatuba, Lagoa Santa, Mário Campos, Mateus Leme, Nova Lima, Pedro Leopoldo, Raposos, Ribeirão das Neves, Rio Acima, Sabará, Santa Luzia, São Joaquim de Bicas, São José da Lapa, Sarzedo, and Vespasiano. The Metropolitan Mesoregion of Belo Horizonte in Minas Gerais, as shown in Figure 1, which shows a map of Minas Gerais, was chosen for this research because, in addition to being one of the twelve mesoregions of the State of Minas Gerais, according to IBGE (2024). Furthermore, socioeconomic issues such as an HDI of 0.756 guided the choice of this territorial cut for this research.

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Figure 1 - Map of Minas Gerais showing its municipalities grouped into micro-regions, which in turn are grouped into meso-regions.

Source: IBGE (2024)

The economy of Contagem is based, according to IBGE(2024), mainly on commerce (30.65%) and industry (25.71%), with a HDI of 0.756, its Gross Domestic Product (GDP) R$ 36,479,764.96 and GDP per capita R$ 54.136,41.

According to IBGE (2024), during the IV Commercial, Industrial and Agricultural Congress, held in Belo Horizonte in 1935, the proposal to concentrate mining industrial activities in a specific area emerged. This proposal aimed to overcome the economic backwardness of Minas Gerais and represented a bet on the path of industrialization. Due to this political orientation, in 1941, Governor Benedito Valadares (1933-1945) inaugurated the system of industrial districts that would also be built in Minas Gerais over the following decades. Thus, the Industrial Park was created, which was later named Cidade Industrial, in Contagem, near the capital. It is worth noting that this was the first and main measure resulting from this new policy.

Later in 1970, through public sector initiative, the second major industrial expansion project in Minas was initiated, located in Contagem. The municipal law no. 911, dated April 16, implemented the Contagem Industrial Center, known by the acronym “CINCO”. This project determined the installation of 100 new factories and the creation of 20 thousand new jobs, using resources from National Bank for Economic and Social Development (40%) and also from the Municipality of Contagem (60%). In 1974, the distribution center of the Central Supply of Minas Gerais (CEASA) was created, and also the emergence of the true commercial center of the city, currently Eldorado. The CEASA distribution center is the most

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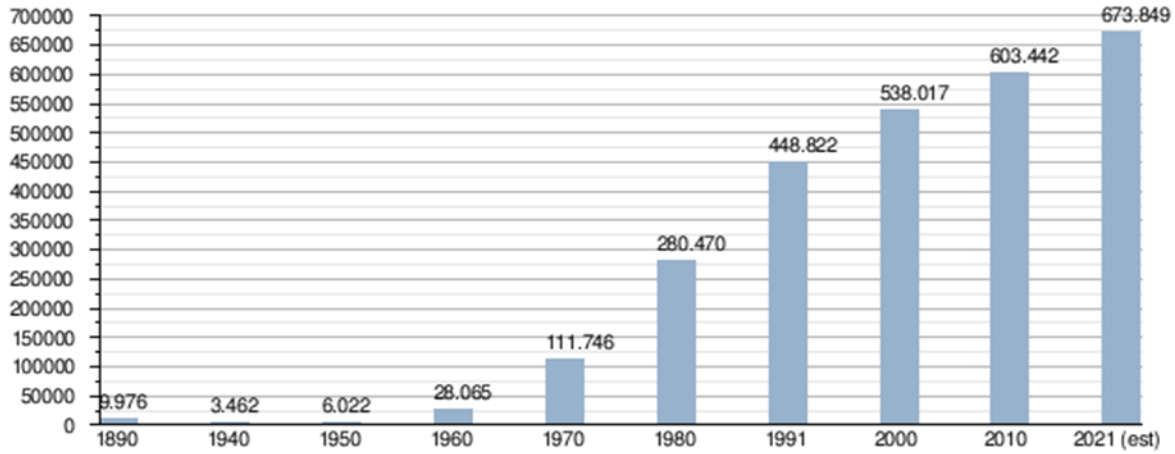
diversified in Brazil, ranking second nationally in the sale of horticultural products. (IBGE, 2024)

In the Metropolitan Mesoregion of Belo Horizonte, the city of Contagem was chosen for the research and is part of the Belo Horizonte Microregion. According to IBGE (2024), Contagem is a municipality in the state of Minas Gerais, Southeast Region of the country. It belongs to the Metropolitan Mesoregion of Belo Horizonte in Minas Gerais, the Belo Horizonte Microregion, and is the third most populous municipality in the state, with a census of 621,865 inhabitants, according to the 2022 census, as indicated by the demographic evolution in Figure 2.

