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Influence of implementing selective collection on municipal waste management systems in developing countries: A Brazilian case study

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ABSTRACT

The aim of this study is to analyse the evolution of the municipal solid waste management (MSWM) system of João Pessoa (Brazil), which is one of the pioneering Brazilian cities to implement door-to-door selective collection programmes to study the effect of policy decisions in the last decade about selective collection. To this end, the present study includes the characterisation of the waste management system in this municipality from 2005 to 2015, and the analysis of the relation of these data with the socio-economic characteristics of the population in different city districts based on the data collected directly from the different stakeholders involved in the MSWM system.

Our results are based on identifying the different socio-economic aspects that may influence the success of implementing recyclable waste selective collection programmes. This study also highlights the great deal of room for improvement in the selective collected waste ratio in João Pessoa as, in 2015, only 1.5% of generated recyclable waste was selectively collected. Spreading and improving awareness-raising campaigns throughout the city are key aspects that can improve this ratio, and the standardisation of registering information on the MSWM system is a basic issue to measure the system and to facilitate the undertaking of future analyses.

1. Introduction

It is well-accepted that municipal solid waste management (MSWM) is one of the premises for urban sustainability worldwide (Castro et al., 2015). Recycling is most important for the sustainability of waste management systems (Marques et al., 2014) as it is a source of both environmental and economic benefits that avoids the burdens that result from the primary material saved/replaced, and from the waste diverted from other waste treatment facilities (Corsten et al., 2012; Da Cruz et al., 2014; Ibáñez-Forés et al., 2018). However for developing countries and for developing areas of countries with mixed economies, proper MSWM is still one of the major pending challenges (Henry et al., 2006; Guerrero et al., 2013; Saikia and Nath, 2015; Al-Khatib et al., 2010, 2007).

In Brazil, the generation of municipal solid waste (MSW) has increased in recent decades (ABRELPE, 2014; Nascimento et al., 2015; Massukado et al., 2013), which is due mainly to the country's rapid economic growth that has led to bigger urban populations and changes in their lifestyles. This situation has encouraged the current legal regulatory framework to be adopted, which was proposed by the National Policy on Solid Waste (Lei 12305, 2010).

Although MSWM systems in Brazil have improved significantly since Law 12,305 (2010) came into force, according to ABRELPE (2014) there is still work to be done because only slightly more than half the collected MSW is disposed of in sanitary landfills (58.3%), and only 64.8% of Brazilian municipalities have initiatives for the separate collection of recyclable materials. Moreover, problems related with the unstable labour conditions of waste pickers and the precarious waste recovery facilities in Brazil have been highlighted by Campos (2014). Hence, municipalities are urged to develop integrated MSWM plans, based mainly on strategies that seek to promote the design and use of sanitary landfills, and to improve current selective collection. To do so, the integration of the informal recycling sector into the formal system is a key aspect.

The role of informal recycling in developing countries and its integration into formal systems is an issue that is recently being analysed in the literature (Wilson et al., 2009, 2006; Ezeah et al., 2013; Campos, 2014), above all in developing countries like China (Hosoda and Hayashi, 2010; Chi et al., 2011; Fei et al., 2016; Linzner and Salhofer, 2014; Yu et al., 2010), India (Saikia and Nath, 2015), Pakistan (Masood

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and Barlow, 2013), South Africa (Godfrey and Oelofse, 2017) and Brazil (Moreira Assis and de Vasconcelos Barros, 2014; Días, 2011; Do Carmo and De Oliveira, 2010; Marello and Helwege, 2014; Rutkowski and Rutkowski, 2015; Eigenheer and Ferreira, 2015), among others.

Another main aspect for managers and researchers when analysing MSWM systems is data availability. Quantitative and qualitative information on MSW is particularly lacking in Brazil (Moreira Assis and de Vasconcelos Barros, 2014), mainly due to irregular disposal, informal collection and insufficient public collection systems (IPEA, 2012).

After taking this framework into account, this study aims to generate information on how the characterisation of the waste management system in the municipality of João Pessoa (Brazil) has improved to analyse the effect of selective collection-related policy decisions made during the decade from 2005 to 2015. During this period, João Pessoa has progressively implemented a programme for segregating recyclable materials through the combination of door-to-door selective collection programmes and the launching of a material recovery facility (MRF), where recyclable materials are manually separated out from the mixed waste flow. This programme has also allowed the social inclusion of waste pickers, who previously collected recyclable materials in non-sanitary landfills and open dumps, into the integrated MSWM system.

