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Challenges in municipal solid waste management- A comparative case study between selected metropolitan areas Brazil and Portugal

Abstract

This research was aimed at analysing the management of urban solid waste in Brazil and Portugal, with an emphasis on the metropolitan areas of Lisbon and Porto and the Recife/PE/Brazil Metropolitan Area. An exploratory research project was conducted with a survey of secondary data, technical visits to institutions and companies in the waste sector, and a comparative analysis of the situation in the areas studied. In Portugal, the management of municipal solid waste in the period before 1995 was predominantly municipal, which evolved into a consortium of municipalities with the entry of Portugal into the European Union in 1986. The country adapted its legislation to the EU Directives, and from 1997, the waste sector suffered a boost with the adoption of the first Strategic Plan for Urban Solid Waste, which was constituted by 40 public waste management companies that associated several municipalities, and some of them also had the state's share in their share capital. However, due to the lack of economic scale of some of these companies, there were mergers, and at the end of 2010, the total number of companies was 23, grouped into entities of a multi-municipal character (when the state enters into the composition of the share capital of the society) and inter-municipal (only constituted by municipalities), currently responsible for the management of waste in Portugal. In Brazil, the National Solid Waste Policy was approved by law in 2010, establishing lines and guidelines for integrated waste management with defined time targets. However, it is not yet fully implemented because about 45% of municipalities still dispose of waste at dumping sites. With regard to the municipalities of the Recife Metropolitan Area, the disposal of waste has already been environmentally appropriate since 2019. According to 2022 data from Brazilian Association of Public Cleaning and Special Waste Companies, the average rate of selective collection in the country is approximately 4%. The research results reveal that Brazil needs to increase selective collection, eliminate approximately 3,600 existing landfills and finally regulate urban solid waste services. While in Portugal, management is well organized as a result of the implementation of PERSU in 1995, there are still challenges to be overcome in order to meet the goals set in the New Legislative Framework, which have not yet been achieved. The specificities and the context are obviously different between the countries, drawing attention to the difference in effectiveness in the implementation of public policies edited by the legal diplomas of the two countries for solid waste management.

Keywords: Municipal solid waste (MSW) Management; Public policy; Metropolitan Areas of Recife (Brazil), Porto and Lisbon (Portugal), circular economy

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Introduction

Portugal, officially the Portuguese Republic, is a State in Southern Europe, founded in 1143, occupying a total area of 92,212 Km^2. Portugal is divided between the mainland regions, whose territory is divided: North, Centre, Metropolitan Areas of Lisbon and Porto, Alentejo and Algarve and the insular region of Madeira and Azores,[1] autonomous regions of the country. According to the 2021, Census, Portugal has 10.6 million inhabitants and a demographic density of 115.4 inhabitants/km^2, with most of its population living along the coastline.[2]

Brazil, on the other hand, is a Federative Republic, with a geopolitical division composed by 5 regions and 26 states and the Federal District, where the capital Brasília is located. It has 5,570 municipalities and an area of 8,510, 345,540 km^2, with a population of 213,317,639 inhabitants.[3] It should be noted that 4,923 of the Brazilian municipalities are small, with less than 50,000 inhabitants. Only 87 municipalities have a population greater than 300,000 inhabitants. Another aspect to be aware of is that there are thousands of small municipalities spread across the country that are very far from each other, which prevents the sharing of infrastructure in a consortium for solid waste management. In Brazil, there are 13 metropolitan areas, including Recife in the State of Pernambuco, in the Northeast Region.

A Figure 1 illustrates the map of Brazil and the Metropolitan Area of Recife and the map of Portugal with Metropolitan Areas of Lisbon and Porto.

The specificities and situation are evidently different between the countries; however, what draws attention is the difference in effectiveness in the implementation of public policies enacted by the legal diplomas of the two countries for the management of solid waste.