Figure 2 - Demographic evolution of Contagem (1890-2021), in inhabitants.



Source: IBGE (2024)

According to IDE-Sisema (2024), Contagem is among the cities in Minas Gerais that manage waste without adhering to management through the legal instruments of Public Consortia, with a total of 34% of Minas Gerais municipalities managing solid waste by their own means, without partnerships with other municipalities, as shown in Figure 3.

Thus, the next section presents the partnerships between the Municipality of Contagem and associations for the final disposal of E-waste.

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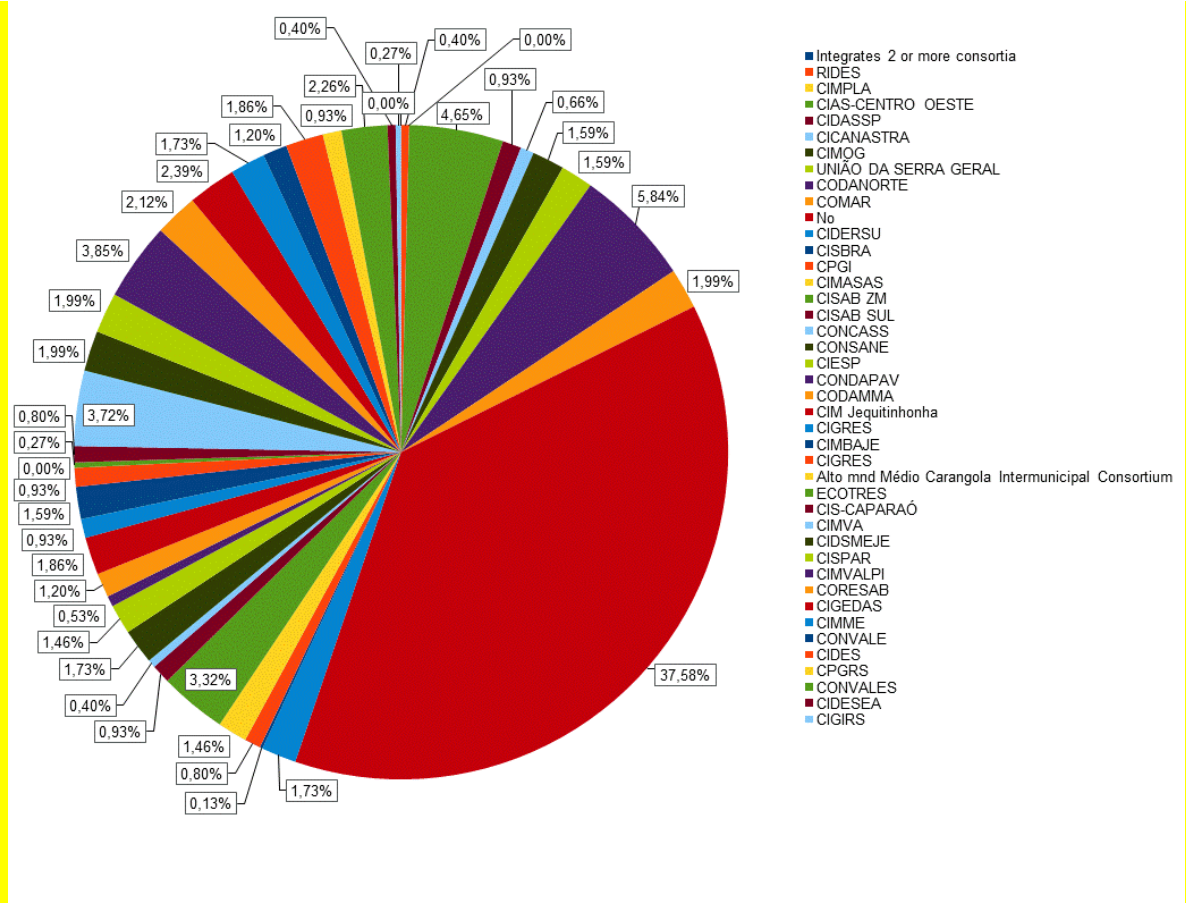
Figure 3 - Solid Waste Consortiums in Minas Gerais and Non-Consortium Municipalities - IDE-Sisema Platform.



