Municipal Solid Waste and its environmental impacts: changing reality of small Brazilian municipalities through better managerial practices

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Cities are highly resource consuming, which causes environmental pressure and consequently negative impacts on the environment (García-Guaita et al., 2018). Factors such as economic and population growth, rising incomes, rapid urbanization and the increasing demand for goods and services directly correlate to a rise in solid waste generation (Minghua et al., 2009). As part of the municipal infrastructure, solid waste management needs to be efficient and effective. Its inefficiency, for example, negatively impacts public health and environmental quality (Tan et al., 2014). The use of indicators aims to improve managerial practices, contributing to a better service delivery system for the community. This is important as the municipalities must collect, transport, process and dispose these wastes in such a way that it is economically, environmentally and socially efficient (Li'ao et al. al., 2009). Smaller municipalities—less than 100 thousand inhabitants—have a significant challenge in management; since they are the majority in Brazil representing the largest total population and also the amount of waste collected. Only 17.9% have selective collection, and 3.6% have composting units (IPEA, 2012). The last report of the Brazilian Association of Public Cleaning and Special Waste Companies shows no progress (ABRELPE, 2017).

The objective of this study is to analyze the environmental impacts, which include the consumption of energy and emissions of carbon dioxide (CO_2e) and carbon (Ce) equivalents, from the small municipalities of the state of São Paulo. The study also aims to create a classification of municipalities related to per capita impacts—using multiple indicators—and to list the management practices of the best-ranked municipalities.

The five stages of this study development are:

Phase 1. Selection of municipalities. 273 cities have up to 10,000 inhabitants in the state of São Paulo, representing 42.3% of the state's municipalities.

Phase 2. Data collection: The following data were collected from municipalities: General gravimetric composition of municipal solid waste; total quantity of each type of waste destined for recycling, composting and incineration (if applicable); total distance traveled by the waste to the landfill, composting and recycling points.

Phase 3. WARM (Waste Reduction Model) (Morrissey and Browne, 2004). It is a choice from the vast scientific literature presenting tools and models that support decision-making in the management of urban solid waste, thereby enabling the assessment of greenhouse gas (GHG) emissions and energy consumption.

Phase 4. Analysis of results (outputs). Analysis of environmental impacts by municipalities measured by CO_2e, Ce and energy consumption (kWh).

Phase 5. Construction of the multiple indicator and comparison between municipalities to analyze management practices. In this last phase of the research, the indicators of solid waste generation and the Waste Quality Index (WQI) were added, which punctuated the sites disposal (landfill) of solid wastes from a technical and environmental point of view. The aggregation was given by the geometric mean of the indicators, after the normalization of the indicators, with each one and the final indicator comprising a value between 0 and 1.

The results of the annual per capita generation of the municipal solid waste of the analyzed sample (kg inhabitant^{-1} year^{-1}) with a mean of 223.89 are represented in Figure 1A. Compared with other Latin American countries, the only countries with a below average mean of the sample studied are Guatemala (222.65 kg inhabitant^{-1} year^{-1}) and Bolivia (178.85 kg inhabitant^{-1} year^{-1}) (Kawai and Tasaki, 2016). In Figure 1, we also observe: Figure 1B Emission of carbon equivalent - Ce (ton inhabitant^{-1} year^{-1}), Figure 1C Emission of carbon dioxide equivalent - CO_2e (ton inhabitant^{-1} year^{-1}) and Figure 1D Energy consumption (kWh inhabitant^{-1} year^{-1}).

After the composition of the multiple indicators, the 10 best municipalities (Figure 2) were carefully analyzed to identify their actions that led to the best results, such as landfill type, public-private partnerships, environmental education, recycling practices, composting, etc. The municipality of Ribeirão Grande/SP, although it has a landfill with 7.4 points (WQI), has a recycling program. According to municipal data, from 900 tons of solid waste collected, 180 tons are made of recyclable material, which are separated in the COOPMARI cooperative shed, and then sent to the CATA-VIDA network in the municipality of Sorocaba/SP - Brazil. The results of the indicators and the best practices highlighted in this research can guide the decisions of each small municipality towards the improvement of waste management.

