Environmental Engineering and Management Journal

December 2019, Vol.18, No. 12, 2719-2728
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

A TEMPORAL HISTORICAL ANALYSIS ON HOW SELECTIVE COLLECTION OF RECYCLABLE WASTE IS INFLUENCED BY EDUCATION-RELATED AND REGIONAL FACTORS AT A UNIVERSITY

Victor Becker Tavares[1], Mateus Amaral da Silva[1], Luiz Otávio de Souza Silva [2], Elen Beatriz Acordi Vasques Pacheco[3,4] *

[1]*Environmental Engineering of Universidade Federal do Rio de Janeiro, 149 Athos da Silveira Ramos Avenue , room D 205, Rio de Janeiro - RJ, 21941-909, Brazil*
[2]*Technology Center of Universidade Federal do Rio de Janeiro, 149 Athos da Silveira Ramos Avenue, Building A, Rio de Janeiro - RJ, 21941-909, Brazil*
[3]*Environmental Engineering Program of Universidade Federal do Rio de Janeiro, 149 Athos da Silveira Ramos Avenue, Building A, Rio de Janeiro - RJ, 21941-909, Brazil*
[4]*Instituto de Macromoléculas Professora Eloisa Mano of Universidade Federal do Rio de Janeiro, 2.030 Horácio Macedo Avenue, Building J, Rio de Janeiro, RJ, 21941-598, Brazil*

Abstract

The aim of the study was to determine the relation between the composition of university recyclable material collected (plastic, paper, metal and glass), education-related factors such as the academic calendar and work stoppages, and regional factors such as climate, regional economy and composition of the urban waste collected over an 8-year period. The study was conducted based on the composition of recyclable dry solid wastes at the Federal University of Rio de Janeiro, quantified after their selective collection between 2010 and 2017. The average proportions of the materials collected were: 63% paper; 19% metal; 8% plastic; 5% glass; and 5% other materials with recycling potential, including Tetrapak™ packaging. The amount of waste was around 20% lower during vacations and long weekends compared to academic periods. There was also a relation between local ambient temperature and plastic composition, which declined in cooler months. The recyclable materials collected in Rio de Janeiro, where the university is located, have different compositions from those of the university, with 41% plastic, 34% paper, 3% metal, 7% glass and 14% of other recyclable materials. For the historical series assessed, it remained unclear whether the economy affected the composition and amount of waste collected. A significant amount of paper was collected at the academic facility, so efforts to decrease its use and/or increase its recycling should be prioritized. This work was one of the first to evaluate an 8-year historical series of waste data collected within a university.

Keywords: characterization, selective collection, solid waste, university

Received: April, 2019; Revised final: June, 2019; Accepted: June, 2019; Published in final edited form: December, 2019

1. Introduction

The generation of waste and its disposal (final destination) is a highly relevant and visible topic in society and widely debated, since it directly affects public health and the environment (Hossain et al., 2017; Spellerberg et al., 2004).

Waste is generated by different sources, including institutions of higher learning which, according to Tauchen and Brandli (2006), can be

*Author to whom all correspondence should be addressed: elen@ima.ufrj.br; Phone: 55 21 39387224; Fax: 55 21 39381317

considered small cities with a large number of generators. Studies at universities such as the Autonomous University of Baja California (Vega et al., 2008); University of Northern British Columbia (Smyth et al., 2010); University of Tabriz (Taghizadeh et al., 2012); Covenant University (Coker et al., 2016); and University of Lagos (Adeniran et al., 2017) seek to characterize their waste in order to plan and implement suitable waste management policies based on knowledge of its composition. To that end, the studies used local sampling and waste classification guidelines of the respective countries or of the American Society for Testing and Materials (ASTM, 2016). At the Universidad Autónoma Metropolitana (Espinosa et al., 2008), a selective collection program was created, in line with federal law, and part of waste management at the institution.

In Brazil, universities have also published scientific articles characterizing their solid waste, emphasizing recyclables: Federal University of Goiás (Cruz et al., 2009), Federal Technological University of Paraná (Gonçalves et al., 2010), Anhanguera Educacional (Nardy et al., 2010), State University of Paraná (Sousa et al., 2015), University of Pernambuco (Silva et al., 2016), Federal University of Amazonas (Caetano et al., 2016), University of Campinas (Fagnani and Guimarães, 2017), Integrated Faculties of Espírito-Santenses (Ker et al., 2017), Maringá State University (Zotesso et al., 2016) and the Federal University of Rio de Janeiro.

At the Federal University of Rio de Janeiro (UFRJ), the Non-Hazardous Solid Waste Collection Program was implemented in 2010. It is important to underscore that Brazil has also instituted the National Solid Waste Policy (Brasil, 2010) and the Environmental Agenda in Public Administration (A3P), which help public institutions seek environmental sustainability. The Program requires the university to strive for sustainability through discussion and the adoption of a formal environmental and waste management system, such as implementing recycling on its campus (Juliatto et al., 2011; Spellerberg et al., 2004).

Gallardo et al. (2017) reported that gravimetric characterization is important in determining the standard waste composition of an area in order to implement an appropriate selective collection program. Additionally, the characterization of recyclable waste from universities that published their studies was based on the result for a specific period, usually less than one year. The present study discusses composition by weight in a historical series (between 2010 and 2017) and, as such, aimed at assessing whether there is a relation between the composition of recyclable waste from a university and the academic calendar, climate, the economy and whether it reflects the same composition of the city where it is located. Universities should be accountable for the waste they generate and investigate its recycling potential. Material that is not recycled will not return to the supply chain, effectively wasting potential raw material (Ebrahimi and North, 2016). Moreover, characterizing composition by weight of university waste is essential in determining a more suitable final destination.