Source: Created by the authors (2024)

Where: RIDES - Integrated Sustainable Development Region; CIMPLA - Multi-Finality Intermunicipal Consortium ff Araxá Plateau; CIAS-CENTRO OESTE - Intermunicipal Landfill Consortium of the Midwest of Minas Gerais; CIDASSP - Intermunicipal Consortium for the Sustainable Development of the São Sebastião do Paraíso Region; CICANASTRA - Serra da Canastra Intermunicipal Consortium; CIMOG - Baixa Mogiana Intermunicipal Consortium; UNIÃO DA SERRA GERAL - General Saw Union; CODANORTE - Multipurpose Intermunicipal Consortium for Sustainable Environmental Development fn the North of Minas Gerais; COMAR - Alto Rio Pardo Multipurpose Public Consortium; CIDERSU - Intermunicipal Consortium for Sustainable Regional Development; CISBRA - Intermunicipal basic Sanitation Consortium of the Circuito das Águas Region; CPGI - Public Consortium for Integrated Management; CIMASAS - Intermunicipal Consortium of Municipalities of the Alto Sapucaí Microregion; CISAB ZM - Intermunicipal Consortium for Basic Sanitation of the Zona da Mata of Minas Gerais; CISAB SUL - Intermunicipal Consortium for basic Sanitation of the Zona Da Mata of Minas Gerais; CONCASS - Intermunicipal Consortium for Urban Solid Waste Management; CONSANE - Regional Basic Sanitation Consortium; CIESP - Intermunicipal Specialties Consortium; CONDAPAV - Public Consortium for the Development of the Alto Paraopeba and Vertentes Microregion; CODAMMA - Development Consortium for the area of Municipalities in the Mantiqueira Microregion; CIM Jequitinhonha - Jequitinhonha Multipurpose Intermunicipal Consortium; CIGRES - Intermunicipal Solid Waste Management Consortium; CIMBAJE - Baixo Jequitinhonha Multipurpose Intermunicipal Consortium; CIGRES - Intermunicipal Solid Waste Management Consortium; ECOTRES - Intermunicipal Solid Waste Treatment Consortium; CIS-CAPARAÓ - Multisectoral Intermunicipal Consortium for the Surroundings of Caparaó; CIMVA - Vale do Aço Multipurpose Intermunicipal Consortium; CIDSMEJE - Intermunicipal Consortium for Sustainable Development of médio Jequitinhonha; CISPAR - Intermunicipal Public Consortium for Sustainable Development of Alto Parnaiba; CIMVALPI - Vale do Piranga Multisectoral Intermunicipal Consortium; CORESAB - Central Minas Gerais regional basic Sanitation Consortium; CIGEDAS - Intermunicipal Consortium for Sustainable Environmental Management and Development of Strains; CIMME - Intermunicipal Multipurpose Consortium of Médio Espinhaço; CONVALE - Intermunicipal Consortium for Regional Development of the Rio Grande Valley; CIDES - Intermunicipal Public Consortium for Sustainable

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Development of the Triângulo Mineiro and Alto Paranaíba; CPGRS - Public Solid Waste Management Consortium; CONVALES - Consortium for Development and Enhancement of Municipalities; CIDESEA - Intermunicipal Public Consortium for Sustainable Development of the Triângulo Mineiro and Alto Paranaíba; CIGIRS - Intermunicipal Consortium for Integrated Solid Waste Management.

