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Characterization of solid wastes as a tool to implement waste management strategies in a university campus

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Received 9 December 2019
Revised 19 May 2020
29 July 2020
6 August 2020
31 August 2020
Accepted 31 August 2020

Abstract

Purpose – Universities are an example of institutions that aggregate people around work/study who consume water, energy and produce waste daily in their activities, generating an impact on the environment. The purpose of this study is to determine the quantity, composition and recycling potential of waste generated at the Faculdade UnB Planaltina (FUP) campus, of the University of Brasilia in the Federal District, Brazil, to develop a waste management strategy compatible with national legislation and sustainable global practices.

Design/methodology/approach – This study was based on conducting on-site visits to identify the sources of generation, hazardousness, management and gravimetric characteristics of residual waste from 2015 to 2016. In 2016, a selective collection was implemented on the FUP campus, and since then, actions to raise awareness for the selective disposal and monitoring of waste were conducted with the academic community.

Findings – The results showed that the campus generates 148 kg of waste/day, whereas the per capita generation is 92 g/day. The production of hazardous waste is related to campus laboratories which manage it under a specific program. The campus restaurant is the place that generates the most waste, of which organic waste is the most representative. When categorizing the waste generated on campus, the authors found that the majority are recyclables at 67% of the total. This category includes material composed of cardboard, paper and plastic, all able to be recycled in the Federal District.

Practical implications – The recyclable waste generated at the FUP campus is being diverted from the city's landfill because they are donated to a recycling cooperative. These actions promote income generation, social inclusion of waste pickers and a circular economy, all in compliance with the National Solid Waste Policy. As a result, the FUP campus is more in line with Brazilian legislation and the global context of adopting sustainable waste management amongst higher education institutions.

Originality/value – This paper contributes to the literature on sustainability in higher education by reporting the process of implementation of a waste management strategy in a university campus. Further, it presents tools and methods that can be used to achieve sustainability in waste management. The study also identifies that the crucial factor for the success of such actions is the mobilization and participation of the academic community in the process. It does so by presenting findings demonstrating how the University of Brasilia has been concerned with adopting pro-environmental measures for sustainable development.

Keywords Universities, Waste generation, Characterization, Gravimetric composition, Management, Diagnosis

Paper type Research paper

The authors would like to thank the Extension Dean (DEX) of the University of Brasilia, the FUP board of directors, the advisor to the board of directors Mr Joaquim Oliveira, and the extension students, scholars and volunteers who collaborated to carry out this work.

International Journal of Sustainability in Higher Education
© Emerald Publishing Limited
1467-6370
DOI 10.1108/IJSHE-12-2019-0358

1. Introduction

The disposal of solid waste has been a problem since humanity began to organize itself in communities. Since then, and especially in recent years, solid waste management has been presented as one of the main challenges in urban areas. Its generation and inadequate disposal cause diverse environmental, social, economic and public health impacts (Tejedor, 2011; Ojeda-Benítez *et al.*, 2013; Triassi *et al.*, 2015). In a matter of public health, debris or even small objects (such as bottle caps or food packaging) can become a breeding ground for disease vectors when placed in open areas without being covered or protected against the accumulation of rainwater. Several countries, such as Brazil, have faced serious health problems due to dengue fever outbreaks as a result of the proliferation of *Aedes aegypti* mosquito in the described environments (Fagnani and Guimarães, 2017).

To contribute to the sustainable waste management and environmental protection, proposing specific legislation becomes necessary to establish the rights and duties of the parties involved, as well as to predict the attributions of each one. In Brazil, the promulgation of Law No. 11,445/2007 (Brazil, 2007) assigned new tools to solid waste management. This law provided the legal framework for the National Policy on Basic Sanitation, and Law No. 12,305/2010 (Brazil, 2010a) and the National Solid Waste Policy (PNRS). These Laws ended a long period of weak legal frameworks in the field of basic sanitation and inaugurated a new phase for solid waste management in the country. Among the principles of Law No. 12,305/10, there is the reusable and recyclable solid waste recognition as having an economic and social value, generating employment and income and promoting citizenship. The non-generation or reduction of the waste volume produced by the general population is one of its main objectives. Selective collection and the waste management plans are instruments of the PNRS, the latter being the basis for the policy implementation.

Consequently, to supplement the actions of solid waste management in 2010, the federal government published Decree No. 7,404 (Brazil, 2010b), which regulated the PNRS and created the PNRS Interministerial Committee and the Guiding Committee for the implementation of reverse logistics systems. The existing legislation is innovative and advanced, as it takes on the following challenges:

- the collection of resources and the planning of the integrated management of urban solid waste;
- the creation of consortia and access to financing;
- economic viability of recycling and the inclusion of waste pickers; and
- the need to engage and mobilize society.

In the scope of federal public agencies, the Federal Decree No. 5,940 was promulgated in 2006. This decree established the separation of recyclable waste discarded directly and indirectly by agencies and entities of federal public administration. It then directs the waste to associations and recyclable waste cooperatives (Brazil, 2006). This is an action of the Brazilian federal government to protect the environment and set an example for the sustainable waste management. In addition, the local legislation of Federal District, Law No. 5,610/2016, requires that large generators of solid waste – those who generate over 120 L in non-residential establishments – have to manage their own waste (Brazil, 2016). Brazilian federal public universities are federal public institutions and large solid waste generators, being obliged to comply with the current legislation in its different aspects. This means that universities are required to minimize, value and implement integrated management of solid waste.

Apart from the presented legal frameworks, the publishing of the Brundtland report in 1987 and the advent of the United Nations Conference on Environment and Development in 1992 put the issue of sustainability issue into the spotlight. Since then, the federal public administration in Brazil has tried to insert the criteria of socio environmental responsibility [1] within administrative duties. In this sense, federal public universities – seen as the government entities – cannot ignore the environmental issues caused by their activities, with solid waste being one of them. Sustainability, aligned with other universities' departments, became a major concern for their managers (Alshuwaikhat and Abubakar, 2008).