2. Methodology

The weight of waste material collected at the Technology Center of UFRJ between 2010 and 2017 was provided by the *Technology Center Recycling Program* team, to which two of the authors of this study belong.

2.1. Description of the collection scenario

The Technology Center of the Federal University of Rio de Janeiro (UFRJ) implemented a selective collection program in 2010. The Technology Center (UFRJ) offers 16 undergraduate and 30 graduate engineering courses, which has several research facilities: the Polytechnical School, School of Chemistry, Alberto Luiz Coimbra Graduate and Engineering Research Institute, Professor Eloisa Mano Macromolecule Institute and Interdisciplinary Center for Social Development. According to information provided by the university, the Technology Center has 6400 undergraduate and 4500 graduate students, 500 professors and around 600 technical-administrative employees, totaling 12,000 individuals.

The regular undergraduate periods are divided into semesters at UFRJ. The first is between March and July and the second from August to December. In some years, academic activities are interrupted by strikes. Strikes at Brazilian public universities involve a collective movement (students, employees and/or professors) against a particular act or situation. Between 2010 and 2017, work stoppages occurred in 2012 (from May to September, almost 110 days) and 2015 (from June to August, almost 60 days).

In years with no strikes, there is a 15-day vacation period in the second half of July and 2 months between mid-December and early March.

2.2. *Collection and recyclable solid waste classification procedures*

The Technology Center Recycling Program is in charge of managing non-hazardous recyclable waste deposited by the generators (students, employees and professors) in colored bins used for selective collection (blue for paper, red for plastic, yellow for metal, green for glass, grey for non-recyclables and brown for biodegradable organic waste), placed around Technology Center buildings at points with a high volume of pedestrian traffic, and near snack bars and restaurants. Banks and printing and copying services at the university have yet to enroll in the collection program. Eighty-six kits were installed, consisting of five (5) 60 L permanent colored bins, totaling 430 bins. They were installed in the common areas of Technology Center, mostly the ground level and food court.

A team of professionals removes the waste from the bins and transfers it to the *Waste Sorting Center* twice a day: first at 6:30 am, before the start of classes, and then again after lunch at 2 pm. The waste is separated into 8 categories and 20 subcategories, considering subdivisions on paper, plastics and metal (Table 1). Trash (non-recyclables and biodegradable organic waste) are disposed of in common waste containers and sent to the city's sanitary landfill.

At the *Waste Sorting Center*, a team of professionals manually separate recyclable materials. Saleable items are separated, categorized and weighed. The different materials are separated according to the interest of local recyclers, whose raw materials are supplied by cooperatives of recyclable material collectors. Finally, the separated recyclables are sent to registered cooperatives at university, which forward them to the recyclers. The descriptive methodology adopted by the *Recycling Program* is shown in Fig. 1, which also contains summarized information about collection, sorting and weighing of the recyclable materials collected.

Table 1. Classification of waste per category and subcategory at the Technology Center Recycling Program

Category	*Subcategory*
Paper	Cardboard – external part
	Mixed cardboards (mixture of various cardboards)
	Paper with glue
	Mixed paper (mixture of various papers)
	White paper
	Newspaper
	Magazines
Plastic	Acrylonitrile butadiene styrene copolymer (ABS)
	Transparent PET packaging
	Colored PET packaging
	PET packaging for edible oil
	Polypropylene (PP)
	White high-density polyethylene
	Colored high-density polyethylene
	White plastic film
	Colored plastic film
	Poly(vinyl chloride)
Metal	Aluminum cans
	Scrap metal without iron
	Scrap iron
Glass	
Tetrapak	
Other recyclable solid material	
Non-recyclable liquid material	
Non-recyclable solid material	

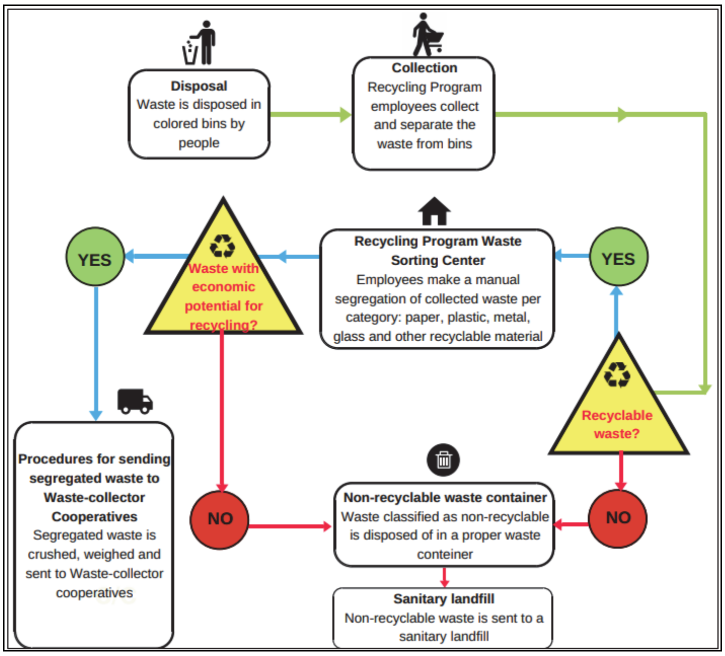

Fig. 1. Collection, classification and weighing procedures for sending waste to the Waste Sorting Center

2.3. Factors evaluated in the analysis of recyclable waste

The parameters studied to analyze the waste collected by the Technology Center Recycling Program are associated with education-related and regional factors. The amount of material collected (t) and weight percentage were used for these analyses.