PARTNERSHIPS BETWEEN ASSOCIATIONS AND THE MUNICIPALITY OF CONTAGEM

Throughout the municipal administration, the municipality of Contagem establishes partnerships to make waste management increasingly efficient, as an example to assist in the sorting stage of the municipal selective collection program, the Rede Solidária de Contagem Association (Coopercata) and the Association of Autonomous Recyclable Material Collectors of Contagem (Asmac). Through Notice 13737077 dated August 13, 2021, Asmac signed a Term of Commitment in the Qualification Procedure for Associations and Cooperatives of Recyclable Material Collectors in Contagem (Contagem, 2024).

These public services are managed, in Contagem, by the Municipal Secretariat for Environment and Sustainable Development. Both Asmac and Coopercata are organizations constituted by low-income and socially vulnerable people who seek, in waste disposal activity, an important support point for sustaining their dignity (Contagem, 2024).

In partnership with the Municipality of Contagem and directly linked to the Rotary Club in the youth training project, the Bela Vista Neighborhood Community Association, (Ascobev) is an association that supports the E-waste management project in Contagem. This association was regulated by Law No. 22,329, dated 11/11/2016, as it was declared of public utility, founded on 9/1/1983, headquartered in the Municipality of Contagem, it is an entity with legal personality, private law, non-profit, with an indeterminate duration. Its main purpose is to promote social mobility and the social well-being of the communities involved through the support of private or public initiatives (Contagem, 2024).

According to the website, the Municipality of Contagem informs that it renewed, on August 21, 2023, the service provision contract with recyclable material associations. This renewal expanded the Municipal Selective Collection Program from 63 to 71 neighborhoods in the city, as well as the incorporation of another vehicle into the fleet that provides the service. This partnership between the Municipality and the associations of Autonomous Recyclable Material Collectors – Asmac and the Rede Solidária de Contagem – Coopercata, currently benefits more than three hundred people who are part of the family nucleus of the 80 associated collectors. This action demonstrates the importance of such partnerships in municipal management, as they affect not only waste management but also families involved in recycling and final disposal processes in general (Contagem, 2024).

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The expansion of selective collection was also extended to the neighborhoods Pedra Azul and Xangrilá, in the National Region; and in the neighborhoods Eldorado, Glória, Jardim Eldorado, Novo Eldorado, and Santa Cruz, in the Eldorado Region. Since 2002, this program has been part of the socio-environmental public policies actions of the Secretariat for Environment and Sustainable Development, consolidated in 2015, through the Municipal Selective Collection Plan. This municipal plan foresees that by 2036 all neighborhoods in the municipality will be served by selective collection, just as conventional collection already serves all neighborhoods (Contagem, 2024).

In conjunction with Ascobev, the Municipality of Contagem used the former carpentry warehouse of the municipality for waste storage. However, in 2023, formally through an agreement with Ascobev, it began using a 300-meter warehouse where E-waste is recycled and used through a cooperation agreement. In this location, waste such as donated notebooks and electronic material used in the course managed by National Service for Industrial Training (Senai) and Rotary Club are received. Some parts are used in other equipment for resale within the community. The income resulting from the parts is reverted to the Bela Vista Neighborhood Residents Association, which is non-profit, generating digital inclusion for underprivileged individuals who gain access to information technology through the project (Contagem, 2024).

MOVEMENT OF E-WASTE IN MINAS GERAIS

The SINIR platform uses indicators of shared management of Urban Solid Waste (USW) to display waste management data in the country. As can be seen in Figure 4, the municipality of Contagem predominantly uses recycling as the final disposal method among the listed waste final disposal methods in the research, which include composting, incineration, recycling, and energy recovery (SINIR, 2024).

Figure 4 - Mass of solid waste by type of treatment, per year.