Universities require services and infrastructure, including waste management at the scale of a small city (Pike *et al.*, 2003; Tangwanichagapong *et al.*, 2017). This is due to their large size, population and the complex activities that occur on campuses (Alshuwaikhat and Abubakar, 2008). As such, universities not only need to maintain adequate physical infrastructure but also require services similar to those of small cities, including accommodation, transportation, shopping, leisure and waste management (Zhang *et al.*, 2011; Vagnoni and Cavicchi, 2015).

As educational institutions, universities have the moral and ethical obligation to act responsibly concerning the environment; they must be leaders in the environmental protection movement, including responsible waste management. In addition, proper waste management brings benefits to the institution, such as the reduction of financial resources for waste management, but, above all, it should be an example for students and the community (Pike *et al.*, 2003; Vega *et al.*, 2008; Lozano, 2010; Berchin *et al.*, 2017; Tangwanichagapong *et al.*, 2017). Integrated waste management is a key element for the sustainable development of universities because they are considered leaders in environmental and social responsibility (Barros *et al.*, 2013; Tangwanichagapong *et al.*, 2017). The specific issue of waste management is also one of the aims of the *2030 Agenda for Sustainable Development* (Goal 12 – Responsible consumption and production) and the Circular Economy (Kirchherr *et al.*, 2017).

In this regard, the first step to implement an efficient waste management system on a university campus is to know the composition, quantity and recycling potential of the waste it generates (Vega *et al.*, 2008; Kassaye, 2018). In other words, it is necessary to make a diagnosis. In university environments, the solid waste generated includes those that are classified as industrial and health services, in addition to urban solid waste. The diagnosis of waste management and the monitoring of activities carried out in each university over time, as well as environmental education activities, is important to guide the segregation, collection, treatment and final destination of these solid wastes generated in this setting because they require special treatment (Albuquerque *et al.*, 2010).

Solid waste management programs at higher education institutions in industrialized countries began more than 20 years ago, ranging from voluntary and local efforts to institutionalized programs (Vega *et al.*, 2003). Several studies have been developed worldwide to propose solid waste management strategies at universities, based on the characterization of residues and their recycling potential (Vega *et al.*, 2008; Taghizadeh *et al.*, 2012; Okeniyi and Anwan, 2012; Ferronato *et al.*, 2020). Similarly, in Brazil, some studies can be highlighted that demonstrate similar practices (Imbroisi *et al.*, 2006; Anjos, 2016; Fagnani and Guimarães, 2017).

Several universities across the globe already have successful cases of solid waste management, in terms of waste characterization and the implementation of actions to reduce waste generation. The Federal Institute of Higher Education, Science and Technology of Santa Catarina, Brazil developed guidelines and plans to implement sustainability by

promoting activities and training to promote environmental awareness for students, professors and other staff members (Berchin *et al.*, 2017). Another higher education institution in Thailand implanted the 3Rs (reduce, reuse and recycle) waste management initiatives on a campus community. These initiatives had positive effects on people's attitudes about resource use, waste management and consciousness around the need to avoid waste (Tangwanichagapong *et al.*, 2017). In another case, the Azcapotzalco campus of the Universidad Autónoma Metropolitana (UAM-A) in Mexico implemented an Integral Urban Solid Waste Management Program. The program consists in separating solid wastes into two classes:

(1) recoverable wastes (glass and PET bottles, aluminum cans, Tetra Pak packages); and

(2) other wastes (non-recoverable).

It promotes concrete actions for the separation of waste and changes in individual values and in the behavior of the members of the UAM-A community (Espinosa *et al.*, 2008).

It is imperative to implement measures that reduce the impact of their own activities, such as the correct management of solid waste (Vega *et al.*, 2008). In this way, it is the responsibility of universities to be more committed towards environmental issues and to comply with legislation related to waste management. According to Vega *et al.* (2008), Benayas *et al.* (2002) and León-Fernández and Domínguez-Vilches (2015), studies on the characterization and management of solid waste in universities deserve special attention for a few reasons:

- there are a few studies in this area;
- university campuses can develop innovative approaches to waste management that could later be applied to other communities;
- the actions taken in campuses can sensitize students to develop good practices in waste management; and
- the practices adopted at universities have significant potential to be adopted in nearby communities because of the consideration that people have regarding educational institutions.

The first step in proposing a solid waste management program is to diagnose the generation of this waste. Thus, the objective of this study is to determine the amount, composition and recycling potential of the waste generated at the Faculdade UnB Planaltina (FUP) campus of the University of Brasilia (UnB) located in the Federal District, Brazil. The data generated from this study demonstrates how to develop a waste management strategy compatible with national legislation and with sustainable global practices.

2. Material and methods

2.1 Study area

The FUP campus is located 40 km from the University of Brasilia's headquarters, the Darcy Ribeiro University campus, in Asa Norte, Brasilia, Brazil. The FUP campus was inaugurated in 2006 and started its academic activities with only two undergraduate degrees. FUP is characterized as being relatively small in size and with a low number of students. At the time of the present study, FUP had four undergraduate and five postgraduate degrees, serving a population of 1,355 students enrolled, 110 professors and 137 administrative and services staff, according to a survey done by the human resources sector.

At FUP, 50% of the students enrolled in undergraduate degrees are reserved those coming from public schools and with a gross household income that is equal to or less than one and a half minimum wages per capita (about US$294). This is according to the Federal Law No. 12,711/2012 that also includes a quota for self-declared racial minorities and indigenous populations. The remaining half of undergraduate enrollment is open under a competitive admissions process. According to data obtained from the Social Development Directorate of UnB, 59% of the students at UnB are classified as in need and receive assistance from the university. This represents an atypical population compared to most universities in the Federal District and very representative for the study.

