Integrated Management of Municipal Solid Waste in Brazil: A Case Study in São Paulo City

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Abstract. Municipal Solid Waste (MSW) Management Systems are constantly changing and innovating around the world. Thus, this work aimed to develop a methodology that allows identifying and understanding the main drivers, barriers and possible pathways for innovative waste management that accelerate the urban sustainability transition and how the political, social and institutional factors can impact operational, economic and environmental indicators in a municipality. The work was developed through a case study in the city of São Paulo (Brazil). It made it possible to identify the main actors involved in the processes of elaboration and conduct of public waste management policies, as well as operational impacts (97.79% of waste sent landfill), economic (US$126,51/ton.msw) and environmental (370.06 kg CO2eq/ ton.msw), contributing to the definition of criteria for the construction of Integrated Solid Waste Management methodology. The results also made it possible to highlight guidelines and practices for the improvement of MSW public policies.

Keywords: municipal solid waste, public policies, transition to sustainability, integrated waste management.

1. Introduction

Significant technological and management innovations in waste management have emerged in the last decade in order to face the growing demand for materials and to confront the increasing ecological and social impact of the disposable consumer economy. Although some guidelines aim at reforming and improving traditional waste management frameworks, others are fundamentally designed to reconceptualise and reformulate them completely [1][9].

For the year 2016, official estimates [24] indicate a daily average generation of 161,400 t Municipal Solid Waste (MSW) in Brazil, where 59% were disposed in landfills, 19.9% were dumped in soil without any treatment, 3.4% were treated and recovered in sorting, composting and recycling units and 17.7% were without information.

In some European Union (EU) countries, such as Germany, Austria, Belgium, Denmark, the Netherlands and Sweden, public policies have raised the rates of reusing, recycling and incineration with energy recovery and/or composting to 95% [4][28]. Even having other destination technologies, sending MSW to landfills is still a major practice in the USA. In 2015, this option was used for 52.5% of the solid waste, followed by incineration with energy recovery (12.8%), recycling (25.8%) and composting (8.9%) [3].

The best indicators can be attributing to the technological advances of the last decades, as well to the management models used, where the effectiveness of public policies is directly linking to the processes of planning, social participation and local control of waste management. In addition how to institutions act in intergovernmental relations, such as sectoral policies, policies at other levels of government, civil society, academic and universities, private initiative and within itself [13][17][18][26].

Authors also highlight that social, political and institutional maturity are crucial for the success of transition and innovation public policies for sustainability, which generate economic and environmental benefits for society [16][27].

Even with some theoretical advances that allow to evaluate the performance of social actors or stakeholders in certain public policies, some methods have not yet been developed for these diagnostics and analysis in waste management policies [7][6][17][25]. Such methods also don't allow to evaluate how such measures of institutional innovation are related to the other dimensions and functional principles of integrated waste management, such as economic and environmental aspects [5][8][10][15][23].

Therefore, this paper aims to develop a method for assessing levels of innovation in waste management, which allows understanding how and why innovations in waste management happen and how these innovations may affect the other aspects (environmental and economic) that make up the concepts of integrated waste management.

2. Method

The works were developed through field work and mostly present primary data, obtained through interviews and technical visits to the sorting, composting and landfill facilities - conducted between May and October 2019 -, as well as public secondary data, such as waste generation and composition data and GHG reduction targets (i.e. PMSP, 2014, 2017). Bibliographic review works were also performed to define the criteria for analysis of Integrated Management of MSW.

For the analysis of the political, social and institutional dimensions, the method known as "*multi-level perspectives (MLP)*" was used [6][7] which propose that the analyses be performed at three different levels, being: 1) niches, which can be understood as those that arise directly from society or even from individuals, as ideas and initiatives from the scientific / academic environment, non-governmental organizations and private initiative, which are independent of local politics. 2) socio-technical regimes, those directly linked to public policies and government management. 3) socio-technical landscapes, which can be understood as the broader context, capable of influencing the other two levels, as it would be something that sustains a society, such as customs, ideologies, values and beliefs, which would be beyond individual control.

For the environmental analysis of the impacts of climate change, was used the tool "CO2ZW (R)", developed by the Institute of Environmental Sciences and Technologies (ICTA) of the Autonomous University of Barcelona (UAB) and by the research company Inèdit [22], already adapted to the Brazilian reality [14]. This tool was developed based on Life Cycle Assessment (LCA) concepts and thus considers direct emissions from these systems - from waste treatment and disposal facilities - as well as indirect emissions - from electricity and diesel consumption - and emissions avoided by the recovery and recycling of waste. [22].

In the economic dimension, also based on complex and broad studies on the themes [11][19][14], the operating and investment costs of the São Paulo city were considered.

After social, political and social analysis and environmental and economic calculations, these results were relating and analysing together.