2.3.1. Weight percentage calculation

The data on the dry weight (t) of each of the materials presented in Table 1 were calculated as weight percentage (%) in relation to the total waste collected, calculated according to Eq. (1) (Vega et al., 2008). The mean weight and mean composition were calculated according to Eqs. (2-3), respectively.

$$Composition\,by\,weight\,(\%) = \left(\frac{Total\ weight\ collected\ of\ a category\ (t)}{Total\ weight\ collected\ of\ all\ categories\ (t)}\right) \quad (1)$$

$$Mean\,weight(t) = \frac{\sum x}{n} \quad (2)$$

$$Mean\,composition\,(\%) = \frac{\sum y}{n} x100 \quad (3)$$

where: x represents the weight in tons (Eq. 2), y the composition calculated in Eq. 1 (Eq. 3) and n the number of elements in the category. The standard deviation of mean weight and mean composition, calculated from Eq. 2 and 3, was obtained according to Eq. 4.

$$Standard\,deviation = \sqrt{\frac{\sum (z - mean\,result)^2}{(n-1)}} \quad (4)$$

where: Z = x, for mean weight; and Z = y, for mean composition.

2.3.2. Ratio between the amount collected and the academic calendar

First, the amounts of all the dry recyclable waste collected every month of every year were added to analyze the variation in composition over time. This analysis considered the examination period, vacation months, long weekends and work stoppages (strikes).

The amounts of recyclable waste were also summed and analyzed every year in order to determine the behavior of the amount collected in years where strikes occurred and post-strike years.

2.3.3. Determination of the influence of local temperature on composition

According to Vega et al. (2008) and Taghizadeh et al. (2012), a large number of beverages packed in plastic bottles were consumed at *Universidad Autónoma de Baja California* and the *University of Tabriz* during the hottest months in Mexico and Iran, respectively. Vega et al. (2008) observed significant variations concerning plastic compositions throughout different climate periods and verified that local ambient temperature affected its consumption over time.

Temperature in Rio de Janeiro varies little between summer and winter. The hottest months of the year are between December and March with averages above 25º C, and the coldest between June and August, with an average of 20º C and minimum of 15º C. Thus, the average composition by weight (%) of plastic in the hottest and coldest months during the years of the study was assessed

2.3.4. Assessment of the influence of the economy on recyclable composition

Campos (2012) investigated whether the local economy caused any variation in the composition of the waste collected, even in a small setting such as a university. The author related gross domestic product (GDP) information to the solid urban waste generated by countries on a time scale. Gross domestic product is the monetary value of all goods and services produced in a particular country over a specific time period (Costanza et al., 2009). In line with Campos (2012), the amount of recyclable waste collected (t) at the Technology Center of UFRJ between 2010 and 2015 was analyzed and compared to GDP data from Rio de Janeiro (CEPERJ, 2018), where the university is located. The values are expressed in American dollars (USD) – according to the commercial exchange rate on December 31, 2015, when USD 1.00 ≅ BRL 3.96 (ADVFN, 2015).

Variations in GDP and the amount of waste collected (%) were calculated from one year to another using Eq 5. Finally, the annual variations in GDP and the amount of waste collected were compared. In Eq. 5, ΔQ is the variation between the amount of waste collected (t) in a given year (Q') and the amount collected (t) the previous year, from 2010 to 2015; and in Eq. 6, ΔGDP is the variation between the gross domestic product of a given year (GDP') and the GDP of the previous year, in USD x 106, for the same period.

$$Annual\ waste\ variation\ (\%) = \left(\frac{\Delta Q}{Q'}\right) x\ 10 = \frac{(Q\ Year\ B) - (Q\ Year\ A)}{(Q\ Year\ B)} \quad (5)$$

$$Annual\ GDP\ variation\ (\%) = \left(\frac{\Delta \mathrm{GDP}}{GDP'}\right) x\ 100 = \left(\frac{(GDP\ Year\ B) - (GDP\ Year\ A)}{(GDP\ Year\ B)}\right) x\ 100 \quad (6)$$

2.3.5. Comparison between waste collected at UFRJ *and in Rio de Janeiro*

The composition of waste collected at the university and in Rio de Janeiro was compared, using the composition by weight data provided by the Municipal Waste Management Company – Comlurb (COMLURB, 2016). The document contains the amount of waste collected in the city between 2010 and 2016, which was compared with data from the Technology Center (UFRJ).

3.1. Percentage composition by weight of the waste collected

The results of composition by weight show the recyclable and non-recyclable materials collected, sent, separated, classified and weighed at the *Waste Sorting Center* of UFRJ between 2010-2017 (Fig. 2). The recyclable materials received at the center are separated and placed in the colored bins, where fewer than 10% of the materials sent are non-recyclable. Details on the amount of all the waste collected and weighed at the Waste Sorting Center and the respective composition by weight (%) (Table 2).

3.2. Amount and composition of recyclable solid waste collected per year

The amount of recyclable materials collected, weighed and sent from the *Waste Sorting Center* of the *Recycling Program* to the Recyclable Materials Collectors Cooperatives is exhibited in Table 2. In 2012, 2014 and 2015, the total collected in the year was lower than the previous year. There were two strikes in 2012 and 2015, which reduced collections by 11% and 7%, respectively. In 2012, this decline was accentuated by staff budget cuts in the Program due to economic difficulties.