In relation to its physical infrastructure, the FUP campus has a total area of 295,200 m^2 (29.52 ha) with a constructed area of approximately 9,344.54 m^2 (0.93 ha). The campus is composed of four buildings, as shown in Figure 1:

(1) Education and Research Unit (ERU), administrative headquarters, with professors' offices, graduate and postgraduate laboratories and administrative sector;

(2) Campus Academic Unit (CAU), with undergraduate classrooms and their respective chemistry and biology laboratories, as well as a cafeteria, a library and an auditorium;

(3) Specialties Module (SM), with the University Restaurant (UR), sports court and some rooms; and

(4) Student Housing (SH), which holds up to 100 students and has dormitories, kitchen, laundry and bathroom facilities.

There are also two parking lots, one in front of the ERU building and another one in front of the CAU building.

The university is open from Monday to Saturday throughout the year, except during the holidays and breaks between Christmas and New Year. On Sundays, access is restricted to the library, SH and the UR. Occasionally, on the weekends, the campus administration makes the CAU building available for events or exams. Normally, the first semester begins in the second week of March and ends in the first week of July. The second semester begins

Notes: Student Housing (SH); University Restaurant (UR); Campus Academic Unit (CAU); Education and Research Unit (ERU)
Source: Couto (2018)

Figure 1.
Location of FUP with the distribution of the campus' buildings

in the second week of August and ends in the first week of December. During holidays, the cafeteria is closed. The UR runs from Monday to Sunday, serving students on campus during the week, for classes and those residing in the campus accommodation.

Figure 2 presents a timeline of the actions taken by FUP for waste management and related regulations. Since 2014, the UnB has been trying to gradually initiate the Solidary Selective Solid Waste Collection Project in its four campuses in order to be in line with Brazil's waste management legislation. In 2015, the diagnosis of solid waste management at FUP was started to adapt the existing structure to the legislation. The diagnosis of waste management at FUP was conducted from 2015 to 2016, involving the second academic semester of 2015 and the first of 2016. The study was divided into four stages:

(1) identification of waste generation sources;
(2) estimation of waste generation;
(3) estimation of waste composition; and
(4) analysis of results.

In the second semester of 2016, a selective collection was implemented and put into action. Since 2017 and until now, the actions to build awareness within the academic community, regarding the separation of waste for disposal, were initiated.

2.2 Identification of waste generation sources and management

To understand FUP's waste management system, interviews were carried out with the cleaning staff, assistant manager, laboratory technicians and the UR staff. Only those responsible for these sectors were interviewed. At the diagnosis stage, all waste generation points were identified through on-site visits to FUP buildings, followed by interviews with the employees of each sector.

Regarding waste management on campus, a third-party company is contracted to do the cleaning and collection services. For each sector of the buildings there is a group of two to three employees responsible for cleaning. The classroom cleaning service runs from Monday to Friday, from 7:00a.m. to 10:30p.m. On Saturdays, the service only works until 1 p.m. and the campus' food activities are also outsourced. The staff responsible for these activities collects residues and store it to be sent to the city's waste collection service (SLU – *Serviço de Limpeza Urbana*).

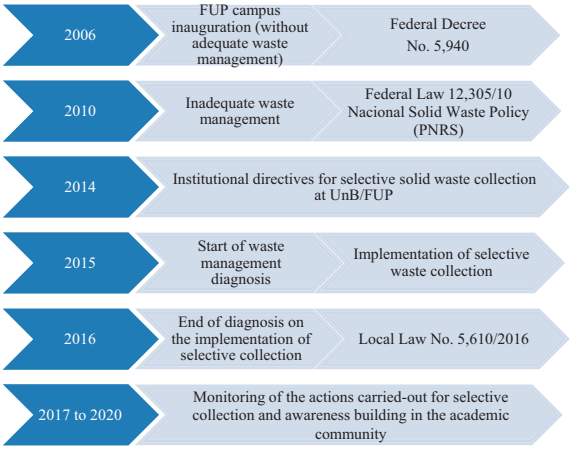


Figure 2.
Timeline of actions developed at FUP for waste management and related regulations

At the time this study began in 2015, it was identified that there was no selective collection operating at the institution. The household/ordinary waste that was generated (organic or recyclable) was disposed of in a single collector. At the moment of collection, which was done by the cleaning staff, the residues were all commingled, including from restrooms, cafeterias, common areas, classrooms, professors' room, administrative departments and dorms. After collection, the waste was taken to two containers, placed in front of the campus main building and awaited for the SLU gathering. All the residues collected in the institution by the SLU were disposed of at the only existing controlled landfill in the Federal District. However, with the opening of the landfill in January 2018, the residues were then forwarded to this new location.

In the case of the UR, the waste produced was managed by its own cleaning staff since its opening in 2015. The organics were sorted from the recyclables inside the restaurant and they were then kept separated into two containers outside of the building until the city's waste collection with SLU was completed. At this stage, all waste was mixed because only one vehicle transported the wastes.

Hazardous waste from laboratories was properly packaged, collected and disposed of by a private company that made the final disposal of it safely and in accordance with federal legislation. Since FUP is a UnB campus, all contracts for building maintenance, cleaning services, collection and disposal of hazardous waste from laboratories and common waste collection are administered by the UnB Academic Administration, which is headquartered at the central UnB campus (named Darcy Ribeiro).