1. Solid waste management comprises a set of strategic decisions and actions aimed at finding solutions, involving public policies, instruments, and institutional and financial aspects.[4] The demographic growth, the intensity of human activities, and the improvement in the standard of living are responsible for the exponential increase in the amount of waste generated.[5] Urban solid waste generation will increase worldwide, from 2 billion tonnes/year in 2016 to 3.4 billion

tonnes in 2050, with most of this increase being observed in low-income countries, where generation is expected to triple.[6] International pressures in both developed and developing countries motivate the implementation of proper sustainable waste management.[7]

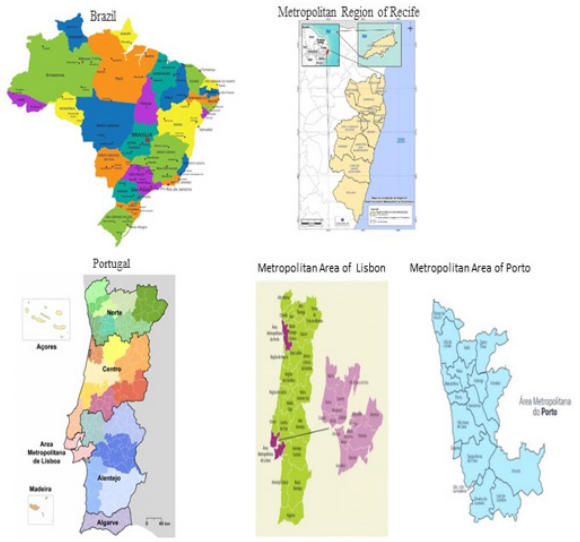

Figure 1 Maps: Brazil, RMR and Portugal AM Lisbon and Porto.

Source: Adapted: Google, 2020; Gama 2020; UOL, 2022.

Brazil established its regulatory instruments for waste management in 2010, with the National Solid Waste Policy (PNRS), and its implementation, even after more than 10 years, has not yet been effective.[8] If compared with other countries, such as the countries of the European Union, whose Directive adopted in 1975 influenced the specific policies or instruments aimed at the sustainable management of waste in the Member States, for example France (1975), Germany (1986), Spain (1998, and Portugal (1997). In addition, with the US, which adopted the law in 1965, and Japan in 1970.

Solid wastes are by-products of anthropic activities and can be classified by origin and their physical, chemical, and biological characteristics. In turn, the treatment of urban solid waste can be understood as a set of physical, chemical, and biological processes that aim to reduce the polluting load on the environment and reduce the health impacts, as well as aiming at the economic utilization of waste (JUCÁ et al, 2013).

Sanitary landfills, when they receive MSW with organic matter, can be considered an anaerobic digestion treatment technology, according to the physical, chemical, and microbiological processes that occur inside them with the generation of biogas.[9]

The current great objective in waste management, materialized in the policies adopted in Europe, the USA, Japan, and Canada, but also in Brazil and many other developing countries, is to move towards a society of recycling and zero waste, that is, waste is a potential resource that is out of place. Thus, the objective is to put all waste in its place of use, constituting the circular economy, in order to preserve natural resources and reduce polluting emissions to the environment.

This article aims to make a comparison between the public policies for integrated solid waste management in the two countries.

Materials and methods

The exploratory research method was used with the collection of secondary data in documents, technical visits to institutions and companies in the waste sector of the two countries, and a comparative analysis of the situation in the studied areas was conducted.

Results and discussion

The results obtained and the discussion on waste management in Portugal and Brazil are below.

Portugal and Brazil: solid waste management

A summary of data from both countries are presented in Table 1, according to official sources, such as IBGE in Brazil and INE in Portugal, for the population. Waste data by ABRELPE and SNIS in Brazil and ERSAR and APA in Portugal. General data on countries according to the World Bank.

Table 1 General data and comparative solid waste from Brazil and Portugal

Data		Brazil	Portugal
Waste Data(**)	Population (2021)	213 317 639	10 344 802
	MSW per capita (kg/inhab. day)	1.07	1.4
	Collection coverage rate	92.10%	100%
	Recycling rate	2.20%	41%
	% MSW in damping sites	30.40%	0%
	Annual per capita cost with waste management	US$ 24,37	US$ 104,80
Country data (*)	GDP per capita	US$ 6 796,00	US$ 22 437,00
	GNI per capita	US$ 7 850,00	US$ 22 000,00
	HDI	0.765	0.864

* Data on countries World Bank Data Report - 2020 (The World Bank (2021). World Development Indicators, (database), https://databank.org)

**** Waste data:** Brazil – SNIS (2019) and ABRELPE (2021); Portugal: ERSAR, 2020 (Annual Report on Water and Waste Services in Portugal – Vol 1. ERSAR), RARU/APA (Annual Report on Urban Waste 2021).