3. Results and Discussions

3.1. Management System Characterization

The MSW Management System (MSWMS) of the São Paulo city is basically divided into two contractual and management models with the private sector. First, through a Utilities Concession Agreement, two companies provide the services of common collection and transportation, transhipment and final disposal in landfill, in addition to selective collection, transportation and sorting of Household Waste. Through a Service Agreement, six more companies are responsible

for Public Cleaning Waste, which consists of the selective collection of organic waste from the free fair and sent to the five composting facilities, besides the collection and disposal in landfill of rubble and inert, sweeping, pruning waste, removal of waste disposed of in inappropriate places, dead animals and expired food.
Figure 1 presents the main activities of the MSW Management System - composed of the generation, collection, transportation, treatment, destination and generation of co-products - in addition to the quantities generated and managed by the São Paulo City Hall.

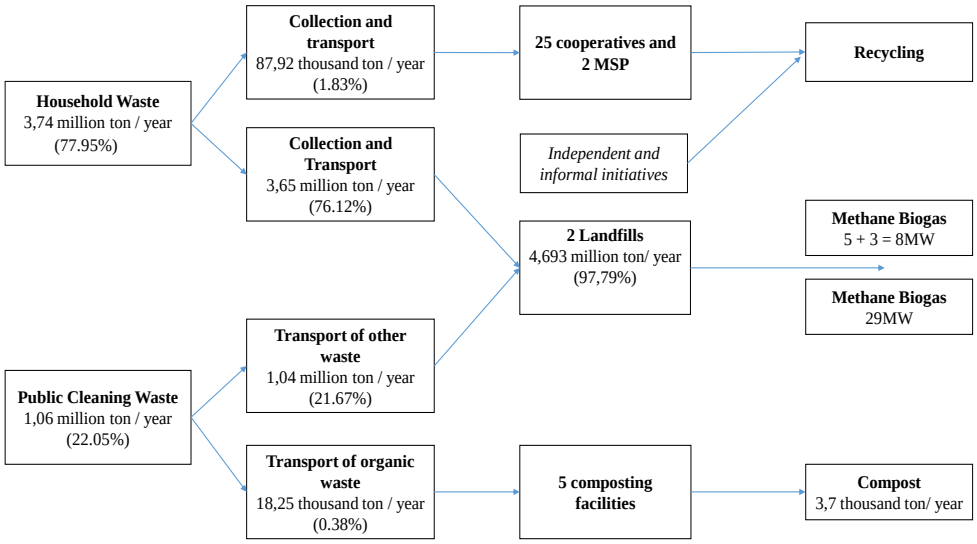

Figure 1: MSWMS of the São Paulo city and the quantities of MSW Generated and Managed in 2017.*MSP: Mechanized Sorting Plants.*

It is important to highlight, through Figure 1, that the city of São Paulo has been seeking information on independent and informal initiatives, which could increase the amount of waste generation and recycled materials in the city.

3.2. Institutional, Political and Social Dimensions
Through the *Multi-level Perspective (MLP)*, applied to MSWMS, it was possible to identify some of the main drivers of public waste management actions and policies, as well as some possible barriers and pathways.
It was possible to understand that the initiatives of some *niches* (which could be quantified) are still timid and have little impact on the efficiency of MSW reuse. However, it is noteworthy that some important actors for the management of MSW in developing countries cannot be identified and quantified in this study, such as informal waste pickers.
The *landscape*, which can be understood here as cultural aspects, values, beliefs, ideologies and customs, has also had little impact on the results of public waste management policies, which can be noticed by the low participation of the population in formal selective collection processes, sorting and recycling. The relationship with indices of human development, education and region of the country can also make to infer that there is a need for greater investment in mobilization and education of the population for such actions to be effective, as highlighted by Mazzola [12].
Following are some of the main drivers, barriers and possible pathways that could be identified within the *sociotechnical regime*.
Drivers: São Paulo City Hall itself, its municipal secretariats and municipalities, such as the Municipal Authority for Urban Cleaning (*Amlurb*), as well as the Councils. The City Council; the State Control Institutions, such as the Public Prosecution Service and the Courts of Auditors. The State through the institution of environmental licensing. The Union through financing agencies,

such as the Ministry of Labor and Employment and the National Bank for Economic and Social Development (BNDES). Civil Society and NGOs through participation in councils, public hearings and specific actions. Universities and Research Centers in Projects and Partnerships. Companies and Service Providers. Recycling and Remanufacturing Industries. The Informal Sector and Independent Initiatives. As well as International Organizations (such as UN and World Bank) through projects and funding.

Barriers: Change of public offices (technical and strategic) during the changes of Municipal Governments. Poor integration between the wishes of the population and service providers. Poor public and population engagement in waste separation. Institutions that allow low change - such as the environmental licensing processes of the São Paulo State Environmental Company (*Cetesb*) and long contracts with service providers that do not encourage the best environmental performance. Low integration of MSWMS with Cooperatives. Little knowledge of Independent and Informal Waste Picker Initiatives and scrap dealers. Mechanized Sorting Plants operating below capacity. There is no specific fund for waste management in the city.