2.3 Estimation of waste generation

The quantification of the residues produced at FUP was obtained by weighing the residues generated in the CAU, ERU and SH buildings for four consecutive weeks (from Monday to Friday) in November 2015. On campus, there are two types of installed collectors, one for recyclables and one for mixed waste (organic and tailings [2]). As agreed with the campus cleaning staff, garbage bags containing recyclable and mixed waste were held onto for 24 h, separated to be individually weighed and later their weights were added to set the amount of the entire campus. Due to the blend of mixed waste with sanitary waste by the cleaning staff, these residues were weighted together. Two digital weight balances were used, one with a capacity of up to 100 kg and another of 500 kg. The data obtained from weighing was stored in an Excel database. To obtain per capita waste generation that reflects the amount of waste generated by person/day, the following formula was used:

$$\text{Per capita generation (kg/inhab.)} = \frac{\text{total weight of daily waste}}{\text{campus users}} \quad (1)$$

Although the FUP campus has been active since 2006, the UR was opened only at the end of 2015. Due to the peculiarities of the waste generated in the UR, these were weighed only for one week, from Monday to Friday, in June 2016. The methodology developed for this stage was similar to the one performed for the other buildings. Subsequently, in 2017, new data on food waste was collected from the UR.

2.4 Composition of residues

The composition analysis of the residues produced at FUP was obtained by separating and weighing the fractions individually. This part of the study was carried out in three stages:

(1) in November 2015, for the waste produced in the CAU and ERU buildings;
(2) in June 2016, only for waste produced in the UR, not coinciding with the study of the quantitative characterization of the waste; and
(3) in November 2016, for the waste produced in the CAU and ERU buildings.

The residues of each building were stored for 24 h. Then, on the following day, they were sent to the characterization site, where one of the scales to weigh the waste was already positioned, according to the evaluated building. The experiment was done following the safety standards with gloves, masks and lab coats and according to the methodology proposed by Gallardo *et al.* (2016).

In the gravimetric characterization stage, the bags containing the residues from each building were weighed individually and then passed over a plastic canvas for sorting and separating of fractions by type: paper, cardboard, plastic, tin, Tetra Pak packaging and styrofoam. As the amount of residues was relatively small, they were sorted without the use of sampling techniques, except in the CAU building.

In the first characterization carried out, the residues generated from the CAU building were analyzed by the quartering method (Monteiro *et al.*, 2001). The residues generated in the ERU building were fully characterized, without using any sampling methodology, as well as in the characterization carried out in the UR. After weighing, the waste was discarded for collection by SLU. To determine the percentage of each of the identified components, equation (2) was used:

$$\text{Material}\,(\%) = \frac{\text{material fraction weight}}{\text{total sample weight}} \tag{2}$$

The evaluation of other parameters was not performed. This is due to the fact that there are limited treatment options for them. For example, the only treatment option for organic waste in Brasilia is composting. While recyclable waste is treated by the sorting and recovery of materials with economic value for recycling, moreover, the FUP campus does not yet have an adequate structure to perform physio-chemical waste analysis.

2.5 Statistical analysis

To determine if the "day of the week" factor affects waste generation, the Mann–Whitney *U*-test was used; statistical analyses were calculated using the SPSS program.

3. Results and discussion

The first step in planning the integrated management of solid waste is to characterize it. Understanding the differentiated composition of waste facilitates the development of strategies for separation at source, collection and knowing its potential for recycling.

3.1 Identification of sources of waste generation

The survey of waste generation sources, types and hazard characteristics of waste generated on the FUP campus are presented in Table 1. The sources of generation are diverse and so is the waste generated. The generation of special waste is related to laboratories, and most of this waste is liquid, such as reagents and solutions used for experimental undergraduate classes. This waste has a potential negative impact on the environment and human health. For this reason, they are classified as hazardous waste,

Generating unit	Types of waste generated	Hazard characteristics*
Ground sorting room	Chemical reagents, paper, cardboard, rock, plastic	Dangerous and non-dangerous
Laboratory of Analytical and Environmental Chemistry	Chemical reagents, paper, cardboard	Dangerous and non-dangerous
Multiuse Laboratory of Environmental and Applied Nanoscience	Chemical reagents, paper, cardboard	Dangerous and non-dangerous
Multiuser Laboratory of Micro and Nanostructured Materials Synthesis	Chemical reagents, paper, cardboard	Dangerous and non-dangerous
Laboratory of Geostatistics and Geodesy	Chemical reagents, paper, cardboard	Dangerous and non-dangerous
Social Science Research Laboratory and Quantitative Methodologies	Organic wastes, paper, plastic, Styrofoam	Non-dangerous
Teaching Lab I (Biology)	Chemical reagents, plastic, cardboard,organic wastes	Dangerous and non-dangerous
Teaching Labs II (Chemistry)	Chemical reagents, glass, paper, cardboard	Dangerous and non-dangerous
Computer Lab	Paper, plastic, cardboard, electronic wastes	Non-dangerous
Library	Paper, cardboard	Non-dangerous
Cafeteria	Organic wastes, paper, plastic, cardboard, aluminium cans, Tetra Pak packaging	Non-dangerous
Classrooms	Paper, cardboard, plastic	Non-dangerous
Reprography	Paper	Non-dangerous
Auditorium	Paper	Non-dangerous
Toilets	Sanitary wastes	Dangerous
Administrative Rooms	Organic wastes, paper, plastic, cardboard	Non-dangerous
Garden	Grass, tree branches, tree leaves	Non-dangerous
University Restaurant	Organic wastes, paper, plastic, cardboard, kitchen oil	Dangerous and non-dangerous
Student Housing	Organic wastes, paper, plastic, cardboard, sanitary wastes	Dangerous and non-dangerous

Note: *Hazard classification in accordance with Brazilian normalization (NBR ABNT 10.004/04)

Table 1. Identification of waste generating units, types of waste generated and their characteristics

according to NBR ABNT 10.004/04 (Associação Brasileira De Normas Técnicas, 2004). The other residues generated can be equated to ordinary household waste.