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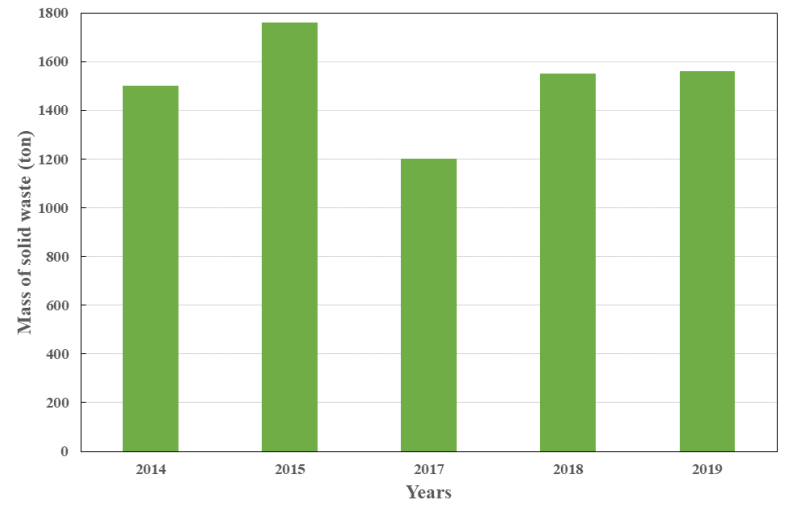

Source: Created by the authors from SINIR (2024)

Considering that recycling was identified as the most used final disposal method in Contagem during the years of investigation between 2014 and 2019 by the Brazilian national system SINIR, it is important to highlight the characteristics of this final disposal method. According to Gregório et al. (2023), recycling processes help minimize the environmental and social impact of generated waste, and waste picker cooperatives emerge as an alternative means to reduce the impacts of waste accumulation, as well as a source of income for the people who form the cooperatives.

According to Barros (2012), recycling is processed through the reinsertion into the economic system of part of the material and/or energy of what would become waste destined for landfill or another irregular disposal method. Recycling allows for the reduction of natural resource use by processing waste for use as raw material in the production of goods, i.e., by substituting virgin raw material.

The next section discusses actions from the course for young people in conjunction with the Municipality of Contagem, Senai, and Rotary Club Cidade Industrial with a central focus on the final disposal of electronics through recycling, both through the practical activities of students and the actions developed by Ascobev.

ROTARY CLUB CIDADE INDUSTRIAL PROJECT - CONTAGEM-MG

In consultation with the Presidency of the Rotary Club Cidade Industrial operating in 2023/2024, the project aims to provide basic knowledge of electronics, robotics, and avionics to young people aged 16 to 18 living in the Bela Vista neighborhood community and the Belo Horizonte region. This project, in conjunction with the Contagem City Hall and

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Senai, seeks to train young people in activities related to the final disposal of E-waste through recycling, which develops creative capacity through activities such as assembling low-cost devices that can improve people's quality of life. Examples of possible developed devices include motorized wheelchairs, presence sensors, alarms, among others. The sale of these devices aims to generate income for recycling and also for the Residents' Association. The young apprentices gain knowledge that may inspire them to pursue a career in the technology field. (Rotary Club Contagem, 2024)

The project uses, in the course, parts of donated electronic equipment and carries out activities involving electronics, enabling practices related to the recognition of electronic components, interpretation of electronic circuits, measurement (resistance, voltage, and electric current). Activities also include the use of electronic measuring instruments, design of electronic circuit layouts, practice of etching phenolic boards in ferric chloride solution, soldering components on Printed Circuit Boards (PCB), performing electrical calculations, correctly recognizing electrical quantities, programming microcontrollers, using PC simulators, among other skills that can be developed through course activities. In the course, students produce equipment, and this activity can generate income for recycling and direct benefits for the Bela Vista Community Association. (Rotary Club Contagem, 2024)

Furthermore, the project enables the implementation of environmental education for young students through classes and the reuse of E-waste parts, as well as the reduction of the environmental liability of Contagem society. Framework 1 indicates the program descriptions. These descriptions were presented by the presidency of the Rotary Club Cidade Industrial. (Rotary Club Contagem, 2024)

Framework 1 – Program of the Rotary Club Cidade Industrial Project - Contagem-MG

Criterion	Method	Frequency	Beneficiaries
Health The Bela Vista neighborhood hosted the "Dump," an open-air landfill in Contagem, for decades. More than 3,000 residents have no income. The growth of the Community Association's income will increase medical, psychological, and physiotherapy assistance already provided to residents of the neighborhood and surroundings.	Increase in the Association's income with the growth of E-waste recycling and the production of electronics during the technical training course. Environmental education for young people will create a multiplier effect on hygiene within families.	Permanent	Community residentes
Economic Development	The training of young people will have a significant impact on family income generation	Permanent	Community residents