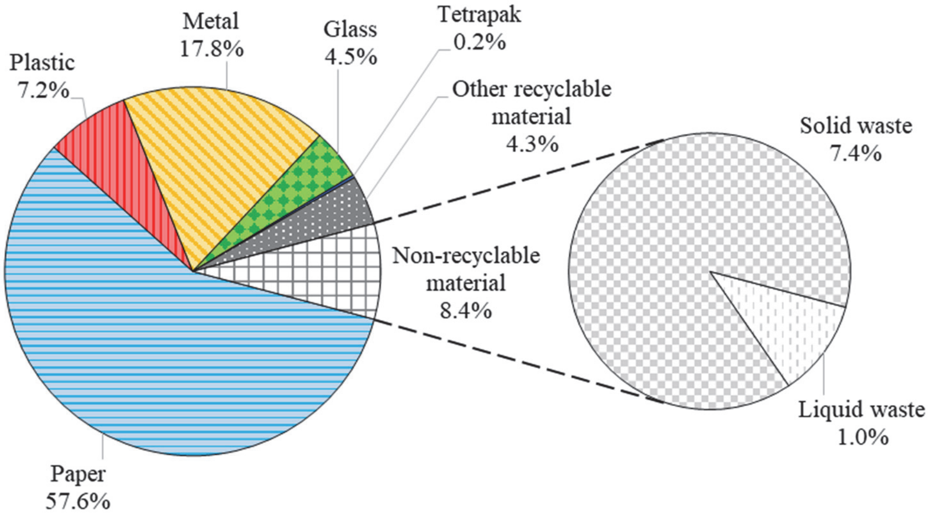

Fig. 1. Mean composition by weight of collected recyclable and non-recyclable waste weighed at the *Waste Sorting Center* from 2010 to 2017

Table 1. Amount and composition by weight of recyclable waste collected and weighed at the *Waste Sorting Center*

Year	*Weight, t (Composition, %)*					*Total collected in the year, t (Mean composition, %)*
	Paper	*Plastic*	*Metal*	*Glass*	*Other recyclable*	
2010	28.9 **(53.4)**	5.4 **(9.9)**	8.1 **(15.0)**	3.0 **(5.5)**	8.8 **(16.2)**	54.1 **(10.3)**
2011	51.3 **(68.8)**	6.3 **(8.4)**	14.1 **(18.9)**	2.2 **(2.9)**	0.7 **(1.0)**	74.5 **(14.2)**
2012	40.7 **(61.3)**	5.7 **(8.5)**	15.6 **(23.4)**	2.9 **(4.4)**	1.6 **(2.4)**	66.4 **(12.7)**
2013	51.4 **(60.6)**	7.3 **(8.6)**	18.1 **(21.4)**	3.1 **(3.7)**	4.9 **(5.8)**	84.8 **(16.2)**
2014	37.3 **(63.5)**	4.4 **(7.5)**	9.8 **(16.6)**	2.1 **(3.6)**	5.2 **(8.8)**	58.8 **(11.2)**
2015	37.1 **(67.9)**	3.4 **(6.3)**	10.9 **(19.9)**	2.1 **(3.8)**	1.2 **(2.2)**	54.6 **(10.4)**
2016	41.9 **(64.2)**	4.1 **(6.2)**	13.6 **(20.8)**	5.2 **(8.0)**	0.6 **(0.9)**	65.4 **(12.5)**
2017	40.3 **(62.2)**	4.9 **(7.5)**	11.7 **(18.1)**	4.8 **(7.4)**	3.1 **(4.9)**	64.8 **(12.4)**
Mean weight[a] (and mean composition [b])	41.1 ± 7.5 **(62.7 ± 4.8)**	5.2 ± 1.2 **(7.9 ± 1.3)**	12.7 ± 3.3 **(19.2 ± 2.7)**	3.2 ± 1.2 **(4.9 ± 1.9)**	3.3 ± 2.9 **(5.3 ± 5.2)**	65.4 **(10.3)**

[a] *Mean weight and mean composition calculated following Eq. 2 and 3*
[b] *Standard deviation (t, %) calculated following Eq. 4*

In 2014, there were technical problems with the carts used to collect waste caused by lack of maintenance, which led to a decrease in the amount collected (31% compared to 2013), especially in June (2.6 t) and July (6.4 t). A reduction was observed, considering that the historical average for these months is 5.4±1.9 t and 7.2±1.6 t, respectively. Thus, it was concluded that technical support infrastructure is essential to maintaining a functioning selective collection program. As such, the program needs a suitable number of employees assigned solely to collect and sort recyclables and perform periodic maintenance on collection equipment. The reduction also occurred as a result of the Football World Cup in Brazil (June – July) since public holidays were declared on certain match days.

Regarding the amount of material according to specific categories, far more paper was collected, with an average of 41.1 ± 7.5 t (62.7 ± 4.8%) per year. The average amount of metal collected was 12.7 ± 3.3 t (19.2 ± 2.7%), followed by plastic with 5.2 ± 1.2 t (7.9 ± 1.3%), and glass with 3.2 ± 1.2 t (4.9 ± 1.9%), in addition to 3.3 ± 2.9 t (5.3 ± 5.2%) of other recyclable dry materials.

Despite the use of multimedia, a significant amount of paper waste is still generated at the university. This result was also reported by Vega et al. (2008), Smyth et al. (2010) and Coker et al. (2016). The application of the Moodle System (Gogan et al., 2015) at universities could also contribute to minimizing paper use. Smyth et al. (2010) suggested that environmental education campaigns should be adopted to alert university administrators to the problem. An attempt at reusing materials should be considered before recycling them, considering the correct waste treatment, that is, reducing waste generation, trying to reuse it and if this is not feasible, sending it to a recycling company (Tangwanichagapong and Nitivattananon, 2017). According to Vega et al. (2008), paper generation can be reduced by using both sides of a sheet or sending documents electronically instead of printing them.