The management of hazardous waste produced in the FUP laboratories is carried out in accordance with the RESQUI program. This program, created by the UnB, is managed and conducted by the Commission for the Management, Treatment, and Disposal of Hazardous Wastes at the University. It manages the hazardous waste produced on all campuses with environmentally adequate collection and disposal. The responsibility of the waste generation points, in the case of laboratories, is only to separate and pack the waste in a suitable way for collection. The remaining non-hazardous waste and household solid waste generated at FUP is deposited in the trash cans distributed on campus. Afterwards, they are destined for collection by the SLU for waste collection.

3.2 Generation of waste in Faculdade UnB Planaltina

Based on the results presented in Figure 3, it can be observed that the volume of waste generated monthly on the FUP campus is 3,794 kg. The UR is the largest producer of waste, followed by the ERU and CAU buildings. Considering each week with six working days for class activities, including Saturday morning when one of the undergraduate courses has classes, 148 kg of waste are generated daily on campus. The UR serves three meals throughout the day: breakfast, lunch and dinner from Monday to Sunday. During the week, an average of 340 meals are served daily at lunch and 250 at dinner. The rates of waste are 16 kg/day at lunch and 13 kg/day at dinner. Waste generation by the UR is up to 3.5 times larger than the ERU and CAU buildings together.

Despite the sanitary and culinary precautions taken with food prep, these do not always meet the expectations of those eating in the restaurant because they do not always consume all the food. Food waste is therefore discarded. The results obtained show that the UR is the best location to mitigate waste.

Gallardo *et al.* (2016) evaluated the waste generated at Jaume I University (UJI), located in Castellón de La Plana, Spain. The authors observed that the cafeteria is the place with the highest generation of waste. On the other hand, Vega *et al.* (2008), characterizing the waste generated at the Mexicali I campus of the Autonomous University of Baja California (UABC), reported that 53.5% of the waste generated on campus came from the buildings of administrative sectors, classrooms, and laboratories. Comparing the data obtained at FUP with the studies mentioned above, it can be observed that the place of greatest generation of residues on a campus can be quite variable.

It is estimated that the per capita generation is 0.0925 kg, i.e. 92 g/person/day according to equation (1). This is based on the estimated academic population of FUP at 1,600 individuals and a daily generated waste of 148 kg. In Brazil, according to data from the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE) in 2018, the per capita generation of urban solid waste by Brazilians was 1.039 kg/inhab./day (ABRELPE, 2019). Waste generation at FUP is much smaller than the Brazilian average. However, when comparing these data with the other universities in Table 2, it is observed that the generation rate of FUP is the third highest. It should be considered that most students who attend FUP have low purchasing power and that the campus infrastructure is very simple compared to other universities presented in Table 2.

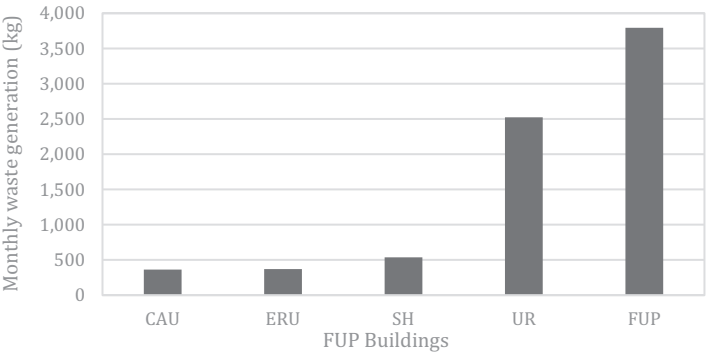


Figure 3.
Monthly waste generation rate (kg) per building of FUP

Notes: Campus Academic Unit (CAU); Education and Research Unit (ERU); Student Housing (SH); University Restaurant (UR)

According to Table 2, the highest rate of waste generation is from the Universidad Iberoamericana in Mexico, D.F. In addition to common residues, garden waste and others, it is the sludge generated in a water treatment plant that places this institution as the largest generator of waste. The second largest producer of waste is the University of Tabriz, Iran. There the largest volume of waste comes from academic departments and administrative buildings. The authors' suggest reducing waste generation, recycling and composting as an effective management strategy.

In the fourth place is the UJI in Spain. It was here that the cafeteria was observed to be the largest generator of waste. Amongst all of the waste generated, 46% was organic. Covenant University in Nigeria produces quantities of waste similar to other universities in more developed countries. This university is private and was considered the best in the country in 2015. Its students have a high economic level, similar to those of developed countries. This indicates that a country's degree of development does not necessarily affect the generation of waste in universities but rather the purchasing power of its users and their consumption pattern (Gallardo *et al.*, 2016). In contrast, FUP serves a significant amount of students who have low purchasing power, yet still has a higher per capita production of waste than Covenant University. This situation reflects different patterns of production, consumption and disposal than those of the universities in Figure 2. Finally, the Prince George campus of the University of Northern British Columbia has a waste generation rate that is lower than FUP. However, in the surveys carried out, the residues generated did not include the dorms and student athletic complex.

The campus of Mexicali I of the Autonomous University of Baja California (UABC – *Universidade Autônoma de Baja Califórnia*) has the second lowest waste generation rate. An important distinguishing point here, in relation to FUP, is that the UABC added data from its gardens and student stores. The lowest rate of waste generation was from the University of Massey in New Zealand at 42.00 g/person/day. This rate is the lowest because it includes only a few areas of the campus and has implemented a Zero Waste program (Gallardo *et al.*, 2016). The latter, by itself, justifies a reduction of the volume of waste.