Solid waste management policy in Portugal

Solid waste management in Portugal has had a real boost since the country's entry into the European Union, Portugal has developed its legal system in the waste sector and established its strategic plans for waste management. In the 1990s, management was carried out in a traditional, predominantly municipal manner, with legislation restricting public sector activities, insufficient resources, and municipalities without plans or, when they existed, were generalists.

In 1995, there were 341 dumping sites in the 278 Portuguese municipalities,; 5 composting plants; and 13 controlled landfills (a euphemism for dumps with operations similar to sanitary landfills). In 1997, the Strategic Plan for Urban Solid Waste (PERSU) in 1997 was approved This established guidelines and targets for the period between 1997 and 2005, which culminated in the closure of all dumps, and the creation of 40 multi-municipal and inter-municipal MSW management systems (MSW management entities), replacing municipal management with 278 municipal entities, as well as the construction of waste recovery and treatment infrastructure and the increase in multi-material selective collection. The economic scale of the established systems soon proved to be insufficient, leading to mergers between waste management systems. In 2005, the system consisted of 8 composting plants, 2 incinerators with energy recovery, and 32 sanitary landfills.[10] When proceeding with the balance of the achievement of the objectives and goals of the first PERSU. A large deviation was found, which determined its revision in 2006, called

PERSU II (2006-2014), in which it provided for the increase in the construction of new units of mechanical and biological treatment and organic recovery of waste to achieve the goal of diverting these materials from the landfill. As well as reinforcing equipment for the recovery of the multi-material fraction of waste, to meet recycling targets, which are increasingly demanding. In 2009, there were fusions of waste management companies in Portugal, rising from 29 to 23 management companies (inter-municipal and multi-municipal companies formed by municipalities and by municipalities and the State in the shareholdings of social capital), that are responsible for the treatment and valorisation of waste (called systems on high).

However, the success achieved with the EU management policy convinced the Member States that the targets for recycling could be more demanding for the period from 2104 to 2020. These new targets forced the revision of PERSU II, implemented through PERSU 2020, which presented measures based on principles of efficiency and valuing waste as a resource, prioritizing action upstream of the value chain, and the integration of the Urban Waste Prevention Program and in 2021 the PERSU 2030 with a focus on the period 2022 to 2035.In this review, measures were established to significantly increase selective collection and recycling, as well as to provide more efficient urban waste management systems and infrastructure. The transformation of the waste sector in Portugal was successful, not only because of the organization, but, in particular, because the measures were always accompanied by financial resources adequate to the challenge, with the participation of the EU and the Portuguese State, in the different phases, in the amount of more than 3.5 billion euros, at current prices, Table 2.

Of this total invested in the sector, around 2,000 million euros came from non-reimbursable EU grants (lost funds). According to the APA, the Portuguese Environment Agency, in 2021, $5.31x10^3$ tons of waste was generated, with a per capita generation of 1.4 kg/inhab./year, 100% undifferentiated and selective collection. INE data indicate that in the period from 1995 to 2011, the population variation had a growth of 3.3%, while the production of waste was 62%. In the period from 2011 to 2021, there was a decrease in the number of inhabitants of 2.7%, but production increased by 1.8% (Table 3).

Table 2 Investment on the waste sector with PERSU at current values in euros

PHASE	Period	CAPEX (2022)	€/inhab	€/t	MSW (t)
PERSU	1996-2000	1 644 900 000 €	164.77 €	78.02 €	21 082 927
PERSU I	2001-2006	528 000 000 €	50.96 €	18.65 €	28 305 550
PERSU II	2007-2014	948 820 000 €	89.81 €	26.40 €	35 934 164
PERSU 2020	2014-2022	376 960 000 €	36.22 €	9.32 €	40 455 785
PERSU 2030	2022-2030	475 000 000 €	45.24 €	-	-

Sources: INE, Portugal e Pordata.

Table 3 Population/Solid Urban Waste Variation – MSW (1995 to 2021)

Description	Unit	1995	2011	2021
Population	Hab.	10 300 376	10 637 346	10 344 802
Population variation		+ 3,3%		- 2,7%
Production of MSW	103 t	3 207	5 184	5 311
		-		
MSW production variation		62%		1,8%

Source: Adapted INE (1995, 2021).