Source: Rotary Club (2024)

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The classes managed by the project in partnership with the Rotary Club, Senai, Contagem City Hall, and Ascobev began in 2022. Thus, the result of this project, through the specialization course, graduated the first two classes in July 2023. Subsequently, two classes were completed in August 2024, with a total of 33 (thirty-three) certified students in each of these classes, meaning 132 (one hundred and thirty-two) young people were benefited in the municipality of Contagem by this program. (Rotary Club Contagem, 2024)

Despite the significant number of graduates, there are still 7 (seven) students pending certification in each of the classes. Thus, it is up to the project managers to analyze what impediments are present so that these young people can complete the requirements to receive the certificate and use it in the job market. Even with this number of students pending graduation in the project, the result of professional training and implementation of environmental education was significantly positive, given a total student graduation rate of 82.5% and only 17.5% of students pending certification. (Rotary Club Contagem, 2024)

MANAGEMENT OF E-WASTE IN CONTAGEM

MUNICIPAL CONTEXT

Contagem, one of the most populous municipalities in the state of Minas Gerais, is part of the Metropolitan Region of Belo Horizonte and stands out as an important industrial and commercial hub. This characteristic significantly contributes to the generation of E-waste in the region, making the management of these materials a crucial challenge for municipal administration.

The waste management in Contagem is governed by a set of legislations that follow national and state guidelines, such as Law No. 12,305/10 (National Solid Waste Policy) and State Law No. 18,031/09. Additionally, the municipality has specific regulations, such as Law No. 3,676/03, which regulates selective collection, and Law No. 188/14, which defines urban cleaning policy and reverse logistics (Contagem, 2003; 2014).

PUBLIC-PRIVATE PARTNERSHIP MODEL

The municipality of Contagem has adopted an E-waste management model based on public-private partnerships, which stands out for its innovative and inclusive approach. This model is characterized by two main types of partnerships: a) Agreements with Waste Picker Associations: The Contagem City Hall has established agreements with two important waste picker associations: Cooperative of Autonomous Waste Pickers and

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Association of Recyclable Material Collectors. These partnerships aim not only at the proper collection and processing of waste but also at the social and economic inclusion of the waste pickers, aligning with the social sustainability principles advocated by the National Solid Waste Policy. Through these agreements, the associations receive logistical and financial support from the city hall to carry out the collection, sorting, and appropriate disposal of E-waste. This model not only contributes to the efficient management of E-waste but also generates employment and income for a vulnerable segment of the population. b) Rotary Club Cidade Industrial Project: A particularly innovative initiative is the project developed by the Rotary Club Cidade Industrial in partnership with the city hall. This project combines electronics recycling with the professional training of young people, creating a solution that simultaneously addresses environmental and social issues. The project involves the collection of E-waste and its disassembly by socially vulnerable young people, who receive technical training in this process. In addition to promoting the proper disposal of E-waste, this initiative offers opportunities for professional qualification and insertion into the job market for these young people.

CHALLENGES AND OPPORTUNITIES

Despite significant advances, E-waste management in Contagem still faces several challenges: a) Infrastructure: The need to expand and modernize the infrastructure for the collection, sorting, and processing of E-waste is an ongoing challenge, especially considering the rapid increase in the volume of these materials. b) Public Awareness: There is still a significant gap in public awareness regarding the importance of proper electronic disposal. Educational and awareness campaigns are essential to increase community participation in collection programs. c) Private Sector Engagement: Although there are promising partnerships, there is room for greater involvement of the private sector, especially from electronics manufacturers and retailers, in implementing more comprehensive reverse logistics systems. d) Financial Sustainability: Ensuring the long-term economic viability of E-waste recycling initiatives is a challenge, considering the costs associated with the collection, processing, and proper disposal of these materials. e) Technology and Innovation: The constant evolution of electronic products demands continuous updating of recycling and material recovery techniques, requiring investments in research and development (Wang et al., 2017; 2021; Yilmaz & Koyuncu, 2023).