3.3. Influences on the amount of recyclable waste collected

The different influences of work stoppages, ambient temperature, academic calendar, local economy and waste collection in the city where the university is located on the composition of recyclable material were evaluated.

3.3.1. Amount of waste collected monthly

The data on the amount of waste collected was obtained from the bins, as stated in item 2.2, according to the procedures detailed in the Methodology Section of this paper. The amount of waste generated was higher in the academic period due to the presence of students, employees and professors, declining during vacations and work stoppages. In the present study on waste from *Technology Center Recycling Program*, the amounts collected in the twelve consecutive months of every year since 2010 were recorded. The total amount of waste collected monthly from 2010 to 2017 at *Technology Center Recycling Program* is presented in Fig. 3.

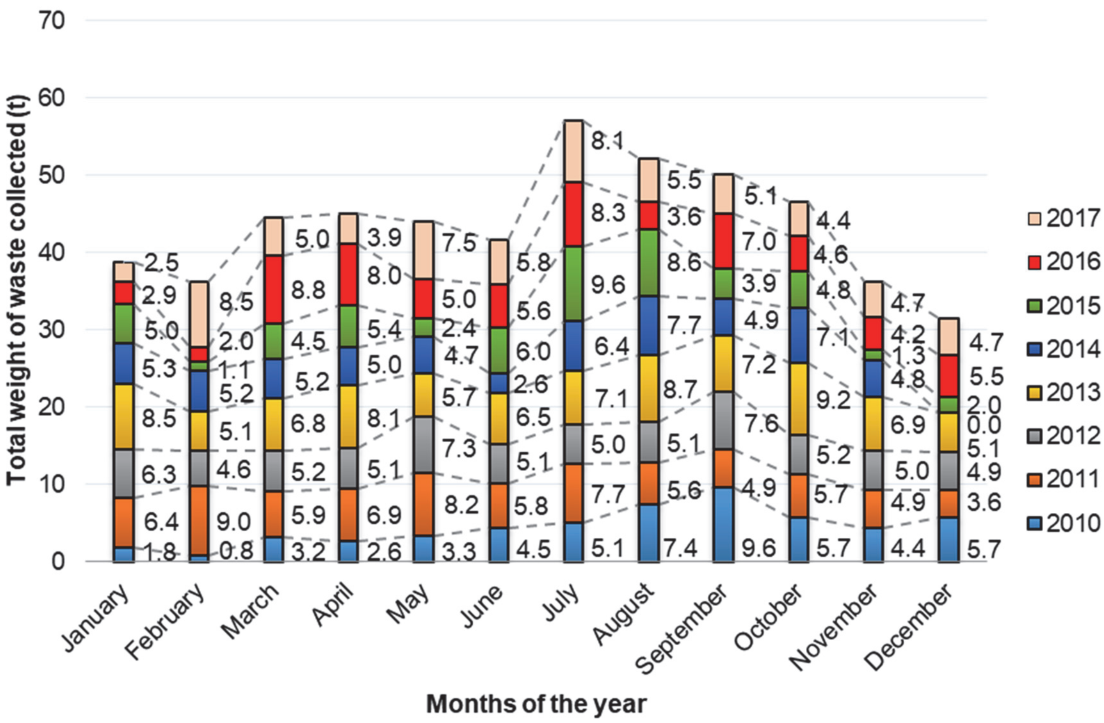

Fig. 2. Total weight of recyclable solid waste collected monthly from 2010 to 2017

The amount of waste collected in the first semester (January to July) was similar to that of the second semester (August to December). Between 2010 and 2017, around 232.6 t were collected in the first semester (March to July) – a monthly average of 46.5 ± 6.1 t, and 216.7 t in the second semester (August to December) – a monthly average of 43.3 ± 9.0 t. The highest amount of waste was produced in July, likely because it is an examination period, but curiously, this did not occur in November, when final examinations are taken.

Significant amounts of waste were collected during the first month of each semester, when new students enroll, with an average of 5.6 ± 1.6 t in March (1st semester) and 6.5 ± 1.8 t in August (2nd semester), between 2010 and 2017.

3.1.2. Influence of work stoppages

There were two strikes during the study period, one in 2012 and the other in 2015, as previously mentioned. In 2012, employees, students and professors were on strike for over three months, from late May to early September and in 2015 for two months, from late June until late August. During these periods there were fewer students on campus, resulting in less waste collected. In 2013, the amount collected was well above average, reaching 84.8 t, a 22% increase over 2012. In that year, the academic calendar was extended due to the strike in the previous year to compensate for the shortened calendar of 2012.

The higher the number of academic days the more waste was collected. For example, in 2013, around 18.4 t (21.7%) more waste was collected than in the previous year, when a 3-month strike occurred, and 10.7 t (16.4%) more in 2016 than 2015.

3.3.3. Influence of academic vacations

As expected, lower amounts of waste were collected during the undergraduate vacation periods and long breaks such as Carnival, Christmas and New Year's, from December to March. These holidays correspond to a period of almost three (3) months, or around 80 days. The average amount of waste collected between 2010 and 2017 was 46.4 ± 6.1 t during semesters and 35.5 ± 3.7 t during vacations, that is, 24% more in the former. Undergraduate vacations use to be between mid-December and early March; however, graduate courses, which have 30% fewer students, do not stop their activities. December and February had the lowest collections.