These results showed the trend of increasing the production of urban solid waste (RSU) recorded in recent years, contrary to the target of reduction in production, which is ratified in the annual reports of the Portuguese Environment Agency (APA) and summarized in Figure 2, in which can be observed the variation of the total production of RSU in millions of tons and per capita daily generation. In the graph in Figure 2, it can be seen that from 2011 to 2013, there was a decrease in the production of waste and, consequently, a lower per capita waste generation, but from 2014, the recovery of waste production started. The decline was a conjectural consequence of the economic crisis that broke down in Portugal and the intervention of the Troika, with an austerity plan that narrowed the economy and consumption. According to APA,[11] in Continental Portugal, in the period from 2019 to 2021, there was a 1% increase in the production of waste, which was registered at approximately 5,04 million tons of waste, representing an increase of 0.6% compared to 2020, resulting from the resumption of economic growth due to the removal of the restrictions applied in the COVID 19 pandemic. The waste per capita output was 511 kg/hab. year.

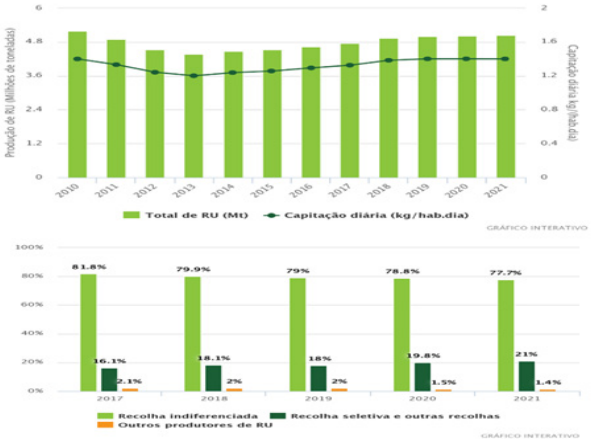

Figure 2 Variation in waste production in mainland Portugal.

Fonte: APA, 2022.

Waste collection is carried out indifferently and selectively in eco points, including in special circuits and eco centres, for four fractions of material:

(i) Glass

(ii) Paper/cardboard

(iii) Packaging (collected through the yellow eco point)

(iv) Bio-waste.

From 2000 to the present, there has been an increase in selective collection. In fact, according to data from INE (until 2001) | INE; APA/MA (up to 2014) | INE (from 2015) - IACSB (up until 2001) - Statistics of Municipal Wastes (up till 2014) - Stats of Urban Waste (up from 2015), it turns out that in 2000 only 3.3% of the wastes were collected selectively. In 2005 it rose to 9%; in 2010 it was 14.5%, and in 2015, it was 15.5%. In 2020, the selective collection rate was 21.5%, increasing to 22.5% in 2022. In the same period, undifferentiated collection experienced a decrease proportional to the increase in the selective collection. In order to meet recycling targets, there has been an increase. With regard to the fraction subject to reuse preparation and recycling, between 2008 and 2011, there was little progress, between 2011 and 2015, a significant increase, however, the years 2016 and 2017 were marked by a stagnation, which is followed in 2018, by a slight growth, a trend that continued in 2019. For the year 2020, there is a substantial decrease in the fraction subject to preparation for reuse and recycling, this is possibly due to the protocols of the health authorities, arising from the pandemic situation of COVID 19, which guided to the non-realization of the differentiated collection and the stop of the mechanized units, and the MSW should be disposed of in landfills or incinerated in energy recovery plants. Causing a reversal in the priority and hierarchy defined in the national waste management policy.

Final destination of urban waste in mainland Portugal

For the final destination, investments adopted by the European Union and the Portuguese Government (Table 2) allowed the construction of the infrastructure park for the treatment and recovery of waste, as shown in Figure 3.

Type of infrastructure	Nº
Waste Sorting Plant	30
Mechanical Treatment Plant	6
Mechanical Biological Treatment	19
Biological Treatment of selective coletion of bio-waste	5
Refuse Derived Fuel Plant (RDF)	5
Incineration with energy recovery	2
Sanitary Landfills	34

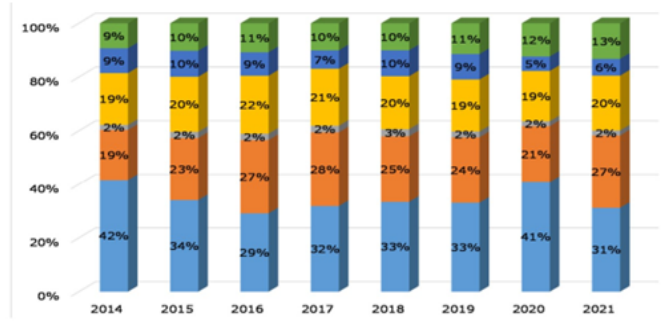

Figure 3 Waste treatment infrastructure and evolution of their final destination in Portugal.