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On the other hand, these initiatives also present significant opportunities: a) Job and Income Generation: Partnerships with waste picker associations and projects like the Rotary Club create employment and income opportunities for vulnerable groups. b) Recovery of Valuable Materials: Proper recycling of E-waste allows for the recovery of precious metals and other valuable materials, contributing to the circular economy. c) Improvement of Municipal Image: Efficient E-waste management can position Contagem as an innovative and environmentally responsible municipality. d) Development of Local Expertise: Ongoing initiatives can lead to the development of specialized knowledge and skills in E-waste management, potentially transforming Contagem into a reference center in this area. e) Expansion of Partnerships: The success of current initiatives can attract new partners, both from the public and private sectors, expanding the reach and effectiveness of E-waste management programs.

Thus, E-waste management in Contagem demonstrates a promising model based on public-private partnerships and innovative initiatives. Although there are significant challenges to overcome, the opportunities for sustainable development, social inclusion, and technological advancement are considerable. The continuous improvement and expansion of these initiatives can position Contagem as an example of efficient and sustainable E-waste management, with the potential to inspire similar practices in other Brazilian municipalities.

RESULTS AND DISCUSSION

The analysis of E-waste management in Contagem revealed a complex scenario, characterized by innovative initiatives and persistent challenges. The results obtained through documentary research and direct contacts with municipal managers and involved partners allowed the identification of the main aspects of E-waste management in the municipality. E-waste management in Contagem is based on a public-private partnership model, notable for its inclusive and innovative approach. The main structures identified are the agreements with waste picker associations, such as Cooperative of Autonomous Waste Pickers and Association of Recyclable Material Collectors, in addition to the Rotary Club Cidade Industrial project. This model demonstrates alignment with the guidelines of the NSWP, especially concerning the social inclusion of waste pickers and the promotion of reverse logistics. The approach adopted by Contagem reflects a trend observed in other

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studies, such as Gregório et al. (2023), which highlight the importance of public-private partnerships in efficient E-waste management.

The evaluation of the effectiveness of the reverse logistics initiatives implemented in Contagem revealed promising results. Data collected from the Contagem City Hall indicate a significant increase in the volume of E-waste collected since the implementation of the partnerships. This result is in line with observations by Neves et al. (2024), pointing to the effectiveness of well-structured reverse logistics systems in improving E-waste collection. The partnerships with waste picker associations have contributed to job and income generation for a vulnerable segment of the population, aligning with the social sustainability objectives of the NSWP. This aspect is particularly relevant considering the findings of Alhaij (2007) and Catão (2019), which emphasize the importance of social inclusion in waste management. The Rotary Club Cidade Industrial project has proven particularly effective in combining electronics recycling with the professional training of young people, creating a dual-impact solution. This innovative approach reflects the recommendations of Parajuly et al. (2024) regarding the need to integrate social and economic aspects into E-waste management.

Despite the advances, the research identified significant challenges in E-waste management in Contagem. The processing and storage capacity of E-waste is still insufficient to meet the growing demand. This challenge is consistent with the observations of Kanta et al. (2024), who point to the need for investments in infrastructure for efficient E-waste management. There is a need to expand environmental education efforts to increase public awareness about the proper disposal of E-waste. This aspect is corroborated by Bilesan et al. (2021), who emphasize the importance of environmental education in the effectiveness of waste management programs. Although there are promising partnerships, the engagement of the private sector, especially large companies and electronics retailers, is still limited. This observation aligns with the conclusions of Blumbergs et al. (2022), which highlight the need for greater private sector involvement in the reverse logistics of E-waste. The lack of advanced technologies for recycling complex electronic components limits the efficient recovery of valuable materials. This challenge is consistent with the observations of Nithya et al. (2018; 2021) regarding the technical complexity of E-waste recycling.

When comparing Contagem's initiatives with other cases reported in the literature, it is observed that the municipality is aligned with best practices in terms of social inclusion and public-private partnerships. The study by Jabbour et al. (2023) highlights the

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importance of these partnerships in efficient E-waste management, corroborating the approach adopted in Contagem. However, in terms of infrastructure and recycling technology, the municipality still faces challenges similar to those observed in other Brazilian urban centers, as pointed out by Marques et al. (2013). The Rotary Club Cidade Industrial project stands out as a particularly innovative initiative, as it is uncommon to find similar projects that combine electronics recycling with professional training for young people in other municipalities. This approach aligns with the recommendations of Parajuly et al. (2024) on integrating social and economic aspects into E-waste management.