3.3.4. Influence of local temperature

The average monthly composition by weight (%) of plastic was related to academic activities in order to demonstrate which periods actually exhibited more or less plastic in relation to the total amount of waste collected. Figure 4 shows the average monthly composition by weight (%) of plastic in relation to the total composition of recyclable waste and average temperatures in Rio de Janeiro in months of undergraduate academic activity.

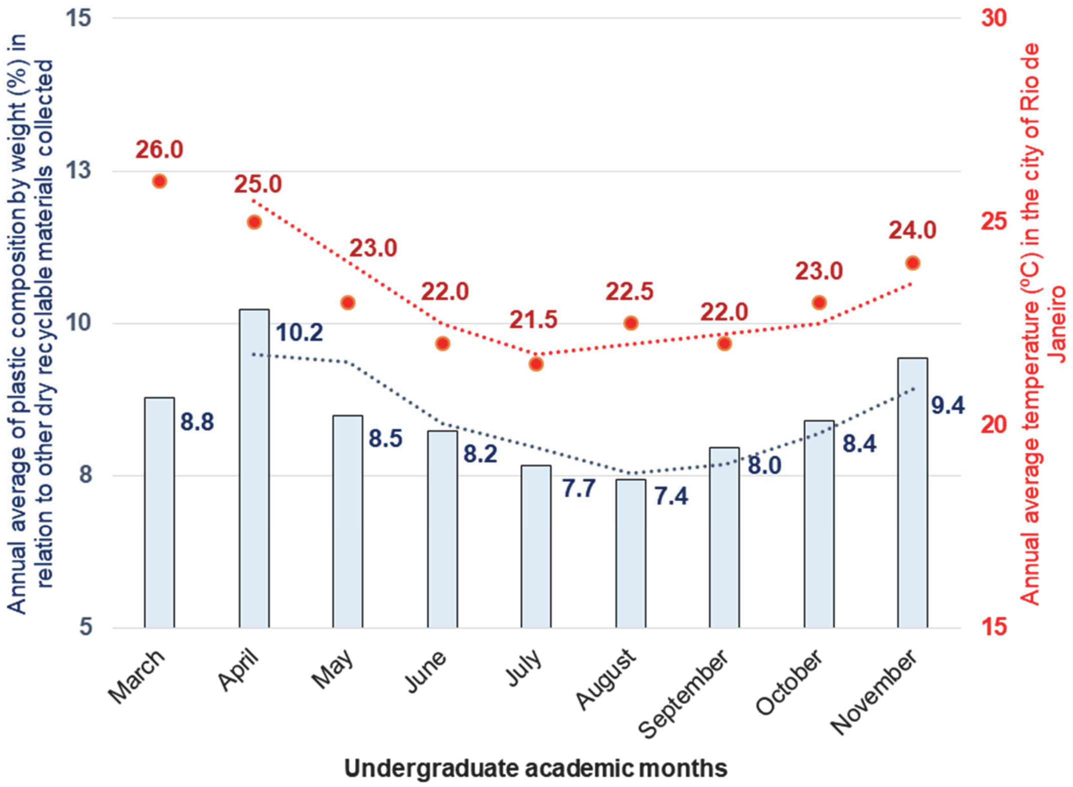

Fig. 3. Relation between plastic composition by weight (%) and average temperature (ºC) during undergraduate academic months in the city of Rio de Janeiro between 2010 and 2017

Trend lines showed a relation between average composition by weight (%) of plastic collected during academic months and local ambient temperature. In general, the lower the temperature, the less plastic in the total composition of recyclable materials. Two months did not follow this trend: March and August, the first months of each semester. In March, there was less plastic, with the highest average temperature of all academic months; less plastic was also collected in August, although its average temperature was higher than the previous and subsequent months (July and September, respectively). This is likely due to the 20-day academic break for graduate students between the two semesters of the year, from mid-July to mid-August.

To promote the generation of less plastic waste, the university must consider the waste destination hierarchy, which includes the 3 R's (reduction, reuse and recycling). With respect to reduction, environmental education programs should be implemented for all academic staff and students, including talks, training sessions and workshops. In relation to reuse, awareness campaigns should be put in place to encourage the use of reusable mugs and bottles for coffee or water consumption, for example (Smyth et al., 2010).

In addition, for recycling, the university should consider investing in the Recycling Plant located in the Professor Eloisa Mano Institute of Macromolecules (IMA) of UFRJ, with a view to transforming its post-consumer plastic into other useful materials, such as bins, chairs, and tables, among others. The plant is a laboratory scale recycler located at the Center for Excellence in Recycling and Sustainable Development (NERDES), which includes a mill, washing tanks, injector, extruder and other equipment to recycle plastic disposable cups and other plastic material collected by the Recycling Program."

3.3.5. Influence of the local economy

Table 3 presents the GDP data and total amount of recyclable waste collected. There was no relation between these two values, unlike the result observed by Campos (2012).

Nevertheless, it is important to underscore that the recession of 2013 may have contributed to the marked decline in waste collected in 2013 and 2014, with a variation of -44%, the largest reduction recorded. The GDP of the city experienced the largest decrease during the same period (11% in 2013 and 5% in 2015).

Thus, the economic downturn that began in 2013 may have affected the amount of waste collected from this year onward. However, collection and GDP data for the years following the recession should be analyzed in order to draw more accurate conclusions and determine the possible relation between the amount collected and the local economy.

3.3.6. Comparison between the waste collected at Technology Center/*UFRJ and City of Rio de Janeiro*

It was also assessed whether there was a relation between recyclable waste collected at the university and in Rio de Janeiro, the city where the institution is located. The composition by weight (%) of recyclable materials collected by Municipal Waste Management Company – Comlurb (2016) can be seen in Table B of the Appendix. However, considering only the dry recyclables, excluding biodegradable organic waste, average composition by weight was reorganized and is shown in Table 4. In the city of Rio de Janeiro, plastic was the most generated waste (41.7 ± 0.7 %) followed by paper (34.4 ± 0.7 %).