Source: Adapted RARU 2022.

The evolution of the destination of waste in the period from 2014 to 2021 is illustrated in Figure 3, in which it can be seen that in period there was a reduction in landfill disposal, which grew again in 2020. However, in 2021 there was a reduction, contrary to the situation in 2020, when the Covid-19 pandemic brought a greater disposal in landfills, according to the guidelines of the health authorities, reversing the hierarchy logic of the waste management system for a short period.

In 2021, according to APA,[12] 31% of waste was sent directly to landfills; 27% mechanical-biological treatment, 2% selective organic recovery; 20% energy recovery; 6% mechanical treatment, 13% multi-material recovery (recycling). In 2020, there was an increase of 8% compared to 2019, in waste deposited directly in landfills, an increase that is largely justified by the guidelines and recommendations for waste management in a situation of the COVID-19 pandemic.

Regulation of municipal solid waste (MSW) in Portugal

In Portugal, public water supply activities, urban wastewater sanitation and urban waste management constitute public services of a structural nature, essential to the general well-being, public health and collective security of the population, to economic activities and to the protection of the environment that are controlled by the Regulatory Entity of Water and Waste Services - ERSAR.

Under the terms of the Law, ERSAR is responsible for ensuring the regulation and supervision of the public water supply (PW), urban wastewater sanitation (WW) and municipal solid waste management (MSW) sector, regardless of state or municipal ownership of the respective systems. In addition, the management model adopted, be it direct provision of the service, delegation of the service or its concession.[13]

Economic Regulation aims to guarantee efficient and socially sustainability (admissible) tariffs for the population, in the logic of the paying user, without prejudice to the economic and financial sustainability of the managing companies (MC). The economic regulation carried out by ERSAR is a tariff supervision mechanism that approves for each MC the nominal value of gate fee to be applied in each year, depending on the specificity of each one of them. It also includes the evaluation of the investments to be made by the companies to meet the established goals.[14]

Fulfilment of EU targets

As for meeting the targets established by EU and Portuguese legislation, the country does not fully comply with expectations, and in 2020, due to the Covid-19 pandemic, the divergence was accentuated. Indeed, regarding the prevention of waste generation, it was observed that the target of 410 kg/inhabitant year was 513 kg, a figure almost 25% higher. The diversion of organic matter from landfills has a target of 35% based on 1995 production. Portugal sent 45% to landfills in 2019, before the pandemic, and 53% in 2020, with the pandemic in place. The preparation for recycling provided for the target of 50%, but Portugal showed 41% in 2019, before the pandemic, and 38% in 2020 with the pandemic, which shows the pernicious effect of the disease on the objectives.

In addition to the targets established by the Portuguese Government for the year 2025, based on the results for 2019, it considers a 5% reduction in waste production per inhabitant, 55% in preparation and reuse and recycling, and a 35% reduction in landfill disposal. Table 4 shows the comparison of the established goals and the results obtained in 2021.

Table 4 Comparison between 2025 targets and results obtained in 2021

Goals	Goal for 2025 phase to 2019	Result in 2021
Per capita production reduction	5	1
Production per capita Kg/hab. year	488	513
Preparation for reuse and recycling %	32	55
Deposition reduction in sanitary landfills	35	53

Author: adapted from APA 2022.

These results suggest that there is a challenge for Portugal in order to reach the targets, even purging the effect of the COVID-19 pandemic. It suggests that it is not just the injection of more financial means for new infrastructures, because the country is well covered with them, but a paradigm shift in waste management by each person and each institution, in the correct separation at source, combining inspection and penalty (aggravated fees) to defaulters or incentives to those who carry out the correct separation at source.