Possible Pathways: More effective staff, beyond qualification, for Increasing Learning Ability. Greater harmonization between Selective Collection, Composting and Landfill, through contracts that stimulate the environmental improvement of the systems. Strengthening Participatory Councils and Environmental Education Actions (formal and informal). Decentralization in MSW Operation and Management through actions and planning via the sub-municipalities. Increased knowledge and integration of Independent Initiatives and Informal Waste Pickers with MSWMS. Strengthening of Follow-up Working Groups on the Municipal Waste Management Plan and the GHG Reduction Targets Program (which aims to reduce 131,000 t.CO2 by Dec. 2020). Use of economic instruments, such as the "waste tax", for greater participation of the population. Need for political prioritization for mobilization and overcoming the city's waste challenges.

3.3. Integration of Analyses for Integrated Management

From the analysis of social, political and institutional dimensions and their operational results, a relationship was then established with the other dimensions (environmental and economic) that make up the concepts of Integrated Waste Management, as can be seen in Figure 2.

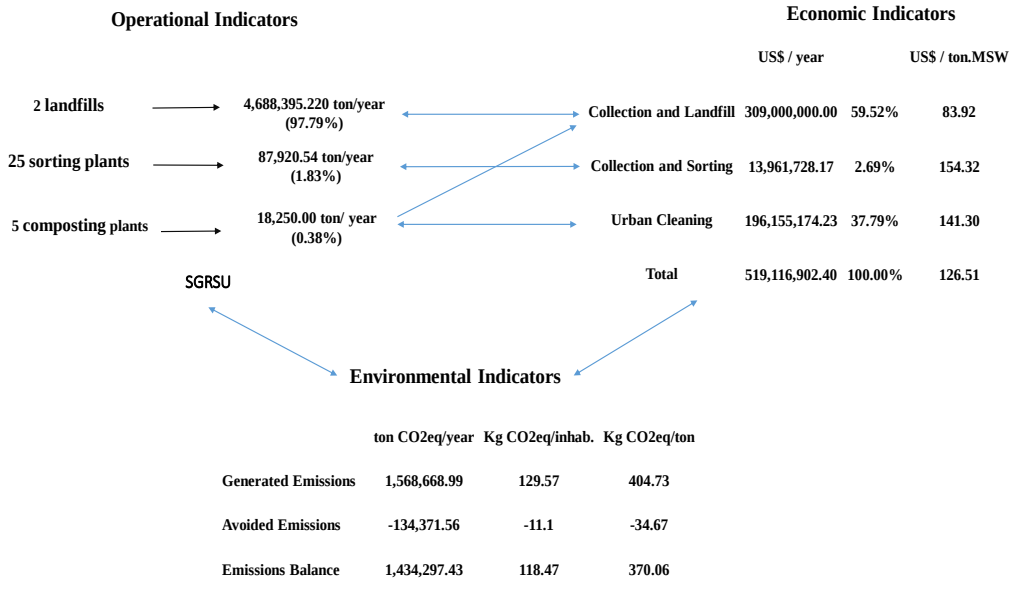

Figure 2: Integration between MSWMS operational, economic and environmental results.

It can be noted, therefore, a lower cost per ton of waste from common collection and landfill actions, while urban cleaning and selective collection sorting actions have higher costs. When

analyzing GHG emissions, it is also noted a low avoided emission (only 8.6%) due to the low rates of waste recovery, but the energy cogeneration (through the reuse of methane) of the two landfills contributes to reduce the emissions generated and the system balance when compared to other locations [14].

When results are related, it can be inferred that institutional, social and policy improvements - identified through the drivers, barriers and possible pathways - could contribute to more efficient indicators, lower costs and emissions. Thus, the need for scale-up in the selective collection and sorting systems can be highlighted, which could occur through the expansion of public campaigns and greater participation of the population in the separation of waste, in addition to the use of economic instruments that encourage separation at source. The installation of Voluntary Delivery Points could also contribute to this increase in scale, while more decentralized composting systems and urban agriculture in neighbourhoods and schools could also avoid costs and emissions with traditional collection and disposal systems.

Therefore, the analysis of social, institutional and operational results, as well as economic and environmental aspects, allowed identifying some actions and guidelines that could be proposed for the system under study, thus filling gaps highlighted by researchers in the area [2][5][8][14][15][23]. Thus, these results may allow new advances and debates in the areas of institutional innovation in local public policies, transition to sustainability and integrated waste management.

4. Conclusions

Through the objectives of this work - to develop a method for assessing levels of innovation in waste management, which allows understanding how and why innovations in waste management happen and how these innovations may affect the other aspects (environmental and economic) that make up the concepts of integrated waste management - it can be concluded that the method has identified the main drivers, barriers and possible pathways and how these aspects impact the operating results, operating and investment costs and GHG (CO2eq) emissions of MSW management systems. Through the integration of analysis and results, this paper aims to contribute to the advance of knowledge for the definition of criteria for a sustainability analysis method and the dimensions of Integrated Management of MSW, also enabling the proposition of actions and guidelines for municipal public policies.

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