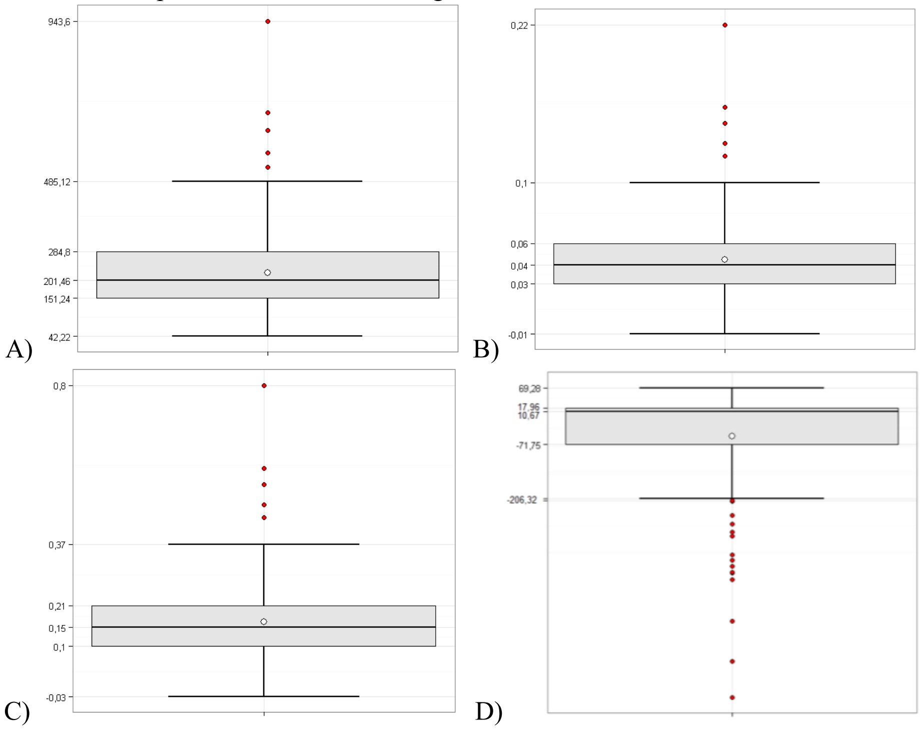

Figure 1. A) Annual per capita generation of municipal solid waste of the sample analyzed (kg inhabitant^{-1} year^{-1}). B) Emission of carbon equivalent - Ce (ton inhabitant^{-1} year^{-1}). C) Emission of carbon dioxide equivalent - CO_2e (ton inhabitant^{-1} year^{-1}). D) Energy consumption (kWh inhabitant^{-1} year^{-1}).

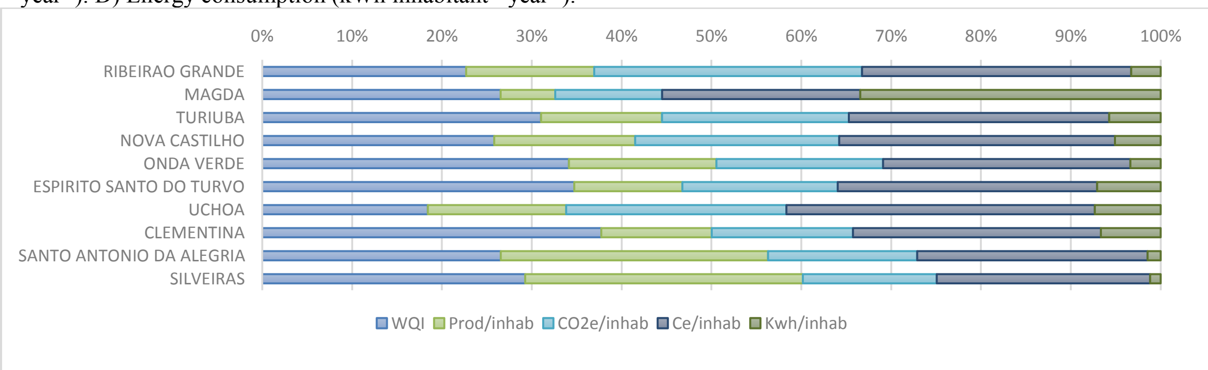

Figure 2. Composition of the normalized indicators of the 10 best ranked municipalities.

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