HOUSEHOLD SOLID WASTE COMPOSITION IN RIO DE JANEIRO CITY, BRAZIL: AN HISTORICAL VIEW

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Abstract

This work presents a compilation of the data from the annual household solid waste (HSW) physical composition produced in Rio de Janeiro City for over a period of 19 years that enable us to verify behavioral changes and consumption trends of the inhabitants. The sampling size and distribution were established considering the average quantities of waste produced, in 27 Administrative Regions (AR) of the city. Different socioeconomic profiles, urban structures and traditions within the ARs as well as the absence of official recycling programs were evaluated. The samples from wastes were always collected in the first semester of the year in order to reduce seasonal interference. Waste samples were sent to the Solid Waste Laboratory of Municipal Urban Cleaning Company (COMLURB) for sorting, weighting and recording of the data. The results showed that organic waste is the largest component of the waste stream (54.4%), followed by recyclables (39.9%) and other components (5.7%). As an urbanized city in which the waste is formally managed on a municipal scale, Rio de Janeiro has exhibited a waste composition comparable to that of undeveloped cities of the world. Information on the physical composition of solid waste may significantly contribute to the efficiency of the solid waste management system adopted in Rio de Janeiro City.

Keywords: household solid waste; Rio de Janeiro; Brazil; composition

1. Introduction

One of the major challenges to cities is waste management. Significant growth in the production of solid waste, especially in developing countries, increases with wealth, urbanization and population, particularly in the rapidly growing cities and towns in the developing world [1]. The quantity and variability in composition of HSW are closely correlated with increasing population, changing socio-economic standards and technological developments [2]. Brazil is an emerging market economy and is urbanizing at a rapid scale. These changes bring new consumers, and the consequences for increased consumption are as follows: more natural resources are used to produce goods, and more waste is produced [3].

According to the Brazilian Policy on Solid Waste [4], HSW is defined as those originating from domestic activities in urban households. These mainly include organic waste, paper/cardboard, plastics, ferrous/non-ferrous metal materials, glass, foil, wood, rubber, clothes and rags, leather, bone, coconut, wax, electronics and inert materials. The composition of household solid waste depends on food habits, collection of recyclable materials, wealth of residents, in-house composting and climate conditions [1, 5]. The characteristics

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and quantity of solid waste arising from domestic activities in a region is not only the result of a growing population, rising live standards and technology development but also the result of the abundance and the type of the regional natural resources [6].

For integrated waste planning, it is indispensable to elucidate municipal solid waste generation and composition in communities [7]. Solid waste management constitutes a combination of methods, policies and behaviors that must be used to control the negative impacts of solid waste, as well as finding solutions to reuse the waste [8]. This management involves several steps: generating, handling at the source, collection, transportation, processing, transformation and disposal [9].

Global trends of increasing production and complexity of discarded waste exacerbate the challenge of managing it [3]. The production of solid waste, which largely arises from household solid waste, and knowledge of its physical composition are the starting points for adequate management of solid waste in a city. Predicting characteristics and socioeconomic factors relevant to communities helps to identify waste generation rates, recycle potential [7, 10, 11] and to verify the viability of composting [12].

This work was conducted to overview the results of the annual work on the physical composition of HSW produced in Rio de Janeiro City for over a period of 19 years in order to verify consumption trends of households and socioeconomic influences.

2. Materials and methods

2.1. City description and waste management

Rio de Janeiro is the second largest city in Brazil and one of the most visited cities in the southern hemisphere. The population in domiciles is approximately 6,429,923 inhabitants in an area of 1,200 km² [13], divided into 33 ARs, administrative sub division of the city, with distinct socioeconomic profiles. In the year of 2013 the city produced 1,869,230 tons of household solid waste, with a daily production of approximately 5,121 tons [14].

Public cleaning and waste management services in Rio de Janeiro City are provided by the Municipal Waste Management Company (COMLURB) and cover approximately 96% of the commercial and residential units of the city. The HSW is collected from garbage cans, buckets and containers disposed by citizens on the curbsides. This service covers all ARs three times per week. After collected, the waste is transported to a sanitary landfill, which is the principal final destination of solid wastes in Rio de Janeiro [15].