The present study also allowed for the evaluation of waste generation variation during the weekdays. It is observed in Figure 4 that the day of greatest generation of waste is Tuesday, with a monthly average of 338.59 kg. Monday is the second day with the largest generation of waste, with a monthly average of 265.25 kg. This result can be attributed to the fact that the first days of the week concentrate a greater number of subjects and students on campus, increasing the generation of waste in that period. The days with the lowest generation of waste are Wednesdays and Thursdays, with 129.75 kg and 162.44 kg,

Universities	Waste generation rate (g/person/working day)
Universidad Iberoamericana[a] (Morales, 2012)	330.00
University of Tabriz (Taghizadeh *et al.*, 2012)	131.50
Faculdade UnB Planaltina (this study)	92.00
Universidad Jaume I (Gallardo *et al.*, 2016)	89.50
Covenant University (Okeniyi and Anwan, 2012)	60.50
University of Northern British Columbia (Smyth *et al.*, 2010)	59.20
Universidad Autónoma de Baja California (Vega *et al.*, 2008)	46.60
Massey University (Mason *et al.*, 2003)	42.00

Note: [a]Typical maximum generation rate
Source: Gallardo *et al.* (2016) modified. Authors' elaboration

Table 2.
Waste generation rates in different universities

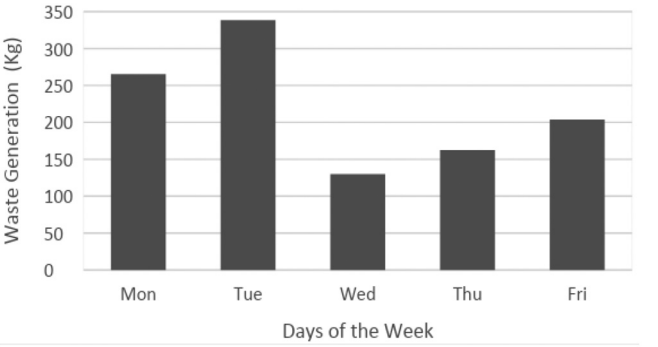


Figure 4.
Waste generation by day of the week at FUP

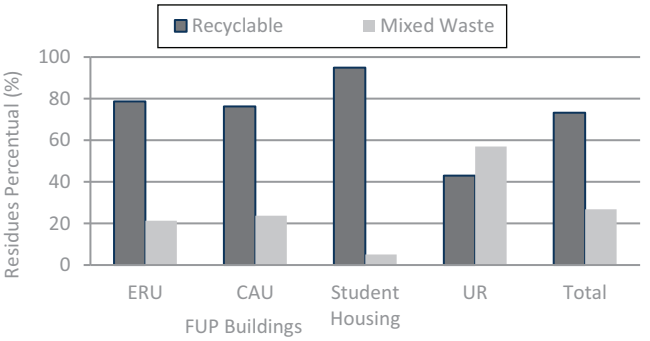
respectively. This can be attributed to the lower supply of subjects on those days and, consequently, the lower circulation of students on campus. According to the Mann–Whitney *U*-test, the averages of waste generation on Monday and Tuesday are equal to the 5% level. Furthermore, the *U*-test identified a statistically significant difference at the 5% level when comparing the aggregate volume of waste generated on Monday and Tuesday with the aggregate generated on the rest of the days of the week, confirming the highest generation of waste at the beginning of the week. Identifying the day of the week with the highest generation of waste is relevant to the adoption of a distinctive action strategy by the campus cleaning team. It can also help establish a link between this variable and the habits and consumption patterns of the academic community.

3.3 Composition of residues generated in Faculdade UnB Planaltina

On the FUP campus the installed collectors are two different types: those for recyclable material and mixed waste (organics and tailings). The composition of residues generated at FUP was determined from the characterization of these residues between recyclable and mixed. Of the waste generated on campus, 67% is recyclable and 33% is mixed waste. In this last type, it is not possible to determine the percentage of each kind of residue. Of the waste generated in the ERU, CAU and SH buildings, the largest proportion is represented by the recyclable fraction (Figure 5), thus indicating the potential of using these with their donation and marketing to recyclable material waste-pickers' cooperatives. A total of 57% of the waste generated from the UR is organic.

Fagnani and Guimarães (2017) identified that 35% of the waste generated in the School of Civil Engineering, Architecture and Urban Design of Unicamp, in São Paulo, Brazil, corresponded to the organic fraction. In studies conducted by Vega *et al.* (2008) with residues generated at the Mexicali I campus of the Autonomous University of Baja California, about 25% of the waste produced was organic. Generally, in the universities presented here and also in FUP, there is a tendency for the percentage of the organic fraction to be lower than the percentage of the recyclables.

A gravimetric composition was obtained by sorting the residues generated in the different FUP buildings, determining the percentage of their most common components. By means of equation (2), the percentages of materials sorted in FUP buildings were calculated and the results are presented in Figure 5. On the FUP campus, plastic, paper and cardboard are the elements with the greatest concentration among the residues produced, with potential recovery through recycling. These results are comparable to the studies conducted by Vega *et al.* (2008), Vega *et al.* (2010) and Fagnani and Guimarães (2017).



Notes: Campus Academic Unit (CAU); Education and Research Unit (ERU); Student Housing (SH); University Restaurant (UR). Mixed waste: organic wastes and miscellaneous materials (wastes that lack commercial value and are not recoverable)

Figure 5.
Waste generation by buildings of FUP (in %)

At a South Indian university campus, the most generated wastes with potential for recycling are paper (11.10%) and plastic (9.15%). The organic residues correspond to a fraction of 47.20% of the global composition (Prasad and Anchan, 2018). At FUP, organic wastes, including those from the UR, cafeterias, toilet bowls and sanitary wastes, represent only 26.70%. Glass was barely found among the residues because there is low consumption of drinks or other products packed in this type of material. The only cafeteria on campus does not sell products with this packaging. Therefore, it is assumed that the glass waste found was purchased off-campus.