The Lisbon Metropolitan Area - LMA

LMA is a set of municipalities in a region located in the center-south of Portugal, with an area of 3 001 km² and 2 870 208 inhabitants, which generates approximately 4.0 x 10^3 t/year of waste. Its population density is 956.4 inhab./km². It is the second most populous region and the fifth most extensive region in the country. The LMA encompasses 18 municipalities in Greater Lisbon and the Setubal Peninsula. The municipalities/municipalities that contain the LMA are the following: Alcochete, Almada, Amadora, Barreiro, Cascais, Lisbon, Loures, Mafra, Moita, Montijo, Odivelas, Oeiras, Palmela, Seixal, Sesimbra, Setúbal, Sintra and Vila Franca de Xira.

Of the 23 Urban Waste Management Systems (SGRU, in Portuguese) in Portugal, 3 serves the LMA, as follows:

VALORSUL, which serves 5 municipalities in the AML and adjacent ones, namely: Alcobaça, Alenquer, Amadora, Arruda dos Vinhos, Azambuja, Bombarral, Cadaval, Caldas da Rainha, Lisbon, Loures, Lourinhã, Nazaré, Óbidos, Odivelas, Peniche , Rio Maior, Sobral de Monte Agraço, Torres Vedras, Vila Franca de Xira. The served population of the total municipalities or municipalities is approximately 1 614 698 inhabitants, 2.26 x10^6 t/year, in an area: 3 391 km².

VALOSUL has a treatment infrastructure of 2 landfills; 1 Organic Valorization Plant; 1 Energy Valorization Plant and 2 Transfer Stations, according to APA,[11] in 2022 around 0.79x10^6t/year of waste were treated.

AMARSUL, serves nine municipalities of the LMA: Alcochete, Almada, Barreiro, Moita, Montijo, Palmela, Seixal, Sesimbra and Setúbal, in an infrastructure that contains 2 Landfills; 2 Mechanical and Biological Treatment Units; 1 Mechanical Treatment Unit and 1 Sorting Station.[12]

TRATOLIXO serves four municipalities in the LMA: Sintra, Oeiras, Cascais and Mafra, with 858 477 inhabitants, treating approximately 0.47x10^6 t/year, in an infrastructure of 1 Landfill; 1 Mechanical and Biological Treatment Unit; 1 Mechanical Treatment Unit and 1 Sorting Station.[12]

Porto metropolitan area

The Porto Metropolitan Area is a Portuguese sub-region located in the northwest of the country, belonging to the North Region, made up of 18 municipalities, namely: Espinho, Gondomar, Maia, Matosinhos, Oliveira de Azeméis, Paredes, Porto, Póvoa de Varzim, Santa Maria da Feira, Santo Tirso, São João da Madeira, Trofa, Vale de Camba, Valongo, Vila do Conde, Vila Nova de Gaia. It has a total extension of 2 040 km², 1 737 395 inhabitants in 2021, with a generation of 2.43x10^6 t/year of waste and a population density of 844 inhabitants per km². It is serviced by 5 of the 23 waste management systems - SGRU, as follows:

LIPOR serves an area of 646 m², with a total of 978 052 inhabitants, receiving about 0.52x10^6 t/year of waste from the eight municipalities of Greater Porto, namely: Espinho, Gondomar, Maia, Matosinhos, Porto, Póvoa de Varzim, Valongo and Vila do Conde, the existing infrastructure is composed of 1 Landfill; 1 Organic Valorization Plant; 1 Incinaration with Energy Recovery and 1 Sorting Station.

SULDOURO, which serves Santa Maria da Feira and Vila Nova de Gaia, has an infrastructure of 2 Landfills; 1 Mechanical and Biological Treatment Unit and 1 Sorting Station where receives about 0.21x10^6 t/year of waste.

RESINORTE, which serves the municipalities of Santo Tirso and Trofa and in addition to adjacent ones, totalling 900 279 inhabitants, in an infrastructure with an area of 8 031 km², consisting of 4 Landfills; 1 Mechanical and Biological Treatment Unit; 2 Mechanical Treatment Unit and 4 Sorting Stations, which bring about 0.40 x10^6 t/year of waste.

ERSUC serves Coimbra, Aveiro, Oliveira de Azeméis, São João da Madeira, Vale de Cambra and adjacent municipalities, covering a population of 928 372 inhabitants and an area of 6 694 km², in an infrastructure of 2 Landfills; 2 Mechanical and Biological Treatment Units; 2 CDR Production Units and 2 Sorting Stations, treating 0.43x10^6 of waste.