2.2 Sampling

The research area covered 27 ARs of Rio de Janeiro City. Every year the sampling size and distribution were established considering the average quantities of waste produced in each AR in the previous year. It also took in account different socioeconomic profiles, urban structures, traditions and life standards within the ARs as well as the absence of official recycling programs. The sampling routes were revised annually considering the changes in the urban structure and if necessary changes were made. In order to reduce seasonal interference the samples were always collected in the first semester of the years.

2.4. Physical composition Determination

After collected, the waste was sent to the Solid Waste Laboratory of the COMLURB where five urban cleaning workers were responsible for hand-sorting each sample and a researcher was in charge of weighting and recording the data. Therefore, identifying the physical composition consisted of determining the weight of each fraction of the waste arising from households and differentiating them into 11 components (i.e., paper, cardboard, plastics, glass, metal, textile, wood, electric/electronic, organic waste, inert materials and other) and into more than 45 sub-components (Table 1).

Table 1 Components and materials of household solid waste for compositional purposes

Component	Materials
Paper	newspapers, magazines, books, advertisements, office paper.
Cardboard	cartons, packaging, bags, aseptic packaging.
Plastic (polyethylene, polypropylene, polystyrene)	beverage, food, medicine, sanitizing and cosmetic bottles, bags, cups and packaging.
Glass (colorless/colored)	beverage, medicine, spice and cosmetic bottles and jars.
Metal (ferrous/nonferrous)	beverage and food cans.
Textile	clothes, leather, rags and cuttings.
Wood	furniture and box scraps.
Electric/electronic	computer devices, cell phones, lamps, batteries.
Putrescible organic waste	raw food, food scraps, garden waste and feces.
Inert materials	ceramic, stone, construction debris, ash, dust.
Other	rubber, bone, coconut, wax, nonrecyclable papers (disposable diapers and tissue paper) and fines.

For effects in this work, the fraction of recyclables corresponds to paper, cardboard, plastic, glass and metal; organic waste corresponds to putrescible organic waste; and the fraction denominated “others” corresponds to textile, wood, electric, electronic and Inert materials

3. Results and Discussion

The growth in HSW generation highlights changes in habits and consuming trends resulting from socioeconomic development and consumption patterns. Fig. 1 presents the household solid waste generated in Rio de Janeiro City over the past nine years and shows an increase of 27.5%, from 1,465,993 tons in 2005 to 1,869,230 tons in 2013 [14].

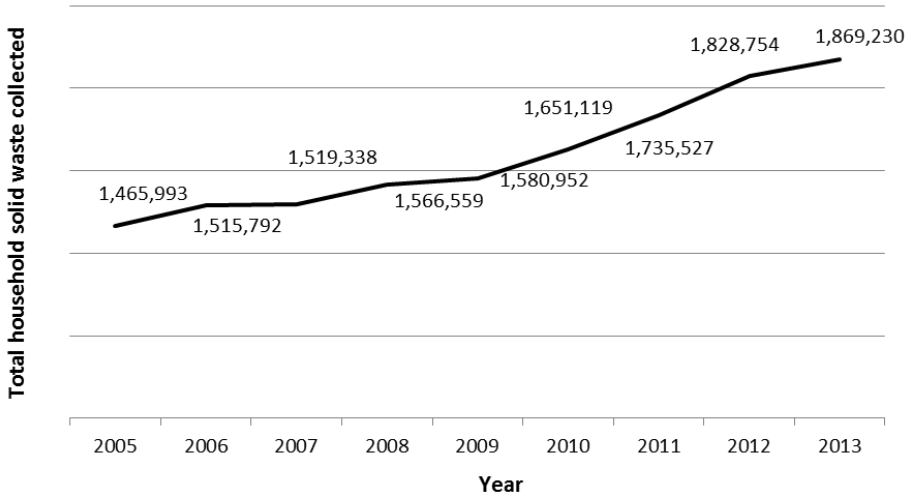

Fig. 1 Rio de Janeiro collected HSW (tons per year).

Considering that the population was 6,429,923 in 2013, each Rio de Janeiro resident produced approximately 290 kg of HSW in the last year. In Belgium, Gellynck et al. [16] stated that a global mandatory goal is to reduce the amount of residual household waste to and maintain it at 150 kg per capita per year between 2010 and 2015. Thus, several policy makers are now turning their attention towards waste prevention and towards habitual forms of reuse as ways to reduce the total amount of waste produced [11]. Household waste has become an increasingly discussed topic in recent years because composition studies have indicated that it correspond to approximately 40–60% of urban waste [5] and investigation of its composition plays an important role in waste management [17].