In the characterization stage, the residues generated in restrooms were grouped in the category of mixed, along with the residues coming from the pantries, kitchens and cafeterias. At FUP, the largest generator of organic waste is the UR (57%). This is due to the meals' preparation, corresponding to the waste of food in the dishes served, in addition to fruit peels, vegetables, among other components.

The company that prepares and serves food in the UR is outsourced and recommends that users dispose of food waste in a separate container from any other material, which makes this fraction adequate and very suitable for composting or energy production. In other buildings, the generation of recyclable waste predominates, Figure 6.

Based on what is known about the characterization of waste generated at FUP, it is possible to state that there potential for recovery of the recyclables through the selective collection, with subsequent sorting and disposal of materials for use in industry. Thus, Brazilian Law No. 12,305/10 is observed with the economic valuation of waste, social inclusion of waste pickers, income generation and jobs. Given the amount of organic waste produced in the UR, these can also be destined for the composting process, animal feed (a very common practice in Brazil) or a bioreactor. Considering the guidelines of a circular economy, a more sustainable waste management model adapted to FUP must including planning natural resource conservation, minimizing waste, promoting equality and social justice as well as the transmission of these values to the society in which it operates. On this latter point, it is important to also consider that FUP is surrounded by agricultural activities and a population with low income. Therefore, the production of organic fertilizer from composting and the delivery of recyclable materials to cooperatives (to generate income) could be some of the first steps to build a model adjusting to the demands of the FUP campus.

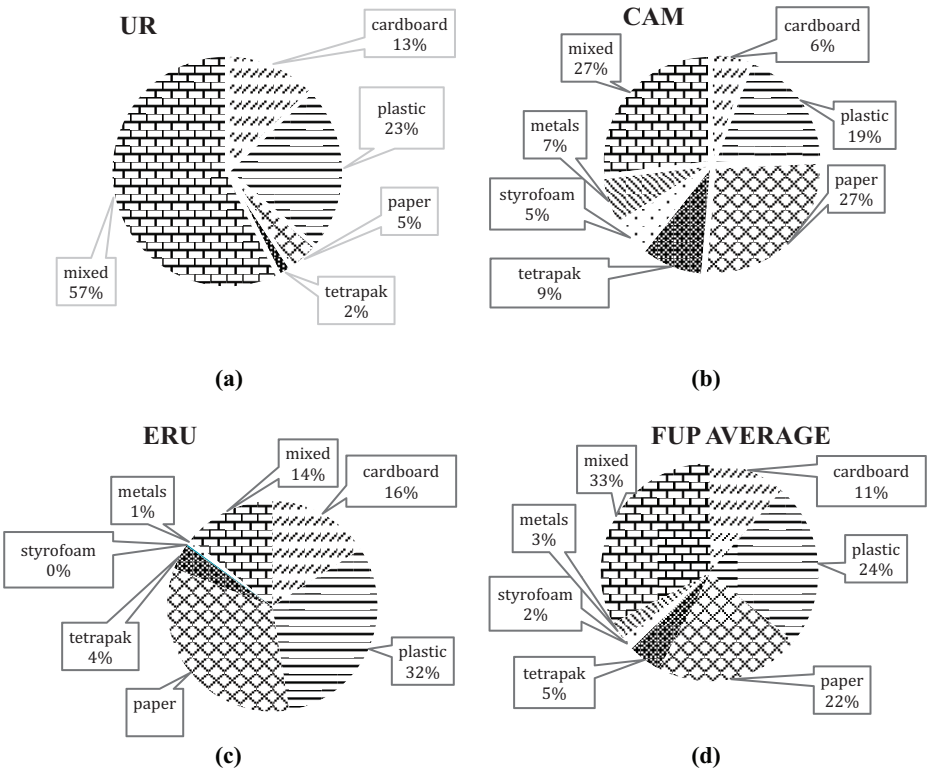


Figure 6.
Gravimetric composition of the residues generated at FUP, per campus building, with an average of two samples taken (except the UR; in %)

Notes: (a) University Restaurant (UR); (b) Campus Academic Unit (CAU); (c) Education and Research Unit (ERU); (d) Average composition of FUP's waste. Mixed waste: organic wastes and miscellaneous materials (wastes that lack commercial value and are not recoverable)

3.4 Actions for solid waste management at Faculdade UnB Planaltina

The quantitative and qualitative aspects have a direct relation to the planning and implementation of strategies for their management. In accordance with Vega *et al.* (2008), comparisons of quantity, types of waste and waste management practices among different universities are important for the following reasons: to serve as a reference for future studies (Table 2); to share waste characterization methodologies; to elaborate waste management plans and; and to know the progress of this type of research internationally.

In the second semester of 2016, after the diagnosis presented in this article, FUP began to structure the solidary selective waste collection through two extension projects:

(1) implementation of a solid waste management plan for FUP; and

(2) environmental education in the implementation of selective waste collection at FUP.

These projects comprise Recicla FUP (www.reciclafup.com.br), a group that develops university extension and research actions related to the theme of solid waste management and environmental awareness with the academic community of FUP.

The projects helped to structure the selective collection of waste at FUP through the disposal of waste collectors, their identification and the hiring of workers from a recycle cooperative to dispose of waste. These workers were chosen by means of public notice and signature of a commitment agreement. The projects aim to raise awareness amongst the university community, through oriented educational actions to stimulate the waste generator to separate them correctly. From 2017 to the present moment, the projects also carry out actions for the implementation of selective collection, sustainable consumption (by encouraging the reduction in the use of plastic cups), and by monitoring printing, water consumption, energy on campus and others, see Table 3.

The monitoring of educational actions carried out with the academic community of FUP identified three main challenges to face:

(1) a lack of personal motivation of students to participate in the selective collection;

(2) a lack of knowledge on how to selectively dispose of waste; and

(3) the need to institutionalize the actions of extension projects.