AMBISOUSA serving Paredes and other 5 neighbouring municipalities, totalling a population of 328 019 inhabitants, which produce around 0.15x10^6 t/year of MSW, in an infrastructure of 2 Landfills and 2 Sorting Stations, with an area of 767 km².

As stated before, all these waste management systems are regulated by ERSAR (regulatory authority).

Solid waste management policy in Brazil

In Brazil, Law 11.445/2007[15] established the National Sanitation Policy (NSP), bringing a paradigm shift, when it established that the scope of the issue of environmental sanitation goes beyond sewage treatment, water supply, and rainwater drainage, including urban cleaning and solid waste management).[4]

It also highlights as urban cleaning a set of activities, infrastructures and operational installations for the collection, transport, waste transfer, treatment and final destination of municipal solid waste (MSW).[15] In turn, the National Solid Waste Policy – PNRS, instituted by Law No. 12 305/2010, brings the concept of integrated solid waste management, defining it as: "a set of actions aimed at finding solutions for waste solid. Then, in order to consider the political, economic, environmental, cultural and social dimensions, with social control and under the premise of sustainable development"[16] and defined the closure of dumps in August 2012, which did not actually occur more than 10 years after the PNRS.

Regulation of urban solid waste in Brazil

The new sanitation framework established by Law No 1406/2020, brings new deadlines for gradual closure of dumping sites, until 2021 for metropolitan regions and until 2024 for municipalities

with a population of less than 50,000 inhabitants. Adequate disposal of waste, a requirement that is ensured financial sustainability by charging for services and creates the National Agency for Water and Basic Sanitation - ANA, to formulate standard guidelines for the regulation of public basic sanitation services, with the States, in a decentralized way, responsible for their regulation.[17]

In 2022, by Federal Decree nº 11,043/2022, instituted the main instrument of the National Waste Policy, the National Solid Waste Plan (Planares, in Portuguese) with a horizon of 2024 to 2040. Which brings the guidelines, goals, strategies and actions to modernize the management of solid waste in the country, in order to put into practice, the provisions of Law No. 12,305/2010.

Planares main goals are related to the elimination of dumps and controlled landfills by 2024; recovery of the organic fraction through biological treatment systems; recovery of the dry fraction of recyclables through recycling processes and energy recovery and use through thermal treatment. To achieve the goals, according to ABRELPE,[18] thirty billion BRL (6.000 million euros) in investment will be needed by 2040.

Final destination of urban waste in Brazil

In Brazil, 82, 664, 312 tons of MSW were generated in 2021, of which 39.5% still have inadequate disposal in landfills. With a per capita generation of 1.07kg/hab./day, a coverage of 93.04% in conventional collection, 75.01% of the municipalities carry out some form of selective collection,[19] which, however, it is incipient for the objectives of the PNRS, accounting for only between 3 and 4% of the waste generated. It is worth mentioning that the generation of MSW in the country was also directly influenced by the COVID-19 pandemic during 2020. There was a significant increase in generation due to new social dynamics that, in a good part of the daily disposal of waste, started to happen in the residences and selective collection suspended in many municipalities as a health precaution, but suspended in the meantime, returning to the pre-pandemic situation. Table 5 shows the evolution of waste generation between 2010 and 2022, in Brazil and Regions, with a significant 23.7% growth.

Table 5 Evolution of MSW generation in Brazil

Brazil/Regions	2010	2019	2020	2021	2022
Brazil	66.695.720	79.069.585	82.477.300	82.664.312	81.811.506
North Region	4.406.280	5.866.645	6.103.320	6.177.019	6.173.684
Northeast Region	17.397.725	19.700.875	20.371.893	20.365.442	20.200.385
Midwest	5.076.055	7.162.760	6.185.796	6.184.989	6.127.414
South Region	7.162.760	8.243.890	8.907.548	8.902.343	8.668.857
Southeast Region	32.652.900	39.442.995	40.991.219	41.034.420	40.641.166

Source: Adapted from ABRELPE, (2020 – 2022).

In 2022, a decrease in waste production was recorded in Brazil for the first time, which, even though it is small, is relevant, as it indicates a tendency to comply with the hierarchy of the PNRS.

According to ABRELPE,[20] the gravimetric characterization of MSW in Brazil, shows that 45.3% is organic matter, plastic represents 16.8%, paper/cardboard 10.4%, glass 2.7% and refuge 14%.