To fulfil this aim, the present study focuses on characterising the evolution of the MSWM system in the municipality under study from 2005 to 2015 based on the data collected directly from the different stakeholders involved in the MSWM system. This has allowed information to be collected on the evolution of waste composition, mixed waste collection, door-to-door selective collection, recyclable materials separated at the MRF, etc., for the municipality of João Pessoa as a whole and for each sorting unit located in it. This information is also about the socio-economic aspects of the population in this municipality (level of education, family monthly income, level of satisfaction with the MSWM system and guidance about the matter). This has allowed the socio-economic aspects that may have influenced the success of implementing the selective collection programme to be identified.

This paper is arranged as follows: the applied methodology is detailed in the next section, followed by the description of the system under study in Section 3. Section 4 provides details of the data collection process, including both the data on the MSWM system and the socio-economic characteristics of the population served by the selective collection programme. Section 5 includes a data analysis. Section 6 discusses the relationship between the results obtained from the indicators that characterise the MSWM system and those that characterise the socio-economic features of the served population. Finally, Section 7 presents the conclusions.

2. Material and methods

The methodology applied in this study consists of four stages (see Fig. 1):

- **Stage 1**: **Description of the system under study**. General information on the municipality and the implemented MSWM system is obtained to define the data needed to model the MSWM system in later stages.
- **Stage 2: Data collection**. According to the conclusions drawn from Stage 1, the data required to model the MSWM system are identified from two different perspectives. On the one hand, the data needed to characterise the MSWM system and to define the different waste flows involved in managing collected waste fractions. On the other hand, the socio-economic data needed to characterise the population served by the selective collection programme to identify the profile of those participating in the programme. All these data are collected for each study period year (2005–2015).
- **Stage 3: Data analysis**. The data collected in Stage 2 are analysed to obtain rates that characterise the evolution of the mixed and selectively collected waste and the socio-economic features of the population, from 2005 to 2015.
- **Stage 4: Discussion**. The relationship between the results obtained from the rates that characterise the MSWM system and those that characterise the socio-economic features of the population need to be analysed to identify whether or not there is a relationship between them and, if so, to know what type of relationship it is.

3. Description of the system under study

This study was conducted in the city of João Pessoa (Paraíba, Brazil), located at the easternmost point of Brazil on the Atlantic coast, as Fig. 2 shows. It has an average altitude of 37 meters above sea level and the city's climate is a Mediterranean or dry North-eastern type, with an average annual temperature of 26 °C.

The city has a population of almost 791,000, occupies an area of 211 km^2 and has a population density of 3421.28 $inhab/km^2$ (IBGE, 2015). It is organised into 63 districts, as shown in Fig. 2.

The MSWM system implemented in João Pessoa has progressively incorporated a programme for the door-to-door selective collection of recyclable waste since 2003 (Coutinho-Nóbrega, 2003). It is one of the pioneering Brazilian municipalities to incorporate the informal waste sector into municipal recycling strategies. The need to improve the socio-economic conditions of the existing local informal waste-pickers led to the development of an integrated MSWM strategy, which included them in a reorganised form as an association of waste-pickers. This fact, coupled with the closure of an open dump and its substitution for a sanitary landfill, plus the establishment of an MRF next to it, has helped to design the current integrated MSWM system (see Fig. 3) and is described as follows.

The MSW in João Pessoa is collected mostly as mixed waste by collection vehicles that take pre-selected routes. A small portion of recyclable waste is collected door-to-door by formal waste-pickers organised in associations. However, this door-to-door recyclable waste selective collection programme has not yet been implemented throughout the city, but has been progressively implemented into 18 districts since 2003 (see Fig. 3).

The waste collected in a mixed form is transported directly to the sanitary landfill located 25 km from the city centre. A small percentage of this waste is diverted to the MRF located next to the sanitary landfill, where recyclable materials are separated out by hand from the flow that is disposed of in the sanitary landfill. The MRF started operating in 2003 and currently has the capacity to manage 2000 t/year. Today, 85 of the waste-pickers, reorganised in different associations, are involved in this task.

The 18 districts currently served by the door-to-door programme for the selective collection of recyclable materials are grouped into five sorting units (Bessa, Cabo Branco, Bairro dos Estados, Caic and Mangabeira; see Fig. 2). This represents approximately 5.1% of the municipal area and about 30% of the total population of João Pessoa (Table 1). Sixty-eight waste-pickers, who have been reorganised in the associations, are involved in this programme, and are distributed by sorting units as shown in the last row of Table 1. The remaining waste-pickers work in the MRF and sanitary landfill, but their labour conditions are unstable and precarious. Recyclable materials, collected door-to-door and separated at the MRF, are recycled and recovered as secondary raw materials. Rejected fractions from all the MSWM system flows are finally disposed of in the metropolitan sanitary landfill.

4. Data collection

The collection of data on the MSWM system was performed by compiling field data from the companies in charge of the system's different life cycle stages and from the municipal authority for the Special Urban Sanitary Management of the City of João Pessoa (EMLUR). The data collection process includes holding interviews with the