Similar challenges have been observed by UNEP (2005), such as changing the habits of individuals in the separation of waste. The separation of waste correctly at the source is the most effective action to facilitate the entire waste management process. Therefore, engagement of the academic community and behavioral change towards a focus on socio-environmental responsibility is fundamental for the effectiveness of selective collection.

Target audience	Actions accomplished by the extension projects
Staff operational	• Meetings with cleaning collaborators for training on the new process of waste generation
Administrative staff	• Conducting education reports on selective collection in the server rooms • Implementation of an electronic process to replace physical document processing (action taken by the institution, efficiency monitored by extension projects) • Outsourcing document printing by administrative staff (action taken by the institution, efficiency monitored by extension projects) • Monitoring the consumption of disposable cups – control of purchases made by the warehouse. A campaign was carried out to promote the use of one's own glass and/or bottles of water and cups • Monitoring the use of bond paper via controls on purchasing from the FUP warehouse
Academic and administrative staff	• Educational panels on selective collection (separating waste) • Production of informational murals and digital content on social networks
Undergraduate and graduate students	• Workshop on the production of waste collectors from recyclable materials • Theatrical performances in classrooms • "Welcome Freshmen" – reception of new undergraduate students with a short informative lecture on the solidarity of selective collection on campus • Production of audiovisual content: the first video addresses the separation of waste in the collectors and temporary packaging on campus; the second video presents the journey waste takes after collection at FUP and its processing at the collectors cooperative • On local commemorative dates, such as World Environment Day and Christmas, actions are taken to mobilize the academic community on the theme of solid waste. Some highlights include a campaign to collect electronic waste and on how to make Christmas ornaments using recyclable materials

Table 3.
Details of the actions carried out by extension projects

This is why educational awareness actions must be continuous and permanent, directed at the personal motivation of individuals on campus.

At the same time, by virtue of a local District Law No. 5,610/16 (Brazil, 2016) FUP started to be considered as a large generator of solid waste, as it produces more than 120 L of undifferentiated waste daily. Thus, to comply with Law No. 12,305/10 and Law No. 5,610/16, the University has been going through a new adaptation phase. As the UR is operated by a third party company, changes have already occurred, such as the hiring of a private company to collect the waste generated in the building. According to Law No. 5,610/16, if SLU continued to collect waste from the UR, it would be necessary to pay a public price for such activity (previously, the collection was free). To minimize costs and the amount of waste disposed of in landfills (the most common form of waste disposal in Brazil), the company that operates the UR has sent its organic waste for use as animal feed. In addition, small amounts have been used for composting at a pilot scale.

Looking towards the future, some actions need to be taken to improve the selective collection process on campus:

- inform individuals of the environmental and legal consequences of their actions in not cooperating with the selective disposal of waste;
- expand the system for disseminating information about the selective collection, ensuring that the information is effectively shared amongst students, professors and administrators; and
- carry out a structural adaptation of the selective collection and waste management on the campus to conform to District Law No. 5,610/16.

The next stage of the project is to move forward on the issue of environmental education for high school and elementary students in the city of Planaltina. This action will help reinforce the educational activities with the academic community (students arriving already educated on the issue) and expand knowledge on sustainable waste collection beyond the campus. To this end, the project intends to create a pedagogical path at FUP with a scalable model to represent the generation of waste, technological routes for treatment and final disposal, a system for composting organic waste and a seedling nursery, the last two on a real scale. The whole model is then aiming to integrate concepts about the circular economy.

4. Conclusions

The characterization qualitative–quantitative analysis of solid waste is the first step in the planning of integrated waste management. Knowing the composition of waste allows for defining the strategies for separation, collection, treatment alternatives such as recycling and composting, thus contributing to divert waste away from landfills. The results presented in this article emphasize the potential of higher education institutions to be protagonists in sustainability generally and taking on the issue of sustainable waste management, more specifically. The study demonstrated guidelines and goals for waste management in FUP, which brought to light important aspects such as:

- waste produced at FUP has the potential to be recycled or composted;
- it is necessary to reduce the generation of waste throughout campus, but especially at the UR;
- educational and sensitizing actions of the academic community for selective collection must be continuous and permanent, directed at individual behavior changes; and

- a need to institutionalize the actions of extension projects.

The stages developed and proposed from this article aimed to be replicated and can be summarized as follows:

- diagnosis (identification of the sources of waste and hazardousness of residues);
- qualitative–quantitative breakdown;
- action plan;
- implementation and awareness of the academic community; and
- monitoring of actions taken.

Above all, the success of the aforementioned steps is intrinsically related to the need of motivating the academic community to engage with and collaborate in the process.

With the implementation of these practices, it will be possible to achieve compliance with Brazilian legislation on waste management, impact the academic and local community in its daily life and supporting the activities of the informal recycling sector. These practices will also support the circular economy through the reinsertion of waste into the production chain. Furthermore, this study contributes to the literature on sustainability in higher education by reporting the process of implementation of a waste management strategy in a university campus. Likewise, it presents tools and methods that can be used to achieve sustainability in waste management and also identifies that the crucial factor for the success of such actions is the mobilization and participation of the academic community in the process. It does so by presenting findings demonstrating how the University of Brasilia is committed to overcoming financial and institutional challenges to promote more sustainable management of waste generated on its campuses. It strives to be a sustainable university, in line with the worldwide trend.

Notes

1. This includes the promotion of social policies, administrative transparency and the efficient use of water and energy, a reduction in waste generation, the rational use of raw materials and a reduction in the emission of pollutants, greenhouse gases and other harmful emissions.
2. Miscellaneous materials, wastes that lack commercial value and are not recoverable.

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