Recife metropolitan area

The RMA, established by State Law 13,306/2007, comprises 14 municipalities, in an area of 2,777,452 km², with a population of 4,047,088 inhabitants,[3] generating approximately 3.7 $x10^6$ kg/day of waste, conventional collection is around 92% and selective collection reaches 3 to 3.5% of the waste produced. Only the municipality of Recife, the capital of the State, implemented a gate fee for the municipal solid waste by IPTU (Property and Urban Territorial Tax).

The Metropolitan Plan for Solid Waste (2011) and revised in 2018, adopts the integrated management principles of the PNRS, whose hierarchy is, reduce, recycle, reuse, treat and proper destination. The municipalities are geographically distributed in three clusters: a) The Metropolitan North composed of the municipalities of Abreu e Lima, Araçoiaba, Ilha de Itamaracá, Igarassu, Itapissuma, Olinda and Paulista. b) The Metropolitan West, formed by the municipalities of Camaragibe, Moreno and São Lourenço da Mata; Metropolitan South, covering the municipalities of Cabo de c) Agostinho, Jaboatão dos Guararapes, Ipojuca and Recife.[4]

Two private treatment centres, which are not regulated (although there is a regulatory agency in the State of Pernambuco that regulates public water, sewage and electricity services) and a public landfill compose the metropolitan system. Where approximately 1.22 $x10^6$ tons of waste from the 14 municipalities of the RMA are discharged, which, unlike other metropolitan areas in Brazil, all municipalities have appropriately waste disposal since 2019. In addition to a transfer station and voluntary delivery points.[8] The Pernambuco Treatment Centre, located in Igarassu, which receives 0.34$x10^6$ t/year of waste from the North cluster, has an estimated life span of up to 2032, embodying an EcoPark with mechanic and biological treatment, production of waste-derived fuel (RDF) and a power generation unit using landfill biogas. The Candeias Treatment Centre, located in Jaboatão dos Guararapes, receives 0.83$x10^6$ t/year with an estimated life span of up to 2033, with an energy generation unit based on biogas, receiving waste from the south and west municipalities. The public landfill is located in the municipality of Ipojuca, receives 0.04 x 10^6 t/year from the municipality itself.[8]

One of the socio-environmental issues of waste management in Brazil is the existence of waste pickers, who derive their livelihood from the waste production chain. In the RMA there are about 5 000 waste pickers, mainly organized in cooperatives.

Municipalities have, in their structure, a management body for public services, usually public companies. However, the operation of conventional collection and transport in most municipalities are outsourced.

Comparative analysis between the metropolitan region of Recife - RMR and the metropolitan areas of Lisbon - AML and Porto - AMP

In terms of territorial space, there is a similarity between the metropolitan areas of Lisbon and Recife, while the area of Porto is a little smaller. It has an equivalent population between the three. With

regard to solid waste management, it appears that both the regions of Portugal and Brazil tend to comply with the legal instruments adopted by their respective countries, especially in the environmentally appropriate disposal.

The treatment and final disposal infrastructure in the three metropolitan areas are equipped with appropriate technological routes and within the standards used worldwide, with the exception of the thermal treatment by incineration with energy recovery, which exists in the two areas of Portugal, while in the RMA it does not exist.

In the socio-environmental issue, RMA follows the PNRS policy for collectors of recyclable materials, but it is still necessary to encourage selective collection and support cooperatives, associations and individual collectors who work in the area. Both to increase recycling, contributing to a circular economy, as well as generating appropriate income for them, to consider as appropriate social inclusion of all these population of workers.[21–23]

Conclusion

The results reveal that Brazil needs better performance with regard to the implementation of the National Solid Waste Policy, especially in relation to final destination, regulation and charging for public services, as well as encouraging selective waste collection. Although Portugal has an organized management system throughout the national territory, did not achieve the objectives of diverting bio-waste from landfills, nor the targets of preparation for recycling. It should be noted that at the time, Portugal was penalized in waste management during the COVID-19 virus pandemic.

In Brazil, there is a lack of a clear framework for funding and objective targets like European Union has established for its Member States.

Waste management lacks funding. Brazil spends about 23% of what Portugal spends. The specificities and situation are evidently different between the countries; however, what draws attention is the difference in effectiveness in the implementation of public policies enacted by the legal diplomas of the two countries for the management of solid waste.

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