The comparative analysis also revealed that Contagem is ahead of many Brazilian municipalities in terms of formalizing the participation of waste pickers in E-waste management. This aspect is particularly relevant considering the observations of Catão (2019) on the importance of social inclusion in waste management. However, compared to international initiatives, such as those reported by Wilhelmsson (2022) in European countries, Contagem still has a way to go in terms of recycling technology and private sector engagement.

The results of this study have important implications for the development of public policies for E-waste management. The effectiveness of the public-private partnership model suggests that this approach can be replicated in other municipalities, with adaptations to local realities. This observation aligns with the recommendations of Gregório et al. (2023) on the importance of partnerships in E-waste management. The need to expand infrastructure and the geographical coverage of initiatives indicates the importance of continuous investments in this sector, as pointed out by Kanta et al. (2024). The success of the professional training project associated with electronics recycling points to the possibility of integrating waste management policies with social and economic development programs, reflecting the recommendations of Parajuly et al. (2024). The persistence of challenges in public awareness underscores the need for long-term educational policies focused on E-waste management, as emphasized by Bilesan et al. (2021).

In summary, the analysis of E-waste management in Contagem reveals a scenario of significant advances, particularly in terms of social inclusion and innovative partnerships. However, persistent challenges in infrastructure, technology, and private sector engagement indicate the need for ongoing efforts and substantial investments to achieve truly sustainable E-waste management. The lessons learned in Contagem can serve as a

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valuable model for other Brazilian municipalities, contributing to the development of more effective and comprehensive public policies in E-waste management.

CONCLUSIONS

The study on E-waste management in Contagem, Minas Gerais, achieved its objectives by analyzing innovative reverse logistics actions through public-private partnerships, outlining the current landscape of electronics management in the municipality, identifying key determining partnerships, and evaluating the effectiveness of the implemented initiatives. The research revealed a complex scenario characterized by significant advances and persistent challenges.

The management model adopted in Contagem, based on public-private partnerships, proved to be effective and innovative, aligning with the guidelines of the National Solid Waste Policy. The main structures identified include agreements with waste pickers' associations: Cooperative of Autonomous Waste Pickers, Association of Recyclable Material Collectors and the Rotary Club Cidade Industrial project, which stand out for their inclusive and dual-impact approach. These initiatives resulted in a significant increase in the volume of E-waste collected, job and income generation for waste pickers, and professional training promotion for young people in vulnerable situations.

The evaluation of the effectiveness of reverse logistics initiatives revealed promising results, although significant challenges persist, mainly related to limited infrastructure, the need for greater public awareness, insufficient private sector engagement, and a lack of advanced technologies for recycling complex electronic components.

Compared to other initiatives reported in the literature, Contagem's model stands out for its emphasis on social inclusion, aligning with international best practices in terms of public-private partnerships and inclusion of waste pickers. However, in aspects such as infrastructure and recycling technology, the municipality still faces challenges similar to those observed in other Brazilian urban centers.

The implications for public policies include the need to expand partnerships, greater investment in infrastructure, strengthening environmental education programs, implementing economic incentives, and fostering technological innovation. The study contributes to understanding E-waste management practices at the municipal level, providing important insights for public managers and researchers in the field.

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The lessons learned in Contagem can serve as a valuable model for other Brazilian municipalities, highlighting the importance of integrated approaches that combine social, economic, and environmental aspects in E-waste management. Although the municipality has made significant progress, it is evident that continuous effort and substantial investments are necessary to achieve truly sustainable and circular E-waste.

Future studies could explore the long-term impact of these initiatives and investigate strategies to overcome the identified challenges, particularly regarding private sector engagement and the development of innovative recycling technologies.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Edgar Vladimiro Mantilla Carrasco: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Marina Ferreira Lapa de Oliveira:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Guilherme Antonio Michelin:** Writing – review & editing, Data curation, Conceptualization. **Matheus Barreto de Góes:** Writing – review & editing, Data curation, Conceptualization.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

Data will be made available on request.

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