In Fig. 2, the average physical composition of the HSW from Rio de Janeiro City between the years of 1995 e 2013 is illustrated. Notably, organic wastes are the largest portion of the waste stream (54.4%), followed by recyclables (39.9%) and others components (5.7%). Similar proportions were found by Ogwueleka [5] and Sabeen et al. [18] in household waste generated in Abuja, Nigeria, and Pasir Gudang, Malaysia, respectively.

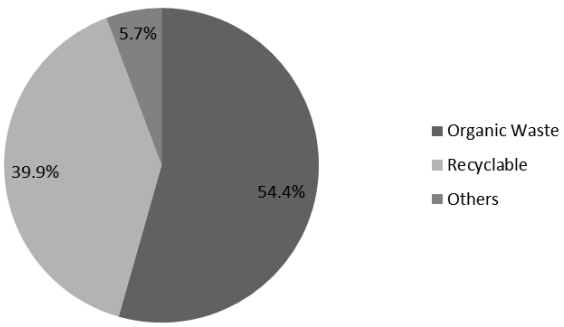

Fig. 2 Average composition of the HSW produced in Rio de Janeiro City during the years of 1995 to 2013

The behavior pattern of the physical composition of the HSW collected in Rio de Janeiro City is observed in **Fig. 3**. Organic waste presented a consistent growth reaching a peak of 61.4% in the year of 2006,

staying above the 50% margin in the most recent years. Comparing the years of 1995 and 2013 there was an increase of 16.3% in the organic fraction and a decrease of 10.0% in recyclables.

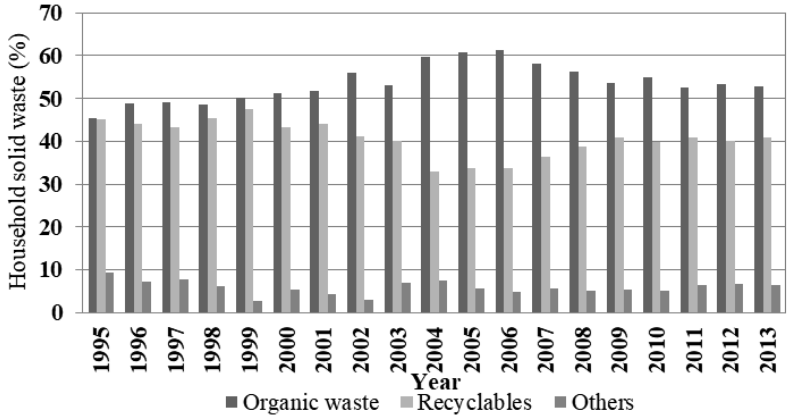

Fig. 3 Behavior pattern of the HSW physical composition produced in Rio de Janeiro City during the years of 1995 to 2013

Research on the HSW generated in Kathmandu, Nepal, which also has a low income economy, revealed that the largest proportion was organic wastes (71%), with approximately 19.5% of the waste being recyclable materials [19]. A study performed by Forouhar and Hristovski [20] in Kabul, Afghanistan, which had the goal of assessing the solid waste management stream, revealed that most household waste was organic, containing large fractions of human excrement and putrecibles. In the present study, the waste composition has revealed the presence of contaminated materials, such as toilet paper, paper towels, disposable diapers, condoms, animal carcasses, dressings and homecare waste, that were classified as "other", in addition to feces from humans and animals (especially cats and dogs).

Recyclables wise, plastic products represent the largest portion averaging 45.1%; papers and cardboard 42.6%; glass 7.8%; and metal 4.8% of the recyclable fraction (**Fig. 4**). These results suggest that the recycling potential of Rio de Janeiro tends to be lower than that of other cities in high income economy countries. Paper and cardboard are the most recycled materials in Europe with more than 40% of the total production collected and recycled annually [21].