Table 3. Relation between gross domestic product (GDP) and total weight of waste collected at *Recycling Program*

Period assessed (2010-2015)	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
GDP[a] (BRL x 10^6)	208.2	229.6	253.2	284.3	300.3	320.8
GDP[b] (USD x 10^6)	52.6	58.0	63.9	71.8	75.8	81.0
Total weight collected (t)	54.1	74.5	66.4	84.8	58.8	54.6

Annual variation (%)[c]	***2010 - 2011***	***2011 - 2012***	***2012 - 2013***	***2013 - 2014***	***2014 - 2015***
GDP	9	9	11	5	6
Total weight collected	27	- 12	22	- 44	- 8

[a] Rio de Janeiro GDP data from 2010 to 2015. Source: Fundação Centro Estadual de Estatísticas, Pesquisas e Formação de Servidores Públicos do Rio de Janeiro (CEPERJ, 2018);[b] American dollar (USD) exchange rate: USD 1.00 ≅ BRL 3.96 (Brazilian Real). Source: ADFN International, 2015; [c] Annual variation calculated in accordance with Eq. 5 and 6

Table 4. Composition by weight of recyclable material collected, except organic matter and electro-electronic waste, in Rio de Janeiro and UFRJ from 2010 to 2016

Category	***UFRJ***	***Rio de Janeiro***
	Average composition	
Paper	63.0 ± 5.1	34.4 ± 0.7
Plastic	7.9 ± 1.4	41.7 ± 0.7
Metal	19.5 ± 2.9	3.5 ± 0.1
Glass	4.6 ± 1.7	7.2 ± 0.2
Other recyclable material	5.1 ± 5.5	13.2 ± 1.7

However, at UFRJ, paper was the most generated, followed by plastic. This result may demonstrate how waste management in these settings is different. The city should seek alternatives to minimize both plastic and paper waste.

At *Universidad Autónoma Metropolitana*, the authors compared the waste generated at the institution and in Mexico City in order to show the difference in waste composition between a university setting and a city. At this university, paper, plastic, glass, metal and others, the most recyclable materials, were estimated at around 95%, while in Mexico City organic matter accounted for nearly 50% of the total weight of the waste. *Universidad Autónoma Metropolitana* generated 26% paper and Mexico City 16% (Espinosa et al., 2008). There was no information on organic waste at UFRJ. The *Recycling Program* did not collect this material up to 2017.

4. Conclusions

The study made it possible to relate waste generation and composition to the academic calendar, seasonality and the economy, since the monthly data covered a relatively long period (8 years). The Waste Sorting Center of the Federal University of Rio de Janeiro separates and sends a large amount of waste generated at the university to recycling companies, although variations occurred due to a range of factors, including work stoppages, ambient temperature, academic calendar, collection infrastructure (equipment and maintenance), and collection personnel.

The factors analyzed showed that the amount of recyclable waste collected during academic activities was around 20% higher than in vacation periods, breaks and holidays. The presence of plastic was higher during academic months with hotter temperatures, likely due to the greater consumption of beverages packaged in plastic bottles, while collection declined at cooler temperatures. There was no relation between gross domestic product (GDP) and the amount collected; however, the latter declined immediately after the onset of the recession.

An average of 65.4 ± 10.3 t of solid recyclable waste per year was collected. Paper accounted for 60% of the total, with an average of 41.1 ± 7.5 t.

In order to reduce paper, the *Recycling Program* could hold campaigns at the start of the semester with new undergraduate students, since they generate the most quantity of waste (more than 50%). These campaigns could include using both sides of a sheet, reusing it as scrap paper and changing to digital systems. The use of plastic bottles and reusable cups should be encouraged to reduce the generation of this material.

References

Adeniran A.E., Nubi A.T., Adelopo A.O., (2017), Solid waste generation and characterization in the University of Lagos for a sustainable waste management, *Waste Management*, **67**, 3-10.

ADVFN, (2015), United States Dollar vs Brazil R Historical Data - USDBRL. USDBRL Historical Prices: From 01 Dec 2015 to 31 Dec 2015, On line at: https://www.advfn.com/stock-market/FX/USDBRL/historical/more-historical-data.

ASTM, (2016), American Society for Testing and Materials, ASTM D 5231, Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.

BRASIL, (2010), Brazilian Policy on Solid Waste. Law # 12.305 02, On line at: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

Caetano R.L., Leal T.S., Gonçalves J.S., Silva M.N.A., Contente E.C.M.S., (2016), Tool to support solid waste management at Faculdade de Tecnologia da Universidade Federal do Amazonas. VII Congresso Brasileiro de Gestão Ambiental: IBEAS, Campina Grande, Brazil, Universidade Federal de Campina Grande, 1-9, On line at: http://www.ibeas.org.br/congresso/Trabalhos2016/I-026.pdf.

Campos H.K.T., (2012), Evolution of income and per capita generation of solid wastes in Brazil, *Engenharia Sanitária e Ambiental*, **17**, 171-180.

Coker A.O., Achi C.G., Sridhar M.K.C., Donnett C.J., (2016), Solid Waste Management Practices at a Private Institution of Higher Learning in Nigeria, *Procedia Environmental Sciences*, **35**, 28-39.

