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Gravimetric composition of the rejects coming from the segregation process of the municipal recyclable wastes

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ABSTRACT

Rejects from selective collection are municipal solid waste (MSW) not used for recycling and are, therefore, destined for the landfill in Brazil. Knowledge of the composition and generation of this waste is important for strategically planning public policies that minimize its generation and its negative environmental impacts. However, this portion of MSW is not very well known. Therefore, the aim of this study was to analyze the rejects from the sorting process of the selective waste collection in the municipality of Blumenau, in the State of Santa Catarina, southern Brazil. The studied rejects came from the largest cooperative in the city, and its composition was sorted into 17 categories of 101 samples over the course of one year, with a total of 3893 kg of analyzed rejects. The waste collected by the selective collection of the municipality was evaluated monthly to determine which part of this quantity became rejects and to determine the composition and seasonality of these rejects. The study found that 30.5% of the waste sorted by the cooperative was rejected. Among these rejects, the presence of materials that could be marketed by the cooperative was verified. Hazardous and/or legally prohibited waste were also identified, as were organics, construction and demolition waste, health care waste, electronics, textiles, footwear, batteries, and bulbs. Seasonal analysis indicated a concerning constant generation of health care waste. Aside from that, there was an increase in the generation of waste from electrical and electronic equipment (EEE) during the Christmas period, when a large part of the population discards their EEE. This information is important for the enforcement of the MSW management structure as well as for educational campaigns aimed at the correct separation of waste that should be sent for selective collection.

1. Introduction

The National Solid Waste Policy (PNRS), Federal Law No. 12,305 (Brazil, 2010a) concerning waste management in Brazil introduced, among other things, the principle of shared responsibility and reverse logistics as well as establishing goals for recycling waste generated from different sources. In consequence, an expansion of selective collection occurred with responsibility put on municipalities (Campos, 2014; Brazil, 2012; Brazil 2010a). However, this expansion was not always followed by structures capable of taking advantage of all the waste as well as by an environmental awareness of the population about sorting waste correctly in terms of what should be effectively targeted for selective collection (Affandy et al., 2017; Lima et al., 2017; Pereira et al., 2015; Castagna et al., 2013).

In this context, a significant volume of rejected waste is generated, meaning there is a large amount of waste that, after all the possibilities of treatment and recovery have been exhausted, has no destination other than the adequate final disposal (Brazil, 2010a). These materials represent an additional cost to municipal public authorities (who are responsible for management of waste) and to cooperatives of recyclable materials for two reasons: first, because they overload the system of transportation and sorting of solid wastes from the selective collection, and second, because some of this waste is capable of being harnessed for other purposes, but they are not for various reasons in each locality (priority for the recycling of other wastes, operational limitations, lack of market knowledge, etc.).

Studies have indicated the presence of organic wastes as well as light bulbs, electronics, and batteries in the selective collection of Brazilian municipalities (CEMPRE, 2016; Lischeski et al., 2011). Furthermore, this problem is not only limited to Brazil. Studies in England showed that the amount of municipal solid waste (MSW) that was recycled increased 3% between 2011 and 2012

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and again between 2014 and 2015; however, in the same period, the amount of recycling that was rejected increased by 84% (BBC, 2016). It is not surprising that this fact generates negative impacts on municipal finances, on the environment, and on the health of recycling workers (Trombin et al., 2017; Rebehy et al., 2017; Oliveira, 2013; Pacheco et al., 2012; Bovea et al., 2010; Cocarta et al., 2009).

Therefore, qualitative and quantitative studies of waste and rejects are important so that the opportunities, challenges, and barriers to MSW management can be effectively known (Rada and Cioca, 2017; Ciuta et al., 2015; Edjabou et al., 2015). There are studies that address MSW (with all content) from companies (Tatàno et al., 2017), cities (Wagner and Broaddus, 2016; Denafas et al., 2014; Ogwueleka, 2013), regions (Edjabou et al., 2015; Sahimaa et al., 2015), and countries (Liikanen et al., 2016; Miezah et al., 2015; Al-Jarallah and Aleisa, 2014; Ranieri et al., 2014); however, there are no studies that use field surveys to determine the composition of rejects coming from selective collection.

The Entrepreneurial Compromise for Recycling estimates that 35% of the MSW sent to selective collection in Brazil become rejects (CEMPRE, 2016). However, this quantity varies according to the region, because some recyclable waste is not used due to the particular structure of each cooperative and each municipality. This is an important and peculiar factor in each region because, in Brazil, a local system of (re)use of solid waste hardly exhausts all possibilities for recycling (Ferri et al., 2015).