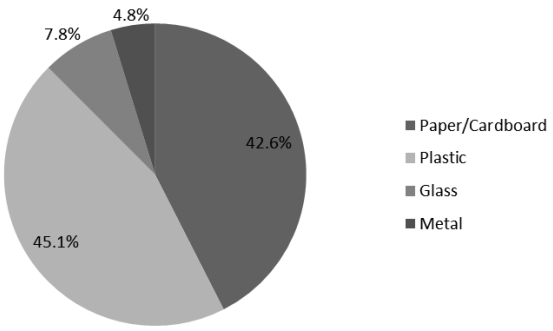

Fig. 4 Average composition of the recyclable fraction of the HSW produced in Rio de Janeiro City during the years of 1995 to 2013

Although the recyclables fraction of the HSW decreased over time its components showed different behaviors. Analyzing this fraction percentages in **Fig. 5**, it is evident a decrease in the amount of paper/cardboard waste produced from 1995 to 2013, with a 30.3% decrease when comparing 1995 to 2013. Increases in the percentages of plastic components were evident over the years. However, there was a weak correlation between the increase in the plastic component and the decrease in the paper component. These percentages should not be interpreted as a decrease in the consumption of paper materials. Instead, it is the result of the introduction of more plastic packaging, such as market bags and processed foods containers. Containers and packaging constitute the largest category of recyclable waste products in the waste stream in urbanized cities such as Rio de Janeiro. Although ecological concerns point the use of paper instead of plastic in packaging, the numbers for plastic either remained constant or increased around the world as stated by Márquez et al. (2008) [22] when studying the waste generation and behavioral patterns in a residential area in the city of Mexicali, México.

As to the metal component, the decrease in the average numbers found over the years can be associated to the removal of aluminum cans by inhabitants or scavengers. Although the recycling rates for other recyclable materials have modestly increased, the market for aluminum cans has been generous with regard to prices. In general, the prices for recycled materials, such as paper, cardboard and beverage plastic bottles, have increased slightly over the studied period.

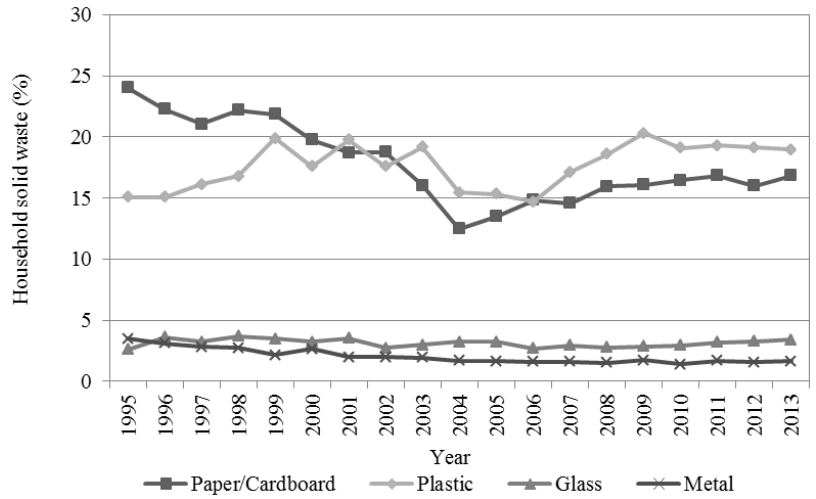

Fig. 5 Behavior pattern of the recyclable fraction of the HSW produced in Rio de Janeiro City during the years of 1995 to 2013

The composition of HSW in different countries is presented in **Table 2** and was used for comparison with the present study. The results indicate that Rio de Janeiro had a percentage of organic wastes similar to cities in undeveloped countries, with the exception of Beijing, China. In that case, the authors attributed the high amount of organic wastes to the different living and dietary habits between Chinese residents and Western populations. In this study, the results support the statement that waste generation is a function of lifestyle and income [8].

Table 2 Physical components of household solid waste in different countries (%).