COMLURB (2016), Companhia Municipal de Limpeza Urbana (Municipal Company of Urban Cleaning), Characterization of Solid Residual Domiciliary of the City of Rio de Janeiro, Rio de Janeiro, Brazil.

Costanza R., Hart M., Posner S., Talberth J., (2009), Beyond GDP: The Need for New Measures of Progress. The Pardee Papers. Boston: Pardee Center for the Study of the Longer-Range Future, vol. 4, 3 – 4, On line at: https://www.bu.edu/pardee/files/documents/PP-004-GDP.pdf.

Cruz J.A., Carvalho, E.H., Simone, (2009), Diagnóstico dos resíduos sólidos da Universidade Federal de Goiás. 25º Congresso Brasileiro de Engenharia Sanitária e Ambiental: ABES. Recife: Centro de Convenções de Pernambuco, Vol. III-244, 1-7, On line at: http://www.ufrgs.br/sga/SGA/material-de-apoio/textos/textos-apoio/links/III-244.pdf.

Ebrahimi K., North L.A., (2017). Effective strategies for enhancing waste management at university campuses, *International Journal of Sustainability in Higher Education* **18**, 1123-114.

Espinosa R.M., Turpin S., Polanco G., De laTorre A., Delfín I., Raygoza I., (2008), Integral urban solid waste management program in a Mexican university, *Waste Management*, **28**, S27-S32.

Fagnani E., Guimarães J.R., (2017), Waste management plan for higher education institutions in developing countries: The Continuous Improvement Cycle model, *Journal of Cleaner Production*, **147**, 108-118.

CEPERJ, (2018), Foundation State Center for Statistics, Research and Training of Public Servants of Rio de Janeiro, Gross Domestic Product of the State of Rio de Janeiro, On line at: http://www.ceperj.rj.gov.br/ceep/pib/pib.html.

Gallardo A., Carlos M., Colomer F.J., Edo-Alcón N., (2017), Analysis of the waste selective collection at drop-off systems: Case study including the income level and the seasonal variation, *Waste Management and Research*, **36**, 30-38.

Gogan M.L., Sirbu R., Draghici A., (2015), Aspects concerning the use of the Moodle platform – Case study, *Procedia Technology*, **19**, 1142-1148.

Gonçalves M.S., Kummer L., Sejas M.I., Rauen T.G., Bravo C.E.C., (2010), Solid waste management at Universidade Tecnológica Federal do Paraná Campus Francisco Beltrão, *Revista Brasileira de Ciências Ambientais,* **15**, 79-84.

Hossain M.E., Al-Majed A., Adebayo A.R., Apaleke A.S., (2017), A critical review of drilling waste management towards sustainable solutions, *Environmental Engineering and Management Journal*, **16**, 1435-1450.

Juliatto D.L., Calvo M.J., Cardoso T.E., (2011), Integrated solid waste management for public institutions of higher education, *Gestão Universitária na America Latina – GUAL*, **4**, 170-193.

Ker A.B., Freitas D.P., Nunes F.R.G., Cruz S.L., Pinto T.G., Gianetti T.T., Theodoro D.C., Pelissari V.B., (2017), Gravimetric composition of the solid waste produced at Campus I of Centro Universitário FAESA", *Revista Científica Faesa*, **13**, 48-53.

Nardy M.B.C., Cunha M.E.G., Bichara J., Poli M., (2010), "Análise de processos em uma instituição de ensino superior visando a implantação de um sistema de gestão ambiental", *Revista de Ciências Gerenciais*, **14**, 33-54.

Silva J.D.J.C., Mocock J.F.B., Cavalcanti B.V.P., Rabbani E.R.K., (2016), *Gravimetric Analysis as an Environmental Education Tool at the Polytechnic School of the University of Pernambuco*, In: *SBE16 Brazil & Portugal - Sustainable Urban Communities Towards a Nearly Zero Impact Built Environment, SBE Series*, Vitória, Universidade do Minho e UFES, 661-670.

Smyth D.P., Fredeen A.L., Booth A.L., (2010), Reducing solid waste in higher education: The first step towards 'greening' a university campus, *Resources, Conservation and Recycling*, **54**, 1007-1016.

Sousa A.O., Almeida A.P.A., Almeida M.S., Neto V.S., Sousa F.R.R., (2015), *Management of Solid Waste at the VIII Campus of the Universidade Estadual da Paraíba*, Proc. of the Brazilian Congress of Environmental Management and Sustainability: Congestas, João Pessoa, Brazil, 320-327.

Spellerberg I.F., Buchan G.D., Englefield R., (2004), Need a university adopt a formal environmental management system? Progress without an EMS at a small university, *International Journal of Sustainability in Higher Education*, **5**, 125-132.

Taghizadeh S., Ghassemzadeh H.R., Vahed M.M., Fellegari R., (2012), Solid waste characterization and management within university campuses case study: university of Tabriz, *Elixir Pollution*, **43**, 6650-6654.

Tangwanichagapong S., Nitivattananon V., (2017), Greening of a campus through waste management initiatives Experience from a higher education institution in Thailand, *International Journal of Sustainability in Higher Education*, **18**, 203-217.

Tauchen J., Brandli L.L., (2006), Environmental management in higher-education instituions: a model for implementation at a university campi, *Gestão & Produção*, **13**, 503-515.

Vega C.A., Benítez S.O., Barreto M.E.R., (2008), Solid waste characterization and recycling potential for a university campus, *Waste Management*, **28**, 1, S21-S26.

Zotesso J., Cossich E., Colares L., Tavares C., (2016), Analysis of solid waste generation in a university cafeteria in Brazil: a case study, *Environmental Engineering and Management Journal*, **15**, 2327-2336.