In this way, the present study aimed to systematically analyze the rejects coming from the sorting process of the selective collection of a municipality in the south of Brazil in order to determine how much is generated, what constitutes these rejects, and when are they generated (seasonality analysis).

2. Methodology

2.1. Study area

The study was conducted in the municipality of Blumenau, State of Santa Catarina (SC), located in southern Brazil. The municipality has 95.5% of the population living in urban areas. The estimated population is 343,715 inhabitants in 2016, and the area is 518.5 km^2 (IBGE, 2017). The Municipal Human Development Index (HDI-M) in Blumenau is 0.806, which places it in the range of "high development" (Brazil, 2010b).

The regular collection is carried out by compactor trucks and this reaches 98% of households and establishments, while the selective collection (recyclable waste collection, except organic matter) of MSW covers 60% of the households/establishments of Blumenau and has been in operation since 1987 (Blumenau, 2016; Blumenau, 2015). The regular collection carried out by compactor trucks collects waste that presents both wet and dry segments that are normally disposed of in plastic bags and have the most varied composition, including organic, paper, metal, and glass. The selective collection is carried out with box trucks collecting potentially recyclable waste.

According to the Municipal Autonomous Water and Sewage Service of Blumenau (SAMAE), a public institution responsible for MSW management, approximately 5.6 thousand tons of wastes were collected in selective collection in 2014 (SAMAE, 2014). However, not all of these wastes were sorted and marketed for recycling, and this is because non-recyclable wastes and/or wastes that should not be there were disposed of in the selective collection. Organic waste, textiles, shoes, batteries, light bulbs, health care waste and construction waste are examples of these rejected wastes.

Selective collection rejects, together with waste from the regular collection, are sent to the sanitary landfill located 42 km away from the study site. Both collections include MSW, meaning originating in urban dwellings and resulting from domestic activities and the wastes of commercial establishments and service providers, with similar characteristics to household solid wastes, according to classifications established by the PNRS (Brazil, 2010a).

In the municipality of Blumenau, recycling cooperatives participate in the sorting and commercialization of selective collection waste because the largest of them also has an agreement with SAMAE. This one was chosen for this study. The waste transport is realized using SAMAE trucks that are driven by the cooperative's workers. The workers of such cooperatives are oriented to collect certain kinds of waste, such as ferrous and non-ferrous metals, white paper, mixed paper, cardboard, glass (shards and containers), and polymers (PET – polyethylene terephthalate; HDPE – high density polyethylene; LDPE – low density polyethylene; PP – polypropylene; PS – polyesthirene; and PVC – polyvinyl chloride). These wastes are sorted and temporarily stored until they are sold and transported to recycling companies. Waste not collected by the workers reaches the end of the conveyor belt, where it is automatically deposited in a truck for later disposal in a landfill.

2.2. Sampling technique

The study was carried out in four stages: (1) analysis of the waste generation process; (2) quantification of the waste coming from selective collection and the rejects; (3) sampling process; and (4) classification of the rejects.

The waste sent by the population to selective collection, the amount of waste sorted, the waste sold by the cooperative, and also the volume of rejects were quantified in the period from December 2014 to November 2015. In the sampling process, for the determination of gravimetric composition of the rejects, the sample size calculation was based on Eqs. (1) and (2) (Barbetta, 2002),

$$n_0 = \frac{1}{E_0^2} \quad (1)$$

$$n = \frac{N.n_0}{N + n_0} \quad (2)$$

where n_0 is the first approximation of sample size, E_0 is the tolerable sample error, n is the sample size, and N is the population size.

Taking into account that in 2013, the generation of rejects in the cooperative was estimated at 54 tons per month (SAMAE, 2014), and foreseeing a 5% increase in the analysis period—the same as the increase recorded in 2013 (SAMAE, 2014), an expected generation of 56.7 tons per month was obtained during the period of study. Thus, applying Eqs. (1) and (2), with an error (E_0) of 10%, it was determined that the required monthly sample size should be at least 99 kg. Therefore, the analysis of the gravimetric composition of the selective collection rejects was performed on different days of the week and randomly spaced throughout the months (Barbetta, 2002), totaling 101 collections during one year equating to approximately two collections per week, with a total sample of 3893 kg (Table 1).

Each sample was taken by a backhoe loader to homogenize the rejects and apply the quartering technique (European Commission, 2004). The rejects were placed in an area inside a covered shed over a firm, dry, and clean surface. The analyzed sample corresponded to one of the randomly chosen parts of the simple quartering, without repetition.

After selecting the sample, classification of the rejects was performed using 17 categories, denominating which have been

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