Country	Country Economy	City	Component (%)								Reference
			Organic	Paper	Plastic	Metal	Glass	Textile	Wood	Other	
Brazil	Upper-middle income	Rio de Janeiro	52.5	17.8	17.6	2.1	3.1	1.7	0.5	4.7	This study
Brazil	Upper-middle income	Uberlândia	72.0	7.0	11.0	3.0	3.0	2.0	-	2.0	[23]
Nigeria	Lower-middle income	Abuja	62.9	10.2	8.9	3.2	2.6	1.6	-	10.6	[5]
Poland	High income	Warsaw	32.2	18.4	16.5	3.0	11.3	2.2	-	3.3	[27]
UK	High income	-	20.2	33.2	10.2	7.3	9.3	2.1	-	-	[21]
Nepal	Low income	Kathmandu	71.0	12.0	7.5	0.5	1.3	0.9	-	7.0	[19]
Singapore	High income	Singapore	13.5	21.2	11.5	14.6	1,0	1.6	4.5	32.1	[6]
Cambodia	Low income	Phnom Penh	61.2	5.2	17.8	0.7	0.8	2.6	8.5	3.2	[25]
Germany	High income	Berlin	15.0	20.0	23.0	2.0	7.0	1.0	13.0	19.0	[6]
Vietnam	Lower-middle income	Mekong Delta	84.1	4.7	6.5	0.5	0.7	0.2	0.3	3.0	[7]
Turkey	Upper-middle income	Istanbul	54.1	16.5	13.7	1.1	3.0	3.4	-	8.2	[2]
China	High income	Beijing	69.3	10.3	9.8	0.8	0.6	1.3	2.7	-	[10]
Macedonia	Upper-middle income	Veles	34.2	12.1	7.6	8.9	3.8	-	-	32.9	[26]
Greenland	High income	Sisimiut	42.8	11.4	2.4	7.1	2.0	-	1.0	33.3	[24]

Source of economy classification: www.data.worldbank.org

Greenland, for example, a high income economy country, which is within the Kingdom of Denmark, produces a low content of paper waste (8%), which is dominated by magazine paper, and a high content of organic waste, which is partly related to the frozen areas [24]. Higher-income countries seem to be generating more paper, plastic, glass and metal wastes. This increased waste generation could be due to the recycling and packaging of products that are typical in urbanized cities, which have more processing, manufacturing and industrial based economies. On the other hand, low income countries generate more biodegradable wastes. Nepal, Sri Lanka and Indonesia have the highest proportion in this category [10, 19]. According to Forouhar and Hristovski [20], factors, such as improved sanitary infrastructure, purchasing power, education and the influx of new products and practices, will create significant changes in solid waste generation rates and composition.

The influence of economy on waste composition was also observed by Othman et al. [8] when comparing different regions of Asia. Recyclables were more abundant in developed countries in Asia such as Japan, China, Korea and Singapore, due to the market value of these products, whereas more degradable organic waste constitutes the bulk of the waste generated in less developed regions such as India and Thailand. In contrast, a study conducted in Tijuana, Mexico that compared socioeconomic status to the waste type produced reported no significant differences, i.e., waste from households of different socioeconomic profiles has similar compositions [28].

4. Conclusions

Changes in the physical composition and quantity of HSW produced by cities have been observed over time as a result of both developmental models adopted and behavioral changes in consumption patterns. In this study, we revealed Rio de Janeiro citizens produce more HSW than ever before, reaching 300 kg per individual per year, an increase of 5% per year for the last three years. The sampling methodology used here showed the real amount of materials that is discharged by citizens and then disposed of at the sanitary landfill. If scavengers or cooperatives do not remove the recyclable fractions from the waste, 39.9% of these materials will be disposed at the landfill. Organic waste accounted for the highest component of household solid waste in all ARs. Approximately 54.4% of all household waste is organic waste, and it is directly landfilled. The organic waste amounts generated in Rio de Janeiro city, even in the highest-income ARs, reveal similarities to other cities in undeveloped countries, such as Nigeria, Cambodia, Nepal, Malaysia and Vietnam. However, the presence of recyclable components can be used as a parameter to indicate purchasing power in the ARs, especially types of waste like magazines, newspapers and delivery food packaging. These data indicate that there should be an effort to reduce the amount of household waste produced through reuse and recycling activities and organic waste recycling via composting. Over the past 19 years, it has been shown that household solid waste collected in Rio de Janeiro city showed a predominance of three elements: organic waste, plastic and paper. As an urbanized city in which waste is formally managed on a municipal scale, Rio de Janeiro has exhibited a waste composition comparable to undeveloped cities in the world. This detailed investigation of household waste composition in Rio de Janeiro city may be a useful tool for the improvement of waste management solutions.

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